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Review of the application of System Dynamics to problems in food supply chains

Sepúlveda Estay, Daniel Alberto; Pankaj, Gokul

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Conference Paper

Gokul Pankaj
Technical University of Denmark
s181359@student.dtu.dk

Daniel Sepulveda Estay, PhD
Technical University of Denmark
dasep@dtu.dk

Abstract

With an increasing population in a world with limited resources, maximisation of food production has become a key metric for industries across the globe. However, distribution problems have led food wastage also increasing as an unexpected and undesirable consequence of this search for food production efficiency. Growing fears of food safety have called for the need for application of innovative concepts that consider the systems where these issues arise, for effective management of Food Supply Chains. In order to understand and manage this problem beyond traditional optimization techniques, this paper aims to understand the application of System Dynamics (SD) as a tool for the management of Food Supply Chains (FSC). By using a structured literature review (SLR) this paper gathers extant scientific literature in order to describe the use of System Dynamics (SD) as a problem-solving tool beyond its traditional use as a simulation tool in FSC Management. This research provides evidence for the current use of SD in FSC for testing strategic decisions, operational problems and various what-if scenario analysis, beyond traditional FSC problems such as Bullwhip effect, Inventory and Process Control. Additionally, this work argues for avenues of future research for the use of SD in FSCs.

Keywords: Supply Chain Management, System Dynamics, Food Supply Chains, Bullwhip Effect, What-If Scenarios, Food safety.

1. Introduction

Food supply has become an increasing topic of concern in the past few decades. Potentially, 9 billion people are expected to be consuming the resources of the planet by 2050, yet addressing the food needs of this growing world population with the current levels of food wastage seems like a herculean task. (Gharehgozli et al. 2017).

Supply Chain Management (SCM) has become crucial for companies and industries across the world to deal with the extensive globalization and myriad of associated problems with which supply chains have to deal with. Since its inception in the early 80s, numerous advancements have been made in SCM, improvements that are crucial also in the management of Food Supply chains (FSC).

Despite humans having managed to use SCM technology in FSCs to maximize the use of natural resources, hunger and malnutrition continue to be a mayor problem mainly in populations across third world countries. Associated technologies not only have accelerated the depletion of natural resources, but also derive in food wastage, becoming cause for important concern.

The effects of food wastage are many-fold. Almost one-third of the global food produce is discarded as waste (FAO 2016), having a carbon footprint of 3.3 billion tones of CO_2 equivalent of greenhouse gases into the atmosphere and consuming over 250 km3 of freshwater per year for the production and distribution of this food wastage, equivalent to three times the volume of Lake Geneva (FAO. 2013).

Consumable food wastage is higher in developed countries than in third world countries. A contributing factor to this claim is the change in trends of globalization, where organization is an important factor. More than 4 billion people live in urban areas globally, and since 2007, more people are living in urban areas than in rural areas, with this number expected to be of over two-thirds for the year 2050 (Ritchie and Roser 2020). Consumer behaviour in the urban world of fast food and processed sources alike have increased the requirement of Food Supply Chains to be be able to respond effectively to an increasingly variable and uncertain environment.

As a result, there is a need for effective design, implementation and management of sustainable food supply chains (FSC). Industrial dynamics was introduced in the 1960's for the modeling and simulation of production-distribution systems, evolving to the present discipline of System Dynamics (SD). Ever since its inception in 1960s, Forester's' work sparked an interest in the application of SD in various industries (Forrester 1994). Supply Chain Management (SCM) as a field, gained prominence in the early 1980s and has progressively seen the application of various technologies to make SCM more efficient and effective. Additionally, the use of System Dynamics as a Strategic and Operational tool has grown in popularity in the past few years (Reiner 2005).

System Dynamics (SD) as a method and philosophy, was derived from the industrial dynamics methodology introduced in the early 1960s by Jay Forrester (Forrester 1961), in order to use a systems perspective for understanding industrial problems, their behaviour over time, and their relationship with structure and policies (Forrester 1994).

Research has also mentioned that despite the virtues of system dynamics modelling, its use in FSC as an operational and/or strategic tool has not been evaluated to its potential, and that its use has a result been undervalued (Schimith et al. 2015). The results presented in this paper expect to clarify the extent of this misconception by pointing out and categorizing current areas of application and by mentioning areas of potential future research.

This paper is organized as follows. Section 2 describes the research questions that are addressed by this paper, section 3 describes the methodology that is used, section 4 describes findings about the use of SD in FSC, section 5 lays out the descriptive analysis of the findings, section 6 analyzes these findings thematically, and finally section 7 set out the conclusions of this work. At the end of the paper a Glossary with abbreviations is provided as a guide to the reader.

2. Research Question

A sustainable supply chain must be able to adapt to the risks posed by unforeseen changes in order to be considered as successful. The need for holistic modelling that capture the extended supply chain has been clearly recognized first by industry and recently by academia (Oliva and Revetria 2008).

Information about the problems that have so far been addressed through the use of SD in the Food Industry, about how has SD been applied to gain insights about these FSC problems, and about where SD been implemented, have the potential of contributing to understanding the current state as well as help propose future research opportunities.

As a result, the following research questions are addressed by this paper:

- What problems have so far been addressed through the use of SD in the Food Industry?
- How has SD been applied to gain insights about these FSC problems?, and
- Where has SD been implemented to FSC?

3. Methodology

In order to propose answers to these research questions, this paper develops reproducible research about the current scope of work and application of the SD Methodology in FSC. The data for this research is obtained from relevant published research in a process that has two main phases, first obtaining a number of relevant publications and then of extracting the information from that sample as required to answer the research questions. This is done through a Structured Literature Review (SLR) and then through a descriptive and thematic analysis respectively.

3.1. Structured Literature Review

The research methodology chosen is the structured literature review of published scientific papers, to gather the work in this arena of FSC Management, and a process of descriptive and thematic analysis of these papers in order to answer the research questions.

A SLR was performed to gather data for this scientific paper. A SLR is different from a narrative review as it follows a specific, reproducible procedure, consisting of a detailed description of all steps taken to identify, select, filter and analyse scientific literature, with the aim of reducing biases and increasing transparency (Tranfield et al. 2003). SLR is a method that has been use in a number of supply chain topics such as Management (Squire et al. 2006), Sustainability (Saenz et al. 2015), Agency theory (Fayezi et al. 2012), Green Supply Chain Management (Malviya and Kant 2015) and Risk (Prakash et al. 2017).

The SLR process followed in this paper is outlined in Figure **??**. This research uses Web of Science as the search engine to obtain the a set of papers complying with the search criteria. An advanced search was carried out using the keywords, “Supply Chain Management” AND ”System Dynamics” AND ”Food Industry”, resulting in a set of 80 papers. Thereafter, this set of papers was shortlisted to those containing research in the field of Food Industry. As a result, a final subset of 27 papers is obtained, and which forms the sample from which data is obtained to answer the research questions addressed in this paper. The SLR process followed in this paper is represented in Figure 1.

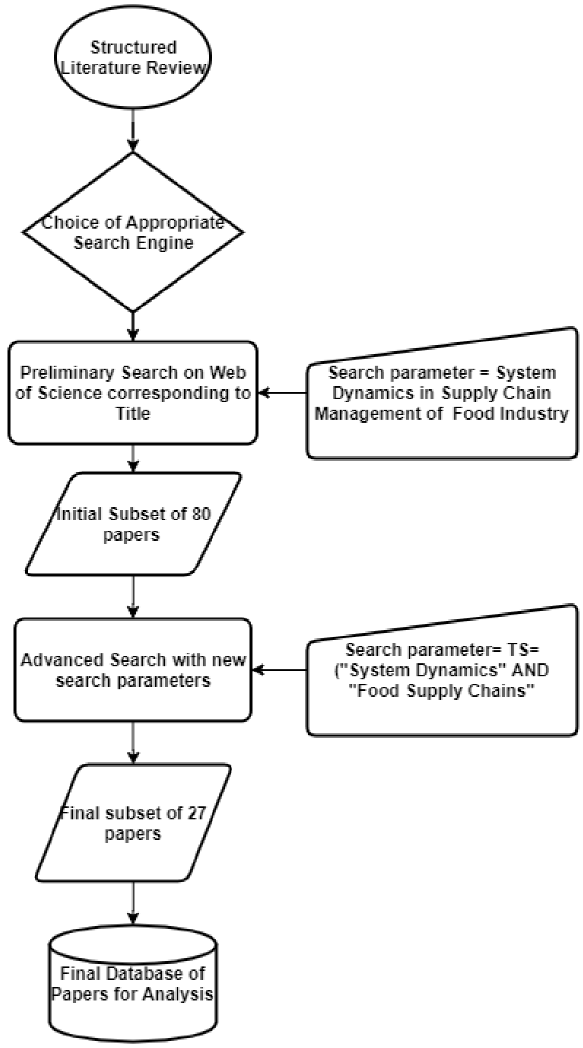

Figure 1. Flowchart describing the process of Structured Literature Review

3.2. Descriptive and thematic analysis

In order to simplify the data gathering process and to ensure judicious use of research time, the sample collection of scientific papers is read from the outside in (Pain 2016). The abstract is first scanned to seek relevance of the paper towards answering the research questions. Subsequently, if the abstract is deemed relevant the conclusion is studied. Only after the paper has passed these two filters, is the paper analysed meticulously according to the descriptive and thematic criteria.

The data collected is thereafter analysed according to a number of thematic analysis categories, such as the region of work and the kind of work carried out in the papers, and if these papers are either Operational or Tactical.

4. Results: Descriptive Analysis

An analysis of the paper sample, it can be seen that the application of SD in FSC has been limited. The sample set of papers published in this field is divided across a period of 8 years to facilitate data analysis. Although the research in this field seems to have decreased during the turn of the last decade, it is encouraging to see the growing interest in this field in this past few years. The number of papers published in the last two years have exceeded the range of work from the 2000s to 2008. Figure 2 illustrates the same and the graphical representation offers better understanding of the analysis.

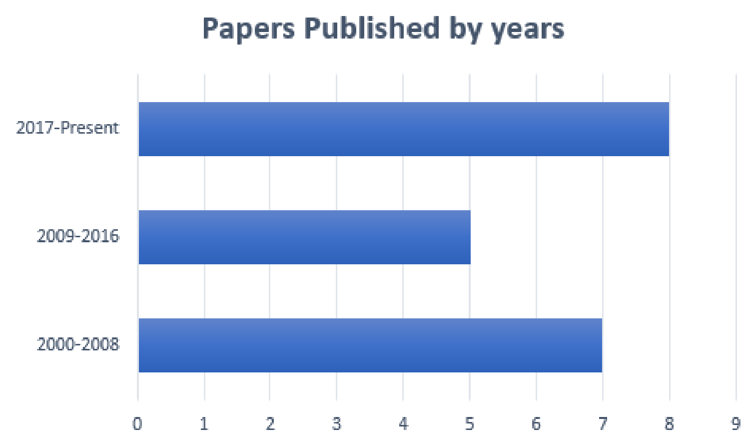

Figure 2. Papers published in sample - SD application in Food SC

Data collected from the sample papers was catalogued according to geographical region, year of publication and type of supply chain problem addressed.

Figure 3 represents the application of SD in Food SCs across the world, as found in the sample according to the countries where the work is prevalent at present. Developing countries such as Colombia, Brazil and Greece present a higher number of papers in the area than developed countries such as US and France.

Following the analysis of Application of SD in Food Scs by country, a list of journals that published this work was made on gathering data regarding the publications of these journals. Figure 4 describes the distribution of papers published in the area of research addressed in this paper. Of the 27 papers that formed the final collection of papers, 12 papers were found to be published in Elsevier Science Journal under different headers, Elsevier Science journal has aggregated work from different parts of the world and this is evident in the data collected as, the papers published in this journal are not restricted to one region. Unlike Elsevier Science Journal, Revista Facultad De Ingenieria contains work carried out by papers published in South America. Similar journals that have aggregated scientific work in the research topic at hand are:

1. Ole Soskin Portal
2. Journal of Industrial Engineering and Management
3. International Journal on Food System Dynamics

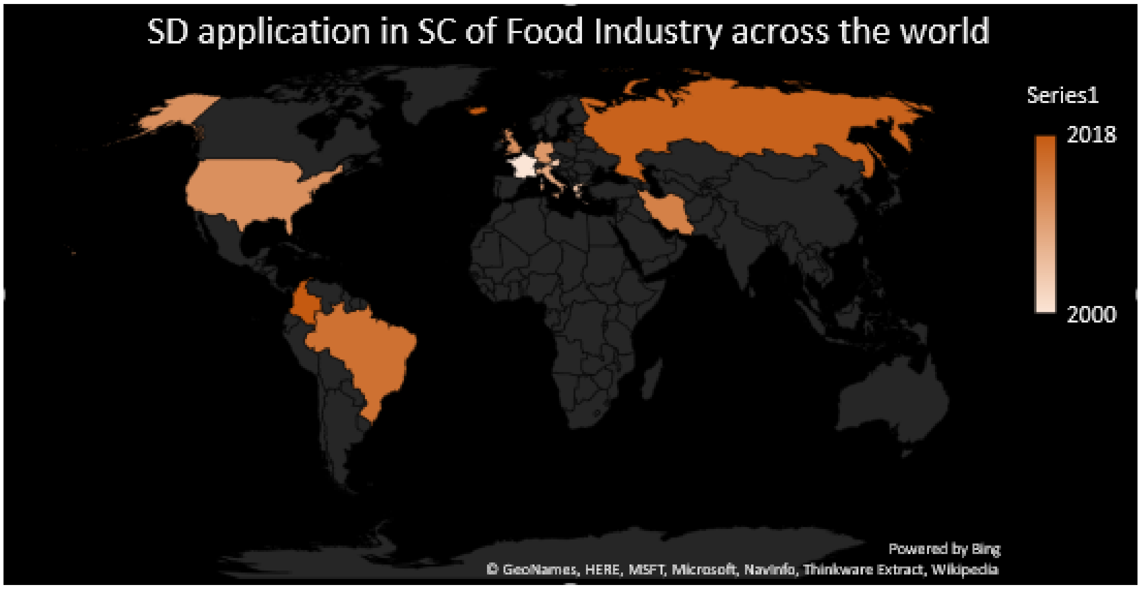

Figure 3. SD application in Food SC by countries across the planet.

The problems in the papers analysed also point towards the research spreading to larger parts of the world. As discussed in the earlier sections, the data holds evidence for the globalization of food supply chains, and this leads to the need for better handling of supply chains. An increased in this field in the recent past, reveals the need and necessity of better management of Food Supply Chains. System Dynamics popularity is a consequence of the same and further sections of the paper will elicit the problems addressed and the appropriateness of System Dynamics for the same.

There are certain problems that are characteristic to Food Supply Chains (Roth et al. 2008). Issues such as traceability are common to non food supply chains alike but are more prominent for, and have a greater impact on Supply Chain performance in this industry. These problems are distinguished as Operational and Strategic which are as shown in Table 1.

These problems are characteristic to Food Supply Chains and reflect the current scope of research prominent in this field. Following sections of the paper aims to clarify the manner in which System Dynamic modelling is used to understand and solve these problems in Food Supply Chains.

5. Results: Thematic Analysis

After the sample paper collection is identified through the use of SLR, our research develops an analysis of the problem areas in Food Supply Chains to which System Dynamic modelling was applied.

The problem areas were broadly divided into Operational and Strategic problems, albeit almost all the papers involved a What-If scenario analysis(Tako and Robinson 2012) that involved addressing both Operational(Minegishi and Thiel 2000 and Strategic aspects of Supply Chain Management(Georgiadis et al. 2005). In 45% of all the papers that were analysed, System Dynamics was

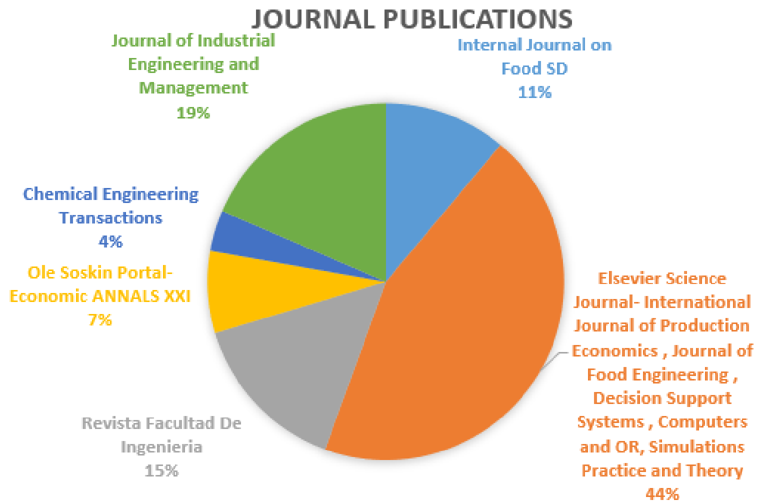

Figure 4. Distribution of Papers by Journals

Table 1. Food Supply Chain characteristic problems

Operational	**Strategic**
Lack of traceability in the Supply Chains (FAO 2016)	Safety and quality of products (Wang and Li 2012)
Communication between parties in the Supply Chain (FAO 2016)	Rising costs of Operation with Globalization (FAO 2016)
Determining decoupling points along the Value Chain (Reiner 2005)	Failure to track and control inventory in the echelons of the Supply Chain (Georgiadis et al. 2005)
	Policy making in Perishable Supply Chains (Teimoury et al. 2013)
	Capacity planning in Reverse Supply Chain (Vlachos et al. 2007)

not used as a stand-alone tool, and SD is used as a What-If analysis tool to address policy making and operational problems. The distribution of papers are as shown below in Figure 5.

After understanding the current scope of work and topics being addressed by System Dynamics, the next aspect of research focuses on the appropriateness of the tool in dealing with the said problems in Food SCs.

Food Supply Chains are more complex to model than a conventional Supply Chain given the effect of globalization (Teimoury et al. 2013), and analytical or optimization models to address operational or strategic issues are cumbersome tasks. Additionally, it is not possible to capture the behavioural aspects of the Supply Chains.

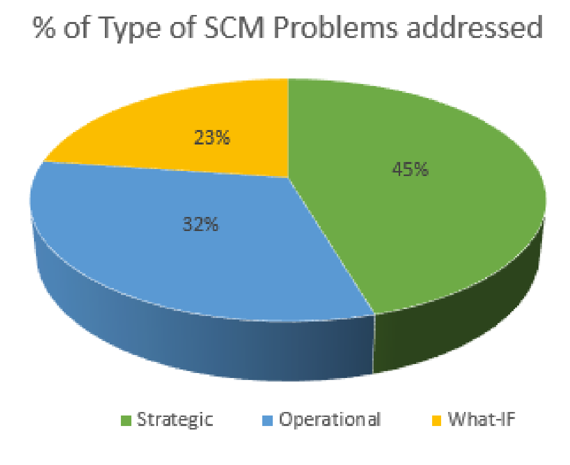

Figure 5. Percentage of Type of SCM problems addressed.

The biggest advantage of using System Dynamics is the requirement of low specificity and volumes of data. Unlike other optimization and simulation techniques, System Dynamics can be run with low specificity of data and deliver insights and actionable results.

SD philosophy enables the user to create Stock and Flow diagrams that represent and quantify feedback loops that track the behavioural aspects of the entities considered in the model. Another aspect of SD modelling in Food SCs is that it could be used in intermediate stages of planning to visualize the effect of policies across the value chain. Evidence suggests that SC is also used for analysing Supply Chain Structure, Replenishment control Policies, Supply Chain Optimisation and Bullwhip effect (Georgiadis et al. 2005). Use of hybrid models combining Discrete Event Simulation and System Dynamic is also gaining popularity in Food SCs (Tako and Robinson 2012).

From the subset of papers, System Dynamics' application in Food Supply Chains could be broadly divided into the following:

- **SD as a simulation tool-** System Dynamics more often than not used as a simulation tool in the food industry (Tako and Robinson 2012). Much like the application of Discrete Event Simulation to simulate various scenarios, SD has been traditionally employed to serve similar purposes. DES is used for tactical and operational problems, where as SD has been used by managers for Strategic purposes to evaluate behavioural interactions between entities across the chain. In Food Supply Chains, SD is employed to model issues regarding information sharing, bullwhip effect and Inventory planning/ management.
- **Behavioural and What-If Analysis-** Majority of the applications of SD involves a what-if analysis that simulates and visualizes the plausibility of various policies in a dynamic environment. This is of particular use in Food Supply Chain since there is a constant need for policy changes due to the ever-changing environment surrounding the Supply Chains. In case of Perishable fruit and vegetable Supply Chains, it is important to understand the complexity involved in modelling the systems. SD is a useful tool that is far more easier to work with than an analytical model (Teimoury et al. 2013). A simulation of this sort could be used to

understand the interactions between Supply, Demand and Price in a constrained agricultural Supply Chain.

- **Strategic issues and Policy making-** Time and again SD has been applied to identify the important feedbacks that may arise, which makes it ideal for Strategic Supply Chain Management (Georgiadis et al. 2005).It is important to understand that Supply Chains are an extended enterprise, which includes vendors, suppliers, manufacturers and retailers alike, those of who could be modelled in a Stock and Flow diagram conveniently. Besides direct applications, SD is found to have been used to simulate and understand the implications of certain policies at different horizons of decision (Minegishi and Thiel 2000). Minegishi & Thiel (2000) have perfectly captured the use of SD as a strategic tool. They used it to study the complex logistics behaviour of the poultry industry.
- **Operational and Tactical Problems-** Operational problems in Supply Chains are spread all over the place. SD is however applied to solve optimization problems such as maximization of capacity utilization, maximization of market share, Design and planning of inventory levels and maximization of shelf life of perishable foods (Vlachos et al. 2007). Though the use of SD is limited in solving operational problems, research findings indicate that SD is often used as a supporting tool with other optimisation techniques (Teimoury et al. 2013). Teimoury, Nedaei, Ansari & Sabbaghi(2013) have developed the near perfect implementation of System Dynamics to solve different kind of problems in the Food Supply Chains. The model developed in their work clearly outlines the different strategies adopted to manage the operations in the upstream and downstream of the SC. The upstream in question in the French Food SC, the company is required to operate by adopting a material flow that is pulled by customer orders. On the downstream, in an irreducible time horizon, the company has to modify its production activities. Although the overall goal is the development of a strategy, the activities simulated are on the operational side of it.

A detailed and structure literature review provided valuable insights into the problems prevalent in Food Supply Chains. Current work on application of SD focuses on inventory decisions and policy development, Demand amplification, Supply Chain Integration and design, Capacity planning of reverse supply chains, bullwhip effect and inventory oscillations (Kumar and Nigmatullin 2011).This section of the paper aims to understand the actual problems targeted by and the method of application of SD in Food SCs. The general methodology in applying System Dynamics modelling involves i) understanding the system, ii)Identifying the stock and flows, iii) Identifying the feedback analysis with data, iv) Developing a causal loop diagram(CLD), v) Final model (Olafsdottir et al. 2018.). Olafsdottir, et al describe the learning loop that involves in creating a CLD for SC analysis.

Olaffsdottir and his team (Olafsdottir et al. 2018) developed a conceptual model to analyse the system dynamics in Food Supply Chains and networks to capture their resilience, integrity, sustainability and efficiency. This model is represented in Figure 6 Their work also involved Mapping food value chains, that enabled understanding the interactions between key stakeholders in the value chain who also control the performance of the system. Modelling Food Supply Chains through System Dynamics is a challenging task indeed, as it involves identifying feedback loops which one may never seem to think existed. These are often the ones that cause problems, tactically or strategically in the Supply Chain.

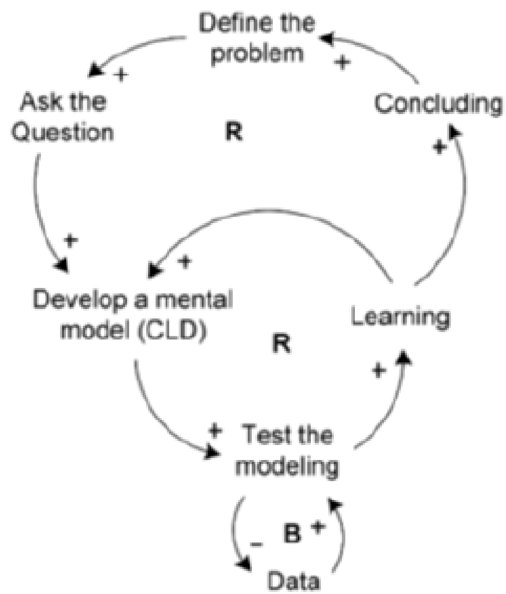

Figure 6. Learning loop in making a CLD (Olafsdottir et al. 2018)

5.1. Strategic Problems addressed by SD in Food SCs

Time and again it has been reiterated in this paper about the importance of the application of SD in tackling strategic problems in Food SCs. Besides the appropriateness of the tool, it is favoured in strategic decision making due to the results. An excerpt from Castro and Jaimes 2017' work shows how SD modelling can be used to structure the perishable food supply chain. Globalization in the Food Supply Chains means that for perishable food supply chains in Columbia, the emphasis on preserving the freshness of food has become more imminent than ever. This has forced the stakeholders to rethink the structure of their SCs (Castro and Jaimes 2017). A causal loop diagram for a PFSC in Columbia looks like the following:

By identifying the stock to be controlled, one can adjust the flow by formulating different hypothesis and test the behaviour of the same. For example, one can understand the implications of different SC structure such as Agile, Responsive, Lean and Flexible SCs. KPIs such as Demand Fulfilment, Waste Inventory and Lead times were used by Castro & Jaimes to measure the performance of the simulation results.

Apart from perishable food supply chains, Kumar & Nigmatullin's work (Kumar and Nigmatullin 2011) illustrates the use of System Dynamics to determine the decoupling point in Non-perishable Food Supply Chain. A SD model was developed to allow identification of critical components of the entire Supply Chain. This in turn was used to create an efficient and sustainable supply chain network. A useful takeaway from their work is the use of Ishikawa Diagram to develop the CLD for the FSC. It was used to determine the factors causing demand uncertainty. This eased the process of identifying the flows and feedback loops present in the system. The resulting model enabled

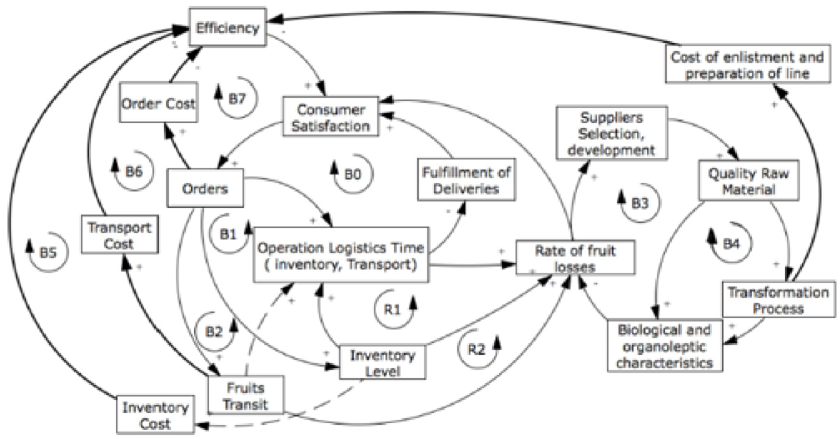

Figure 7. CLD describing the relationship between stocks in PFSC (Castro and Jaimes 2017)

the elimination of uncertainty and variability in demand which lead to reduced business costs and increased returns. Additionally, the number of dissatisfied customers plummeted and the brand image of the company in case improved, in turn increasing operational returns. Effect of strategies such as postponement or pushing the DCP along the downstream could also be tested by the model.

Almost all Strategic planning and implementation involve the simulation of certain operational improvements. It is not possible to clearly distinguish between the two, but topics involved in addressing operational problems through SD have been identified.

5.2. Operational Problems addressed by SD in FSC

A very common misconception is that SD modelling is not suitable in addressing operational problems (Tako and Robinson 2012). Despite that there is sufficient evidence from literature to suggest the contrary. Food chains incur great losses due to failures in their logistics systems.

Orjuela-Castro (Orjuela-Castro et al. 2017) addressed the impact of asymmetries in packaging on controlling the efficiency of inventories, transportation and product quality. The authors analysed the Supply Chain of Mangoes in Columbia. The Heterogeneity of the Colombian fruit chain actors' logistics practices offered a lot of ambiguity and variability that called for a need for control. Different kinds of packaging involved are simulated and the KPIs were monitored to determine the most efficient packaging practice. The simulation in this study also suggested the asymmetry of the packaging and repackaging between the actors negatively impacted the storage, transportation and quality of products. The model developed allowed the commissioners of the study to employ the best practices to standardize the operations of the Mango SC.

The aforementioned Stock and Flow diagram is a model developed for warehousing in a closed loop peach supply chain. Herrera et al., (Herrera et al. 2018 developed the model as represented in Figure 8 to perform a dynamic behaviour analysis of production capacity, traceability and recovery along the value chain. The results from the model explain the reason behind delay in waste recovery

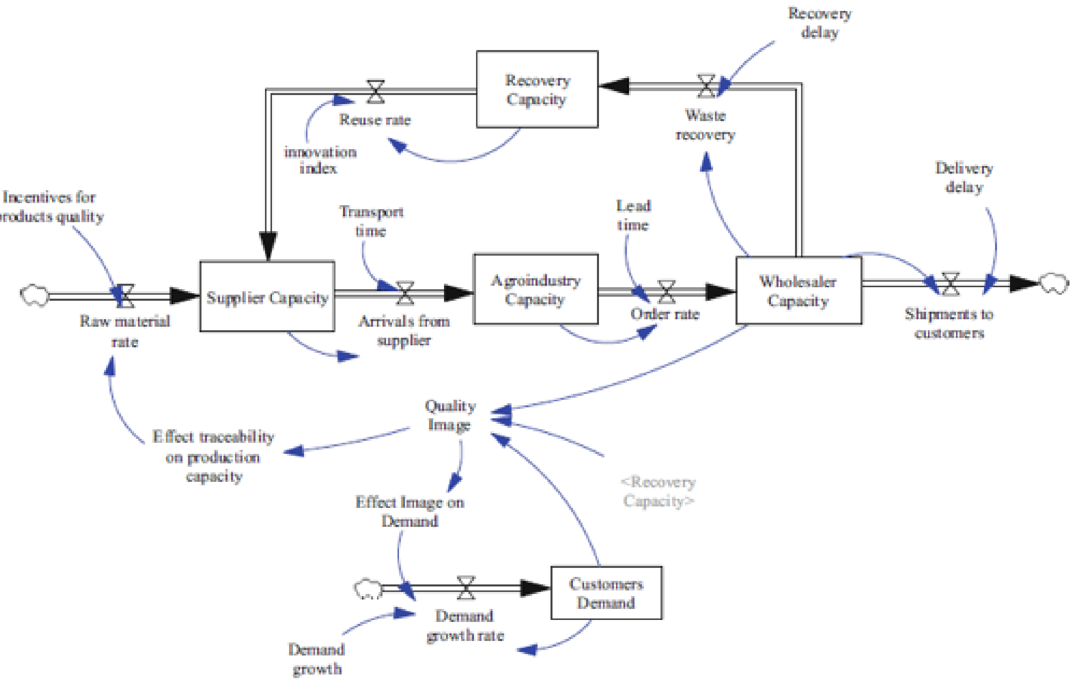

Figure 8. Closed loop SD model Food SC (Herrera et al. 2018)

and traceability, simultaneously suggesting optimum settings for the same. The model described contains three subsystems that constitute the entire supply chain. The first is the structure of customers demand, peach supply chain and recovery chain make up the remaining subsystems. Their work also gives insights into designing a sustainable supply chain. The resulting model enables the determination of best practices for traceability and recovery along the entire Supply Chain.

The use of simulation in operational problems differs in the aspect that the flows and feedback loops present in the system are affected directly to determine the best scenario, unlike strategic modelling where the strategies were manipulated to see the changes in the operations of the FSC.

6. Discussion

The descriptive and thematic analyses of sample papers in this research allow for a number of insights. This section mentions the most relevant insights and discuss their implications and derived future actions.

It is surprising to see the limited number of published scientific publications that apply SC methodology to understand and manage problems in FSCs. Our search by using the Web of Science search engine and thereafter applying exclusion criteria, delivered 27 articles, which allows for an analysis, somehow limited, yet representing the reality of this topic in literature. Our search can have been extended by using multiple search engines, and by scanning the sample's references for literature that is not necessarily found by search engines. This is a first research opportunity that results from this work.

The research shows two distinct types of food supply chains, perishable and non-perishable FSC, and the application of System Dynamics is similar in both Supply Chains. Castro & Jaimes (Castro and Jaimes 2017) describe the application of System Dynamics in Perishable Food Supply Chains (PFSC). For example, a System Dynamic model is proposed by Aung & Chang to test the impact of different structures of a PFSC on the logistic performance of the SC, and given that PFSCs are critical and distinct, requiring special attention (Aung and Chang 2014). Perishable foods such as meat, fruits and vegetables need refrigerating equipment throughout their supply chains to maintain the freshness of the products by keeping their bacteria content low as a result of the low temperature.

The publication of research of food supply chains by using SD is mainly concentrated in developing countries. The causes for this, as can be derived from the papers in the sample, have to do with the specific food supply chains that are addressed in the papers.

Oliva (Oliva and Revetria 2008) describes the use of a System Dynamic model to determine the advantages of using a Temperature monitors and RFIDs to monitor the temperature that the food has been exposed to, throughout its life. On the other hand, Minegishi & Thiel (Minegishi and Thiel 2000) modelled the complex logistic interactions of an integrated Non perishable food industry, using System Dynamics Methodology.

An additional reason for this not present in the papers could also be the use of other methods for the modelling and analysis of system dynamics in the food industry. This results the future research opportunity of addressing this knowledge gap to explore the different modeling techniques being used to understand the dynamics of food supply chains.

The application of System Dynamics to understand problems in Food Supply Chains is usually done alongside other methods such as Discrete Event Simulation(Kumar and Nigmatullin 2011) or Multi-Objective modelling(Tako and Robinson 2012) for best results. The use of SD includes what-if analyses and causal loop identification and description. This joint use of methods might reside in the insufficiently specific scope of the research papers, but also the very specific scenario simulation application of SD considered by those authors.

Some of the applications indicated by authors as SD, only amount to a network of quantified causality structures, as these have neither stocks nor feedback loops, and therefore are unable to represent dynamic behavior. SD has been found to be used alongside Multi-objective analysis(Teimoury et al. 2013) and just as a simulation tool to aid policy analysis in strategic supply chain management (Reiner 2005). Despite the intention of these authors to use SD as the tool to model appropriate behaviors, there is insufficient rigour in the creation of the models, their testing and their validation. The philosophy of System Dynamics outweighs its value as a simulation tool. The interactions between feedback loops and stocks and flows is what that makes System Dynamics unique, By disregarding the philosophy of SD, one might as well make use of other Simulation Programs to serve their purpose. Additionally, the publication of faulty SD models or of models which claim to use SD but do not, reveal important opportunities in the peer-review process, to effectively filter these defective papers before they are published. There is additional opportunity for future research about the types of mistakes that published models include, in order to improve training.

7. Conclusions

The data obtained offers useful insights into the peculiarities of FSCs and the challenges faced in the industry that limit the application of modelling tools. Despite this, the answers presented to the research questions proposed in this paper effectively identify potential areas of application of SD in Food SCs, highlights problems prevalent in FSCs and lays out the current scope of the use of SD in the Food Industry.

Based on the analysis of various simulation models found in published literature, the two main branches of problems in FSC targeted by SD modelling were found to be Strategic and Operational.

The paper provides evidence that, despite SD modelling methodology being more appropriate for policy making and strategic problems in FSC, this does not imply that SD modelling can not be employed as an operational tool, involving the standard steps traditionally required for simulation modelling through SD philosophy (Heyder et al. 2010).

Since SD models are deterministic, and variables used represent average values, SD is suitable while taking a distant perspective while simulating the system. On the other hand, SD models represent a dynamic view of the cause and effect relationship, and provides an ease of modelling attributed to low data requirements as compared to other simulation tools.

SD models are found to be useful in studying relationships between supply chain stages, as well as to analyse the effect of changing values for model variables. The overall objective for the use of SD modelling in FSC is obtaining parameters for the validation of models and identifying key drivers of performance, so as to make FSC resilient to changes. Vital decisions require accurate estimation of their consequences, and SD application to FSC can provide a glimpse into these consequences.

The philosophy of visualizing the Supply Chain as a collection of subsystems and identifying important feedback loops amongst the actors makes SD ideal for problem solving in Food Supply Chains. Insights obtained from the research include that SD modelling is not used in Food Supply Chains as a standalone tool. The analysis of the dynamics of the system can made easier by using Ishikawa's Diagram to identify all the feedback loops prevalent in the system. Any possibility of a What-If scenario analysis can be carried out with SD modelling (Holweg and Bicheno 2002).

Opportunities for future research derived from this work include identifying the common aspects of similar FSC to modularize and standardize the aplication of SD to certain FSC to extend its use for different Supply Chains. Certain issues such as demand variability, inventory management, bullwhip effect, cost maximization are common to all kinds of Supply Chains. By making SD models modular and thus more accessible, the popularity and utilization of System Dynamics framework would be enhanced in the SCM of Food Industries. Just like Python packages that are made to facilitate cross application of packages, generic and modular System Dynamics models could also be developed for problems that are recurring in Food Supply Chains.

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Glossary

CLD	Causal Loop Diagram
FSC	Food Supply Chain
PFSC	Perishable Food Supply Chain
SCM	Supply Chain Management
SD	System Dynamics
SLR	Structured Literature Review

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