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SERVICE LEVEL improvement through LEAD TIME reduction and INVENTORY optimization

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by

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IMPRIMATUR POUR LA THÈSE

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Reduction and INVENTORY optimization

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ABSTRACT

This Ph.D. thesis aims to understand, first, why some companies excel at logistics service level while others do not and, second, how to improve logistics service level. More in detail, the goal of this research is to investigate and analyse both the drivers and the obstacles of logistics service level excellence.

Logistic service level represents increasingly today, in very competitive markets and in the presence of very demanding customers, a crucial element for differentiation and a source of competitive advantage in many different businesses. There are different facets of logistics service level, defined as a bundle of different attributes. This thesis has focused on two of them: *speed* and *inventory availability*.

Given the nature of the research objectives developed, an exploratory case study research methodology has been chosen to gain an in-depth understanding of a phenomenon: drivers and obstacles of service level improvement. First, *lead time reduction* has been investigated through *make-to-order* cases. The focus has been, first, on manufacturing lead time, analysed through a single in-depth case study, and then has moved to order-to-delivery lead time, studied through a multiple case study research. Second, *inventory availability* has been investigated through multiple *make-to-stock* cases.

The first output, a theoretical contribution, of this thesis consists of a conceptual foundation for theory development concerning logistics service level improvement. Three frameworks, focused respectively on manufacturing and order-to-delivery lead time reduction and inventory availability improvement, have been developed combining the knowledge emerged from the literature, the case studies and the observations and the experience of the researcher.

The second finding, a practical contribution, is that, although lead time reduction is increasingly today a key driver for competitive advantage or even for survival in many different businesses, there is still substantial room for improvement and, more dangerously, managers are often unaware of this opportunity. In addition, this research highlights that the main obstacles of lead time reduction seem to be more related to other management areas, such as people behaviour, organisation and accounting, than to technical operations management issues. As far as inventory availability is concerned, the main practical finding is that managers should not only focus on inventory management, but also to other related processes such as warehouse management and forecasting and that there are different ways, not a single recipe, to reach logistic service level excellence.

KEYWORDS:

Service level, lead time, speed, agility, availability, inventory management, warehouse management, quick response manufacturing, lean, logistics, operations, supply chain.

MOTS CLES:

Niveau de service, délai d’approvisionnement, vitesse, agilité, disponibilité, gestion de stocks, gestion d’entrepôt, quick response manufacturing, lean, logistique, opérations, chaine d’approvisionnement.

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1. INTRODUCTION

1.1 LOGISTIC SERVICE LEVEL and PROBLEM STATEMENT

Logistic service is a bundle of attributes that concerns mainly speed, dependability, completeness, precision and flexibility of deliveries as well as the immediate availability of the items the client wishes to buy. Manrodt and Davis (1992) and Rushton et al. (2006) define logistic service as the ability of a company to offer good levels of availability, speed, dependability and flexibility of deliveries.

Looking just at the definition, this list of attributes is quite broad and articulated; in addition, they differ not only in definition, but also in nature. In fact, while speed and dependability are time related attributes, completeness and precision of deliveries are physical related measures. Flexibility is not only rarely measured in practice, but also vaguely defined in theory. Finally, inventory availability does not have a unique definition and corresponding measurement metrics and systems. For a complete and exhaustive definition of logistics service related attributes and measures, refer to the SCOR model developed by the Supply Chain Council (2004).

In recent years, relevance of logistic service as a competitive weapon has increased enormously in several industries. This is proven extensively both in literature and in practice (Rushton et al., 2006; Corsten and Gruen, 2004).

Although with differences, an excellent logistic service level is important for companies competing with different production approaches, ranging from make-to-stock to engineering-to-order. In make-to-stock, where the delivery time accepted by customers is very short, the immediate and prompt product availability is crucial because stock-outs correspond frequently to lost sales. On the other extreme, short lead times of all processes, ranging from engineering and procurement to manufacturing and logistics, are relevant in engineering-to-order. In the intermediate make-to-order cases, it is important to excel both in inventory availability, mainly of materials at the decoupling point, and in lead times mainly related to the production phases after the decoupling point. Finally, short lead times, especially of final production and logistics processes, help companies move from a pure PUSH production approach, heavily affected by sales forecast accuracy, to more mixed PUSH-PULL settings, which may benefit from important effects such as risk pooling just to cite one of them.

The increased relevance of logistics service level is related also to some recent global trends observed in several different businesses such as shortening of product life cycles and higher innovation rates, shorter customer expected delivery times, larger product portfolios, proliferations of distributions channels, increased demand volatility and unpredictability, higher normative pressures, outsourcing and delocalization, etc.. While shorter product life cycles, linked to higher innovations rates, require better capabilities to manage properly inventory levels during a short period for sales, shorter customer expected delivery times require either shorter lead times or better sales forecasting accuracy in make-to-stock cases. The proliferations of both product portfolios and distribution channels increase demand fragmentation and volatility which, as a consequence, require more agile supply chains characterized by shorter lead times or more delocalized inventories closer to final customers. In addition, the more fragmented and the less collaborative supply chains, the higher the volatility because of the well known Bullwhip effect. Higher normative pressures, such as stricter expiration dates of products in pharmaceutical and food sectors, and outsourcing and delocalization trends are other aspects that make inventory availability and lead times more relevant. To cite also some trends in specific businesses, the higher penalty clauses in JIT (Just-in-time) contracts and the increased number of collections in the fashion industry require excellent logistics service levels. Serdarasan (2013) made a review of the typical complexity drivers that are faced today in different types of supply chains.

The relevance and the articulated definition of logistics service level, together with the lack of standardised KPIs (Key Performance Indicators) and measurement systems, make logistics service level analysis, diagnosis and improvement an interesting topic to study. Among all the different attributes, which compose logistics service level, *speed* and *inventory availability* are the two ones I have selected to further investigate in this research.

The main reason for this choice is based on the key role they both play today for different companies in several industries, which is, in turn, strictly related to the increased relevance gained over the years by *time* as a source of competitive advantage. In fact, not only speed but also inventory availability is somehow a *time* related measure; inventory availability is relevant in those cases where the delivery time requested by customers is very short and a lack of immediate availability of a product results in a stock-out or even worse in a lost sale.

A second reason of this choice is linked to the "power of time" (Suri, 2010). Suri demonstrated, through the implementation of QRM (Quick Response Manufacturing) in several companies, that the huge impact of lead time reduction in operations does not only affect lead time to customers, but also cost, quality and other measures of operational effectiveness. When QRM methods are capable of reducing costs by 30%, as many companies have achieved, the low labour cost advantage of many countries does not hold anymore.

A third reason of this choice relates to the *Operations Management triangle* (Figure 1 - Schmidt, 2005) which states that capacity, inventory and information are substitutes in providing customer service. Companies, operating at the *capacity point* (point (a) of Figure 1) of the OM triangle, provide service levels to customers and cope with demand volatility through short lead times and low WIP running at low utilization levels due to the presence of some slack capacity. Vice versa, companies, having high fixed capacity costs and aiming at highest utilization, operate at the *inventory point* (point (b) of Figure 1) of the OM triangle providing service levels to customers and coping with demand volatility through buffered and high inventory levels. Therefore, the OM triangle suggests two different ways to provide service levels to customers and to cope with demand volatility: the first, through short lead times, low WIP and buffer capacity, the second, through high inventory levels. The OM triangle suggests also a third way to guarantee service levels to customers which consists in reducing variability through better information and coordination (e.g. adopting collaboration practices such as Vendor Managed Inventory). In this case companies operate at the *information point* (point (c) of Figure 1) of the OM triangle which provides good service levels to customers running at higher utilization, so exploiting more capacity, without increasing inventory levels. De Treville and Hameri (2004) provided an interesting contribution about the relationship between lead time reduction and information flow improvement at supply chain level. A OM triangle related empirical study, conducted by Poiger, Reiner and Jammernegg (2010), has analysed, applying rapid modelling techniques, two companies capable of providing good service levels to customers decreasing inventories and lead times and reducing internal variability induced by batch sizes.

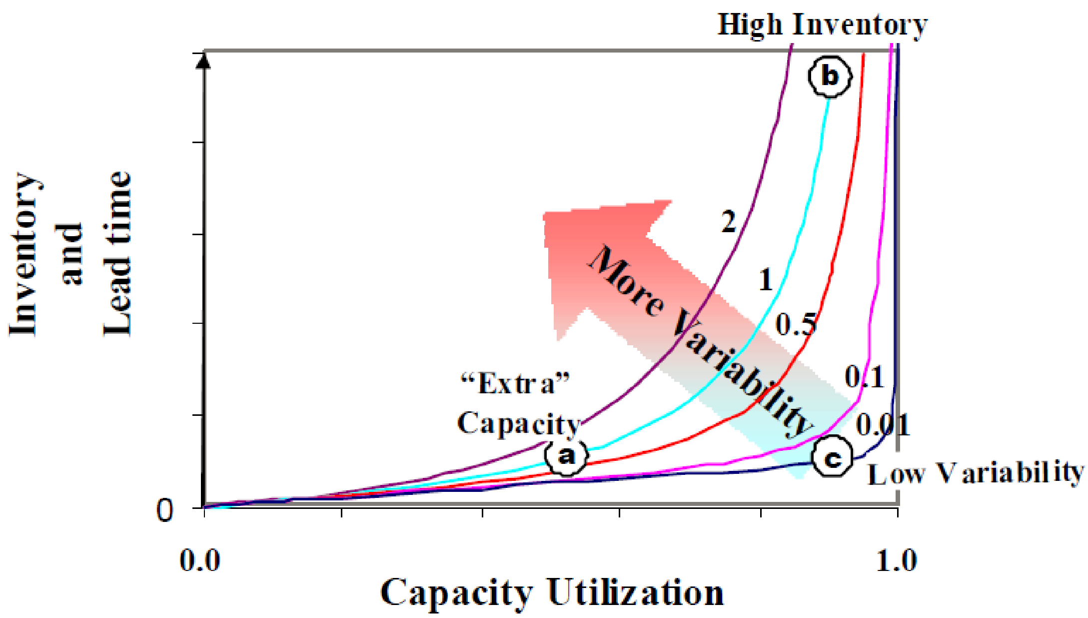

Figure 1 - Operations Management triangle (Schmidt, 2005)

I have not focused this research on *reliability*, although it is another time related measure of logistics service level, because of some grounding principles of the QRM managerial philosophy. In fact, according to his "response time spiral", Suri (1998) believes that *reliability*, on one hand, does occur automatically when lead times are short and, on the other hand, has even negative outcomes, prolonging lead times and frozen periods and increasing sales forecast errors, when it is used as main performance goal. According to the QRM approach, the focus should be only on reducing lead times and on-time deliveries are just a consequence. Finally, focusing this research on *time* related measures of logistic service level, *completeness* and *precision* of deliveries, physical related measures, have not been investigated.

In the following paragraphs, I address separately these two dimensions of logistics service level both from a theoretical and empirical point of view: first speed, then inventory availability.

Beginning with *speed*, consider a firm that makes a product for which complete information concerning specifications or quantity is available 2 weeks before delivery, but the time required to produce the product is 6 weeks. The production decision, actually made based on forecast, could be made on actual data were the company able to reduce manufacturing lead times from 6 weeks to 2 weeks. The cost of having lead times longer than the time window during which accurate information on actual orders is available, includes production of items that are not needed, shortages of items that are needed, and high stocks to maintain a reasonable level of responsiveness. Beyond such cost reduction, lead times that are short enough to permit incorporating actual customer needs into production planning can tremendously increase competitiveness. The expectations are, therefore, that decision makers from firms in such a position would make lead time reduction an absolute top priority, that is, they would have a time-based mindset (Suri 1998).

Let us add to the picture that reducing lead times is not difficult: it follows well known and understood mathematical principles, and simple analytical tools are available to assist in setting up an action plan to radically reduce lead times for a often modest investment (e.g., see the potentials of Rapid Modeling in Schold et al., 2010). In short, lead times exceed processing times by a wide margin when utilization of any resource is high, lot sizes are large, and system variability is high. I refer to a combination of activities to reduce excessive utilization, lot sizes, and variability as *lead-time-reduction behaviour*.

The competitive power of lead time reduction is so obvious and demonstrated in practice (see QRM applications and results at http://qrm.engr.wisc.edu/index.php/results) and the actions required for lead time reduction are so well known, that lead time reduction seems easy and straightforward to achieve. Why then, do so many companies lose competitive ground because their operations are too slow? Why is so much production shipped offshore, guaranteeing extremely long lead times, when loss of responsiveness, increased supply chain inventories, and increased complexities quickly overwhelm the 30% cost reduction that results in the "China price"? (For a concise practitioner-oriented summary of the China price, see Engardio et al. 2004).

One objective of this research is to open a discussion around these questions and lay a foundation that facilitates addressing them. It is imperative to stop considering lead time reduction as obvious and begin to understand what factors must be in place if lead time reduction is to succeed.

Moving to the second aspect of logistics service level under investigation**,** *inventory availability* has also gained a lot of importance throughout the years. One of the reasons is the commoditization process seen in many industries which brings about an ever-decreasing willingness on the part of the customer to wait for delivery. In this new setting, guaranteeing the prompt availability of the product is a new challenge that requires a deep understanding of the levers that a company can use to increase service level without incurring extra costs. Given the well known trade-off between stock availability and holding costs, companies need to understand how they can enhance logistic service without increasing inventory levels. Corsten and Gruen (2004) and Abernathy et al. (1999) demonstrated that product availability is considered key to survival, respectively, in FMCG (fast moving consumer goods) and in the apparel industry.

Let us add to this that much has been already discovered and done to improve inventory availability within the field of inventory management. Established mathematical principles and managerial best practices have already helped companies reach satisfactory results. However, managing inventory availability in a excellent way has become increasingly difficult and challenging over the years due to all or some of the following recent trends already mentioned before: product portfolio proliferations, product life cycle reductions, increased number of distribution channels, reduced delivery times requested by customers, unpredictability and seasonality of demand, etc..

Finally, although improving inventory availability has been addressed in other streams of research, such as warehouse management and supply chain management, there is still a lack of an integrated cross-discipline framework.

Based on these premises, a second purpose of this research is to understand, on one hand, what are the main challenges and obstacles of inventory availability excellence and, on the other hand, how best performing companies strive to improve their inventory availability and what levers must be in place to achieve this goal.

1.2 RESEARCH OBJECTIVES and SCOPE

The research problems illustrated before can be very briefly summarized saying that, although logistics service level has gained an increased relevance throughout the years in several different businesses and the knowledge, tools and approaches to improve it exist and are often easier and cheaper to apply than managers often believe, in practice many companies struggle in excelling in service levels and this implies the existence of obstacles and challenges that have to be removed or managed differently. In addition, it is not clear how to improve logistics service levels in different businesses and cases. Are there standard recipes to apply or optimal service level *journeys* to follow? If yes, to which extent could these best practices be replicated and adopted in different businesses? If yes, how to select the most appropriate ones for a specific case? All these questions and issues represent not only a theoretical, but also a practical real life problem. More specifically about lead times, the main problem is that managers do not apply well know and often cheap tools to reduce lead times and often take counterintuitive decisions that, instead, prolong lead times. The result is that, in practice, there is a still a good room for improvement in lead time reduction. About inventory availability, where this theory-practice gap seems to be less relevant, the main problem is about the understanding of which are the best approaches to apply and under which circumstances to manage inventory availability at best.

Based on these premises, the main *objective* of this Ph.D. thesis is to investigate the obstacles and the drivers of logistics service level in order to identify paths to follow and best actions to implement to excel in logistics service level. As a consequence, the resulting main research questions, that this Ph.D. thesis aims at addressing, can be summarised as follows:

a. *Why* is logistics service level excellence so difficult to achieve in practice extensively? What are the main obstacles that have to be removed?

b. *How* to reach logistics service excellence? What are the main drivers to leverage on and the best approaches to adopt to excel in logistics service level?

Because of the articulated definition of logistics service level, as a bundle of different attributes, and the decision to focus this research on two of them, also the objective has been split into two different ones, focusing separately on speed and inventory availability. As a consequence, the generic research questions about logistics service level introduced above have been differentiated for the two different areas of study.

As far as *speed* is concerned, where the main problems relate to longer lead times observed in practice compared to what would be achievable applying well known theories and using cheap and available modelling tools, the resulting research questions are the followings:

a. *Why* is lead time reduction not achieved in practice extensively, while knowledge and tools to do so are available and cheap? What are the main obstacles that have to be removed?

b. *How* to reduce lead times? What are the main drivers to leverage on and the best approaches to adopt to reduce lead times?

As far as *inventory availability* is concerned, where the main problems seem to be related more to the identification of the most suitable practices to apply for each specific case and of the best managerial path to follow (if any), the resulting research questions are the followings:

a. *Why* is optimal inventory availability difficult to achieve in practice, while inventory management knowledge and tools have been available for a long time? What are the main obstacles that have to be removed?

b. *How* to improve inventory availability in practice? What are the main drivers to leverage on and the best approaches to adopt to improve inventory availability?

The *scope* of this research differentiates for speed and inventory availability, although they represent two attributes of one single concept, logistic service level.

To investigate *speed*, I have focused the research only on *make-to-order* cases. The main reason of this is that, in make-to-order cases, logistics service level perceived by customers is directly influenced also by manufacturing and assembling lead times, not only by planning or order management lead times and inventory availability of semi-finished products. In a make-to-stock case, short delivery lead times to customers may also be achieved, in the short term, through high inventory levels of finished products while manufacturing or assembling lead times are long. As I am going to explain better later, in this research I analyse *speed* obtained through short lead times of operating processes, not through high inventories positioned close to customers or at strategic decoupling points in the Supply Chain.

To investigate *inventory availability*, I have focused the research only on *make-to-stock* cases. The main reason of this is that, only in make-to-stock cases, logistics service level perceived by customers is mainly influenced by inventory availability of finished products. Transportation lead times, which are often today not under direct control and management of companies because of the outsourcing transportation trends, are out of scope in this research and I look at inventory availability of finished products at companies' warehouse level, not at customer site. If I had chosen, for example, also make-to-order cases, logistics service level perceived by customers would have been influenced simultaneously by both manufacturing lead times and inventory availability of semi-finished products. This would have mixed the two aspects of lead times and inventory availability making the identification of obstacles and drivers of logistic service level more difficult and confusing. In addition, the main interest of this research is to look for obstacles and drivers of inventory availability of finished products, not of semi-finished products or raw materials, because they impacts directly logistic service level perceived by customers.

1.3 THESIS OUTLINE

This Ph.D. thesis is grounded on four papers, which investigate different aspects of logistic service level. However, in order to avoid repetitions and to make the flow of the thesis easier to follow, the four papers have being modified and adapted to fit with the overall structure.

One paper, focused on finished product availability in make-to-stock cases and titled *"Linking service level, inventory management and warehousing practices: A case-based managerial analysis"*, has been already published in 2011 by *Operations Management Research* (vol.4, n.1-2, pp.28-38), Springer Science. The authors are myself, as first and corresponding author, and Prof. Valeria Belvedere. Another output linked to this research has been the book, of which I am the main author (*"a cura di"*), *"Logistica&Servizio"*, edited by Egea Milano in 2009.

A second paper, focused on manufacturing lead time reduction and titled in its first three versions *"Human and organizational factors in lead-time reduction"*, has gone through several revisions and modifications and has been presented in 2008 at the HOPS (Human and Organisational Factors in Planning and Scheduling) conference at EPFL, Lausanne. It is a single in-depth case research that, although written by several authors (Gallmann F., G. Reiner, S. de Treville, M. Bornoz) with myself being the first one, it has been fully based on a three months full-time period I have spent located abroad in a international company producing industrial polymer solutions. This single case study research has been part of a broader project titled "Keeping Jobs in Europe" financed by the Marie Curie Industry-Academia Partnerships and Pathways (IAPP), supported by the EU's Seventh Framework Programme (FP7) for RTD (2007-2013).

The last two papers, focused on order-to-delivery lead time reduction and titled respectively *"Obstacles of order-to-delivery lead time reduction"* and *"Manufacturing versus office lead time reduction"*, are, at the moment, conference papers presented at the annual EUROMA conferences (Palermo, 2014 and Neuchâtel, 2015). Before becoming two distinct papers, the output has been in the form of a evolving working paper which has been presented in two different editions of the Euroma Doctoral seminar (Amsterdam, 2012 and Dublin, 2013). This research, supported partially by a grant of the FNS (Fonds National Suisse), is based on in depth interviews and visits I have conducted in the period 2010-2013 in four Italian companies. The authors are myself, as first and corresponding author, and Prof. Gerald Reiner. Because the two papers are based on the same set of companies and they address similar topics although from different perspectives, they have being unified in a single chapter.

This thesis is structured in several chapters in the following way. After this introduction about overall research problems and objectives, chapter 2 addresses lead time reduction. It starts with a literature review and then focuses on the queuing theory based mathematical principles governing lead time. It is then presented a conceptual model which, however, needs to be modified and further developed because of the theory-practice gap in lead time reduction anticipated before. Section 2.5 addresses manufacturing lead time reduction, which has been studied through a single in-depth make-to-order case study. Because of the limitations of a single case study research and that focusing only on manufacturing lead time represents an additional limitation, section 2.6 refers to a second research carried out on the broader order-to-delivery lead time topic using four make-to-order cases. Chapter 3 addresses finished product inventory availability, the second aspect of logistic service level under investigation, through a multiple case study research analysing six make-to-stock cases. Chapter 4 summarises the main results and findings, highlights the theoretical and practical overall contributions of this thesis, comments on limitations and suggests further research.

2. LEAD TIME REDUCTION

2.1 INTRODUCTION

"Everyone knows that time is money, but time is actually a lot more money that most managers realise!" (Suri, 2010). This is the starting sentence of Suri in Chapter 1 (The Power of Time) of his book "It's About Time" (2010). Although the relevance of time is clear to everybody, short lead times bring more benefits than just higher service levels and customer satisfaction. In fact, short lead times, according to QRM theories, bring also other advantages such as more reliable deliveries, lower costs, higher quality, higher flexibility and cheaper product customization. This view of speed, which goes beyond the traditional trade-off view among operational performances, can be easily understood following the "Lead Time spiral" reasoning of Suri (1998) (Figure 2). Starting from the top box and following the spiral clockwise, longer lead times cause inaccuracy of planning, lower logistics performance, higher WIP and inventories, more urgent jobs, more delays and the final outcomes are longer lead times, which get higher and higher the more times you go through this vicious cycle. The consequences are, therefore, not only longer lead times, but also higher costs, higher scrap rates, lower reliability of deliveries, lower flexibility, etc. This theoretical and qualitative reasoning has been also confirmed in practice. It has been proven, in fact, that those companies, which have invested heavily in lead time reduction initiatives such as QRM, have benefited from relevant improvements not only in lead time, but also in costs, quality, flexibility and on-time performances (For more information refer to the extensive list of cases on the QRM Center website at http://qrm.engr.wisc.edu/).

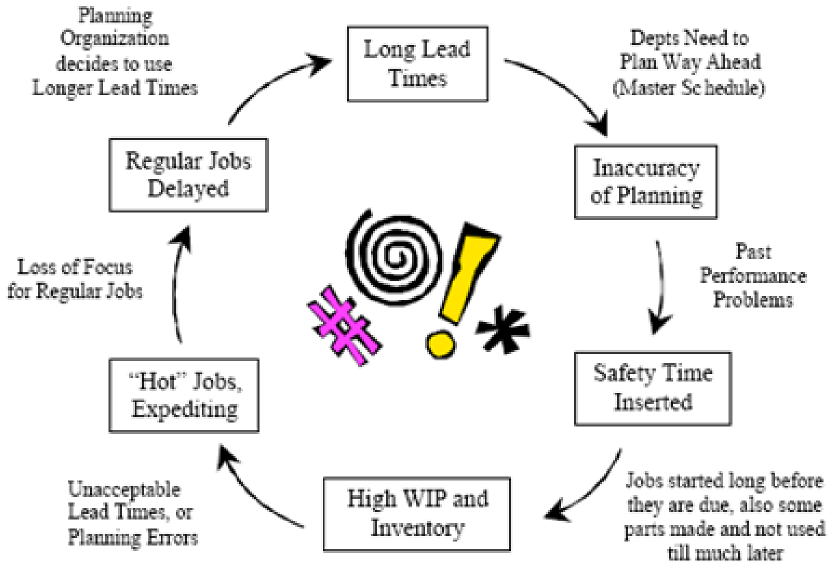

Figure 2 – The Response Time Spiral (Suri, 1998)

Finally, lead time reduction is important not only in make-to-order, but also in make-to-stock. In fact, while faster deliveries to customers are the main benefits in make-to-order, short lead times mean, in make-to-stock, higher accuracy in sales forecasting and operation planning, lower inventory levels and lower safety stocks to guarantee same service levels and higher flexibility. However, as explained before, I have focused this research on lead time reduction only on make-to-order cases.

In general terms, lead time of a process is defined as the time interval occurring between the initiation and execution of a process. Silver et al. (1998) defined lead time as the time that elapses between the placement of an order and the receipt of the finished product. While this definition is quite simple and straightforward, there are several definitions of lead time both in theory and in practice: external lead time, internal lead time, quoted lead time, planning lead time, manufacturing lead time, delivery lead time, supplier lead time, just to cite some of them (Suri, 2010).

As far as this research is concerned, the focus of the analysis is not only on *manufacturing lead time*, but also on *order-to-delivery lead time*. There are three main reasons of this choice. First, the focus only on manufacturing lead time, which may represent in some cases a small portion of the overall lead time, seems to be a non neglectable limitation. Second, order-to-delivery lead time gives an external customer view of lead time, while manufacturing lead time gives mainly an interval company view. Finally, it seems that too much attention, both in academia and practice, has been devoted to improve manufacturing lead times, while other relevant non-manufacturing processes may have been wrongly neglected.

Manufacturing lead time is the time raw materials take to be transformed into finished products and relates mainly to all those activities occurring within a factory (Senapati et al., 2012). Manufacturing lead time is composed by several different lead times such as processing or transformation times, set-up times, queuing times, inventory times, quality control and reworking times, internal transportation times, just to cite some of them. In addition, following the Lean approach, these several different times can also be grouped in the following two categories: *value-added times*, defined as those times linked to activities customers are willing to pay for, and *non-value-added times*, linked to those activities that represent waste (MUDA) and that should be reduced as much as possible. Senapati (2012) says that less than 10% of the total manufacturing lead time is spent actually manufacturing the product.

Order-to-delivery lead time is the time elapsing from the customer order issuing date to the delivery of goods or services to the customers (Senapati et al., 2012). However, because transportation is often outsourced and therefore not fully and directly controlled by companies, the perimeter of analysis of this research ends with goods and services ready for delivery at manufacturer site. Order-to-delivery lead time is a lead time from a customer point of view and, in make-to-order cases, manufacturing lead time is just one of its components. In fact, order-to-delivery lead time may be decomposed in several different sub-elements such as manufacturing lead time (in make-to-order), order processing, production planning, handling & picking and even supplier delivery lead time, in case of stock-outs of some components or semi-finished products.

In addition to the lead time definitions and the scope of analysis discussed above, it is important to define *lead time reduction* for this research. In fact, while several different approaches exist for a company to serve customers faster, the focus of this research is about reducing the single components and sub-components of lead time; it is not about other interventions such as over-stocking, positioning stock at different strategic points in the supply chain or moving the decoupling point closer to customers because of long lead times of some downstream operations. The main reason of this choice, which comes from the QRM grounding principles and the QRM definition of MCT (Manufacturing Critical-Path Time) (Suri, 1998), is that only by tackling lead times in all processes real speed is achieved together with other benefits such as costs, quality, reliability and flexibility. All other ways of being fast hide, in fact, some inefficiencies and cannot last in the long term.

2.2 THEORETICAL and EMPIRICAL BACKGROUND

Interest in lead-time reduction, defined for the purposes of this research as the time that elapses between the beginning and completion of a process, was originally awakened by Just-in-Time (JIT) production, even though lead-time reduction has been considerably less emphasized in the JIT literature than reduction in waste (Schonberger 1982, Hall 1983, Monden 1983, Suzaki 1987, Womack et al. 1990, Blackburn 1991, Suri 1998). Whereas JIT and its offspring lean production are primarily focused on repetitive manufacturing in assembly lines, Goldratt and Cox (1984) addressed lead-time reduction in a batch flow environment, highlighting the central role of bottleneck utilization and lot sizing on lead times.

As reduced in-process inventories and infrastructure changes to improve flow (e.g. a product layout) led to shorter lead times, the competitive implications of short lead times caught the attention of the business community, leading to the identification of a competitive strategy based on speed, referred to as “Time-Based Competition” (Stalk 1988, Stalk and Hout 1990, Blackburn 1991, Holmstrom 1995, Suri 1998, Schmenner 2001). In a first effort at theory development, Schmenner (2001) proposed a theory of “Swift, Even Flow,” positing that an emphasis on flow at the company level would be positively related to productivity.

Whereas much of the literature on lead-time reduction had been largely anecdotal and exploratory, Hopp and Spearman (1996) compiled a set of the mathematical principles determining lead time, resulting from basic and universal insights that emerge from queuing theory, which they referred to as “Factory Physics.” Suri (1998) simultaneously developed a manufacturing strategy, also informed by queuing theory, entitled Quick Response Manufacturing (QRM) that addressed implementation of lead time reduction principles in manufacturing environments. Factory Physics and QRM formalized the relationship of bottleneck utilization, lot sizes, and variability to lead times. The underlying mathematical relationships had been well-known in the field of queuing theory for many decades (see Suri et al. 1995), but the work by Hopp and Spearman (1996) and Suri (1998) represented the first comprehensive application of these principles to the general body of knowledge in operations management.

The mathematical principles underlying lead time reduction are axiomatic and instruct how to reduce lead times. They are commonly known and accepted among researchers in the field of operations management, and are commonly covered in introductory operations management courses. Suri (e.g. 1998) demonstrated empirically, however, that managers tend to be unaware of these mathematical relationships, believing that lead time reduction is difficult and costly. Furthermore, these principles are not emphasized in much of the operations management literature on lead time reduction.

Lead time reduction has become a relevant topic not only in manufacturing, but also in service industries and service operations. For example, Caridi et al. (2008) presented a case study of a lead time reduction project in a bank that tested the impact of seven different policy changes, most of which can be categorized according to the definition of lead-time-reduction behaviour given before. Utilization, non-strategic variability, and lot sizes (that is "batching of requests") were targeted through several actions: formalized dispatching rules (that limit arrivals to the service rate), automation of risk calculations, improving the training of operators, "automation" of the transport operations (transferring documents to the next process stage in electronic form), and increasing the frequency of approval meetings. Linked to this last action, it is particularly interesting to notice the huge increase in lead time arising from the fact that various approval groups met weekly, meaning that on average lead times increased by 0.5 weeks for each approval required. This effect, typically completely unseen by managers, was also observed in a study about reducing lead times to get tuberculosis medications to developing countries (De Treville et al., 2006). The lead time remained long relative to processing times (1-3 days of lead time relative to a few hours of processing time), indicating that lead-time-reduction behaviour would still be useful in spite of the actions taken.

Lead time reduction has been addressed in the literature not only from an Operations Management point of view, but also from the perspective of many other disciplines. In spite of this, there is a lack of a complete theory of lead time reduction that integrates the different disciplines.

Taking, for example, the behavioural and organisational point of view, most of the research on lead time reduction is represented by often untested propositions. Behavioural aspects of lead time reduction have been addressed primarily through the lean production and JIT literature. These behavioural aspects have often not been grounded in the organizational behaviour and other related literatures, but have stemmed from shop floor practices observed anecdotally. Much of the foundational literature on JIT is based on lists of practices, many of which are largely behavioural (Davy et al. 1992, Flynn et al. 1995, Sakakibara et al. 1997, White et al. 1999, Shah and Ward 2003, Bendoly et al. 2015).

Koufteros, Vonderembse, and Doll (1998) proposed a set of seven "time-based manufacturing practices," including shop-floor employee involvement, reengineering setups, cellular manufacturing, quality improvement efforts, preventive maintenance, dependable suppliers, and pull production. In their theoretical model (supported in empirical testing), the ability to compete on time came from pull production. Shop floor employee involvement led to pull production, mediated by the other five factors. The authors went so far as to state that "Employee involvement in problem solving is an antecedent to other time-based changes."

Tu, Vonderembse, Ragu-Nathan, and Sharkey (2006) built on this model, proposing absorptive capacity (i.e., the capacity to absorb and put to use new, external information) as an antecedent to customer value, mediated by the seven time-based manufacturing practices. Absorptive capacity was proposed to result from constructs such as worker and manager knowledge, communications network and climate, and knowledge scanning. The model was supported in empirical testing.

The practitioner literature has influenced development of (often untested) assumptions about behavioural aspects of lean production (related to lead time reduction). Authors such as Monden (1983), Adler (1993), Hall (1983), Harmon and Peterson (1990), Schonberger (1982, 1994), and Suzaki (1987) have emphasized treating workers with respect and investing in worker competences. Other practitioner-oriented literature, however, gives examples of lean production environments in which behavioural aspects of lean production failed, with workers moving from trust and high motivation to disaccord with management (Kamata 1982, Fucini and Fucini 1990, Graham 1995, Adler et al. 1997, Rinehart et al. 1997, Post and Slaughter 2000).

A few authors have attempted to test behavioural assumptions about lean production empirically, or to link operations management and organizational behaviour theories in the lean production context. Schultz, Juran, and Boudreau (1999), for example, ran an experiment that explored the relationship between in-process inventory and worker productivity. Authors such as Bendoly, Donohue, and Schulz (2006) have called for increased empirical behavioural research in the field of operations management.

From a behavioural viewpoint, little distinction is made between lean production and lead-time reduction based on the mathematical principles outlined in QRM and Factory Physics. This holds even in the work done specifically on time-based manufacturing. Irrespective of the absorptive capacity, employee involvement, trust, and other behavioural factors implied by the collection of practices underlying lean and other approaches, lead times will not be reduced without a reduction in bottleneck utilization, lot sizes, and variability.

Suri (e.g. 1998) makes extensive normative propositions about systems, mindset, and training that are required to support lead-time reduction in the QRM approach. These propositions have not been integrated with the operations management or organizational behaviour literatures.

As a result of this analysis, the aim of this research is to contribute to bridge the gaps in the literature identified mainly in the following three aspects. First, there is a gap between theory (lead time reduction principles are well known and their application seems to be quite easy and inexpensive) and practice (lead time is not reduced in practice) that needs to be further studied and explained. Second, there is a lack of exhaustive, wide-scope and cross-disciplinary frameworks on lead time reduction. Third, most of the research has been mainly focused on manufacturing lead time, ignoring lead times related to all those non-manufacturing activities which may play a relevant role in the overall order-to-delivery lead time.

2.3 MATHEMATICAL PRINCIPLES of LEAD TIME

What does a firm need to do to reduce its lead times? As already mentioned before, a set of mathematical principles and practical rules to reduce lead times, resulting from basic and universal insights emerged from queuing theory, have been formalized through the “Factory Physics" laws and incorporated into the QRM strategy.

The first key principle of lead-time reduction is illustrated in Figure 3. Although different definitions exist and vary between theory and practice, utilization is determined, according to QRM, by the effective capacity of process bottleneck resource(s) in relation to demand for that resource, and represents the probability that a resource is busy. It is calculated by dividing mean arrival rate by mean service rate. As utilization increases, average waiting times increase at exponential rate. Thus, lead time reduction often implies reducing utilization of the bottleneck resource (i.e., adding a capacity buffer), either through adding resources (equipment, labour) or through reducing the demands on that workstation. By Little’s law (1961), we know that utilization impacts not only system waiting time, but also in-process inventories. Nieto, Gläßer and Reiner (2010), investigated, using empirical data, the relationship between utilization and lead time in the context of complex manufacturing processes.

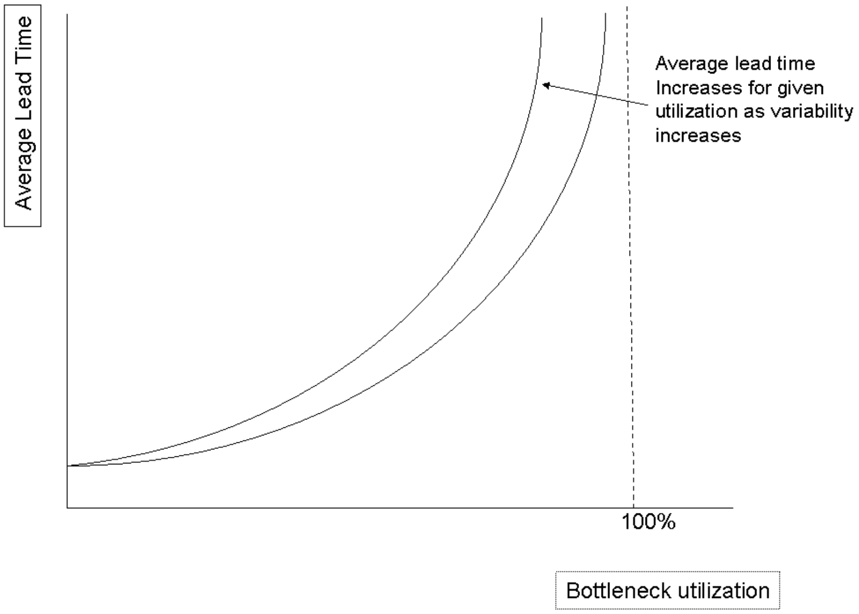

Figure 3 - Bottleneck Utilization and average Lead Time (Suri, 1998)

The second key principle concerns the relationship between lot sizes and lead times, as illustrated in Figure 4 (for a complete analysis of the relationship between lot size and lead time see Karmarkar 1987). In situations where a setup or major transportation operation is required for each new lot, the increase in capacity utilization from the incremental setups may cause a net increase in lead time, or even a lack of capacity, if lot sizes are reduced too much without reducing setup times. Once the setup or transportation operation has been reduced to fit existing capacity (or capacity has been increased), however, the relationship between lot sizes and lead time is approximately linear. This means that, assuming sufficient capacity, a 50% reduction in lot size amounts to a 50% reduction in lead times.

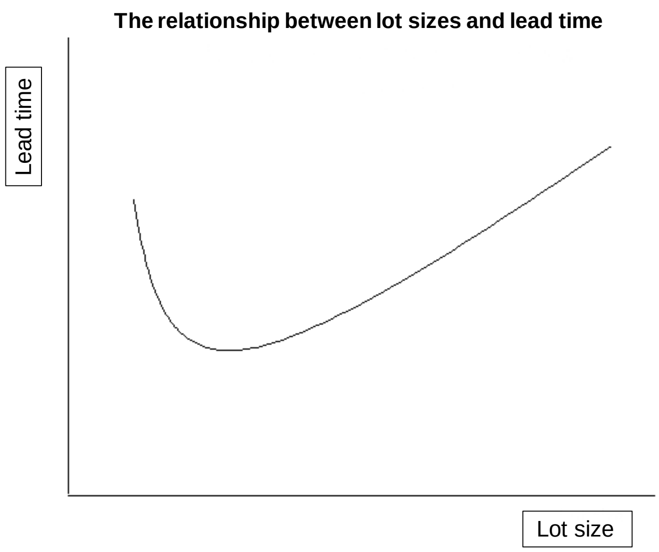

Figure 4 - Lot Size and Lead Time (Suri, 1998)

Finally, lead-time reduction is facilitated through reduction in variability (whether in arrivals or service rates) of the operation. Operating at the *information point* in the OM triangle (Schmidt, 2005) is aligned with this view. The curve to the left in Figure 3 shows the impact on lead time as the coefficient of variation (i.e., the ratio between the standard deviation and mean) increases for either service or inter-arrival times. However, not all variability is bad according to QRM principles. For example, consider a market in which customers do not have precise information about their needs until just before delivery of the product. Structuring operations to permit last-minute responsiveness implies leaving variability in the system as a source of competitiveness. Such variability is referred to as "strategic variability" (e.g., Suri 2003). In other words, demand and process variability can be either strategic or non-strategic depending on the context. Other variability (e.g. defective parts, machine downtime or worker absenteeism) has no strategic value and serves only to reduce system performance. An effective lead time reduction strategy calls for the reduction of non-strategic variability while creating capacity buffers to respond to strategic variability. This QRM view of variability represents one important difference between QRM and LEAN, which, on the contrary, aims at reducing all kinds of variability without differentiating between strategic and non-strategic variability.

These mathematical principles give clear and specific guidelines concerning how to reduce lead times, as was summarized into the QRM approach to manufacturing (Suri 1998): reducing bottleneck utilization, reducing lot sizes, and reducing non-strategic variability. However, Suri (1998) demonstrated empirically that managers tend to be unaware of these mathematical relationships, believing that lead time reduction is difficult and costly. In addition, there are very few empirical exploratory studies of these principles based on comprehensive empirical data, such as the work done by Dominik Gläßer (2012).

The actions taken to reduce lead times (capacity buffer at bottleneck, lot size reduction, and elimination of non-strategic variability) operate configurally. A reduction in lot sizes, for example, can increase utilization unless the relevant setup times are reduced. Similarly, a reduction in variability permits the system to operate at a higher utilization for given lead times. For this reason, the actions must be considered together, in line with a *lead-time-reduction behaviour*, to avoid misleading results and efforts to reduce lead times. One of the researcher in our team, for example, observed a plant that was attempting to reduce lead times through bringing workers together to brainstorm. These workers, however, did not understand the relevant mathematical relationships, had no analytical tools to test their ideas, and continued to be evaluated both individually and as a group on their ability to maintain high utilizations. Needless to say, the project did not result in any reduction in lead time. Company managers stated that they were involved in major lead-time-reduction activities, but according to our definition they were not displaying lead-time-reduction behaviour.

What is the importance of *lead-time-reduction behaviour*? Doesn't a company have the option to choose whether to reduce lead times through redesigning the supply chain or the product, rather than attacking the system dynamics of the internal order-to-delivery processes, including manufacturing? A supply chain made up of manufacturing operations with long lead times will not be responsive in the medium/long term, no matter what its design. A product redesign that improves the design for manufacturability but is manufactured in a plant with high utilizations, large lot sizes, and high variability will suffer from excessive lead times. For these reasons, this research, in line with the QRM principles, looks at *speed* obtained only through reduction of lead times of the most critical activities linked to the order-to-delivery process.

Although lead time reduction recipes seem to be easy and straightforward for implementation, isn't it usually too expensive to reduce utilization of bottleneck machines or reduce setup and transportation times to allow lot sizes to be cut? As already mentioned before, not at all or at least much less than what managers believe: such activities are often surprisingly inexpensive, and may be accomplished more through redeploying existing resources than huge investments (for several excellent examples of increasing capacity through better deployment of resources at a modest cost, see Goldratt and Cox 1984). Similarly, it is well established that reducing setup times for a given machine is often quite inexpensive (e.g., Shingo and Dillon 1985).

Let us add that these simple and inexpensive changes can have a dramatic effect on lead time because of the non-linearity in the system dynamics. Although companies might also consider streamlining their supply chains or redesigning their products to make them more manufacturable, these actions should never replace process improvement based on these mathematical principles. Furthermore, taking actions based on these lead time reduction principles often gives insights also into how to redesign the product (for practical examples, see Goldratt and Cox 1984, Suri 1998).

Although real-life operations cannot be completely modelled as one-station queues, the mathematical insights still apply. Product mix or lot size changes may apparently shift the bottleneck, for example, but calculating this impact and making adjustments to apply these principles is not too difficult (for an in-depth discussion of various measures of work-station and system capacity, see Cigolini and Grando 2009). Furthermore, simple mathematical modelling tools are available that facilitate identification of bottlenecks, determination of lead-time-minimizing lot sizes for a given configuration, and evaluation of improvement alternatives (Suri et al. 1995, de Treville et al. 2006, de Treville and Van Ackere 2006).

Finally, let me add that these three mathematical principles are valid in general for any kind of process, not only within a plant. They apply both to manufacturing and non-manufacturing operations and the differences are mainly related to the definitions and measurement systems of the variables: utilization, lot size and variability. Nevertheless, their main field of application has been manufacturing first for historical reasons. A second issue relates to definitions. In fact, while variables such as utilization, lot size, and variability of internal processes have been well defined and measured in manufacturing, this is not the case for non-manufacturing operations. Try for example to answer to the following questions related to office operations: “What is the definition of a lot size in production planning? How do you measure utilization of a worker processing orders? How to define and measure the “non-busy” time for an employee in an office?”. The answers to these questions are not so straightforward, easy and unique, as I have also experienced in interviewing several managers for the purpose of this research. A third reason is that operational improvements have mainly happened in plants and only recently they have expanded to non-manufacturing processes and service industries. Only recently, in fact, we have learnt about Lean office projects in manufacturing or commercial companies or Lean initiatives in a banks and hospitals.

2.4 STARTING MODEL

Driven by the theoretical literature gaps identified and the real practical needs of the high number of companies struggling with slow operations and delays in deliveries, a goal of this research is to build both a theoretical and practical model for lead time reduction. Therefore, the model aims to contribute not only to academic literature, but also to practice, providing concrete guidance to companies looking for faster operations together with the other related benefits.

Looking just at the theory, a model based on the three mathematical principles of Factory Physics and QRM is quite simple and straightforward (Figure 5). According to these principles, decreasing utilization at bottleneck, decreasing lot sizes and decreasing non-strategic variability, driven by the competitive needs for short lead times, should automatically translate, also in practice, into lead time reduction.

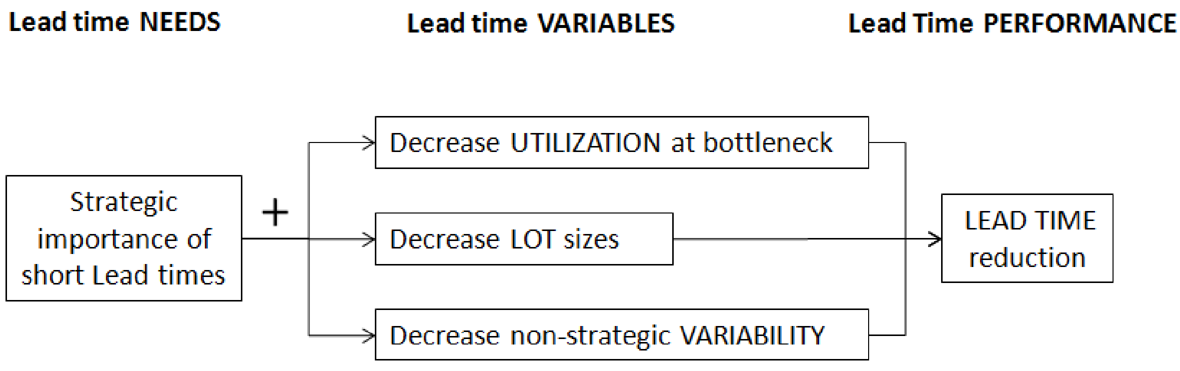

Figure 5 - Theoretical Lead Time reduction MODEL

Because the three mathematical relationships are valid for any kind of process, the theoretical model of Figure 5 could be further developed splitting the order-to-delivery process between manufacturing and non-manufacturing processes. Doing so, it would be possible to analyse more in detail obstacles and drivers of lead time reduction separating between manufacturing and non-manufacturing. The resulting theoretical model is represented in Figure 6.

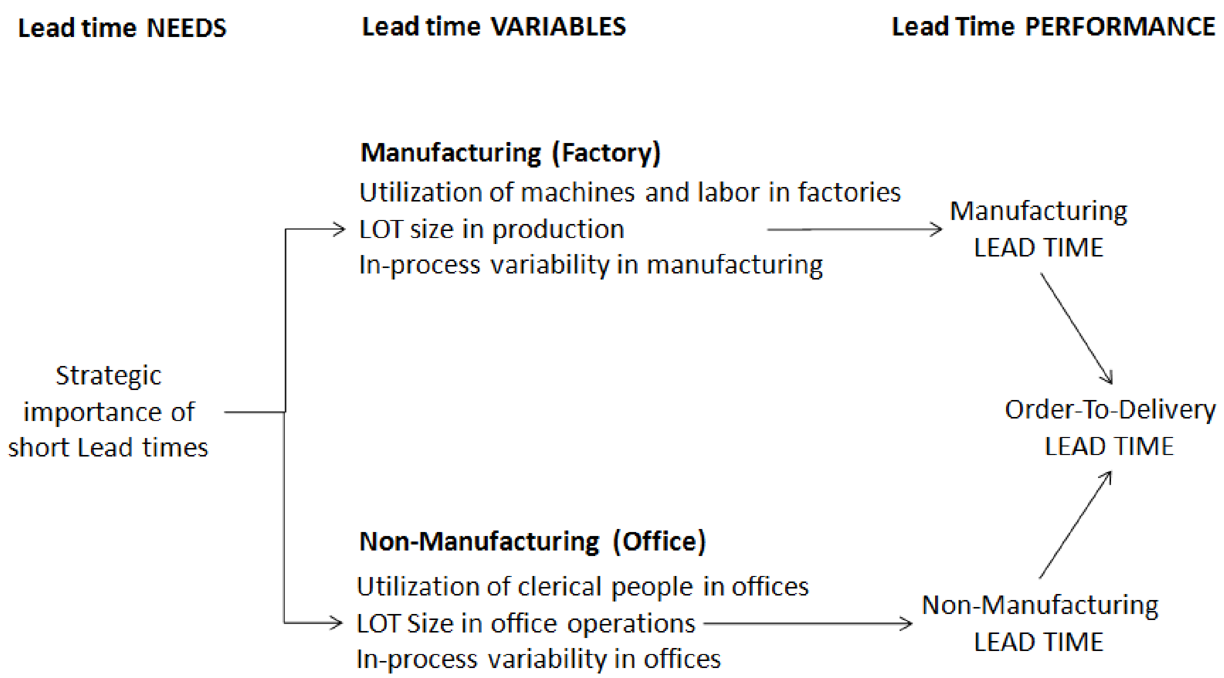

Figure 6 - Theoretical order-to-delivery Lead Time reduction MODEL

On one hand, utilization of machines and workers, production and internal transportation lot sizes and internal variability in a plant (related for example to scraps, machine downtimes, skills of workers, etc.) impact, in factories, on manufacturing lead times. On the other hand, utilization of clerical people in offices, lot sizes for example in processing orders or planning production and internal variability in offices (related for example to missing standard times for office operations or to too variable skills of clerical people) influence, in offices, lead times of all those non-manufacturing activities related to the order-to-delivery process. Managing all these elements together, both in manufacturing and in offices, and according to the three Factory Physics laws should automatically translate into order-to-delivery lead time reduction also in practice.

However, when we began the research project, we recognized that companies in desperate strategic need of shorter lead times were not taking the necessary actions to get their lead times lower. Our initial objective was to better understand how to help these companies. During the course of the project, we realized that there is a long-standing assumption through the operations management literature that 1) we have known how to reduce lead times for many decades and this information is generally available both to academics and practitioners, 2) it is obvious that many companies stand to benefit strategically from shorter lead times, so 3) there is nothing left to be done, as companies are already equipped as necessary. Hence the paradox. On one hand, the relationship between competitive need for short lead times is "obviously" positively related to a configuration of actions taken to add a capacity buffer to bottleneck, reduce lot sizes, and eliminate non-strategic variability. On the other hand, in practice, we see exactly the opposite. Companies with a strategic need for short lead times are observed to:

- Work to increase all utilizations (including that at bottlenecks);
- Work to increase lot sizes;
- Work to eliminate strategic variability (e.g., through outsourcing to a low-wage country, which reduces responsiveness) while tolerating non-strategic variability.

Because of this theory-practice paradox, the models presented above and based only on the theory do not hold in practice and should be modified adding some new elements, on one hand, to explain the theory-practice gap, and, on the other hand, to become practical and useful tools for companies. Based on these premises, an important goal has been, in both research projects on lead time reduction, to look for moderating factors of the relationship between lead time reduction needs and actions to be taken to reduce lead times, linked to utilization, lot size and non-strategic variability. The resulting frameworks, presented in the following chapters, represent one of the main outcome of this thesis contributing both to theory and to practice.

2.5 MANUFACTURING LEAD TIME REDUCTION

2.5.1 INTRODUCTION

The first research project has focused primarily on *manufacturing lead time*. The are two main reasons behind this choice. First, we wanted to see if and to which extent manufacturing lead time is not reduced in practice while knowledge and cheap tools exist and have been available for a long time. Second, we were interested in looking for the main obstacles within factories that have prevented operations managers to apply well-known principles and tools to reduce manufacturing lead times. If this is confirmed, are these obstacles mainly related to technical manufacturing issues or also to other managerial areas? How to remove them and make managers realize the dramatic benefits of short manufacturing lead times?

As already introduced before, we will refer to manufacturing lead time as the time that elapses within the manufacturing operation between releasing the item to production and its completion. We are referring to repetitive manufacturing, rather than completion of projects or production of individual items such as prototypes. We are looking at the production of a given item with a relatively established production process, rather than reducing lead times through a redesign of the item to be produced. Furthermore, we are not talking about building stocks at strategic points in the supply chain to allow fast delivery. Although these other approaches to reduce lead time are often valuable, we only address manufacturing lead time because, aligned with QRM principles, this is the prime way to get faster operations in a structural way and in the medium/long term and to improve, at the same time, costs, quality and flexibility.

2.5.2 RESEARCH PROBLEM and QUESTIONS

Focusing on *manufacturing lead time*, two main problems have been identified both in literature and in practice: first, a lead time reduction theory-practice gap even looking only at manufacturing processes occurring within plants; second, a lack of a lead time reduction framework which goes beyond operations management and integrates aspects belonging also to other disciplines, such as organisation & behaviour, accounting and strategy.

As far as the theory-practice gap is concerned, the road to short lead times has not been easy for many companies also within plants, in spite of the obvious benefits related to manufacturing lead time reduction and the high managerial expertise and knowledge developed in this area. Even when managers demonstrate a good knowledge of the mathematical principles that explain the system dynamics of flow, Suri (1998) demonstrated empirically that managers tend to neglect these laws or even not to understand their implications and often take counterintuitive actions that increase lead times. For example, in facing a situation with high capacity utilization (e.g. 85%), a lot size large enough to affect lead times, and substantial variability, production managers often respond counterproductively by attempting to increase utilization close to 100% (which is surprisingly often the target value), increasing lot sizes, and ignoring the variability and resource interactions.

As far as lead time reduction frameworks are concerned, models, laws and studies have been mainly constrained into the technical and tool-based domain of manufacturing and operations management. Because of the limitations and the problems of lead time models purely based on theory, discussed in previous chapters, I have looked, driven by QRM theories, for new elements also related to other managerial areas that could help in creating more integrated frameworks and in bridging the theory-practice gap identified.

Based on these premises, the main objective of this research is to investigate the behaviour of managers in making decisions that impact manufacturing lead times. The aim is to explore whether operations managers take decisions that are congruent with lead time reduction goals and, if not, what are the main reasons and factors that make manufacturing lead times long. Are there corporate obstacles to reducing manufacturing lead times? If not, what keeps managers from putting their knowledge into practice?

The resulting research questions could be summarized as follows:

- *Why* is *manufacturing lead time* reduction not achieved in practice extensively, while knowledge and expertise in factories are high and cheap improvement tools are available? What are the main obstacles that have to be removed?

- *How* to reduce *manufacturing lead times*? What are the main drivers to leverage on and the best approaches to adopt to reduce manufacturing lead times?

The objective of this research is not to develop a new theory of manufacturing lead time reduction, but rather to better understand why generally known and accepted theories combined with mathematical relationships have not been applied to practice as extensively as it would be expected. In particular, we examine closely several aspects that may impact on lead time related also to other (not OM) managerial areas and disciplines. The result of this study will be insights that can be used to develop testable propositions that will extend existing theories of lead time reduction and make them more accessible to practitioners, following recent calls for an increased emphasis on evidence-based practice (e.g., Rynes 2007).

2.5.3 METHODOLOGY

Given the nature of the research objectives stated above, an exploratory case study research methodology has been chosen. The aim of this study is to gain an in-depth understanding of a phenomenon (why lead time is not minimised and how to reduce lead time) and it can be effectively achieved through the analysis of case-studies (Yin, 2009 and 2003; Meredith, 1998; Eisenhardt, 1989).

We have based our research on a *in-depth single case study* because of in-depth research needs. In fact, although manufacturing lead time has been well and deeply studied from a theoretical point of view for many years, it suffers from that theory-practice paradox well discussed before. Therefore, this research had to investigate deeply the reasons behind counter-intuitive managers' decisions and a single in-depth case study in combination with direct observations on site, for a reasonably long period of 3 months, seems to have been a good choice.

Our objective is to lay a conceptual foundation for theory development concerning lead-time reduction. Following Bacharach (1989), a theoretical model is helpful in taming the complexities and richness of a given situation. Weick (1989) describes theory development as a sensemaking exercise. Modelling the world begins with establishing *what* factors relate to each other, *how* they relate, and *why* this model of what has been observed should be accepted, with regular rebalancing between completeness and parsimony (Whetten 1989).

In situations, like this one, where a complete scientific model is not yet available for verification according to the scientific method, qualitative research, allowing data and observation to inform theory, can facilitate theory and model development (Glaser and Strauss 1967). The data and observation aid in the formulation of the theory, which is subsequently empirically tested. Case studies allow us to grapple with the richness of the interaction between behavioural aspects of the decision-making process and the mathematical elements of the decision itself in a practical setting (as recommended by Miles and Huberman 1994, Stuart et al. 2002, Yin 2003). Case-based analysis, whether during the theory development or empirical testing phase of knowledge creation, is not about generalizability, but about sensemaking and seeking a detailed understanding (this trade-off is particularly well explained in Ketokivi 2006).

We choose to ground the project with a single in-depth case study which we used to calibrate the model that emerged from the literature. Is it acceptable to calibrate a model with a case study? Experts in qualitative research differ concerning how much theory emergence should be permitted, ranging from Glaser's (1992) recommendation that not even a literature review be carried out prior to data interpretation, to Strauss and Corbin's (1990) insistence that the research question be formally developed prior to any data collection. Literature on qualitative research in the operations management field tends to seek a middle ground, with prior literature review and relatively complete formulation of research questions, but recognition that some theory emergence will occur as the data is collected and analyzed. Stuart et al. (2002) observe that the research question may well change during the course of the project. Lewis (1998) goes even further, proposing a theory-development process based on iterations between literature, cases, and the intuition of the theorist.

Following Lewis' (1998) iterative triangulation approach, we refined the literature, protocol, and interview results into a theoretical model linking competitive need to reduce lead times with decisions and behaviour that result in reduced lead time. There are three reasons behind this choice. First, there is a lack of a complete theory of lead time reduction that integrates elements such as behavioural and organisational aspects with implementation of the mathematical principles of lead-time reduction. Second, the lead-time-reduction literature is scattered among a variety of disciplines, ranging from industrial engineering, applied mathematics, and operations management to organizational behaviour. Finally, as described before, the relative scarcity of lead-time-reduction behaviour, in contexts where we would expect it to be common, can be seen as a paradox, encouraging us to expect some theory emergence during our data collection. We did not, therefore, begin with data collection and a fully formed theoretical model, as would be recommended by Strauss and Corbin (1990), but allowed the case to play a catalytic role in model emergence as we iterated between case, protocol, and literature.

We did not initially see the paradox as a simple model, but began with a hodge-podge of literatures, experiences in the field, and frustrations that we sought to put into order to address a real problem that exists in manufacturing. We thus went into the company with a long list of questions that included everything that we collectively could think of. It was only when the interviews had been conducted and we were analyzing the coded data that the underlying model emerged. That the model is consistent with what we observed does not in any way "prove" that the model holds, but rather illustrates the sense-making role of the case in model development.

This model thus represents a first step toward an enhanced understanding of how to help companies to reduce their manufacturing lead times. The ordering of the literature, observations, and intuition into a model facilitates continued learning. Researchers can take this model and test it as it is, or adjust it according to their perceptions, reading of the literature, and experience. Knowledge is created just as much when researchers explain what they find wrong with our model at the theoretical level, as when they test it empirically.

The choice of research site for the case study was not random, but was done in concordance with our research objectives (as suggested by Stuart et al. 2002). We selected a company (identity disguised) that is an international leader in producing plastics-related solutions used in industries requiring a combination of short lead times and a high level of responsiveness with high demands for quality. The company is headquartered in Western Europe and active on five continents. The objective of the company is to open new application areas through technical and scientific product development, focusing on offering its customers added value through creative solutions. Company managers consider superior technological knowledge to be a major competitive advantage. The company was formed several decades ago, and has grown steadily since, with most growth internal.

The company has focused on developing the interaction between application and process technologies, laboratories, and its own tool and machine construction shop so that it can offer system solutions to customers. In these industries, products and applications are specific to the customer. Quality is essential, leading the company to continually work to improve processes as well as the quality management system. The company has received ISO 9001:2000 and ISO/TS

16949:2002 certifications. These activities join with an emphasis on ecological and sound environmental management.

Company plants produce both make-to-stock and make-to-order products. The research project, however, focused primarily on the *make-to-order* products, for which responsiveness and service dominate cost as key success factors. Another reason of this choice is that we would expect higher managerial attention and performance in manufacturing lead time for make-to-order products because of their direct and immediate impact on delivery times to customers, hence to customer satisfaction.

We developed a research protocol to collect information in a structured way concerning the initial beliefs and expectations of company managers concerning lead-time reduction, their existing decision structures and processes, as well as basic information concerning the company's processes, objectives, managerial practices, and performance. The protocol allowed interviews to be structured but sufficiently open to avoid overly guiding respondents' answers. The protocol was tested with a liaison officer from the company assigned to the project.

The design of the protocol was driven by the structure of the theoretical model for manufacturing lead time (see later Figure 7); each section and each question of the questionnaire had the purpose to investigate a specific aspect of the theoretical model. More specifically:

- the "introduction" section was useful to collect information about the interviewees (role, position and decision making power) to understand the extent to which they could influence lead time;
- the "market and customer" section, linked to the "lead time needs" of the model, helped understand the relevance of lead time also from an external (market and customer) view and to assess the degree of coherence between the external (market and customer) and the internal (managers') view;

- the "strategy, performance and rewarding" section, linked both to the "lead time needs" and to the "lead time performance" of the model, aimed to assess, through multiple questions, the relevance of lead time according to the managers' point of view, the current lead time performance levels and the lead time reduction potential;
- the "managerial choices and drivers" section, linked to the "lead time variables" of the model, aimed to assess the lead time reduction potential looking, in an indirect way and according to the Factory Physics laws, at utilization, lot size and non-strategic variability variables (and some of other influencing factors) linked to manufacturing processes;
- the "theoretical competences" section, linked to the "lack of management understanding of system dynamics" moderator of the model, is a 9-question test to assess the theoretical competences in lead time reduction of the people interviewed.

Finally, the other three moderators present in the model have been evaluated in the following ways. First, the "accounting system" peculiarities have been analysed through a separate in depth interview, without following the research protocol, with the person responsible of the accounting department where the main objective was to assess the extent to which lead time reductions were detected by the accounting system in terms of cost reductions. Second, the "time-based mindset" moderator has been assessed mainly through some questions within the questionnaire related to the relevance attributed to the different operational performance profiles. Finally, "layouts" peculiarities have been evaluated through both direct observations and company documents about layouts and material flows.

Items that were not clear from the transcript were checked via a follow-up interview. In addition to the interview data, the company made many other documents available that I used to check the accuracy of the interview data and to better understand the company and its activities. Being physically present at the company on a full-time basis over 3 months and being involved in day-to-day operations and improvement projects, I was able to compare information from interviews with direct observation of the operations. In addition, my previous ten-years-long manufacturing experience, also in practice working as operations manager in a multinational company, has helped in going in depth during the interviews.

The data were collected through 15 interviews of senior executives, middle managers, and shift supervisors. The interviews were all carried out by myself in full autonomy (being the only researcher of our team based full-time at the company) during a period of approximately 3 months together with a liaison officer from the company. Each interview lasted about 2 hours. A transcript was made of each interview and was reviewed by the interviewee for accuracy. Four of the people selected to be interviewed turned out to have too limited roles within the company to be able to respond effectively to the questions posed in the protocol, so I ended up with 11 usable interviews.

About the coding, we have coded all the variables, linked to the three mathematical principles governing lead time, and all the new factors, moderating potentially the relationship between lead-time-reduction need and lead-time-reduction behaviours, introduced in a new version of the theoretical model for manufacturing lead time reduction (see next section).

In addition, the authors elaborated a coding scheme using the categories low, medium, and high to assess both quantitative variables, such as utilization and lot size, and qualitative aspects, such as human behaviours and attitudes. For example, a respondent that was able to describe efforts to reduce unplanned downtime, defective products, and other sources of non-strategic variability would be coded as high on this factor. A respondent showing less awareness and ability to describe concrete actions would be coded lower for this factor.

The data were coded by myself and another researcher. We assessed the inter-rater agreement by calculating Cohen's Kappa (Cohen 1960). The Kappa coefficient was 0.61, which is at the lower end of good agreement. A third author coded items on which the first two raters did not agree.

2.5.4 MODEL

The purely theoretical model, introduced in section 2.4 and based only on the three mathematical principles of Factory Physics and QRM, does not hold referring to manufacturing processes. In fact, it has been demonstrated that the lead time reduction theory-practice gap, discussed extensively before, exists even limiting the scope of analysis to production processes occurring within a plant (e.g. Suri, 1998). Therefore, that model is not applicable to practice. In addition, this theoretical model is limited mainly to operations management technical issues, while general wisdom would expect also other elements, related to other management areas and disciplines, to play a role in lead time reduction decisions and performance.

Because of the problems and limitations stated above, there must be some factors that moderate the relationship between lead time reduction needs and behaviours making it less positive or even negative. Factors moderating a relationship are constructs that cause a change in the relationship between independent and dependent constructs, perhaps even changing the sign of the relationship. (For a complete description of the role moderating factors, see for example Baron, R.M. & Kenny, D.A., 1986).

In order to make the model applicable to practice and to more exhaustive, we propose a new framework that includes potential moderating factors which we have identified through iterating between the relevant literatures and observations of a company combining competitive need for short lead times with struggles to take the necessary actions. Because the literature itself gave limited help (proclaiming that the operations management community has known how to reduce lead times for many decades, that this information is generally available both to academics and practitioners, so there is nothing to be done as companies are already equipped as necessary), we have mainly used data and information emerged during the interviews and direct observations as main sources to identify potential moderators. This approach of pulling together literatures and case insights into a model to capture a paradox and to open the door for empirical testing seems to be correct especially in the field of operations management. In fact, while historically theoretical models have tended to be developed based solely on the literature, in the field of operations management there has been recognition that having one or more practical cases can enhance theory development (e.g., Lewis 1998).

Putting together literature, case insights and direct observations, we have developed a theoretical model for manufacturing lead time reduction represented in Figure 7.

Recognizing that we were dealing with a paradox encouraged us to model human, infrastructure, and organizational elements as moderating factors, while the three variables, bottleneck utilization, lot size and non-strategic variability in production processes, come from the well known mathematical principles of Factory Physics and QRM. In brief, we propose that 1) utilization-based accounting systems and efficiency-based performance measurement systems, 2) a poor flow on the production floor hindered, for example, by poor layouts, 3) lack of understanding of the system dynamics or Factory Physics of lead time, and 4) lack of a time-based mindset, which occurs when time is not the primary organizational performance measure (as defined by Suri, 1998), moderate the relationship between competitive need for short lead times and the lead-time-reduction behaviour on the part of executives, managers, and supervisors.

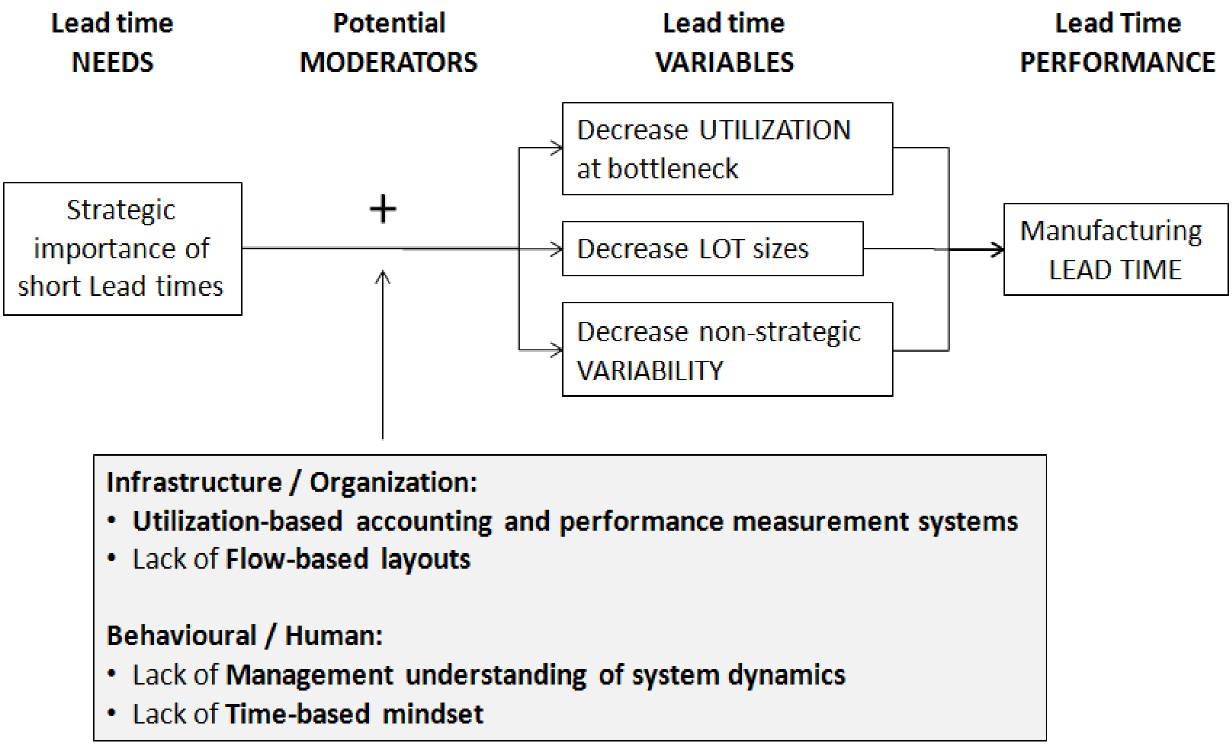

Figure 7: Theoretical Model for manufacturing lead time reduction with moderating factors

About the moderating factors introduced, utilization-based accounting systems refer mainly to traditional cost accounting systems which are capable to detect cost reduction only in case of processing time reduction, not in case of lead time reduction. Efficiency-based performance measurement systems focus measurements mainly on efficiency, which is also the main performance goal. The final outcome is that, accounting and performance systems structured in this way reward cases of high utilization and saturation of any resource in a plant. Suri (1998 and 2010) had already highlighted the flaws of most of traditional accounting systems that, allocating overhead in an artificial way with drivers such as direct labour, do not identify a clear connection between costs associated to lead times (overheads which can account for large amounts) and specific products and therefore are not capable to detect unit product cost reductions in case of lead time reduction. Similarly, De Treville et al. (2004) examined the conflict between traditional management accounting and lead time reduction suggesting, as solution, a new approach based on a more holistic view of costs, costing at the cell and production line or plant level rather than at the individual item level of analysis.

A poor flow on production occurs, for example, in cases of poor layouts. In these situations, it is difficult to identify the flow of materials during *gemba* walks on the shop floor and the managerial attention is often more on single machine productivity, rather than on bottleneck management and continuous flow. Hameri (2011) demonstrated that the transformation of functional layouts into product-oriented ones, through production flow analysis, implies substantial lead time reduction. Also Kumar (1995) speaks about increased material and information flows provided by product or cellular layouts.

Lack of understanding of the system dynamics and Factory Physics of lead time refers to cases where managers are not aware of the mathematical relationships governing lead times. Managers saying that target value for utilization is 100% and that they measure only averages, not standard deviations, of internal production variables, is already an important evidence of lack of understanding of these laws. Knowing vaguely the existence of the relationships between some variables, such as utilization and lead time, but being unaware of their exponential shape, represents anyway a limitation that could impact heavily on decision making. Suri (1998 and 2010) had already highlighted, through a survey involving 400 U.S. managers, that 70% of policies in use by these managers and their companies were major obstacles of lead time reduction. The biggest problem was, however, that most managers were unaware that the principles applied were wrong. Traditional beliefs and applied policies relating to high utilization, large lot size and neglecting variability are a clear sign of lack of understanding of the system dynamics and Factory Physics together with their related consequences on lead times. As far as variability is concerned, also Christensen et al. (2007) demonstrated the relevance of managing variance, more than averages, in supply chain systems.

Lack of a time-based mindset, a concept defined by Suri (1998), happens when costs and efficiency, instead of time in terms of speed, are the primary organizational performance goals and measures. If the trade-off view among performance goals is the prevailing one and the cost, quality, reliability and flexibility benefits associated to speed are unknown, neglected or underestimated, this is another sign of lack of a time-based mindset. Even a "being *on-time*", instead of "being *fast*", attitude is not considered sufficient. In fact, according to the QRM principles, while "being *fast*" implies automatically "begin *on-time*", vice-versa, having reliability as ultimate goal means longer lead times and higher costs because of longer frozen periods and safety times inserted for example in planning (see also Figure 2, about the "Response Time spiral" of Suri). Linked to this concept, one of the grounding QRM principle is that, contrary to common belief, M.R.P. (Material Requirement Planning) systems, whose functioning rules are based on reliability and synchronization of processes, prolong lead times in practice.

We cannot say that the proposed model, which includes moderators derived both from literature and case insights, is valid in general terms. That the model is consistent with what we observed does not in any way prove that the model holds, but rather illustrates the sense-making role of the case in model development. This model, thus, represents a first step toward an enhanced understanding of how to help companies to reduce their manufacturing lead times. Researchers can take this model and test it as it is, or adjust it according to their perceptions, reading of the literature, and experience. If this model were to be validated in the future through empirical testing, an important piece of new knowledge would be created to close the theory-practice gap of lead time and to give practical guidelines to companies about manufacturing lead time reduction.

2.5.5 RESULTS

Table 1 displays the main data and information, collected through the eleven interviews and enriched through direct observations, about the variables and the potential moderating factors linked to the model introduced before and about other related elements that have helped to go deeper in data analysis and interpretation. Table 1 contains both quantitative data, whenever available, and qualitative information, including assessments given during coding. Doing on average one visit per day both of assembling and extrusion areas, I have used, in addition to interviews, direct observations and new daily practical experience both to check data and information collected in the interviews and to add any missing element. Analysing performance reports displayed daily in the plant, checking real production and transportation lot sizes on the shop floor and assessing directly to which extend layouts were favouring a smooth and continuous flow, are just examples of valuable direct observations that have helped in collecting more realistic and reliable data.

	Person 1	Person 2	Person 3	Person 4	Person 5	Person 6	Person 7	Person 8	Person 9	Person 10	Person 11
General information											
Department	plant manager	others	inbound logistics, RM warehosing, mixing	outbound logistics, packaging, SF/F warehousing	Extrusion	Extrusion	Assembling	Assembling	Assembling	Assembling	Assembling
Role/position	top management	other middle management	head of department	head of department	production planner (extrusion profiles)	head of department (extrusion)	other middle management	production planner (assembling profile)	head of department (assembling)	shift leader (assembling)	shift leader (assembling)
Team and people management responsibilities	High	Low	High	High	Low	High	Medium	Low	Medium	Medium	Medium
Decision power (on labour and machines)	High	Low	High	High	Medium	High	Medium	Medium	Medium	Medium	Medium
Scope of activities under responsibility	Wide	Medium	Wide	Wide	Medium	Medium	Medium	Medium	Medium	Limited	Limited
Competitive advantage from lead time reduction											
Competitive advantage from **lead time reduction (market point of view)**	High	High	High	High	High	High	High	High	High	High	High
Competitive advantage from **lead time reduction (manager point of view)**	Medium	Medium	Low	Medium	Medium	Medium	High	Medium	Medium	High/Medium	Medium/Low
Lead time reduction behaviour											
Capacity buffer at Bottleneck	Medium	Low	Low	N.A.	Medium	Medium	Medium	Low	Low	Low	Low
***Machines** utilization targets*	not 100%	100%	95%	N.A.	100%	100%	92%	100%	100%	N.A.	100%
Machines utilization actual values	65% for profiles 79% for pipes	N.A.	75%	N.A.	80% avg. 65% min - 95% max	78%-80%-85%	84%	not full capacity utilization	N.A.	N.A.	N.A.
***Labour** utilization targets*	105%	100%	95%	N.A.	N.A.	100%	105%	100%	100%	100%	100%
Labour utilization actual values	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Reduction of lot sizes	Low	Low	Low	N.A.	Medium/Low	Low	High	Low	Medium	Low	Low
Lot size targets	no	no	no	N.A.	no	no	yes (30-40%)	no	yes (informally)	no	no
Lot size actual values	N.A.	N.A.	2% - 200%	N.A.	2% (30 min)-500% (1 week)	50% (12h)-100% (24h)	30-40%	30-40%	15%	N.A.	N.A.
Reduction of setups	Medium/Low	Medium/Medium/Low	N.A.	N.A.	Medium	Medium	High	Medium	Medium	Low	Low
set-up target time	N.A.	N.A.	N.A.	N.A.	8-10%	Std set-up	3%	3%	3,5% (7 min avg.)	N.A.	N.A.
set-up actual time	6%	N.A.	N.A.	N.A.	4% (1h) - 33% (8 hours)	8%-10%	5%	5%	5% (12 min avg.)	1-2% (5 min avg.)	2% (for cutting machines) (15-20 min)
Reduction of non-strategic variability (processing time)	Low	Medium/Low/Low	Low	N.A.	Medium/Low	Low	Medium	Low	Low	Low	Low
Processing time variability	Low	unknwon	unknwon	N.A.	unknown	N.A.	unknwon	N.A.	N.A.	unknwon	N.A.
Reduction of strategic variability (demand)	Low	Low	Low	N.A.	N.A.	N.A.	High	Medium	Low	Low	Low
Demand variability	unknwon	unknwon	unknwon	N.A.	Low	N.A.	unknwon	Low	Low	Low	Low
Forecasts error	unknwon	unknwon	unknwon	N.A.	Low	Low	unknwon	Low	N.A.	Low	unknwon
MODERATORS											
Understanding of system dynamics of lead time	High	Medium	Medium	N.A.	Medium/Low	Medium/Low	High	Low	Medium	Low	Low
basic OM knowledge	High	High	Medium	N.A.	High	Medium	High	Medium	Medium	Medium	Medium
Lead Time principles knowledge (tested)	High	Medium	Medium	N.A.	Low	Low	High	Low	Medium	Low	Low
Lead Time principles knowledge (self perception)	High	Medium	High	N.A.	Medium	Medium	High	Low	Medium	Low	Low
Time-based mindset	Medium	Medium/Low	Low	High/Medium	Medium	Medium	High	Medium	Medium	Medium	Medium
"being fast" mindset and attitude	Medium	Medium	Low	Medium	Medium	Medium	High	Medium	Medium	Medium	Medium
"being on-time" mindset and attitude	High	High	High	High	High	Medium	High	High	High	High	High
Decision making based on **utilization/efficiency-based accounting and performance measurement** systems	Medium	N.A.	High/Medium	N.A.	Medium	High	Low	N.A.	Medium	Medium/Low	Medium
Operational targets induced by accounting and PM systems	High utilization	High utilization	High utilization	N.A.	High utilization	High utilization	Medium utilization	High utilization	High utilization	N.A.	High utilization
Incentive systems impacts on lead time reduction	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low
Incentive systems structure and formalization	High	High	High	High	Low	Medium	Medium	Low	Medium	Medium	Low
Impacts of pricing tecquiques on lead time	High	High	N.A.	N.A.	High	High	High	N.A.	N.A.	N.A.	N.A.
Flow-based layout implementation	Medium/Low	Medium/Low	Medium	N.A.	Medium	High (already in place)	Medium	N.A.	Medium	Medium	Medium

Table 1: Main data and information collected through the interviews

LEGEND of TABLE 1

Variables	**Categories and scales**
General information	
Department	inbound logistics, mixing, extrusion, assembling, packaging, outbound logistics, RM warehosing, SF/F warehousing, quality, maintenance, others
Role/position	top management, production planner, head of department, other middle management, shift leader, direct worker, others
Team and people management responsibilities	High, Medium, Low, none
Decision power (on labour and machines)	High, Medium, Low, none
Scope of activities under responsibility	Wide, Medium, Limited
Competitive advantage from lead time reduction	
Competitive advantage from **lead time reduction (customer&market point of view)**	High, Medium, Low
Competitive advantage from **lead time reduction (manager point of view)**	High, Medium, Low
Lead time reduction behaviour	
Capacity buffer at Bottleneck	High, Medium, Low, unknown
***Machines** utilization targets*	x %
Machines utilization actual values	x %
***Labour** utilization targets*	x %
Labour utilization actual values	x %
Reduction of lot sizes	High, Medium, Low
Lot size targets	no, yes (avg. Lot production time / avg. Production time %)
Lot size actual values	avg. Lot production time / avg. Production time %
Reduction of setups	High, Medium, Low
set-up target time	x % (as total available time = 8h*n.shifts)
set-up actual time	x % (as total available time = 8h*n.shifts)
Reduction of non-strategic variability (processing time)	High, Medium, Low
Processing time variability	High, Medium, Low, unknown
Reduction of strategic variability (demand)	High, Medium, Low, unknown
Demand variability	H (>35%), M (15%-35%), L (<15%), unknown
Forecasts error	H (>35%), M (15%-35%), L (<15%), unknown
MODERATORS	
Understanding of system dynamics of lead time	High, Medium, Low
basic OM knowledge	High, Medium, Low
Lead Time principles knowledge (tested)	High, Medium, Low
Lead Time principles knowledge (self perception)	High, Medium, Low
Time-based mindset	High, Medium, Low
"being fast" mindset and attitude	High, Medium, Low
"being on-time" mindset and attitude	High, Medium, Low
Decision making based on **utilization/efficiency-based accounting and performance measurement** systems	High, Medium, Low
Operational targets induced by accounting and PM systems	
Incentive systems impacts on lead time reduction	High, Medium, Low
Incentive systems structure and formalization degree	High, Medium, Low
Impacts of pricing tecquiques on lead time reduction	High, Medium, Low
Flow-based layout implementation	High, Medium, Low

LEGEND of Table 1

Table 2, based on Table 1, is a summary of the interview results referred only to those variables and factors strictly linked to the model. Table 2 displays the results of the coding process, described before in the methodology chapter, where the evaluation scale LOW-MEDIUM-HIGH used in coding, has been transformed into a 1-10 scale (1 = LOW; 5 = MEDIUM; 10 = HIGH) through an aggregation process. Just to give an example, a LOW-MEDIUM assessment of a construct, given by myself and another member of the research team, has been transformed into a 3 evaluation. Table 2, therefore, contains the aggregate assessment (among the researchers involved in coding) on the most relevant lead time related variables and potential influencing factors contained in Table 1. In addition, the evaluation of managers' *lead-time-reduction behaviour* (which is a variable in Table 2) is the result of a second aggregation process of the three separate assessments given on managers' attitude toward decreasing utilization, lot size and non-strategic variability respectively.

To support the analysis and the interpretation of data and the formulation of testable propositions for future research, we have also used simple data mapping (see Figures 8-9-10-11 later in this section), plotting the results of all interviewees (Table 2) in graphs displaying lead-time-reduction behaviour, on the Y-axis, and each potential moderator, on the X-axis.

	Interviews										
	person 1	person 2	person 3	person 4	person 5	person 6	person 7	person 8	person 9	person 10	person 11
Competitive need for short lead times (managers' view)	5	5	1	5	5	5	10	5	5	7	3
Lead-time-reduction behaviour											
Lead-time-reduction behaviour	3	2	1	N.A.	4	3	7	1	3	1	1
Capacity buffer at Bottleneck	5	1	1	N.A.	5	5	5	1	1	1	1
Reduction of **lot sizes**	1	1	1	N.A.	3	1	10	1	5	1	1
Reduction of **non-strategic variability**	1	2	1	N.A.	3	1	5	1	1	1	1
MODERATORS											
Understanding of system dynamics of lead time	10	5	5	N.A.	3	3	10	1	5	1	1
Time-based mindset	5	3	1	7	5	5	10	5	5	5	5
Decision making based on **Utilization/Efficiency-based accounting and performance measurement** systems	5	N.A.	7	N.A.	5	10	1	N.A.	5	3	5
Flow-based layout implementation	3	3	5	N.A.	5	10	5	N.A.	5	5	5

LEGEND
1 - LOW
5 - MEDIUM
10 - HIGH
N.A. - Not Applicable

Table 2: Summary of interview results

Although the 11 people interviewed belong to different departments, ranging from assembling and extrusion to logistics and packaging, and cover different roles at different management levels, all of them have a full view on the entire production process and management and, more importantly, have the power to take decisions on variables and factors that impact or may impact, also in a relevant way, on lead time.

With respect to competitive needs for lead time reduction (Table 1), lead time reduction would, from a market point of view, be appreciated by customers increasing customer satisfaction and company market share and, from an internal point of view, reduce costs and improve quality and flexibility. However, managers seem to agree that further lead time reduction, going beyond what customers demanded, was clearly not a priority. Although it was generally agreed that reduced lead times had paid off in the past, there was no vision for going beyond what customers demanded. The response to a question given by the plant manager was enlightening: "Lead time reduction is not really important, and is not at the top of the list of priorities. There are currently no projects planned to reduce it, with the exception of implementation of an E.R.P. (Enterprise-Resource-Planning) system. Although this system is likely to reduce lead times somewhat, lead time reduction is not a primary goal of the implementation. Around once a year someone suggests that we work to reduce lead time, but we tend to conclude that the plant has other priorities."

Aligned with this managers' view, lead-time-reduction behaviour (according to our definition) seems to be relatively low across all managers interviewed (Table 2), except for one who was much focused mainly on setup and production lot size reduction. It is not a coincidence that this manager, in charge of process improvement, was the leader of a previous lead time reduction project implemented few years before through the application of a queuing-based modelling software that represented a very limited investment for the company.

While setup time and lot size reduction was, except for the manager in charge of process improvement, clearly not a priority (this is confirmed also by the lack of reduction targets), elimination of non-strategic variability, mainly assessed though processing time variability, was even not feasible because of lack not only of quantitative measurements, but also of qualitative managers' perceptions (Tables 1 and 2). More than this, managers seemed to neglect or even not to know relevance and impacts of non-strategic variability on operations, in particular on lead time. Even demand variability and forecast errors, classified as strategic variability according to QRM, were not measured.

About utilization (Tables 1 and 2), respondents indicated that the target utilization for equipment was at least 90%, and usually higher. For labour, the target utilization was usually either 100% or 105% and this opened also a discussion about the definition and the measurement system of utilization. The plant manager mentioned the need to run equipment slightly below 100% to allow a measure of flexibility, but the 30% capacity buffer, used in the past that had led to the current improvement in flow, was clearly regarded as being excessive. Actual equipment utilization values, in the range of 65% in assembling and 80% in extrusion, represented, for the managers, a real problem to be addressed. About personnel, the plant manager stated: "Personnel should be planned according to the utilization of machines. Personnel utilization should always be 105% and should fulfil machines requests". High emphasis on high utilization targets, equivalent to low attitudes to add capacity buffers at bottlenecks, is clearly proven also by the following statement written in the company manual (translated from the original language): "... the higher the utilization, the better the production results and the lower the prices. Therefore, the target is to reach maximum utilization".

Finally, it is important to note that decision making and attitudes of all managers related to utilization, lot sizes and non-strategic variability were not in contrast each other, as far as impacts on lead time are concerned. For example, there are no cases of managers aiming at reducing lot sizes and increasing utilization at the same time. This has simplified the coding process especially when assessing, in a aggregate way, lead time-reduction-behaviour of managers. Because of the low lead-time-reduction behaviour widespread across almost all managers (Table 2), except for one, I can conclude that, although faster manufacturing processes would increase company competiveness, a significant additional room for further lead time reduction still exists. This evidence confirms findings of previous studies.

Analysing in Table 1 the potential moderators introduced in the model, *knowledge about lead time reduction principles,* on top of basic operations management knowledge, has been assessed both directly, asking to managers their education level and training, and indirectly, through a simple but powerful 10-questions test designed by Suri (1998). Only two out of the eleven respondents demonstrated a clear understanding of the system dynamics of lead time. Not surprisingly, these were the plant manager and the young engineer who had played a key role in that past lead time reduction project using a queuing-theory based software. Other respondents showed less of an understanding. The result of the coding is that only those two managers have been assessed as high in terms of understanding of the system dynamics of lead time (Table 2).

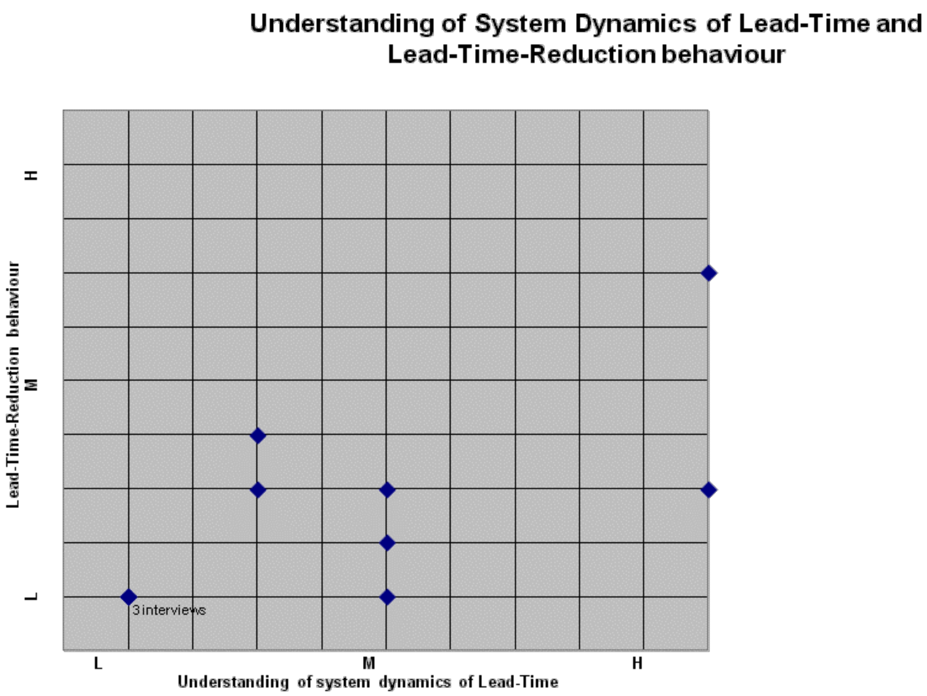

Figure 8: Understanding of System Dynamics and Lead-Time-Reduction behaviour

Looking at Figure 8 (obtained by mapping data of Table 2), it is clear that while low understanding of system dynamics is associated with low lead-time-reduction behaviour for three respondents, the contrary does not hold and an high understanding of such laws does not imply automatically high lead-time-reduction behaviour evoking the existence of other lead time reduction obstacles. Because the respondent presenting an high knowledge of lead-time-reduction principles and medium/low lead-time-reduction behaviour is the plant manager, we may expect the existence of factors related to his high management position, such as rewarding and bonus systems, which may impact significantly on his behaviour. However, these aspects have not been analysed in detail in this research.

Based on this evidence and somehow aligned with our expectations, a first finding of this study is that while, on one side, a *low understanding of the system dynamics of lead time represents an obstacle for lead time reduction*, on the other side, an *high understanding of the laws governing lead time does not imply automatically short lead times* and is just a necessary condition for lead time reduction.

Summarising this finding in the form of a *proposition* we may state that: *The relationship between competitive need for short lead times and lead-time-reduction behaviour is moderated by understanding of the system dynamics of lead time, so that the relationship may become less positive in the lack of such understanding.*

Moving to *accounting and performance measurement systems,* the company used a traditional cost accounting system capable of detecting cost reduction only in case of processing time reduction, not in case of lead time reduction, and implemented a performance measurement system very much focused on efficiency. More generally, interviews and direct observations made it clear that utilization and efficiency are extensively measured, whereas time is not and time related KPIs are almost absent. Looking at Table 1, this led to very high utilization targets and to managers' decision making based mainly on unit production cost reduction through high utilization, ignoring other induced logistics and supply chain costs (such as stock-out, inventory, obsolescence, new personnel required in warehousing and general overhead and delays-related costs) according to a holistic view of costs. Although incentive systems do not seem to impact significantly lead times, I have not gone into detail in this issue which is, instead, covered in the second research of this thesis on lead time. Finally, pricing techniques, too peculiar to be analysed in detail, encouraged internal production managers to increase lot sizes and customers to increase their purchase quantities. For the reasons explained above, we coded almost all respondents as HIGH with respect to taking managerial decisions driven by utilization and efficiency based accounting and performance measurement systems (Table 2).

Looking at the mapping of Figure 9, it is interesting to note that the upper-right-hand quadrant is empty. This means that managers taking decisions driven mainly by the traditional accounting system in place and by the high company utilization targets, did not show a lead-time-reduction behaviour. On the contrary, the only interviewee ranked high in terms of lead-time-reduction behaviour, who is that young engineer in charge of process improvement, was not subject to the accounting system in place and was taking decisions using other tools, including the queuing-theory-based software applied in the past. Finally, that the lower-left hand quadrant is empty implies that there is never an association between low influence of utilization-based accounting and low lead-time-reduction behaviour.

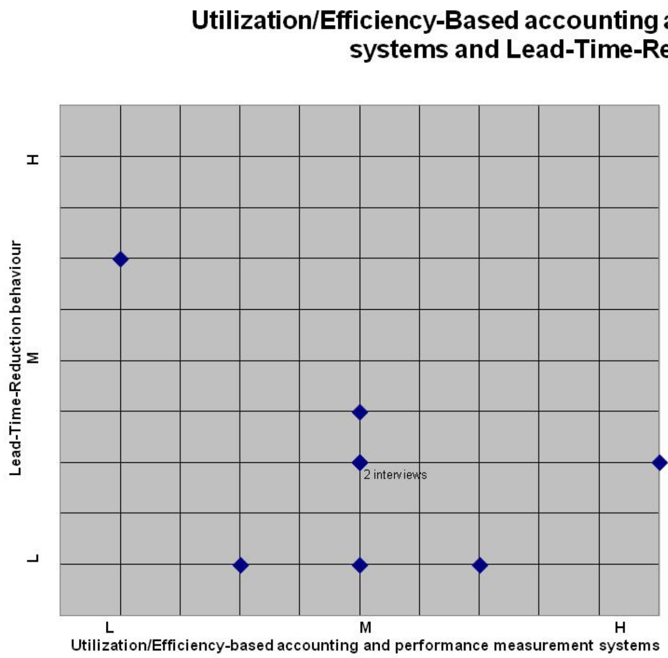

Figure 9: Utilization/Efficiency-based accounting and performance measurement systems and Lead-Time-Reduction behaviour

Based on this evidence and considerations, a second finding of this research is that the *presence of traditional utilization-based accounting systems and efficiency-based performance measurement systems together with managers' decision making processes driven mainly by such systems and ignoring costs from a more holistic total-supply-chain view, represents a major obstacle for lead time reduction*. On the contrary, independence of decision making from utilization-based accounting systems seems to favour short lead times, but we cannot say that this is a sufficient condition. This is an interesting new result that we were not sure to expect.

Summarising this finding in the form of a *proposition* we may state that: *The relationship between competitive need for short lead times and lead-time-reduction behaviour is moderated* *by use of accounting and performance measurement systems based on utilization, so that the relationship becomes less positive when employees base their decisions on such systems.*

Analysing *time-based mindset* in Table 1, respondents indicated that lead time was not measured, which limited formation of a time-based mindset. I confirmed this evidence also analysing directly monthly and weekly performance reports and detecting the absence of time related KPIs. Although many respondents demonstrated some awareness of the importance of time, only the young engineer in charge of process improvement showed a true time-based mindset. In fact, while a "*being on-time*" is a widespread mindset and attitude among almost all managers, only the young engineer had a high "*being fast*" mindset and attitude which, as already said before, is the key distinguishing element of a true time-based mindset according to the QRM definition. A "*being on-time*" approach, such the one embedded in M.R.P. systems, is not sufficient and has a negative influence on lead times, increasing safety times and counter-productive planning times. The result of the coding about time-based mindset (Table 2), is that most respondents have been coded as MEDIUM and only one person has been assessed as HIGH.

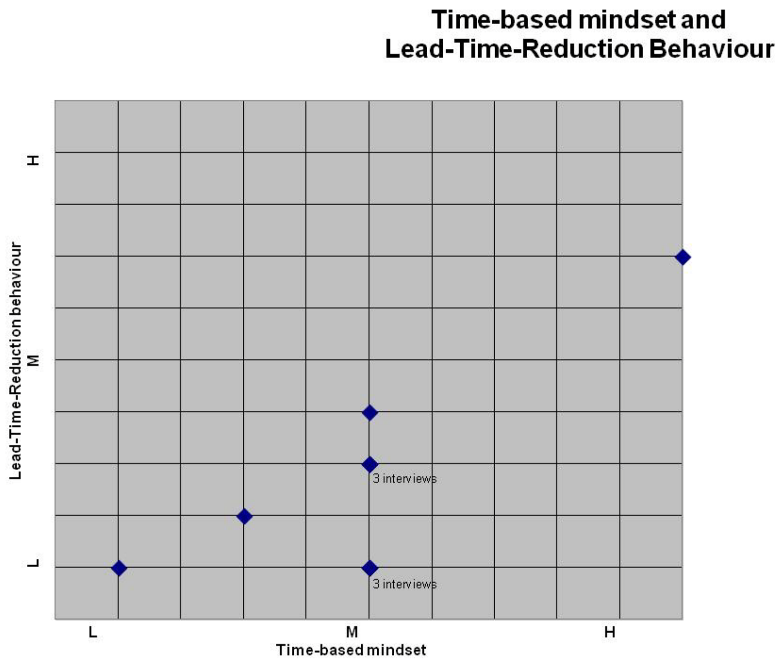

Figure 10: Time-based and Lead-Time-Reduction behaviour

Looking at the mapping of Figure 10, it results that a low time-based mindset is never associated with high lead-time-reduction behaviour. No one who was coded low for time-based mindset was above low for lead-time-reduction behaviour. On the contrary, that respondent showing a "*being fast*" attitude and mindset is the only one having a high lead-time-reduction behaviour. His behaviour has been influenced most probably also by the lead time reduction results he had been capable of achieving in the past using that queuing-theory based software. Finally, that the lower-right hand quadrant is empty implies that there is never an association between high time-based mindset and low lead-time-reduction behaviour.

Based on this analysis, a third finding is that *a lack of time-based mindset is an obstacle for lead time reduction*. On the contrary, the development of a time-based mindset seems to be a key facilitator of short lead times, but we cannot say that this is a sufficient condition.

Summarising this finding in the form of a *proposition* we may state that: *The relationship between competitive need for short lead times and lead-time-reduction behaviour is moderated by a time-based mindset, so that the relationship may become less positive in the lack of such a mindset.*

Analysing potential impacts of a lack of a *flow-based layout*, I have first to say that the evaluation and interpretation of this aspect has been difficult for two reasons. First, layout is very much linked also to the peculiarities of production processes. Because extrusion, a more constrained process and closer to continuous flow, and assembling, a more flexible process and closer to discrete manufacturing, are very different processes, it has been difficult to analyse together opinions and views about layouts of people working both in extrusion and assembling. Second, the lead time reduction project implemented in the past had already somehow modified layout according to concepts of flow. Some respondents referred to the improvements already made in the past, more than critically assessing current layouts, believing than nothing else would be needed. My opinion, shared also with my research colleagues, is that managers' evaluations about layouts were wrong or at least too positive from a flow perspective and that a considerable room for further improvement was, instead, still possible especially in assembling and at plant general level. Results and indications emerged from that past lead time improvement project and my direct observations about flow, in fact, may be a good proof that managers' evaluations about flow-based layouts were somehow biased. In conclusion, although managers thought that the current level of flow was adequate, in reality there was still a good room for further improvement.

If our opinion of biased information is correct, a more realistic view about flow-based layout should, in Figure 11, shift somehow to the left (toward lower values) the assessments given by all managers.

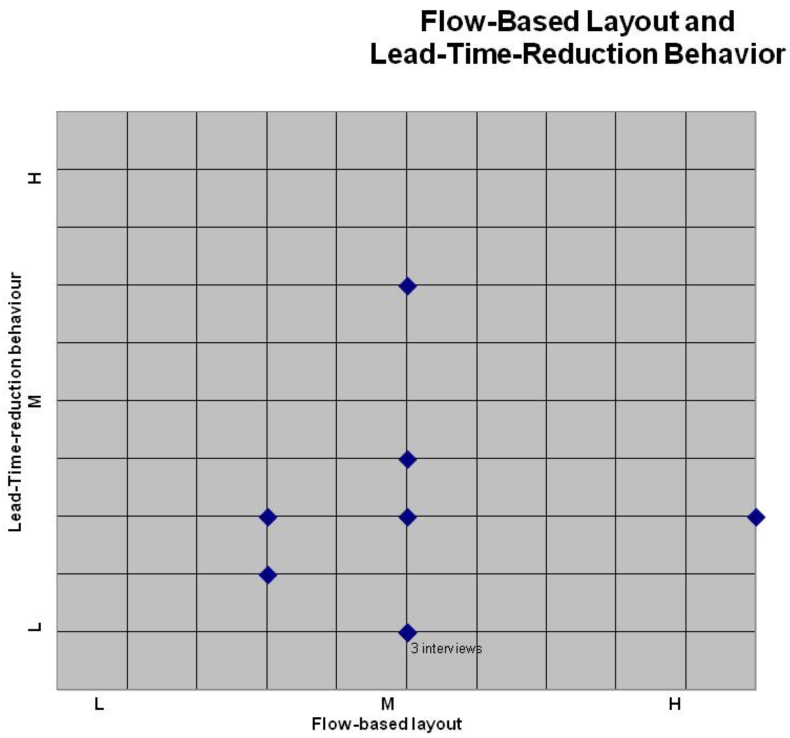

Figure 11: Flow-based layout and Lead-Time-Reduction behaviour

Based on these considerations and accepting our opinion about the positively biased managers' views on the flow while still room for layout improvement exists, a fourth finding is that *a lack* *of flow-based layout is an obstacle for lead time reduction.* Although the data do not help, we can expect, anyhow, that a good flow on the factory floor is a key driver for lead time reduction (for lead time benefits of flow based and product oriented layouts refer to Hameri 2011)

Summarising this finding in the form of a *proposition* we may state that: *The relationship between competitive need for short lead times and lead-time-reduction behaviour is moderated by the degree to which work flows smoothly on the factory floor, so that the relationship may become less positive in the absence of such a smooth flow.*

In conclusion, our understanding entering the project was that the firm stood to gain competitive advantage from continuing to push ahead with lead time reduction beyond what was required by customers. We thus expected the time-based opportunities to be positively related to lead-time-reduction behaviour. However, this relationship was heavily influenced by the emphasis on utilization and lack of time-based mindset. A reasonable level of knowledge of lead time reduction laws and a decent flow at shop floor level could not overcome those two factors.

2.5.6 LIMITATIONS

This work is subject to all of the usual limitations of theory development and of case-based research, in that it trades generalizability for detailed understanding. The results are exploratory rather than generalizable, representing a first step toward understanding how competitive need for short lead times translates into action and why this is so difficult to achieve.

Although it helps in detailed understanding, the single case study approach further limits generalizability.

The scope of the analysis limited to manufacturing processes is an additional limitation. In fact, manufacturing lead times may represents just a small portion of the overall lead time. In these cases, managers should focus on reduction of lead times also in other areas outside manufacturing plants.

Finally, the identified list of presumed obstacles of lead time reduction does not pretend to be exhaustive and complete. This encourages further research to look for additional factors also in other areas.

2.5.7 CONCLUSIONS

The ability to reduce and control lead times is essential to competitiveness. Given that the axiomatic mathematical relationships between bottleneck utilization, lot size, and variability and lead time were established decades ago and are well known, it is surprising that so few companies compete based on their ability to reduce lead times.

Our objective has been to explore this paradox, within manufacturing processes, pulling together what is known about lead time reduction with in-depth observation of a company that needs short lead times but is having difficulties achieving them. We proposed a theoretical model in which four factors moderate the relationship between competitive need for speed and behaviour that reduces lead times: a) lack of understanding of the counter-intuitive system dynamics of lead time, b) decision making based on accounting and performance measurement systems that emphasise utilization, c) lack of time-based mindset, and d) lack of flow-based layouts.

We calibrated the model using an in-depth case study describing a firm that used in the past lead time reduction tools to meet customer demands for lead time reduction, but was hindered from going the whole way to time-based competition by all the four factors mentioned above, but especially because of the firm-wide emphasis on maintaining a high utilization and the fact that lead time is not measured (essential to a time-based mindset), whereas utilization was. A reasonable level of understanding of the system dynamics of lead time on the part of two respondents and an adequately smooth flow on the factory floor did not compensate for these factors. Medium/Low lead-time-reduction behaviour of almost all managers interviewed and mathematical modelling of the plant's operations done in a recent past, demonstrated clearly that the plant had further scope to reduce lead time, but organizational and behavioural factors stood in the way of the firm fully exploiting this potential source of competitive advantage.

Our contribution is to recognize that manufacturing lead-time reduction does not occur automatically when there is competitive need, and to generate testable propositions about why this is true. With our model we have contributed also toward the integration of the mathematical principles of lead time reduction as laid out in QRM and Factory Physics with other branches of operations management theory. If the model is shown to be generalizable in empirical testing, these results will be directly applicable to practice: managers need to think through the competitive implications of speed and understand what is possible through managing the mathematical relationships that determine lead times. As they move to reduce bottleneck utilizations, lot sizes, and non-strategic variability, it will be important to a) avoid decision making based purely on misleading traditional accounting systems not capable of detecting cost reductions in presence of lead time reductions, b) train managers to develop their understanding of the system dynamics of lead time, c) encourage a time-based mindset throughout the company, and d) facilitate organizing the manufacturing layout to support flow.

2.6 ORDER-TO-DELIVERY LEAD TIME REDUCTION

2.6.1 INTRODUCTION

A second research project has extended the scope of the analysis from manufacturing lead time to *order-to-delivery lead time*. Several reasons justify this choice and move. First, as already said in the conclusions of the first study, constraining the research to manufacturing processes occurring within a plant may represent a limitation to get a full picture about what is important to increase company competitiveness. Manufacturing lead time, in fact, may represent just a small portion of the overall lead time perceived by customers, as Suri has already proven (Suri, 2010). In many companies less than 5% of the total customer lead time is spent in the production process (Senapati et al., 2012). Second, if the goal is to improve customer satisfaction and market share, an external/customer measure and view of speed, not just an internal/production oriented one, is needed. It is important to reduce as much as possible the risk of giving practical recommendations to companies to improve some irrelevant, or less relevant than others, aspects which do not bring a true competitive advantage. Third, investigations in other non-manufacturing areas, much less studied and analysed both in academia and practice, may bring surprising results also in terms of costs and benefits to reduce lead times. Finally, Suri suggests to look into office operations, such as quoting, engineering, scheduling, and order processing, because they tend to be neglected as a source of improvement in manufacturing companies. Yet, these operations can account for over 25% of costs, consume more than half of quoted lead time, greatly influence order capture rate and impact overall market share (Suri, 2010).

Let's start defining *order-to-delivery lead time* in *make-to-order* which represents the area of analysis for this study. As we have already said before, order-to-delivery lead time is the time elapsing from the customer order issuing date to the delivery of goods or services to customers. As far as this research is concerned, transportation lead times are, however, not considered mainly because of two reasons related to transportation management. First, the very frequent current adoption of transportation outsourcing practices leaves limited internal management to companies. Second, the high competitiveness in the sector made transportation companies reach excellence in transportation lead times, which represent very seldom one of the weakest points in the order-to-delivery process. Order-to-delivery lead time includes, therefore, all those activities between the reception of an order to the delivery of goods and/or services to a customer which, depending on the supplier-customer agreement, may occur at the customer site, at the supplier factory (ex-work), or at any other agreed point within the supply chain between customer and supplier.

In order to analyse in depth and then to improve lead times, order-to-delivery time should be decomposed in its sub-processes and activities which, in general terms, may consist of all or some of the followings: order management and processing (which may be further split into a commercial and a logistic activity), production planning, scheduling, manufacturing and eventually assembling, packaging, handling & picking, delivery preparation and transportation, whenever applicable. Looking at all the activities described above and aiming at deepening lead time analysis, order-to-delivery lead time may be also grouped in two different components: the first, *manufacturing lead time*, which is linked to physical-transformation and tangible activities mainly occurring in a plant or in a warehouse; the second, non-*manufacturing or office lead time*, which refers to those more intangible and information-based processes mainly occurring in offices, such as order management, production and delivery planning. On top of deepening the analysis, the main reason of this grouping is that there may exist significant differences, in terms of lead time reduction, related to the different nature of different activities (tangible vs. intangible, physical vs. information based, plant vs. office related). Because this issue may hide interesting and unexplored aspects, I have decided to analyse it more into detail.

2.6.2 RESEARCH PROBLEM and QUESTIONS

Referring also to order-to-delivery lead time, the main research problem is represented by the theory-practice gap about lead time reduction already discussed. While the benefits of short lead times are well known both in pull and push environments, and the knowledge and rapid modeling tools to reduce lead times are available for a relatively modest investment (Reiner, 2009), it is hard to believe how many companies do not reduce lead times in practice and how many managers take decisions that, instead, prolong lead times. This theory-practice gap has been also demonstrated empirically by Suri (1998) who highlights that managers tend either not to understand or to ignore the implications of the factory physics laws governing lead time.

A second problem is that often managers focus investments in wrong or at least not in the most important areas. Ignoring that manufacturing lead time represents often a limited portion of the overall lead time, often managers focus on shortening production lead times, while they should look into other areas, such as office operations. In fact, as Suri (2010) says, office operations have been too much neglected as a source of improvement in manufacturing companies, while they can account for over 25% of the costs.

The lack of exhaustive, wide-scope and cross-disciplinary frameworks on lead time reduction and that most of research has mainly focused on manufacturing lead time, ignoring the lead time related to all those non-manufacturing activities occurring in offices, are two additional problems already discussed.

Finally, the experience of the first research on manufacturing lead time encouraged me to broaden the perimeter of analysis while looking for obstacles of lead time reduction.

Based on these premises, the objective of this research is to understand why managers often take decisions that increase order-to-delivery lead time, while lead time reduction is both beneficial and easy to achieve in theory with limited investments. More in detail, the goal is to identify those factors that represent an obstacle toward order-to-delivery lead time reduction in practice. Similarly to the research on manufacturing lead time, the objective is not to develop a new theory of lead time reduction, but rather to better understand why generally known and accepted theories combined with mathematical relationships applicable for any kind of process, not only in manufacturing, have not been applied in practice as extensively as one would expect. The result of this study will be in the form of a number of recommendations and insights that can be used to develop testable propositions that will extend existing theories of lead time reduction and make them more accessible to practitioners, following recent calls for an increased emphasis on evidence-based practice (e.g., Rynes 2007).

Thus, the resulting research questions are:

- *Why* is *order-to-delivery lead time reduction* not achieved in practice as extensively as one would expect, while knowledge and relatively inexpensive tools exist? What are the main *obstacles* that have to be removed?

- *What* are the most critical/longest components of lead time in practice?

- *How* to reduce *order-to-delivery lead time*? What are the main *drivers* to leverage on and the best practices to adopt to reduce order-to-delivery lead times?

Looking at lead time from a customer point of view, the scope of this research comprises the overall order-to-delivery lead time, which is analysed from both the perspectives of its decomposed elementary activities and of the "manufacturing vs. non-manufacturing" split introduced before.

2.6.3 METHODOLOGY

Because the main difference between the two studies on lead time, respectively on manufacturing and order-to-delivery lead time, relates to the scope of analysis, while research problems, objectives and questions are very similar if not identical, the research methodology applied is exactly the same for both projects.

The only but relevant difference is that, in this second study, I have opted for a multiple, instead of a single, case study research not only to overcome the well known limitations of single case study research, but also because of the larger scope of research needed to look for new lead time reduction obstacles. An additional reason of this choice is that the lack or at least the lower adoption of managerial best practices in office operations suggested to look into more cases. Therefore, given the nature of the research objectives, an exploratory multiple case study research methodology has been chosen. Because the aim of this study is to gain an in-depth understanding of a phenomenon (why order-to-delivery lead time is not reduced in practice, while short lead times are both beneficial and easy to achieve in theory), it can be effectively achieved through the analysis of multiple case-studies (Yin, 2009 and 2003; Meredith, 1998; Eisenhardt, 1989).

Because of exactly the same methodology for the two studies on lead time, I avoid repeating it. For a complete overview you can refer to chapter 2.5.3-Methodology. However, to briefly summarise, the main distinguishing elements of the methodology used are: theory development, qualitative case based research sacrificing generalizability for a more in depth understanding of a phenomenon, multiple case studies to calibrate the model and to formulate testable propositions, middle ground approach applied in OM research to design research allowing data collection to complete prior literature review, and Lewis (1998) iterative triangulation approach between literature, cases and intuition/experience of researchers.

About the case studies selection, the following criteria have been applied:

- cases where lead time reduction is a key driver for competitive advantage;

- Make-to-order operations, for which also manufacturing lead time plays a direct role within the order-to-delivery lead time perceived by customers;
- companies that have in place a comprehensive performance measurement system, that collects regularly data about lead times, utilization, quality, etc.

Based on these criteria, four companies, belonging to four different sectors, have been selected for interviews and visits. We have opted for a multi-sector study in order to eliminate the influence on results and findings related to the peculiarities of a specific industry.

The four companies have been analysed through both in-depth recorded interviews with managers lasting more than six hours each and "gemba" walks in plants and visits to offices in order to go more in depth in the analysis and to assess the validity of the information provided in the interviews (e.g., to check if visual management practices or a flow-based layout were really in place). This detailed analyses required a minimum of two visits per company.

Interviewees have been selected among decision makers having both a full overview and an impact, through their decisions, on the overall order-to-delivery process. Although different case by case, they covered one of the following positions: supply chain, operations, logistics or distribution manager. To answer in detail to such a variety of questions linked to the order-to-delivery process, they involved, whenever needed, collaborators and other people belonging both to their and other departments. The answers provided were supported, in several cases, by company documents and reports.

A wide-scope research protocol, linked to the theoretical model (see later Figure 12), has been developed to collect information on issues such as order-to-delivery processes, actual and target operational performance, managerial decisions on variables (utilization, lot sizes and non-strategic variability both in manufacturing and in offices) impacting lead time and many other factors linked to several different areas, such as OM strategies, OM best practices, layouts, people knowledge and behaviour, organisational structures, accounting and rewarding systems, IT tools, etc., that may influence somehow lead time performance. In order to assess separately manufacturing and non-manufacturing processes, the protocol and the way of interviewing separated these two aspects. The protocol structure allows interviews to be structured but, at the same time, is sufficiently open to avoid overly guiding respondents' answers. Finally, a pilot version of the protocol has been tested with few managers of some companies (not belonging to the ones later interviewed) in order to improve quality and readability. In designing the protocol and the overall research more in general, the main objective has been to get useful information on the decision-making processes that impact the overall order-to-delivery lead time and to understand the main drivers of managers' behaviours. During the interviews the most prepared managers understood the design logic of both the model and the research protocol and gave some relevant contribution to adjust the model adding or eliminating some elements. Analysing more in detail the structure of the questionnaire:

- the "introduction" section was useful to collect information about the interviewee;
- the "general information on the company" section helped in understanding the supply chain structure and complexity and in mapping the order-to-delivery process together with its sub-processes and sub-activities;
- the "strategy and performance" sections, linked both to the "lead time needs" and to the "lead time performance" of the model (see later Figure 12), aimed at assessing the relevance of lead time, in relation to other performance attributes, the actual lead time performance levels and the lead time reduction potential, splitting between manufacturing and non-manufacturing processes;
- the "managerial decisions in manufacturing" section, linked to the "manufacturing lead time variables" of the model, helped evaluate manufacturing lead time reduction potentials

looking, in an indirect way and according to the Factory Physics laws, at utilization, lot size and non-strategic variability in plants;

- the "managerial decisions in administration processes" section, linked to the "office lead time variables" of the model, helped evaluate non-manufacturing lead time reduction potentials looking, according to the Factory Physics laws which apply for any kind of process, at utilization, lot size and non-strategic variability in offices;

- the sections "Organization", "Behaviours", "Accounting systems", "Performance and Rewarding systems", "Layouts", "ICT", "Best Practices in Manufacturing and in Administration processes", linked to the "moderators at plant, office and company level" of the model and split for manufacturing and administration processes, were useful to assess all these aspects which represent potential obstacles and drivers for order-to-delivery lead time reduction;

- finally, "questions 1, 2 and 3" sections are three tests, each composed by several questions, used to evaluate, respectively, the following three aspects related to people knowledge and attitude: "awareness of lead time reduction benefits", "lead time reduction theoretical knowledge" and "people time based mindset".

2.6.4 MODEL

Because the perimeter of analysis covers both manufacturing and office operations and the Factory Physics laws of lead time are valid for any kind of process, the starting point to build a framework for order-to-delivery lead time reduction has been the theoretical model presented in Figure 6 (Chapter 2.4), which splits manufacturing and office processes in two separated components.

However, also in this case, the theory-practice gap about order-to-delivery lead reduction implies that such model, as it is, does not hold and some moderating factors the relationship between lead time reduction needs and behaviours have to be added to explain this paradox and to make the model useful for practical improvement purposes.

To look for new factors that may represent obstacles for order-to-delivery lead time reduction, I have iterated between literatures, interviews, direct observations during *gemba* walks, analysis of company documents and personal intuition and experience. Because of the wide scope of the project (manufacturing and office operations) and not to constrain the research to some predetermined factors and aspects (e.g. behavioural and organisational aspects), the approach chosen to look for potential moderators has been slightly different compared to the one followed in the project on manufacturing lead time. First, I have selected areas of investigation (such as Best Practices, IT systems, accounting systems, etc.) instead of specific predetermined factors (such as flow-based layouts) derived from other studies. Second, these areas of analysis, which cover both manufacturing and office operations, are numerous and at company, not just at operations, level. The ultimate goal was to look for obstacles and drivers of lead time without restricting the search to narrow and predefined areas.

Following this process, the resulting theoretical framework is represented in Figure 12.

Utilization, lot size and non-strategic variability variables relate to lead time according to the mathematical principles of Factory Physics. Having decomposed order-to-delivery lead time in the two components of manufacturing and non-manufacturing lead time, the model also split these variables for manufacturing and non-manufacturing processes. This is a first innovative aspect of the model that aims at addressing the gap in literature that most of the research has mainly focused on manufacturing lead time.

About potential moderating factors included in the model, as anticipated before, they are linked to a wide range of areas and aspects, not only related to technical issues in OM such as layout design, bottleneck management or setup reduction techniques. In fact, they also relate to wide-company-level aspects such as strategy, organisational structures, people behaviour, training and knowledge, performance and rewarding systems, accounting systems, ICT systems and Best Practices in factories and offices. For a more detailed understanding of this issue, refer also to the research protocol in APPENDIX 2. This wide-scope approach at company, not functional, level followed in looking for potential moderators aims also at addressing the gap in literature about the lack of exhaustive, wide-scope and cross-disciplinary frameworks on lead time.

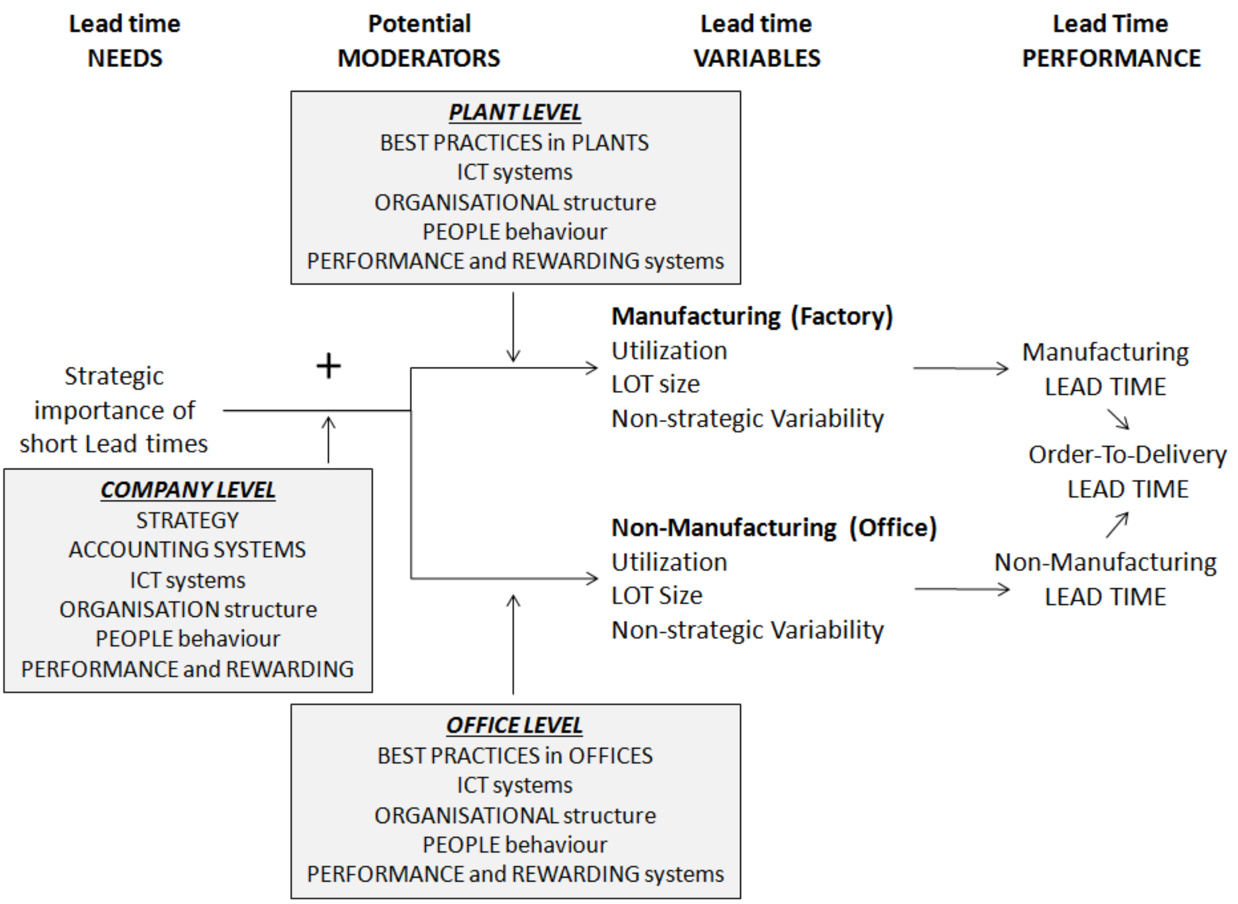

Figure 12 - Order-to-delivery lead time model

Looking in detail at the different potential moderators introduced, traditional-cost-individual item based (vs. activity-time-total cost based) accounting systems refer, exactly in the same way as in the manufacturing lead time project, mainly to traditional accounting systems which are capable to detect cost reduction only in case of processing time reduction, not in case of lead time reduction. The final outcome is that accounting systems structured in this way reward cases of high utilization and saturation of any resource in plants and offices. As previously said, Suri (1998 and 2010) had already highlighted the flaws of most traditional accounting systems that, allocating overhead in an artificial way with drivers such as direct labour, do not identify a clear connection between costs associated to lead times (overheads which can account for large amounts) and specific products and therefore are not capable to detect unit product cost reductions in case of lead time reduction. Similarly, De Treville et al. (2004) examined the conflict between traditional management accounting and lead time reduction suggesting, as solution, a new approach based on a more holistic view of costs, costing at the cell and production line or plant level rather than at the individual item level of analysis.

With regards to performance measurement and rewarding systems, efficiency based (vs. lead time based) performance and rewarding measurement systems focus measurements and rewards mainly on efficiency performance. The final outcome is that performance systems, structured in this way, reward cases of high utilization and saturation of any resource. Suri (1998 and 2010) had already discussed about the consequences on lead time of such efficiency based performance and rewarding measurement systems.

The introduction of organisational and behavioural factors as potential moderators derives, first, from the recognition of the lead time theory-practice paradox that suggests investigating people behaviours and organisational settings. In addition, organisational and human resource factors, in terms of training and education, employee empowerment, flexible, cross-trained and multi-skilled workforce, number of hierarchical levels and flexible information flows, had already demonstrated to have a certain influence on agility and lead time (Kumar, 1995). Finally, as already introduced, Suri (1998) gave a definition of "time-based mindset" and discussed its impacts on organisations.

Layout has been introduced as a potential moderator also in this study because a poor functional-fragmented-closed (vs. a flow based-concentrated-open space) layout prevents a good flow of materials and information both in plants and offices representing a potential obstacle for lead time reductions. In these situations, it is difficult to identify the flow of materials during *gemba* walks on the shop floor and the managerial attention is often more on single machine productivity, rather than on bottleneck management and continuous flow. In addition, Hameri (2011) demonstrated that the transformation of functional layouts into product-oriented ones, through production flow analysis, implies substantial lead time reduction. Also Kumar (1995) speaks about increased material and information flows provided by product or cellular layouts.

ICT systems have been introduced as potential moderators as suggested by many other studies. To cite one of them, the agility matrix of Kumar (1995) includes many technologies (e.g. CAD/CAM, flexible and agile manufacturing systems, integrated databases, EDI, etc.) as drivers of specific lead times.

Finally, numerous best practices to reduce lead times both in plants and offices have been introduced as moderators based on several established and consolidated studies (e.g. Kumar 1995 to cite one of them) on best practices which are often linked to managerial philosophies such as QRM, LEAN and JIT, TPM, etc.

2.6.5 RESULTS

Table 3 summarises general information about each of the four companies, together with a description of their supply chain structure and complexity. The four companies are SMEs with a turnover ranging from 20 M€ to 140 M€, all operating in BTB (Business-To-Business) businesses (for a study on responsiveness of SMEs refer to Belvedere et al. 2011). Companies 1, 2 and 3 have international customers, mainly local suppliers or subcontractors and multi-plants located in different countries, whereas company 4 has mainly local sales, world-wide suppliers and one single plant. Companies 1 and 3 mainly opt respectively for a pure buy and pure make strategy, whereas companies 2 and 4 adopt a balanced make or buy policy. In terms of production approaches, while all companies produce different products in different ways ranging from Make-to-Stock to Engineering-to-Order, the focus of this study, according to the case selection criteria stated before, is only on Make-to-Order or Assemble-to-Order products. Finally, all companies, except for company 1 which is mainly labour intensive, present a mix of capital intensive and labour intensive processes: the former more upstream, the latter more downstream in the overall production process.

The four cases differ substantially in terms of *supply chain complexity* which could be estimated through some parameters such as volume/mix ratio, product customisation, life cycle and obsolescence risk, demand seasonality and predictability, order composition and requested delivery time by customers (refer to Serdarasan (2013) for a review of typical supply chain complexity drivers). While the supply chain complexity of company 1, characterised by a very low volume/mix ratio, high product customisation and a relevant amount of special orders, may be considered as high, the supply chain of company 4, characterised by a relative high volume/mix ratio, medium/low degree of product customization and low seasonality, seems to be relatively easier to manage. Doing similar assessments for companies 2 and 3, their supply chain complexity could be evaluated respectively as medium/high and medium.

	COMPANY 1	COMPANY 2	COMPANY 3	COMPANY 4
General company information				
Industry	Air-Conditioning Equipment	Pumps & Pumping Equipment	locking and security systems	mechanical and industrial components
Products	air conditining systems, high tech floors	hydraulic pumps and motors	locking and security systems	clamping and fastening solutions
Selected product (for this study)	air conditining systems	hydraulic pumps and motors	cylinders for locking and security systems	connecting clamps
Total Turnover	80M€	100M€	140M€	20M€
Role of the company in the SC	manufacturer	manufacturer	manufacturer	manufacturer and distributor
BTB - BTC	BTB	BTB	BTB	BTB
Degree of vertical integration	medium	low	medium	medium/low
Employees (F.T.E.)	300 ca 50% blue collars, 50% clericals	600 ca (450 ITALY, 150 CHINA) 65% blue collars, 35% clericals	800 ca WW (330 HQ ITALY) 50% blue collars, 50% clericals	22 45-50% blue collars, 55-50% clericals
Overall company production approach	Assemble to order (70%) Engineering to Order (30%)	Assemble to order (90%)	Make To Stock (70%) Assemble To Order (30%)	Make To Order (50%) Make To Stock (50%)
Selected product production approach	Assemble to order	Assemble to order	Assemble To Order	Make To Order
People interviewed				
Role / Job title	Operations Manager multi-country	Global Operations Manager	COO (Chief Operating Officer)	Owner/CEO & General/Logistic manager
Position	top management	top management	top management	top management
Scope of activities under responsibility	wide	very wide	very wide	very wide
Supply Chain structure				
Customers	owned & independent distributors (one per country)	1.000 ca 20% customers - 60% sales 2%-3% max customer weight on sales	distributors, door manufactures, competitors fragmented sales	60% OEMs vs 40% distributors OEMs: 1500, fragmented sales Distributors: variable size
Customers location	mainly Europe	mainly Europe, China and USA 65% export, 35% Italy	WW	mainly Italy OEMs mainly north/center Italy
Suppliers	200 ca	min 2 suppliers per component	suppliers and subcontractors	100 ca 80% volumes on 20% suppliers
Suppliers location	locals for custom materials WW for catalog materials	80% in Italy, 20% mainly in China	suppliers mainly located in Europe subcontractors all located close to the plants	WW 30-40% Italy, 70-60% abroad
Manufacturing plants	4	2	7	1 (acquired in 2008)
Manufacturing plants location	Italy, India, China, California	Italy and China	Italy (3), Germany (2), Spain (1), France (1)	Italy
Make / Buy	mainly buy	50% make - 50% buy	mainly make	35% make - 65% buy
Manufacturing process (from downstream to upstream)	Mechanical and electrical assembly testing finishing packaging	pump manufacturing (casting, mechanical processing, thermal treat.) assembly testing painting packaging	mechanical transformation preassembly (part. outsourced to local subcontractors) assembly testing packaging	cutting & shaping mounting delivery preparation
Bottleneck operation	none	testing	preassembly	cutting & shaping
Degree of automation	labour intensive	capital intensive in pump construction labour intensive in assembly	capital intensive in mech transformation labour int. in preassembly, assembly and testing	capital intensive in cutting & shaping labour intensive in mounting and delivery prep.
Warehousing & transportation	warehousing internally managed transportation outsourced	4 warehouses in Italy internally managed transportation outsourced	warehousing internally managed transportation outsourced	warehousing in Italy internally managed transportation outsourced
Supply Chain Complexity	high	medium/high	medium	low
Company development phase	maturity	growth/maturity	growth	growth
Volumes	8K units/yr	1M units/yr	12M units/yr	40M units/yr
Mix	45.000 products just in catalog	15.000 products just in catalog	8.000 products in catalog + customised	2.000 produts
Volume/Mix	Very low	Low	Medium	High
Product customisation	High	Medium	medium/low	medium/low
Product Life cycle	6 - 12 years	10 years ca	decades	> 5 years
Product obsolence risk	medium/low	low	low	low
Demand seasonality	medium	low	Very low/ Absent	low
Demand predictability	medium/low	medium	medium	medium
Order composition	70% standard; 30% special	10 urgent (3 days delivery) orders per month	job order, catalog order, contracts	< 10% urgent orders
Requested delivery time by customers	4 weeks	8 weeks	1 week	days by distributors; 1-2 mo by OEMs

Table 3 - Companies' general information and Supply Chain structure and complexity

Table 4 contains information about lead time goals and performance, splitting manufacturing and office activities, of each of the four companies analysed.

About performance goals, while lead time reduction is a priority for all the four companies, the actions already undertaken in the past to reduce it are different not only in the approaches chosen, but also in the areas of application. In fact, while companies 3 and 4 focus primarily on manufacturing lead time reduction, companies 1 and 2 aim to reduce both manufacturing and non-manufacturing lead time.

With regard to lead time performance, companies 1 and 2 seem to have reached good levels both in manufacturing and in office activities. First, they meet, on average, customer expectations in terms of speed of deliveries. Second, they have already implemented relevant lead time reduction actions, such as, lean initiatives both in plants and offices. Companies 3 and 4, instead, have a higher potential for lead time reduction. In fact, while company 3 is planning to increase planning frequency, by investing in IT scheduling systems and by decreasing the frozen period, and to invest in new technologies in the preassembly process, company 4 estimations of potential lead time reduction are around 30% both in plants and offices. Finally, even though the focus of the analysis has been mainly on lead times after the decoupling point because of make-to-order and assemble-to-order operations, the lead time before the decoupling point has also been detected in order to assess its possible impact on overall lead time in cases of stock-outs of semi-finished products. Actually, it has been discovered that this is a real problem especially for company 1, suggesting that also lead times before decoupling point should not be neglected.

However, no matter of the lead time performance achieved, all the four companies present still a good room for improvement in lead times, at least for the following two reasons. First, lead time variability is too high in all cases reducing, as a consequence, service levels. In addition, managers seem to underestimate its relevance because of the widespread lacking of lead time variability measurements. Second, all managers interviewed have listed numerous lead time reduction potential actions to implement in the future, both related to plants and offices, and this is an additional proof that further lead time reduction is feasible. However, most of these potential actions refer to expensive investments in equipment and IT systems and this goes against the basic lead time reduction principles of QRM, which are rather easy and cheap to implement.

Finally, looking at Table 4, the highest lead time reduction potential, assessed both asking directly to managers and analysing the past and future actions for lead time reduction, seems to be more related to office operations rather than to manufacturing. While companies 1 and 2 have implemented Lean Office projects, company 3 aims to reduce planning lead times mainly increasing planning frequency. Company 4 plans to do the same although its smaller size, reflected both in its organisational structure and in a smaller number of employees, facilitates simple processes and fast decision making in offices.

	COMPANY 1	COMPANY 2	COMPANY 3	COMPANY 4
Operational and Lead Time objectives				
cost vs differentiation strategy	differentiation through materials and innovation	differentiation through speed	differentiation through personalisation	differentiation
Key operational performance targets (in order of relevance - from 1 most relevant)	1 quality 2 speed 3 reliability	1 quality 2 TOTAL supply chain COST 3 speed	1 quality 2 reliability 3 speed and inventory availability 4 cost & efficiency	1 quality 2 reliability 3 delivery completness 4 speed
Lead time reduction as strategic priority	medium/high on a continuos base	medium/high as key differentiation attribute	medium/high to meet customer requested delivery time	medium
Lead time performance				
Requested delivery time by customers	4 weeks	8 weeks	1 week	days by distributors 1-2 months by OEMs
Average Order to delivery Lead Time	4-5 weeks avg (4 weeks for std pdts; 7-8 weeks for custom pdts)	5 weeks avg (1 week min, 8 weeks max) 60% reduction in last 3 yrs	2 weeks avg (13 days for std pdts; 15 days for custom pdts) 10 days (target) - stable (trend)	5,9 days avg (1 day min, 12 weeks max) 4,3 days avg (target)
Order to delivery Lead time variability	medium (Not measured)	medium/high (Not measured)	medium (Not measured)	very high (Not measured)
Customer satisfaction (speed of deliveries)	medium	medium	low	low
Lead time reduction actions already implemented	Lean production and Lean office production capacity increases	Lean production transformation since '08 Lean Office project	significant lot size reduction due to setup reduction (from hours to seconds in mech tranformation)	improved production planning and resource allocation to increase efficiency and reduce MLT
Lead Time reduction potential actions for the future	Material inventory optimizations, supplier LT reduction, JIT supplier deliveries, component standardisation and product modularity	substitution of equipments for mechanical processing to reduce manufacturing LT time from 2 to 1 week new ERP implementation & Lean Office to further reduce planning LT from 4 to 2 days	investing in technology to reduce preassembly LT Investing in RF tech. to reduce delivery prep LT Frozen period reduction Planning frequency increase from weekly to daily IT sys to reduce scheduling time	Higher frequency production planning Improving production scheduling Improving delivery preparation
Manufacturing & Office Lead time				
Manuf. LT vs Office LT reduction priority	Manufacturing and Office LT reduction	Manufacturing and Office LT reduction	Manufacturing LT reduction	Manufacturing LT reduction
Lead time decomposition (in sequence from order to delivery) (*office LT* vs manufacturing LT) **(first process after DP)**	*order processing* LT 1-2 days *planning* LT 1-2 days procurement LT 3-4 weeks (3 weeks std pdts; 6-7 weeks custom pdts) **assembling** LT 3 days (3 days std pdts; 4-5 days custom pdts)	*order processing and planning* LT 1 week procurement LT 6 weeks in parallel with manufacturing LT 6 weeks (casting 4 wk + mechanical processing 2 wk) **assembling**, testing and painting avg LT 1 week packaging LT 2 days	*order processing* LT 1 day *planning* LT 1-3 days RM procurement LT 20 days production LT 9 days (mech transf LT 3 days; **preassembly LT** 3 days; assembly LT 3 days) delivery preparation 2 days	*order processing* LT 1-2 days *planning&scheduling* LT 1-10 days procurement LT 3 days-3,5 mo **production** LT 3 days-2 mo delivery preparation 0,5-2 days
Decoupling point (DP)	procurement & assembling	pump manufacturing & assembling	mechanical transformation & preassembly	procurement & cutting/shaping
Manufacturing Lead Time after DP	3 days (3 days std pdts; 4-5 days custom pdts)	2,5 days - 1,5 week (assembling, testing and painting avg LT 1 week packaging LT 2 days)	8 days avg (preassembly+assembly+del prep LT 6 days delivery preparation 2 days)	3,5 days - 2 months (production LT 3 days-2 mo delivery preparation 0,5-2 days)
Non Manufacturing Lead Time	2-4 days	4 days (actual) 8-9 days (past)	2-4 days	2-12 days
Lead Time before DP	3-4 weeks	6 weeks (actual) 3 months (past)	3-4 weeks	3 days - 3,5 months
Manufacturing Lead Time after DP reduction potential	low	low	medium from 3 to 1 day in preassembly from 2 to 0,5 days in delivery prep.	high 20-30% in production 15-20% in delivery preparation
Non manufacturing Lead Time reduction potential	low	medium/low from 4 to 2 days in planning	medium/high from 3 to 0,5 day in plannig from 3 to 2 weeks in frozen period	medium/high 30% in prod planning
Lead Time before DP reduction potential	high 3 weeks waiting time for unavailable materials	high from 2 to 1 week in mech. Processing	Not relevant	Not relevant
Value added time / Total Lead time	20%	N.A.	neglectable (0,5 min / 3 weeks)	neglectable (minutes/6days) in manufacturing 3%-6% (0,5h/1-2days) in offices

Table 4 - Lead Time objectives and performance

Although Table 4 could be already sufficient for some conclusions on lead time performance, I have gone more in depth in the analysis looking at, separately for plants and offices, the decision variables impacting lead time according to the Factory Physics laws in order to estimate even better lead time reduction potentials. Table 5, linked to the model and the research protocol, reports the information about utilization, lot size and non-strategic variability collected both for manufacturing and office operations.

About MANUFACTURING, non-strategic variability reduction seems to be the main aspect that could be improved for companies 1 and 2, that have already reduced substantially manufacturing lead time, while utilization is already below 80%-85% and lot size is very small or even "one" (one-piece flow) thanks to relevant set-up time reduction activities. Although company 3 has attempted to limit non-strategic variability using levelling techniques, it appears that there is further additional room for improvement by decreasing utilization and making lot sizes less variable through setup standardisation and reduction. Finally, company 4 has the highest potential for improvement acting on all the three variables: reducing utilization, reducing setups and lot sizes, and starting at least by measuring some aspects of non-strategic variability.

About OFFICE operations, company 2 seems to be the most advanced in office lead time reduction. The establishment of an official Lean Office project made the company implement concepts such as people utilization analysis, process decomposition into sub-processes, maximum lead times defined per individual activity, cut-offs and deadlines, standardization of tools, and even communication rules. Company 1 is not far behind thanks to the application of time & methods approaches. Company 3, instead, has adopted a few good approaches but in a scattered way, and company 4, although facilitated by its smaller size, is still missing the awareness of people saturation in offices.

Making a cross-case analysis, Table 5 seems to confirm, even better, both our preliminary and previous literature findings that *order-to-delivery lead time reduction, although very beneficial and easy to achieve in theory, does not occur automatically in practice and that there is often a high* *potential, more than what managers believe, for further lead time reduction*. In fact, while setup and lot size reduction is a consolidated practice, managers seem often to be unaware of the exponential impact on lead time of both internal-process variability and utilization. Looking at the data in Table 5, current or target utilization levels are often close to 100% and internal-process variability is, in most cases, even not measured, and therefore not managed. Although with significant differences, this evidence is valid both for plants and offices and for all the four cases.

A second finding, that confirms preliminary statements mentioned before, is that the *highest potential for lead time reduction seems to be in non-manufacturing operations,* although further room for improvement exists also in manufacturing. Data in Table 5 show, in fact, that all companies interviewed do not even measure variables such as internal-process variability and utilization in offices. As a consequence, these variables are not managed properly and are out of control, impacting negatively on lead times. However, although the lack of proper measurement systems, I can state, based on managers' qualitative assessments, that utilization and internal-process variability are higher in offices than in manufacturing.

Several different reasons could explain this evidence. First, there is a problem of missing or vague definitions, not even of measurement systems, for utilization, lot size and non-strategic variability in office operations. What is a lot size for a production planning process? How to define utilization of a clerical worker in charge of order entries? All managers interviewed had different concepts in mind about these issues. Second, operations management techniques and best practices have been mainly used in plants and, only recently, have been applied in office operations. Third, the more intangible and less visible nature of office operations make office processes more difficult to measure, control and manage. Finally, people’s resistance to be monitored and controlled may be higher for non-manufacturing processes, which are less visible and tangible by nature. All these considerations have emerged during the interviews.

A third finding is that *also manufacturing lead time may still be further reduced* in all cases, although managers are often not aware of this. In fact, the most critical issue, for manufacturing lead times, relates to internal-process variability which is often neglected in terms of impacts on lead time and often not measured. In addition, while the relevance of small lot sizes is well known and managed, the impact of utilization on lead time is still a concept not always consolidated and there are still companies targeting maximum saturation of resources and neglecting the benefits of having some slack capacity.

The final finding is that companies, aiming at reducing lead times, seem to follow a specific *lead time reduction journey. At early stages, the focus is mainly on manufacturing lead time,* which is easier to tackle and manage. *Only at later stages, the managerial attention shifts also to non-manufacturing lead time*, which does not rely on standard and consolidated approaches and seems to be more difficult to reduce. Therefore, this research seems to exclude the existence of cases where lead time reduction starts from office operations and moves later to manufacturing.

	COMPANY 1	COMPANY 2	COMPANY 3	COMPANY 4
Manufacturing Lead time variables				
utilization	62% on max potential output (actual) 80% on max potential output (target) moderately increasing (trend)	*Assembly (labour)* 85% std hours / total hours (actual) > 70% (target) increased (from 70% to 85% in last yr) (trend) *Manufacturing (machines)* 84% std hours / total hours (actual) 84% (target) increased (from 70% to 84% in last yr) (trend)	*Labour* 92% labour eff. prod. hours / hours presence (actual) 95% labour eff. prod. hours / hours presence (target) *Machines* not measured (actual) max 70% (target)	close to 100% machine saturation (actual) structured quantitative measuremet under implementation
lot size	one piece flow	*Assembly* 30 units lots for std pdts - one piece flow for special pdt (actual) extend lot size rules to all prod lines (target) 50% reduction in last 4 yrs (trend) *Manufacturing components* 1 month coverage for gearing sys (actual) stay as it is (target) avg 20% reduction in the last 4 years (trend)	one piece flow for FP variable depending upon setup times for SF	10.000 units (4h production) lot size (actual) lot size reduction (target)
setup time	neglectable	neglectable in assembling from 8% to 3% of total hours in manufactuing in last yr	seconds (decreased from hours) for *machines* 1 hour for presses 20 min for assembly	2h automated setup (actual) setup reduction (target)
non-strategic variability	partially measured used to update SS, reduction through component standardization and product modularity	not measured Current projects: 6 sigma, use of standards, multi-skilled labour and job rotation	not measured weekly production leveling technique mainly due to mix variations	not measured separately from demand variability
demand variability	measured	randomly measured, but no operative impacts	not measured	mesured monthly std deviation / mean
Office Lead time variables				
utilization	not measured somehow improved in the past through the application of time&methods logics	not measured low people utilization perceived (actual) improvement potential higher than in manufacturing (target) already tackled through Lean Office project (trend)	not structurally measured people saturation awarness 10% free personnel time planned	not measured no awarness bonus rewards based on presence (if > 95%)
lot size	single job order	lot size reduced through process decomposition, max LT definition activities, increased output delivery frequency through cut-off / deadlines rules	single job order	single lot size in general bigger lot size when combining different delivery orders FIFO order evasion
non-strategic variability	not measured higher than in manufacturing somehow improved in the past through the application of time&methods logics	not measured reduced through an high standardization of communication rules&tools	not measured standardized procedures standardization improvement actions & projects some fixed deadlines but no maximum process time	not measured cut-off times and maximum process times used (36h max order load time; KPI order load speed) perceived equal or lower than in manufacturing

Table 5 - Manufacturing and Office Lead Time decision variables

In order to answer to the main research question and to understand WHY lead time is not reduced in practice, Tables 6 and 7 summarise the most relevant information and data collected on factors, linked to several different managerial areas, that may influence, either positively or negatively, lead-time-reduction behaviours and decision making processes. These factors include lead time reduction best practices and IT systems, layout configurations, characteristics of organisational structures (process vs. functional oriented, flat vs. hierarchical, etc.), people attitude and behaviour (lead time vs. cost mindset, lead time reduction knowledge and training, etc.), performance, rewarding and accounting systems design and management. Since most of these factors differ in manufacturing and office environments, they have been collected separately for plants and offices.

About accounting systems (Table 6), none of the companies has a system with the following features: activity and time based, total supply chain cost oriented and overhead allocation using job orders instead of direct labour. All of them, companies 3 and 4 in particular, have accounting systems which can be classified as traditional systems, cost based, production (not total supply chain) cost oriented and direct labour overhead allocation based.

Starting from MANUFACTURING (Table 6), companies 1 and 2, the ones considered the most advanced in manufacturing lead time reduction, present many similarities: Lean Production adopted as main managerial philosophy (not only as a set of standalone managerial tools), a flow based, uninterrupted and open space layout, a process oriented, flat and team based organisational structure, high skilled people with a strong time based mindset and a lead time based performance measurement system. Company 3, which seems to present a higher margin in manufacturing lead time reduction, differs from companies 1 and 2 mainly in the following aspects: the absence of an official managerial philosophy adopted in the operations, although an extensive adoption of several lead time reduction standalone tools is in place, a more functional layout, a very functional, hierarchical and centralised organisational structure and a cost based mindset people. Company 4, which has the highest potential for improvement in manufacturing lead time, is even more distant from companies 1 and 2 presenting the following characteristics: absence of both a managerial philosophy in the operations and tools and IT systems to improve lead time, a functional and interrupted layout, a functional, hierarchical and top-down organisation and cost based mindset people. Finally, all four companies seem to have in common, on one hand, well prepared and trained managers with a high knowledge on lead time reduction and, on the other hand, rewarding systems very much efficiency-oriented and somehow misaligned with more time-based performance management systems.

Moving to OFFICES (Table 7), Companies 1 and 2, which are the most advanced in office operations, present again many similarities in the following aspects: implementation of Lean Office projects and office lead time reduction practices and IT systems, flow based and open space layouts, process oriented, team based and centralised organisational structures, skilled and time based mindset people. It is worth to point out that the office layout of company 1 is characterised by one single room that is 150 meters long for the entire company, with two tables: one table, more or less 100 meters long, for employees in charge of primary processes (marketing, sales, R&D, planning, production, purchasing and logistics), and a second table, 50 meters long, for employees in charge of supporting processes (e.g. finance and accounting, IT, HR, etc.). Company 3, that has even more potential room for improvement in offices, differs from companies 1 and 2 mainly in the following aspects: absence of official office lead time reduction projects, fewer lead time reduction best practices and IT systems, functional layouts and functional and fragmented organisational structure. Although its smaller size could be an advantage, company 4 has similar characteristics, even more evident and substantial, to company 3. Finally, all the four cases seem to have in common, also for offices, sufficiently prepared and knowledgeable managers in lead time reduction and efficiency-based rewarding systems, which seem to be again misaligned with the more time-oriented performance measurement systems.

Making a cross-case analysis and looking at Tables 6 and 7, the first result, which confirms previous findings, is that *good knowledge in OM lead time reduction principles is not sufficient itself to lead to shorter lead times in practice.* Although all the managers interviewed both in manufacturing and office operations had good knowledge and training in lead time reduction principles, this has resulted in being insufficient to reduce lead time in practice.

A second important finding is that *efficiency (versus lead time) and individual (versus company) based rewarding systems seem to represent an obstacle for lead time reduction both in manufacturing and offices,* influencing people's behaviour. In fact, all four companies are characterized by efficiency (versus lead time) based and individual performance (versus company) based rewarding systems both in manufacturing and offices. This result is aligned with the expectations that incentives on cost and efficiency obstruct lead time reduction and reduce the positive impacts on lead time of other time oriented tools and approaches. In almost all the four companies analysed, it is surprising to notice a sort of misalignment between the rewarding systems, more efficiency-oriented, and the performance measurement systems, more time-based. Nevertheless, people behaviour and decision making seem mainly driven by the incentives set through rewarding systems.

A third evidence, confirming the results emerged in the manufacturing lead time project, is that *traditional cost-based (versus ABC and time-based) and individual item production cost-based (versus global Supply Chain) accounting systems*, which characterize all four cases, *represent an additional obstacle for lead time reduction*, being not capable of detecting positive economic impacts in presence of lead time reductions. In fact, traditional cost-based (versus time-based) accounting systems are capable to detect cost reductions only when the single process touch-time, not the total process elapsed time, is reduced (Suri, 2010).

A fourth finding is that *to reduce lead times, a multiple OM tool approach, not a single method, is needed*. Stand alone OM tools such as SMED (Single Minute Exchange of Dies) techniques, standardized work or visual management have little value if not integrated all together in a multiple tool approach. This good practice is, however, not sufficient. In fact, even extensive applications of technical OM lead time reduction best practices, detected for example in companies 1 and 2 both in manufacturing and in offices, are not sufficient by themselves to minimise lead time in practice and additional reduction is feasible.

To lead to shorter lead times, it seems that companies should do more and that a *company-wide and multiple function, not just a multiple OM tool, approach should be in place*. This is proved by the higher performance in lead time reduction of companies 1 and 2 which are characterized, on one side, by an extensive application of lead time reduction practices both in manufacturing and offices, and, on the other side, by time oriented company settings not only related to OM, such as process oriented and flat organisations and people time based mindset. This is a fifth relevant result of this study.

Finally, the *lower number of established and tested lead time reduction practices and IT systems and the lower process improvement knowledge and attitude in offices seem to represent two additional* (to the potential factors already discussed before) *obstacles for lead time reduction in offices*. This observation confirms our previous finding that the *highest potential for lead time reduction seems to be in non-manufacturing operations*.

	COMPANY 1	COMPANY 2	COMPANY 3	COMPANY 4
Accounting systems				
Activity based costing vs traditional	traditional	traditional	traditional	traditional
time based vs cost based	cost based	cost based	cost based	cost based
total SC cost vs item production cost	item production / total SC cost	item production / total SC cost	item production cost	item production cost
OH allocation driver	direct labour	direct labour	direct labour	direct labour
Practices and settings in MANUFACTURING				
BEST PRACTICES and IT systems				
Main managerial approach	LEAN PRODUCTION	LEAN PRODUCTION		
Lot size reduction	high	high	high	medium
Set-up time reduction	medium/high	high	medium/high	medium
Slack-free capacity planning	medium/high	medium/high	medium	low
Equip. and labour proc. time variability reduction	medium	low/medium	medium	low/medium
Bottleneck management and process levelling	medium	medium	medium/high	low/medium
High frequency and long time horizon planning	high	high	high	medium
Visual management time based approaches	medium/high	high	low	low
Standardized work	medium	medium/high	high	low
Project management (CPT) techniques	high	high	low	low
Other relevant LT reduction best practices	component standardization and product modularity, raw material in-line storaging	Supplier management: consignment stock and LT & del precision based pricing in contracts From Job Shop to Flow Shop layout	lot size & setup reduction; outsourcing to local subcontractors; IT to load automatically prod orders on machines; cells with integrated and balanced cycle	lot size and setup reduction, process leveling
LT reduction manufacturing IT systems		Rapid modelling simulation, ATP-CTP	ATP-CTP	ATP-CTP
LAYOUT and FLOW				
flow based layout vs functional	flow based	flow based	flow/functional based	functional based
continuous flow vs many storage areas layout	continuous flow	continuous flow/many storage areas	continuous flow	many storage areas
open vs closed space	open space	open space	open/closed space	open space
concentrated vs dispersed space	concentrated space	concentrated space	concentrated space	disperced space
ORGANISATIONAL STRUCTURE				
Process vs functional oriented	process oriented	process oriented	functional oriented	functional oriented
Flat vs hierarchical	flat	flat	hierarchical	hierarchical
bottom-up vs top-down approach	bottom-up	bottom-up & top-down	bottom-up & top-down	top-down
Centralised vs fragmented	centralised	centralised	centralised	centralised
Team vs individual based	team based	team based	team/individual based	team based
delegated vs centralised decision making	delegated	delegated/centralised	centralised	delegated
PEOPLE BEHAVIOUR and KNOWLEDGE				
time vs cost based mindset	time based mindset	time based mindset	cost based mindset	cost based mindset
proactive vs reactive behaviours	proactive	proactive/reactive	proactive/reactive	proactive/reactive
skills level	high	medium/high	high	high
education level	medium	medium	medium/high	low
OM knowledge (decision maker)	high	high	high	high
OM LT reduction knowledge (decision maker)	high	high	high	high
OM training (decision maker)	medium	high	high	low
PERFORMANCE MEASUREMENT Systems				
lead time vs efficiency based	lead time/efficiency based	lead time based	lead time based	lead time based
end-to-end vs local process view	end-to-end view	end-to-end/local view	end-to-end view	end-to-end view
PM process vs set of KPIs	PM process	PM process	PM process	PM process/set of KPIs
REWARDING Systems				
lead time vs efficiency based	efficiency based	efficiency based	efficiency based	efficiency based
company vs individual based	company/individual based	company/individual based	individual based	individual based
results vs presence based	results based	results based	results based	results/presence based
variable vs fixed salary system	fixed	variable	variable	fixed

Table 6 - Accounting systems and Manufacturing Lead Time potential influencing factors

	COMPANY 1	COMPANY 2	COMPANY 3	COMPANY 4
Practices and settings in OFFICES				
BEST PRACTICES and IT systems				
Main managerial approach	LEAN OFFICE	LEAN OFFICE		
End-to-end overall process approach	medium/high	medium/high	medium	low/medium
High frequency and long time horizon planning	medium/high	medium/high	medium/high	medium/high
Bottleneck management and process levelling	medium	medium	low	low
Slack-free capacity (people) planning	medium	low/medium	medium/high	low/medium
Visual management	low/medium	high	low	low
Standardized work	medium/high	high	medium/high	low
Project management (CPT)	medium/high	low	medium	low
Explicit vs tacit knowledge	explicit/tacit knowledge	explicit/tacit knowledge	explicit knowledge	tacit knowledge
Other relevant LT reduction best practices	IT sys syncronisation for order mgmt non-manufacturing lead time decomposition and measurement	office flow and open space layout, standardized and regular inter-functional meetings	EDI, standardized work, automated order loading on machines	36h max order processing time; frequent internal/external expediting actions
LT reduction IT systems in offices	Order tracking, Alerting systems, Workflow mgmt	EDI, Alerting systems	EDI, Order tracking	
LAYOUT and FLOW				
flow based layout vs functional	flow based	flow based	functional based	flow/functional based
continuous flow vs many storage areas layout	continuous flow	continuous flow/many storage areas	continuous flow/many storage areas	continuous flow/many storage areas
open vs closed space	open space	open space	open space	open/closed space
concentrated vs dispersed space	concentrated space	concentrated space	concentrated space	concentrated space
ORGANISATIONAL STRUCTURE				
Process vs functional oriented	process oriented	process oriented	functional oriented	functional oriented
Flat vs hierarchical	flat/hierarchical	flat	flat/hierarchical	flat
bottom-up vs top-down approach	bottom-up & top-down	bottom-up & top-down	bottom-up & top-down	top-down
Centralised vs fragmented	centralised	centralised	fragmented	centralised
Team vs individual based	team based	team based	team/individual based	team based
delegated vs centralised decision making	delegated/centralised	delegated/centralised	delegated/centralised	delegated
PEOPLE BEHAVIOUR and KNOWLEDGE				
time vs cost based mindset	time based mindset	time based mindset	time based mindset	time based mindset
proactive vs reactive behaviours	proactive/reactive	proactive/reactive	proactive/reactive	proactive/reactive
skills level	high	high	high	medium/high
education level	medium/high	high	medium/high	medium
OM knowledge (decision maker)	medium	high	medium	medium/high
OM LT reduction knowledge (decision maker)	medium/high	high	medium	medium
OM training (decision maker)	low/medium	high	medium/high	medium
PERFORMANCE MEASUREMENT Systems				
lead time vs efficiency based	lead time/efficiency based	lead time based	lead time based	lead time based
end-to-end vs local process view	end-to-end view	end-to-end/local view	end-to-end view	end-to-end view
PM process vs set of KPIs	PM process	PM process	PM process	PM process/set of KPIs
REWARDING Systems				
lead time vs efficiency based	efficiency based	efficiency based	efficiency based	efficiency based
company vs individual based	company/individual based	company/individual based	individual based	individual based
results vs presence based	results based	results based	results based	results based
variable vs fixed salary system	fixed	variable	variable	fixed

Table 7 - Office Lead Time potential influencing factors

2.6.7 LIMITATIONS

This work is subject to all of the usual limitations of case study based and theory development research. As the evidence of this study derives from a qualitative analysis conducted across multiple cases, it suffers from the limitations characteristic of such a research approach. The results are exploratory rather than generalizable, representing a first step towards understanding how competitive need for short lead times translates into action and why this is so difficult to achieve in practice.

In addition, the framework elaborated cannot be considered exhaustive, including all possible factors that may play a role in reducing lead times. In this research I have mainly looked for potential lead time reduction obstacles and drivers inside the company analysing internal processes, functions and elements that could impact somehow on order-to-delivery activities and performance. Further research, focused also on some external aspects, such as supply chain complexity just to cite an example, is needed to look for new obstacles and drivers of lead time reduction.

Finally, the next step of research is to test the validity of the propositions developed and to check their generalizability. In fact, the research approach chosen made me develop testable propositions that need to be confirmed through quantitative empirical testing to reach general validity.

2.6.8 CONCLUSIONS

This research focuses on a in depth multi-case-study based analysis of order-to-delivery lead time through its decomposition in the main elementary elements which are then grouped together into two different categories: manufacturing and office lead times.

The main contribution of this research is to bridge, at least partially, the theory-practice gap and paradox of lead time (that is: 1) shortening lead times is very relevant and has many benefits, 2) lead time reduction is, in theory, easy and achievable through very modest investments in existing simulation tools, but 3) lead time is not minimized in practice and there is still relevant room for further improvement), recognizing that some obstacles should be removed in order to facilitate lead time reductions.

Second, the most relevant lead time obstacles identified are the presence of *efficiency (versus lead time) and individual (versus company) based rewarding systems,* that drive people behaviour, and the use of *traditional cost-based (versus ABC and time-based) and individual item production cost-based (versus global Supply Chain) accounting systems*, that are not capable of detecting positive economic impacts in the presence of lead time reduction.

Third, *good knowledge in lead time reduction principles is not sufficient* itself to lead to shorter lead times in practice if lead time reduction obstacles are not removed.

Forth, *a multiple operations management tool*, not a single method, and a *company-wide*, not a single function, approach (characterised by multiple lead time reduction best practices and IT systems both in plants and offices, process oriented and flat organisations, time based mindset people and flow based layouts) seems to represent a key facilitator for lead time reduction, but still this is not sufficient itself if lead time obstacles related to rewarding and accounting systems are not removed.

An additional practical finding of this research is the identification of *higher potential for lead time reduction in office operations compared to manufacturing.* The lower presence of established and tested lead time reduction practices and IT systems and the lower process improvement knowledge and attitude in offices seem to represent two major obstacles. In addition, problems of vague definitions in offices of lead time variables (such utilization of clerical people processing orders and lot size in production planning), the intangible and less physical nature of office operations and the associated higher people resistance to be monitored are additional potential obstacles, emerged during the interviews, of lead time reduction in offices.

A final relevant practical contribution consists in the identification of a *lead time reduction journey*. In fact, it seems that companies focus, in their earlier stages, mainly on reducing lead times in plants, which are associated to activities more physical, visible and maybe also easier to improve. Only at later stages, when a certain degree of maturity is reached, companies move their managerial attention also on reducing non-manufacturing lead times in offices, which are associated to more intangible, less visible and maybe more difficult processes to improve.

All these findings, if empirically validated in further research, will represent practical recommendations for companies about how to reduce lead times, which requires to remove some obstacles and to apply consolidated knowledge and quite inexpensive modelling tools.

As far as contribution to theory is concerned, this research has developed a wide-scope order-to-delivery lead time framework which has been built through interactions between literature, cases and observations. Second, this study has extended lead time frameworks, usually used in manufacturing, to office operations highlighting some issues, such as vague definitions in offices of some lead time related variables, that have to be addressed both in literature and practice. Finally, this research has created new connections among different disciplines because of the identification of potential lead time reduction obstacles linked not only to OM, but also to other managerial areas such as accounting and organisation.

3. INVENTORY AVAILABILITY IMPROVEMENT

3.1 INTRODUCTION

In recent years, the relevance of logistic service as a competitive weapon has increased enormously in several industries. Logistic service is a bundle of attributes that concerns mainly speed, dependability and flexibility of deliveries, as well as the immediate availability of the items the client wishes to buy. The importance of stock availability, compared with other attributes, has increased a great deal. This is due to the commoditization process seen in many industries, which brings about an ever-decreasing willingness on the part of the customer to wait for delivery. In this new setting, guaranteeing the prompt availability of the product is a new challenge that requires a deep understanding of the levers that a company can use to increase service level without incurring extra costs. Given the well-known trade-off between stock availability and holding costs, companies need to understand how they can enhance logistic service without increasing inventory level.

Although the relationship between service level and inventory management has been extensively studied, there is still room for further investigation. In fact, the physical availability of stock does not always turn into the ability to fulfil the order, due to a number of problems that affect warehouses. For instance, the product may be stocked in the wrong position, or the information stored in the warehouse information system about actual stock levels may be inaccurate. Thus, inadequate practices, technology and equipment at the warehouse can keep companies from properly serving the customer. On the basis of this evidence, the purpose of this paper is to understand how best performing companies strive to improve their service levels and what levers they use to achieve this goal. To address this issue, a multiple-case study was conducted on six companies that share some relevant features: they adopt a “make-to-stock” approach; they operate in industries (namely, pharmaceuticals and food distribution) in which the prompt availability of the product is essential for market success; they enjoy an excellent service level and can be considered the “best performers” in their industry, as far as Italy is concerned.

In the remainder of this paper a brief literature review on the topic is presented. Then the empirical findings are reported and managerial implications and conclusions are drawn.

3.2 LITERATURE REVIEW

Stock availability is one of the attributes that characterize logistic service. Logistics is generally assessed by its efficiency and effectiveness. The former is generally quantified through the total logistic cost, while the latter is thought of in terms of “logistic service”, which concerns the ability of a company to offer good levels of availability, speed, dependability and flexibility of the delivery process (Manrodt and Davis 1992; Rushton et al. 2006).

Previous studies on stock availability address mainly the problem of properly quantifying the volume of goods to hold in the warehouse to offer to customers a satisfactory service level and to keep inventory-related costs within acceptable limits. From this perspective, the inventory level of a company can be effectively determined through the application of proper formulas, especially those that relate safety stock to the desired service level (Silver et al. 1998).

More recently, given the importance of logistic performance, especially stock availability, for corporate competitiveness, decisions concerning the service level that a company should guarantee to its customers have been addressed in other streams of research. In recent years, influential studies have tried to highlight *when* it is necessary to leverage stock availability and *how* to improve it without increasing inventory level. In this regard, the literature on supply chain management has provided numerous frameworks that can support practitioners in coping with these problems. In the late 1990s, Fisher (1997) maintained that the relevance of stock availability depends on the nature of the products, which can be either *innovative* or *functional*. As far as the former are concerned, given their high margins, their short life cycles and, in particular, their unpredictable demand, it is mandatory to foster the responsiveness of the supply chain and to avoid stock outs. In this setting, holding a proper inventory level and speeding up the materials flow along the pipeline are key conditions for achieving better service levels. Later studies (Christopher 2005) argue that there can be products that cannot be considered "innovative", but for which the demand is also highly unpredictable. This is due to the commoditization process, which reduces the product life cycle of many different categories of items, even those characterized by low margins. In such cases, holding a high inventory level can lead to negative economic outcomes. Thus it is necessary to look for a higher level of efficiency and responsiveness along the pipeline through stronger integration with the main players of the supply chain. Actually, in recent years several contributions have demonstrated that such integration leads to enhanced operating performance. Frohlich and Westbrook (2001) claim that the extent to which the company is integrated with its clients and suppliers is correlated to a number of performance improvements, which can affect also inventory turnover, delivery lead time and dependability. Similar findings are obtained by Salvador et al. (2001), who demonstrate that the interaction with upstream and downstream operators in the supply chain leads the company to carry out its internal processes in a more effective and efficient manner, thus obtaining several performance improvements. Also Flynn et al. (2010) come up with similar evidence, highlighting that supply chain integration has a positive impact on both operational and business performance.

This issue is addressed also by the stream of literature concerning collaborative practices along the supply chain. As a matter of fact, several successful studies have demonstrated that cooperation among players of the pipeline can help in improving both logistic efficiency and effectiveness (Forrester 1961; Simatupang and Sridharan 2002; Wagner et al. 2002). For example, Disney and Towill (2003) demonstrate that the application of Vendor Managed Inventory (VMI) can bring about a significant reduction of the bullwhip effect.

In the above mentioned studies, the authors highlight the necessity to offer a good service level not only by holding higher amounts of stock, but also by properly managing the whole logistic process, from the purchase of raw materials to the delivery of finished products. This approach is effectively summarized in the model proposed by Lutz et al. (2003). According to this model, service level is very much influenced by safety stock, with the amount depending on a number of factors connected to the operating conditions of the sourcing and production processes. In this case, guaranteeing a good service level through a proper amount of inventory is not only a matter of properly computing safety stock, but also of improving such operating conditions.

Although the problem of service level and of proper definition of stock levels has mainly been addressed in the streams of research mentioned above, studies in the field of warehouse management have pointed out some other factors that can influence such performance. Frazelle (2002) claims that there are three main categories of warehouse performance: productivity, which measures the level of asset utilization; quality, thought of as the level of accuracy in order picking and shipping; cycle time, i.e. the responsiveness of order picking and shipping. Such performance categories, which are consistent with the ones peculiar to the logistic process as a whole (Rushton et al. 2006), can be deeply influenced by the way in which warehouses are designed and managed. For instance, Denis et al. (2006) state that an improper balance between the amount of stock and the capacity of the warehouse can turn into poor safety conditions for the workforce and also into less responsive picking activities. Also Berger and Ludwig (2007) demonstrate that the use of modern technologies in picking, for example voice picking, have a dramatic impact on the reduction of employee error in order preparation. Thus, the service level that the company wants to guarantee to its customer must be taken into account, when designing and managing the warehouse. According to recent contributions (de Koster et al. 2007; Gu et al. 2007; Rouwenhorst et al. 2000), *design decisions* for warehouses concern overall features, dimensions and capacity, layout, equipment and operating processes, while *management decisions* concern receiving, storage, order picking and shipping.

Although warehouse design and management are considered relevant in influencing service level, there is not an integrated framework that explains how companies leverage them to improve their logistic effectiveness and efficiency. This gap in the studies on logistic management is particularly relevant, considering the increasing importance that service level and stock availability have gained in recent years.

The relevance of both logistic efficiency and effectiveness for companies' competitiveness has been discussed in several contributions. Recent studies demonstrate that the impact of logistic costs on income statements in many industries is high, ranging from 1.52% of company turnover in the electronics sector up to 46% in the cement sector (Rushton et al. 2006). Also from a macroeconomic standpoint logistics is a relevant activity since, even in countries where updated practices and technologies are applied in this field, the logistic sector represents on average 10% of GNP (Rushton et al. 2006).

Within the bundle of attributes that concerns logistic effectiveness, one that has gained greater importance in recent years is availability. As demonstrated by Corsten and Gruen (2004) through a field survey of fast moving consumer goods (FMCG), when the item is not available in the store, only 15% of consumers buy it later, while most of them act in a way that is unfavorable for the producer and/or for the retailer. Even though this analysis was conducted for FMCG, similar trends can be observed in other industries. For instance, in the apparel industry, the ability to promptly deliver items in the correct quantities is considered key to survival in a sector where stock outs and mark downs on items not sold by the end of the selling season are costly (Abernathy et al. 1999).

On the basis of such evidence, it is important to gain an in-depth understanding of the drivers of service level to properly manage performance, which is becoming more and more relevant as an element influencing customer purchasing decisions. As a matter of fact, there is no suitable existing framework to explain how warehouse management together with inventory management can affect such performance.

In order to develop a framework we must recall that, as claimed above, the main driver of service level is inventory level (Silver et al. 1998; Waters 1994), with the average amount depending on a number of factors described by Lutz et al. (2003) that mainly concern the way in which forecasting, purchasing and production processes are performed. However, as claimed by other contributions (Denis et al. 2006; Frazelle 2002), the way in which warehouse processes are managed can also affect the ability of the company to promptly and properly deliver items. This literature analysis led us to assume that there are mainly two categories of factors that drive service level: the first category concerns inventory management and the processes that can influence it, namely forecasting, purchasing and production (Lutz et al., 2003); the second concerns warehouse management processes, namely receiving, storage, order picking and shipping (Denis et al. 2006; Frazelle 2002; Gu et al. 2007).

Building on this underlying assumption of service levels being driven by both inventory and warehouse management, we can develop an interpretative framework suitable for conducting an empirical analysis aimed at understanding how companies improve their service levels. This framework is described in Figure 13.

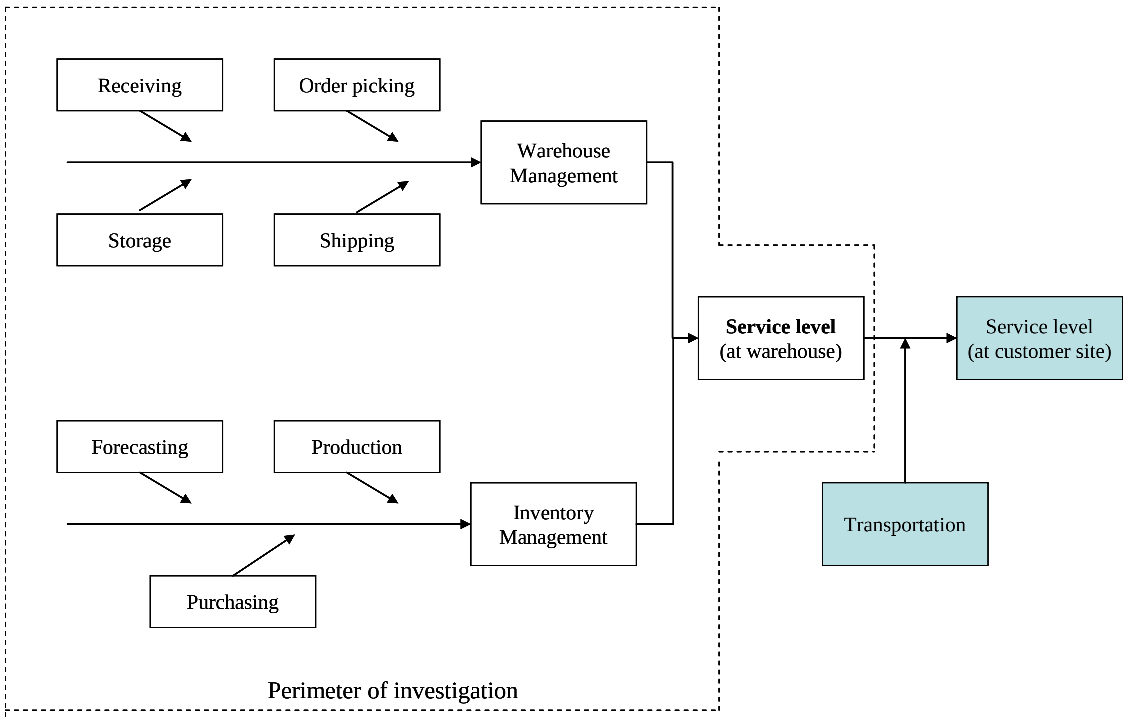

Figure 13 - The interpretative framework

3.3 RESEARCH QUESTION and METHODOLOGY

Based on the analysis of the literature, we developed the following research question:

How do best performing companies strive to improve their service levels?

In order to answer this question, we adopted the framework described in Figure 13 as an interpretative model suitable for describing factors that, according to previous studies, influence service levels. Then, we carried out an empirical study to understand how companies leverage these factors, through the adoption of particular technologies and up-to-date managerial practices.

A case-based methodology was selected for this empirical analysis. The aim of this study is to gain an in-depth understanding of a phenomenon (*how best performing companies improve their service level*) through the analysis of multiple cases (Eisenhardt 1989; Meredith 1998; Yin, 2009 and 2003). This paper has a theory building intent since there is no existing framework. This makes the case-based methodology appropriate. Furthermore, such a research strategy is consistent with the type of research question, the low level of control of the authors on the reported events and the focus on contemporary events (Yin 2003).

In each case-study, our unit of observation was the *finished product warehouse*. Furthermore, in Figure 13 the perimeter of investigation is clearly highlighted. In fact, we decided to measure service level in terms of physical availability of items *at the warehouse*, not at the customer site. These two measures can be slightly different depending on the operating conditions of transportation, which, in turn, are affected by factors over which the company has little control (e.g. damage during transportation), namely when transportation is outsourced to third-party logistics providers.

In order to analyze relevant case-studies, we selected companies that: 1) compete in industries where service level is a key success factor; 2) enjoy excellent logistic performance. The first criterion was employed in order to observe companies for which improving service level is essential for survival. This led the authors to focus on industries where reaching a high service level is considered a "must" and turns into the widespread adoption of a "make-to-stock" planning approach. The selected industries were food distribution and pharmaceuticals, where guaranteeing prompt delivery is a key condition for corporate success. The second criterion was used to select firms that are considered best performing players in Italy, in order to analyze companies that have effectively invested to improve service level.

The study included six companies:

- 2 pharmaceutical producers;
- 2 pharmaceutical distributors;
- 2 food distributors.

All these companies adopt a make-to-stock planning approach and compete in industries where reaching the customer very fast is a key success factor. Therefore, all of them fit the first selection criterion for this empirical analysis. Furthermore, such companies enjoy a logistic performance that is considered very good for the industries in which they operate. They can guarantee to their customers a very high level of stock availability and very prompt deliveries (performance details are provided in the remainder of this paper). Thus, within the industries in which they operate, these companies are considered the best performing ones from the logistic standpoint. Consequently, they fit the second selection criterion of this study.

In order to produce comparable results across all six cases, we developed a research protocol through which we conducted interviews, each lasting about 2-3 hours, with the supply chain and/or logistics directors of each company. In addition to the interviews, a site visit lasting one to two hours was undertaken, encompassing the main warehousing facilities of each company. Each interview was recorded and later transcribed.

The research protocol comprised a questionnaire suitable for conducting interviews, the structure being derived from the interpretative framework described in Figure 13. More precisely, the questionnaire started with a section aimed at gathering general data and information about the company, its supply chain structure, its logistic and product portfolio complexity and, finally, its main logistic operational and economic performance results. The subsequent sections of the questionnaire were explicitly linked to the processes highlighted in Figure 13 (inventory, demand, production and purchasing management, on one side, and warehouse management together with receiving, storage, picking and shipping which are its sub-processes, on the other side) and aimed at identifying the specific practices and technologies employed by the companies to improve such processes.

To interpret data and draw relevant conclusions, we analysed each case individually to understand how the observed companies reached outstanding service levels. Then, we conducted a cross-case analysis to identify differences and commonalities among cases, as well as their drivers. We report the main evidence of each case in tables that summarise the key data and information. This analysis led to three propositions that generalise our key findings.

3.4 EMPIRICAL FINDINGS

3.4.1 Companies' presentation

Table 8 reports, for all cases, a synthesis of data and information collected through interviews and site visits, in relation to the first section of the questionnaire.

	Company 1	**Company 2**	**Company 3**	**Company 4**	**Company 5**	**Company 6**
General information						
Industry	Food	Food	Pharma	Pharma	Pharma	Pharma
Role of the company in the SC	Distributor	Distributor	Distributor	Distributor of a manufacturing company	Producer	Producer
People interviewed						
Number of people	1	2	2	3	1	1
Role	Head of Logistics	Commercial and Logistics directors	Head of Operations and Central Logistics	DC, Warehouse and Distribution managers	Material manager at plant (Italy) level	Supply Chain manager
Position	Top management	Top & middle management	Top & middle management	Top & middle management	Middle manager	Middle manager
Supply Chain Description						
No. of customers	230	483	> 12,000	Thousands	> 10,000	> 15,000
No. of suppliers	1,500	1,200	600	Under 100	Under 100	Under 100
No. of plants of the company	Not applicable	Not applicable	Not applicable	> 11 in Europe (3 in Italy)	4 in Europe (1 in Italy)	3 in Europe (1 in Italy)
No. of distribution warehouses of the company in Italy	5 distribution centres and 4 logistic platforms	3 distribution centres	33 depots	1 distribution centre	2 distribution centres	3 distribution centres
Logistic and Product Portfolio Complexity						
No .of SKUs	25,000	10,000	120,000	3,500	130	120
Product life cycle	From 0 to ∞	From 0 to ∞	2-5 years	3 months-5 years	From a few years to decades	From a few years to decades
Forecasting accuracy	N.A.	N.A.	N.A.	N.A.	85%	90%
No. of orders/year	> 200,000	> 215,000	> 6,000,000	> 50,000	> 90,000	>60,000
Order fragmentation	200-500 lines/order	200-500 lines/order	25-30 lines/order	10 lines/order	Not precisely quantified; a few lines per order	6-7 lines/order
Product's morphological homogeneity (size and shape of items stored)	Low	Low	Medium-High	Medium-high	Medium	Medium
Logistic Performance						
Stock availability	>99%	>98.5%	98.5%	98.5%	98%	99% of orders ready to ship within 24 hours
Delivery lead time	24-72 hours	2-30 hours	2-4 hours	36-96 hours	24-72 hours	24-72 hours
Delivery errors	0.02%	< 0.3%	< 0.2%	< 0.4%	N.A.	< 1%
Inventory levels	3 weeks for dry products, 3 months for non food products	1 month for dry products	3-4 weeks	6 weeks at central DC level 2 weeks at local DC level	2-3 months	1-1.5 months
Supplier delivery reliability	94.8%	N.A.	70%	50%	90%	N.A.
Purchasing lead time	1-5 days for perishable and dry products, 2-3 months from Far East	3-15 days	4-10 days	1- 4 weeks	2-3 months	Variable, from a few days to 4-6 months

Table 8 – Main information on case studies

Concerning the structure of the supply chain, the cases differ substantially mainly in terms of upstream and downstream capillarity (i.e. number of players). While Companies 1 and 2 are characterised by a relatively small number of customers, the downstream supply chains of Companies 3, 4, 5 and 6 are very fragmented. By contrast, the level of upstream capillarity of the supply chain decreases moving from Company 1 to 6.

“Logistic and Product Portfolio Complexity” refers to variables that can influence both the ability to forecast future demand (and then to properly quantify the necessary inventory levels) and the level of complexity of warehousing processes.

The former (ability to forecast demand) is influenced by the total number of stock keeping units (SKUs) held in the warehouse and by the average length of their life cycle. It is evident that Companies 5 and 6, characterised by a relatively small number of SKUs and long product life cycles, differ from the other cases, characterised by wider product portfolios and shorter product life cycles. Table 8 reports also a measurement of forecasting accuracy, which, however, was provided only by Companies 5 and 6.

The latter (warehousing complexity) is very much influenced not only by the above mentioned factors, but also by the volume of activities measured in terms of number of orders shipped per year, by the fragmentation of each single order, measured in terms of number of lines per order, and by the product’s morphological homogeneity, assessed in terms of the extent of differences in size and shape of the items stored. Companies from 1 to 3 seem to be dealing with higher degrees of Logistic and Product Portfolio Complexity, compared to the other three cases. Company 3, with 120,000 SKUs and more than 6 million orders per year to manage, seems to be the most complex case from this perspective.

Finally, it is worth noting that all the companies enjoy very good Logistic Performance, measured in terms of stock availability, delivery lead times, delivery errors and inventory levels.

Stock availability, ranging from a minimum of 98% (Company 5) to nearly 100% (Companies 1 and 6), can be considered a strength of all the companies.

Table 8 also reports logistic performance results that the companies “receive” from their suppliers, in terms of purchasing lead time and of delivery reliability. It is worth noting that all the companies are able to deliver very good service levels to their customers, even though they suffer from poor performance on the part of their suppliers.

3.4.2 Companies’ managerial practices

Table 9 reports a synthesis of the most relevant information collected during visits and interviews, concerning the main managerial practices, technologies and equipment that the companies in the study use to govern the main processes (Figure 13) related to both inventory and warehouse management.

	Company 1	Company 2	Company 3	Company 4	Company 5	Company 6
Inventory Management						
Techniques applied	Reorder point	Reorder intervals (weekly)	Reorder intervals (weekly-monthly)	MRP	DRP with safety stocks	MRP and DRP with safety stocks
Stock parameters update and stock control	Continuous	Parameters updated on the basis of information gathered through CRP with clients; Monthly stock control	Continuous	Continuous	Parameters updated annually; Monthly stock control	Parameters update every 3-6 months; Monthly stock control
Collaboration practices with clients	CRP with main points of sales	CRP with main points of sales	VMI with a very limited number of clients	VMI with a few clients (only clinics)	No	No
Forecasting process						
Structure of the process	High	Medium-Low	N.A.	High	Very high, consensus forecasting	Very high, consensus forecasting
Forecasting frequency	Daily	N.A.	Daily	Weekly	Monthly	Monthly
Forecasting model	At item level, algorithms based on time series and on promotions	At item level, algorithms based on time series and on promotions, sell-out POS visibility	At item level, algorithms based on time series	At item level, algorithms based on time series and on tenders, 3 months time horizon	At item level, algorithms based on time series, 24 months time horizon	At item level, algorithms based on time series, 36 months time horizon
Production planning						
Structure of the process	Not applicable	Not applicable	Not applicable	High	High	High
Planning model	Not applicable	Not applicable	Not applicable	3 levels (Budget, monthly planning, scheduling)	3 levels (Budget, monthly planning, scheduling)	3 levels (Budget, monthly planning, scheduling)
Purchasing						
Purchasing model	Daily-weekly frequency	Weekly frequency	N.A.	Based on MRP	Based on MRP	Based on MRP
Collaboration practices	CRP implemented with the 2 largest suppliers	CRP implemented only with the largest suppliers	No	No	No	No. However, good visibility and sharing of data with the main suppliers
Warehouse Management						
"Make or buy" decisions	In house	In house	In house	In house	Outsourced	Outsourced
Receiving and storage	Layout by product categories (same as at retail level)	Layout by product categories (same as at retail level), incoming visibility, dynamic locations	Automated conveyors and sorters, stocking on ABC rules, incoming plans	Dynamic locations, ABC rules	Dynamic locations, ABC rules	Fixed locations, ABC rules
Order picking and shipping	Order picking, picking routes optimization, on-line workload control	Order picking, picking routes optimization	Order picking (batch picking for "controlled temperature" products)	Order picking limited to high volumes; in the other cases, batch picking grouping 4-8 orders	Batch picking, "First Expiring First Out" (FEFO) picking rule, cross docking and multi-drop	Batch picking, "First Expiring First Out" (FEFO) picking rule, cross docking and multi-drop
Technology and equipment	Barcode, voice picking, RFID and GPS to track and control trucks	Voice picking for frozen products, barcode, radio frequency	Barcode, Radio frequency, automated conveyors and sorters, dispenser for picking	AGV systems, conveyors and sorters, rotating warehouses	Barcode, Radiofrequency	Barcode, Radiofrequency

Table 9 – Main empirical findings

It is not surprising that all the companies consider inventory management a key to achieving excellent service levels; however, the companies pursue different routes to excellence in inventory management.

First, during the interviews we have observed that all the companies have a profound knowledge of inventory management techniques and consider this essential to achieving a high service level. Observable differences concern the type of technique implemented (push vs. pull) and the frequency of update and control of stock parameters. Companies 5 and 6 apply push techniques (Material Requirements Planning – MRP - and Distribution Requirements Planning - DRP) and show a lower frequency of update and control of parameters. The opposite can be observed for Companies 1, 2 and 3. This clustering seems to be due to the varying levels of Product Portfolio Complexity, namely in terms of number of SKUs. Company 4 shows an intermediate positioning compared to the two clusters mentioned above.

Second, the application of collaborative practices related to inventory management can be found especially in those cases (Companies 1 and 2, which extensively apply Continuous Replenishment Programs - CRP) characterised by the lowest number of clients. In the other cases, the widespread application of collaborative practices seems to be prevented by the much higher level of capillarity of the downstream supply chain.

If one focuses on forecasting, production and purchasing - the three processes that can affect the effectiveness of inventory management - some interesting outcomes are noticeable.

We observed a very high level of managerial attention toward forecasting in all cases, but some differences were found as far as the structure and the frequency of the forecasting process are concerned. Companies 5 and 6 exhibited a more structured forecasting process compared to the other cases, which however was carried out with a lower frequency. By contrast, the other companies exhibited a less structured forecasting process, but seemed to pursue the effectiveness of such process through a higher frequency of update. Also, this clustering seems to be correlated with the differing number of SKUs that these companies offer. In cases 5 and 6, where the figure is clearly lower, the forecasting activity is inherently easier. This probably leads to the high level of forecasting accuracy characteristic of such companies (see Table 8).

As far as the production process is concerned (namely, the planning process), only Companies 4, 5 and 6 were analysed, since the others do not perform any transformation activity. In these cases, no relevant differences were observed either in the structure of the process or in the planning model.

As far as the purchasing process is concerned, no relevant differences were found, except for the application of collaborative practices with suppliers. From this perspective, the most relevant experiences are those observed in Companies 1 and 2, where however CRP is implemented only with the largest suppliers.

Moving on to warehouse management, Companies 5 and 6, characterised by lower product and logistic complexity, have outsourced warehousing, whereas Companies 1 to 4 manage their warehousing facilities internally.

Second, it is interesting to underline the differences among the companies in terms of the practices and technologies applied, which again seem to be related to the number of SKUs. In this regard, two clusters can be identified: one encompasses Companies 1 to 4, the other includes Companies 5 and 6.

The former cluster seems to be characterized by a wider use of up-to-date warehousing solutions. For instance, in Companies 1 to 4 the high number of SKUs calls for careful management of all warehouse processes. In such cases, a high level of service requires effective planning of receiving, storage and, mainly, of picking and shipping. In fact, in these companies, order picking is used, as opposed to the batch picking that is used by Companies 5 and 6. This choice involves warehouse equipment suitable for supporting such a frequent picking process. Company 1, for instance, is now introducing *voice picking* and already uses RFID (Radio Frequency Identification) transponders on its trucks to track their precise position and the timing of deliveries through a GPS (Global Positioning System). Similar solutions are observed in Company 2. Companies 3 and 4, compared to Companies 1 and 2, exhibit a higher level of automation, not only in picking and shipping, but also in material handling and storage processes, where automated conveyors and sorters, AGV (Automated Guided Vehicles) systems and automatic rotating warehouses are employed.

The difference in the degree of automation of the warehousing solutions adopted in Companies 1 and 2, on the one hand, and Companies 3 and 4, on the other, seems to be due to two factors: the level of fragmentation of the orders and the level of morphological homogeneity of the products. In fact, in Companies 1 and 2, the high level of order fragmentation (200-500 order lines/order) and the variable product morphology (in terms of size and of shape of the items stocked in the warehouse) are obstacles to automation, even if the high volumes and number of orders would well justify the investment. On the other hand, Companies 3 and 4 present a higher degree of automation due to the lower level of order fragmentation and to the more homogeneous product morphology that make the choice of automation feasible.

The greater focus on up-to-date practices, equipment and technology in Companies 1 to 4, compared to Companies 5 and 6, is necessary to guarantee prompt, complete and correct deliveries to customers, even in the face of the higher level of complexity of warehousing facilities peculiar to these companies.

3.4.3 Companies' patterns of behaviour

All the companies analysed in this study offer excellent service levels, which is imposed by the features of the industry. However, some important differences can be found among the ways in which the six companies strive to improve such performance.

This study was conducted under the basic assumption that not only inventory management, but also warehouse management is an important driver of service level (see Figure 13). The empirical evidence reported above shows that this is true in some cases, where relevant investments in warehouse management equipment and technology have been carried out and up-to-date practices have been implemented. Furthermore, the empirical analysis shows that some differences can be observed as far as inventory management is concerned. Thus, recalling our research question (i.e. *how do best performing companies strive to improve their service levels?*), it can be claimed that different patterns of behaviour have been observed, whose main drivers seem to be Downstream Supply Chain Capillarity, quantified through the number of customers, Product Portfolio Complexity, measured in terms of number of SKUs and Logistic Complexity, assessed in terms of order fragmentation and product morphological homogeneity. These relationships are shown in the matrix in Figure 14.

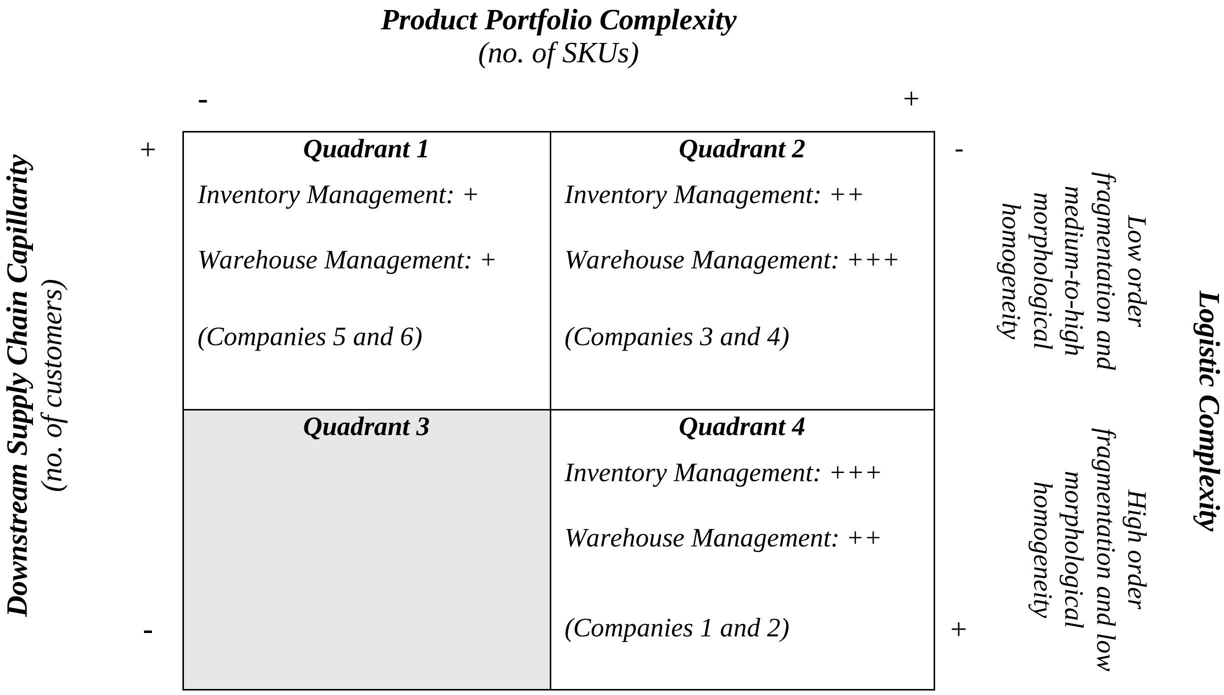

Figure 14 – Summary of the evidence emerging from the cases

Figure 14 reports for each quadrant a qualitative assessment of the degree of attention and excellence, observed in the cases, of both inventory and warehouse management; in addition, it highlights the positioning of each company within the matrix.

The qualitative assessment is expressed through a scale (+++, ++, +) based on the distinctive features reported in Table 10.

	Level of managerial attention and excellence	*Distinctive features*
Inventory Management	+	▪ Low frequency of stock parameters update and control ▪ No collaborative practices with clients
	++	▪ Continuous stock parameters update and control ▪ Limited application of collaborative practices
	+++	▪ High frequency of stock parameters update and control ▪ Extensive application of collaborative practices
Warehouse Management	+	▪ Low investment in equipment and technology ▪ Batch picking
	++	▪ Medium investment in equipment and technology ▪ Order picking
	+++	▪ High investment in equipment and technology ▪ Order picking

Table 10 – Scale adopted for the qualitative assessment of inventory and warehouse management

A description of the characteristics of each quadrant is reported below.

Quadrant 1 comprises Companies 5 and 6, which are characterized by low Product Portfolio Complexity, high Downstream Supply Chain Capillarity and low Logistic Complexity. In such cases, the lowest level of managerial attention and excellence has been observed in both inventory and warehouse management. As a matter of fact, such companies face very fragmented demand, which makes it impossible to implement any collaborative practice with downstream players. Furthermore, the frequency of stock parameters update and control is fairly low. These two pieces of evidence bear witness to Companies' 5 and 6 weaker managerial emphasis on inventory management, compared to the other cases. Moreover, these Companies have not invested much in advanced technology, equipment and practices related to warehousing. In these two cases, the effectiveness of the delivery process – i.e. stock availability – seems to rely mainly on the accuracy of the forecasting process, which in turn seems to depend on the limited number of SKUs and on their long life cycle.

By contrast, Companies 1 and 2, positioned in Quadrant 4, show a low Downstream Supply Chain Capillarity, a high Product Portfolio Complexity and a high Logistic Complexity. These cases are characterized by the strongest level of attention to and excellence in inventory management, which is pursued through the extensive implementation of collaborative practices with customers (namely CRP), which allows an extremely frequent update and control of stock parameters. The choice to seek high integration with downstream players is made possible by the low number of clients. Thus, to provide an excellent logistic service, these companies mainly rely on inventory management, and more precisely on demand management. However, tight control on warehousing processes is also considered necessary to guarantee accurate deliveries, because of the high number of SKUs. This goal is achieved through the adoption of best practices, such as order picking, and of technology, such as bar coding systems, radio frequency, voice picking and GPS. However, these companies do not invest much in automation due to the high level of Logistic Complexity, assessed in terms of order fragmentation and product's morphological homogeneity.

Companies 3 and 4, placed in Quadrant 2, are characterized by a high level of both Downstream Supply Chain Capillarity and Product Portfolio Complexity and by a low Logistic Complexity. In such conditions, reaching strong integration with the customer is not feasible. Furthermore, the high number of SKUs makes the forecasting process complex and less reliable. Companies 3 and 4 seek to cope with these difficulties through a very frequent update and control of stock parameters. But, it is worth noting that Companies 3 and 4 show the highest level of managerial attention to and excellence in warehouse management, evidenced by the adoption of advanced practices and by important investments in equipment and technology. In fact, compared to cases 1 and 2 (Quadrant 4), Companies 3 and 4 have chosen to automate most warehousing activities, because of the performance improvement that this choice brings about in terms of the accuracy and speed of the delivery process. This choice seems to be affordable thanks to the low level of order fragmentation and to the high morphological homogeneity of the products. The emphasis on warehousing is essential in an environment where managing demand is not straightforward and where the risk of inaccurate deliveries is high due to the large number of SKUs.

Quadrant 3 does not lead to any conclusion since no cases belong to it.

The analysis reported above can be summarized through the following propositions:

PROPOSITION no.1: The higher the product portfolio complexity, the greater the managerial emphasis on warehouse management and on inventory management.

This Proposition comes from a comparison between Quadrant 1, on one hand, and Quadrants 2 and 4, on the other. As it can be easily observed, in Quadrant 1 companies show a lower level of managerial attention and excellence in both warehouse and inventory management. Furthermore, the differences that can be seen between the companies in Quadrant 2 and those in Quadrant 4 can be explained through Propositions 2 and 3.

PROPOSITION no.2: The lower the downstream supply chain capillarity, the greater the managerial emphasis on inventory management.

This proposition comes from a comparison between Quadrants 1 and 2, on one hand, and Quadrant 4, on the other. As a matter of fact, companies placed in Quadrant 4 deal with a lower number of customers, which makes it possible to establish collaborative practices that heavily enhance the effectiveness of inventory management.

PROPOSITION no.3: For situations of high product portfolio complexity, the lower the logistic complexity, the greater the level of automation of warehouse processes.

This proposition comes from a comparison between Quadrants 2 and 4. When companies deal with a high number of SKUs, offering a high service level (especially in terms of speed and accuracy) is more difficult. To improve the effectiveness of their delivery processes companies can invest in higher levels of automation in order to make it faster and more accurate. However, to make this kind of investment affordable from both a technical and financial viewpoint it is necessary to be dealing with repetitive and stable picking and shipping processes. This happens when order fragmentation is quite low and when product morphological homogeneity is high.

3.5 CONCLUSIONS

This paper was aimed at understanding how best performing companies strive to improve their service level, starting from the assumption that not only inventory management, but also warehouse management plays a key role in achieving this goal.

The evidence presented in this paper demonstrates that this assumption holds under specific conditions. In all observed companies, mastering the technicalities of inventory management is considered essential if the company is to offer a satisfactory service level. More precisely, the companies seem to focus their improvement efforts on the forecasting process and on demand management, as the effectiveness of any inventory management technique seems to rely on the accuracy of demand forecasting. However, the empirical analysis also shows that, in some cases, this is not enough. In fact, when the companies deal with a very high number of SKUs, they need to properly manage warehousing processes to guarantee fast, complete and correct deliveries to customers. This results in the adoption of best practices, technology and equipment appropriate to the warehousing function. Furthermore, this empirical analysis also shows that, to further improve the performance of picking and shipping processes, the companies tend to automate their activities, but only when the level of order fragmentation is low and the degree of morphological homogeneity is high.

As the evidence of this study derives from a qualitative analysis conducted across six cases, it suffers from the limitations characteristic of such a research strategy. The authors' aim was to explore the drivers of service level and, in particular, of stock availability, starting from the assumption that effective warehouse management is also essential if such performance is to improve. The cases in question seem to support this assumption, but of course this could be influenced by the peculiarities of the companies themselves and/or of the industries to which they belong. Furthermore, even though the framework conceived by the authors and presented in Figure 13 seems to hold under specific conditions, it cannot include all possible factors that may play a role in improving service level and stock availability. Thus, on the one hand, it would be necessary to adopt a replication approach – both literal and theoretical - in order to test the validity of our propositions in similar cases and also to check their generalizability through the analysis of different cases.

On the other hand, it could be useful to conduct further analysis to identify other relevant drivers of service level. In particular, it might be worthwhile conducting a quantitative study to check the existence of significant correlations between service level, number of SKUs and investment in warehousing best practices, technology and practices. Moreover, replicating this study in other companies could lead to the identification of other drivers of service level, not included in the framework presented in this paper.

4. CONCLUSION

4.1 SUMMARY of FINDINGS and CONTRIBUTIONS

This Ph.D. thesis is about logistics service level, whose relevance has increased enormously in recent years in several different industries and sectors. Both literature and practice have proven that logistics service level excellence is often a key success factor to beat competition and a key distinguishing element which may impact significantly on customer satisfaction. Jammernegg, Kischka, Reiner and Boettcher (1999) have developed an interesting framework to evaluate the relationship between business process performance and customer satisfaction. Although with differences, an excellent logistic service level is important both in make-to-order and in make-to-stock. However, practice demonstrates that logistics service level excellence is either not achieved or at least a challenging task to achieve. To improve logistics service levels there are different ways and paths to follow and a single recipe applicable in a undifferentiated way to different cases does not exist.

Because logistics service level is defined as a bundle of different attributes, comprising speed, dependability, completeness and flexibility of deliveries as well as inventory availability (Manrodt and Davis, 1992; Rushton et al., 2006), I have designed this research analyzing separately these different aspects and focusing mainly on two of them: *speed* and *inventory availability*. A first reason of this choice relates to the relevance of *time* as source of competitive advantage. Inventory availability, not only speed, is somehow a time related measure because of the immediate delivery requested by customers in make-to-stock. According to the "power of time" and the "lead time spiral" concepts and reasoning of QRM (Suri 1998), short lead times do not only affect positively deliveries to customers, but also costs, quality and flexibility. Second, while inventory availability is crucial especially in those make-to-stock businesses where stock-outs imply lost sales, short lead times after decoupling point (but not only) can increase competiveness in mixed push-pull approaches such as make-to-order and assemble-to-order cases. Third, the *OM triangle* (Schmidt, 2005) suggests three alternative ways to provide service level: short lead times together with some slack-capacity and high inventory availability are two of them. Information sharing and collaboration is the third one.

In addition to the reasons stated above, I have focused this research on logistics service level improvement, lead time reduction and inventory optimization in particular, because of some gaps identified in literature. As far as *speed* is concerned, the main issue consists of a theory-practice gap and paradox: while lead reduction principles are well known and their application seems to be quite easy and inexpensive, lead time is not reduced or minimized in practice and managers take often counterintuitive decisions that, instead, prolong lead times. Other gaps concern the lack of exhaustive, wide-scope and cross-disciplinary frameworks about lead time reduction and that most of research has mainly focused just on manufacturing lead time, ignoring that it may represent, in some cases, just a small portion of the overall order-to-delivery lead time. As far as *inventory availability* is concerned, the relationship between service level and inventory management has been already extensively studied. However, there is still room for further investigation because physical availability of stock does not turn always into the ability to fulfill orders due to a number of problems related to warehouse management. Although inventory and warehouse management are both considered relevant in influencing service level, there is not an integrated and cross-disciplinary framework that explains how companies leverage on them to improve logistics service levels.

Based on these premises, the main objective of this Ph.D. thesis has been to investigate the obstacles and the drivers of logistics service level in order to, from a practical point of view, identify best practices to implement and paths to follow for excellence and, from a theoretical point of view, to build some more exhaustive and wide-scope frameworks for service level improvement. More in detail about *speed*, the goal has been to identify main obstacles of lead time reduction in practice trying to close that theory-practice gap. About *inventory availability*, where good levels of performance have been reached more frequently, the goal has been to identify drivers and managerial paths for excellence.

As far as *speed* is concerned, I have started the study from a theoretical model derived from the Factory Physics laws of lead time. However, the immediate conclusion was that such model could not hold because of the lead time theory-practice gap, implying that some factors should exist moderating the relationship between the competitive need for short lead times and lead-time-reduction behaviours.

In order to look for those moderators, I have started with a first project focused on manufacturing lead time, which has been studied using a single in-depth make-to-order case study. Being based three months full time at one plant of the company, I could enrich data and information collected through in depth interviews to managers with direct daily observations of company operations. Although the company produces different products both in make-to-stock and make-to-order, I have analyzed only *make-to-order* products because in such cases manufacturing lead time impacts directly on customer delivery lead times and on customer satisfaction and is therefore expected to be minimized. Following Lewis' (1998) iterative triangulation approach, I have developed a new model about manufacturing lead time where four factors were proposed to moderate the relationship between lead time reduction needs and behaviours. Analyzing data and information collected, the main finding of this research, aiming to solve at least partially that theory-practice gap, is that all the following four proposed factors represent real obstacles for lead time reduction: 1) utilization-based accounting systems and efficiency-based performance measurement systems, which do not detect cost reductions in case of lead time reductions and drive managers toward maximum utilization decisions, 2) lack of a time-based mindset, 3) lack of understanding of system dynamics of lead time, and 4) lack of flow-based layouts. This result is, however, under the form of four testable propositions which require empirical testing in further research to reach general validity. If these propositions were to be proven, results would be directly applicable to practice: recommendations to managers, moving to reduce bottleneck utilizations, lot sizes, and non-strategic variability, would be to 1) avoid decision making based purely on misleading traditional accounting systems, 2) get training to develop a good understanding of the system dynamics of lead time, 3) encourage a time-based mindset throughout the company, and 4) facilitate organizing manufacturing layouts to support flow. About theory, the main academic contribution of this research is the development of a new manufacturing lead time model which integrates the mathematical principles of lead time reduction, as laid out in QRM and Factory Physics, with other disciplines.

Because manufacturing lead time may represent in some cases just a small portion of the overall lead time perceived by customers and because of the limitations of single case study research used in the manufacturing lead time project, I have decided to run a second project on lead time reduction both enlarging the scope of the analysis to order-to-delivery lead time and using multiple case studies. Applying some defined selection criteria, I ended up with four cases belonging to four different sectors to avoid any risk of sector biased results and I focused again only on *make-to-order* products for the same reasons of before. An additional goal was to look for new potential lead time reduction obstacles in broader areas and with a more 360-degrees view. To deepen the analysis, I have split order-to-delivery lead time into *manufacturing lead time*, which is linked to physical-transformation and tangible activities mainly occurring in a plant or in a warehouse, and *non-manufacturing or office lead time*, which refers to those more intangible and information-based processes mainly occurring in offices, such as order management, production and delivery planning. The different nature of activities associated to manufacturing and offices (tangible vs. intangible, physical vs. information based, plant vs. office related) may hide and imply significant differences in terms of lead time reduction obstacles and practices. Because the Factory Physics laws are valid for any kind of process and to enlarge the scope of the analysis, I have developed a new model for order-to-delivery lead time reduction splitting manufacturing and office lead time and proposing broader areas of investigation, both in plants and offices, to look for new obstacles and drivers for lead time reduction. On top of behavioural and organisational aspects, these areas of analysis comprise best practices and IT systems, rewarding, performance and accounting systems and layouts both in plants and offices. The main contribution of this second research about lead time is to add new knowledge to further bridge the lead time theory-practice gap recognizing that some additional obstacles, not only related to manufacturing, have to be removed to reduce lead times. The most relevant lead time obstacles identified consist in the presence of *efficiency (versus lead time) and individual (versus company) based rewarding systems,* that drive people behaviour, and the use of *traditional cost-based (versus ABC and time-based) and individual item production cost-based (versus global Supply Chain) accounting systems*, that are not capable of detecting cost reductions in the presence of lead time reduction. Because of the alignment of results between the two research projects on lead time, findings about impacts of traditional accounting systems on lead times are even more grounded. In addition, this research recognises that both a *good knowledge in lead time reduction principles* and a *multiple operations management tool,* not a single method, and a *company-wide,* not a single function, approach (characterised by multiple lead time reduction best practices and IT systems both in plants and offices, process oriented and flat organisations, time based mindset people and flow based layouts) seem to represent key drivers for lead time reduction. However, they are not sufficient themselves to minimize lead times, if the obstacles related to rewarding and accounting systems are not removed. An additional practical finding of this research is the identification of *higher potential for lead time reduction in office operations compared to manufacturing.* The lower number of established and tested lead time reduction practices and IT systems and the lower process improvement knowledge and attitude present in offices seem to represent two major obstacles. In addition, problems of vague definitions of lead time variables in offices (such utilization of clerical people processing orders and lot size in production planning), the intangible and less physical nature of office operations and the related higher people resistance to be monitored are additional potential obstacles, emerged during the interviews, of lead time reduction in offices. A final relevant practical contribution consists in the identification of a *lead time reduction journey*. In fact, it seems that companies focus, in their earlier stages, mainly on reducing lead times in plants and, only at later stages, when a certain degree of maturity is reached, move their managerial attention also on reducing lead times in offices. Also for this second research, results are in the form of testable propositions that need to be empirically tested in further research to acquire general validity. As far as contribution to theory is concerned, this research has developed a wider-scope lead time reduction framework. On one side, it extends lead time models, traditionally developed just for manufacturing, to office operations and, on the other side, it adds new additional potential obstacles of lead time related to broader areas and disciplines.

As far as *inventory availability* is concerned, we have used a multiple case study research approach selecting six companies belonging to the pharmaceutical and food sectors and all operating according to *make-to-stock,* so that logistics service level to customers is mainly influenced by inventory availability of finished products. Both literature and practice demonstrate, however, that a proper inventory level and mix may be not sufficient to guarantee excellent logistics service levels and that managerial attention should be placed also on warehouse management and, more in general, on managing properly the whole logistics process. Starting from the service level framework developed by Lutz et al. (2003), we have elaborated a interpretative framework for logistics service level in make-to-stock which includes, on one side, inventory management together with forecasting, production and purchasing as its upstream processes and, on the other side, warehouse management together with its sub-processes related to receiving, handling, picking and shipping. The main finding of this research is that there are different ways to reach excellence in logistics service level in make-to-stock depending on some drivers such as downstream supply chain capillarity (quantified through the number of customers), product portfolio complexity (measured in terms of number of SKUs) and logistics complexity (assessed in terms of order fragmentation and product morphological homogeneity). Nevertheless, an important evidence is that not only inventory management, but also warehouse management plays a key role to achieve excellence in logistics service levels. In addition to this, managerial attention should also be high in their upstream and/or sub-processes: forecasting, production and purchasing for inventory management and receiving, handling, picking and shipping for warehouse management. Going more into detail in the analysis, it seems that the higher the product portfolio complexity, the higher the managerial emphasis on both warehouse and inventory management but with some differences. In fact, while inventory management (through collaboration practices) is the key driver for excellence in cases of low downstream supply chain capillarity and high logistics complexity, warehouse management (through investments in technology and up-to-date picking practices) is the key driver for excellence in opposite cases of low logistics complexity and high downstream supply chain capillarity. Finally, accuracy in forecasting seems to be a key driver for excellence in cases of low product portfolio complexity. Also in this research results are in the form of testable propositions that need to empirically tested in further research to acquire general validity. About theoretical contributions, this third project has developed a logistics service level framework which, on one side, integrates inventory and warehouse management in one single model of service level and, on the other side, expands the analysis also to their upstream and/or sub-processes to look for drivers and obstacles of logistics service excellence.

Summarising the contributions of these three research projects, I have developed testable propositions for service level improvement both in make-to-stock and make-to-order cases, which, if they are going to be confirmed though empirical testing, would become practical recommendations for companies aiming to reduce lead times and improve inventory availability.

About theory, the main academic contribution of this Ph.D. thesis consists in the development of wider-scope, more exhaustive and more cross-disciplinary (compared to the ones already existing in literature) models about lead time reduction and inventory availability which have helped in bridging the lead time theory-practice gap and in identifying some managerial paths toward service level improvement.

4.2 RESEARCH QUALITY

Several actions have been taken to increase the quality of this research, determined by internal and external validity, construct validity and reliability.

Internal validity, also called "logical validity" by Yin (2009), refers to the extent to which conclusions regarding causal relationships between variables are certifiable, established and supported by evidence (Karlsson, 2009). Internal validity is of particular relevance in causal and explanatory studies, such as this one, where the conclusions are in the form of tentative statements and testable propositions about cause and effect. The three useful strategies, which I have aimed to apply in this research, to identify cause and effect relationships and to enhance internal validity are: methods triangulation, data triangulation and the "researcher as detective" approach (Karlsson, 2009).

As far as the first single case study project on manufacturing lead time is concerned, data triangulation, which refers to data gathering from several different sources, has been aimed through the simultaneous use of face-to-face interviews with several different types of people (having different management positions, roles, responsibilities and decision power), quantitative KPIs present in many company reports, several company documents and in-depth observations through daily *gemba* walks in the factory during my 3-month full-time period based at a company plant. The 3-year experience at the company of a young engineer, I was sharing the office with, responsible for continuous improvement was also a very useful source of information. In addition, to improve the reliability and robustness of the data collected, I have investigated some of the more important aspects by asking multiple questions in different ways. I asked not only direct/explicit, but also indirect/implicit questions helpful to assess a particular aspect to reduce the risk of information distortions by managers during the interviews. Just to cite an example, to assess the level of theoretical competencies of managers in lead time reduction, I have not only directly asked them for a self-evaluation, but also included a 9-question test about the theoretical pillars of lead time reduction. Another example refers to the way I have assessed the lead time reduction potential using three different sources of information: current, past and target levels of performance through lead time related KPIs, past and future lead time reduction projects and current levels of utilization, lot size and non-strategic variability. The combination of multiple interviews and direct observations through daily *gemba* walks in the factory for a 3-month period enriched by the extensive experience of that young engineer responsible for continuous improvement are also evidence of both methods triangulation and "researcher-as-detective" approach. Finally, the good inter-rater agreement in the coding performed by two researchers and assessed through the Cohen’s Kappa calculation, is an additional element supporting internal validity.

As far as the second multiple case study project on order-to-delivery lead time reduction is concerned, data triangulation has been achieved gathering data simultaneously from face-to-face interviews with top management, supported also by other people in the company in data collection, quantitative measures included in performance reports, several company documents and direct observations through the visit of both factories and offices. The level of depth and detail of the data collected is supported by the 2-3 visits lasting few hours each needed to cover all the aspects under investigation in the research protocol. Similarly to the first study, data have been collected both through direct/explicit and indirect/implicit questions in order to reduce the risk of information distortion and increase data robustness. Three extensive tests (question 1, 2 and 3) have been used to assess in an indirect way the following aspects: "awareness of lead time reduction benefits", "lead time reduction theoretical knowledge" and "people time based mindset". The combination of multiple interviews and direct observations through the visit of both factories and offices are also evidence of both methods triangulation and "researcher-as-detective" approach. Finally, the intensive cross-case analysis conducted in this study and the sharing of data collected and analysis in plenary sessions with other researchers are additional important elements supporting internal validity.

Referring to the last multiple case study project on inventory availability, data and methods triangulation has been aimed also in this case through the simultaneous adoption of face-to-face interviews with several different types of people, quantitative performance measures and direct observations visiting the warehousing and manufacturing facilities of the companies investigated. The intensive cross-case analysis and the coding and data analysis conducted by two researchers are important additional evidence of internal validity.

External validity relates to the general applicability of the conclusions. While population validity is an important concern in survey research, ecological validity refers to the degree that a result is valid in different settings and temporal validity refers to the degree that a finding generalises across time (Karlsson, 2009).

Although results of this Ph.D. thesis are in the form of testable propositions that require further empirical testing to achieve general validity, the three research projects conducted differ in terms of external validity.

As far as the first research study is concerned, the choice of a single case study represents the biggest limitation for generalizability, but nevertheless favours a very deep understanding of the phenomena under investigation. This issue was one of the major reasons that made me develop the second multiple case study on order-to-delivery lead time reduction. Although results are also in this case in the form of testable propositions that require additional empirical testing to gain generalizability, external validity has increased because of the following aspects: multiple cases, companies that are at different stages in their *lead time reduction journey*, multi-sector study in order to eliminate sector specific influences and high level of depth of data and information collected. Although results of the third project on inventory availability still remain in the form of testable propositions, external validity of this multiple case study research is supported by the increased number of cases. In addition, despite the fact that all the six companies investigated have reached excellent levels of performance, contrarily to the two previous studies on lead time reduction, an intensive cross-case analysis has brought to the clear identification of different companies' patterns of behaviour, influenced by supply chain capillarity, product portfolio complexity and logistic complexity, that do not have any contradictions not be valid in general terms.

Finally, while data and methods triangulation and the mix of both explicit/direct and implicit/indirect questions supports *construct validity* in all the three projects, *reliability* of this Ph.D. thesis is provided by the development and the use of very structured, extensive, validated and tested case study protocols and the development of rich and robust case study databases.

4.3 LIMITATIONS

Because of the nature and the characteristics of the research questions developed, the research approach used in all the three projects of this Ph.D. thesis has been qualitative case-based research for theory development purposes. Results are in the form of testable propositions that require further empirical testing to achieve general validity; they are exploratory rather than generalizable. Therefore, this work is subject to all the usual limitations of theory development and case-based research.

The focus on just two aspects of logistics service level, speed and inventory availability, may represent an additional limitation of this thesis, although I gave some reasons of this choice. For example, I have not analysed dependability, which is another time related measure of logistics service level, because, according to the QRM grounding principles, while speed implies dependability, the contrary does not hold and dependability prolongs lead times, when it is set as main performance goal.

As far as the project on manufacturing lead time is concerned, additional limitations, on top of those related to theory development and case-based research, consist in the followings: 1) one single case study, which further limits generalisation, 2) the limited scope of the analysis to manufacturing lead time, while it may represent in some cases just a small portion of the overall lead time, 3) the limited list of potential obstacles of manufacturing lead time reduction, which does not pretend to be exhaustive and relates mainly to behavioural and organisational aspects.

About the project on order-to-delivery lead time, the main limitations, on top of those linked to the research approach chosen, consist both in the internal company oriented scope of the research, not considering for example potential impacts on lead time of external aspects such as supply chain complexity, and in the not exhaustive list of all possible factors that may influence lead times.

As far as the project on inventory availability is concerned, additional limitations may consist in the peculiarities of the sectors selected (pharmaceutical and food) and, once again, in the list of the potential factors indentified which may not represent all possible factors impacting inventory availability and service level.

4.4 FURTHER RESEARCH

Further research should first address the limitations, discussed above, of this study.

First, the propositions developed should be tested to acquire general validity and to be used as practical recommendations for companies striving for improving logistics service levels. This would require to carry out quantitative / survey-based research to carry out using large samples.

Second, additional research using similar methodology and approach should explore new areas to look for additional obstacles and drivers for service level improvement. To do so, it could be helpful to segment them in different clusters: internal (e.g. at process, function or company level) vs. external factors (e.g. linked to business environment, markets, regulators, competitors, customers, suppliers, etc.), easy&quick vs. difficult&long to implement, cheap vs. expensive to adopt, low vs. high impact on performance, linked to different stakeholders, etc.

About speed, because of the internal-company focus of this research on lead time reduction, additional obstacles and drivers should be searched mainly in external-company aspects such as supply chain peculiarities, competitors, customers, suppliers, regulators, etc.

With regards to inventory availability, instead, I would suggest to look more in depth into other company processes influencing both inventory management and warehouse management. In doing so, the result could be the development of a more cross-process and cross-function view and approach for inventory availability improvement. In addition, similarly to what has already been done in the lead time reduction projects, it could be interesting to look into, on one side, organisational (organisational charts, hierarchical vs. flat organisations, etc.) and behavioural aspects (skills, attitude, approach, mindset, etc.) and, on the other side, accounting and rewarding system peculiarities to analyse their potential impacts on inventory availability.

Linked to this, additional research should aim to further develop more wide-scope, cross-disciplinary and integrated frameworks for logistics service level improvement addressing also the other aspects of logistics service level such as dependability, completeness, precision and flexibility of deliveries. Because of the continuous increase of volatility and variability due to not only contingent, but also structural changes in supply chains and the lack of standardization in measurement systems, I believe that flexibility would be the most relevant aspect of logistics service level to investigate more into detail in order to explore related drivers and obstacles.

In addition, the development of more customised models for specific cases (e.g. discrete vs. continuous flow processes, low volumes / high variability vs. high volumes / low variability cases, etc.) would enhance practical applicability of such models.

Finally, although much has been already done in supply chain management studies, further research could look, especially for lead time reduction purposes, not only at best practices and tools to adopt within a company, but also, according to a more strategic, long term and supply chain approach, to new ways of working and collaboration among different companies at supply chain level to reach excellence in logistics service level.

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APPENDIX

Appendix 1: Research protocol 1

CASE STUDY PROTOCOL

EU Project

How to keep JOBS in EUROPE

(English version)

Introduction

Which is the **role** you have in the company?

……………………………………………………………………………………………

Which are the **activities / processes** under your responsibility?

……………………………………………………………………………………………

Do you have the responsibility to modify the number of **resources** (labour and equipment) in the Operations?

……………………………………………………………………………………………

Do you have people to manage? If yes, please describe how is structured the **team** you lead (who is doing what).

……………………………………………………………………………………………

Market and Customers

Who are your main **customers**?

……………………………………………………………………………………………

What do they **require/expect from your company?** Please <u>indicate</u> and then <u>rank</u>, in order of importance (1-higest importance, 2, 3, …), the attributes expected by your customers:

Attributes	*Ranking (1-higest importance, 2, 3, ..)*
- lowest prices in the market	…
- fast deliveries	…
- on-time deliveries	…
- completeness of deliveries	…
- best quality	…
- best after sales service	…
- high flexibility	…
- high personalization	…
- ……………………	…
- ……………………	…
- ……………………	…
- ……………………	…

Which are the strengths and weaknesses (if any) of your company compared to other **competitors** in the market? (e.g. lowest prices in the market, fast deliveries, on-time deliveries, completeness of deliveries, best quality, best after sales service, high flexibility, high personalization, etc.)

Strengths	Weaknesses
…………………………	…………………………….
…………………………	…………………………….
…………………………	…………………………….
…………………………	…………………………….
…………………………	…………………………….
…………………………	…………………………….

Strategy in the Operations & Performance measurement & incentive systems

What are the main **strategic objectives of your company** at a business unit or corporate level (low cost vs. differentiation, serving niche market segments, etc.)?

……………………………………………………………………………………………

What are the most important **objectives of the Operations**? Please <u>indicate</u> and then <u>rank</u>, in order of importance (1-higest importance, 2, 3, …), the performance attributes of the Operations:

Attributes	*Ranking (1-higest importance, 2, 3, ..)*
- Costs&efficiency	…
- speed of deliveries	…
- on-time deliveries	…
- inventory availability	…
- completeness of deliveries	…
- quality	…
- after-sales service	…
- flexibility (volume, mix, plan)	…
- product personalization	…
- …………………………	…
- …………………………	…
- …………………………	…
- …………………………	…

Which are the most important **projects** implemented to improve operational performances (indicate which ones) in the <u>last 3 years</u>? Which is plan for the <u>next 3 years</u>?

Operational performances	*Projects*
- Costs & efficiency	……………………………
- speed of deliveries	……………………………
- on-time deliveries	……………………………
- inventory availability	……………………………
- quality	……………………………
- flexibility	……………………………

Which **KPIs** do you use to measure operational performances (costs, efficiency, quality, speed of deliveries, on-time deliveries, inventory availability, completeness of deliveries, flexibility, product personalization, etc.)? Which are **targets, actual and past values?** Please provide any REPORTS if available.

Operational performances	*KPIs*	*Actual*	*Target*	*Past*
- costs	…………………	…	…	…
- efficiency	…………………	…	…	…
- quality	…………………	…	…	…
- speed of deliveries	…………………	…	…	…
- on-time deliveries	…………………	…	…	…
- inventory availability	…………………	…	…	…
- completeness of deliveries	…………………	…	…	…
- flexibility	…………………	…	…	…
- product personalization	…………………	…	…	…
- …………………….	…………………	…	…	…
- …………………….	…………………	…	…	…
- …………………….	…………………	…	…	…

How do you **define Lead Time**? Do you decompose overall Lead Time (from order to delivery) in several shorter (processing, waiting, set-up, order, delivery, etc.) Lead Times?

……………………………………………………………………………………………

Is **Lead Time reduction** an important objective in your company? Are Lead Time targets explicit/written or are they implicit? Have you ever undertaken (in your or other departments) or plan to launch in the near future **actions and projects** to measure and then to reduce Lead Time? Please describe the most relevant ones.

……………………………………………………………………………………………

What do you measure about Lead Time? **Mean, min, max values**? Do you measure also variability? If yes, how? Which are **targets, actual and past values?**

……………………………………………………………………………………………

Do you have a **production / logistic cost budget**? Which are the main elements of both production and logistic costs?

……………………………………………………………………………………………

How is determined the **cost of a product**? Which are the main elements taken into consideration?

……………………………………………………………………………………………

What are your **personal and team objectives/targets** you and your team have to reach? Have they been set by your boss? Are they explicit/written or implicit? How and how often are they measured?

……………………………………………………………………………………………

What are for you and your team the **consequences** of reaching or not reaching your personal and team objectives? If you reach them, does the company **reward** you? If yes, how (economic bonus, career progress, formal/informal recognition, etc.)? If yes, is this reward based **on individual, group or company** performance? Describe the reward.

………………………………………………………………………………………………

Managerial Choices and drivers (in planning and scheduling)

(EXPLICIT QUESTIONS)

What impact do the decisions that you make as a manager have on Lead Time? Which decisions that you make effect Lead Time?

………………………………………………………………………………………………

Considering each single decision you take that influences Lead Time, please describe the **decision** taken and its evolution / change through the years, as well as the **main reasons** behind the decision.

………………………………………………………………………………………………

Do you know the **consequences** both on **operational** performances and on **economic performances** of **decisions, actions and projects** undertaken to **improve Lead Time**? If yes, please describe them. If not, what would you suggest to investigate this issue?

………………………………………………………………………………………………

(IMPLICIT QUESTIONS)

Do you know which is the **Bottleneck** in your operations? Has the Bottleneck ever changed in the past? If yes, what are the most important actions, projects and decisions you have taken and/or will take to improve performances at Bottleneck?

………………………………………………………………………………………………

Do you measure **Utilization**? If yes, which mathematical formula do you use to measure it? If yes, for which processes do you measure Utilization? Which are **targets, actual and past values** for Utilization? Have you ever undertaken or plan for the future actions and projects to improve Utilization?

………………………………………………………………………………………………

Do you have, through your decisions, any **impact on Utilization?**
If yes, what are the **main reasons that drive you in these decisions?**

………………………………………………………………………………………………

When **scheduling production**, which are the most important **objectives and criteria** (minimizing set-ups, maximising utilization, minimizing scrap and defects, meeting delivery dates, etc.) planners follow and apply?

……………………………………………………………………………………………

When **scheduling production**, are there any rules and limits set for **lot size**? Which are **targets, actual and past values?** Have lot sizes ever changed? If yes, why?
What are the main **reasons** that drive you in lot size decisions?

……………………………………………………………………………………………

Do **lot size** and **batch size** have the same meaning for you? If not, please describe the difference. If not, please tell **the reasons why you made them different.**

……………………………………………………………………………………………

Do you measure **set-up time**? If yes, which are **targets, actual and past values** for set-up times? Have you ever undertaken or will take **actions or projects to reduce** set-up times? If yes, please describe some of them.
What are the **main reasons that drive you in these decisions?**

……………………………………………………………………………………………

Do you measure **forecast error**? If yes, which are **target, actual and past values?** Have you ever undertaken or plan for the future any **action, project** to improve forecasting? Do you apply any particular **forecasting approach and or technique**?
What are the **main reasons that drive you in these decisions?**

……………………………………………………………………………………………

Do you measure **demand variability**? Have you ever undertaken or plan for the future any **action, project** (such as supply chain collaboration practices downstream, VMI, Consignment Stock, etc..) to reduce demand variability?
What are the **main reasons that drive you in these decisions?**

……………………………………………………………………………………………

Do you measure **processing time/rate variability**? If yes, which are **target, actual and past values?** Have you ever undertaken or plan for the future any **action, project** to reduce processing variability? Do you apply any particular **statistical technique** (SPC, Six-sigma, etc.) or any other managerial practice to reduce processing variability?
What are the **main reasons that drive you in these decisions?**

……………………………………………………………………………………………

Do you measure **MTBF** (Mean Time Between Failures) and **MTTR** (Mean Time To Repair)**?** If yes, which are **targets, actual and past values** for MTBF and MTTR? Have you ever undertaken or plan for the future any **action, project** to reduce MTBF and MTTR? Which approaches/managerial practices (T.P.M., ..) do you apply to manage **maintenance**?

What are the **main reasons that drive you in these decisions?**

…………………………………………………………………………………………………

Are you aware of the **MPX improvement project** developed in the past at REHAU? What have been the impacts of that project on your company? Has that project influenced somehow your decision making? If yes, why? Are you interested in other MPX simulations? Any specific area / aspect you would be interested in investigating through MPX simulations?

…………………………………………………………………………………………………

Theoretical competences

Please tell me if you agree or not with the following statements:

- **maximising Utilization** of operations is a key factor to reduce **costs**	yes	no
- The **target for Utilization** should be to reach the theoretical value of **100%**	yes	no
- **maximising Utilization** is even more important at **Bottleneck**	yes	no
- **Utilization** may somehow have an **impact on Lead time**	yes	no
- **Lot size** may somehow have an **impact on Utilization**	yes	no
- **Reducing Lot Size to 1** would **minimize Lead Time**	yes	no
- **Increasing Lot Size** would increase **Set-up times**	yes	no
- **Increasing Lot Size** would reduce **overall costs in the long term**	yes	no
- **Increasing WIP** would **decrease Lead Time**	yes	no

Appendix 2: Research protocol 2

SELECT THE MOST REPRESENTATIVE PRODUCT FAMILY for your company and ANSWER the following QUESTIONS in relation to the selected product family.

Introduction on the interviewee

Which is the **job title / role** you have in the company? Which are the **activities / processes** under your responsibility?

…………………………………………………………………………………………………

General information on the company

To which **sector(s)** does your company belong to?

…………………………………………………………………………………………………

What are your main **products and services**? Please briefly describe them.

…………………………………………………………………………………………………

Please classify your products and services in terms of the following:

- Volumes: High – Medium – Low. Annual volumes: …………...………………………………
- Mix: High – Medium – Low. Number of finished products: ……………………………………..........
- Product Customization: High – Medium – Low
- Seasonality: High – Medium – Low
- Demand predictability: High – Medium – Low
- Product Life cycle: High – Medium – Low. Average years: ……………………………………..........
- Obsolesce risk: High – Medium - Low
- Delivery time requested by customers: High – Medium – Low. Days: ……………………….............................
- Company development phase: growth, stability, decline

Who are your main **markets and customers**? (How many? Where are they mainly located? Are sales concentrated on few of them or vice versa?)

…………………………………………………………………………………………………

To which extent is your company **vertical integrated**?

…………………………………………………………………………………………………

Who are your main **suppliers**? (How many? Where are they mainly located? Are purchased volumes concentrated on few of them or vice versa?)

…………………………………………………………………………………………………

Provide a brief description of the **manufacturing process**:

…………………………………………………………………………………………………

What is your main **production approach** (Make to Stock, Assemble to Order, Make to Order, Purchasing to Order, Engineering to Order)?

…………………………………………………………………………………………………

How many **plants** do you have? Where are they mainly located?

…………………………………………………………………………………………………

Do you use more a **Make or Buy** policy? To which extent? For which processes/activities?

…………………………………………………………………………………………………

About **transportation and warehousing**, have you **outsourced** them? If yes, how and why?

…………………………………………………………………………………………………

Can you describe the **process from the reception of an order to the start of manufacturing**?

…………………………………………………………………………………………………

% of **standard / special – urgent**:

………………………………………………………...

How many **employees** (F.T.E.) are working in your company? Please indicate the number of **blue collar** workers vs number of **clerical** workers.

…………………………………………………………………………………………………

Please describe your **organisational structure** focusing more on primary functions linked to the <u>Order to Delivery process</u>

Please provide any material about general information on your company.

Operative & Economic/Financial Performance

Which are the most common **KPIs**, present in your reporting, you use to measure operational performance? What are **actual, target value** and last 3 years **trend?** Please provide any **REPORTS** if available.

Operational performances	*KPIs*	*Actual*	*Target*	*Benchmark*	*Trend*
- costs	…………………	…	…	…	…
- efficiency	…………………	…	…	…	…
- quality	…………………	…	…	…	…
- speed of deliveries	…………………	…	…	…	…
- on-time deliveries	…………………	…	…	…	…
- inventory availability	…………………	…	…	…	…
- completeness of deliveries	…………………	…	…	…	…
- precision of deliveries	…………………	…	…	…	…
- flexibility	…………………	…	…	…	…
- …………………….	…………………	…	…	…	…
- …………………….	…………………	…	…	…	…
- …………………….	…………………	…	…	…	…

About **time related KPIs**, please provide more information about definitions and calculation formulas?

……………………………………………………………………………………………

If you measure **Lead Time**, how do you define and measure it? If you decompose Lead Time in **partial lead times** (e.g. order processing, planning&scheduling, procurement, manufacturing, delivery preparation, transportation, etc.), how much do they count in % on the total order to delivery Lead Time? (both in <u>production</u> and in <u>administration</u>)

……………………………………………………………………………………………

Do you measure also **variability** of lead time (or just average values)? If yes, about which lead times (e.g. manufacturing, purchasing, etc.)? How much is it?

……………………………………………………………………………………………

How much is the ratio of the **effective value added processing-transformation time** (of 1 unit) over total order-to-deliverylead time? (both in <u>production</u> and in <u>administration</u>)

……………………………………………………………………………………………

Are there any **potentiality for improvement in Lead Time reduction**? If yes, how much is it? Considering both production and administrative operations, where is the highest potential for lead time reduction?

……………………………………………………………………………………………

Please provide the following data (if possible and available):

	KPIs	*Actual*	*Target*	*Benchmark*	*Trend*
- Cash to cash cycle time	…………………	…	…	…	…
- Account payables	…………………	…	…	…	…
- Account receivables	…………………	…	…	…	…
- Inventory	…………………	…	…	…	…
- Working Capital	…………………	…	…	…	…
- Return on Sales	…………………	…	…	…	…
- Return on Investment	…………………	…	…	…	…
- EVA (Economic Value Added)	…………………	…	…	…	…
- Return on Investment	…………………	…	…	…	…

Managerial decisions in MANUFACTURING affecting Lead Times

Please ANSWER the following QUESTIONS only for MANUFACTURING

How do you define **UTILIZATION**? Which are **target and actual values and last 3 years trends** for **labour and equipment utilization** (in case you differentiate them)? Have you ever undertaken in the past or plan in the future actions and projects to increase Utilization?

…………………………………………………………………………………………………

Which are **target, actual** values and **last 3 years trends** for **LOT SIZE?** When scheduling production, do planners aim at decreasing or instead increasing **lot size**? Are there any constraints / limits set for **lot size**?

…………………………………………………………………………………………………

Do you measure **set-up time**? If yes, which are **targets, actual and last 3 years trends** for set-up times? Have you ever undertaken or will take **actions or projects to reduce** set-up times?

…………………………………………………………………………………………………

Do you measure **demand VARIABILITY**? If yes, which are **target, actual and last 3 years trends?** Have you ever undertaken or plan for the future any **action or project** (such as supply chain collaboration practices, etc..) to reduce demand variability?

…………………………………………………………………………………………………

Do you measure **processing time (labour and equipment) VARIABILITY**? If yes, which are **target, actual and last 3 years trends?** Have you ever undertaken or plan for the future any **action or project** to reduce them? Do you apply any particular statistical technique (SPC, Six-sigma, etc.) or any other managerial practice to reduce them?

…………………………………………………………………………………………………

Managerial decisions in ADMINISTRATION processes affecting Lead Time

Please ANSWER the following QUESTIONS only for the ADMISTRATION processes occurring in OFFICES which are linked to the ORDER to DELIVERY process

Do you have a measure or at least an estimation about **UTILIZATION of people in offices**? If yes, which are **target and actual values and last 3 years trends**? Have you ever undertaken in the past or plan in the future **actions or projects** to increase it?

…………………………………………………………………………………………………

Which are the main **time consuming activities** which reduces people availability?

…………………………………………………………………………………………………

Comparing **UTILIZATION of people in manufacturing and in offices**, which is higher and roughly by how much?

…………………………………………………………………………………………………

Do usually people in offices work on different individual tasks, so that we can consider that **LOT SIZE=1?** If not, how much could be considered the LOT SIZE associated to their tasks? Are there any rules and objectives set linked to lot size in offices?

…………………………………………………………………………………………………

Have you ever undertaken or will take actions or projects to **reduce set-up times in offices**? If yes, which ones?

…………………………………………………………………………………………………

Do you have a measure or at least an estimation about **processing time VARIABILITY of people in offices**? If yes, which are **target, actual and last 3 years trends?** Have you ever undertaken or plan for the future any **action or project** to reduce them?

…………………………………………………………………………………………………

Do you have **maximum process times** for order processing (e.g. orders should be confirmed within 24 hours, etc.)

…………………………………………………………………………………………………

Comparing **labour processing time VARIABILITY in manufacturing and in offices**, which is higher and roughly by how much?

…………………………………………………………………………………………………

Strategy in the Operations

What are the main **strategic objectives of your company** at a business unit or corporate level (low cost vs. differentiation, serving niche market segments, etc.)?

…………………………………………………………………………………………………

What are the most important **objectives of the Operations**? Please <u>indicate</u> and then <u>rank</u>, in order of importance (1-higest importance, 2, 3, …), the performance attributes of the Operations:

Attributes	*Ranking (1-higest importance, 2, 3, ..)*
- Costs & efficiency	……………………………
- speed of deliveries	……………………………
- on-time deliveries	……………………………
- completeness of deliveries	……………………………
- inventory availability	……………………………

- quality ……………………………
- flexibility ……………………………
- product personalization ……………………………
- ………………………… ……………………………
- ………………………… ……………………………

Which are the most important **projects** implemented to improve operational performance (indicate which ones) in the last 3 years? in the next 3 years?

………………………………………………………………………………………………
………………………………………………………………………………………………
………………………………………………………………………………………………

Have you ever undertaken (in your or other departments) or plan to launch in the near future **actions and projects to reduce Lead Time**? If yes, are these more linked to **manufacturing-physical** related lead time or to **administration-information** related lead time)? Please describe the most relevant ones.

………………………………………………………………………………………………
………………………………………………………………………………………………
………………………………………………………………………………………………

Please ANSWER the following questions at COMPANY LEVEL in case there are no differences between manufacturing and administration processes. Otherwise, provide different answers (when applicable) in case of MANUFACTURING and ADMINISTRATION processes.
Scales for answers can be scales for comparison or scales for judgements (1 = low – 5 = high)

Organisation (Manufacturing & Administration)	**Manuf**	**Admin**
Functional vs. **process** oriented organisation	1-2-3-4-5	1-2-3-4-5
Fragmented vs. **centralised** organisation	1-2-3-4-5	1-2-3-4-5
Hierarchical vs **Flat** organisation	1-2-3-4-5	1-2-3-4-5
Individual vs **team based** organisation	1-2-3-4-5	1-2-3-4-5

Behaviours (Manufacturing & Administration)	**Manuf**	**Admin**
Cost based vs. **time** based **mindset** (culture and attitude)	1-2-3-4-5	1-2-3-4-5
Skills' level of people	1-2-3-4-5	1-2-3-4-5
Education level of people	1-2-3-4-5	1-2-3-4-5
Operations Management **knowledge** (at decision maker level)	1-2-3-4-5	1-2-3-4-5
Factory Physics knowledge (at decision maker level)	1-2-3-4-5	1-2-3-4-5
Operations Management **training** (at decision maker level)	1-2-3-4-5	1-2-3-4-5
Top-down vs. **bottom-up** approach	1-2-3-4-5	1-2-3-4-5
Centralized decision-making vs **Delegated** decision-making across the company at the point of application	1-2-3-4-5	1-2-3-4-5
Reactive vs **proactive** behaviours	1-2-3-4-5	1-2-3-4-5

Accounting systems (Manufacturing & Administration)	
Traditional accounting systems vs. Activity Based Costing	1-2-3-4-5
Cost based vs. **time** based accounting system	1-2-3-4-5
Individual item/product cost vs. **total cost** view and analysis	1-2-3-4-5
Direct labour vs **job order overhead allocation drivers**	1-2-3-4-5

Performance Measurement & Rewarding Systems (Manufacturing & Administration)

	Manuf	Admin
Which performance (cost&efficiency, utilization, quality, speed, on-time, flexibility, etc.) does your **performance measurement system** mainly measures?		

……………………………………………………………………………………………

Efficiency and "on-time" vs **lead time** based Perf. Meas. sys	1-2-3-4-5	1-2-3-4-5
Local vs. **global process** performance **measurement** focus	1-2-3-4-5	1-2-3-4-5
Set of indicators vs. performance measurement **process** in place	1-2-3-4-5	1-2-3-4-5

Note: A performance management process (design, implementation, use and evolution) is in place if the following activities are in place: defining of KPIs, reports and frameworks, calculating and analysing performance, taking actions based on performance analysis and updating the PM systems

Which performance (cost, efficiency, utilization, quality, speed, on-time, flexibility, etc.) does your **rewarding system** mainly reward?

……………………………………………………………………………………………

Efficiency and "on-time" vs **lead time** based rewarding systems	1-2-3-4-5	1-2-3-4-5
Individual vs. **company** performance based rewarding system	1-2-3-4-5	1-2-3-4-5
Presence vs **results** rewarding system	1-2-3-4-5	1-2-3-4-5
Fixed salary vs **variable** salary system	1-2-3-4-5	1-2-3-4-5

What are your **personal and team objectives** you and your team have to reach?

……………………………………………………………………………………………

What are for you and your team the **consequences** of reaching or not reaching your objectives?

……………………………………………………………………………………………

Layout (Manufacturing & Administration)

	Manuf	Admin
Traditional-functional vs. **flow-process-product** based layout	1-2-3-4-5	1-2-3-4-5
Fragmented-dispersed vs. **concentrated-limited** space and area	1-2-3-4-5	1-2-3-4-5
Presence of many s**torage** areas vs uninterrupted **flow** based layout	1-2-3-4-5	1-2-3-4-5
Closed vs **open** space layout	1-2-3-4-5	1-2-3-4-5

ICT (Manufacturing & Administration)

State to which extent are the following ICT systems in place and used

- ERP system (low) 1-2-3-4-5 (high)
- CRM (low) 1-2-3-4-5 (high)
- MRP system (low) 1-2-3-4-5 (high)
- APS (Advanced Planning Systems) (low) 1-2-3-4-5 (high)
- ATP (Available To Promise) or CTP (Capable to Promise) sys (low) 1-2-3-4-5 (high)
- Order tracking systems (low) 1-2-3-4-5 (high)
- Alerting systems (low) 1-2-3-4-5 (high)
- Work flow management systems (low) 1-2-3-4-5 (high)
- Rapid modelling simulation software (low) 1-2-3-4-5 (high)
- EDI (Electronic Data Interchange) (low) 1-2-3-4-5 (high)

- Other "time" control and improvement ICT systems:

…..…………………………………………..

Best practices in MANUFACTURING

Do you apply any **Managerial Best Practice** in the Operations? (see annex 1 for a list)

…………………………………………………………………………………………………

Among the following practices, indicate if you apply them and the correspondence degree of application:

Lot size reduction techniques (low) 1-2-3-4-5 (high)

Set-up time reduction practices (low) 1-2-3-4-5 (high)

Slack-free capacity design and planning (low) 1-2-3-4-5 (high)

Equipment and labour **processing time variability reduction** (low) 1-2-3-4-5 (high)

Demand variability reduction (low) 1-2-3-4-5 (high)

Bottleneck management and process levelling techniques (low) 1-2-3-4-5 (high)

High frequency and **long time horizon planning** (low) 1-2-3-4-5 (high)

Visual management <u>time based</u> approaches (low) 1-2-3-4-5 (high)

Standardized work techniques (low) 1-2-3-4-5 (high)

Project management (Critical path identification) techniques (low) 1-2-3-4-5 (high)

List any other **relevant practice** in place that may reduce **lead time:**
…………………………………………………………………………………………………
…………………………………………………………………………………………………

List any relevant **OM improvement projects** implemented in the past and planned in the future:
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………

Best practices in ADMINISTRATION processes (Order to delivery lead time)

Do you apply any kind of **Managerial Best Practice** in the Operations? If yes, please list them and indicate the degree of application.

…………………………………………………………………………………………………

Among the following practices, indicate if you apply them and the correspondence degree of application:

Tacit vs explicit knowledge approach 1-2-3-4-5

Overall process measurement&management approach and tools (low) 1-2-3-4-5 (high)

Bottleneck management and process levelling techniques (low) 1-2-3-4-5 (high)

Slack-free capacity (people) design and planning (low) 1-2-3-4-5 (high)

Visual management approaches (low) 1-2-3-4-5 (high)

High frequency and **long time horizon planning** (low) 1-2-3-4-5 (high)

Standardized work techniques (low) 1-2-3-4-5 (high)

Project management (Critical path identification) techniques (low) 1-2-3-4-5 (high)

List any other **relevant practice** in place that may affect **administration related lead time:**
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………

List the relevant **improvement projects in administration** implemented in the past and planned in the future:
…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………

Questions 1

For each of the activities and costs listed below, say if they would be substantially reduced or even eliminated in case of substantial lead time reduction:

- Expediting of hot jobs or late orders (which requires Systems, Air Freight, People, even Top Management time)

  True False

- Production Meetings required to change and update priorities

  True False

- Overtime costs for trying to speed up late jobs

  True False

- Time spent by Sales, Planning, and other Departments to develop and update forecasts

  True False

- WIP and Finished Good holding costs, including space

  True False

- Obsolescence of parts made to forecast but not used

  True False

- Quality problems not detected till much later; lots of rework or scrap

  True False

- Cases and opportunities for:
  - Order changes or even cancellations True False
  - Feature and scope creep True False
  - Loss of sales to competition True False

- Sales time devoted to expediting and explaining delays to customer

  True False

- Complex systems required to manage the dynamic environment

  True False

Questions 2

Please tell me if you agree or not with the following statements:

- Increasing utilization has as consequence an increase in lead time yes no
- Utilization and lead time have an exponential relationship yes no
- Reducing lot sizes to 1 unit has as consequence lead time minimisation yes no
- Lot size and lead time have a linear relationship yes no
- WIP reduction has as consequence lead time reduction yes no
- Decreasing variability in labour and equipment time decreases LT yes no

Questions 3

For each of the following assertations, ask yourself: “Do the key managers in my company consider this statement to be True or False?” You need to answer these questions based on the policies in use at the company, not based on your opinion on what is correct.

- Everyone will have to work faster, harder, and longer hours, in order to get jobs done in less time

  True False

- Does the company frequently use overtime? yes no

- Does it take a lot of expediting to get jobs out on time? yes no

- Do people at the company often work on weekends? yes no

- To get jobs out fast, we must keep our machines and people busy all the time

  True False

- In order to reduce our lead time, we have to improve our efficiencies

  True False

- We must place great importance on “on – time” delivery performance by each of our departments, and by our supplires.

  True False

- Installing a MRP system will help in reducing lead times

  True False

- Since long lead items need to be ordered in large quantities, we should negotiate quantity discounts with our suppliers

  True False
- We should encourage our customers to buy our products in large quantities by offering price breaks and quantity discounts

True False

- The reason for reducing lead times is so that we can charge our customers more for rush jobs

  True False

- Reducing lead times will require large investments in technology

  True False

Annex 1 – Managerial Best Practices in the Operations

- Lean and Just-in-time
- Visual management
- One piece flow / lot size reduction
- Quick changeover, Rapid Tool setting, SMED (set-up reduction)
- Flow based layout
- Cellular manufacturing
- Continuous improvement
- Standardized work
- Variability reduction programs
- Quick response manufacturing
- Queuing theory based simulation tools
- Bottleneck management
- theory of constraints
- Manufacturing and/or logistic postponement

- ISO quality standards
- Six Sigma
- Statistical process control
- Total Quality Management
- Total preventive maintenance (T.P.M.)

- Multi-skilled employees
- Job rotation
- Job enlargement, job enrichment, autonomous working groups

- Collaboration practices with customers (VMI, Consignment Stock, CPFR, …)
- Collaboration practices with suppliers (VMI, Consignment Stock, CPFR, …)

- Modularity in design
- Component standardization
- Variability reduction
- Mass customization
- Co-design with customers and/or suppliers
- Design for manufacturing, logistics, etc.

- Others:
  ……………………………………………………………………………………
  ……………………………………………………………………………………
  ……………………………………………………………………………………
  ……………………………………………………………………………………
  ……………………………………………………………………………………
  ……………………………………………………………………………………
  ……………………………………………………………………………………

Appendix 3: Research protocol 3

PROGETTO DI RICERCA

IL LIVELLO DI SERVIZIO LOGISTICO, LA GESTIONE DELLE SCORTE E LA GESTIONE DEI MAGAZZINI: PRASSI E PERFORMANCE

Struttura di Intervista

OBIETTIVO DELLA RICERCA

Il progetto si propone di comprendere e valutare i legami tra **livello di servizio al cliente, gestione delle scorte di prodotto finito e scelte di warehousing** tramite l'analisi di alcuni casi di aziende eccellenti appartenenti a tre diversi settori.

La traccia dell'intervista si compone di domande di natura qualitativa e quantitativa, volte ad esaminare le performance raggiunte in termini di Inventory Management e Customer Service Level, le prassi gestionali che impattano su tali performance e le scelte effettuate dall'azienda per il supporto di tali prassi.

Il questionario completo è strutturato come segue:

1) dati di inquadramento generale;
2) breve descrizione della struttura della supply chain e del prodotto/mercato;
3) analisi delle prassi gestionali e delle scelte effettuate che impattano sui livelli di scorta di magazzino; esse sono suddivise in:
    - gestione domanda
    - gestione della produzione (laddove esistente)
    - gestione degli approvvigionamenti
    - gestione delle scorte
4) analisi delle prassi gestionali e delle scelte effettuate che impattano sulle attività distributive dell'azienda
5) analisi delle performance produttivo-logistiche;
6) analisi della struttura e costi di gestione delle attività di Inventory Management;

Nel caso non sia possibile fornire tutti i dati e le informazioni richieste per motivi di **privacy** o di mancanza del dato, l'azienda potrà lo stesso partecipare alla ricerca come caso aziendale citato, a condizione che le informazioni fornite siano sufficienti per una buona comprensione degli aspetti oggetti di studio (livello servizio, gestione delle scorte e scelte di warehousing).

Data:

Azienda:

Nome e cognome del
rispondente:
Posizione aziendale:

Telefono:

E-Mail:

1. Dati di inquadramento generale

Fatturato Italia
………………………………

Fatturato worldwide
....

Numero dipendenti Italia
………………………………

Numero dipendenti worldwide
……………………………………..

Indicare le **principali famiglie di prodotto gestite e la loro scomposizione (% fatturato)**
…………………………………………………………………..…………………………

Nel portafoglio prodotti, indicare la **famiglia di prodotti più rilevante e significativa** con le motivazioni che vi hanno portato a questa scelta
…………………………………………………………………..…………………………

*Nelle successive domande del questionario, ove le risposte siano differenti a seconda delle diverse famiglie di prodotto, riferitevi alla **famiglia di prodotti più rilevante e significativa** sopra citata.*

Il **numero di referenze attive** (codici articolo) ………………..…………………………

Numero di ordini cliente all'anno
…………………………………………………………...

Numero di righe ordine evase all'anno
…………………………………………………….........

Durata media del **ciclo di vita del prodotto** (mesi) ……………………………………

Time to market medio (mesi) …………………………………………………………

Marginalità media del prodotto (%) …………………………………………………..

2. Descrizione struttura della supply chain e del prodotto/mercato

Descrivere la struttura della supply chain in termini di **numero di stabilimenti/fornitori** da cui arrivano i prodotti finiti e loro dispersione geografica, **numero di magazzini di prodotto finito** e loro dispersione geografica, **canali distributivi** utilizzati, numerosità dei **punti vendita** e loro dispersione geografica

…………………………………………………………………..…………………………

Quantificare, se possibile, i flussi sopra descritti

…………………………………………………………………..…………………………

Qual è il profilo/pattern della **domanda**? Esiste **stagionalità**? Qual è la sua **variabilità**?

………………………………………………………………………………………………

Qual è la **struttura di costo del prodotto** (incidenza % di materiali, manodopera, macchine/mezzi)

………………………………………………………………………………………………

3. Analisi delle prassi gestionali e delle scelte effettuate che impattano sui livelli di scorta di magazzino

3.1 Gestione domanda

Descrivere brevemente il **processo di forecasting dei prodotti finiti**

…………………………………………………………………..…………………………

Chi è **responsabile** delle attività di forecasting? Quali sono le **funzioni coinvolte** nel processo di forecasting ?

…………………………………………………………………..…………………………

Qual è **l'orizzonte temporale** che viene preso in considerazione? Qual è la **frequenza di revisione** delle previsioni? Con quale **granularità/dettaglio** viene effettuata (settimana, mese, trimestre, ecc.) ?

…………………………………………………………………..…………………………

Vengono utilizzati **sistemi informativi** di Demand Planning?

………………………………………

Vengono applicati degli **algoritmi**? Se sì, quali?

……………………………………………………

Esiste un **processo strutturato di Sales & Operations Planning**?

……………………………………

Esiste un processo **e delle regole di allocazione delle scorte agli ordini cliente e di datazione degli stessi**? Se, sì, su quali logiche/regole si basa (il primo cliente che ordina impegna la merce,

viene considerata la data di richiesta consegna, viene considerata la priorità del cliente, la marginalità del canale, ecc.) ?
……………………………………………………………………..…………………………

Tale processo è eseguito **automaticamente mediante un algoritmo o è un processo manuale?**
……………………………………………………………………..…………………………

L'allocazione e la datazione degli ordini viene eseguita nel momento dell'acquisizione dell'ordine o successivamente?
……………………………………………………………………..……….

Che visibilità avete della domanda del vostro cliente? Esistono prassi collaborative attivate con i propri clienti (Vendor Managed Inventory, Continuos Replenishment Program, Collaborative Planning Forecasting & Replenishment, Consigment Stock)?
……………………………………………………………………..…………………………

3.2 Gestione della produzione

Secondo quale logica di pianificazione gestite la produzione (**PUSH vs. PULL**) ?
……………………………………………………………………..…………………………

Descrivere brevemente il **processo di pianificazione e schedulazione della produzione**
……………………………………………………………………..…………………………

Chi è **responsabile** delle attività di pianificazione e schedulazione?
……………………………………………………………………..…………………………

Qual è **l'orizzonte** che viene preso in considerazione? Qual è la **frequenza di revisione** del piano di produzione? Con quale **granularità** viene analizzato (giorno, settimana, mese, ecc.)
……………………………………………………………………..…………………………

Vengono utilizzati **sistemi informativi** di pianificazione e schedulazione?
……………………………………………………………………………………………..

I piani di produzione sono realizzati a **capacità infinita** o considerando la **capacità effettiva** degli impianti?
……………………………………………………………………..……………………...........

Descrivere brevemente i principali **obiettivi** perseguiti nelle attività di pianificazione e schedulazione delle produzione (minimizzazione dei setup, rispetto date di consegna, produttività delle linee, ecc.)
………………………………………………………………………………….....................

Qual è l'ampiezza del **periodo congelato**?
……………………………………………………...

Qual è la **velocità di reazione della produzione a variazione/urgenze provenienti dal mercato**?
…………………………………………………………………..………………….........

3.3 Gestione degli approvvigionamenti

Descrivere brevemente il **processo di approvvigionamento** dei materiali
…………………………………………………………………..…………………………

Chi è **responsabile** delle attività di approvvigionamento?
…………………………………………………………………..…………………………

Qual è **l'orizzonte** che viene preso in considerazione? Qual è la **frequenza di revisione** del piano di acquisto?
…………………………………………………………………..…………………………

Vengono utilizzati **sistemi informativi** di pianificazione degli approvvigionamenti?
………………………………………………………………………………………………

Avete visibilità della **capacità dei vostri fornitori critici**? In tal caso i piani vengono realizzati considerando la capacità effettiva dei vostri fornitori?
…………………………………………………………………..…………………...

Qual è il **livello di visibilità che date ai vostri fornitori**? Esistono prassi collaborative attivate con i propri fornitori (Vendor Managed Inventory, Continuos Replenishment Program, Collaborative Planning Forecasting & Replenishment, Consigment Stock)?
…………………………………………………………………..…………………………

3.4 Gestione delle scorte

Descrivere brevemente i principali **obiettivi** perseguiti nelle attività di gestione delle scorte (minimizzare le scorte, massimizzare la disponibilità, minimizzare gli obsoleti, minimizzare i costi di ordinazione, etc…)
……………………………………………………………………………………..

Chi è **responsabile** della gestione delle scorte di prodotti finiti ?
…………………………………………………………………..…………………………

Indicare quali sono le principali **tecniche** adottate **per la gestione delle scorte** di prodotti finiti (M.R.P. vs. tecniche a reintegro a tempi fissi, a quantitativi fissi; min-max, etc ...)
…………………………………………………………………..…………………………

Utilizzate prassi evolute di gestione delle scorte (**VMI, Consignment Stock,** etc..) che si basano sulla collaborazione con i fornitori ?
…………………………………………………………………..…………………………

Quali sono i principali **parametri** (lotti minimi, Lead time, Intervalli di riordino, Livelli di Riordino, Lotti economici, Scorte di Sicurezza, etc..) utilizzati nella gestione delle scorte ? Chi è il responsabile dell'aggiornamento? Con quale frequenza vengono aggiornati?
…………………………………………………………………………………………………….

Definite le **Scorte di Sicurezza**? Se si, secondo quale criterio / tecnica / formula ? Il livello di servizio obiettivo ha un impatto sulle Scorte di Sicurezza ?
…………………………………………………………………………………………………….

Indicare quali sono le principali tecniche di **analisi e controllo delle scorte** (indici di copertura e di rotazione, analisi slowmover, analisi ABC, matrici ABC incrociate, simulazioni what-if, etc.).
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Quali sono i **sistemi informativi** a supporto della gestione delle scorte ?
……………………………………………………………………………………………………..

La gestione dei magazzini, nel caso ne abbiate più di uno, è indipendente o congiunta (magazzino unico virtuale vs. magazzini separati senza "visibilità" reciproca, etc.) ?
……………………………………………………………………………………………………..

4 Analisi delle prassi gestionali e delle scelte effettuate che impattano sulle attività distributive dell'azienda

Quali sono i criteri e le prassi di **presa in carico della merce a magazzino** (Advanced Shipping Note, Pianificazione degli arrivi, multi picking su più fornitori, gestione resi a fornitore, etc..)? Quali sono le **tecnologie** a supporto dell'inbound (radiofrequenza, linee di smistamento, RFId, ecc.)?
……………………………………………………………………..…………………………

Quali sono le prassi e i criteri di **stoccaggio della merce** (locazioni fisse vs. dinamiche, utilizzo di regole ABC di rotazione delle scorte, etc.)? Quali sono le **tecnologie** a supporto dello stoccaggio ?
……………………………………………………………………..…………………………

Vengono utilizzati dei **magazzini automatici**? Se si descriverli brevemente.
……………………………………………………………………..…………………………

Vengono utilizzati dei **sistemi di material handling automatici** (rulliere, AGV, etc..)? Se si descriverli brevemente.
……………………………………………………………………..…………………………

Quali sono le prassi e i criteri di **picking** (order vs. batch picking, etc..)? Quali sono le **tecnologie** a supporto del picking (radiofrequenza, lightpicking, voicepicking, RFId, ecc.)?
……………………………………………………………………..…………………………

Quali sono gli obiettivi (saturazione mezzi, puntualità di consegna, etc..) e le prassi / criteri nella **pianificazione e gestione della distribuzione** (cross docking, multi drop, etc.)? Quali sono le **tecnologie** (HD e SW**)** a supporto della distribuzione ?
………………………………………………………………………..…………………………

Vengono utilizzati dei sistemi informativi verticali di **Warehouse Management System**?
………………………………………………………………………..…………………………

Quali sono i principali investimenti fatti negli ultimi 5 anni nel warehousing ? Quali sono le principali motivazioni sottostanti ?
………………………………………………………………………..…………………………

5. Analisi delle performance

*Nelle domande seguenti si richiede, ove possibile, il **valore attuale** di performance e il **trend** (stabile, in miglioramento, in peggioramento) avuto negli ultimi tre anni.*

Indicare la **% di consegne puntuali** a cliente ………………………………………………....

Indicare i **leadtime medi di consegna a cliente** (cioè il tempo che mediamente trascorre dalla data di ricevimento dell'ordine alla consegna)
………………..……………………………………………..

Indicare il **leadtime medio di approvvigionamento** dagli stabilimenti produttivi e/o dai fornitori di prodotto finito?
…………………………………………………………………………………….....................

Indicare il **livello di stock di prodotto finito** (indice di rotazione o periodo di copertura) per le famiglie di prodotto di rilevanti
………………………………………………………………………..…………………………

Indicare la **% di affidabilità della previsione della domanda a volume e a mix (MAPE)**
………………………………………………………......……………………………………

Indicare la **% di rispetto dei piani di produzione rilasciati dalla pianificazione a volume e a mix**
………………………………………………………………………………………………..

Indicare la **% di rispetto dei piani di consegna da parte dei fornitori**
……………………………..

Indicare il **leadtime medio di presa in carico della merce a magazzino** (dal momento dello scarico merce al momento della disponibilità della merce a magazzino e a sistema)
…………………………………………...

Indicare il **leadtime medio di allestimento ordine** a magazzino (dalla data di emissione dell'ordine di picking al completamento dell'allestimento dell'ordine pronto per la consegna)
…..…………………………………………………..……………………………...................

Indicare la **% di errori di consegna a cliente**
……………………..…..……………………………..

Indicare se e come viene misurata la **produttività del magazzino** e il rispettivo valore di performance
……………………..…..……………………………..

6. Analisi struttura e costi di gestione delle attività di Inventory Management

Fatto 100 il costo logistico della vostra azienda, indicare la **struttura dei costi e la rispettiva scomposizione in %:**

- costi di trasporto (%): …………………………………………………………….......................
- costi di warehousing (%): ……………………………………………………........................
    - Affitto/costi dello spazio (%) ………………………………………….........................
    - Assicurazioni (strutture e stock) (%) ……………………..……………........................
    - Ammortamenti delle strutture e dei macchinari (%) ……………………......................
    - Altri beni e servizi non ammortizzabili (%) …..…………………………......................
    - Personale (diretti, indiretti, totale) (%) ……………………..
    - ………………………………………………………………………............................
    - ………………………………………………………………………............................
- Costi delle Scorte (%)
    - Costi di immobilizzo delle scorte (%) ……………………………………........................
    - Costi di obsolescenza (%) …………………………………………………......................
    - ………………………………………………………………………............................
- Altri costi ...……………………………………………………………………......................