Traceability performance of peaches supply network

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Abstract

The traceability allows, for each product, to sketch the manufacturing process through a system documentary, enabling to identify the operational structures involved, the products and the lots, to define the flows of production, packaging and distribution. Some researchers investigate the traceability within the firm, but little work has been carried out on the investigation of the traceability system over the whole supply chain.

The supply-chain of fresh fruit produce has many links: producer/grower, warehouse, packing centre, distribution centre, retailers and finally the consumer. Each of these is a system itself that interacts with the other components of the supply-chain. The non-conformity could occur in each of these links, and could be monitored in any of the links.

When a non-conformity occurs, the time to recall the product depends on many factors: lot size, the lead time for information spreading from link to link, product transit time among links, product storage procedures and times, the point in the supply chain where the problem occurred, and the point where is detected. To study with a system approach different scenarios for the recall procedure the authors realised a discrete event dynamic simulation model using Extendsim®. The case study is related to peaches distribution to assess the traceability performance of a supply chain during recall process.

The model has activities typical of the supply chain such as transport, storage and packing. For each traceable unit (TU) defined by the user at the beginning, the model record all activities on a single item. Also, the inspection activity could operate in different modalities to improve the non-conformity found. Different methods and logistic solutions are compared to see the performance of the supply chain to recall products with some non-conformities.

The model is connected to SQL database to ensure data input and result collection easy to elaborate. The model trace single items, even if they are packed together on the pallet, or they are purchased as a single item.

In the paper is described the model framework and one practical example.

Keywords: Traceability, Logistics, Dynamic simulation

1 Introduction

Nowadays consumers and public opinion are increasingly focused of the implications of nutrition and health, and accordingly on environmental sustainability. This trend is more evident in developed countries but also in emerging markets. Policy makers respond to these needs by imposing more restrictive production standards. As a consequence, the demand for traceable and certified food products has an even more important role (Goedde et al. 2015).

The traceability allows, for each product, to sketch the manufacturing process through a system documentary, enabling to identify the operational structures involved, the products and the lots, to define the flows of production, packaging and distribution.

The traceability system could be used as a risk management tool, providing easy information retrieval, cost reduction in product recall and lowering consumer concern. In fact, in case of public product recalls, the supply chain should act quickly, reliably and accurately (Dupuy et al. 2005; Heyder et al. 2010).

Public product recalls pose a major threat to food manufacturers, and the performance of the traceability system during this process is influenced by logistics factors: lot size, batch mixing, information lead time, product transit time, storage procedures and locations. Batch mixing and lot size directly influence the cost of the recall. For this reason, has been investigated for different categories of agro-food processes like grain production (Berruto & Busato 2008) fruit packaging (Riden & Bollen 2007; Bollen et al. 2007), sausage production (Dupuy et al. 2005), milk and cheese production (Skoglund & Dejmek 2007).

Simulation models were used for the maximisation of the benefits arising from capital investments in food preservation facilities considering an uncertain demand and production. An example is a model developed by Maia et al.(1997) which can select the best design, between the harvest and the final market, for the postharvest handling of fresh vegetable crops.

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Some researchers investigate the traceability within the firm, but little work has been carried out on the investigation of the traceability system over the whole supply chain. This integration could lead up to several advantages, for instance, the performance in the tracking and tracing procedures could be improved sharing information and knowledge along the chain (Busato et al. 2007; Theuvsen et al. 2004). Several research projects focused on the application of IT technologies to improve the effectiveness of the tracking and tracing management along the chain (Bollen et al. 2007; Doluschitz et al. 2010).

Furthermore, considering the supply chain scale, another significant improvement could be achieved through the use of system approach to investigate all the factors together. For this purpose the discrete event simulation could be applied (Berruto & Busato 2008; Bollen et al. 2007).

Busato and Berruto (2006) developed the FruitGame, a library of customs blocks, dedicated to the simulation of a supply chain of fruits and vegetables. The library provided specific supply chain performance indicators (Busato et al. 2007; Prussia & Mosqueda 2006). However, did not implement the tracing the history of each item and for this reason is not appropriate to simulate the product recall.

The logistics of the food supply chain has the main purpose of sell perishable food to the consumers before than the deterioration processes occurs, to maximize profit even granting high food quality and safety (Wang & Li 2012).

Fresh commodities are characterised by short shelf life and by susceptibility from physiological breakdown due to natural ripening processes, temperature and physical damage, water loss, or invasion by microorganisms. The shelf life of food products is usually prejudiced by: high temperature and humidity, potential interactions between product constituents, narrow time windows for product deliveries, high customer expectations, and low-profit margins. These factors make food distribution management a challenging area that, only in recent times, has started to be considered in the operations management literature (Akkerman et al. 2010).

The aim of the study was the creation of a discrete event simulation model, with the implementation of a custom blocks library, capable of simulating the products recall along the supply chain. The library incorporated performance indicators to assess operation, logistic and product costs when a product recall occurs.

2 Material and method

The discrete event simulation models embed the main features required to simulate a system: complexity, interactivity, and dynamicity. These models allow tracing a single item or a batch of items in the food supply chain because each item has its attributes and follow the flow of the system.

To simulate a real system, the objects moving in the model mostly are stored in a queue waiting for some activities. Therefore the main components of the model will be the queue blocks and the activity blocks. In this type of models the time steps are determined by the events happening in the system. Hence the event modifies a state variable of the model or an item attribute.

The simulation model was developed using the ExtendSim® programming environment (Imagine That Corporation, San Jose, CA, USA). ExtendSim is a professional and powerful tool for simulating processes. Particularly, this tool helps to understand complex systems and produce better results faster. In fact, these models provide very nice results when there is a need to evaluate complex chains or networks.

The entities move from one block to the next, within the model, through connection lines. Groups of blocks can be pooled into hierarchical blocks (H-blocks) with unlimited nesting layers (Krahl 2001). This approach allows the development of models with several degrees of detail, in function of the objectives to be reached with the simulation study (Busato & Berruto 2006).

With simulation models users can enhance system operations, explore the potential effects of modifications in actual systems, evaluate ideas and identify inefficiencies, comprehend why observed events happen and evaluate integrity and feasibility levels of plans (Busato & Berruto 2016; Busato 2015).

The relevance of every traceability system parameter varies for each link (Busato & Berruto 2009). In the discrete event model, these parameters depend on how is managed the flow of product and information along the chain, and they characterise the recall process performance.

When a non-conformity occurs, the time to recall the product depends on many factors: lot size, the lead time for information spreading from link to link, product transit time among links, product storage procedures and times, the point in the supply chain where the problem occurred, and the point where is detected. To study with a system approach different scenarios for the recall procedure the authors realised a discrete event dynamic simulation model using Extendsim®.

The model has activities typical of the supply chain such as transport, storage and packing. For each traceable unit (TU) defined by the user at the beginning, the model record all activities on a single item. Also, the inspection activity could operate in different modalities to improve the non-conformity found. Different methods and logistic solutions are compared to see the performance of the supply chain to recall products with some non-conformities.

The model trace single items, even if they are packed together on the pallet, or they are purchased as a single item. To simulate the recall process with a discrete event model, it was implemented a library of blocks that describe the tracking and tracing activities of the produce, that could be a single item or a batch. Batch represent in the simulation a group of items, that act as a single item in the model until unbatch occurs. In a specific point of the model, the fruits are batched together, for instance when they are loaded on the truck, or stocked on a pallet, therefore the unit to be moved changes in the batch (a joint group of fruits items) itself.

2.1 The simulation model

The simulation model developed represents a hypothetical fresh peaches supply chain, and during the simulation, a random quantity of peaches are generated with quality/safety unconformity.

Figure 1 illustrates the supply chain structure as shown in the developed Extendsim® model; below is described the structure above by segmenting it into sections in order to explain it more clearly.

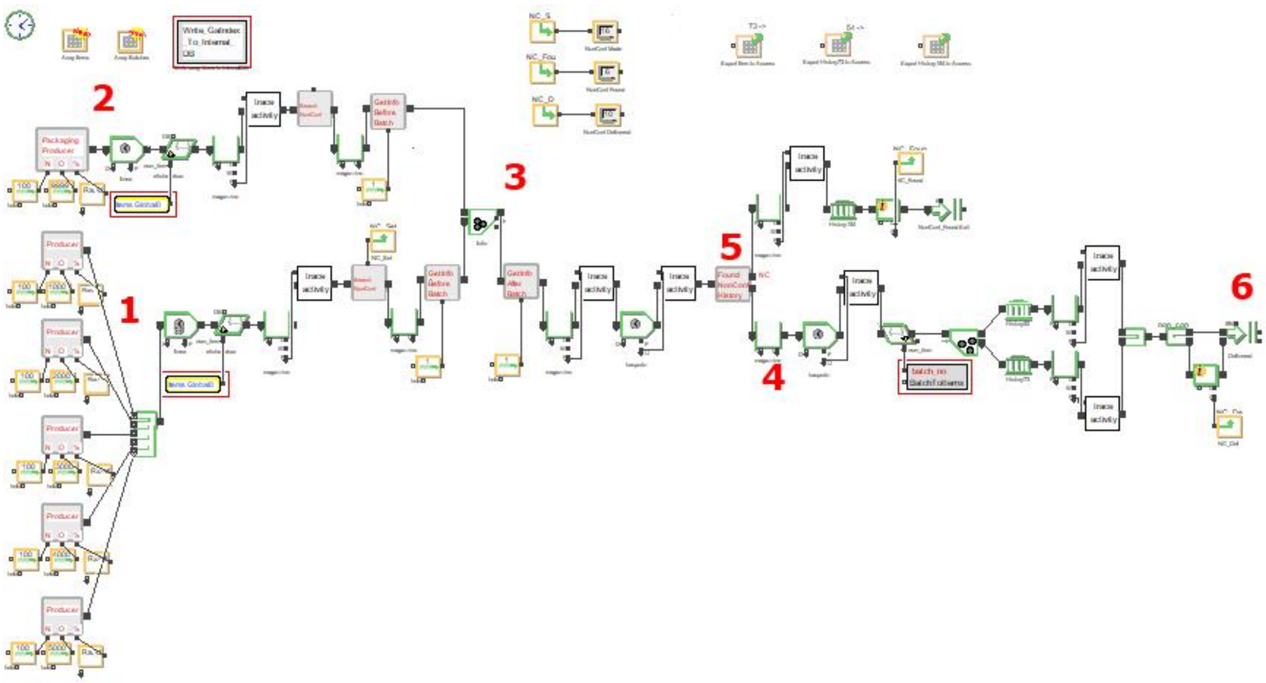

Figure 1 - overview of simulation model structure

A small supply chain was simulated to show the ability of the proposed library to track single items and batches. A group of blocks represents each link of the supply chain. The lines that connect the blocks represent the flow of product or the flow of information.

In detail, the simulated chain considers five peaches producers (point 1) and one packaging producer (point 2). In point 3 of Figure 1 the produce #1 (peaches) and #2 (packaging) are batched in item #3 (pallet of peaches) and transported to the wholesaler (point 4). Before the warehouse, the pallets with non-conformity (they contain at least one peach with quality/safety unconformity) are rejected (point 5). Finally, the produce #1 and #2 are unbatched and shipped to a distribution centre (Point 6).

3 Case study

The following case study shows an example of the potentiality of the realised discrete event dynamic simulation model. This case study is related to peaches distribution to assess the traceability performance of a supply chain during recall process.

Table 1 shows part of the results obtained at the end of a simulation run. The second column reports the *Item number*, which at run start refers respectively to a pallet if the item origin is 9999 or to peach boxes if the item origin is 1000, 2000, 3000, 4000 or 5000 (these values represents the five different producers origin). During firsts run steps the *item origin* of every *item* remains unchanged; so the *Item destination* [IND] (third array column) matches the *Item origin* [INO]. Since the items preserve their uniqueness and carry out activities like transport (*Activity* block) and *storage* (Queue block) such as unique items, their identity in the simulation do not change at this stage.

Table 1 - Extract of *array items during the case study*

Step	**INO(1)**	**IND(2)**	**AB(3)**	**PO(4)**	**Simulated Time**	**NC(5)**	**NC_Found(6)**
1	1	1	316	9999	1	0	0
2	2	2	44	3000	1	0	0
3	3	3	44	3000	1	0	0
4	4	4	44	3000	1	0	0
5	5	5	44	3000	1	0	0
6	6	6	44	3000	1	0	0
7	**1**	**7**	0	9999	1	0	0
8	**2**	**7**	0	3000	1	0	0
9	**3**	**7**	0	3000	1	0	0
10	**4**	**7**	0	3000	1	0	0
11	**5**	**7**	0	3000	1	0	0
12	**6**	**7**	0	3000	1	0	0
13	7	7	622	-	1	0	0
14	8	8	316	9999	2	0	0
15	9	9	44	4000	2	0	0
16	10	10	44	5000	2	0	0
17	11	11	44	1000	2	0	0
18	12	12	44	2000	2	0	0
19	13	13	44	3000	2	0	0
20	8	14	0	9999	2	0	0
21	9	14	0	4000	2	0	0
22	10	14	0	5000	2	0	0
23	11	14	0	1000	2	0	0
24	12	14	0	2000	2	0	0
25	13	14	0	3000	2	0	0

(1) INO – *Item Number Origin*, indicated as *Item_origin* in the text

(2) IND – *Item Number Destination*, indicated as *Item_destination* in the text

(3) AB – *Activity Block*

(4) PO – Product origin - Producer

(5) NC – Non-conformity: 1=non-conform peach, 0 = conform peach

(6) NC Found – Non-conform peach detected in the simulation, 1=detected, 0= undetected

In the step #7 to #12 items 1 to 6 are batched together to form a unique item (#7). After this point, they will move in the simulation as one item, until the batch is not divided again in small quantities (e.g. the original items). Because we know the composition of this batch, we can trace all the activities occurring to a batch of items (e.g. box of peaches on the pallet) with the same level of information as the item was travelling in the simulation as a single item. With this detail in the simulation, we can simulate the performance of the detection system when NC items travel through the simulation, and also simulate, for each single item, activities occurred, batch and unbatch activities and so on.

The array extract shown in Table 2 reports items that have been generated as non-conform; among the reported items only # 500, coming from producer 1000, has been rejected in the studied scenario. The other 5 items were not detected, so they were distributed along the chain until reaching their final destination.

Table 2 - Extract of *items* with non-conformity

INO[(1)]	**IND**[(2)]	**PO**[(3)]	**NC**[(4)]	**NC_Found**[(5)]
66	70	5000	1	0
209	212	1000	1	0
434	440	4000	1	0
492	496	5000	1	0
500	503	1000	**1**	**1**
538	539	3000	1	0

(1) INO – *Item Number Origin*, indicated as *Item_origin* in the text

(2) IND – *Item Number Destination*, indicated as *Item_destination* in the text

(3) PO – Product origin - Producer

(4) NC – Non-conformity: 1=non-conform peach, 0 = conform peach

(5) NC Found – Non-conform peach detected in the simulation, 1=detected, 0= undetected

Table 3 reports the item # 500 tracing process result. We can see this item was found and expelled from the simulation, and we know what nodes the item (e.g. a single box of peaches) touched of simulation network. In this case, in the activity Block 426, representing the defect detection, the single item #500 is being found and exits from the simulation. This exit occurs about 12 hours from simulation beginning (711 minutes), while the item was generated at minute 44 of the simulated time. So the item stayed 640 min in the simulation before being detected.

Table 3 – Non-conform item tracing process

INO[(1)]	**IND**[(2)]	**AB**[(3)]	**PO**[(4)]	**Simulated Time**	**NC**[(5)]	**NC_Found**[(6)]
500	**500**	44	1000	71	0	0
500	503	0	1000	71	1	1
503	**500**	-	-	711	0	0
500	**500**	426	1000	711	1	1

(1) INO – *Item Number Origin*, indicated as *Item_origin* in the text

(2) IND – *Item Number Destination*, indicated as *Item_destination* in the text

(3) AB – *Activity Block*

(4) PO – Product origin - Producer

(5) NC – Non-conformity: 1=non-conform peach, 0 = conform peach

(6) NC Found – Non-conform peach detected in the simulation, 1=detected, 0= undetected

In addition to the showed case study, the proposed simulation model is set to evaluate distribution costs and shelf life for single items in the system (e.g. peaches packed one by one versus peaches shipped in pallets, local sourcing of produce vs long distance delivery, change of transportation systems).

Future work is made to tackle more performance indexes inside the models, to exploit functions that could reveal in detail the logistic costs for each option considered. The system will allow in the future to compute Activity Based Costs of the supply chain.

4 Conclusions

The proposed simulation model with custom libraries allows for complete tracking and tracing activities along the supply chain, for single produce or a batch, and is suitable to model the distribution of any fresh food produce. This discrete event simulation with traceability is the starting point for a detailed calculation of warehouse and transport costs along the whole chain. Also, the model could predict the shelf life of perishable items in the systems.

The simulation is the best suitable method to compare complex networks without excessive model simplification required by optimisation tools. In particular, for the traceability, will allow investigating transportation lead time effect.

With the built library will be possible to expand the network representing the real distribution network.

The use of this type of libraries significantly expand the use of discrete event simulation also for the preventive analysis of tracking and tracing procedures. In detail, it will allow comparing also other aspects of the distribution systems, performance regarding time, costs, emissions and waste that characterise the agro-food chain.

References

Akkerman, R., Farahani, P. & Grunow, M., 2010. Quality, safety and sustainability in food distribution: A review of quantitative operations management approaches and challenges. *OR Spectrum*, 32(4), pp.863–904.

Berruto, R. & Busato, P., 2008. Modeling the Impact of Traceability on Harvest and Transport Operations of Rice Crops. In *Proceedings of the Fourth International Symposium on Applications of Modelling as an Innovative Technology in the Agri-Food-Chain*. Madrid, pp. 213–219.

Bollen, A.F., Riden, C.P. & Cox, N.R., 2007. Agricultural supply system traceability, Part I: Role of packing procedures and effects of fruit mixing. *Biosystems Engineering*, 98(4), pp.391–400.

Busato, P., 2015. A simulation model for a rice-harvesting chain. *Biosystems Engineering*, 129, pp.149–159.

Busato, P. & Berruto, R., 2006. FruitGame: Simulation model to study the supply Chain logistics for fresh produce. In *Computers in Agriculture and Natural Resources - Proceedings of the 4th World Congress*. St. Joseph, MI: American Society of Agricultural and Biological Engineers, pp. 488–493.

Busato, P. & Berruto, R., 2016. Minimising manpower in rice harvesting and transportation operations. *Biosystems Engineering*, 151, pp.435–445.

Busato, P. & Berruto, R., 2009. Use of Simulation Models to Study the Dynamic of Recall of Non-Conform Perishable Produce Through the Supply Chain U. R. M. Fritz G. Schiefer, ed. *3nd International European Forum on System Dynamics and Innovation in Food Networks*, I, pp.455–463.

Busato, P., Berruto, R. & Brandimarte, P., 2007. FruitGame: a Simulation Tool to Evaluate Supply Chain Logistics and the Effects of Information Sharing for Fresh Produce. In *5th Efita-WCCA Conference*. Glasgow, UK.

Doluschitz, R., Engler, B. & Hoffmann, C., 2010. Quality assurance and traceability of foods of animal origin: Major findings from the research project IT FoodTrace. *Journal fur Verbraucherschutz und Lebensmittelsicherheit*, 5(1), pp.11–19.

Dupuy, C., Botta-Genoulaz, V. & Guinet, A., 2005. Batch dispersion model to optimise traceability in food industry. *Journal of Food Engineering*, 70(3), pp.333–339.

Goedde, L., Horil, M. & Sanghvi, S., 2015. Pursuing the global opportunity in food and agribusiness. *Mckinsey Quarterly*. Available at: http://www.mckinsey.com/insights/Food_Agriculture/ Pursuing_the_global_opportunity_in_food_and_agribusiness?cid=other-eml-alt-mip-mck-oth-1507.

Heyder, M., Hespos, T.H. & Theuvsen, L., 2010. Agribusiness Firm Reactions to Regulations : The Case of Investments in Traceability Systems. *International Journal on Food System Dynamics*, 2(2), pp.133–142.

Hu, Z. et al., 2009. Modeling method of traceability system based on information flow in meat food supply chain. *WSEAS Transactions on Information Science and Applications*, 6(7), pp.1094–1103.

Krahl, D., 2001. Extend: the Extend simulation environment. In *Proceedings of the 2001 Winter Simulation Conference*. pp. 217–225.

Maia, L.O.A., Lago, R.A. & Qassim, R.Y., 1997. Selection of postharvest technology routes by mixed-integer linear programming. *International Journal of Production Economics*, 49(2), pp.85–90.

Prussia, S.E. & Mosqueda, M.R.P., 2006. Systems Thinking for Food Supply Chains: Fresh Produce Applications. *Acta Horticulturae*, (712), pp.91–104.

Riden, C.P. & Bollen, A.F., 2007. Agricultural supply system traceability, Part II: Implications of packhouse processing transformations. *Biosystems Engineering*, 98(4), pp.401–410.

Skoglund, T. & Dejmek, P., 2007. Fuzzy traceability: A process simulation derived extension of the traceability concept in continuous food processing. *Food and Bioproducts Processing*, 85(4 C), pp.354–359.

Theuvsen, L. et al., 2004. Transparency in netchains as an organizational phenomenon : exploring the role of interdependencies. In *EFITA 2003 conference*. pp. 125–138.

Wang, X. & Li, D., 2012. A dynamic product quality evaluation based pricing model for perishable food supply chains. *Omega*, 40(6), pp.906–917.