INSTITUTO TECNOLÓGICO DE BUENOS AIRES

TESIS DE GRADO
EN INGENÍERIA INDUSTRIAL

CONTROL DE GESTIÓN DE LOS TIEMPOS DE PRODUCCIÓN EN SISTEMAS INDUSTRIALES CON PRESENCIA MULTINACIONAL

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RESUMEN EJECUTIVO

Este trabajo se ubica dentro el marco conceptual de las ciencias de gestión, y mas en particular dentro de los sistemas de control de gestión. Se hace foco en la medición de tiempos en todas las dimensiones de una compañía, y como resolver esta necesidad con indicadores y reportes oportunos.

Se ha llevado a cabo un análisis critico de la literatura existente sobre el tema, organizando los conceptos y modelos que se han propuesto. Finalmente, se hace una aplicación practica de la teoría: un reporte de control de tiempos de producción para una compañía multinacional.

El método y los resultados de esta aplicación son explicados en detalle, y un análisis críticos de los mismos es realizado. Se identifican claramente las limitaciones de este trabajo, así como posibles direcciones para futuros desarrollos sobre este tema.

EXECUTIVE SUMMARY

This is a work within the framework of Management science, in particular management control and reporting activity. The focus is made in lead times within management control and reporting, and how to practically address the issue by indicators and reports.

A literature review is made, with an organization of its concepts and models. Finally a practical application is made: a production lead times report for a multinational company.

The method and results of this application are fully explained, and a critical analysis is made, indicating limitations and possible directions for new developments on the matter.

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1.INTRODUCTION

Lead times are an important dimension of business worldwide. No matter the industrial sector or activity of a company, time has a direct impact in the generation (or destruction) of value within a company. From an operative point of view, time affects key performance measures such as service level, compliance, stocks level and efficiency, thus the importance of its measurement arises.

Management science has pay attention to time management for some time now. It has studied how time generates value, how it impacts compliance service level and overall performance. Attempts to propose an adecuate way to manage and control this dimension of business were made, always within the reporting activity.

This work will make a brief review of how literature of the subject describes management science's advance on this matter. It will highlight the different concepts, models and structures proposed by different authors through time.

Taking all this into account, the objective of this work will be to propose a proper reporting structure for production lead times in a particular scenario.

The given scenario is in a delocalized industrial system within a multinational company (Tenaris). An introduction to the company will be given in order to provide the reader of the proper context to both, understand and evaluate, this work. Detailed explanations will be given for the company's business and operation, giving importance to the internal organization of its Supply Chain.

The reporting structure will be described and analyze in full detailed. The process in which indicators and structure were defined will be shown to the reader, showing its strengths and limitations.

2.LITERATURE REVIEW

Lead time reduction was originally awakened by JIT production literature and theory. Reduction in waste was particularly emphasized in JIT theory, especially excess inventory, but lead time reduction was also focused by this papers. Even though JIT was primarily focused in the universe of repetitive manufacturing, Goldratt and Cox (1984)[1] analyzed the impact of lot sizing and bottleneck resources on lead times, by addressing the issue in a batch flow environment.[2]

Moreover, results of this works and other on lead time reductions, led to the identification of competitive strategies based only on speed ("Time-Based Competition") and consequently, management control models that focused their attention on time-based performance measures were born, as part of a new "Time-based management".

Time as a strategic dimension of a company was first addressed by Christopher and Braithwaite (1989)[3] in their work titled "Managing Strategic Lead Times". In this paper lead time throughout all the company process was taken into consideration, showing management success and failure with time in the different functional areas (Fig. 1).

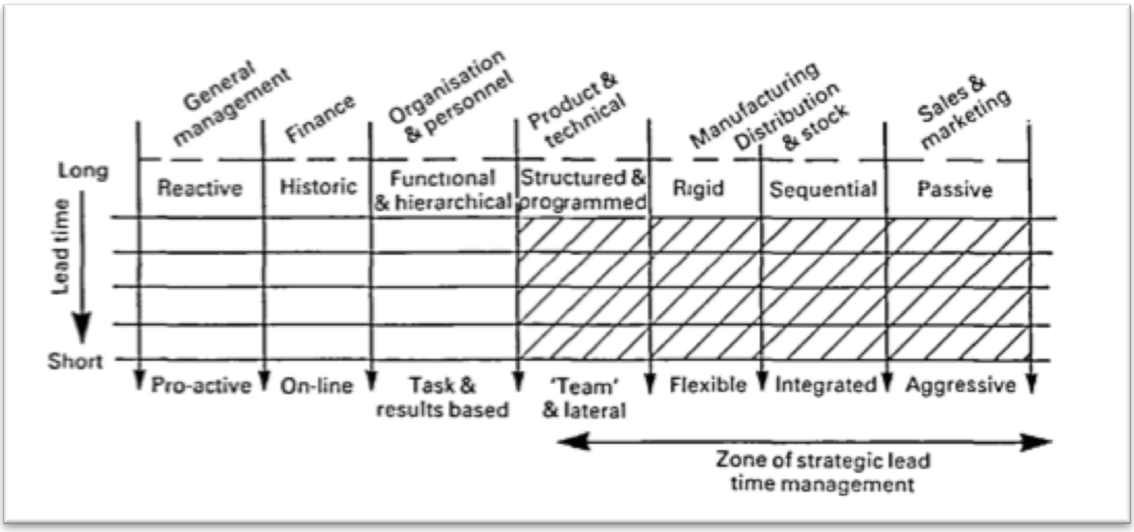

Figure 1. Time throughout a company (Braithwaite , "Managing Strategic Lead Times" 1989)

(It is worth to mention that this work was done before the concept of Supply Chain was a common word in management science, hence the functional division.)

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[1] Goldratt, Cox "The Goal" 1984

[2] As stated by Treville, Shapiro and Hameri in "From supply chain to demand chain: the role of lead time reduction in improving demand chain performance" 2003.

[3] Christopher, Braithwaite "Managing Strategic Lead Times" 1989

Christopher and Braithwaite define time as “a business commodity which has an enormous opportunity cost” but also state that “normal business control make no attempt to value or identify the scale of nature of this”. They affirm that measuring the company-wide lead time efficiency would led to a trade-off analysis to assess the benefits and costs of reducing time constrains within company processes.

In a more managerial view of the matter, Stalk and Hout (1990)[4] define the “Time-based company” as a company in which time leads all their performance measures, metrics, and diagnostic tools. In their work they state that time based companies will follow two rules in measuring time: “Keep the measure physical, and measure as close to the customer as possible”.

They state the differences between “Time-based companies” and what they called “Traditional Companies”, regarding their management metrics. They summarize it as Fig.2 shows.

Traditional Companies	*Time-based Companies*
Cost is the metric	Time is the metric
Look to financial results	Look first to physical results
Utilization-oriented measures	Output-oriented measures
Individualized or department	Team measures

Figure 2. Management Metrics (Stak, Hout “How Time-based Management Measure Performance” 1990)

Despite all the previous works in the matter, the first one to address the subject with the objective of giving a guide to practitioners were **Azzone, Masella and Bertelè (1991)**[5] that, as they wrote, the objective of their work “is to suggest some guidelines for the design of a performance measurement system which is consistent with time-based principles”.

They address with mathematical precision the issue of how time creates value. For this they define value as the difference between cash in-flows and out-flows. They define the following conceptual model:

[4] Stak , Hout “How Time-based Management Measures Performance” 1990
[5] Azzone, Masella, Bertelè “Design of Performance Measures for Time-based Companies”, 1991

“A company operates in an environment (A) which is described by a demand for products and services and by the availability of a set of resources (technologies, know-how and people). To handle environmental dynamics, a firm must choose the external configuration (CE), i.e. the products and services the company is going to produce, and the internal configuration (CI), hence the set of resources used to satisfy the requirements of the chosen external configuration. The external configuration determines cash inflows of a company; changes in product mix or in its features (quality, timeliness and cost), i.e. directly affect revenues. Cash outflows depend directly on the internal configuration, as costs are related to changes in efficiency and flexibility.

Time and responsiveness can act both on the external configuration, improving the timeliness of products and on the internal configuration, reducing non-value added activities. In terms of the external configuration, better responsiveness may cement customer loyalty, improve differentiation and increase the value perceived by customers. This can obviously lead to premium prices and higher market share, or in other words, higher cash inflows. ***Friedel and Stalk***[6] *relate this market behavior to the presence of a "time elasticity of demand". This means that demand, as well as potential profits, is sensitive to changes in total lead time. As can be seen from Figure 2”(Figure 3 in this work)”, the customer is willing to choose your products and to pay much more for them than he/she would otherwise if he/she can obtain what he asks for in a very short time. When the response time lengthens, the customer will look around for better prices or better products.”*[7]

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[6] Friedel, Stalk “The time Elasticity of Profitability” of “Time based competition series (BCG)” 1988

[7] Azzone, Masella, Bertelè “Design of Performance Measures for Time-based Companies”, 1991

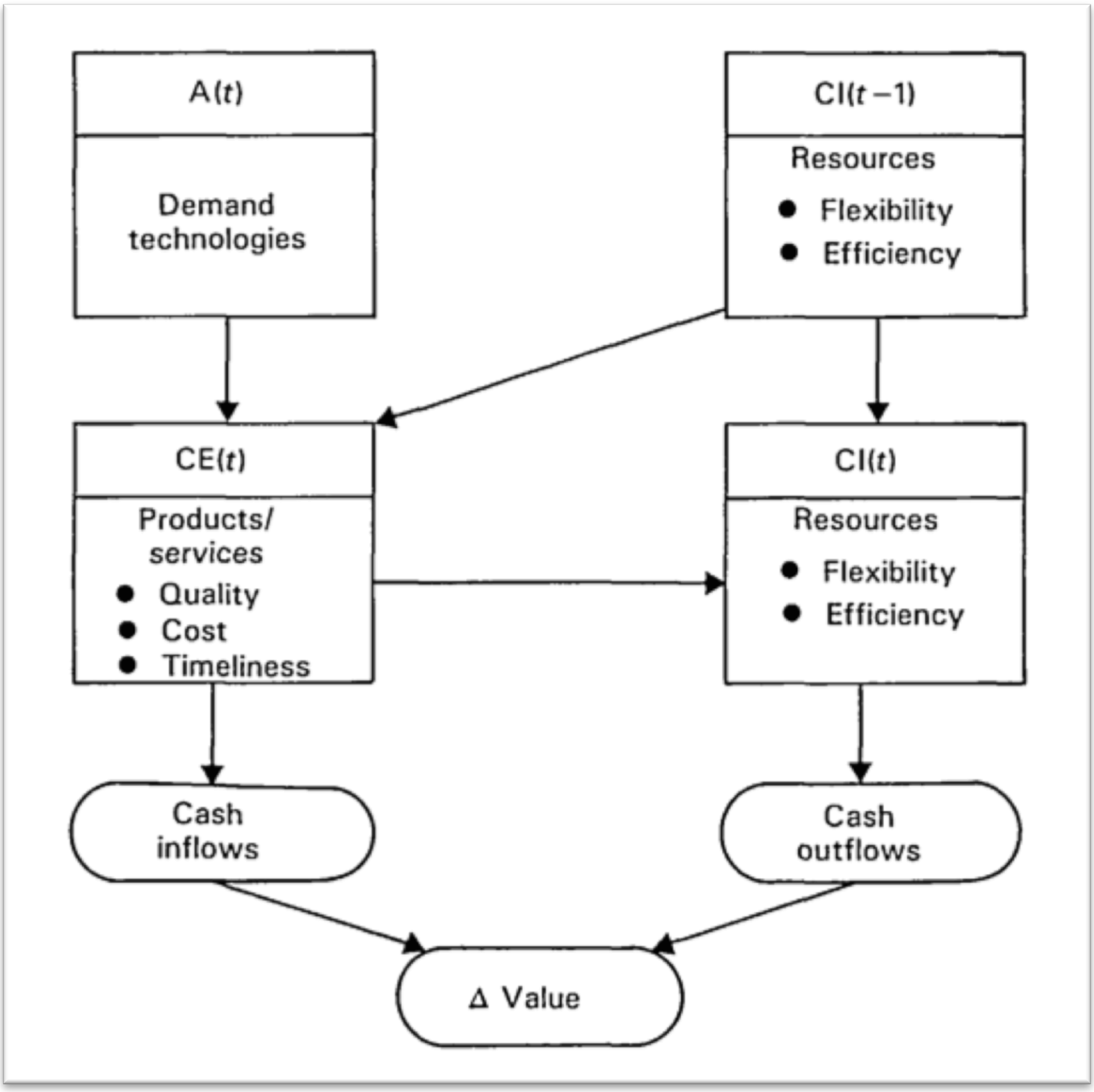

Figure 3. How times creates value from Azzone, Masella, Bertelè (1991)

Moreover, they developed a framework of performance measures for time-based competitors as shown in Fig.4. They state that the selection of indicators must be consistent with the company strategic objectives and organizational structure. In concordance with what was mentioned in previous work, they state "Time-based competitors should consider not only manufacturing, but the firm as a whole, focusing holistically on the system's cycle time. Thus, efforts have to be addressed to all the activities of a company's value chain."

	Internal configuration		External configuration
R&D	Engineering time	Number of changes in projects Δaverage time between two subsequent innovations	Development time for new products
Operations	Throughput time	Adherence to due dates Incoming quality Distance travelled Value-added time / Total time Schedule attainment	Outgoing quality Manufacturing cost
Sales and marketing	Order processing lead time	Complexity of procedures Size of batches of information	Cycle time Bid time

Figure 4. Performance measures framework from Azzone, Masella, Bertelè (1991)

Within this conceptual frame, the scope of this work fits within the Operations function, at an Internal Configuration level (second row, second column in Fig.4). It will aim, as it will be explain further in this work, to give visibility to the top management of production lead times, hence it is consistent with time-based principles.

Finishing this chapter, and hoping it is useful for the reader, a conceptual framework's evolution of lead time reduction in management science is offered in Fig.5.

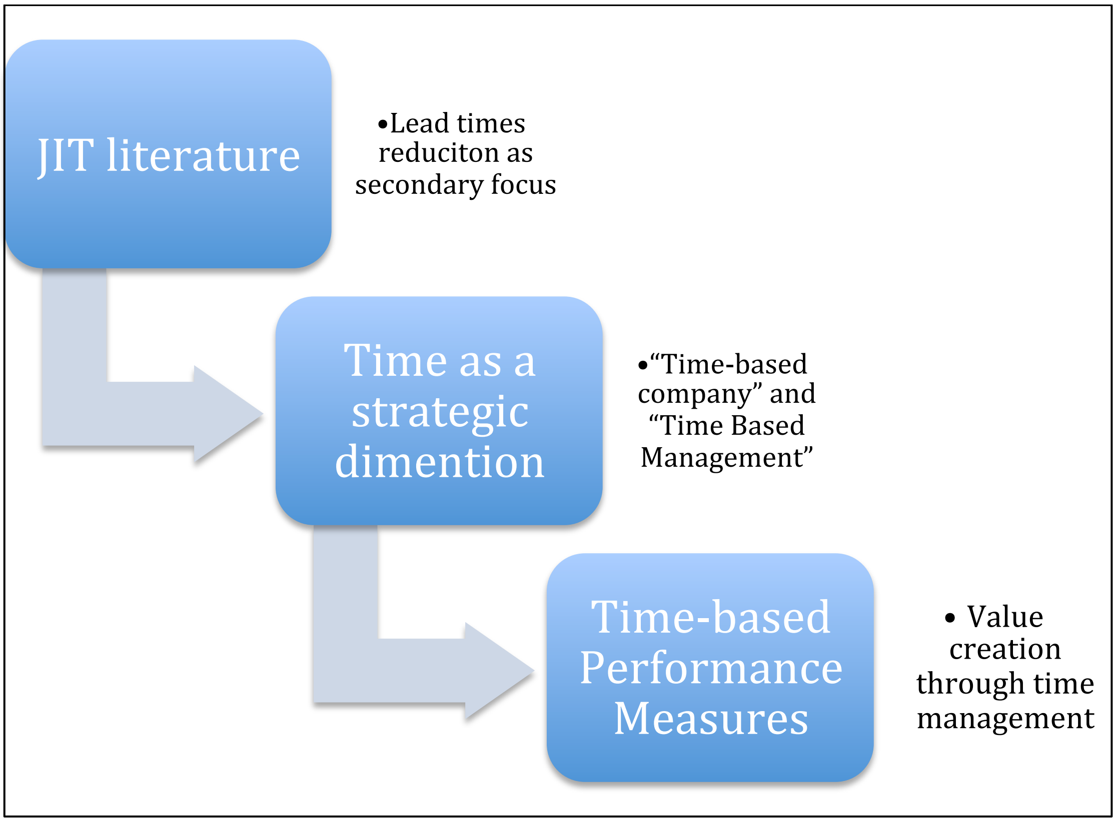

Figure 5. Conceptual framework's evolution

3.INTRODUCTION TO THE COMPANY: TENARIS

Tenaris is the leading global manufacturer and supplier of tubular products and services used in the drilling, completion and production of oil and gas and a leading supplier of tubular products and services used in process and power plants and in specialized industrial and automotive applications[8].

Through their integrated global network of manufacturing, R&D and service facilities, they work with their customers to meet their needs for the timely supply of high performance products in increasingly complex operating environments.

In order to offer the reader a general view of Tenaris global supply chain and organization, the next picture can be useful.

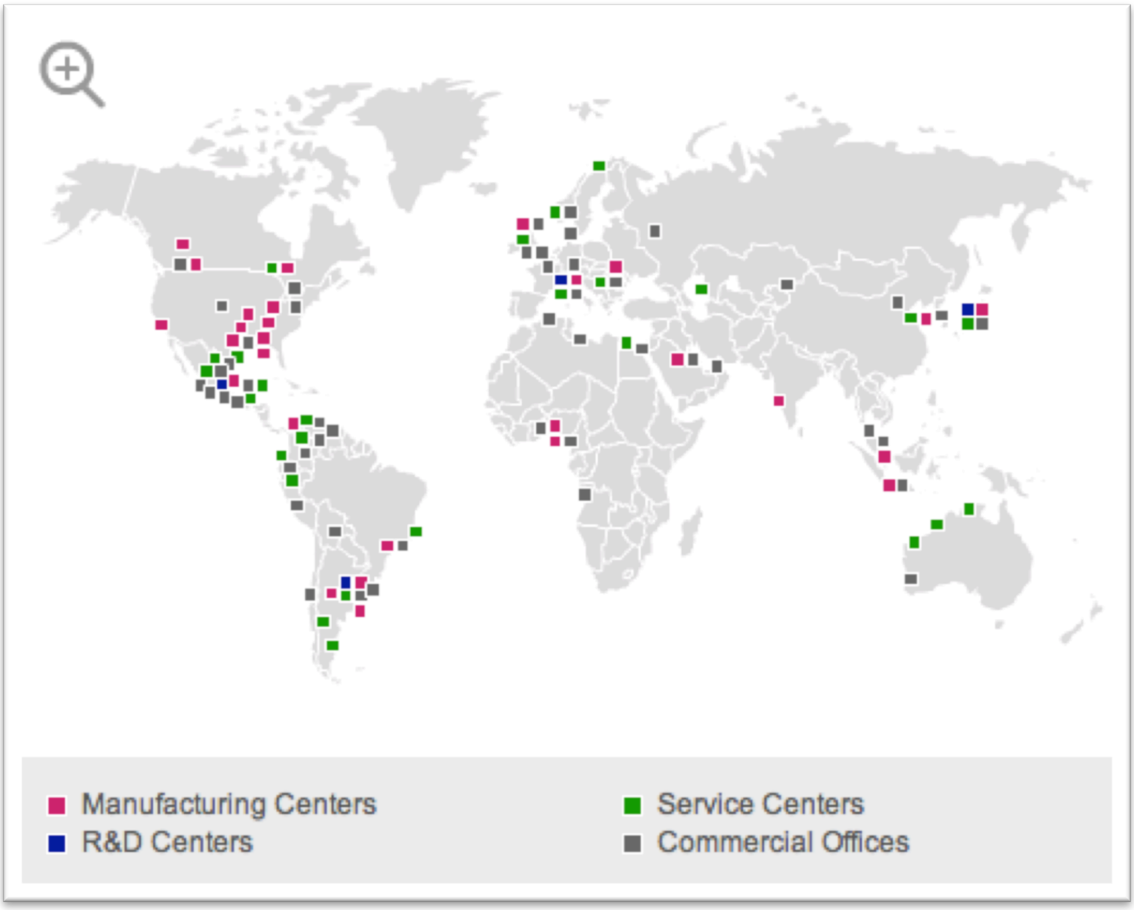

Figure 6. Tenaris presence worldwide.

[8] Tenaris Institutional (www.tenaris.com)

3.1.Global Business Units

Tenaris has four global business units serving four specific business segments:

Process & Power Plant Services

Tenaris provides comprehensive material planning and supply chain management services and on-time delivery of quality products to enable customers in the process and power plant industry to meet the demanding needs of major refinery, petrochemical and power plant contracts.

Industrial & Automotive Services

Tenaris provides a wide variety of mechanical, structural and cold- drawn seamless pipe products for industrial applications with a focus on segments such as automotive components, hydraulic cylinders, construction machinery, gas cylinders and architectural structures where we add value with specialized product development and supply chain management expertise.

Oilfield Services

Tenaris supplies a comprehensive range of high quality seamless and welded casing and tubing, drill pipe, premium connections and accessories for use in even the most demanding oil and gas drilling and well completion activities. Using our network of manufacturing, customer service and R&D facilities, we focus on reducing costs and risks for our customers through integrating supply chain management and developing industry leading tubular goods.

Pipeline Services

Tenaris supplies an extensive range of seamless and welded line pipe products complete with coatings and accessories for use in onshore, offshore and deep water pipelines with onsite, ready-for-installation delivery. They are a major player in the offshore markets (mainly deep water and ultra deep water) of the Gulf of Mexico, West Africa, Far East, United Kingdom and Scandinavia.

3.2.Production Processes

Tenaris provides a complete range of tubular products for the world’s energy industry and certain other industrial applications. All of their manufacturing facilities share a unified global quality policy and have ISO 9001 certification.
Tenaris manufactures a complete range of seamless and welded steel tubular products.

3.2.i.SEAMLESS PIPE MANUFACTURING

Their seamless pipe manufacturing process involves the following steps:

- Transformation of raw materials into steel bars (Electric arc furnace, ladle furnace, vacuum degassing and continuous casting processes)
- Transformation of steel bars into mother pipe, which is manufactured in different types of rolling mills

Each product is manufactured in accordance with customer specifications, including heat treatment for more demanding applications. Our pipes are threaded and undergo non-destructive testing before delivery to the customer.

We also offer cold-drawing for pipes with the diameter and wall thickness required for use in boilers, superheaters, condensers, heat exchangers, automobile production and several other industrial applications.

Tenaris seamless pipe production facilities are located in North and South America, Europe and Asia.

3.2.ii.WELDED PIPE MANUFACTURING

Tenaris manufacturing facilities perform three types of welding processes:

- Electric Resistance Welding: During ERW, a high frequency electrical current is transmitted to the material by means of copper sliding contacts so that the abutting edges initiate fusion as they come into contact.
- Longitudinal Submerged Arc Welding: In LSAW, the butt joint of the pipe is welded in at least two phases, one of which is on the inside of the pipe. The welds are made by heating with an electrode arc between the bare metal electrodes. Pressure is not used. Filler metal for the welds is obtained from the electrodes.
- Spiral Submerged Arc Welding: Spiral SAW allows large diameter pipes to be produced from narrower plates or skelps. During this process, the weld pool is protected against oxidation by a flux produced from the electrode fed separately onto the weld.

Their welded pipe production facilities are located in North and South America.

The focus of this work will be exclusively on the seamless pipe manufacturing process. An extension on this process description will be provided in this text.

3.3.Products & Services

Tenaris offer mainly a wide range of products of tubular technology and a supply chain integration with their customers. For this last point, they work on:

- Using the global network of manufacturing and customer service centers and IT solutions.

- Creating a transparent system that integrates under a single responsibility manufacturing, procurement, distribution and customer service.
- Working directly with customers to minimize risk and save costs.
- Extending services developed in local markets globally to set new standards in the industry.

It can be easily inferred that, in this organizational and market context, the measurement of lead times (in particular, production lead times) is a crucial keystone of management control.

3.4. Supply Chain Management in Tenaris

Supply Chain Management refers to business integration between customers and suppliers along the sequence of processes required to fulfill the final customer's demand.

It is described by the functional integration of manufacturing, transportation, purchasing, services and warehousing activities. The trend is to establish longer and solid connections between each link of the chain, in order to streamline the flow of material, information and cash.

Supply Chain Management collaborative approach implies a higher efficiency in terms of internal processes and the use of resources, allowing lower inventories, shorter lead times, higher predictability, lower total costs, lower risks and better margins. However, the main and final goal is to add value to the customer.

Supply Chain Mission
"Added value services and efficiency in the supply chain in order to achieve the new positioning and the consolidation of a new global company."[9]

Tenaris Main Goal regarding Supply Chain Management
"To improve Compliance and Service Level towards our customers while optimizing the contribution (minimizing costs) and providing an effective overall management control".[10]

In Tenaris, the Supply Chain Department (DISC) is responsible for the integration between customers and suppliers from the commercial management cycle up to the delivery to the final customer.

DISC is responsible for the:
• whole business visibility and management, so the interaction "SC – other areas" is high and the information flow is strong.
• Service Centers management.
• Chain's total synchronization.

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[9] Core Program: Supply Chain Management. Tenaris University
[10] Core Program: Supply Chain Management. Tenaris University

DISC is not responsible for the:
• Purchasing of raw materials (scrap, iron ore and spare parts), which is Exiros' responsibility.
• Manufacturing process in Tenaris main facilities.

As an integral part of the process, the Supply Chain operates at different levels.

Regarding the requirements set by the different participants interacting within the chain DISC is not involved in the operation of the rolling mill at each Production Unit (PU), but is responsible for planning and programming each mill's activities in order to ensure on–time delivery to the customer.

This is why although that production lead times may seem a purely mill issue, it's essential for the Supply Chain to have visibility over production lead times, and manage that information at a global level.

3.4.i.Supply Chain Main Functional Areas

Global and Regional Functions

Activities performed by SCM organization, can be differentiated between Global and Regional Functions.

Figure 7. Supply Chain Global and Regional functions.

Executive Functions
Are those dealing with the company's operative activities (Order Management, Resources Planning, Shipping Contracting, etc).

Staff Functions
Are those giving support to the executive functions (Planning, Quality Assurance, etc). Is within this function that the work of this tesis was developed.

Regional Functions
Are those related to mill programming, logistics and services operations in SCM regions.

3.4.ii.Supply Chain Planning

Since the scope of this work is a part of the Planning function, their activities will be analyzed in detail.

Planning core activities are:

• Profitability Optimization.
• Management Control Development (Compliance metrics implementation and monitoring).
• Definition of Standards for the Supply Chain.
• Mass Balance Control based on BU's plans and Investment Definitions; capacity allocation.
• Analysis and control of SC's operational and structural expenses.
• Coordination and evaluation of the SC investments and initiatives (including implementation support).

3.4.iii.Relationship among Supply Chain and other areas

Supply Chain's interaction with the different Areas (internal and external) is determined by the definition of "Service Level Agreement" (SLA) considering the specific requirements per business segment.

The following Chart shows these relations graphically:

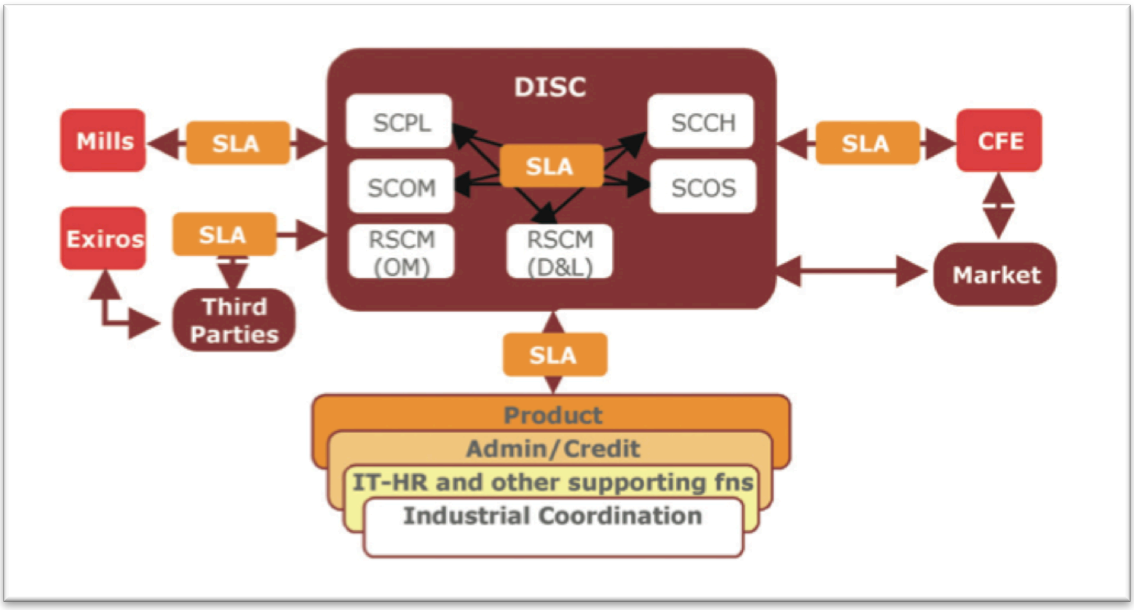


Figure 8. Relationships within the Supply Chain and with other areas.

We will not analyze all the relationships present at this graphic. Just the ones relevant for the purpose of this work.

The different SLA are composed by the different points as follows.

SLA: Within DISC
• Agreed response LTs.
• Agreed necessary information.

SLA: Mill – DISC
• Available capacities.
• **Lead time per product.**
• Flexibility (program frequency, frozen period, product structure postponement).
• Manage different tolerances (t,Q) based on service level requirements.

SLA: Third Parties – DISC
• Agreed Lead Time.
• Agreed quotas.
• Level of integration.
• Pay for performance.

SLA: CFE – DISC
• CFE[11]: Definition of segments and required Service Level.

[11] CFE: Commercial Front End: Business Unit staff that shall act as a referent for a certain Offer or Order depending on the region and/or the Customer involved.

• SC: Definition of cost – to – serve

SLA: Support Functions –DISC
• Agreed requirements approach and due dates.

As it can be seen, production lead times are a key point in the relationship between the mills and the supply chain. Moreover, lead times, as a general concept, are present in almost all the SLA analyzed.

3.5.Tenaris Management Control

Tenaris will have to take advantage of its global character to efficiently allocate resources and costs.

For this, it has designed a management model to split responsibilities so that each area specializes in specific tasks.

The Tenaris Management Model is based on the following structure:

- Economic Management: Profit Centers
- Tubes Commercial Management: Global and Regional Business Units
- Industrial Management: Production Units
- Integrated Management: Supply Chain
- Integrated Procurement: Exiros
- Centralized Departments: Functional Areas

This structure is designed to maximize the Net Income, the EBITDA and cash generation.

The development of this thesis fits into the "Integrated Management" structure.

3.5.i.Supply Chain Management Control (SCMC)

Supply Chain manages all the activities carried out once the materials are outside the mills (after Production Units' Finished Product) until they reach the end customer or other Tenaris Mills (intercompany operations).

Nevertheless, they control and follow the evolution of the operations within mills when necessary, that is why the work of this thesis has been placed within this structure.

The greatest part of Supply Chain costs is transferred to the Business Units using standards quotas.

This area has 3 objectives of simultaneous fulfillment:

- Deliver products and services in the agreed terms with the customer;
- Improve operating and logistics efficiency; and
- Improve order allocations

Once the objectives of the SCMC are established, the importance of measurement of time in management control arises. It is in this context that the work of this thesis has been developed. (SCMC is itself an area within Supply Chain Planning.)

3.5.ii. Management control lines within Tenaris

In order to have a more comprehensive approach on this work, a proper mention of the management control lines of this company is needed. This will provide context knowledge concerning how the measure of activities, and it's consequent management, is approached in Tenaris.

Management Control Lines objective is to measure Tenaris´activity, represented by the quantity of business that moves along the process chain, in a homogeneous way. The purpose is to create an "operations thermometer" which will measure the number of businesses at each stage.

The milestones within this process chain and the responsible person for each milestone shall be clearly identified and registered as well as how and when they apply to each of the business models carried out.

3.6.Global vision of Tenaris business life-cycle

There is a global vision of Tenaris business life-cycle where the whole production system and the Supply Chain are viewed as a single entity. This vision allows us to measure the business flow along its stages to assess Tenaris' activity level. The limits of each process are clearly defined. Global Stages provide a consolidated vision of 100% of Tenaris' businesses.

This vision is useful not only to measure the business flow but also to build the different management visions that cut through the various business stages. This approach makes it easier to find answers to essential questions to the monitoring of the business (and activity) evolution, such as: sales per period, orders under production, existing stock, number of businesses delivered or invoiced, etc.

3.7.Lead times report

It is in the context previously described that a control on production lead times, at a global level, is required. The objective of this work is to construct an adequate report, defined in detail (KPIs, frequency, etc..) and taking into consideration the characteristics of the company, the product itself, and the way management control is already done inside the organization.

4.LEAD TIMES REPORT

In this chapter the development and construction of the report will be explained in detail. As commented previously (see 3.7), the necessity for a global report of production lead times is clear within Supply Chain Management Control reporting activities.

For the construction of the report and it's KPIs there were different key factors to take into consideration, such as: the clients of the report, the information systems that support it, product characteristics, aggrupation within industrial management (order and items), statistics behavior of samples, etc. All this issues will be analyzed in this chapter.

4.1. Information Systems

As explained in the previous chapter, Tenaris is a multinational and decentralized organization. Therefore, for a proper planning process at central level and in order to enable a correct visibility for the top management, information systems are a key management support tool.

All of the reporting activity at a corporate level is based upon a central source of information, named "ODS", that feeds automatically from all transactional systems in each region. Transactional systems are mainly ERP softwares used by local users at an operational level (a.e. SAP for invoicing orders).

ODS is formed by a group of tables, each of which is designed with its own logic and to serve different purposes. All ODS tables can be linked with another one through one or more key fields. For instance, there is a table with all the production orders that, linking through a field called "product code", you can obtain all product characteristics from a table especially done for that purpose.

In order to use the information in the ODS system to support a lead times report, a model in Microsoft Access has been built. This model is a group of consequent logics that, with simple operations and temporal tables, construct a final database with the information needed for a proper production lead times report.

It is from that model that a Microsoft Excel file, with many pivot tables in it, feeds itself. And by last, a Fronting made with the information of the pivot tables is made in another Microsoft Excel file.

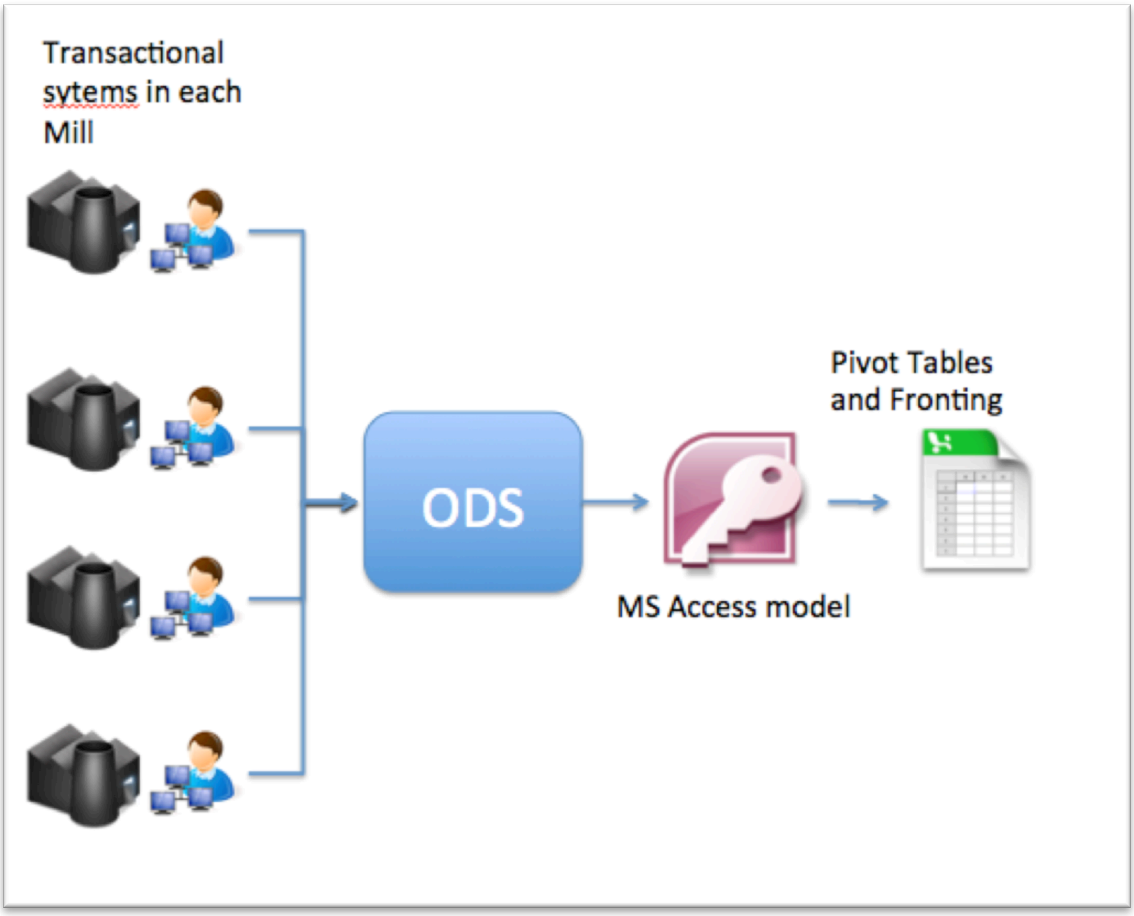


Figure 9. How Information Systems support the report.

4.2. Report's Clients

In order to have a correct and useful approach for the construction of any report, it is crucial to understand who is going to use it and for what purpose. It is not the same thing to have a report addressed to the top management that to have one specially done for a middle management or even an analyst or operative user. Requirements in each case are going to be different, and implications in the construction of the KPIs can diverge quite a lot between each one.

In this work, it was of crucial importance to understand who was going to be the user of the lead times report and, in each case, what was going to be its use. The first thing to take into consideration is that the report is going to have to very different kind of users.

On one hand, the top management of the supply chain is going to use this report to monitor the performance at a production mill level and to evaluate each mill in particular. On the other hand, regional supply chain management (middle management) will use the pivot tables in order to analyze particular cases and, if necessary, give further explanation to issues that the top management can encounter in the fronting (a.e. excessive lead time in certain product).

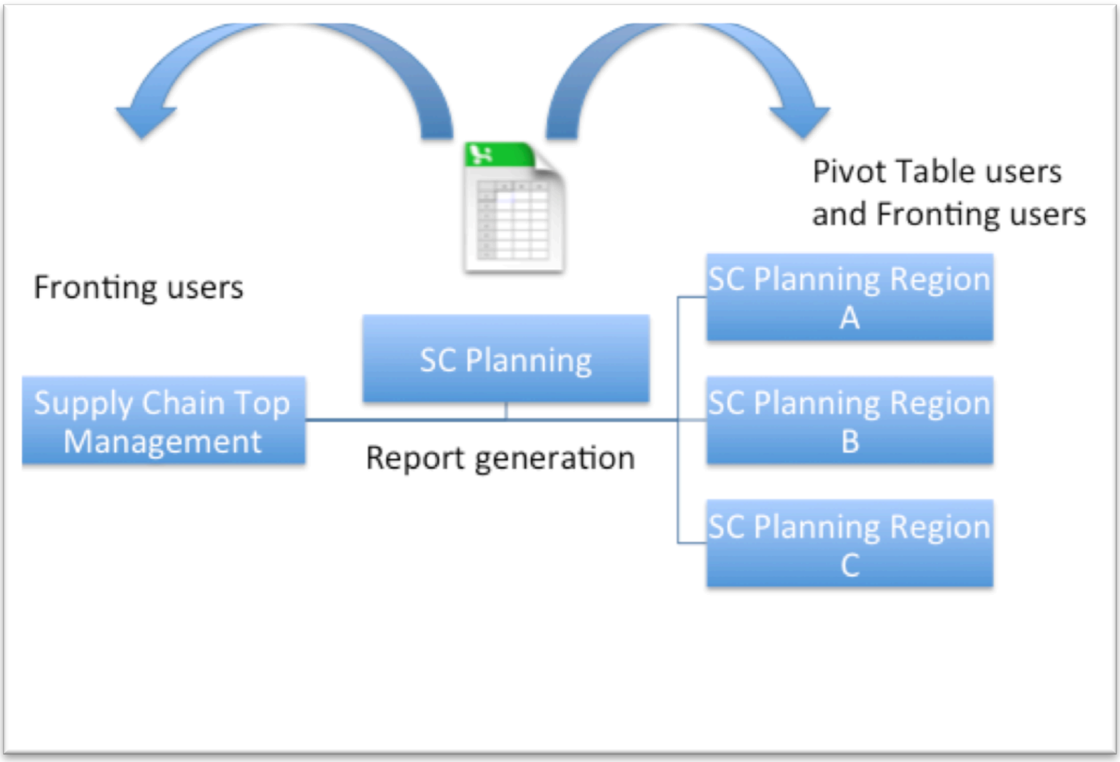


Figure 10. Report users within Supply Chain

Moreover, it is important to remark that there are several uses for the information obtained from the model that supports this report. As explained in chapter 3, production lead times are closely connected to all of Tenaris business cycle. This last thing makes that another use of the lead times report is as a service center for any other area within the company who has necessity of analyzing lead times within the scope of this report. An example of this, with delivery times, will be given further on in this chapter.

4.3. Aggrupation within the Report

The information obtained from the model is vast and various, it can be arranged in very different ways. The necessity of having a standard way of arranging information and grouping registers within the model's database is imperative. The attributes chosen to group information were Orders and Items, and Product characteristics.

4.3.i Order and Items

The business cycle in Tenaris is constructed by different orders: purchase orders (SO), sale orders (SO), production orders (PRO). Being this a production lead times report, it will gather information about production orders. Orders are identified with a unique numerical code for each mill.

At the same time, orders are composed by items, a subgrouping of the order itself. Items have the virtue of having a unique set of product characteristics for each one, and thus refer to exact one kind of product. This is very relevant because product characteristics are strongly related to production lead times, and there is a imperative need to unify them. Items are identified with a unique numerical code for each order.

Every record in the production lead time database is going to be analyzed, at the more detailed level, as an order-item.

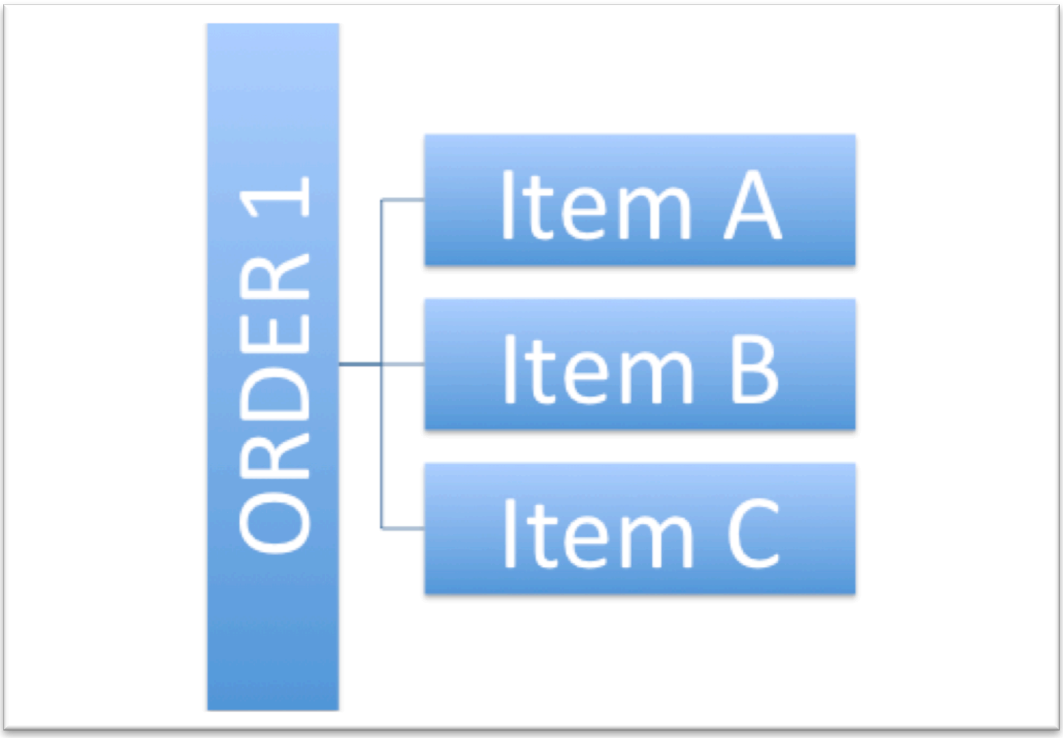


Figure 11. Items compose orders

4.3.ii. Product Characteristics

As mentioned before, product characteristics are strongly related to production lead times. For instance, the fact that a product has or not certain treatment can double its lead time, even if the product is exactly the same in all the other attributes.

According to what was previously exposed, a set of characteristics was selected in order to define what a product is within the scope of this report. These characteristics were carefully analyzed and validated (with referents of the matter within the organization and against the available data) in order to comply with the following requirements:

- To be relevant for the production lead time: in order to verify this, it has to be confirmed that lead time for a given product varies significantly with the variation of a given characteristic. For instance, “wall thickness”, a product attribute was discarded because of its little correlation with production lead time.

- To be relevant for commercial/marketing readings: it was very important to “translate” things from a purely industrial point of view to a more commercial one in order to give relevance to the data in the report. In this line of thinking, attributes like “Product Family” or “Product Use” rise as important ones.

Following this guidelines, and after modifying the first selections, a set of characteristics was selected. Within the scope of this report, a product is uniquely defined as the concatenated of the following attributes.

Family	Sub Family	Use	HT	SS	Range Group	End Group

Figure 12. Product attributes within the report.

Family: Product´s families are defined by marketing/commercial functions and are aligned within Tenaris Global Business Units and the different markets the company serves. (INDUSTRIAL, LINE PIPE, OCTG for oil industry, and ACCESSORIES).

SubFamily: Is a division within each family to identify different segments within each market. A.e: CASING&TUBING for OCTG or STRUCTURAL for INDUSTRIAL.

Use: it describes the final usage for which the product is designed. For instance, PROCESS tubes of the LINE PIPE family or CASING tubes for OCTG family.

HT and SS: they indicate where the product has suffered heat treatment (HT) or sour service (SS) in its production process. These attributes are of particular relevance for the production lead time.

Range Group: It classifies products according to their diameter as follows.

Range Group Desc	Diam from	Diam to
SMALL	0	7
MEDIUM	7	10 3/4
LARGE	10 3/4	16
EXTRA LARGE	16	80

Figure 13. Range Group definition. Values in inches.

End group: it identifies which kind of thread the product has on its end, particularly important in the OCTG products.
According to what was previously defined, an example of a product list is given below.

Family	Sub Family	Use	HT	SS	Range Group	End Group
OCTG	CASING & TUBING	CASING	HT	NSS	EXTRA LARGE	PREMIUM
OCTG	CASING & TUBING	CASING	HT	NSS	LARGE	API

Figure 14. Product list example.

4.4.Universe of measurement

The universe of this report will be defined, at first instance, by the production of five production mills: Siderca (Argentina), Tamsa (Mexico), Dalmine (Italy), Silcotub (Romania), Algoma (Canada). As it can be seen by the locations of the different mills, this report has the challenge of unifying, under one set of indicators, five different realities of five different countries, also represented by different transactional systems. All of this mills are focused on Seamless Pipe Production (see 3.2.i) and serve markets worldwide.

At second instance, there is a limitation in how systems operate that makes this report to lose some items out of scope. Since sometimes production of one particular product is done after producing a semi-elaborated pipe for that purpose, new orders are done in the system from which it is impossible to track their beginning. Hence it is not possible to assign a beginning date for some items (rolling date).

Nevertheless, analysis about the coverage of this report were realized, and it was verified that it approximates 85% of the production of the five mills.

At last, all lead times exceeding 180 days are automatically excluded. This is because it's considered a system´s error such a measurement for a production lead time (also known as outliers).

4.4.i TOP Products Approach

Regardless the limitations state above, there was a particular approach for the information in the fronting that led to further reduction in the universe of measurement.

With the intention of focusing management efforts into relevant actions and analysis, the decision of reducing the scope to a few products per mill was taken. Therefore a list of "TOP Products" was defined for each mill. The criteria for determining if a product is TOP or not was formed by three issues:

- It's volume of production, measured in order-items.
- It's Commercial relevance
- It's complexitiy within the production process

For these decisions, referents of different areas were consulted. To understand which product was interesting to follow due to its complexity in the production process, local supply chain analysts and programmers were consulted. To decide which products were commercially relevant, we consult the team of global programmers of all Tenaris, based at Buenos Aires, that have a global vision of Tenaris production.

This analysis led to a final list for each mill, in which just a few products of the whole produced by them are taking into account. This is the list of products that is shown in the fronting.

Nevertheless, it´s important to remember that, both the Microsoft Access model and the pivot tables, contain the information of all the production. That is because, as mentioned before, this report serves also as a center of services linked to lead times information.

4.5. Indicators

First of all, it is important to understand which milestones defines the production lead time within this report. Even though there are different milestones before and after the ones chosen for this report, it was established that the production lead time was going to be defined as follows:

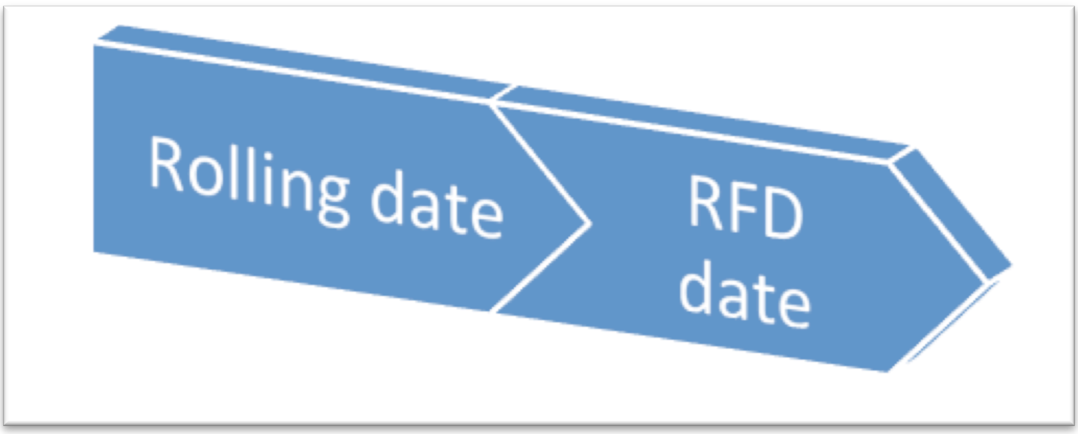


Figure 15. Lead time milestones.

Rolling date: First rolling date associated to an order item.

RFD date: Date in which the fulfillment of minimum tolerance[12] at RFD state is reached by an order item. RFD stands for Ready for Delivery, and it defines when an order item is ready to be shipped without further operations or documentations.

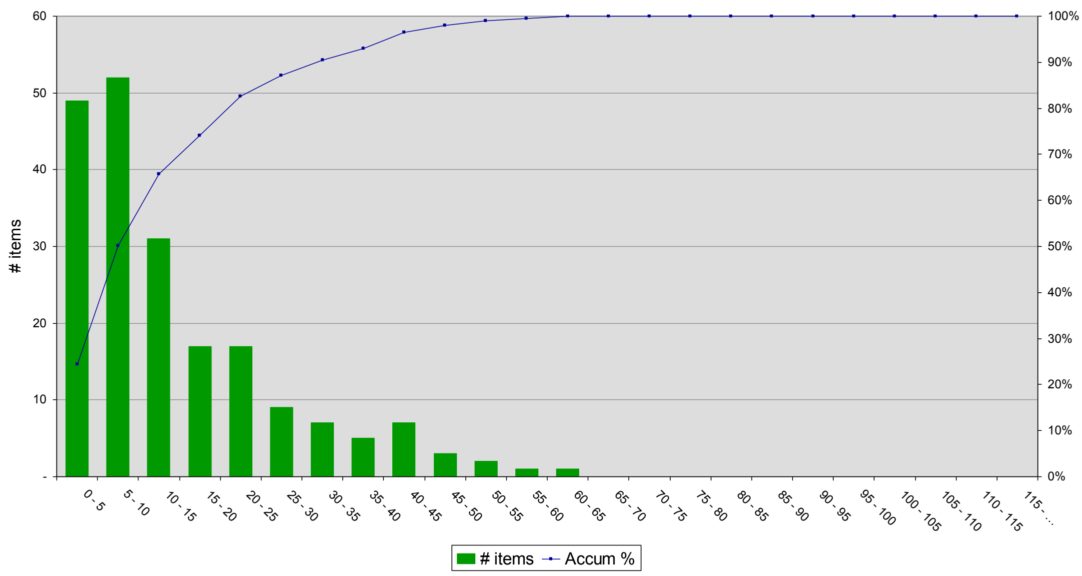
From now on, every time that production lead time is mentioned, it has to be remembered that, within this work, it means the difference between the two dates explained above.

4.5.i. Statistic behavior of the samples

In order to have a more profound understanding of the phenomena (from a statistic point of view) that defines the production lead time, it is imperative to analyze which distribution follows.

It was found by comparative analysis of histograms, that production lead times fit very well into a Poisson distribution. Even more, it was often an indicator that the aggrupation chosen for a specific product was erroneous if its histogram did not fit into a Poisson distribution.

In order to see what was previous explained, the figures that follow are offered.



[12] Minimum tolerance makes reference to the fact that each order item can arrive to an state previous to its total fulfillment (a.e. 90% of its weight in tons) and still be dispatched. This concept will be named as common from now on within this work.

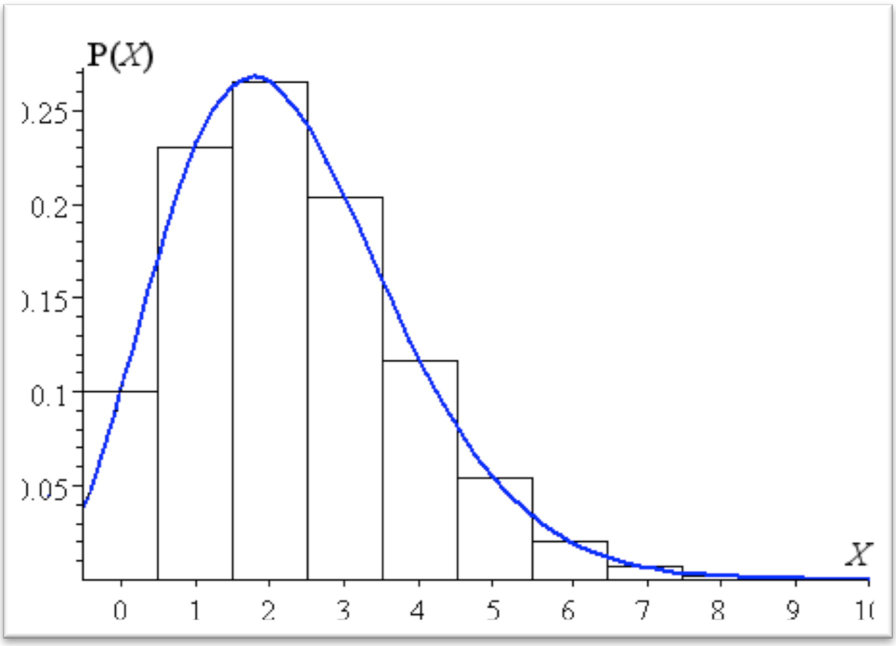


Figure 16. Typical Poisson Distribution histogram.

4.6. Indicators

The report has two evaluation levels, first a Production Mill Level and then a Product level. Each one has its unique set of indicators, since they must mirror different realities and management issues.

At each level, there are three fundamental dimensions or measures to evaluate:

- Performance: to understand whether the mill/product is having a particularly long or short lead time, and its evolution through time.
- Volume: to understand the production level that goes with each measure.
- Dispersion: to understand the consistency of performance within each measure.

It's worth to mention the principles that this author followed when designing each indicator. They are the following:

- Parsimony: it was always a challenge to take the most complex statistic concept and turn it into something simple and understandable for anyone. This has the intention to enable discussion with all the parties involved in management by making the indicators transparent and understandable.

- Relevance: it was always mandatory that the indicator focused a relevant dimension of lead time management.

- To mirror reality: it was always mandatory to verify that the indicators indicate something that was actually happening in each mill. Thorough analyses were made, involving regional management, to check this issue while designing the report.

4.6.i. Indicators at a Production Mill Level

As mentioned before, three indicators were developed to evaluate production lead times: one for performance, one for volume and another for dispersion. At a Production Mill Level, they are the following:

Production Volume

Since the fundamental unit of this report is the order item (see 4.3.i), production volume is measured in order item numbers. Hence the indicator "**#items**".

Dispersion

Dispersion was the most challenging measure to materialize, at least in a simple and understandable way (according to the parsimony principle).

Several indicators were proposed before arriving to the definitive one. It was natural to focuse the firsts approaches into statistics parameters such as the standard deviation. But these were always discarded for two main reasons.

First of all, the samples did not follow a Normal distribution but a Poisson one (see 4.5.i), and most of people tend to think in a Gaussian distribution when talking about standard deviations, what always led to misleading conclusions. The other reason, linked to the parsimony principle, was that referring to mathematical concepts is not precisely a way to make things understandable and transparent but to make them more complex and sophisticated.

In an attempt to solve the apparent tradeoff between the simplicity of the indicator and its capacity to measure dispersion within a sample, the concept of "window" around the average is proposed.

By doing this, an imaginary "window" of tolerance is defined, by locating its center in the average value and its limits in +/- 20% of the same average value. Then the percentage of items that are outside this "window" are measured as a percentage of the total number of items.

This means, for instance, that 0% dispersion means that the whole sample fits within +/- 20% the average value, and 100% dispersion is that none of the items are inside that interval of tolerance. The indicator was named "**LT Dispersion**". As a didactic example the following figure is offered to illustrate this concept.

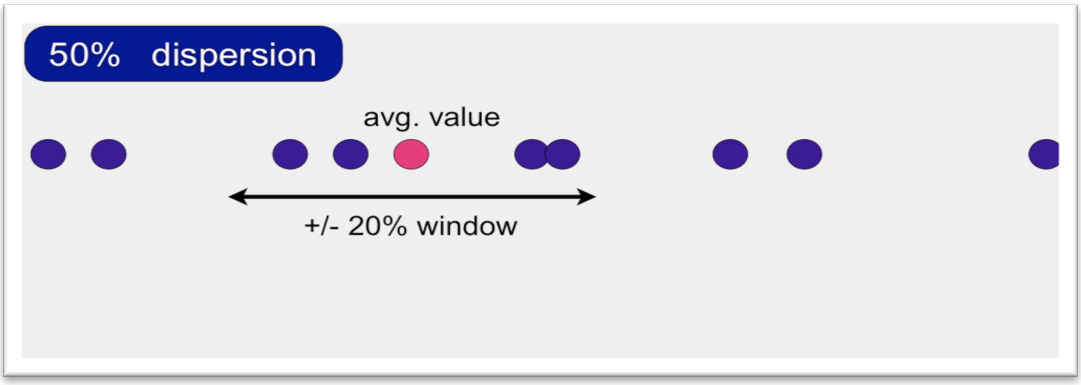


Figure 17. Sample with 50% dispersion according to the LT Dispersion indicator. Figure not to scale.

Performance

Once more, to design this indicator was a challenging endeavor. Performance is easy to visualize at a product level, since it would be as simple as the average value of the sample, but to evaluate this at a Production Mill level is quite different.

As mentioned before, each mill has a different reality and culture of management, they operate in quite a different way, so to have the same indicator for all of them seems really difficult. Moreover, because of what was explained in 4.3.ii, production mix is a determinant variable in production lead time determination. It is impossible to compare values over time for a production mill, when the production mix varies.

Since the top management has a genuine interest in evaluate the global performance of a production mill in order to monitor the overall management of lead times, an indicator was designed regardless the difficulties mentioned above.

A solution to all this questions was found in the form of a new indicator called "**LT Performance**", which this report uses to evaluate the performance of each production mill. The idea of this indicator is to evaluate each mill against itself, independently of the production mix of a given period.

In order to achieve this, the indicator is defined as the percentual difference between the average lead time of the production of a mill (weighted average by items number) and the twelve months moving average lead time of the same mill applied to the same production mix.

An example is offered in order to clarify this concept as follows:

Product	LT period	12 month avg.
A (3 items)	5	7
B (7 items)	11	9
avg.	9,2	8,4

Figure 18. LT Performance example.

$$LT\ Performance = \frac{8,4 - 9,2}{8,4} = -9,52\%$$

In this case, the indicator indicates that the actual performance of the mill in that period was 9,52% below of what it would be expected taking into consideration its performance.

A risk of this indicator is to hide systematic increase of lead times, since it always take into consideration historic values. As an explanation to accept this cost, the fact that constant monitoring of these indicators will indicate by themselves improvement or not of production lead times.

Taking into consideration all the indicators explained above, and a graphical interphase, the fronting of this report for the Production Mill level is the following.

Mill		Q1 0910	Q2 0910	Q3 0910	Q4 0910	Avg
Siderca	#items	145	173	144	175	621
	LT Dispersion	59%	52%	61%	61%	60%
	LT Performance	3%	4%	2%	10%	0
Dalmine	#items	190	230	202	282	862
	LT Dispersion	49%	64%	59%	54%	58%
	LT Performance	5%	-9%	-4%	-13%	0
Tamsa	#items	345	240	264	264	923
	LT Dispersion	66%	64%	66%	64%	64%
	LT Performance	16%	7%	7%	7%	0
Silcotub	#items	113	154	325	400	907
	LT Dispersion	55%	65%	47%	52%	59%
	LT Performance	-2%	-8%	-6%	-24%	0
Algoma	#items	37	60	59	77	282
	LT Dispersion	47%	59%	55%	58%	64%
	LT Performance	9%	0%	-5%	29%	0
Total	# items	**830**	**857**	**993**	**1198**	**3595**
	LT Dispersion	**58%**	**61%**	**57%**	**57%**	**53%**
	LT Performance	**9%**	**1%**	**1%**	**-1%**	**0**

Figure 19. Fronting report at a Production Mill Level.

Values shown are not real because of confidentiality issues, they were all multiplied by a random factor.

4.6.i. Indicators at a Product Level

At a product level, the same three dimensions were evaluated: Volume, Dispersion and Performance.

For the first two, volume and dispersion, the same indicators explained above were adopted: "**#items**" and "**LT Dispersion**".

Regarding performance, the problem is much more simpler at a product level. In this case it was enough to take the average value of the sample calculated at an item level. The indicator was called "**LT avg**".

As mentioned in 4.4.i, a TOP Product approach was followed, so for each mill a fronting was offered with the three indicators for all the TOP Products. Moreover, a particular fronting for each product was offered with a graphical representation of the evolution and values of each indicator. An example of this can be found in the following page (values were multiplied by a random factor).

OCTG-CASING & TUBING-CASING-HT-NSS-MEDIUM-API

Back

Siderca

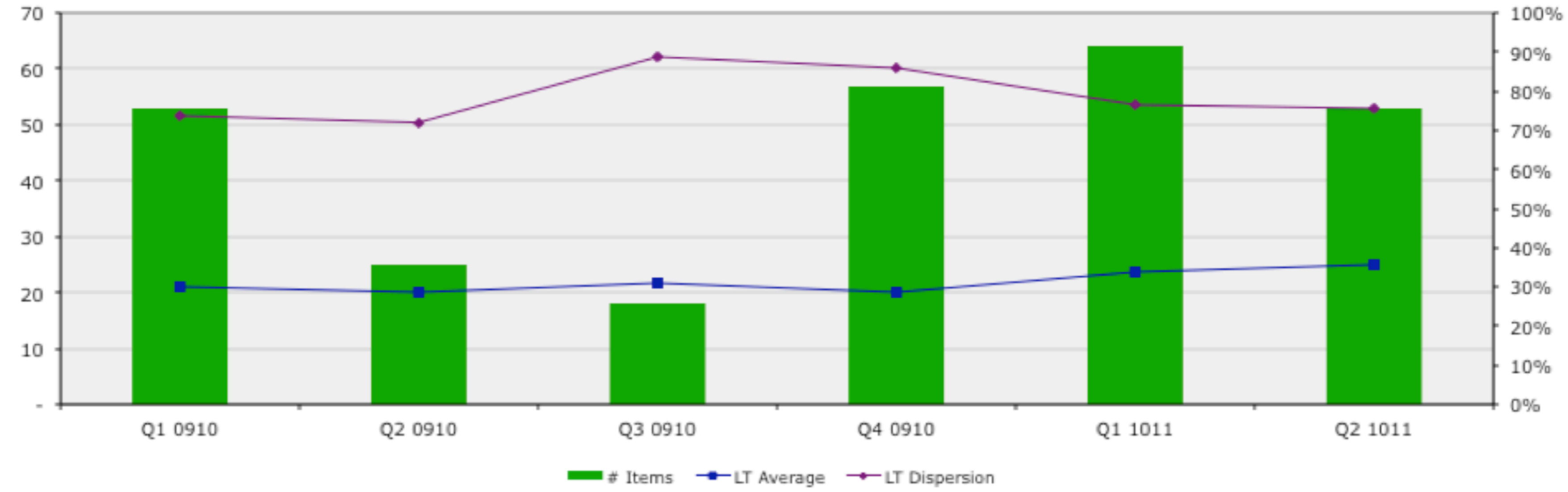
	Q1 0910	Q2 0910	Q3 0910	Q4 0910	Q1 1011	Q2 1011	Avg
LT Dispersion	74%	72%	89%	86%	77%	75%	79%
LT Average	21	20	22	20	24	25	23
# Items	53	25	18	57	64	53	192

Last 12 months moving average

Universe

Updated up to Dec 2010

Lead Times >=180 days are not included



4.7. Frequency and usage

The fronting is designed to be updated on a quarterly basis. This follows the logic of having regular meetings, with the same quarterly frequency, to review the issue of production lead times at a global level with Supply Chain top management.

Regardless this last issue, the Access model runs on a monthly basis. This enables the analysts, both corporate and regional ones, to have a more updated version of the database to work with and prepare reports and conclusions for the top management or other areas. The database is updated every month into an intranet site where all parties involved have access.

4.8. Challenge to Delivery Times

As mentioned previously in this chapter (see 4.2), the information generated is too valuable to be used only by this report. An example of this is the challenge that can be made to delivery times with the database of the model.

Tenaris uses delivery times in order to allocate production and stock around the globe. Production lead time is an important component of this time.

Through the usage of histograms, a challenge to the production lead times supposed by delivery times can be made, for the first time, against real information.

Results could indicate that product lead time supposed by the delivery time was the same (or approximately) than the one represented by the 90th percentile of the histogram. This equals to say that it was the time that it can be assured with 90% of probability of achievement, quite a logic statement in terms of reliability and delivery times. But, in some cases, it could be found that lead times supposed by delivery times are excessively long and not correlated with the reality of the production process for a given product (a.e. a lead time considerably longer than the 90th percentile of the sample).

The next figure shows an example of this. Numbers are fictional, and just serve the purpose of illustrating the idea.

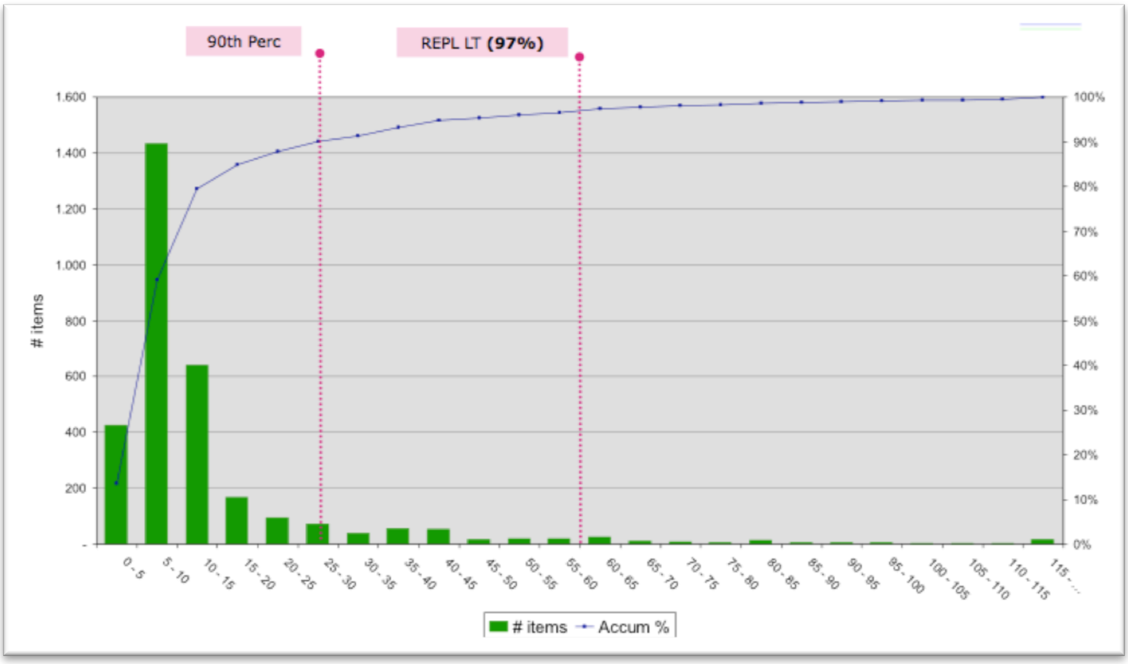


Figure 20. Histogram showing 90th percentile and delivery times.

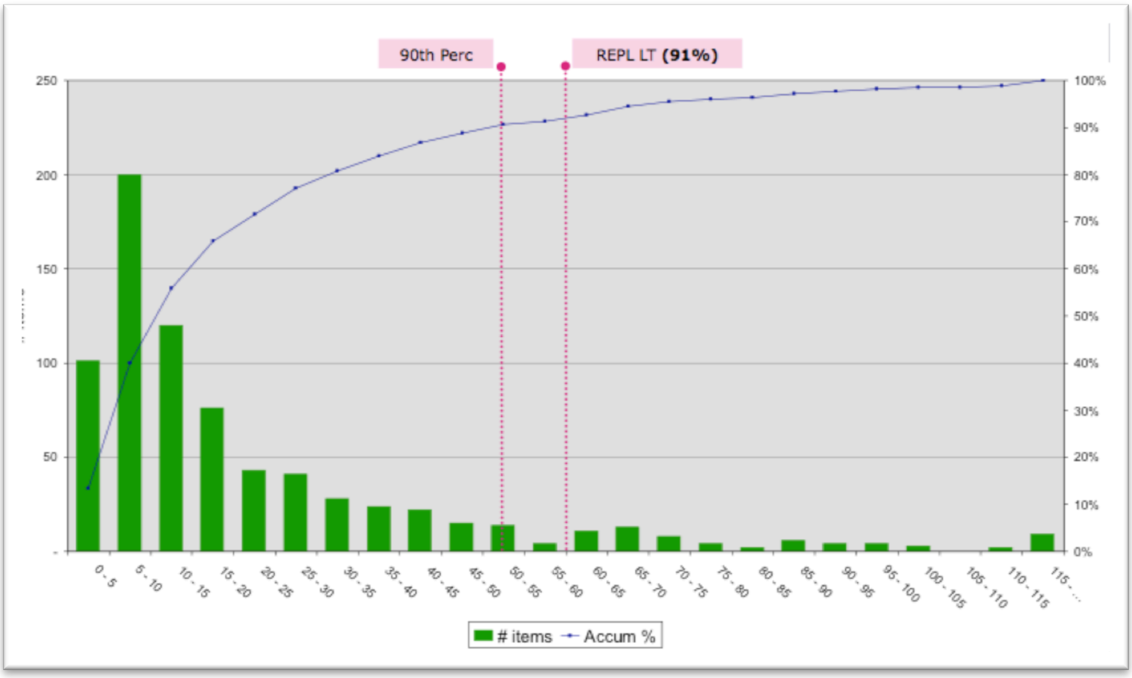


Figure 21. Histogram showing 90th percentile and delivery times.

5. CONCLUSION

Lead times are a fundamental dimension of any business, as they affect costs, customer service, and competitiveness in general. As the reviewed literature indicated, lead times are closely related to the creation of value. Hence the importance of having an adequate managerial system of performance measures related to time throughout the business processes.

In Tenaris reality business cycles are complex, delocalized and decentralized, and therefore the issue of a global management control of the overall system is imperative. Such a system for production lead times was absent till the development of this work.

Throughout the design process of the report and indicators, considerations about management control, statistics and parsimony were taken into account. The final result was a report simple enough to be understandable by all parties involved and, at the same time, broad enough to cover various managerial necessities.

Moreover, a new service center within the Supply Chain was created through the generation of a production lead times database. A possible usage of this service center was rapidly shown with a possible challenge to delivery times used to allocate stock and production in an international system.

It is a debt of this work, and an indication for future developments, both expanding the lead time measurement scope and linking this information to another reports within Supply Chain Planning.

First of all, an expansion of this report in order to include also invoicing dates can be done. And in this way give visibility to the invoicing processes related to production orders, and estimate a financial cost for its delay. To expand the lead time horizon to all the business cycle could be enable through an extensive work and data mining of the information systems and the information they offered at a corporate level. It is worth to mention, that in the case of such expansion, one report would not be enough, and the generation of a series of reports related to time should be taking into consideration.

Secondly, and maybe in a shorter term, a linkage between the production lead times information and another reports should be made for further analysis. An easy example of this is the “Origin Region” report that measures compliance of the production mills with their requested dates for finishing orders [13]. Understanding production lead times should led to a better management of compliance against deadlines.

[13] An attempt to do this was made, but because some database issues and agenda priorities it was abandoned before it could offer visible results.

It is also worth mention the direct link that exists between lead times and stock days. Having an exact measure of lead times will lead to a more rational management of intermediate stocks .

In conclusion, the objective of this work was achieved since it offers a report for the management control of production lead times in five different production mills around the globe and part of the same overall industrial system. Moreover, it offers for the first time visibility to production lead times at a top managerial level, taking into consideration the complexities of the company, the statistics phenomena of the samples, and the production processes it represent.

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