Freight Transport Time Savings and Organizational Performance: A Systemic Approach

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Abstract

This paper investigates the effect of freight transport time savings (FTTS) on the performance of transport consuming companies. In the first part existing methods on FTTS valuation are critically discussed and their limitations are identified. Following, a conceptual model is built introducing an alternative approach for the valuation of FTTS that is based on the system perspective of firms, integrating the disciplines of systems thinking, performance measurement, transport and logistics decision making. Evidence from a Systems Dynamics' simulation experiment on a retailer suggests that the effect of FTTS on performance depends highly on the structure of the firm's transport related processes and decision making process. Through the development and simulation of several scenarios concerning the reaction of the firm to the FTTS, it is concluded that the value of FTTS is sensitive to the type of the reaction and its time profile.

Keywords: Performance, Freight Transport Time, Cost-Benefit Analysis, State Preference Surveys, Systems Thinking

JEL Classification: L91, L25, R41

1. Introduction

Despite the wealth of information on transportation's contribution to the economy, debate continues on the linkages between transportation improvements and economic performance and the relative strength of these links (US DOT FHWA, 2004). Focusing at the micro level, the aim of this paper is to investigate the ways in which improvements in freight transport time and business performance are linked and how to measure the effects between the two. In particular, the paper focuses on the demand side of the transport market,

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that is companies producing and/or trading goods and consuming transport services for two reasons: first due to the serious questioning of the ability of current methods to fully capture the effect of FTTS on such companies and secondly due to the difficulty of performance measurement systems to be implemented and used in practice.

Although FTTS are expected to have a positive effect on carriers' efficiency and effectiveness reducing time related transport costs and improving service, this is not the case for their customers: shippers and consignees. Microeconomic research, particularly cost-benefit analysis (CBA) does not fully account for the benefits of transport improvements that accrue to shippers from cost savings and service improvements (US DOT FHWA, 2004). Furthermore, despite the effort to expand CBA in order to capture the full effect of FTTS for the owners of the freight being transported, serious consideration has been raised regarding the ability of existing data collection methods to safely elicit the value of FTTS (De Jones, 2000; Massiani, 2003; Zambarini and Reggiani 2007a; 2007b).

On the other hand, despite the fact that numerous performance measurement systems (PMS) and measures have been designed a lot of obstacles arise when it comes for their implementation and use in practice (Bourne et al., 2000). In their definition of performance as "doing today what will lead to an outcome of measured value tomorrow" Lebas and Euske conclude that performance is a complex concept that can be expressed as a set of parameters or indicators that are complementary and sometimes contradictory describing the process through which the various types of outcome and results are achieved (Lebas and Euske, 2007, p. 130). According to this view, in order to create something in the future a causal model is necessary, so that the process through which performance is to be created can be identified and managed by firms. Also, conflicting performance measures lead to trade-offs among them that must be made explicit not only in theory but in practice also. Existing PMS such as the Balanced Scorecard by Kaplan and Norton (1992; 1996) focus on mapping the relationships between the factors affecting performance but assume linearity, while in reality there are non-linear interactions, delays and feedback loops making it difficult to understand the process of performance creation.

The key argument of this paper is that the above weaknesses could be addressed through the application of an alternative approach for the evaluation of FTTS. A framework is developed that is based on system dynamics modelling and simulation aiming at the identification of the transport time related factors that affect performance, the understanding of their relationships and possible trade offs and finally the monetization of their effect on performance. In this model Massiani's definition of transport time is used, that is the total time (e.g the number of hours or days) that elapses between the dispatching of a shipment from the consigner until its receipt from the consignee (Massiani, 2003).

The paper is structured as follows. In section 2 we discuss why current methods may fail to fully capture the effects of FTTS on transport consuming companies. In section 3 we develop a procedural framework aiming at identifying the process through which FTTS can create performance. In section 4 we develop an illustrative example based on evidence from a retailing company and finally we conclude with some closing remarks.

2. Assessing the value of freight transport time savings

In this section we briefly discuss the methods and practices that have been developed and used in order to assess the value of FTTS. After presenting their basic characteristics we proceed with a discussion of their limitations, justifying the need for an alternative approach.

2.1 Current practices

Based on the microeconomic theory, the value of freight transport time savings (VFTTS) is the benefit that derives from a unit reduction in the amount of time necessary to move a shipment from an origin to a specific destination. The US Federal Highway Administration (US DOT FHWA, 2001) classified benefits from FTTS as first, second and third order ones that take place in different time points. First order benefits include immediate time related transport cost reductions to carriers and shippers. Second order gains include reorganization effects for shippers stemming from improvements in logistics and represent additional economic benefits beyond traditional travel time and cost savings. Finally, third order effects include benefits such as improved and new products that derive from improvements in logistics and supply chain management.

Traditional CBA focuses on first order benefits from shorter transport time that include reduced vehicle operating times and reduced costs through optimal routing and fleet configuration for the carriers. Transit times may affect shipper in-transit costs such as for spoilage, and scheduling costs such as for inter-modal transfer delays and port clearance. Under this spectrum, in the short run nothing changes for the shippers except for the cost of freight movement, since they continue to ship the same volume of goods the same distance between the same points (inelastic demand for transport) (US DOT FHWA, 2001).

The reduction in transport cost resulting from the FTTS can be calculated using a general formulation of the transport production cost, taking into consideration the effect of speed under the form (Massiani, 2008):

$$ct(d_\mu,k) = w.\ d_\mu + v.\ d_\mu + k.g(k/d_\mu) \qquad (1)$$

where $ct(d\mu,k)$ is the transport cost as a function of travel duration (d_μ) and travel distance (k), w is the hourly cost of the driver, v is the hourly cost of the vehicle and $g(k/d\mu)$ are the vehicle operating costs per kilometre as a function of speed.

Second order, long term reorganization gains include three types of firm's responses that will occur as a result of changes in transport times (Tavasszy, 2008):

- transport reorganization (transport facilities and services markets) that involves changes in routes, type of vehicle, modes of transport with time influencing the amount of inventory in transit and the value of the product;
- inventory reorganization (logistics facilities and services markets) that involves the

number, location and volume of inventories with time determining which clients can be served by which warehouse within service level targets;

- production reorganization (production facilities an goods markets) involving a shift between materials used, changes in production location or basic production technology changes.

Such benefits are very difficult to be monetized and used in CBA but are expected to be 15% above direct user benefits (US DOT, 2004). FTTS enable shippers to buy and ship smaller shipments, lowering the average order quantity both on the supply and the demand side, thereby lowering the average level of inventories. Reduced (time related) transport cost advocates smaller and more frequent shipments. In the case of internal transporting between the facilities of a firm, lower freight transport times translate to lower production times allowing for the materialization of a lean inventory policy. Smaller shipment sizes and order quantities also create other benefits including a more responsive supply chain that results in higher order fill rates and a wider product mix that results in more orders, sales, and profits. Reduced transportation time not only enable shippers to buy from less expensive suppliers but also have a broader range of supplier options, and hence input quality and differentiation. A reduction in transport time can allow a firm to expand its selling market, since the distance covered in a certain amount of time will increase. Small time to market enables firms to be flexible and able to adapt to customer requirements more rapidly increasing customer satisfaction, loyalty and profitability. Reduced transportation times and costs can allow firms to concentrate production and distribution processes in a more limited number of locations, giving them the opportunity to take advantage of possible economies of scale and higher return on asset (US DOT, 2006).

Research has been conducted in order for BCA to account for such benefits and avoid underestimation. Mohring and Williamson (1969) provided the first formal analysis of what has been termed "reorganization effects" demonstrating the validity of using consumer surplus in estimating net benefits of transportation investments including possible logistics re-organization. FHWA's 2001 Freight BCA Study rests on estimating the change in consumer surplus reflected in the 'shift' in the demand curve for freight transport that follows the improvement. In order to calculate benefits of transport improvements, the elasticity of transportation demand (expressed in vehicle miles - VM) with respect to transportation cost (η_C^{VM}) is required, that is expressed as the ratio of the elasticity of transport demand with respect to travel time (η_T^{VM}) and the elasticity of transportation cost with respect to travel time (η_T^{C}). For the estimation of these elasticities there is a need for surveys designed to capture re-organization effects while the value of travel time savings and reliability is based on surveys using a stated preference methodology (US DOT FHWA, 2001).

A later research by Boston Logistics Group concluded that reorganization effects are firm specific (US DOT, 2006). They categorized firms into six unique Supply Chain Types (extraction; process manufacturing; discrete manufacturing; design-to-order manufacturing; distribution and reselling), that they differentiated according to their production strategy (flow/continuous vs. batch/cellular); the transportation mode (ship/railcar, truckload/intermodal, or LTL/small package/air); the order trigger (make to plan, make to stock, assemble to order, make to order, or engineer to order); and the breadth of coverage between the raw material supplier and the end consumer. Based on surveys on real firms they provided rough "first-cut" estimates of second order, supply chain benefits from a 10% transportation improvement. Yet, as they point out their estimates are indicative and preliminary and special indexes were developed for each type of company.

2.2 Limitations

In order to establish a link between savings in transport time and business performance there are numerous information requirements and a heavy reliance on stated and revealed preference studies in order to discover how the firm values transport attributes. Data obtained through RP surveys are cognitively congruent with actual behaviour providing information on how decision-makers really behave through the identification of the current levels of service offered by the transport alternatives of their choice set and their real choice. However, there are practical limitations basically associated with the high survey costs; the inability to distinguish the trade-offs between alternatives; the difficulty to detect the relative importance of variables that do not dominate the observed behaviour; the difficulties in collecting responses for services, alternatives and policies which are entirely new; the ambiguity of the choice set (Morikawa, 1994; Ortúzar and Willumsen, 2011).

In cases where data from real markets are not available for predicting long term and/or hypothetical behaviour in order to elicit reliable preference functions, stated preference (SP) techniques are used. SP techniques analyse the response to hypothetical choices using contingent valuation (CV), conjoint analysis (CA) and stated choice (SC) methods. Each of the choices has a cost and so by choosing it the respondent indicates how much he or she is willing to pay for having it and this way the value of each alternative is elicited. The data are then subject to econometric modeling techniques such as multinomial logit (MNL) and mixed logit.

In transport research De Jong (2000) concluded that mostly data come from contextual, highly customized SP computer interviews with carriers and shippers who are asked to compare pairs of alternatives, using logit models with linear utility functions. Zambarini and Regiani (2007a; 2007b) and Feo-Valero et al. (2011) reviewed several empirical studies in an attempt to provide a quantitative estimation of the value of freight travel time savings. They confirmed the dominance of SP surveys and behavioral models and showed a remarkable variation in the values that users put on FTTS. Such differences are explained partly by the different methods adopted to collect observations and partly by the influence exerted by contextual factors such as the trip distance, the country where the study is developed, the per-capita GDP, the category of transported goods, the transport unit.

Despite its dominance, there is a lot of criticism regarding the SP method and the ability to elicit safe values of FTTS. SP data are hypothetical and therefore researchers cannot be certain that should a given situation arise, decision-makers will behave exactly as they said they would in the SP study. Zambarini and Regiani (2007a; 2007b) list several reasons behind 'hypothetical bias' a term used to denote the deviation from real market evidence (Hensher, 2010). First, the reliability of the data obtained by a SP survey strongly depends on the capability of the researcher to describe and choose the alternatives amongst which the firm's representative has to choose. Moreover, it might be the case that the answer does not reflect the behaviour that the respondent to the questionnaire would adopt in a real situation. It may also be the case that the respondent is not aware of all the gains that a saving of travel time might generate for the firm. To overcome some researchers propose the coupling of Stated Preference questions with Revealed Preference questions in order to ascertain the robustness of obtained estimations. Hensher et al. (2005) and Heshner (2010) raised questions about the influence that the design of the experiments has on the behavioral outputs of such models and list several directions for specifications regarding their presentation.

Another issue is the difficulty to identity the decision-maker or makers in a firm. Whereas the individual passenger is easily identified as the decision-maker who undertakes the actual movement in passenger travel models, the decision-making unit for freight modal choice is uncertain. While existing approaches assume that there is a unitary decision-making process in reality there are diverse actors involved in the process coming from the procurement, production, inventory, marketing or distribution department of the firm. They have no control or knowledge of all decisions made throughout the firm's supply chain plus their requirements may be conflicting. What is going to happen if for example the transport manager has different information, opinions and goals than the company owners? (Danielis et al., 2005). Therefore, it is unrealistic to equate the individual (mainly the transport or logistics manager) with the firm in eliciting the VFTTS.

Additionally, it is unrealistic to assume perfect knowledge on the part of the firm, especially when it comes to estimating long term, reorganization effects. FHWA (2001) recommended the use of SP surveys in order to estimate logistics costs savings from FTTS. This translates to a great effort for data collection about logistics decisions of companies while it assumes full information and complete certainty about future decisions. Is this realistic?

According to Forrester (1961) all decisions are based on models, usually mental ones that reflect peoples beliefs about the networks of causes and effects that describe the real world (i.e. the operation of the firm, its structure and its processes). Yet decisions based on mental models are not optimum because people learn to reach their current goals based on their existing mental models that do not change easily. In our case, decision makers usually operate in the context of existing decision rules, strategies, culture and institutions which in turn are derived from existing mental models. This means that a change in transportation time may alter decisions but not decision rules that are anchored on existing mental models (business as usual). In the longer run, decision makers should be able to alter their mental models according to the information feedback they have about the real world. Feedback from the real world stimulates changes in mental models resulting to a new understanding of the situation leading to new goals, new decision rules, policies and so on (Sterman, 2000).

Yet, there are impediments to learning that hinder the above mechanism. As Morecroft (2007) points out, most people posses a typical event-oriented thinking style that is linear, from problem as event to solution as fix, ignoring possible feedbacks. But even if Senge's (1990) "shift in mind" towards feedback systems thinking is accomplished there are still barriers that hinder the learning procedure and include dynamic complexity (due to the time delays between taking a decision and its effects, the dynamicity and nonlinearity of systems etc.); limited information about the state of the real world; confounding and ambiguous variables; poor scientific reasoning skills leading to judgmental errors and bias; defensive routines and other barriers to effective group processes; decisions implementation failure due to local incentives; asymmetric information and private agendas leading to game playing; and misperceptions of feedback hindering peoples' ability to understand the structure and dynamics of complex systems (Sterman, 2000).

The above suggest that the valuation of time in freight transportation is a much more complex process than it is accounted for in current methods. This stems from the fact that the movement of goods is quite different from the movement of people. Unlike personal travel the decision-maker does not undertake the actual movement and there is likely to be a number of decision-makers, each with different interests that may be conflicting while information is limited. It is therefore unrealistic to use individual models in order to elicit the value of transport time savings. Boston Logistics Group developed indexes for each supply chain type in order to estimate the effect of FTTS (US DOT, 2006). Yet, in this paper it is argued that even the most detailed taxonomy cannot provide safe values for the FTTS. This is due to the fact that the effect of FTTS depends not only on the transported good, the position of the firm in the supply chain and the macro environment of operation but on the firms' reactions to FTTS. Therefore, the key idea of this paper is to focus on the firms' processes in order to understand how they operate and their decision making process in order to anticipate their longer term reactions to FTTS.

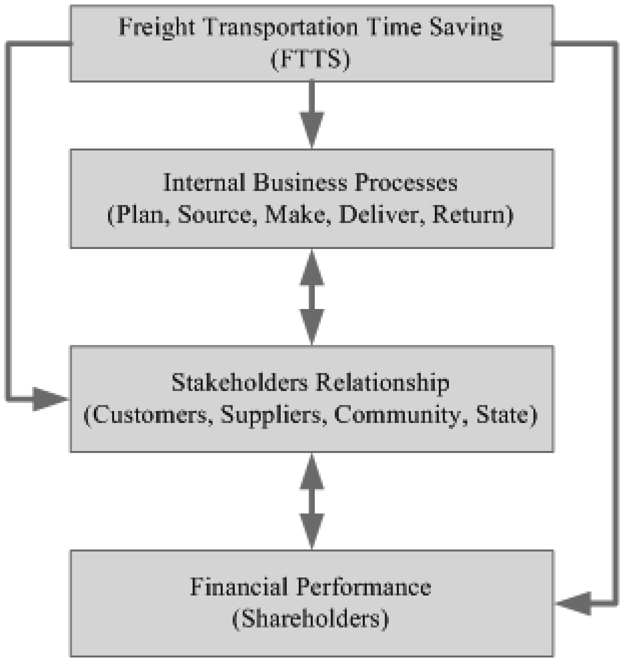
3. A new framework for the valuation of FTTS

3.1 Aim and structure of the framework

The proposed framework is built on the thinking that the value that a firm will put on a FTTS reflects the anticipation on the effect that this saving will have on its financial performance. Bearing in mind the diverse actors this framework tries to integrate, all processes affected by FTTS and trade offs are considered. In order to overcome possible contradictions we do not focus on people' perceptions and beliefs but on the structure of the business processes that are affected by FTTS and use selected performance metrics in order to form causal paths to financial performance. The current structure of business processes reveals the way that business is currently done and reflects the short term responses to FTTS. Changes in decisions and decision rules can then be added in several realistic time points to capture the medium and long run effects of FTTS. The elasticity of profit with respect to FTTS can then be derived for several time phases.

In this model we consider transport improvements that result to FTTS as exogenous ones. This means that they are the result of investment projects or policies external to the shipper's operations and are presented in the form of sudden changes (in a later version this assumption could be eased in order for the model to be more realistic especially for the estimation of induced traffic). FTTS will first have an impact on the shipper's internal business processes then affect stakeholder relationship and ultimately alter the firm's financial performance (Figure 1).

Figure 1: Generic framework linking FTTS to performance



In order to identify the effect of FTTS on internal business processes, we use the process categorization proposed by SCOR: plan, source, make, deliver and return (SCC, 2006; 2008). Further, we use the "stakeholder mix" proposed by the Performance Prism framework so as to assess the effect of changes in internal processes to stakeholder's relationships (Neely et al., 2002). Finally, for the building of the causal mechanisms, we use performance measures that we derive from the existing literature in the field of performance measurement.

Grobler and Schieritz (2005) highlight the methodological difficulties in modeling business processes, since it is difficult to apply pure formal modeling, empirical observation and experimentation in firms. They advocate the use of simulations that share a characteristic feature with classical experiments: the possibility to alter one variable (in our case freight transport time) and hold all other variables fixed. Simulation models develop according to Morecroft (1988) ‘microworlds’, do not require specific mathematical forms and provide the possibility to include estimations of difficult to measure (and “soft”, qualitative) factors allowing the inclusion of all important parameters based on real world data or on estimates from actors within firms (Grobler and Schieritz, 2005).

3.2 Linking FTTS to internal business processes

The first step is to identify and map the effects of FTTS on internal processes. Based on SCOR, planning refers to the processes that balance aggregate demand and supply to develop a course of action which best meets sourcing, production, delivery and return requirements (SCC, 2006, 2008).

Sourcing refers to the process of obtaining the right materials, at the right place, at the right time, at the right quantity, at the right condition/quality from the right supplier and at the right price (Lambert et al., 1998). Planning in source refers to the development of procurement plans. For companies buying production materials, demand depends on the company's schedule of production and calls for a requirements approach such as MRP (Material's Requirements Planning) and JIT (Just In Time) (Muller, 2003). In both systems, transportation time plays a vital role since is affects Input Inventory Replenishment Time (IIRT), that is the time that elapses between the placing of an order to the supplier and its receipt. IIRT includes order preparation and transmittal, order receipt and entry into supplier's system, order processing, order picking/production and packing by the supplier, transportation time and time for receiving and placing into storage by the customer (Lamber, 1998). In the case of sourcing for resale, demand is influenced by exogenous market conditions (independent) and call for a replenishment approach. The Reorder Point (ROP) and the Economic Order Quantity (EOQ) formulas are mostly used in order to approximate the optimum order point and order quantity (Muller, 2003). In the ROP formula IIRT is taken into account, while for the EOQ formula to work IIRT must be known and stable (Lambert, 1998).

Making, consists of all processes that the company develops in order to transform materials into finished products. In the case of internal transportation between distant assembly lines and warehouses transportation time affects total production time. Planning in make refers to the process of building a Master Production Schedule (MPS) based on actual production orders and replenishment orders (demand) taking into account any possible capacity constrains (production, warehouse, transportation). MPS tells what products are to be produced, in what quantity, and what product must be ready for delivery, taking into account the existing inventories (Kumar and Suresh, 2008). Transportation time needed to move goods between different production facilities affects the scheduling of production.

Delivery comprises of all those processes that elapse between receiving an order from a customer until shipping it to his premises and invoicing him. Transportation is a part of this process affecting total delivery time. Planning in delivery, is conducted through the development of a Distribution Resource Planning (DRP) that takes into account the

Master Schedule (MS) for distributions which identifies product requirements stemming from demand and plans replenishment orders to the higher echelon in order to meet them, the Bill of Distribution (BOD) that contains the distribution network structure of a product and the transportation time associated with each link in the BOD (Ho, 1990; Ross, 2004). The scheduler then would assign gross requirements (product demand) to transportation means on specific dates based on transportation times and quantities and create a shipping schedule (Bookbinder and Heath, 1988).

Finally, planning in return refers to the process of aggregating planned returns and generating a Return Resource Plan (RRP) (Bolstorff and Rosenbau, 2007). Yet this is a very difficult task due to the uncertainty regarding the reason of return (and therefore the further use of the returned item), the amount of returned products and the time of the return. In the case of returned products that can be reused then the finished goods inventory and consequently the MRP system could be affected and also in the case of reproduction the MPS (Fleischmann et al., 1997). Materials inventory could be affected in cases where returned products are used after dis-assembly as materials for production. If returns can be associated with demand (this stands mainly for handling materials, packages and repairs) then planning can be achieved. In cases of stochastic demand for returns then the whole procedure cannot be easily patterned (Guide, 1996; Guide et al., 1997).

3.3 Linking FTTS to stakeholder satisfaction

After having identified and mapped the effect of FTTS on internal processes, the next step is to see how changes in internal processes propagate to affect the effectiveness of the firm that is its relationship with key stakeholders. They mainly include customers, suppliers and ultimately shareholders. According to the Balanced Scorecard performance measurement system causal paths from all the measures on a scorecard should be linked to the financial objective that is the focus for the objectives and measures in all the other scorecard perspectives (Kaplan and Norton, 1996).

3.3.1 Customer and supplier satisfaction

Customer satisfaction and loyalty are affected by the product attributes (quality, price, functionality), the customer relationships (time, dependability, flexibility) and the firm’s image and reputation (Kaplan and Norton, 1996).

Based on Slack et al. (2007, p. 39) quality is “consistent conformance to customers expectations” and is affected by transportation time especially in the case of perishable goods and other time sensitive products. Melnyk and Denzler (1996) distinguished between six lead times that have to do with product design and engineering, procurement, production, delivery, order management and other times (i.e. time to respond to a claim). SCOR uses the measure Order Fulfilment Cycle Time (OFCT) as a measure of supply chain responsiveness to include the above mentioned lead times (SCC, 2006, p. 445). Transportation time reductions add value for time competing companies that need small

OFCT but is not always a necessity compared with the associated cost of speed mainly in the cases of easily anticipated demand and low value products (Harrison and Hoek, 2007).

Short delivery times due to small delivery times and available finished goods inventory allows for the delivery of goods at the right time while low return time from customers ensures that the right product will be delivered to the customer and Perfect Order Fulfilment will be achieved.

Flexibility reflects the ability of organizations to exploit opportunities stemming from changes in their environment that stem from new customer needs and wants (Dreyer and Gronhaug, 2004). Companies can react by increasing internal flexibility (focus on their operations) and/or external flexibility (focus on their customers). Transportation time mainly affects external logistics flexibility that refers to the ability of a company to change the place and time of its products delivery (Slack et al. 2007). SCOR (SCC, 2006) uses the metric Upside Supply Chain Flexibility defined as the number of days required to achieve an unplanned sustainable increase in quantities of raw materials (Upside source flexibility); in production (Upside make flexibility); in quantity delivered (Upside deliver flexibility); in the return of raw materials to suppliers (upside source return flexibility); and of finished goods from customers (upside deliver return flexibility) with the assumption of no other constraints. In a similar way, transport time can affect Upside (and respectfully Downside) Supply Chain Adaptability that is defined as the maximum sustainable percentage increase in quantity of raw materials, production, goods delivered and returned that can be achieved in a predefined number of days (SCC, 2006).

Moreover, transportation time can affect the image and reputation of a company especially in the case of companies selling time-sensitive products or trying to differentiate focusing on specific transport strategies that include transportation quality in terms of speed among other attributes (Konings et al., 2008). In such cases an unanticipated increase in transit times will harm a firm's competitive advantage and reputation while a reduction will strengthen its market position.

Supplier Relationship Management (SRM) defines how a company interacts with its suppliers with a desired outcome of a win-win relationship (Lambert and Knemeyer, 2007). Neely et al. (2002, p. 318) point out that the desirable supplier must be fast, right, cheap and easy to do business with. Transportation time affects the total inventory replenishment time justifying the renegotiation with existing suppliers or even the development of new partnerships.

3.3.2 Shareholders' satisfaction

Improvements in the planning and execution of internal processes will benefit a company only when they can be translated into financial performance in the form of revenue growth, cost reduction and better asset utilization (Kaplan and Norton, 1996).

Revenue growth can be affected by FTTS in the case of increased demand and sales due to the reduction of OFCT. Supply Chain Cost is defined by SCOR (2006) as the sum of costs in planning, sourcing, making, delivering and returning. It can be affected indirectly due to changes in the order quantity and consequently the frequency of orders to supplier and the cost of placing them, the inventory quantity and the cost associated with holding it.

In the area of asset management several measures have been proposed. Among them Cash to Cash Cycle Time (CCCT) is a measure of efficiency of the working capital that represents the time required for a company to convert cash payments to suppliers of inputs to cash receipts from customers (Stewart, 1995; Kaplan and Norton, 1996, p. 58):

$$\text{CCCT} = \text{IDS} + \text{DR-DP} \quad (2)$$

Inventory Days of Supply (IDS) reflect the number of days "demand" that a given amount of inventory could cover. Usually, a firm keeps enough inventories to cover demand during IIRT. Days Receivable (DR) reflect the time (days) that elapses between selling to customer and collecting cash, while Days Payable (DP) correspond to the time between purchasing from a supplier and paying him. Reducing transportation time leads to a reduction in the inventory days of supply ratio and the cash to cash cycle time.

Savings in transport time affects also the level of inventory as well as the amount of accounts payable (to suppliers) and receivable (from customers) therefore affecting Return on Working Capital, that is expressed as (SCC, 2006):

$$\text{Return on Working Capital} = \frac{\text{Supply Chain Revenues - Supply Chain Cost}}{\text{Inventory + Accounts Receivable - Accounts Payable}} \quad (3)$$

Finally, reducing production and warehousing locations increases the ratio Return on Supply Chain Fixed Assets according to the expression (SCC, 2006):

$$\text{Return on Supply Chain Fixed Asets} = \frac{\text{Supply Chain Revenues - Supply Chain Cost}}{\text{Fixed Assets used in Source, Make, Deliver, Return}} \quad (4)$$

4. Developing a simulation experiment

In this section we apply our framework in a retailing company using system dynamics modelling and simulation. First we map the decision rules governing the processes affected by freight transport time and their effect on selected performance measures. Then, we introduce a sudden exogenous change in freight transport time in see the impacts on performance measures.

4.1 Company profile and decision rules

The experiment is held in a retailing company operating in the market of electric devices spare parts. It is part of a traditional supply chain where demand information flowing upstream, beginning with the customers while the producer (supplier) only receives order information from the retailer. For simplicity reasons we model one specific item that is sourced from a manufacturer abroad and then resold to on-site retail customers. The firm's

Inventory Replenishment Time (IRT) is estimated at 26 days and consists of three distinct times: the supplier's order processing time (15 days), the transportation time (10 days) and the time to unload, inspect and store (1 day).

The firm has a clear focus on immediate demand coverage with error free goods (returns are less than 1%) and keeps no backlog, so in the case of stockouts, the sale is lost. Long IRT (26 days) and small storage space is counterbalanced by holding 10 days' sales on inventory. Furthermore, orders are released to supplier based on expected demand (EDD) (estimated at 20 items/day), available inventory of goods (GI), expected receipts from previous orders, IRT, transportation cost (TC) and inventory holding cost (IHC) (estimated at 30% of item value annually). Based on negotiations with the supplier transportation cost is a fixed percentage set at 4% of the price (IP) of the ordered good. Also, the supplier has set a Minimum Order Quantity (MOQ) of 300 items/order. Each item costs 5€ to buy and is sold for 10€. The firm reviews inventory and incoming orders on a daily basis.

Using the above data we build a causal model using Cash Balance (CB) as the primer financial performance measure and Unfilled Orders (UO) as a measure of customer satisfaction. Cash Balance is measured as the difference between inflows from sales and outflows stemming from supply chain processes that include order placing (ordering costs are estimated at 3€/order), transportation cost and inventory holding cost (other non logistics costs are excluded from the model). Unfilled Orders (UO) increase every time an order is not satisfied due to inventory shortage.

4.2 Model description and parameters setting

In the model there are six levels (or stocks) that are represented by rectangles (Figure 2):

- The Orders to be Released (ORS) to supplier, that is the number of items that the firm must order to the supplier and is estimated as the difference between the Necessary Order Rate (NOR) and the Allowed Order Rate (AOR) (items);
- the Supply Line (SL), reflecting the number of goods that have been ordered to the supplier but have not been received yet, estimated as the difference between Order Rate (OR) and Order Receipt Rate (ORR) (items);
- the Goods Inventory (GI), indicating the number of goods available for selling, expressed as the difference between Order Receipt Rate (ORR) and Order Delivery Rate (ODR) (items);
- the Accounts Payable (AB), expressing the amount of money the company owes to supplier resulting from the difference between the Supplier Credit Rate (CR) and the Cash Payments Rate (CP) (€);
- the Cash Balance (CB), resulting from the difference between Cash Inflows (CI) and Cash Outflows (CO) (€);
- the Unfilled Orders (UO), resulting from the rate of unfilled orders (Unfilled Order Rate – UOR), that is orders that have been placed by customers but have not been filled due to the lack of inventory (items).

Each level is an accumulation that is increased by an inflow and decreased by an outflow. Stocks are integrals or state variables while flows are rates or derivatives (expressed as goods/time step), so for every level we have:

$$ORS_t = \int_{t_0}^{t} (NOR\text{-}AOR)ds + ORS_{t_0} \tag{5}$$

$$SL_t = \int_{t_0}^{t} (OR\text{-}ORR)ds + SL_{t_0} \tag{6}$$

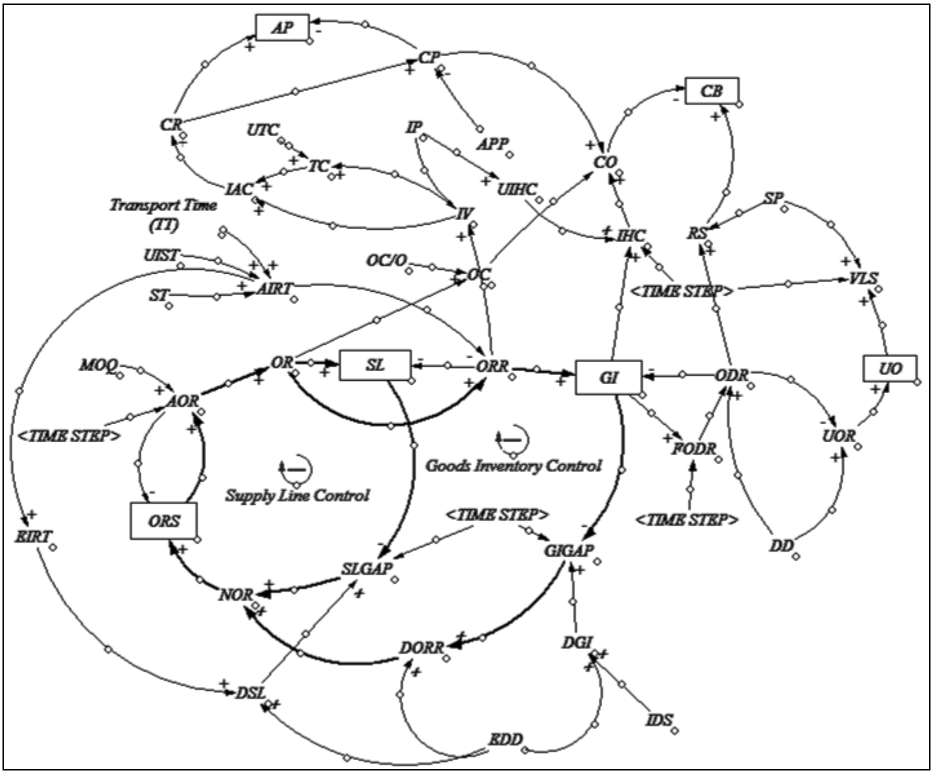
$$GI_t = \int_{t_0}^{t} (ORR\text{-}ODR)ds + GI_{t_0} \tag{7}$$

$$AP_t = \int_{t_0}^{t} (CR\text{-}CP)ds + AP_{t_0} \tag{8}$$

$$CB_t = \int_{t_0}^{t} (CI\text{-}CO)ds + TP_{t_0} \tag{9}$$

$$UO_t = \int_{t_0}^{t} (UOR)ds + UO_{t_0} \tag{10}$$

Figure 2: Causal model for the simulation experiment



The model is built around two negative feedback loops, the Supply Line Control and the Goods Inventory Control. Feedback loops are the basis of the systems perspective where the typical thinking style is not linear but circular starting from a problem expressed as a discrepancy between a goal and the current situation, moving to a solution and then back to the problem. Problems do not just appear, they spring from other decisions and actions that may have obvious or even hidden side effects (Morecroft, 2007). In this model, Supply Line (SL) and Goods Inventory (GI) reflect the situations while Desired Supply Line (DSL) and Desired Goods Inventory (DGI) are the goals, the desired state of the system. Should there be a gap between the actual and the desired state of the system, then the firm proceeds to corrective action. This means that once a day (Time Step = 1day) the gap between desired and actual supply line (Supply Line Gap – SLGAP) and the gap between desired and actual goods inventory (Goods Inventory Gap – GIGAP) is corrected and a decision is taken whether to release or not an order. Therefore,

$$\text{SLGAP} = (\text{DSL-SL})/\text{Time Step} \tag{11}$$

$$\text{GIGAP} = (\text{DGI-GI})/\text{Time Step} \tag{12}$$

The quantity of the order to the supplier depends on these two gaps and the Expected Daily Demand (EDD) but is constrained by the Minimum Order Quantity (MOQ), that is subject to negotiation with the supplier and set at 300 items/order. Desired Supply Line (DSL) and Desired Goods Inventory (DGI) are a function of Expected Inventory Replenishment Time (EIRT), Expected Daily Demand (EDD) and Inventory Days of Supply (IDS).

$$\text{DGI} = \text{EDD x IDS} \tag{13}$$

$$\text{DSL} = \text{EDD x EIRT} \tag{14}$$

Therefore, Necessary Order Rate (NOR) to supplier depends on the Supply Line Gap (SLGAP) and Desired Order Receipt Rate (DORR), that is the sum of the Goods Inventory Gap (GIGAP), the Expected Daily Demand (EDD) and the Minimum Order Quantity (MOQ). In order to keep the formulations robust, we have to ensure that NOR is nonnegative, therefore:

$$\text{NOR} = \begin{cases} \text{SLGAP} + \text{DORR}, \text{ if } \text{SLGAP} + \text{DORR} \geq 0 \\ 0, \text{ if } \text{SLGAP} + \text{DORR} < 0 \end{cases} \tag{15}$$

$$\text{AOR} = \begin{cases} \text{ORS}, \text{ if } \text{ORS} \geq \text{MOQ} \\ 0, \text{ if } \text{ORS} < \text{MOQ} \end{cases} \tag{16}$$

$$\text{DORR} = \text{GIGAP} + \text{EDD} \tag{17}$$

Once an order is released to the supplier, then its receipt is realized after Actual Inventory Replenishment Time (AIRT = 26 days), while each receipt increases the Goods Inventory (GI), that is then decreased by Order Delivery Rate (ODR) to customers. AIRT is the sum of Transportation Time (TT), Supplier Time (ST) and internal company time required to Unload Inspect & Store (UIST). Expected Daily Demand (EDD) is anchored at 20 items/day based on the firm's perception. Yet, actual Daily Demand (DD) is modeled following a normal distribution pattern with a Mean (M) value set at 20 items/day and a Standard Deviation (SD) of 5 items/day. Finally, minimum demand observed is 0 items/day and maximum is 40 items/day. The Order Delivery Rate (ODR) to customers is a function of the actual Daily Demand (DD) and the Feasible Order Delivery Rate (FODR) that is determined by the available Goods Inventory (GI) at that day since the company will deliver what is demanded or what it can actually deliver, whichever is less:

$$ODR = \begin{cases} EDD, & \text{if } FODR \geq EDD \\ FODR, & \text{if } FODR < EDD \end{cases} \tag{18}$$

Every time an order from a customer is satisfied then Revenue from Sales (RS) increase triggering Cash Inflows (CI). Every time ordered goods from a supplier are received then the Accounts Payable (AP) increases denoting an obligation towards the supplier that equals the Input Acquisition Cost that is the sum of the Invoice Value of the inputs and their Transportation Cost (IAC = IV + TC). Based on negotiations with the supplier, the company pays 10 days after the receipt of the ordered goods (APP = Average Payment Period = 10 days). Each Cash Payment (CP) to the supplier along with Ordering Costs (CO) and Inventory Holding Cost (IHC) increases the company's Cash Outflows (CO) that is the supply chain cost. Finally, every lost order due to inventory shortages increases the Unfilled Orders (UO) level and accordingly the Value of Lost Sales (VLS), that is a measure of customer dissatisfaction. Actual Daily Demand (DD) is considered to be exogenous and not affected by the level of customer satisfaction, so what the company losses is the revenues from those lost sales.

4.3 Scenarios building and simulation results

Five scenarios are developed in order to see how a reduction in Transportation Time (TT) propagate and affect selected performance measures (Cash Balance (CB) and Unfilled Orders (UO)). In all scenarios, the simulation lasts 600 days. The value of the FTTS is calculated at the end of the simulation as the difference between Cash Balance for each scenario (i = A,B,C,D) and Cash Balance for the Base Case (BC).

$$VFTTS_i = CB_i - CB_{BC} \tag{19}$$

The firm starts at day 1 with a zero Goods Inventory (GI = 0 items) and expects no orders to be received (SL = 0). The assumptions for each scenario are presented in Table 1.

After a reduction at Transportation Time (TT) and Actual Inventory Replenishment Time (AIRT) by 4 days at the 200th day of the simulation, the firm gradually proceeds with changes in decisions rules. The Expected Inventory Replenishment Time (EIRT) adjusts to the new AIRT at the 300th day of the simulation (Scenario B) the Inventory Days of Sales (IDS) is reduced at the 400th day of the simulation (Scenario C) and finally, the company re-negotiates with its supplier and face an increase in transportation cost at the 500th day (scenario D).

Table 1: The value of FTTS for the simulated scenarios

Scenario (i)	**Transport Time (TT)**	**Actual IRT (EIRT)**	**Expected IRT (EIRT)**	**Inventory Days of Supply (IDS)**	**Transport Cost (TC) as % of Input Price**	**Cash Balance**	**Value of FTTS**
Base Case	10 days	26days	26days	10 days	0,04	51.936,7€	
A	6 days (at day 200)	22days	26days	10 days	0,04	51.812,4€	-124,3€
B	6 days (at day 200)	22days	22days (at day 300)	10 days	0,04	52.877,1€	940,4€
C	6 days (at day 200)	22days	22days (at day 300)	5 days (at day 400)	0,04	51.665,5€	-271,2€
D	6 days (at day 200)	22days	22days (at day 300)	5 days (at day 400)	0,05(at day 500)	51.562,0€	- 374,7€

Based on the results as they are presented in Table 1, scenario B has the greatest FTTS value. In all other cases, the effect of the FTTS is negative. The model allows for the tracing of the reasons behind this behaviour. In all cases the Supply Line (SL) and Goods Inventory (GI) develop a behaviour of oscillation where the state (SL and GI) overshoots its goal (ESL and EGI), reverses and undershoot and so on. The reason behind this behaviour is the two negative feedback loops (Supply Line and Inventory Control) and the delays caused by the Actual Inventory Replenishment Time (AART) and the Minimum Order Quantity (MOQ). Scenarios C and D due to the reduction in Inventory Days of Sale (IDS) have lower level of inventory targets (Desired Goods Inventory - DGI) and therefore lower average inventory leading to lower costs of holding them (Figure 3). Yet, smaller inventory lead to increased Unfilled Orders (UO) compared to the other scenarios (Figure 4) resulting to lower Cash Balance. It is therefore evident that the effect of FTTS on performance is very sensitive not only to the response of the firm but also the timing of this response.

5. Concluding remarks

In this paper we developed a theoretical framework mapping how exogenous freight transportation time changes may affect performance of a typical organization that consumes transport services The novelty of this approach lies in its holistic systems thinking, according to which organizations are best understood when seen as holistic systems, where the various processes and their activities interact via a web or relationships and constitute a whole. In systems theory, it is the system's structure (causal links) that determines its behaviour, and if this structure is well understood and explained then a greater insight into the behaviour of complex phenomena can be achieved (Senge, 1990). Evidence from the simulation experiment has shown that under certain operating conditions and decision rules a company may or may not fruitfully exploit freight transport time savings.

Figure 3: Goods Inventory for all scenarios

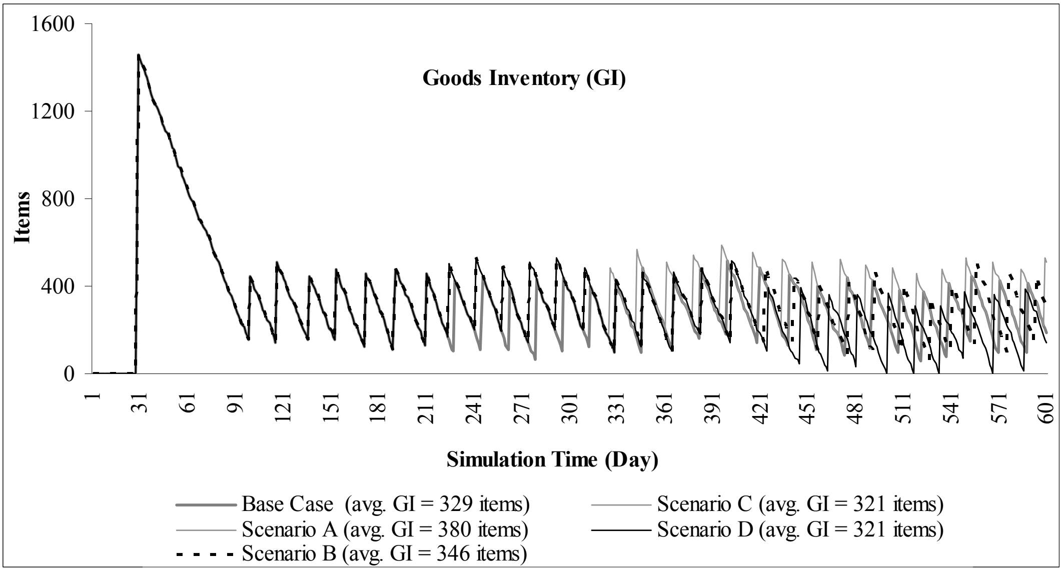
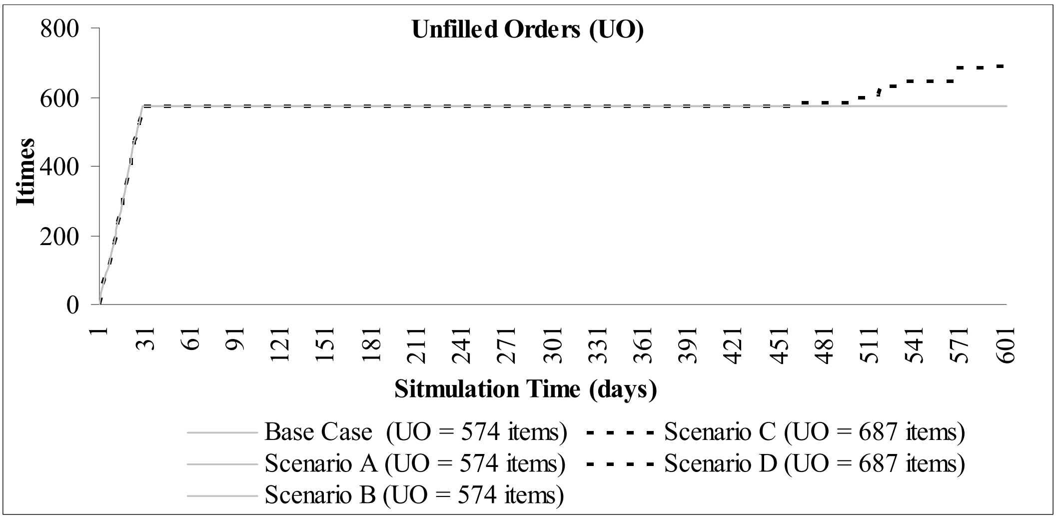


Figure 4: Unfilled Orders for all scenarios



Based on this framework, in order for shippers to estimate the effect that a change in transportation time will have on their performance, first they have to identify how such a change will affect the planning and execution of internal business processes (source, make, deliver, return). The next step is to identify how changes in internal processes affect stakeholders (customer, suppliers, community, regulators and shareholders) so as to develop the appropriate performance measures for each perspective and map the causality links between them. In order to elicit the effect of FTTS on performance and result to quantified conclusions the next step is to consider existing or develop hypothetical scenarios and simulate the causal model.

Using system dynamics modeling and simulation this framework brings new insights into the evaluation of FTTS and it is worth consideration for a number of reasons. First of all it returns time profiles for all variables, from the initial time until the end of the time horizon allowing for comparisons between them with and without the exogenous stimuli (change in transportation time). Also, it allows for the gradual introduction of transportation changes as well as alterations in decision rules and operating conditions of the firm resulting from those changes in a more realistic way. It allows for the introduction of several decision criteria and performance measures as variables of the system participating in several feedback mechanisms and even interact with each other. Moreover, it allows the tracing of all variables' values on a step by step basis and not just at the beginning and the end of the time horizon, however long. Finally, it enables the track and tracing of the causes - parameters and conditions – behind the effects that may hinder or enhance performance.

This approach could be further used for the uncovering of the linkages between improvements (or deteriorations) in other transport attributes (e.g. in transport cost, travel time reliability) and organizational performance. This is a realistic scenario, since transport projects rarely affect only one transport parameter and in this case it is required to assess the joint effect of these changes to performance. Considering that there may be trade offs between them (e.g. a decrease in transport time may result in increased transport cost) and the reactions of the firms, this framework provides a tool for the comprehensive observation of the causalities between transport improvements and organizational performance.

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