Theoretical Economics Letters, 2023, 13, 1418-1433
https://www.scirp.org/journal/tel
ISSN Online: 2162-2086
ISSN Print: 2162-2078

Exploring the Use of Systems Dynamics for the Valuation of Freight Transport Time Changes

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How to cite this paper: Ramfou, I., & Sambracos, E. (2023). Exploring the Use of Systems Dynamics for the Valuation of Freight Transport Time Changes. *Theoretical Economics Letters, 13,* 1418-1433.
https://doi.org/10.4236/tel.2023.136080

Received: October 9, 2023
Accepted: December 8, 2023
Published: December 11, 2023

Abstract

This article aims to explore the use of System Dynamics modeling as a tool to assess the impact of changes in Freight Transport Time (FTTC) on transport companies. After conducting a thorough literature review, it became clear that there is no consensus on the appropriate methods used, and the estimates of freight travel time values vary significantly. The two primary tools currently employed in Benefit-Cost Analysis (BCA) to estimate the value that shippers and carriers place on FTTC are the Factor Cost and Willingness-to-Pay methods, akin to valuing travel time changes in passenger transport. However, due to the distinct characteristics of freight transport, traditional methods are less effective in accurately gauging FTTC values. In this paper, we adopt a methodological stance grounded in Systems Thinking. In contrast to existing methods, which primarily rely on event-oriented thinking and perceive freight transportation as an activity isolated from the broader company ecosystem, we consider the interconnections between freight transportation and other business operations. Lastly, to demonstrate the application of the Systems Thinking approach, we utilize Systems Dynamics modeling and simulation in a typical retail company that forms part of a traditional supply chain to determine the value of FTTC.

Keywords

Systems Thinking, Freight Transport Time, Systems Dynamics, Benefit-Cost Analysis, Supply Chain Management

1. Introduction

In an effort to rationalize expenses and satisfy customers so as to overcome increasing competitive pressures, transport using companies show a growing interest in managing freight transport time more efficiently and more effectively.

Freight transportation is an activity that spans organizational boundaries, encompassing shippers at the input side, and consignees at the output side (Lai et al., 2004). Rather than a separate service used from companies in order to respond to demand conditions, it is built into the supply chain complex system and associated with the effectiveness of value chains, thus facilitating the transformation of inputs into outputs and satisfying the needs of internal and external customers (Rowbotham et al., 2007; Rodrigue, 2020). Therefore, any improvement in freight transportation speed affecting either shipment or transshipment or in the overall degree of reliability is associated with more efficient value chains (Rodrigue, 2020).

Current statistics show that in the period between 2013 and 2017 national transport in the EU (63.5% of total transport) recorded a 9.9% hike, while cross-trade and cabotage transport (12.1% of total transport) recorded a considerable increase of 38.5% (EUROSTAT, 2019). Inevitably, the higher volume of freight transport, which is coupled with existing inland passenger car transport, is straining existing transportation infrastructure, thus leading to congestion and delays. As a result, transportation times are also prolonged, reducing transport time reliability and increasing cost for the users of the transportation system. Investments on transport initiatives, especially on transport infrastructure, are inherently capital-intensive since they require the commitment of a large number of financial resources. To ensure that their limited financial resources will be efficiently allocated, governments and funding organizations call for a careful assessment of the costs and potential benefits expected to ensue from specific transportation projects. Cost-Benefit Analysis (CBA) has been identified as the most important and widely accepted decision-making tool for the appraisal of investment decisions to assess the welfare change attributable to different alternatives (Veryard, 2017; EU, 2015; ITF, 2011; World Bank, 2004). Several authors (Zamparini and Reggiani, 2007; Shires and de Jong, 2009; Mackie, 2010) provide a discussion and meta analysis of empirical studies in freight transport and cost benefit analysis.

In CBA a reduction in travel times is viewed as hugely beneficial for freight transportation as it reduces per-trip driver and vehicle operation costs (EU, 2015). The factor cost method, however, does not consider second-order effects such as long term, reorganization effects which, according to Mohring and Williamson (1969) who first coined the term, refer to the adjustments that shippers make in their logistics configuration in response to lower (or increased) costs of freight transport resulting from lower (or increased) transport time. These adjustments may include, for example, sourcing from different suppliers, changing the size of the shipments and inventory levels to harvest benefits due to lean operation that may include fewer plants and/or warehouses, changes in the location of plants/warehouses, fleet rationalization in case of owned transport and number of employees to serve customer demand (US DOT, 2006). To identify and monetize benefits from such reorganization effects, the willingness-to-pay method is usually used.

Several authors however have criticized the fact that methods primarily used for transport modeling are mainly derived from passenger transport (De Jong, 2000; Massiani, 2003; Danielis et al., 2005). In the following paragraphs, we discuss in more detail the difficulties involved in safely deriving the value of FTTC for transport consuming companies. We then proceed to offer an alternative perspective based on a Systems Thinking approach that employs System Dynamics simulation modeling.

2. Current Methods for the Valuation of FTTC

Time is a source of competitive advantage for companies and increases a firm's value (defined as the difference between cash inflows and cash outflows) in two different ways: either directly, by contributing to the firm's achieving a higher market share and price (stemming from the firm's external configuration); or indirectly, through the widespread improvement of efficiency and productivity within the company (stemming from the firm's internal configuration) (Azzone and Masella, 1991). A reduction in transport time allows companies to expand their sourcing and selling market, therefore enabling them to seek low cost and/or better-quality suppliers and a larger customer base. In the latter case, firms benefit from higher market shares stemming from better responsiveness to customer needs, allowing for premium prices and translating to higher cash inflows. Therefore, a firm's willingness-to-pay for reduced transportation times may be justified by customer willingness-to-pay to have the goods available on time. Apart from market expansion, McKinnon (1995) also pointed out spatial concentration and tighter scheduling as a means for reducing cash outflows. Indeed, reduced transport times can allow firms to concentrate their production, warehouse, and distribution processes in a smaller number of locations, allowing them to take advantage of possible economies of scale. Tighter scheduling translates to reduced driver wage costs, which constitutes a large portion of transport costs.

Benefit-Cost Analysis is an analytical tool for measuring in money terms all the positive (benefits) and negative (costs) welfare effects of transportation projects to society, assessing whether or not the costs for the construction and operation of a project or the introduction of a policy can be justified by its positive outcomes and impacts over its lifespan. It is a microeconomic approach, facilitating the appraisal of a project and assessment of its impact on society as a whole, with the use of performance indicators that render it possible to develop a financial (use of Financial Net Present Value and Financial Rate of Return) as well as an economic analysis of the project (use of Economic Net Present Value and Economic Rate of Return), both of which help the firm to explore how desirable a project is from a financial and socio-economic perspective (EU, 2015). ITF (2011) identifies several challenges that fall into three broad categories: the relevance of information offered to decision-makers called on to plan their actions based on results; the practical limitations of forecasts and potential benefit calculations; and, finally, the effects of transport intervention when the theoretical assumptions of perfect competition and economies of scale do not apply.

Jones et al. (2014) have identified several weaknesses of CBA, arguing that CBA is only "as good as the assumptions or estimates that have been made for its inputs and calculations". Major flaws have to do with the demand forecast, which is usually overestimated; the estimation of costs, which are usually underestimated; the selected discount rate, the estimation of which is usually very difficult for projects with a long lifespan; the estimation of the value of time, which is usually derived from Stated Preference analysis; the residual value, which is usually overlooked or estimated using different ways; as well as the existence of regional, local and environmental factors that are difficult to monetize.

Despite the importance of transport time for transport using companies on the use of transport, few studies have considered the value of transport time changes in freight transport, and the majority of them have a clear focus on the producers of transportation and not on the demand side of transport, i.e., shippers. The dominant practice in freight transport research is to use data that come from contextual, highly customized Stated Preference computer interviews with carriers and shippers who are asked to compare pairs of transport time and cost alternatives and then analyzing the findings using logit models with linear utility functions. While this practice is widely used in passenger transportation and has received more attention from the community of transport economists, the value of time changes for freight lags far behind both regarding the availability of a widely recognized theoretical analysis and the number of empirical results available (Massiani, 2003). Several reasons for this could be identified, including:

- the separation between the decision-maker and the actual object of transportation: in passenger transportation, it is the traveler who decides while in freight transport the good transported cannot decide for itself (De Jong, 2000; Massiani, 2003);
- the heterogeneity of the shipments, which are likely to have a higher number of characteristics or attributes (size, value, etc.) thus resulting in the need for segmentation (De Jong, 2000; Massiani, 2003);
- the heterogeneity of shippers, which Boston Logistics Group (US DOT, 2006) has categorized into six groups depending on the mode of transport they use (LTL—small package—air, ship—railcar, truckload—intermodal), the strategy of their production (batch—cellular or flow—continuous), the order trigger (make to order, make to stock, make to plan, assemble to order or engineer to order) and supply chain coverage between the first tier supplier (raw material) and the final customer (end-user).
- the difficulty to uncover linking mechanisms between freight transport and business performance, since transportation is not an isolated activity but embedded in the complex web of interrelated activities of companies' supply

chain with a lot of tradeoffs existing between them (Sambracos and Ramfou, 2013, 2014, 2016);

- the need to ensure that double counting of benefits is avoided and that benefits due to savings in freight transport time are not lost in other parts of the logistics chain (EU, 2015).
- the difficulty to predict and monetize the long-term, second-order effects of transport changes on shippers (FHWA, 2001; US DOT, 2006);
- the scarcity of reliable and complete information in a context where confidentiality often matters, rendering the Stated Preference method inadequate to fully elicit the value of FTTS for transport users (De Jong, 2000; Massiani, 2003).

Freight transport is part of companies' complex supply chain systems and that is the key issue when trying to understand and value the effect of non-market impacts such as savings in transport time. Complex systems' behavior is dynamic and changes as their configuration shifts to achieve resilience following exogenous disturbances e.g. changes in transport time. Often, they behave in counterintuitive ways making it difficult to anticipate and assess the effects of decisions and policies. A careful analysis of complex system structures, at the right level of abstraction, yields significant insights about a system's behavior (Hawes and Reed, 2006; Herrera de Leon and Kopainsky, 2019).

Forrester (1961, 1980) argued that human decisions are based on their mental models that reflect their beliefs about the cause and effect networks that evolve in the real world (i.e., the structure, processes, and decisions within firms). Mental models refer to people's beliefs about the networks of causes and effects that form the system's structure as well as the boundary of the model and the time horizon they consider for the framing of a problem (Sterman, 2000). Forrester (1961, 1980), identified three types of data that mental models focus on: observations about the current structure of the system and the decisions that govern it, the actual behavior of the system and the expected behavior of the system following a disturbance. Although, the structure and current behavior of the system are usually well-documented research has shown that mental models are often erroneous and biased due to the lack of knowledge or even overconfidence of experts even regarding the current structure, existing decision processes, policies, and behavior of the interviewee or other actors. When people are asked to provide explanations about their beliefs and decisions, they provide accounts that are not always rational and may be based on unreliable prior medal models. This is due to bounded rationality because people's knowledge is incomplete, perceptions are selective, time is always a burden when it comes to decision making and the ability to process information is limited (Sterman, 2000, 2018). Morecroft (2015) pointed out that people tend to possess a linear event-oriented mindset that is simple and linear, action-oriented, and often myopic since it ignores feedback.

When it comes to anticipating the future behavior of the system, research has proved that the dynamic complexity of systems due to time delays, nonlinearities, and feedback loops as well as the limited information about the structure and operation of the system, silo mentalities, defensive routines, local resistance, private agendas, groupthink and silencing of individuals with minority views hinders people's understanding of the structure of complex systems and consequently their dynamics (Sterman, 2000, 2018).

To better understand the roots of complex system behaviors to safely predict them decision-makers must develop a solid grasp on System Thinking. The term System Thinking was penned by Richmond who pointed out that interdependency among systems and complexity requires decision-makers to share their knowledge and not just focus on their "piece of rock" (Richmond, 1991). Models can be created within which researchers can understand the structure of systems, rehearse new decisions and decision rules, and experiment with the use of simulations. Senge (1992) pointed out that feedback systems thinking is actually a "shift in mind" for organizations to understand the business systems within which they operate.

Based on these thoughts, we propose the use of System Dynamics modeling as a tool for mapping and understanding the structure of supply chains and the role of transportation in order to be able to anticipate how a change in transport time will affect the system's behavior and estimate its impact on the company's value.

3. Towards a New Approach for the Valuation of Freight Transport Time Changes

3.1. Systemic Approach

Our proposed framework is based on the methodological position of Systems Thinking. Systems thinking is defined as a "set of synergistic analytic skills used to improve the capability of identifying and understanding systems, predicting their behaviors, and devising modifications to them to produce desired effects" (Arnold and Wade, 2015: p. 675). Under this perspective, an organization can be better understood when is conceived as a system, a network of subsystems, and activities that interact and develop a web of connections that constitute a whole. The building block of systems thinking is that the system's structure (expressed as an influence or causal loop diagrams) determines its behavior, and therefore only when this structure is well defined then people can achieve greater insight into the system's behavior (Senge, 1992).

To map the structure of a system the use of Systems Dynamic modeling is proposed. Models serve as virtual worlds or "microworlds" according to Morecroft (1988) allowing for low-cost experiments and enabling the consideration and inclusion of "hard" and "soft" variables based on data from actors within firms and supply chains. The aim is twofold, to understand the structure of the system, experiment with it, and get immediate feedback. Since experimentation in real systems is not feasible, simulation becomes a viable alternative for decision-makers to discover how a complex system works and to examine unlimited and even catastrophic (for the real world) alternatives.

The field of system dynamics was initially known as Industrial Dynamics and as its origins in the simulation of problems pertaining to industrial supply chains. Forrester (1958, 1961) was the first to coin the term and to examine thoroughly the dynamics of supply chains.

In System Dynamics modeling, there is a specific and closed boundary around the system in which dynamics have endogenous cause from within systems boundary due to feedback loops although the initial stimulus for those changes in the behavior may be exogenous. They allow the evaluation of information and resource flows which are assumed to be continuous and interconnected forming feedback loops. They identify two variables in the system, the independent stocks that represent accumulations within feedback loops, and the rates (flow) variables representing activity within the feedback loops. Inflows add to stocks while outflows drain them. Stocks are affected by resource flows and they affect rates via information links. However, stock variables are put to the forefront since in System Dynamics models focus on the behavior of the stocks of the system (expressed as integral equations). Feedback (positive or negative) is an essential building block of system dynamics where information about the current state of the system is used to fix possible discrepancies between the actual and desired level of the stocks. Also, material and information delays are modeled since they are the source of dynamics in all systems. Finally, they allow for the inclusion of numerical as well as "soft" or unquantified variables (e.g. reputation) in case they have a causative influence in the system (Richardson, 2011; Dangerfield, 2014; Sterman, 2018).

3.2. Developing the Model

The model aims to map the internal supply chain processes of a fictional company that are affected by transport time in an effort to identify and explain the impact of exogenous disturbances (change in transport time) due to a new transportation investment or policy on its behavior. We model a typical retail company that buys and sells a specific commodity to on-site customers and is part of a traditional supply chain with demand information flowing upstream as described by Disney et al. (2003).

We build the model using several assumptions. First of all, we assume that the expected demand for the item the company sells is stable and not variable. We do that to ensure that perturbations are introduced only as a result of changes in transport time and therefore any changes in *Cash Balance* (*CB*) are not caused due to changes in demand. To simplify the model, it is also assumed that transportation and warehouse capacities are infinite as this will make it easier to interpret the results that will therefore not be confounded either by constrained transport and warehouse capacity or by variable demand conditions. Finally, the item does not possess any characteristics that require special conditions in its transporting and warehousing. We should mention, however, that the above assumptions can be easily relaxed and that the impact of limited transport and warehouse capacity, as well as variable demand, should receive further attention and be addressed in future modeling efforts.

Transport time is defined as the sum of travel time during which a vehicle is moving goods from one location to another, plus all the delays that may occur during the transportation of the goods between the origin and the destination (O-D) of the shipment and may include border-crossing, cross-docking, trans-shipment, intermediate warehousing, grouping/degrouping, etc.

$$\textit{Transport Time} = \textit{Travel Time} + \textit{O-D Logistics Operations} \quad (1)$$

Furthermore, we use the term *Supplier Order Processing Time* (*ST*) to denote the time needed for a company to process the orders received from customers internally before the goods are finally loaded on the vehicle and are ready for transportation. *Order Delivery Time* is therefore the *Supplier Order Processing Time* (*ST*) plus the *Transport Time* (*TT*). Therefore:

$$\textit{Order Delivery Time} = \textit{Supplier Order Processing Time} + \textit{Transport Time} \quad (2)$$

Transport using companies are additionally concerned with another dimension of the transportation service, namely the *Inventory Replenishment Time*, denoting the time that elapses between the placement of the goods' order to the supplier and time the goods are ready for use at the company's warehouse. *Time to Store* refers to the time needed by the company to unload, inspect, and put the received items in the warehouse.

$$\text{Inventory Replenishment Time} = \text{Order Delivery Time} + \text{Time to Store} \quad (3)$$

Ensuring that transport times are kept short is a source of advantage since *Inventory Replenishment Time* affects a firm's inputs inventory policy, production schedule, and final product inventory, thus impacting both efficiency (low cost) and effectiveness (customer satisfaction). In case of more complex models, like in cases of production companies (make to stock or make to order) and/or where internal transporting is required between facilities of the firm, transport time also affects *Materials Handling Time*, while in the case of returns from the customer, or to the supplier, *Time to Return* is also affected. All the above possible implications of transport time relating to primary business processes can be extracted from **Figure 1** where a generic traditional supply chain is mapped to include the supplier(s), the company and the customer(s), as well as the busness process of sourcing (from suppliers), making (producing/assemplying), delivering (to customers) and returning (from customers and to suppliers).

Based on the definition for travel time savings provided by Zamparini and Reggiani (2007), we define the value of FTTC as the profit (or loss) deriving from a unit change in the amount of *Transport Time* needed to transport a good from the shipper to the consignee. Profit (or loss) is calculated as the *Cash Balance* (*CB*) that is calculated as the difference between sales (inflow) and logistics costs that include apart from transportation costs, the cost for placing orders to suppler, the inventory holding costs (outflows).

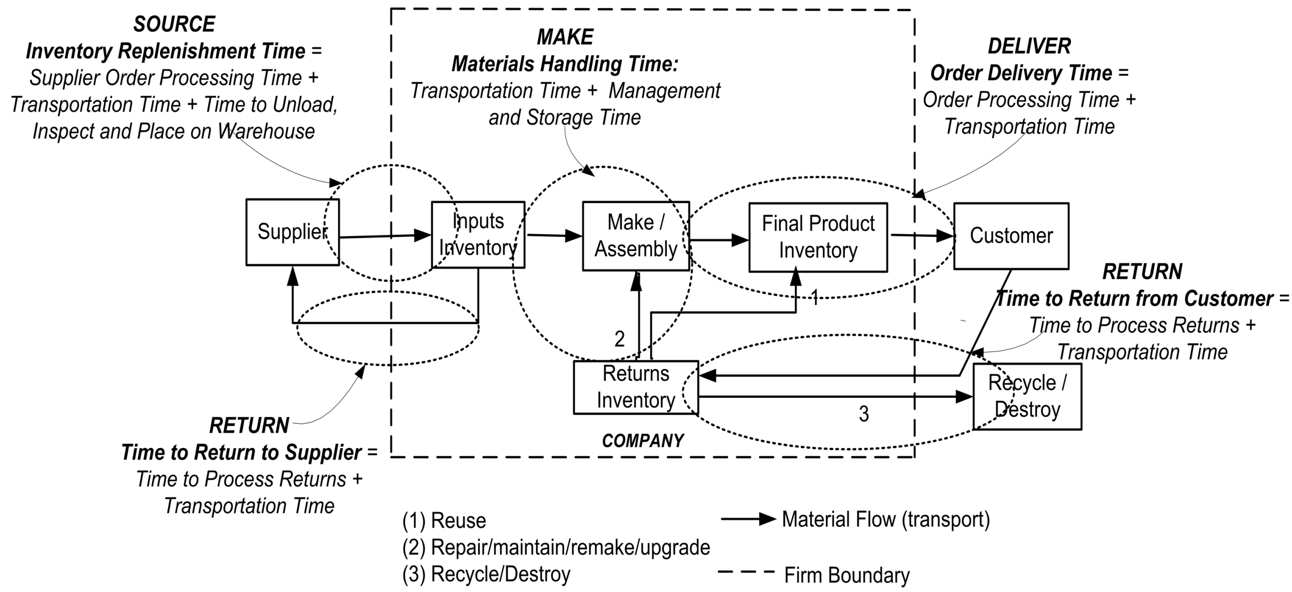

Figure 1. Transport time and business processes.

The internal supply chain of the company is modeled with the use of four stocks mapped as rectangles in **Figure 2** aiming at the mapping of business processes affected by transport time and finally measuring the effect of transport time on Cash Balance. In the following **Figure 2** the *Supply Line* (*SL*) measures the commodities that have been ordered to the supplier and the company awaits their receipt. The *Goods Inventory* (*GI*), measures the items that have been received from the supplier and are available in the company's warehouse for selling. The *Accounts Payable* (*AB*), measures the amount of money (€) the company owes to the supplier for the items received. Finally, the *Cash Balance* (*CB*) measures the difference in the company's Profit (*Cash inflow* minus *Cash outflow*).

Each Stock is a cumulative sum that is increasing by an inflow (represented as a pipe adding to the stock in **Figure 2**) and decreasing by an outflow (represented as a pipe subtracting from the stock in **Figure 2**). For every stock we have

$$Input_t = \int_t^{t_0} (Inflow - Outflow)\,\mathrm{d}s + Stock_{t_0}$$

So, in our model we have:

$$Supply\ Line_t = \int_t^{t_0} (Order\ Rate - Order\ Receipt\ Rate)\,\mathrm{d}s + Supply\ Line_{t_0} \tag{4}$$

$$Goods\ Inventory_t = \int_t^{t_0} (Order\ \ \mathrm{Re}ceipt\ Rate - Order\ Delivery\ Rate)\,\mathrm{d}s + Goods\ Inventory_{t_0} \tag{5}$$

$$Accounts\ Payable_t = \int_t^{t_0} (Credit\ Rate - Cash\ Payment\ Rate)\,\mathrm{d}s + Accounts\ Payble_{t_0} \tag{6}$$

$$Cash\ Balance_t = \int_t^{t_0} (Cash\ Inflow - Cash\ Outflow)\,\mathrm{d}s + Cash\ Balance_{t_0} \tag{7}$$

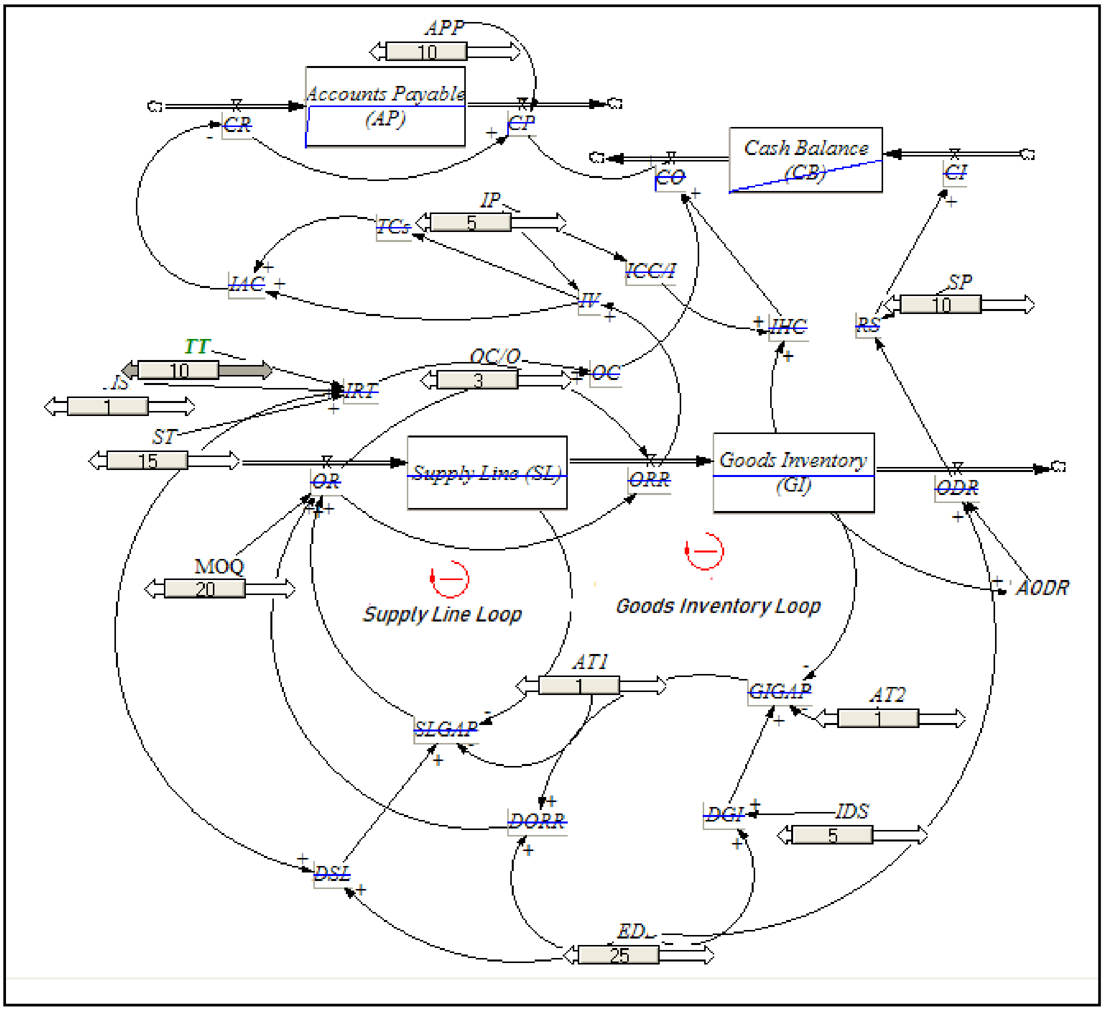

Figure 2. Model structure and simulation run-base case.

There are two negative feedback loops in the model that define its structure and therefore behavior, the *Supply Line Loop*, and the *Goods Inventory Loop*. Feedback loops are the building blocks of System Thinking and reflect a circular mentality starting from a problem, moving to a solution based on the discrepancy between the goal and current status, and then return to the problem. Problems have endogenous causes, they do not just appear but are the impacts of other decisions and actions within the boundaries of the system. So those responsible for achieving a goal e.g. have a specific number of items in inventory reach a solution in case of a discrepancy and take corrective action to match the *Goods Inventory* with the *Desired Goods Inventory*. This action inevitably will further impact the system. In our model company employees review the *Supply Line* and *Goods Inventory* gap daily and take corrective actions. Polarity, either positive (+) or negative (−), in each causal link, indicates how the dependent variable changes when the independent changes. A positive link polarity indicates that ceteris paribus if the cause increases (decreases) then the effect increases (decreases) above what it would otherwise have been; while a negative link polarity indicates that, ceteris paribus if the cause increases (decreases) then the effect decreases (increases) below what it would otherwise have been.

The number of goods to be ordered to the supplier depends on the difference between the actual and desired levels of both Stocks, taking into consideration the *Minimum Order Quantity* (MOQ) negotiated with the supplier, *Inventory Replenishment Time* (*IRT*), *Expected Demand* (*ED*), and *Inventory Days of Sales* (*IDS*). The firm applies a continuous review inventory system.

So,

$$\textit{Desired Goods Inventory} = \textit{Expected Demand} \times \textit{Inventory Days of Sales} \quad (8)$$

$$\textit{Desired Supply Line} = \textit{Expected Demand} \times \textit{Inventory Replenishment Time} \quad (9)$$

and,

$$\textit{Order Rate}(OR) = \begin{cases} \textit{Supply Line GAP}(SLGAP) + \textit{Desired Order Receipt Rate}(DORR), \\ \quad \text{if } SLGAP + DORR \geq MOQ \\ 0, \text{ if } SLGAP + DORR < MOQ \end{cases} \quad (10)$$

$$\textit{Desired Order Receipt Rate}(DORR) = \begin{cases} \textit{Goods Inventory GAP}(GIGAP) + \textit{Expectd Demand}(ED), \\ \quad \text{if } GIGAP + ED \geq 0 \\ 0, \text{ if } GIGAP + ED < 0 \end{cases} \quad (11)$$

The amount of goods sold and to the customer *Order Delivery Rate* (*ODR*) is a function of the *Expected Demand* (*ED*) and the *Actual Order Delivery Rate* (*AODR*) to the customers that since the company will actually sell the smaller quantity between the one requested by its customer (expected demand) and what it is in a position to deliver (actual).

$$\textit{Order Delivery Rate} = \begin{cases} \textit{Expeced Demand}(ED), \text{ if } \textit{Actual Order Delivery Rate} \geq \textit{Expected Demand}(ED) \\ \textit{Actual Order Delivery Rate}(AODR), \text{ if } AODR \leq ED \end{cases} \quad (12)$$

Every time a customer buys an item there is an increase in the company's *Revenues* (*RS*), further increasing *Cash Inflows* (*CI*). Every time the ordered items are received from the supplier, the supplier's account payable is *Credited* (*CR*) to reflect the company's financial obligations towards the supplier. The *Average Payment Period* is 10 days meaning that the company pays its suppliers 10 days after the receipt of goods. Finally,

$$\begin{aligned} \textit{Cash Outflows}(CO) = \textit{Cash Payment}(CP) + \textit{Ordering Costs}(Oc) \\ + \textit{Inventory Holding Cost}(IHC) \end{aligned} \quad (13)$$

For model testing reasons, we start the model ensuring a balanced equilibrium for the two stocks, the *Supply Line* (*SL*) and the *Goods Inventory* (*GI*), meaning that, at the starting point, inflows and outflows for these two levels are equal. *Accounts Payable* (*AP*) and *Cash Balance* (*CB*) start with zero values, to ensure that all inflows and outflows result from the simulation period and not the previous one(s).

Base case parameter settings are presented in Table 1.

3.3. Scenario Building and Derivation of FTTC Value

To illustrate the derivation of FTTC values we have developed certain simulation experiments whereby a change in transport times is imported in the model as a sudden, exogenous disturbance turmoil, propagating alterations in the system's behavior. To derive the value of these changes, we examine how a sudden change in transport time will affect the firm's value as expressed by *Cash Balance* (*CB*) at the end of the simulation period (day 300).

In the first scenario, we assume that from the 20th day and until the end of the simulation time, due to exogenous reasons *Transport time* (*TT*) from supplier increases by 5 days, bringing *TT* to 15 days and therefore raising *IRT* to 31 days. In the second scenario, we assume that from the 20th day and until the end of simulation time, due to exogenous reasons *Transport time* (*TT*) decreases by 5 days, resulting in a new *TT* of 5 days and *IRT* of 21 days. In both scenarios, all other parameters and values are kept constant to evaluate changes in *CB* due to

Table 1. Base case parameter settings.

Parameters	Initial Settings
Supply line (SL)	Initial Value = 650 items = Desired supply Line (DSL)
Goods Inventory (GI)	Initial value = 125 items = Desired Goods Inventory (DGI)
Order Rate (OR)	Initial Value = 25 items/day = Desired Order Rate (DOR)
Order Receipt Rate (ORR)	Initial Value = 25 items/day (Order Rate (OR) = Desired Order Receipt Rate (DORR))
Order Delivery Rate (ODR)	Initial Value = 25 items/day = Order Receipt Rate (ORR)
Supplier's Order Processing Time (ST)	15 days
Minimum Order Quantity (MOQ)	20 items/order
Transport time (TT)	10 days
Time to Store (TS)	1 day
Expected Demand (ED)	25 items/day
Inventory Days of Sales (IDS)	5 days
Inventory Holding Cost (IHC)	30% of items value annually
Ordering Cost (OC)	3€/order
Cost of goods	5€/item
Price	10€/item
Accounts Payable (AP)	Initial Value = 0€
Cash Payments (CP)	Initial Value = 0€

Table 2. Deriving the value of transport time changes for simulated scenarios.

Scenario	Transportation Time	Cash Balance (t = 300)	FTTC value
Base Case	10 days	36,128.9€	
Scenario 1	15 days (from day 20)	36,010.2€	−118.7€
Scenario 2	5 days (from day 20)	36,143.9€	+15.0€

TT changes only. The results of these two simulations using Equations (1)-(13) described above along with the Base Case run are exhibited in Table 2 where:

$$FTTC\ value_i = Cash\ Balance\ scenario_i - Cash\ Balance\ Base\ Case, \quad (14)$$

with i = *scenarios* 1 *and* 2.

Ceteris paribus, a 50% increase in freight transport time in the 20th day of the simulation will create a loss of 118.7€, while a decrease will increase the company's value by 15€. In both cases, the company does not make any alterations in the decisions or decision rules, therefore the value of the change is estimated based on the current policies applied by the company. Inevitably, if the company proceeds to changes then the final result will also be altered.

4. Conclusion

Valuing freight transport time changes is a key concept in transport project appraisal and transport modeling since its value of FTTC is an input into the Benefit-Cost Analysis of transport projects and the generalized cost equation (Shires and de Jong, 2009). In this paper, we focus on transport time, a wider term than the more frequently used traffic time, to illustrate the usefulness of our approach in assessing the effect of any intervention from new infrastructure to a new policy that alters total transport time.

Estimating the value of freight transport time changes has rather recently emerged in the field of transport economics and is defined as the benefit (or loss) that derives from a unit change in the amount of time necessary to move a particular quantity of goods from one origin to a specific destination. Transport time can be a powerful resource for companies against competition, affecting input replenishment time, materials handling and production time, delivery time and returns time. Yet there are a lot of issues to be solved regarding the estimation of the FTTC value. Existing methods for the estimation of the FTTC value rely mainly on practices used in valuing passenger transport time changes and include the factor cost method; and the willingness-to-pay method that is based on Stated Preference Data.

Existing methods have advantages but also weaknesses that may endanger the safe derivation of FTTC values. Among the latter, we highlight the inability of the factor cost method to consider changes in other logistics costs affected by transportation (i.e. inventory holding costs) and by long-term effects. In the latter case, Stated Preference surveys provide an estimate of FTTC values and have been widely used by researchers, as the literature review revealed. The fact that SP studies rely on the human judgment is the most important drawback of such a method. This is because different actors are usually involved in decision-making, who may have different opinions and perceptions and also set varying future targets regarding the transported goods and the firm as a whole. Also, even in the case of a single decision-maker or converging opinions and targets, it is difficult to assess the full effects of a change in freight transport time both in the present and the future. Morecroft (2015) says "*People and organizations are boundedly rational. They cannot gather or process all the information needed to make* '*best*' (*objectively rational*) *decisions*". Additionally, Sterman (2000) points out that "*people cannot simulate mentally even the simplest possible feedback system, the first order linear positive feedback loop*" while "*are unable to infer correctly the dynamics of all but the simplest causal maps*". Complexity along with limited and ambiguous information, misperceptions, and judgmental errors are all impediments in our effort to safely estimate how an increase or decrease in transport time will affect the value of a company.

Considering the above, in this paper, we developed an alternative approach under the Systems Thinking perspective that uses System Dynamics modeling simulation as a tool for estimating the value of FTTC. Based on the systems perspective paradigm, this simulation tool allows for experimentation with alternative futures and could be used as part of the cost factor and the willingness-to-pay method. The use of this method to model a fictional company in the retailing sector revealed that even simple models with low combinatorial (detail) complexity may show high dynamic complexity due to nonlinearities, delays, and trade-offs that mental models cannot account for.

Future research could further include several more realistic scenarios that could include limitations in the capacity of warehouses therefore affecting the maximum inventory level, a variable demand from customers that would call for higher safety stocks, customer satisfaction and therefore demand as a function of order receipt rate that could make the model even more constructive.

Acknowledgements

The publication of this paper has been partly supported by the University of Piraeus Research Center.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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