Waste Management xxx (2017) xxx–xxx

Contents lists available at ScienceDirect

Waste Management

journal homepage: www.elsevier.com/locate/wasman

A focus on the state of the art of food waste/losses issue and suggestions for future researches

Cinzia Muriana [1]

90100 Palermo, Italy

ARTICLE INFO

Article history:
Received 15 August 2016
Revised 10 June 2017
Accepted 26 June 2017
Available online xxxx

Keywords:
Food waste/losses minimization
Food waste/losses prevention
Food waste/losses management
New research topics for food/waste management
Supply chain models redesign for food waste/losses prevention and minimization
Suggestions for future research topics

ABSTRACT

Today, the role of the supply chain (SC) strategies in Food-Waste/Losses (F-W/L) generation is neglected, because F-W/L are generally considered an unavoidable consequence of accidental events. Therefore, only operating plans are today put into practice, which aim at reducing the impact of product losses along the SC. This involves that structured analyses and strategic SC approaches are not available for the prevention/minimization of F-W/L. The paper aims at changing the perspective, and promoting the hypothesis that generation of F-W/L mainly depends on the SC strategies put into practice that are usually optimized on the basis of the market demand. The paper considers the F-W/L an intrinsic characteristic of the SC, which must be put in relation with the market demand and the shelf life of products, for given boundary conditions (legal constraints, politic decisions, climatic and micro macro-economic factors). Thus, the paper aims at reviewing the state of the art of the F-W/L issue, and proposing new research topics in the field of the prevention and minimization of F-W/L, by focusing on: (i) the forecasting of F-W/L, the implementation of adaptive-holistic approaches that model the non-stationary and holistic behaviour of the phenomenon; (ii) the determination of analytical conditions that entail the generation of F-W/L, in relation to the implementation of specific SC strategies; (iii) the study of mathematical models for the assessment of the shelf life, and the evaluation of innovative technologies, which enable the shelf life monitoring; (iv) the study of new shelf life-dependent demand models based on the consumer-utility theory; (v) the redesign of the logistic SC management models, by proposing new SC coordination models, planning and replenishment strategies, and pricing models, for the prevention/minimization of the predictable component of F-W/L; (vi) the design of new risk assessment plans for the management of the accidental component of F-W/L.

1. Introduction

1.1. Background

The supply chain (SC) is today affected by loss of products that cannot be sold in the target market for many different reasons. These products are known as food waste or losses, which indicate respectively the food deteriorated and not suitable for consumption and the food still suitable for the human or animal consumption. As regard the attempt of quantifying the F-W/L and their main causes, a keen interest of the scientific community can be evidenced (see, e.g., Brautigam et al., 2014). However, under the standpoint of the impact of SC strategies in generating and managing the F-W/L, such an issue has been not properly investigated until now, because F-W/L are generally considered an "entail" of accidental events that cannot be neither avoided by implementing specific SC strategies, nor mitigated through risk management-related policies.

Thus, the attention of SC practitioners is generally focused on operating actions, which can mitigate the phenomenon. Such actions relate with the possibility of donating the food losses still edible to non-profit organizations or selling them to livestock markets or to markets with less stringent quality standards (see for example the experience of the Feeding America® Food Banks, http://www.feedingamerica.org, or the Italian experiences of "Last Minute Market", http://www.lastminutemarket.it, "Pane Quotidiano", http://www.panequotidiano.eu, and "Banco Alimentare", http://www.bancoalimentare.it/it). This implies that structured

Abbreviations: AI, Artificial Intelligence; ARIMA, Auto-Regressive and Moving Average; BPS, By Products Synergy; CL, Characteristic Life; CLSC, Closed Loop Supply Chain; CSL, Cycle Service Level; EOQ, Economic Order Quantity; F-W/L, Food Waste Losses; GDP, Gross domestic Product; MAP, Modified Atmosphere Packaging; MSW, Municipal Solid Waste; RFID, Radio Frequency Identification; SARIMA, Seasonal Auto-Regressive and Moving Average; SC, Supply chain; SL, Shelf Life; TTI, Time-Temperature Indicators; VC, Value Chain; WMH, Waste Management Hierarchy.

[1] Production Engineering PhD.
E-mail address: cmuriana@live.it

http://dx.doi.org/10.1016/j.wasman.2017.06.047
0956-053X/

analyses are not available that allow us to study the F-W/L phenomenon. On the contrary, the present research wants to stress the hypothesis that the generation of F-W/L mainly depends on the SC strategies put into practice. Moreover, in studying possible solutions of the phenomenon, the impact of some "exogenous variables" and "boundary conditions" it to be considered, since they are out of the control of the SC. In the following, the term "exogenous variables" will be referred to those elements that vary over the time horizon of observation, while "boundary conditions" to those elements that are kept constant over this time. The generation of F-W/L can be put in relation with exogenous variables, such as the market demand:

$$\text{F-W/L generation} = f(\text{Market Demand}). \quad (1)$$

The market demand is in turn dependent on:

- Microeconomic parameters, such as purchasing power of households, income, elasticity of demand, cost-of-living index, economies of scale, marginal costs, prices, etc.,
- Macroeconomic parameters, such as inflation, mean or marginal consumption propensity, mean or marginal saving propensity, mean or marginal investment propensity, interest rate, gross domestic product (GDP), unemployment rate, real balance effect, consumer credit, etc.,
- Environmental parameters, such as culture, legal, institutional, government, regulations, political factors,
- Climatic parameters,

considered like boundary conditions.

$$\text{Market demand} = f(x_1, \ldots x_n) \quad (2)$$

where $x_1, \ldots, x_n$ are parameters independent of each other.

At the same time, the dependence of the consumer demand on the residual quality of products is to be taken into consideration, in setting F-W/L management strategies (for reference about quality-dependent demand see, e.g., Mahapatra and Maiti, 2005; Ma et al., 2013; Seifbarghy et al., 2015; Demirag et al., 2017; Maiti and Giri, 2017; Dobson et al., 2017). In this context, the idea of the present work is to stress the dependency of the market demand on the Shelf Life (SL), for given boundary conditions.

$$\text{Market demand} = f(SL: \ x_1, \ldots x_n) \quad (3)$$

By consequence, given the position (1), the present research hypothesizes that two exogenous variables, namely the market demand and the SL, have to be taken into consideration in minimizing the F-W/L:

$$\text{F-W/L generation} = f(\text{Market demand}(SL: \ x_1, \ldots x_n)) \quad (4)$$

However, the current SC strategies and market demand models tend to neglect the role of the SL; this involves that the SC strategies are optimized on the basis of the boundary conditions. This is because the focus of the current SC strategies is on the optimization of the total management cost/total profit, in which the economic impact of the F-W/L is overlooked. In this context, the prevention of F-W/L relates to the strategies devoted to avoid that F-W/L are produced by the SC, while the minimization states with the possibility of reducing the presence of F-W/L along the chain. This implies that, even if F-W/L cannot be prevented, due to unforeseeable events, they can be at least contained, by carrying out risk management-related policies that allow the SC actors the minimization of the phenomenon.

Given the link between the generation of F-W/L and the exogenous variables, the F-W/L can be considered as sum of a predictable component, which can be modelled and forecasted, and an accidental component, which is related to unpredictable events that occur along the SC. The idea of the author is that the predictable component can be identified by studying the SC coordination models, the planning and replenishment strategies and the logistic contracts implemented today, and by determining the analytical conditions that foster the generation of F-W/L, in cases in which the exogenous variables have both a deterministic and a stochastic behaviour.

1.2. Goal of the study

Given that the F-W/L are a holistic and non-stationery process, the advice of the author is that they can be forecasted by means of adaptive-holistic approaches that take into account the influence of the boundary conditions over time. This will allow the SC actors to set strategic plans for the prevention/minimization of the phenomenon. With regard to this aspect, we found that the F-W/L are not considered like a logistic variable that is to be optimized, when modelling SC strategies. Therefore, the contribution of the present work is to take into account this variable in the optimization of the profit/cost function. This approach will allow the SC actors the prevention/minimization of the F-W/L phenomenon, allowing the F-W/L to turn in the accidental component, which can be tackled through risk response plans. The generation of the F-W/L is also put in relation to the perishability of products in terms of their limited SL and to the dependence of the market demand on the SL; these conditions should be included in the SC coordination models, planning and replenishment strategies and logistic contracts. This topic has not been analysed until now by the scientific community. Several Economic Order Quantity (EOQ) models have been proposed that include the deterioration rate of products in the cost/profit function optimization; however, none of these addressed the relation between the decay rate and the SL over time, and only few papers quantified the deteriorating and shortage costs, which are consequence of overcoming the SL (see e.g., Muriana, 2016, as a first attempt of doing this). This means that there is not the possibility of setting the replenishment cycle in presence of products whose marketability depends on the achievement of the SL. This is obvious for canned products that are sold at the retailing stage, for which the legislation requires that they be sold during the "use by date" or "sell by date", but it is also valid for the upper stages of the chain, for which the contractual terms require that the products reach the lower stage of the SC with at least 60–70% of their initial SL (see Garrone et al., 2012). This is true even for fresh products like meat, fish, fruits and vegetables. Having an uncertain SL, the decay of the SL is to be monitored, especially if it is short. Thus, the author proposes to design new SC coordination models, planning and replenishment strategies for the minimization of the F-W/L function, taking into account the perishability of products in terms of SL and the SL-dependent demand, in cases in which the exogenous variables have both a deterministic and a stochastic behaviour. The possibility of including information about the SL in logistic SC optimization models requires that such a variable be monitored. This can be done by considering mathematical models and technologies, which enable the assessment and monitoring of the SL. In this context, the introduction of these technologies is to be investigated, by considering both the fixed and operating costs joined to the technological investments that are needed. Therefore, the affordability of SL-based optimization models is to be proven. These models will allow the prevention/minimization of the wasted products; in fact, the real-time detection of the residual quality of products will enable their early withdrawal, and the possibility of sending them to alternative destinations. However, the affordability of this approach requires that the policies that push the SC actors to privilege the donation of food be investigated, and that incentives and penalty schemes for the achievement of a common benefit (SC coordination) leading to better results as compared to policy of fiscal donations today enforced, be determined. Finally, even pric-

Please cite this article in press as: Muriana, C. A focus on the state of the art of food waste/losses issue and suggestions for future researches. Waste Management (2017), http://dx.doi.org/10.1016/j.wasman.2017.06.047