INTEGRATED LOGISTICS:
A STUDY ON ITS APPLICATION IN A PHARMACEUTICAL COMPANY

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ABSTRACT

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Two activities of research were pulled together in this study. The first objective was to review the literature dealing with integrated logistics form both a qualitative approach and a quantitative modeling standpoint. The review led to the building of an analytical framework to evaluate the potential for logistics integration of an organization. The second objective was the application of the framework on a pharmaceutical company and the identification of some industry-related environmental and operational constraints.

The concept of integrated logistics has recently emerged from both the academic and corporate world. The increasing competition and the new technologies have forced a redefinition of product cost so that it is now more relevant to focus on the logistics cost, or total cost, of the goods sold. This is possible only if a company is willing to move from the traditional fragmented view of functional optimality to the evolved integrated approach, understanding by this matter that integration is principally a process of trade-offs. This evolution has captured a lot of attention from researchers and models dealing with integration are becoming more and more reliable and complex. These models, either optimization or simulation models are expected to become key decision-making tools for

the redesign of more effective and efficient supply-chain as integral part of a company's decision support system

At the pharmaceutical company XYZ Ltd , the heavy environmental and operational constraints common to many multi-national pharmaceutical company, the analysis of the supply-chain for one product category revealed some inequalities with respect to the degree of integration achieved Whereas the activities downstream production demonstrate a heavy concern for and substantial achievement toward integration, the lack of integration of external suppliers as well as a recurrent tendency for functionality represent the areas where major improvements can be made

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INTRODUCTION

Increasing competition and decreasing margins are forcing companies to improve their service level to customers and to decrease their costs. Often, companies focus on the reduction of production costs or transportation costs independently. However, in today's fierce market pressure, this is not enough and there is a strong need to reduce the overall cost of the product through a tighter control of the set of activities adding value to the raw materials. It is therefore more relevant to focus on the logistics cost of the finished goods. Traditionally, logistics have been divided into two distinctive activities: internal logistics (material handling and storage) and external logistics (transportation). As a result, any efforts to optimise the logistics costs have been fragmented the same way, leading to sub-optimal performance of the overall system since no common goal had been defined. In order to achieve better performance, academics and professionals started to develop a more homogeneous and complete approach to the management of logistics to minimize costs and ensure co-ordination of the entire system: the concept of "integrated logistics" was born. The emergence of this integral approach has been recognized and documented by many logistics professional and originated the creation of specific operations management concept like Materials Logistics Management and Supply Chain Management.

The objectives of this paper are two-fold. First, to review both the qualitative and quantitative aspects of the integrated logistics concept. Second, to observe and investigate through a case study the supply-chain issues in a pharmaceutical company.

PART ONE

INTEGRATED LOGISTICS:

A REVIEW

1. THE EVOLUTION OF LOGISTICS

1.1 The Traditional Fragmented View of Logistics

For a long time, the logistics mission of the company has been to balance inventories between both production capacity and demand from customers (Oliver and Webber, 1982) Logistics was fragmented into two distinctive parts the internal activities such as procurement and production (inbound logistics), and the external activities such as distribution (outbound logistics) (Peterson, 1993) This separation was not only conceptual but also physical Efforts to improve the performance were pursued at these two different levels with barely any concerns for the interaction of one with the other

Up to the last two decades, traditional management practices fitted well with this fragmented approach Organizations were still perceived as a set of functions (production, distribution, marketing, etc.) trying to make the best of their assets through a search of functional optimality and excellence At the same time, for most of the manufacturing corporations, direct labour was the most important and most visible of the costs Under these circumstances, companies which were able to minimize those costs while still maintaining quality and reliability were promised the greatest successes This high visibility of direct labour costs attracted so much attention from management that the rest of the companies' activities were somehow neglected At a time when companies were focusing principally on local production for local sales, procurement and distribution costs were not very significant compared to labour costs

Today, things have changed dramatically The globalization of markets, the increasing competition, the slower economic growth have forced companies to extend their geographical customer base and therefore to increase distribution costs in order to be present in a market where the service level to customers has never been more important The increasing competition and the advance in technology have considerably shortened the Product Life Cycle so that the throughput time for some existing logistics systems is longer than the PLC itself. This, associated with increasing customers' demand for variety enhance the risk of obsolescence of finished goods stock (dead stock) for wider product lines

Another interesting change in the market place is the shift of power from producers to traders In the past, when production capacity hardly satisfied consumers' demand, manufacturers were able to impose their conditions to distributors (margins, lead-time, etc) Today, there is a large excess of capacity for many products and the increasing world-wide competition gives to distributors the power of dictating their conditions to manufacturers, increasing the need of the latter for better logistics performance in a more global market through cost reduction and better service level

The globalization is also evident in the view of trade agreements such as the European Community or the North America Free Trade Agreement. It is expected that these agreements will change drastically the way companies do their business As reported by Coopers (Turner, 1993), the emergence of the European block will create a need for a Pan European approach to the firms' activities for reasons such as the harmonization of standards, the recognition of economies of scale, the removal of barriers and the deregulation of transport All of the above factors could create some fantastic opportunities for market development associated with a frightening and increasing competition

In order to be not just present but also active in such a global market, companies need to have a better control of their costs to absorb the decreasing margins resulting from this wild competition As well, they need to provide a service level to customers as good as possible with increased promptness and reliability. Finally, since this geographic expansion requires the participation of an increasing number of partners (local suppliers and distributors), there is a strong need to provide them with more rapid and reliable order filling to help minimize their cost and, by repercussion, the total cost of goods sold (Billington, 1994).

In such an environment, the traditional "wild stock building" practice to hedge against the unpredictability of customers, the unreliability of suppliers and the variation in product quality is obsolete, though still observed, since it is too costly and reduces flexibility One approach to consider would be the adoption of the Just-In-Time policy successfully implemented in Japanese manufacturing This practice, whose success is due in greatest part to partially-owned suppliers by the manufacturer, would be difficult to adapt in the Western environment due to the structure of the economy However, this does not mean that Western firms cannot smooth the flow of material within their logistics channel. Rather, it implies that the creation of a tighter flow must come from a better co-ordination of the channel partners In other words, if one cannot copy a winning system, one has to try to make its existing system a winning one (Scott and Westbrook, 1991) This co-ordination means that the different actors have to work closely together in order to pursue a common objective, i.e. cost minimization with outstanding service level This is the challenge of integrated logistics

1.2 The Integrated View of Logistics

As defined by Stock and Lambert (1987),

> " The foundation of the integrated logistics management concept is total cost analysis, which we have defined as minimizing the total cost of transportation, warehousing, inventory, order processing and information systems, and lot quantity cost, while achieving a desired customer service level"

The total cost analysis does not mean the analysis of the sum of the costs incurred at each functional level of the company Rather, it implies the monitoring of the total cost of processing the material through the logistics chain But, isn't it the same, i.e if a company manages to optimise each functional cost, shouldn't the sum of the optima be equal to the optimal cost? Consider a pull approach to demand filling Under a fragmented approach of logistics, distribution planners will request a desired level of finished goods inventory to ensure availability in order to meet demand and optimise the distribution costs In turn, production planners and schedulers will optimize the sequencing of production, given the demand at the finished goods stockpile Then, given the production schedule, the Material Requirement Planning will dictate the ordering of the required raw materials But is the ordering pattern really optimal for the procurement function, given the ordering , handling and storing costs ? Does the order for finished goods replenishment really enable production planners to minimize production costs, given set-up and change-over costs? Could they take advantages of some economies of scale with longer runs of some of the products and delays for the production of the others? This could require a redefinition of the optimal distribution policy but could decrease the total cost

It is now obvious that true minimal total cost depends on the interaction of all the decisions taken at all levels of the logistics chain This chain is in fact a succession of customer-supplier relationships and is more and more referred as the Supply Chain with the suppliers upstream and the customers downstream

The integrated approach to logistics management requires a global analysis of all the trade-offs between distribution, production, inventory and procurement costs, given the desired service level Obviously, it is not an easy process but it is the only way to ensure that the final cost of the products is truly optimal, not necessarily at each functional level, but at the aggregated one, the supply-chain level As Bill Coppacino, Managing

Partner for logistics at Andersen Consulting reported (Turner, 1993), there is a strong need to move from functional efficiency in which each function is independently optimized to functional integration by which excellence is achieved according to some global and common performance measure Ultimately, this integration should be extended to all channel members such as suppliers and customers

This "total (integrated) approach" allows the creation of a formal link among all levels in a marketing channel and the development of a smooth and consistent flow of material and information relative to supply and demand by means of three related advantages over fragmented logistics First, it provides visibility into the needs of all customers throughout the entire supply-chain Second, as a result of visibility, it helps reducing demand uncertainty Third, as a result of reduced uncertainties, it provides better service, helps consolidate distribution centers and reduces transportation costs (Turner, 1993).

Finally, it should be noted that the integration of the logistics activities can help reduce the problem of 'demand amplification' As reported by Burbridge (1987), "if demand for products is transmitted along a series of inventories using stock control ordering, then the demand variation will increase with each transfer" Without going too much into the details of industrial dynamics, the amplification is the result of cumulative uncertainties against which each level tries to hedge itself and of the lead-times existing at each level. As a result, in the case of multiple supplier-buyer relationships like in the supply-chain, the amplification grows dramatically, starting at the finished goods stockpile and ending with raw materials orders. By substituting integrated ordering policies to stock control ordering policies, the amplification is reduced since the transfer of orders is co-ordinated, not fragmented

2. THE ESSENCE OF INTEGRATION

As one can expect, integration requires the acceptance of two realities First, the organization must follow several gradual steps to reach a stage of successful integration. Second, they must understand that integrated logistics management is essentially a trade-off process

2.1 The Stages of Integration

Since the need for integration has been identified, many authors have documented the necessary steps to reach a fully-integrated supply-chain As recommended by Stevens (1989), successful integration requires actions that are operational, strategic and tactical

Robert Sabath (Turner 1993), while managing partner at A T Kearney described three distinctive stages of integration First, the company views logistics as a control of finished goods transportation and warehousing on a daily basis (strictly operational). Second, it evolves to an integration of finished goods distribution by means of planned activities to ensure optimum customer service level (tactical) Finally, logistics is an interaction between materials management and physical distribution (strategic)

Towill, Naim and Wikner (1992) describes the integration process in four stages that they call 'echelon integration' In the first echelon , the functions are independent within the company Second, there is a functional integration aiming at cost reduction only and using inventory as buffers between functions I will call this effort a purely operational one since it does not go beyond cost reduction and ignores the impact of upstream functions on customer service level In the third, there is an internal integration of all the functions, combining the objectives of cost reduction and increased performance It appears to me to be rather tactical since it represents some short-term efforts toward better competitiveness Finally, the integration extends to external agents such as suppliers and customers I believe that this last step is really strategic since it requires establishing long-term relationships in order to gain and maintain market superiority

2.2 A Trade-off Process

We have mentioned that the traditional view of logistics was a balancing of inventories between capacity and demand In the fragmented approach to logistics, there is also a general balancing mechanism with trade-off between reliable, prompt customer service on the one-hand and manufacturing and inventory management costs on the other (Sharman, 1984)

In more details, one can classify the trade-offs of integrated logistics in two sets The first refers to cross-functional trade-offs and represents a major barrier to the overall performance if logistics are not integrated (adapted from Billington, 1994) The second deals with trade-offs at the operational level (adapted from Sharman, 1984) Table 2 2 presents both sets

The above-mentioned trade-offs, although sometimes very obvious, need some explanations The design of a product affects greatly its manufacturing cost and it is on a common agreement that both the R&D and Production functions have to find the optimal combination The availability of products at the finished goods stockpile allows marketing to be more responsive to market demand variations However, this is no free of cost and the best balancing have to be commonly agreed by both functions
The time-to-market a new product depends heavily on the total throughput times The more complicated the design, the longer the production and the longer the time to market If there is a market niche that must be captured immediately, the design has to allow fast and relatively simple production

Procurement costs include ordering, storing and handling costs It might be tempting to minimize those costs by using some EOQ However, it might be better, when production and procurement costs are combined, to order a different quantity It could reduce the number of costly set-up or change-over that might occur due to material shortages or which could be avoided by longer and more economical production runs

TABLE 2.2: TRADE-OFFS OF INTEGRATED LOGISTICS

Cross-Functional Trade-offs	Operational Trade-offs
R & D - Manufacturing Design cost vs Processing cost **R & D - Marketing** Feasibility vs Time to market **Purchasing - Manufacturing** Procurement cost vs Production cost **Manufacturing - Marketing** Inventory cost vs Market share	Inventory cost vs. Service Level Cost of Rush Orders vs Value to Customers Inventory cost vs Distribution cost Forecasting cost vs. Inventory cost Forecasting cost vs Process rate Stock Level vs Production rate Commonality of parts vs Customer needs

At the finished good stockpile, the larger the inventory, the easier it is to satisfy very high service level (availability of goods) The dilemma here is how much service level is optimal in order to minimize inventory while making customers satisfied

The same question arises when it comes to expenses for rush orders It is necessary to evaluate how important is the rush order to customers and adjusting the trade-off

At the distribution centers, there is an unavoidable balancing between distribution decisions (size, frequency and consolidation of shipments) and inventory cost. The more frequent and large the shipments, the least the inventory cost but the higher the distribution costs A major analysis has to be done in order to minimize the sum of the costs while maintaining a desired service level

In some very irregular markets, accurate forecasting can help tightening the flow of material but can be very expensive It is sometimes cheaper to maintain inventory than to use more sophisticated forecasting techniques In turn, this might affect the production quantity The tighter the forecasting period, the smaller the production quantity but the higher the production costs Also, short production runs might minimize the level of stocks but the change-over cost might outweigh some higher inventory cost

Finally, manufacturing would benefit greatly from a high commonalities of parts in the case of multiple products This has to be balanced with the needs and requirements of customers for specific and tailored design It is worth noting that the particularity of integrated logistics does not properly reside in the existence of the trade-offs described above but in the fact that these trade-offs become a part of the organizational culture They have always been a reality since they represent the very core of the decisions within the supply-chain but have been ignored or under-estimated for a long time Integrated logistics offers a constant reference to these compromises at the time of the decision-making.

2.3 The Strategic Content of Integration

The term "supply-chain" is somehow ambivalent On the one hand, it is used to illustrate the chain of supplier-customer relationships that exist between all the functions of a manufacturing firm On the other hand, it is used to represent the network of organizations that together contribute to the marketing of a product This differentiation is useful in determining the strategic impact of integration In the first case, the major advantage of integration is operational In the second, beyond the operational advantages, there are some strategic implications that one needs to be aware of

Companies have followed two different ways to achieve co-ordination within the network by means of integrating partners First, the creation of obligational contracts by which firms commonly and legally agree on an on-going co-operative relationships Second, the vertical integration of some organizations in order to multiply the in-house functions Both carry advantages and disadvantages and must be applied in certain favourable situations The interested reader should refer to Ellram (1991) for a complete review on the subject According to Ellram, Supply-Chain Management (SCM) offers a third alternative to integration This alternative would have advantages that are shared with both obligational contract and vertical integration while reducing the disadvantages caused by both the traditional approaches Table 2 3 presents a summary of these factors as well as the situations in which SCM fits

TABLE 2.3: SCM AS AN ALTERNATIVE TO CLASSIC INTEGRATION

Advantages Which SCM shares with Vertical Integration and Obligational Contracts	Disadvantages of Vertical Integration and Obligational Contracts reduced by SCM	Situations where SCM would fit
Vertical Integration Co-ordination and control Communication Goal congruence Uncertainty Reduction (Improved Assets Utilisation, Economies of Scope)	**Vertical Integration** Exclusive asset ownership Generate all own technology Diseconomies (Scale, span of control) Reduced "market" incentive to perform Exit barriers	Recurrent transactions requiring moderately specialised assets Recurrent transactions requiring highly specialised assets
Obligational Contracts Risk sharing (Spread asset ownership) Uncertainty reduction (Commitments to price, to quantity and quality, information sharing future orientation) Reduced barriers to entry (Not required to own all assets) Increased flexibility in comparison to ownership	**Obligational Contracts** Limited to dyadic co-ordination and control . Duplication of efforts . Difficult to manage multiple relationships Difficult to transfer due to relationships dependence	Operations under moderately high to high uncertainty

from Ellram (1991)

Without going into a detailed analysis, it should be noted that both recurrent transactions and uncertainty fit well with the SCM concept since they create respectively a desire for a long-term commitment and a need for increasing reliability between partners Finally, specialization of assets plays an important role since it requires both heavy capital investment and high technological skills that might be too costly to bring in-house In such a case, the integration of partners for long-term objectives might well be the key to success

2.4 The Barriers to Integration

In view of the many advantages that offer integration of the logistics chain over traditional and fragmented logistics, it is surprising to observe that only a few companies have reached the stage of full and successful integration The reason is fairly straight-forward there are many existing barriers that make integration difficult to achieve

First, companies focus on inventory control, order processing and shop floor management which provide no visibility into the real flow of goods and information going through the organization Second, companies are still at a transaction level (implementation) and fail to shift to the planning level coupled with efficient Decision Support Systems Third, management fails to pay attention to the process re-engineering required by the new reality of integrated logistics (Turner, 1993)

As mentioned earlier, functional managers are still making decisions aiming at optimizing their own functions but which are suboptimal for the organisation as a whole Sometimes, they even make decisions that cost more than the profits they generate (Billington, 1994), e g investing in additional capacity for processes that do not represent a bottleneck

Another potential difficulty to overcome is the division of costs resulting from integration. As defined by Sharman (1984), the integrated view of logistics divides costs in three categories of different visibility The most visible are transport and handling costs on which the organization often focuses on attempting to minimize logistics costs Next in visibility are inventory costs which are often underestimated and their tractability poses some problems. Finally, the least obvious and almost always neglected are the costs of forecasting, planning, procuring material and processing orders This division is a potential barrier since it could result in a weak perception of what integration really represents in terms of cost savings and trade-offs As well, the 'total cost' approach of integrated logistics cannot be successfully implemented if this total cost is not perfectly known In addition to this division of costs, today's accounting systems also strengthen the barriers

Lee and Billington (1992) suggested that some of the pitfalls with the effective management of supply-chain inventory can be attributed to eight factors, some of which have already been discussed in our review First, the lack of performance measures for the supply-chain as a single entity Second, an inadequate definition of what customer service is Third, the existence of inadequate delivery status Fourth, organizations still suffer from inefficient information systems Fifth, the ter ncy of some companies to discriminate against some internal customers Sixth, a lack of co-ordination between the functions Seventh, an incomplete analysis of shipment methods and finally, some organizational barriers are still present

In the case where integration is also external, Ellram (1991) suggest that the biggest downfall of the SCM approach is the potential for opportunism that may exist if one partner is only interested in its own benefits and profits from integreation Therefore, partners should be chosen in such a way that the relationships will be mutually beneficial and commitments to potential weak partners should be avoided In addition, I also believe that the necessary integration of information within the chain could represent a threat since it could lead to sharing confidential information Therefore, the selection of partners is an essential challenge of SCM

Finally, since integration is a trade-off process, the balancing often produces conflicting objectives in terms of total cost Table 2 4 presents the impact of some functional decisions on inventory, service level and total cost According to Jones & Rilley

(1984), the conflicts arise due to a lack of common and integral measure of performance and the multiplicity of agents in the supply-chain

TABLE 2.4: AREAS OF CONFLICT FOR INTEGRATION

FUNCTIONAL OBJECTIVES	IMPACT ON INVENTORY	CUSTOMER SERVICE	TOTAL COST
High customer service	Increase	Increase	Increase
Low transportation cost	Increase	Decrease	Decrease
Low warehousing cost	Decrease	Decrease	Decrease
Reduced inventories	Decrease	Decrease	Decrease
Fast delivery	Increase	Increase	Increase
Reduced labor cost	Increase	Decrease	Decrease
DESIRED RESULTS	**Decrease**	**Increase**	**Decrease**

from Jones and Rilley (1984)

2.5 Removing the Barriers to Integration

Although the list of potential barriers to integration is big, companies can use a variety of tools in order to overcome them Lee and Billington (1992) suggested five actions in order to avoid the pitfalls with integrated inventory management They include the need to design mechanisms for SCM, to integrate databases throughout the supply-chain, to redesign organizational incentives, to institute supply-chain performance measures and to expand the view of the supply-chain to external entities

In a similar way, Barry, Terranova and Roetter (1992) presented some suggestions to improve the logistics performance of a telecommunication company They suggested to rationalise the distribution network, to standardize and consolidate material, to manage quality of the supply-chain, to manage inventory and assets more carefully and to define some logistics benchmarks Finally, Scott and Westbrook (1991) offered a three-stage process to reduce the difficulties mapping the pipeline, positioning the organization in terms of suppliers relations and selecting actions to enhance supply-chain effectiveness

2.5.1 Mapping The Pipeline

During this first stage, the organization has for objective to learn what is actually going on within their logistics channel with respect to the flow of material

A good starting point is to measure the total throughput time (length) and the total stock level (width) all along the channel This could help identify activities whose duration could be reduced Since there might be several parallel branches in the network representing the pipeline, one should focus on the critical path where the length is maximum Then, one should identify the cumulative inventory cost, the value-adding activities as opposed to cost-adding ones and the point(s) where product flexibility is reduced (specialization of materials) This can also be achieved by representing the variety funnel to identify where there is explosion of product variety. Finally, compare the pipeline measures (width, length and the sum of both, the volume) with industry averages to get an idea of comparative performance

2.5.2 Organization/Suppliers Positioning

It is possible to measure the relationships according to two dimensions: the number of suppliers and the closeness of the relationships Ideally, a firm should replace the concept of 'buying' by the one of 'collaborative product development' However, this does not mean, in terms of the dimensions cited above, that being very close to a single source is the best It is sometimes wiser to ensure second source of supply to reduce the dependence The positioning is therefore contingent upon the nature of the supply and the characteristics of the suppliers Typically, the relationships are determined according to some factors and the following list is illustrative, not exhaustive. extent of dependence of the supplier on the chain, longevity of the relationships, technological links, existence of legal agreement and complexity of the chain

2.5.3 Enhancing Supply-chain Effectiveness

The key idea is to manage forward and backward flows of information and materials in such a way that the existence of a single entity is not only conceptual but also physical With this in mind, it is possible to gradually modify the shape of the pipeline to reduce lead-times, inventories and increase reliability. Finally, the development of some common measure of performance should be done according to the new nature of integration

3. INTEGRATED CONTROL OF FLOWS IN ACTION

As mentioned earlier, the key to a better competitive position is to maintain a total control over the costs all along the supply-chain This control should be permanent and over both the flow of material and the flow of information to ensure operational integration and managerial co-ordination

To illustrate these requirements, it is interesting to look at two concepts that have emerged at both the academic and professional levels Supply-Chain Management (SCM) and Material Logistics Management (MLM)

3.1 Fundamentals of Supply-Chain Management

The Supply Chain Management concept differs from classic materials and manufacturing control in four respects First, it views the supply-chain as a single entity rather than a collection of fragmented functions Second, it calls for strategic decisions making at each level since "supply" is an objective that is shared by all the channel partners, should they be in-house functions or external entities Third, it requires real integration and not simply interface Finally, it offers a different perspective on inventories as the last and not first resort as balancing mechanism (Oliver and Webber, 1982)

Scott and Westbrook (1991) offer three blocks for integration First, to recognize end customer service level requirements Second, to determine the optimal level and position of inventories in the supply-chain Finally, to develop policies to manage the supply-chain as a single entity Bill Perry cited in Turner (1993) sees three tools for a successful integration within the Supply Chain First, the use of consistent and time-phased planning tools at each level of the supply-chain like Distribution Resource Planning or MRP II Then, the integration of the information systems in order to push demand from one echelon to the next. Finally, the creation of effective and timely communication between echelons.

As a summary, one can adopt the list given by Herbert Davis and Co. (Turner, 1993) This list, presented in table 3 1, identifies several key building block systems to implement integrated SCM

TABLE 3.1: KEY BUILDING BLOCKS FOR SCM

Order Management
Forecasting
Distribution Resource Planning (DRP)
Warehouse & Inventory Management
Manufacturing Planning/Production Control (MRP II)
Integrated Logistics Research

3.2 Fundamentals of Material Logistics Management

The concept of Materials Logistics Management (MLM), developed at the University of Michigan, has for principal goal a better co-ordination and integration of the logistics channel by means of five objectives First, a need to control customer service performance. Second, to control product quality Third, to reduce variance (uncertainty) all along the supply-chain Fourth, to ensure minimum total cost of operations and procurement Finally, to reduce inventory levels (Bowersox, Carter and Monczka, 1984)

In order to take advantage of the integrated concepts, it is necessary to identify the key functional issues that could help this integration becoming a successful reality in organizations. Table 3.2 presents these functional issues, as recommended by the MLM concept

TABLE 3.2: KEY BUILDING BLOCKS FOR MLM

Functions	Areas of Improvement
Physical Distribution and Customer Services	Accuracy of forecasting Order substitution acceptance Distribution schedule Consolidated transports Postponement of orders
Manufacturing	Master Schedule Management Just-In-Time scheduling Flexibility
Purchasing	Supply Management Schedule of requirements Responsiveness

Adapted from Bowersox, Carter and Monczka (1984)

3.3 Realities of Integrated Logistics

So far, I have given the conceptual reasons and advantages that recommends the integration of logistics It would then be relevant to illustrates the concept by showing how different the integrated approach is from the traditional one

3.3.1 The Case of Finished Goods Inventory

Inventories are often ironically defined as a blanket hiding the imperfections resulting from cross-functional conflicts These conflicts arise at every level and the most famous one is certainly the one existing between marketing and manufacturing Traditionally, marketing is reluctant to deny customers and wishes to provide all customers with the highest service level and a large variety of goods at the lowest cost and lead times In opposition to that, manufacturing wants to keep things simple, increase standardization of products to allow more steady and economical production

The traditional way of solving this conflict is to build inventories of finished goods thus giving marketing availability of products and allowing production some economies of scale (Bowersox, Carter and Monczka, 1984) The principal risk, in addition to the high cost of capital frozen in stocks, is to ship the wrong product at the wrong time to the wrong people The integrated view suggest that this conflict be eliminated or at least greatly reduced first by improving accuracy of forecasts (use of electronic data interchange -EDI- to get a better "feeling" of sales or better forecasting methods). However, this might not be the panacea since forecasting does not totally hedge against market aberrations

Another way to reduce the conflict is to postpone product and market specialization and to increase product and market flexibility The later the material becomes earmarked for a specific finished goods, the greater the product flexibility Similarly, the later the product becomes earmarked for a specific customer zone, the greater the market flexibility Increased product flexibility allows longer production runs of the "neutral" product to gain economies of scale while giving marketing a variety of products almost available for sale after some minor processing. Increased market flexibility allows a quicker response to unusual demand in a set of traditionally separated customer zones I later review specifically the strategic value of this inventory, the decoupling point that separates forecast driven activities from planning driven activities.

Finally, following the concepts of product flexibility and market flexibility, the decentralization of product specialization activities is another efficient way to reduce the total stock value in the supply-chain A recent application has been done at Hewlett-Packard (Lee, Billington and Carter, 1993) To reduce investments in inventories at the distribution center for Europe and Asia, the authors have evaluated the impact of decentralizing the assembly of country-specific components such as power supply and user's manual at the distribution center This resulted in a total decrease in inventory cost of 21% while maintaining a high service level Under this decentralized approach, if demand for one type of product in a certain market became higher than forecasted, supply could come from the distribution center inventory after assembly of country-specific components. The existence of a common inventory of non-specialised products allowing a faster response to demand and a lower total inventory of the core product Overall, a greater flexibiltiy is achieved at a more competitive cost

3.3.2 The Case of Service Level

With the increasing competition, customers are getting more demanding in terms of service level A US-based multinational pharmaceutical company was facing this problem due to relatively poor delivery performance (Oliver and Webber, 1982) Marketing blamed manufacturing for insufficient productivity and poor scheduling In turn, manufacturing blamed marketing and purchasing for unreliable forecasts and long purchasing lead-times

A classic logistics approach would have been to decrease total production lead time by reducing capacity bottleneck This might have solved the problem but there was no evidence that lead time reduction was what customers wanted

The integrated approach first recommended a survey to find out the exact value of both lead times and delivery reliability to customers When it appeared that customers valued reliability very highly and lead time relatively lowly, the company took actions to increase delivery reliability

3.3.3 The Case of Demand Uncertainty

The same pharmaceutical company was also facing another problem with distributors ordering more often and in smaller quantities This resulted in orders being filled by the distribution centers (DC) rather than by the manufacturer directly A traditional approach would have been to increase production rate to reduce raw materials and work-in-process inventories in order to increase the DC's inventory since management did not want to increase the total value of inventories within the supply-chain

The integrated approach calls for a different solution involving all functional groups within the channel They identified that an increase in forecasting accuracy combined with improved distribution policies and plant scheduling could solve the problem The traditional way of building inventory was therefore left aside. This resulted in a total improvement of the service level from 60% to 75% with no change in inventory turnover and production rate.

As these examples demonstrate it, the concept of SCM allows to solve problems by co-ordinating actions between functions, and avoids the easy way-out, namely stock build-up It requires more effort than the traditional approach of logistics, but results in supply-chains that are more effective, more flexible and more efficient.

3.4 The Decoupling Point

The majority of the concepts presented below have been exposed in Hoekstra et al (1991). The interested reader should refer to the source for a more detailed analysis

3.4.1 Definition

A key concept in logistics is the one dealing with the decoupling point (DP) or sometimes called the order-penetration point (OP) It is defined as the point at which a product becomes earmarked for a specific order or, equivalently, the point where product specification gets frozen and separates the part of the organization driven by customer orders from the part based on planning In other words, it is how deep a customer order penetrates into the supply-chain

With respect to inventories, it is the last point at which inventory is held in the supply-chain (Sharman, 1984) There should be no stock downstream and only upstream if it is economically justified In terms of Material Requirements Planning, it is the place where independent demand is converted into dependent demand Therefore, it allows a certain degree of freedom to optimize the upstream activities independently from irregularities in market demands The DP is often called 'distribution stock' since it absorbs the fluctuations in demand and is therefore both a point in the supply-chain and a major inventory.

3.4.2 Determining Factors

It should be noted that there is no single DP for all the products within a company Rather, each product can have its own optimal DP

3.4.3 Possible Positions of the Decoupling Point

Depending on the nature of the business, there are five possible positions for the DP In a make and ship to stock business, the DP or last inventory in the supply-chain will be located at the retailers In a make to stock business, the DP will be at the finished goods stockpile In an assemble to order business, the DP will be Work In Process inventory In a make to order business, raw materials and components inventories will represent the DP Finally, if it is a purchase and make to order, the DP will not physically exist since there would be no stock at all in the supply-chain As a rule of thumb, the positioning of the DP is a balancing between investments that occurred upstream the DP and the service level desired downstream

TABLE 3.4: FACTORS DETERMINING THE DECOUPLING POINT

Market	Requirements for speed and reliability of delivery Geographical span of customer base Predictability Competitive pressure
Product	Complexity and cost Degree of specialization (vs standardization) Product life cycle (risk of obsolescence)
Process	Lead time vs delivery time Lead time and cost of steps in primary process Controllability of manufacturing and procurement Cost of stock holding Value added between stock

Adapted from Hoekstra et al (1991)

3.4.4 Effects of Integration on the Decoupling Point

Given that the DP or OP represents how deep a customer order penetrates into the supply-chain, it would be logical to believe that the higher the co-ordination between functions in the supply-chain, the deeper (more upstream) the order penetrates. Effectively, experience confirmed this tendency and the ultimate penetration would be total with no stock at all as suggested by the Just In Time philosophy. In such an environment, any order will pull the activities in the supply-chain so far upstream (procurement) that 'zero stock' (no physical DP) will be held within the chain

However, I already noted that the JIT concept might not be truly applicable in the Western world due to the structure of the economy Therefore, the DP plays a strategic role in the case of integrated logistics since it allows to respond more rapidly to market irregularities

In fact, the concept of the decoupling point represents the separation between what industrial theory could suggest to logistics management and what the company is actually facing given its process, procurement and delivery capabilities There is no point in trying to move the DP further upstream if the rest of the company suffrers form this action Rather, the use of analytical tools like simulation should help a firm to test different positions for the DP and to conclude on what is the optimal location, given the company's characteristics

A last but important remark should be made in order to differentiate the existence of the DP and the supply-chain strategy consisting in a decoupled production-delivery decision making The former recognize the need for a strategic inventory within the supply-chain The latter implies that botl activities, production and delivery, are optimally scheduled independently and delivery is organized according to the optimal production plan This fragmented approach, sub-optimal as I exposed it earlier, is the decoupling of two activities that should be linked within the supply-chain This is why under the integrated logistics approach, the existence of a main stocking point in the supply-chain is not contradictory to the co-ordination of activities With this in mind, I prefer the strategic definition of 'last major inventory' given to the DP to the one of 'separation of upstream and downstream activities' One refers to a capability for the firm to absorb fluctuation in demands, the other referring to a traditional fragmented view of the logistics chain

4. ANALYTICAL TOOLS FOR INTEGRATED LOGISTICS

To fully discuss the integrated logistics concept in action, it is necessary to realize that its implementation requires the use of scientific tools Although the objective of this paper is not to address the issues in information systems technology, one should be aware of the importance of them to support the efficient management of the integrated logistics channel. By looking at the practices in the industry, the growing investments in information systems illustrates the need for more efficient data management The evolution is toward the use of Decision Support Systems (DSS) in which information is collected and analyzed according to the user's needs For integrated logistics, the DSS should allow any user to know instantaneously what is happening with the flow of materials and the position of a particular order in the logistics chain As components of the DSS, optimization models and simulation appear to be the most recommended tools

4.1 Optimization Models

As written by Shapiro (1992), "Optimization models are the only analytical tools capable of fully evaluating large numerical databases to identify least cost, or demonstrably good logistics strategies" These models, varying from simple deterministic linear ones to stochastic non-linear ones, help management in evaluating the set of trade-offs imposed by good logistics management and offer optimal or at least most satisfying solutions to strategic and tactical concerns Deriving from the early concepts of Economic Order Quantity and optimal sequencing of production or distribution activities using linear programming, the models have gone through a substantial evolution The independent optimization of functions has been replaced by the simultaneous determination of optimal policies for two functions such as the integration of buyers and vendors lot sizing, of production and distribution scheduling, of inventory (finished goods stockpile) and distribution policies We will review them in section 4.1.1.

Subsequent to the development of these models, academics attempted to extend the integration to more than two functions to reach, ultimately a total integration of the supply-chain As one will observe, there is still room for improvements in both the scope of the models and their ease of use for managers but the latest developments are very promising

4.1.1 Two-step Integration

4.1.1.1 Buyer-Vendor Integration

Many articles have been published with respect to the first integration in the supply-chain, the procurement These articles cover different integration and co-ordination, with and without the determination of the optimal simultaneous order quantity The interested reader should refer to Goyal and Gupta (1989) for an extensive review of integrated inventory models dealing with buyer-vendor co-ordination. We will limit ourselves to reviewing the models which deal with the co-ordination of inventory by simultaneously determining the order quantity of the buyer and the seller

All of the models presented below share the following assumptions. The demand rate is independent of changes in price of the item and is continuous; the inventory policies of both the buyer and the vendor are described by simple EOQ models, the demand for the item is deterministic and the replenishment lead-times are either deterministic or null (instantaneous replenishment), no shortages or backorders are allowed and the vendor knows buyer's holding and ordering costs by guessing through the ordering pattern Since the price of the item is given, these models do not allow for determining a pricing policy The major objective of the models is to find a joint economic order quantity that minimizes the total relevant cost for both the vendor and the buyer. It is worth reminding that integration of the supply-chain can only take place efficiently if there is mutual benefits for both parts

Monahan (1984) demonstrated that the vendor can entice his customer to increase the EOQ by a factor k by offering a price discount to compensate for the increased inventory expenses. The major assumptions were a lot-for-lot policy, the price of the item as decision variable and no constraint on the amount of discount offered In his model, the vendor's frequency of order processing and manufacturing set-up is the same as the buyer's frequency. As well, the vendor's inventory and carrying costs are unaffected by the buyer's ordering frequency Rosenblatt and Lee (1985) relaxed Monahan lot-for-lot policy assumptions They demonstrated that the vendor's EOQ is an integer multiple of the buyer's EOQ Their model is based on a linear discount schedule to determine the optimal pricing policy Lee and Rosenblatt (1986) formulated a model by assuming that the vendor's processing cost of the buyer's order is negligible compared to the vendor's set-up cost As well, they generalized Monahan model by limiting the amount of discount that the vendor can offer. Goyal (1987a) criticized Lee and Rosenblatt (1986) for the constraint on the amount of discount that the vendor can offer He demonstrated that a higher volume may lead anyway to greater economies for the vendor Goyal (1987b) determined the vendor's EOQ by taking into account the amount of quantity discount to be offered He assumed constant holding cost, independent of the amount of the discount offered

The table below summarizes the models described earlier with respect to simultaneous determination of the EOQ

Buyer-Vendor Integration (Simultaneous EOQ)
Monahan (1984) Rosenblatt & Lee (1985) Lee & Rosenblatt (1986) Goyal (1987a, 1987b)

4.1.1.2 Production-Distribution Integration

These models can be classified into two different categories. First, those dealing with the planning of both the production and the distribution activities with or without a wholesaler as intermediary echelon and under either deterministic or stochastic demand Second, those dealing with the integration of production and vehicle routing.

* Production-Distribution Planning

King and Love (1980) described the implementation of a co-ordinated production-distribution system at a major tire manufacturer with four plants and nine distribution centers in the US The system resulted in a reduction of annual cost by almost $8 million and drastic improvements in overall lead-times, customer service and average inventory levels J Williams (1981) developed a joint scheduling of production and distribution in a complex network aiming at minimizing the average production and distribution cost per period The demand rate was assumed to be constant and the model used dynamic programming T M Williams (1984) described a system consisting of a manufacturing facility and a finished goods stockpile under a 'pull' approach and stochastic demand He analyzed the problem of expediting, the allocation of capacity, quantity to stock and the amount of make-to-order business to accept Blumenfeld et al. (1987) modelled the scheduling of production and distribution for a parts producer supplying a final assembly manufacturer. They showed a reduced cost by up to 42% with maximum savings when the item value, the demand and the variable costs are the same for all items. They assumed one destination per part type, fixed transportation cost per shipment and identical production cycles each including a production run of every parts The application of their research at the Delco electronics division of General Motors led to a 26% reduction in total logistics cost

Pyke (1987) developed an analytical model of a simple 3-node system to examine the properties of the cost function in the case of a single product Expediting is allowed at the production facility but he provided no issues on cost of transportation, nor timing, from the stockpile to retailers. Ishii, Takashi and Muramatsu (1988) described the determination of economic levels for the base stock and lead-times under a 'pull' type ordering system in order to minimize the amount of 'dead stock', products left over at the end of the product life cycle Pyke and Cohen (1990a) modelled an integrated production-distribution system to illustrate push from pull policies and the effects of expediting under stochastic demand

Pyke and Cohen (1990b) offered a simulation model to discuss the effect of flexibility on the level of stocks within the supply -chain Defining flexibility as the capacity of either reducing manufacturing set-up times or expediting orders, they observed that the set-up time reduction is more powerful than expediting The performance measure used was the level of inventory in the distribution system and the demand was stochastic Pyke and Cohen (1990c) analyzed the case of a single product, three-node system consisting of a factory station, a finished goods stockpile and a retailer with multiple products under stochastic demand Pyke and Cohen (1993) examined the performance characteristics of the model used in (1990c) to address the key trade-offs of batch production size

* Production-Vehicle Routing Integration

This problem has not been extensively studied and only one example integrates the problem of vehicle routing with the one of production planning Chandra and Fisher (1992) co-ordinated the capacitated lot-sizing problem at the plant and the reduction of distribution cost to serve a set of geographically disbursed customers having deterministic demands They assumed the case of several products and a single plant as well as fixed vehicle cost per route

The following table presents a list of the existing models dealing with the integration of production and distribution

Production-Distribution Integration	
Production / Distribution	**Production / Vehicle Routing**
Deterministic Demand King & Love (1980) J Williams (1981) Blumenfeld et al (1986), (1987) Ishii, Takashi and Muramatsu (1988) **Stochastic Demand** T M Williams (1984) Pyke (1987) Pyke & Cohen (1990a,b,c),(1993)	Chandra & Fisher (1992)

4.1.1.3 Finished Goods Stockpile -Distribution Integration

These models have for common objective to minimize the total cost of inventory and distribution by deciding the replenishment policy at the warehouse and the distribution schedule for each customer Often, they offer an analysis of the trade-off of a reduction in inventory cost versus an increase in transportation cost

Bell et al (1983) developed a computerized multi-period co-ordinated model in order to integrate inventory control and distribution scheduling Federgruen and Zipkin (1984) modelled a one-warehouse, multiple-retailer system for a single planning period with random demands at the retailers. Burns et al (1985) developed an infinite horizon co-ordinated model for the model described below in Chandra (1990) Dror and Ball (1987) reported heuristic solution for co-ordinated multi-period models. Chandra (1990) did the same, assuming a finite planning horizon of discrete time periods He allowed shipment before the due dates but not after He reported some substantial savings compared to a non-coordinated approach His model is particularly relevant when transportation costs are an important part of the total cost for the firms Anily and Federgruen (1990) modelled Chandra (1990) problem where one warehouse supplies several geographically dispersed customers gathered in "regions" Each time a customer in one region is visited, the vehicle visits all other customer in the given region They presented heuristics for computing the upper and lower bounds on the system cost but did not address the case of stochastic demands or the role of safety stock at different locations

The following table lists all existing models dealing with the integration of finished goods stockpile inventory and distribution

Finished Goods Stockpile-Distribution Integration
Bell et al (1983)
Federgruen & Zipkin (1984)
Burns et al (1985)
Dror & Ball (1987)
Chandra (1990)
Anily & Federgruen (1990)

4.1.2 Toward Total Integration

Attempts to build models of the entire supply-chain are few and it is expected that future researches will go in that direction since it represents the ultimate integration These models take into account the major activities from procurement of raw materials and components to distribution

Hanssmann (1959) described what is considered as being the earliest attempt to link material procurement, production and distribution in a complex network with normally distributed stochastic demands The objective of his work is to identify the optimal inventory at each functional level within the supply-chain His assumptions, constant production times independent of lot size reduces the applicability of his model. So does the nature of his objective functions including sales revenue and inventory carrying cost only Lee and Billington (1992) offers insight on the management of supply-chain inventories and the related difficulties Lee and Billington (1993) described what manufacturing managers at Hewlett-Packard Company identify as needs to use modelling support in supply-chain management. They present a model and its implementation for decentralized supply-chain and report some overall reduction in logistics cost by more than 20% Cohen and Lee (1988) described a framework for linking decisions and measuring performance throughout the entire supply-chain Since it appears to be the most comprehensive and complete approach to represent the integrated logistics concept, a detailed description of the model is presented below

4.1.2.1: Cohen and Lee (1988) Integrated Supply-chain Model

The model is composed of four approximate stochastic and tractable sub-models that are then linked together The overall objective is to minimize total cost while using stockpile service levels at each of the four sub-models They consider three types of demand , direct from customers, normal replenishment from stocking point and expedited from stocking point

* Model Structure and Formulation

The system is represented as a network which is formulated as a stochastic and hierarchical model made of four sub-models having specific control parameters meeting some specific targets These sub-models, each representing a part of the supply-chain, are material control, production control, finished goods stockpile and distribution network control

* Overview of the Model Structure

In order to optimize the overall system, a decomposition approach has been adopted by the optimization of each sub-model according to some specific service target

These levels would then be used as linkages between the various sub-models in the final attempt to optimize the overall logistics chain

The material control submodel allows for stochastic demand and supply lead times from vendors. It takes into account set-up costs, holding costs, shortage costs and the impact of stockout on production The objective here is to determine optimal ordering policies and the output obtained represents the service level for raw material availability at the production stage.

The production submodel includes queuing relationships for each work center so that the lot size is related to the time spent in the queue waiting The lot size represents the optimal trade-off between Work In Process (WIP) holding cost and production processing cost including set-ups The objective here is to determine optimal lot sizes for each finished product on each product line

The stockpile submodel considers replenishment under fixed batch size filled after the production lead-time has elapsed The objective is to find the best replenishment policy so that the lead-time for delivery to the distribution system is optimized according to some holding cost Finally, the distribution submodel, linked to production by the replenishment lead-time at the stockpile, determines the optimal distribution policy to meet some customer fill rate service level under stochastic distribution lead-time but deterministic demand.

* The Mechanism of Integration

As described earlier, the overall objective is to define an optimal policy for the management of the entire supply-chain by the use of four submodels independently optimized This implies then that all submodels be linked together so that the decisions made at one level affect in turn the decisions to be made at the subsequent level

The material control submodel determines the availability of raw materials for production which directly links both submodels since any shortages would result in production delays, affecting the production lead-time As well, production lot size decisions will affect the demand pattern for raw materials so that the interaction between these two submodels goes both sides

In turn, production lot size affects the availability of products to be stored in the stockpile at each plant On the other hand, replenishment of stockpiles represent an order for production which eventually translates to demand for raw materials

Finally, the availability of products in the stockpile will determine the availability of products for delivery This way, the replenishment lead-time of stockpiles will affects distribution lead-times as well as distribution stocking policies The ultimate backward interaction consists of the demand for finished products at customer levels affecting distribution stocking policies which in turn influences stockpiles replenishment and so on until the first node, material control, is reached

* Procurement

The procurement policy assumes a continuous review inventory control policy so that the inventory position is in the interval [R+1, R+Q]. The amount of raw material requested depends on the requirement for the production batch size of the end-product and backorders are allowed. Production is in batches of size Q and the requirement for raw material is rQ with r the need for materials for each batch. The demand request for raw material follows a Poisson distribution with mean rate the ratio of the average production required over the batch size. The total cost is a sum of material, inventory and backorder costs Service level and stockout probability are included in the model to evaluate the product-specific material delay time.

* Production

The model represents a serial multistage, multiline production process The principal objectives is to account for both the total production lead-time (weighted sum of set-up times, processing times, material delay times and waiting times at the workstations) and the total production cost (sum of set-up, processing and holding cost for the product)

* Stockpile Inventory

A (Q, R) inventory control system is assumed where R is the trigger point at which a production request is initiated The time unit is one review period for distribution Both normal and expedited replenishment transportation lead-time are taken into account to calculate the overall expected replenishment lead-time.

* Distribution

Each stocking facility in echelons is related to a unique distribution center for resupply Demands for products are either normal customer demand or replenishment demand from stocking points or expedited demand for stocking points and the total cost under service level is calculated in this submodel

* Algorithms & Solving Procedures

It is somewhat obvious that the true optimal policy should be derived from the solving of the four sub-models simultaneously However, this would lead to a constrained, non-linear optimization problem which is not tractable

Rather, the approach taken here is to solve each model independently to derive approximate optimal production and material resupply lot sizes This is obtained by searching for lot sizes over a range centered around the EOQ, selecting the ones giving the best performance for a combined material plus production plus stockpile cost function Each respective lot size for production and stockpile is determined, the one for raw materials being derived from the material control submodel

The following table list the existing models dealing with total integration of the supply-chain and a general summary of the models dealing with the integration issues that have been presented in section 4 is presented in Table 4 1

Toward Total Integration
Hanssmann (1959) Cohen and Lee (1988) Lee and Billington (1992,1993)

TABLE 4.1: SUMMARY OF LITTERATURE REVIEW ON THE INTEGRATION OF THE SUPPLY-CHAIN

OPTIMIZATION ISSUES

LEVEL OF INTEGRATION	DECISION ISSUES	AUTHORS	APPROACH	FUTURE DIRECTIONS
BUYER & VENDOR	- Establish a simultaneous EOQ for both the vendor and the buyer by showing the trade-off of an increase in inventory costs versus price discount for larger EOQ - Minimize overall system costs - No pricing models	- Monahan (1984) - Rosenblatt & Lee (1985) - Lee & Rosenblatt (1985) - Goyal (1987a), (1987b)	- Lot for lot policy Illimited discount - Relaxed the lot for lot policy - Limited amount of discount - Illimited amount of discount EOQ determined as a function of item price & amount of discount	1 Define models under stochastic demand and/or stochastic replenishment lead-times 2 Combine model to determine the EOQ and to define pricing strategies
PRODUCTION & VEHICLE ROUTING	- Coordinate the capacitated production lot size problem & the reduction of distribution costs	- Chandra & Fisher (1992)	- Formulation of a model including distribution policies to serve a set of geographically dibursed customers having deterministic demand Several products, one single plant & fixed vehicle cost per route	Integration of production, distribution and vehicle routing problems for multiple item & multiple plant situations under either deterministic or stochastic demand

Table 4.1 (cont'd)

LEVEL OF INTEGRATION	DECISION ISSUES	AUTHORS	APPROACH	FUTURE DIRECTIONS
INVENTORY & DISTRIBUTION	- Minimize the total cost of inventory and distribution by deciding replenishment policies at the warehouse and distribution schedules for each customer - Analyze the trade-off of a reduction in inventory cost versus an increase in transportation cost.	- Bell et al (1983) - Federgruen & Zipkin (1984) - Burns et al (1985) - Dror & Ball (1987) - Chandra (1990) - Anily & Federgruen (1990)	- Computerized multi-period coordinated model - A one-warehouse, multiple retailers model for a single planning period under stochastic demand. - Infinite horizon coordinated model for problem described in Chandra (1990). - Heuristics solutions methods for coordinated multi-periods models - Heuristics solutions to a coordinated multi-period model with finite horizon of dicrete time periods. - Deterministic model using Chandra (1990) with clustering of customers and touring distribution	1. Develop exact solutions for these problems 2. Integrate the inventory-distribution problem with other functions across the supply-chain

Table 4.1 (cont'd)

LEVEL OF INTEGRATION	DECISION ISSUES	AUTHORS	APPROACH	FUTURE DIRECTIONS
PRODUCTION & DISTRIBUTION	- Establish a joint production and distribution planning schedule in order to minimize the overall "system cost" under deterministic conditions	**Deterministic Demand** - King & Love (1980) - J. Williams (1981) - Blumenfeld et al (1986), (1987) - Ishii, Takashi & Muramatsu (1988)	- Case-based description. - Dynamic, deterministic network - Formulation for one destination per product & fixed transportation costs. - Minimize "dead stock" inventory	1 Integrate these models with some vehicle routing models
	- Analyze special problems such as expediting, make-to-order business and comparison of pull and push policies	**Stochastic Demand** - T M Williams (1984) - Pyke (1987) - Pyke & Cohen (1990a,b,c),(1993)	- Stochastic 2-node problem to analyze expediting, capacity and make-to-order volume - Simple 3-node system to examine the properties of the cost function, single product - Stochastic model to compare pull and push policies and the effects of expediting Simulation of stock level flexibility Stochastic 3-node -batch production system for a single product	2 Build models under stochastic demand and stochastic production lead times

Table 4.1 (cont'd)

LEVEL OF INTEGRATION	DECISION ISSUES	AUTHORS	APPROACH	FUTURE DIRECTIONS
TOWARD TOTAL INTEGRATION	- Coordinate the entire supply chain in order to achieve optimal logistics cost	- Hansmann (1959)	- Complex procurement-production-distribution system with normally distributed stochastic demand Identify optimal inventory level at each functional level	1 Depart from Cohen & Lee to adapt assumptions and model structure to specific cases
		- Cohen & Lee (1988)	- Model composed of four stochastic but tractable submodels related to supply, production, warehousing and customers. Submodels are then linked together to minimize the overall cost.	2 Integrate vendors and location -routing issues in the framework
		- Lee & Billington (1992, 1993)	- Insights on supply-chain inventories management difficulties Model for decentralized supply-chain	3 Trace the properties of the complete supply-chain under stochastic conditions

4.2 Simulation Models

Simulation is another tool which is very helpful in the design of supply-chain Towill, Naim and Wikner (1992) reported how the use of simulation can help a firm to find the best configuration of its logistics chain in order to achieve the desired service level given the constraints imposed to the organization Once the model is built, a series of 'what-if analysis' allows the user to evaluate the impact of different decisions on the performance of its logistics chain

Newhart, Stott and Vasko (1993) suggested that both simulation and optimization methods could also be used in a separate but complementary manner to design the optimal supply-chain Their approach consisted of first using mathematical programming to minimize the number of products held at different positions in the supply-chain and then using spreadsheet simulations to estimate the need for safety stock with randomly distributed demand and lead times

Finally, there is a growing interest for the combination of the 'what's best' method of optimization and the 'what if' of the simulation It allows the use of rather simple optimization models which bring some type of 'intelligence' to the simulation As well, it allows the generation of stochastic transactions in a more tractable manner than with stochastic optimization models I believe that the combination of both could better serve the actual implementation of the integrated logistics concept since pure optimization is often too time-consuming to be used as a tactical tool and pure simulation lacks some intelligence when it comes to the search of optimality

5. INTEGRATED LOGISTICS: A FRAMEWORK

The preceding pages represent the first objective of this paper, i e an attempt to better understand the foundations of the integrated logistics concept, as well as a presentation of the functional blocks and analytical tools through which successful supply-chain management can be implemented The table presented in the next three pages summarizes the key concepts in an attempt to build a framework that will be applied to our case-study of the logistics at XYZ Ltd , a pharmaceutical company

TABLE 5: A FRAMEWORK FOR SUPPLY-CHAIN INTEGRATION

ACTIVITY	ISSUES
1. Analyzing the existing supply-chain	
Mapping the pipeline	Inventory level and supply-chain leadtime
Analyzing the inventory variety funnel	Product flexibility
Positioning suppliers	Dependency and integration
Screening distribution management	Degree of integration and effectiveness
2. Detecting existing barriers to integration	Functional vs total approach Controlling vs planning Lack of process reengineering Inadequacy of performance measures Low visibility of cost-adding activities Weak definition of customer service Inadequacy of delivery Low efficiency of information systems Biased relationships with internal customers Lack of coordination between functions Incomplete analysis of shipment methods Potential for opportunism Confidentiality of information
3. Building integration with existing tools	
Demand Management	Sales Forecasting Order Management Distribution Resource Planning (DRP)
Supply Management	Master Scheduling Material Requirements Planning (MRP)
Resource Management	Capacity Requirement Planning Schedule Optimization

4. Evaluating trade-offs of integration	
Cross-functional trade-offs	Process cost vs design cost Inventory cost vs market share Feasibility vs time to market Procurement cost vs production cost
Operational trade-offs	Inventory cost vs service level Cost of rush orders vs value to customers Inventory cost vs distribution cost Forecasting cost vs process rate Forecasting cost vs inventory cost Stock level vs production rate Commonality of parts vs customer needs
5. Achieving effective integration	
Functional	Achieving excellence within functions Understanding impact of integration
Operational	Initiating cross-functional coordination Defining common performance measures
Tactical	Achieving total internal integration Reducing total logistics cost Increasing service level Positioning the decoupling point
Strategic	Full integration of external agents Integration as a corporate strategy

PART TWO

SUPPLY-CHAIN ISSUES IN THE PHARMACEUTICAL INDUSTRY:

A CASE STUDY

1. PARTICULARITIES OF THE PHARMACEUTICAL INDUSTRY

If this industry has always considered itself as a special case in the manufacturing world, it is because the number of constraints imposed on it These constraints can be classified into two categories, environmental and operational

1.1 Business Environment

In a large multinational pharmaceutical company, the business environment presents ten key difficulties

First of all, this industry suffers from heavy pressure from governments when it comes to cost control, pricing and marketing In many developed countries, the gratuity of medical care and the reimbursement of medicines by governmental programs represent one of the largest contributors to national deficits As it is often quoted, the difficulty with medical care budgets is the absence of budgeting since no definite amount can be decided in advance as it can be done for other expenses like military or educational programs As a result, since it is difficult to control the consumption of medicine, governments have decided to control the cost of this consumption Heavy pressures are now on pharmaceutical companies to better control their cost and to reduce their margins In addition, it should be stated that marketing medicines in the home country or abroad is influenced by political reasons and product superiority and competitiveness are not the only deciding factors for a successful expansion

Second, while companies are asked to decrease their margins and their return on investments (essentially research costs), the cost of research and development is getting higher and higher. New challenges like AIDS illustrate the difficulty and time required to develop a cure

Third, the long development lead times are not accompanied by longer patent protection period For example, twenty years ago, a medicine would have taken five years to be developed and under a twenty-year patent protection period, the company would have enjoyed 15 years of exclusivity on the market Today, it easily takes ten years to market a new product so that the exclusivity is reduced to ten years Under these circumstances, the ratio of time-to-development / time-to-harvest has tripled which could easily affects profitabilty since prices are more constrained than they used to be

Fourth, there is increased competition among fewer companies since the world-wide market is dominated by less than a dozen of multinational companies This regrouping of companies is easily explained by the need for financially stronger organizations, covering wider geographical segments. As medical care progresses, there are fewer diseases needing discovery of a cure which increases the competition on fewer market niches

Fifth, the growing number of markets is translated to increasing number of product variety and packaging diversity This not only reduces the opportunities for economies of scale but also increases the complexity of supply, production and packaging planning with shorter production runs of greater variety In addition, the transportation costs are higher which brings the logistics cost of pharmaceutical activities to a level having no antecedent

Sixth, the raw materials are more and more specialised This means longer development and production lead times with increased costs for these materials, especially for the active ingredients which represent the core of the medicine

Seventh, the pressure on product life cycle due to increasing R & D lead times and shorter pay-back period is accompanied by a reduction of the technology life-cycle. Since ethics are a growing concern for pharmaceutical industries, the transfer of technology to less advanced countries in the world occurs more often and at an earlier period of the technology life-cycle Therefore, the time peiod during wich a company can take advantage of its discovery and not facing competition is decreased and so is the return on investments As well, the moral obligation to provide health care at an affordable price leads companies to sell to less advanced countries some products at thiner margins.

Eighth, in this trend of moral obligation, companies are investing to develop cure for diseases that sometimes affect a small number of people In fact, they position themselves on narrow market niches which, with the pressures on prices, offer very low potential for return on investments

Ninth, this industry suffers from increasing environmental pressures which turn out to be very costly, a reality that they share with chemicals companies

Finally, they are operating on very sensitive domains and the pressure from consumers and the public opinion in general are becoming increasingly stronger against this industry that has been considered as principally profit-driven as well as very "fat" for a long time. The table below summarizes these factors

THE PHARMACEUTICAL INDUSTRY: A CONSTRAINING BUSINESS ENVIRONMENT
Governmental Pressure
Higher Research & Development Costs
Shorter Pay-Back Period
Stiffer Competition on Fewer Segments
Larger Variety of Customer Base and Products
Higher Raw Materials Lead Time and Cost
Shorter Technology Life Cycle
Moral and Ethical Obligations
Environmental Pressure
Consumers and Public Opinion's Pressure

1.2 Operational Constraints

Pharmaceutical companies must conform to a set of regulations such as Good Manufacturing Practice Regulations (GMP), Good Laboratory Practice Regulations (GLP), Good Distribution Practice Regulations (GDP) and so on In other words, any activities within the supply-chain is regulated in order to maintain a high quality of materials, product integrity and good information control within the supply-chain

Conformity to these regulations has a cost that should not be underestimated In addition, these rules often impose limits to the development of improved production and operations management techniques like just-in-time or stretched flows Further constraints to better operations management come from the medicines themselves, their ingredients or their therapeutic objectives as I will explain in section 1.2 5 of this second part

1.2.1 Quality Control

Within the pharmaceutical supply-chain, materials are controlled at many different stages First, suppliers are asked to check the quality compliance of their materials. The materials are further analyzed upon receipt, lot by lot, package by package Once the materials have been transformed to bulk of semi-finished products, they have to be sent to quality control Also after the bulk is packaged in the finished product format, more quality control has to be done Finally, when they are shipped to customers, some type of control is done to ensure conformity In addition, many different control from machine operators are done during materials transformation As a result, it can take up to 40 days to release raw materials and roughly the same period to release a lot of finished product. When one knows that a batch of tablets can be produced, packaged, packed and shipped in a couple of days, it appears evident that quality control represents a major bottleneck in the entire supply-chain and that working with stretched materials flow is somehow unrealistic inventory has to exist at the stage of the quarantine Also, rush and unexpected commands from hospitals (in case of epidemia for example) have to be supplied immediately and due to quality control delays, it is not physically possible to satisfy rush orders from the origin of the supply chain In other words, it is not possible to place the decoupling point at the raw materials stage so inventory are needed somewhere downstream production

The bottleneck at quality control can be exarcebated by a shortage of labor which creates long waiting lines before analysis and this can be improved But even when there is enough capacity, some chemicals reactions in quality control required before a batch can be released need 30 days, a time which cannot be reduced In these conditions, it is necessary (but not always done) that quality control lead times be analyzed and included as integral part of the order-to-delivery cycle

In the case of raw materials, every lot has to be analyzed This poses two problems to the reduction of raw material inventories that could be achieved by a more frequent delivery of smaller quantities First, if a certain quantity of materials arrives in n packages, n samples have to be analysed which is very time consuming Second, the cost of raw material varies enormously and for example, a sample of sugar costs only a few cents but some active ingredients can cost up to a couple of million dollars per gram It is obvious that in these conditions, using the standard Economic Order Quantity (EOQ) is a bit too simple a principle and that the cost of sampling should be incorporated in the decision criteria as well

1.2.2 Qualifying and Validating Principles

One standard of the Good Manufacturing Practice is the obligation for pharmaceutical companies to qualify installations and information systems and to validate processes Qualifying installations means testing that any piece of equipment involved in the transformation of materials conforms to quality and safety rules and that the equipment as a whole is capable of producing under the right conditions As a first result, any investment to increase production capacity has a long lead time before it may operate effectively. This means that it takes a long time to react to unanticipated variations in demand or to a special order if they require addition of production capacity As a consequence, the reduction of stock levels is a very sensitive problem and the ultimate target of 'zero stock' is unrealistic

The validation of processes is somehow similar since it requires that the company produce in batches of a declared size through a sequence of documented, controlled and consistent set of activities In practice, the very first impact is the obligation for the company to validatea batch size, a time-consuming and costly activity As a consequence, any variations in demand cannot be absorbed by varying the batch size unless the company has validated their processes for different batch sizes which is fairly unrealistic In fact, the concept of optimal batch-sizing under stochastic demand is not realistic and I observed that the batch size commonly used is the full capacity of the production equipment for one run Under these circumstances, just-in-time production with stretched material flows is purely theoretical and as with the case of qualification of installations, 'zero stock' is purely a theoretical objective

A second difficulty comes from the fact that every batch has to be sent to quality control Therefore, the smaller the batch size, the larger the number of controls to be done for a fixed total quantity produced Since the quality control is a bottleneck, costly and time consuming, it is easy to imagine the handicap associated with a large number of different small batches

The same problem occurs with packaging If a batch of bulk semi-finished product is packaged in n times, this creates n finished goods batches to be sampled for control Under these circumstances, it is common to produce in large batches and to package the bulk at one time, creating costly finished goods inventory but reducing production costs. A key issue of integration appears with the comparison of the trade-off between inventory costs and production costs

1.2.3 Changeover time

GMP emphasizes that equipment be cleaned between batches of the same product and of course, batches of different products in order to avoid cross-contamination and to preserve product integrity It is common that these clean-down operations take from half a day to a day for both manufacturing and packaging equipment Therefore, it is commonly observed that changeover minimization drives the planning and scheduling activities As a consequence, production is organized in campaigns, i e the entire monthly demand for one product is produced at one time and the average finished goods inventories in the pharmaceutical industry are high

One solution would be to dedicate some production and packaging lines to a single product It is obvious that this solution must be economically justified and that it is seldom the case A second solution would be to increase flexibility as in many other industries but the clean-down requirements represent an unavoidable limit to changeover time reduction

Therefore, the objective of inventory reduction is very sensitive and just-in-time production is not a realistic goal for pharmaceutical companies

1.2.4 Total Supply-Chain Lead Time

We already mentioned that raw materials lead time can be extremely long In fact, a simplified supply-chain illustration shows that whereas the throughput time between processing of raw materials to delivery of finished goods takes from 9 to 100 days, the average total lead time, including raw materials supply, varies between 3 to 9 months

A first consequence is that orders for raw materials are based on long term therefore, approximate sales forecasts Second, it is very difficult to respond to a rush order by any other means than sufficiently large safety stock Third, according to the law of industrial dynamics, demand amplification is higher when lead times are long This implies that in the pharmaceutical industry, the tendency of all the actors in the supply-chain to hedge against fluctuations by increasing safety stocks is accentuated

Therefore, it appears that reduction of inventories can only come from a reduction of lead times and its concomittent, demand amplification between stages But as Roderick Moulding, former President of the Forum of European Production and Inventory

Management Societies-FEPIMS indicated [XYZ Ltd internal document], to reduce the lead time, one has to reduce the stocks This vicious circle is unavoidable and emphasized in the case of the pharmaceutical industry where inventories are costly and lead times are extremely long I believe that one way to reduce lead times and inventory resides in the principles of supply-chain integration

1.2.5 Rationalization and Product Design

In order to face the explosion of product variety that accompanies the new rules of a world-wide market base, many companies, in the electronic or automotive business, try to postpone as late as possible product specialization by designing items with as much commonalties as possible In the mean time, they try to extend these commonalities to packaging design in order to minimize the need for different equipment and to reduce changeover time In the pharmaceutical industry, this objective would be a fantastic opportunity to reduce the throughput time and to increase flexibility However, there are a number of constraints that make this goal very difficult to achieve.

First, the format of a tablet for instance depends on the percentage of active ingredients it contains Therefore, the size of a 500mg tablet cannot be the same as the size of a 1g tablet This implies changes of format for both production and packaging.

Second, products are packaged according to posology. If a cure is supposed to last 30 days at a rate of one tablet a day, it is relatively obvious and economically justified to design a package containing no less than 30 tablets but no more A smaller content would cause unnecessary and expensive packaging whereas a larger content would produce wastes, both alternatives being contrary to the desire of health care programs to reduce medicine costs.

Third, medicines are subject, as any other product, to marketing considerations with respect to product design, content and packaging This is not so relevant for ethical drugs (prescription drugs) but it is pronounced in the case of the Over The Counter -

OTC- drugs These products are commonly presented on point-of-sales display or as any other product on shelves and many of them compete on the same therapeutic segments with no distinctive advantages As it is also the case for some vitamins, consumer decisions are not only influenced by prices but also by packaging features Therefore, it is necessary to be innovative relative to packaging and format and this creates standardization problems for operations

Fourth, medicines are subject to the taste and preferences of the consumers It is interesting to observe that, for example, suppositories are not sold everywhere or that customers in the UK are more receptive to sweeter syrups than French or German

Therefore, medicines, due to the specificity of their 'raison d'être', carry more constraints for standardization than some other types of products, but they share, with the others, some marketing constraints This is why, when both therapeutic and marketing constraints are added together, make medicines very difficult products to standardize

1.2.6 Expiration of Validity

The validity of a medicine from its date of fabrication is roughly between one and five years Therefore, the notion of 'dead-stock' does not only apply here for the left-overs at the end of the product life-cycle (marketing obsolescence) but also at the end of the product legal life (therapeutic obsolescence) With the exception of some extension of validity that can be accorded by special requests, this poses a serious problem of production planning and inventory management In addition, if one couples this difficulty with the reality of long supply-chain lead times and variable and/or cyclical demands, it appears more and more obvious that the planning of pharmaceutical operations is extremely complex

**THE PHARMACEUTICAL INDUSTRY:
SOME CONSTRAINING OPERATIONAL REALITIES**

Heavy Quality Control
Rigid Qualifying & Validating Principles
Limited Changeover Time Reduction
Long Supply-Chain Lead Time
Difficult Rationalization of Product Design
Constraining Expiration of Product Validity

2. XYZ Ltd.

2.1 Introduction

XYZ Ltd is a subsidiary of a large pharmaceutical company composed of more than 100 subsidiaries in more than 50 countries in the world XYZ Ltd consists of five different geographical units and eight manufacturing centers XYZ Ltd. develops, produces, distributes and exports more than 60 specialties its home country.

The present study took place at one manufacturing center that I 'll name Pharmatown and at one distribution center named for the same purpose, Distritown The total production, in packaged units, averages 100 millions. This production consists in two main families, solids (tablets, coated tablets, capsules) and liquids (syrups, suppositories, drops, injectables)

2.2 Description of Production Processes

In order to better understand the operational issues in the pharmaceutical industry, it appears necessary to offer a description of the production processes First, it is important to recall that the manufacturing of pharmaceuticals is product-focused and that there are two principal manufacturing activities. First, the production of bulk in batches of definite size (according to the GMP) Second, the packaging of this bulk in finished products of different format or style A product-focused manufacturing can take the form of either dedicated systems or batch systems At XYZ Ltd , both systems can be found in the packaging area and the degree of dedication depends on the demand size On the one hand, there is a packaging line entirely dedicated to one product since the large demand justifies the corresponding investments On the other hand, products with smaller demand share some packaging facilities Concerning the production of bulk, there is no dedicated facilities to one particular bulk type Scheduling is done according to stock level and demand forecast

At XYZ Ltd., the analysis of both the production of tablets and syrups leads to an interesting contrast since they represent opposite extremes on the automation scale in the factory.

2.2.1 The Manufacturing of Tablets

As the French word for tablets, *comprimés*, indicates, a tablet is obtained by compressing a 'powder' into a cast. From the stage of ingredients to the one of packaged tablets, there are several steps First, ingredients are blended together Second, the resulting powder is mixed with some liquids, the granulating stage Third, the resulting wet paste is placed into a dryer Fourth, the result, an homogeneous powder, is gauged to ensure a certain caliber. Fifth, some lubricants are added in a blender At this stage, the bulk is placed into some containers which will feed the compressing machines The set of preceding activities will be referred as 'granulating' in the rest of the paper since it is the term used in the planning department After the compression, tablets may be sent for coating or not and they are placed into containers that will be transferred to packaging when desired. As mentioned earlier, the production of tablets is of low automation since there are some manipulations by operators between every stages Concerning the clean-down operations, they are very time-consuming since it takes up to a day to disassemble, clean and reassemble all the equipment

It is worth noting that the evolution of technology tends to integrate many stages into a single machine This is the case for a machine which accommodates, without manipulation, the blending, granulating and drying stages In addition, the transfer from the lubrication stage to the compression is sometimes automated, using pipes feeding directly compression machines Since it is possible to imagine pipes transferring tablets to packaging, it is expected that future production facilities will limit manual manipulation to ingredients weighing and loading This will certainly reduce the total cycle time but will pose two challenging issues First, the quality control done by operators between each stage will have to be automated Second, the integration of several activities in a same machine will reduce equipment flexibility since a machine will become ready for the next blending only at the end of the entire production cycle.

A direct observation of the production of tablets at XYZ Ltd. leads to several comments. First, there exist no planning for the compression stage. It seems that it is taken for granted that when the bulk is ready for compression, there is enough capacity to process it This creates no specific difficulty today given the compression capacity but it could become critical if the production increased In addition, it is difficult to tighten the production flow if one activity remains unplanned between two planned activities, i e. granulating and packaging Also, the implementation of some on-line/real-time monitoring of production would be impossible Second, the transfer between granulating and compression is in the process of being automated (pipes) which should increase production security and efficiency. Third, it seems that the number of containers in which the granulated bulk is placed to be sent to compression is insufficient and therefore increases the total cycle time since it is not uncommon to find some bulk waiting for a container to be released and therefore occupying unnecessarily the granulating equipment. Finally, the clean-down operations require the manipulation of heavy and numerous pieces of equipment which certainly increases the total change-over time between products.

Therefore, it seems that there is room for improvements in the production of tablets, some depending on additional investments, some depending on more accurate planning tools Such improvements are only justified if the volume of tablets to be produced is expected to increase at Pharmatown in the future

Process Diagram for Tablets

BLENDING
↓
GRANULATING
↓
DRYING
↓
GAUGING
↓
LUBRICATING
↓
COMPRESSING
↓ |
COATING |
↓ ↓
PACKAGING & PACKING

2 2 3 The Manufacturing of Syrups

If the production of tablets still requires several manipulations by operators, the production of syrups is highly automated and is an application of Computer Integrated Manufacturing (CIM) Once the ingredients are loaded, manually, into the tanks, the operator enters from a computer terminal the values of the parameters required for a specific blending (temperature, pressure, cycle-time, etc) Then, the computer controls the process ensuring that it is correct and at the end of the blending (the only stage in the production of the bulk of syrup), the syrup is sent through pipes to the storage tanks which will feed via pipes the bottling line when desired The clean-down operations, which take up to a day, are automated and managed by the computer In addition, the computer provides the operators with many on-line control parameters and is capable of blocking the production process in case of a problem As one can observe, it is difficult to make the process simpler and safer, and contrary to the production of tablets, the production of syrups represents somehow the state-of-the-art of what is available today. A comparison of the equipment for both tablets and syrups reveals so many differences in technology that it seems to be more the sign of a future specialization of the production site to liquids than the sign of inconsistencies in technological choices

Process Diagram for Syrups

LOADING OF INGREDIENTS

↓

BLENDING

|

(Pipes)

↓

STORING

|

(Pipes)

↓

BOTTLING

|

↓

PACKAGING & PACKING

2 2 4 The Packaging Facilities

At XYZ Ltd , packaging is a very important activity benefiting from advanced technologies and careful planning As a rule of thumb, regardless of the productivity of the packaging line, it takes longer to package a batch of a pharmaceutical product than to produce it

Packaging facilities for tablets are of three types For small series (campaigns), it is common to observe a manual packaging since it is not worth setting up a line for the number of products to be packaged For large campaigns of low to average frequency, packaging is done on automated lines of varying degree of automation. For large campaign of high frequency, there is a dedicated line on which the pharmaceutical product is packaged almost continuously

Concerning the syrups, there is one bottling line that is shared by all the varieties The line is fed directly from storage tanks and automation is total since the output is a shipment pallet.

The observation of all the packaging facilities at XYZ Ltd leads to the following comments First, this activity represents a bottleneck in the manufacturing process and it is common to observe saturation of capacity at the current two-shift policy Eventually, operators are asked to work during the week-end. Second, the actual capacity is below the line capabilities since minor break-downs occur frequently Third, the flexibility of the packaging lines for tablets is limited by the packaging formats and not by the equipment itself. Future improvements to increase flexibility should therefore come from more commonalities in design rather than investments in better technologies

A last comment, common for both the tablets and syrups packaging lines, concern the clean-down operations. They are the major criterion upon which scheduling of packaging activities is determined, given the demand forecast As mentioned earlier, it can take up to a day to clean a line for a product change-over As a result, a traditional practice is to launch large packaging campaigns and to schedule consecutive products in order to minimize the change-over time between them. This fits well with the practice of producing large batches of bulk as it is done today but creates a storage problem for finished-product It is expected by production managers that the storage capacity at Pharmatown will soon be not sufficient A solution could come from more frequents shipments to the distribution center located in the vicinities if the latter is capable of accommodating increasing stock volume Another solution would be to reduce the campaign sizes and to increase inventory turnover It is worth noting that the average inventory for the group is 150 days and that a reduction in inventory (as a consequence of supply-chain lead time reduction) would represent a cash saving of US$ 10,000 a minute! Another solution would be to pull more upstream the decoupling point so that the total value of stock would be less

2.3 The Distribution Center (DC)

At the end of the manufacturing process, the majority of products are shipped to a distribution center located a few miles away at Distritown. This DC of 10,000 square meters can accommodate 5,240 pallets and roughly 3,000 different items The current processing rate is of 750 orders per day which represents 3,650 parcels or 14 tons of products Annually, this statistics represent 86 millions of units processed

The order processing activity is highly automated For important customers such as hospitals, a system of Electronic Data Interchange has been installed so that orders are received instantaneously at any time of the day Once recorded, the order is transmitted to the order preparation department There, the products are transferred from the storage area to the parcelling lines by two automated transpackers which are responsible for storing incoming products, recording their positions and picking them up for parcelling when needed In the case of large orders, called standards since the parcel size is a multiple of the storage format, orders are dispatched to the parcelling line automatically and parcelled manually For smaller orders requiring partitioning of a storage format, operators dispatch and parcel manually. Then, all the parcels are sent to the shipping area using automated conveyors At this point, parcels are palletized and loaded into the trucks Finally, it is worth mentioning that the current storage capacity is greater than the processing capacity of the DC.

3. ANALYSIS OF EXISTING SUPPLY-CHAIN

The second objective of this paper is to investigate the degree of integration at XYZ Ltd , and to study the steps required in order to achieve further integration

Since the company is evolving toward a specialization for the production of liquids (syrups and injections), I shall focus the study on the syrups supply-chain to evaluate different aspects of integration The specificity of the syrup line will be more exposed in the third part of the study at the time of simulation whereas the following qualitative analysis will use both information relative to syrups only and to XYZ's supply-chain in general. The analysis will be using many key concepts that have been exposed earlier in the paper Particularly, since the objective is to study the potential benefits of integration, tools such as 'barriers removal', which consists of learning more about the existing supply-chain, will be used right from the beginning to screen the supply-chain and not as reactive instruments as the notion of 'removal' could imply In other words, the analysis will use the framework introduced in section 5 of the first part of the paper

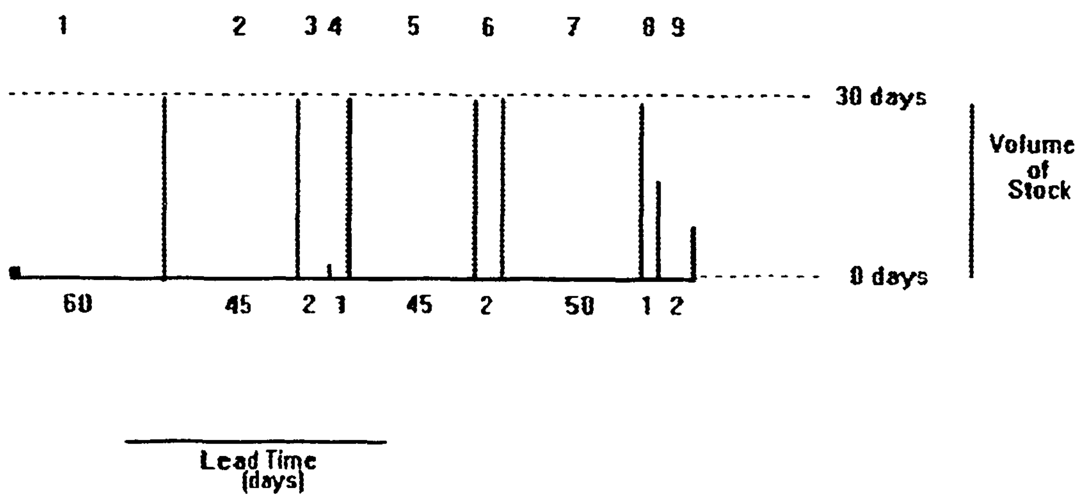
3.1 Introduction

XYZ Ltd 's syrup line consists of two brands, Alpha and Beta Whereas Beta is only produced for the UK market and presented in one type of package, the Alpha line consists, at this date, of 3 different varieties of syrup (bulk) packaged under 5 formats (difference in size, presentation, etc)

For Alpha, the bulk of syrup requires, on average for the different varieties, the blending of 11 ingredients and packaging and packing materials consist of 10 components This decomposition ignores the raw materials (chemicals) required to obtain some of the ingredients in laboratories but includes the packing materials used both before the production process (containers and bags for weighted ingredients) and after the process (carton) Similarly, Beta consists of 12 ingredients and 6 packaging and packing materials

3.2 The Pipeline Map

Another interesting tool to evaluate the supply-chain is to represent the pipeline map (Scott and Westbrook, 1991) As it has been introduced earlier in this paper, this map indicates on the vertical axis the volume of stock held at various points in the chain and is represented in the present case in days of demand (either customer demands for the finished-goods or next echelon demand within the company) On the horizontal axis are indicated the lead-times for each activities Two important measures can be derived from this map First, the pipeline length which is the sum of all the lead-times (horizontal axis) and represents the total throughput time from raw materials supply to end-product delivery Second, the pipeline volume which is the sum of both the vertical axis (stock level) and the horizontal axis (lead-time) The data used in the following map represent, in case of multiple parallel activities (multiple incoming materials, alternate activities), the longest lead-times or the highest stock level so that the measures represent some type of critical path



1 materials order-delivery cycle
2 quality control and inspection on incoming materials
3 preparation of materials for manufacturing
4 blending and transfer to storage tanks
5 quality control and inspection of bulk
6 packaging and packing
7 quarantine + transfer to DC
8 order preparation + shipping to clients

3.3 The Variety Funnel

Among the ingredients, some are common to both brands, some are high-volume, low-cost while some, the active ingredients, are low-volume, high-cost items Among the packaging materials, some are common to both brands In fact, the variety funnel for the production of all the varieties of both brands is the following 29 ingredients and 15 packaging materials that lead to 3 bulks which are divided into 6 varieties (5 Alpha and 1 Beta) As a reverse, the flexibility funnel goes from 6 varieties of finished goods to 44 materials This observation allows a first remark the problem of product flexibility is not applicable to the syrup line before the packaging stage since it is only at this stage that one can observe an explosion, although very limited, of product varieties This mean that product flexibility increases from materials to bulk and reduces from bulk to finished products Therefore, the shape of the funnel gives a first indication of the possible position of the decoupling point in the syrup supply-chain It is then possible to say that an interesting issue is determining the stock level of bulk

Variety Funnel for the Syrups

3.4 Suppliers' Positioning

At XYZ Ltd , suppliers can be divided into two categories First, suppliers of relatively low cost-high volume ingredients and packaging materials Their selection is the responsibility of purchasing managers at Pharmatown and depends on their price competitiveness and reliability Second, supplier(s) of active ingredients which are most of the time high cost-low volume and some packaging elements (ampoules) In this case, there is a single supplier, the parent company based in a different European country The active ingredients represent the very core of the pharmaceutical products and are patented by the group The distinction matters in the way supply management is done.

In the case of local suppliers, ordering quantities and leadtime are specific to each supplier They are bound to meet some quality standards by XYZ Ltd. but quality ckecks are done upon receipt and ingredients are sampled and analyzed according to the GMP and to the group 's standards It is worth noting that most of the time, the standards and controls imposed by the company are more strict than those dictated by the GMP In terms of supply-chain, one can say that local suppliers are not integrated at all. There exist no programs of suppliers qualification at this date and this poses some substantial problems to XYZ Ltd First, quality is not always at the level one could expect from a supplier of such an important pharmaceutical company and it is not uncommon to observe a switch in suppliers from one year to another Second, this absence of qualification programs obliged XYZ Ltd to some heavy, time-consuming and costly quality controls to ensure supply conformity This creates not only delays in the total supply-chain leadtime but also an important workload for the quality insurance department With this workload being added to the control of finished products, it is not uncommon to observe some finished goods shortages at the stockpile, not because of real shortages, but because some batches have not been released from inspection due to the workload created by the inspection of incoming materials The same problem occurs at the raw materials stages when production has to be delayed because the materials are still being inspected

In the case of the supply of active ingredients and ampoules, a logistics strategy has been implemented by the parent company and it is called ESN, European Supply Network The materials are ordered to the parent company and are usually delivered Just-in-Time. As observed, some very expensive ingredients arrive the day they are used for production Since the ingredients come from the internal network where quality conformity has been checked before shipping, quality control is done differently from the case of external supply If there are no visible damages (packaging), the ingredients are still sampled (smaller sample size than for external materials) but are used directly in production, without waiting for the results of the quality inspection For the batch to be released, the conformity still has to be proven but the origin of the materials (ESN) makes very small the chance that the batch will be rejected afterwards This way, the lead time is reduced. According to the Supply Manager, the principal and apparently only problem with ingredients supplied through ESN is the variability of packaging formats form one delivery to the next An order of ten kilograms can once be delivered in one 10 Kg-bag and in two 5 Kg-bag the next time If an order arrives fragmented in n packages, the number of samples to be taken is multiplied by n Given the waste resulting from sampling, the quantity left-over for use is sometimes insufficient whereas the total quantity shipped would have been sufficient if the order had not been fragmented It is then possible to say that ESN is a strategy to ensure supply-chain integration of materials procurement It allows a reduction of supply-chain leadtime and frozen capital by providing materials just-in-time and of approved quality However, the integration is not total at this point since local suppliers are still considered as external agents in the logistics chain. It is therefore a necessary step to implement some type of suppliers qualification programs if XYZ Ltd wants to achieve an efficient integration of all of their suppliers In the mean time, it would be wise to evaluate both the degree of dependency of XYZ Ltd to each supplier for each specific supply and the importance of XYZ Ltd orders for each supplier This would enable XYZ Ltd to detect the suppliers with whom the relationships could be switched from simple buyer-vendor to partners In these circumstances, it would be possible to find some simultaneous optimal order size, to reduce the leadtimes by reducing hedging inventories and eventually collaborate in the development of new materials

3.5 Screening of Distribution's Methods

The shipment of pharmaceutical products from Pharmatown is of two types First, some products are shipped directly from Pharmatown to customers. These customers are either member of the group or other pharmaceutical companies for whom XYZ subcontracts some manufacturing activities

Second and representing the larger distribution activity, pharmaceuticals are transferred to the distribution center at Distritown by a shuffle, six times a day on average.

From there, after customers' orders have been processed, distribution is organized as follows 90% of the products are distributed in the local national market, 10% are exported For exports, products are shipped to exporting wholesalers for regular orders In the case of exceptional destination or quantities, the export manager defines the proper way to ship products which can take the form of rather complex air-rail-road combinations

For the home country, the distribution strategy changed 15 years ago Before that, XYZ Ltd operated several warehouses in the country Products were transported to these warehouses by independent carriers and final distribution to customers within a region was operated by XYZ Ltd This way, the company had a great control over customer service since it was their responsibility to ensure fast and accurate local delivery. At a certain point in time, the increasing competition in the hauling business resulted in very attractive subcontracting prices Transport companies had to bid very low to maintain a certain market share and avoid bankruptcy. At the same time, XYZ Ltd. was facing increasing demand for pharmaceuticals from a growing number of geographically dispersed customers In addition, hauling companies started operating warehouses, offering full distribution services XYZ Ltd decided to close down intermediary depots and to give to subcontractors the full responsibility for finished goods delivery from Pharmatown first and from the recently built distribution center at Distritown Only the vicinities are served from Distritown by a company-owned truck

The subcontracting activity has the main advantage of enabling XYZ Ltd to play on the competition and request the greatest quality of services As it is often said for cost-adding activities, it is easier to fire a subcontractor and to hire a better one than fixing quality in-house At the same time, XYZ Ltd recognized the advantages of supply-chain integration versus vertical integration

Today, distribution management at XYZ Ltd is a real example of downstream supply-chain integration. The home country is divided in four regions, a single carrier being given responsibility for each one The carrier leaves a trailer at the distribution center in front of the shipping area and picks it up every day at the same hour The cost of shipping is not fixed, e g cost per trailer, but is variable according to the weight of goods loaded In addition, given the relatively stable loading per day and the substantial volume per year, carriers offer a single cost per ton (with the exception of exceptionally small or large shipments) Therefore, the cost function is linear which transfers the problem of profitability to the contractors and the problem of shipments consolidation to gain economies of scale becomes most of the time irrelevant to XYZ In the seldom cases of very small orders, XYZ uses the mail In case of express orders that the warehouses cannot satisfy, express couriers are used but it is more and more exceptional

Each carrier operates its own regional distribution network In fact, the selection of a transporter at XYZ is greatly dependent on the level of integration of the carriers Knowing that goods, once shipped from Distritown, will be under the responsibility of a single contractor makes the distribution much easier and safer In addition, due to the lucrative aspect of this distribution, many carriers are now specialised for pharmaceuticals. It is important to recall that Good Distribution Practices impose the presence of a pharmacist in the warehouse in which pharmaceuticals are stored. This condition, which obliged pharmaceuticals companies to operate their own warehouses years ago is now met by independent carriers As one can observe, carriers have adapted their operations to pharmaceutical companies which is a first sign of integration

The second sign of integration is the way transportation fares are negotiated. Each year, carriers receive from XYZ a transcript of the volume shipped during the year On the basis of the volume transported, fares are re-negotiated These adjustments are very close to a simultaneous determination of optimal distribution costs for both parts In addition, the percentages of orders delayed and orders damaged are calculated and sent to carriers every year If such failings exceed 5% a year, then contractors are not allowed to increase their fare for the following year This measure has for objective a commitment to quality In exchange, XYZ guarantees to contractors the exclusivity of the region and the renewal of their collaborative agreement. The ultimate objective for the managers of the distribution center is certainly to benefit from the best financial conditions but essentially to create a long-term partnership with the same carriers.

A third sign of integration is the Electronic Data Interchange (EDI) that exists between carriers and XYZ. The volume and destination of each order is sent instantaneously to the carrier which helps the automatic billing In addition, each order is controlled by a computer and at any time, XYZ is able to know the position of the package (distance from customers) This allows XYZ to inform the customer of the expected delivery time of its order which is greatly appreciated given the urgent character of certain orders

In view of the way distribution is organized from Distritown, it is possible to say that supply-chain integration is total downstream Contractors and XYZ work closely together to elaborate an efficient distribution strategy and communication between them is excellent given the real-time control over shipments The only improvement that distribution managers wish concerns the quality standards of the carriers They are not all meeting the 5% defects criterion but it is a matter of time. The company has installed a program of transporters qualification which should result in the selection of some high-quality carriers in the near future

It appears then that in a couple of years, distribution at XYZ will be an example of efficient and effective supply-chain integration The EDI that exists both between customers and XYZ and between XYZ and carriers, coupled with the degree of automation and accuracy of order processing will certainly reach some kind of state-of-the art in the industry

4. DETECTING EXISTING BARRIERS TO INTEGRATION

To prepare an organization for a total integration of the logistics chain does not only consists in evaluating the existing degree of integration but also to anticipate the operational and organizational factors that could represent a barrier to a further integration With respect to the potential barriers that have been identified earlier in this paper (part 1, table 5), three situations can exist First, there is a barrier and its presence can be explained. Second, there exist no such barrier but the current policies are not really meeting the integration concept requirements Third, barriers do not exist and the policies satisfy the integration requirements Therefore, once the analysis done, it will be possible to tabulate the results according to th[illegible] situations harmful for integration, neutral vis-à-vis integration and helpful for integratio[illegible] [illegible]y, some factors such as division of costs and visibility of costs will not be analyzed

4.1 Fragmented vs. Integrated Approach to Logistics

The first potential barrier could be the existence of a fragmented approach to logistics management in the company in place of a favourable total or supply-chain approach At XYZ Ltd , management seems to recognize the need for integration. On the one hand, this is obvious in view of the supply network ESN and the integration of carriers However, the lack of integration of external suppliers weakens this perception

On the other hand, it is quite difficult to say that the company adopts either a total cost approach or a real fragmented one The total cost approach should be reflected by a decision-making process that takes into account the impact of any decisions on the rest of the supply-chain At XYZ, for example, each specialty is produced in one and only one batch size per speciality and the eventuality of using smaller batches is not yet considered This makes sense since it offers a larger volume for the same fixed change-over costs but sometimes creates some unanticipated difficulties for either packaging or quality inspection or even bulk storage Another example is the stocking problems at the supply receiving area It is not uncommon to observe a discrepancy between supply ordering patterns and storage capacity due to unbalanced material flows. This imperfect balancing of flows also exist between production of bulk and packaging or bottling.

In opposition, a true fragmented approach would be reflected by a total absence of coordination leading to huge buffers between two consecutive supply-chain echelon, to a desire of meeting functional objectives such as minimization of supply stocks leading to shortages or minimization of production costs by unnecessarily large batches and this is not the case at XYZ Therefore, the approach to logistics management at XYZ Ltd. (which does not necessarily represents the Group approach) is rather neutral with respects to integration

4.2 Reactive Controlling vs. Proactive Planning

A second barrier could be the tendency to manage reactively by controlling the material flow instead of anticipating the flow with decision support systems and planning tools.

On the one hand, there still exist some reactive decisions at XYZ Inventory shortages such as supply or finished goods leading to planning modifications are still observable even if they are often due to supplier deficiencies, unanticipated demand or rejection of products by quality inspection Any improvements at this point would come either from a greater ability to predict the unpredictable (hazardous!) or from an action to reduce the sources of uncertainty As it has been stated earlier in this paper, integration and coordination of the supply-chain represent two opportunities to better control a company's environment In particular, achieving increased supply quality and reliability should help a lot

On the other hand, it should be said that first, controlling by reaction to uncertainty is the common reality facing modern organizations and that second, planning at XYZ seems to be globally efficient Contrarily to the case of some other companies having adopted MRP II and following the proposed planning, planners at XYZ are constantly evaluating the possible discrepancies between what should be done to meet a certain demand for finished goods and what is suggested

In terms of decision support system, XYZ adopted a production management software called AMAPS/Q which consists in the following modules a bill of material system (BMS), a material control system (MCS), a material requirements planning (MRP), a lot tractability system (LTS) and three modules oriented toward cost management The principal objective for the production department is to provide the distribution center with finished products without creating a disruption of the logistics chain

Planning and stock management consists of three activities stock management with sales forecast, order management and stock management with sales forecast for certain orders requiring a two-month leadtime It is worth noting that the average total leadtime for an order is three months which includes, on average, a 45-day total lead-time for the supply to be available for production (ordering plus supplier plus inspection leadtimes) In these conditions, it is obvious that accurate planning is a key element in XYZ's ability to not disrupt the supply-chain It is also a fairly high leadtime compared to other industries and its reduction is a major objective for pharmaceutical companies since the shorter the leadtime, the lower the inventory and the greater the cost savings

One of the principal tools that XYZ does not possess upstream the distribution echelon is a system of real-time monitoring of material flows At no point in time (except when planners call the person in charge or go to the production lines) does the planning department know exactly when to expect either supply delivery or the state of a bulk with respect to quality inspection In addition, there exists no decision support system capable of providing the company with the impact of batch size or campaign size on the total cost of the supply-chain activities The batch sizing issue is tackled in order to meet demand and to maintain, on average, an inventory level at the finished goods stockpile that corresponds to two weeks of consumption It has been an effective way to maintain the desired service level and not to disrupt the chain but its efficiency could be revised. In other words, instead of optimal planning and optimal total cost, decision making is based on satisficing Optimality would certainly be rather complex to achieve given the number of variables and constraints to take into account but it is in no case more difficult to implement than for other companies or other industries that did it One explanation for the absence of optimal planning is the current redefinition of production policies given by the parent company which results in major modifications in capacity, objectives and technology at XYZ Ltd It is however important, once the production policies are decided for a sufficiently stable period of time, to worry about increasing cost efficiency and optimal decision-making

In these conditions, one can say that XYZ is definitely more inclined to act proactively and use planning tools than to manage reactively The major weakness still resides in the absence of a decision support system to guide the company toward optimal cost efficiency and effectiveness It represents a barrier since integration is only beneficial if the organization possesses the tools to identify the cost advantages of an integrated approach However, given the current approach to activity planning and the management concern for the relationship between cost effectiveness and service level , it seems that the adoption of tools leading to a search of optimality would be a success XYZ does not belong to the category of companies that ignore the concept of optimal operations management but rather to the growing category of companies having difficulties to find the right decision support system As it has been stated in the first part of this paper, one of the principal failure of the implementation of integrated logistics is the inadequacy between what a company needs in terms of DSS and what is usually proposed by information systems specialist.

4.3 Attitude Toward Process Reengineering

For a company to move form the traditional functional approach to the integrated approach of logistics management, some modifications have to occur not only in the way coordination is done between functions but also in the wav functions operate In other words, there is little gain in devoting heavy organizational resources to develop supply-chain integration if internal operations remain based on the traditional way of doing things

Process reengineering is an emergent concept whose objective is to increase competitiveness by reducing cost while maintaining a given service level It usually includes concept such as manufacturing by design, continuous improvements and statistical process control, group technology and so on At XYZ, there seems to be a constant effort to develop better production methods, either by investing in more advanced technologies or by continuously improving the existing methods

One of the principal opportunities for process reengineering at XYZ is the increase in flexibility of production equipment that could come from both manufacturing by design and reduced clean-down operations As stated earlier, standardization is rather difficult in the pharmaceutical industry given the constraints imposed by the nature of pharmaceutical ptoducts However, one can observe that the development of new packaging at XYZ attempts to standardize, as much as possible, the formats so that the change-over time between two formats is reduced and the number of pieces of equipment to change is minimized

In addition, in the case of the syrup packaging line, the number of parts to disassemble and clean-down were greatlygreatly reduced after operators suggested modifications in the feeding-pipes system This is an example of employees' participation in improving existing methods as well as a desire to modify processes.

One aspect that is apparently missing at XYZ Ltd is the use of SPC In fact, there exist no records and analysis of machine breakdowns or productivity measurements which could allow a collective attempt to achieve greater efficiency For the case of machine breakdowns, apart from major interruptions of production, operators do not communicate minor irregularities that can occur As long as they can fix it right away, it does not appear necessary to them to inform maintenance people This creates a natural barrier toward improvements and is somehow in conflict with other company's attempts to increase productivity Therefore, process reengineering at XYZ is present and satisfies the requirements for a move towaerds further integration of the supply-chain but this reegineering should be accompanied by a tighter comparison between process capability and achieved quality standards Otherwise, reengineering processes without beeing able to measure their performance leads to wastes

4.4 Adequacy of Performance Measures

The concept of integrated logistics is based on a total cost approach of the supply-chain This means that the ultimate objective is to minimize the sum of all the costs incurred throughout the material flow It is in essence contrary to the functional cost approach which only focuses on the cost minimization of each function independently

At XYZ Ltd , there is no evidence that such a total approach is done As illustrated by the previous discussion on the absence of decision support system, it seems that the company is still operating under some functional performance standards Through interviews and observation, it appeared that the purchasing function manages independently the supply pattern in order to provide production with sufficient materials while respecting the budget At the production level the same functionality occurs, batch sizes, even if they were optimal (doubtful), their optimality would be with respect to production costs and not the total cost Finally, at the distribution center, distribution patterns follow the principle of order fulfilment, and eventually the concern for distribution cost minimization but they are heavily dependent on the decisions made at the production stage for inventory levels

One of the reasons for this lack of total approach could be the nature of the relationships between the different echelon in the supply-chain The parent company is the supplier for active ingredients and the distribution center acts as a service company taking responsibility for finished goods delivery Under these conditions, there seems to be a sort of disintegration of echelons, each operating with independent cost objectives

A second reason, perhaps more important, is the 'raison d'être' of the company itself within the group and by extension, the nature of the pharmaceutical industry itself The mission is to generate sales volume, not to disrupt the logistics chain in particular for the leading products, the new products and the products for hospitals In fact, the total cost approach is the responsibility of the parent company at the time of allocating a specific production to a specific site Does it mean that the cost analysis, present at the group level, is not passed down to subsidiaries? There is not enough evidence at this point to judge but one can wonder if the nature of the pharmaceutical industry itself is not a natural barrier to the total cost approach It is important to recall that the largest cost of a pharmaceutical is the development cost As well, one should keep in mind that up to this time, price has not been a decision criterion in the choice of an ethical drugs, choice which usually depends on the prescriber and not the patient Given that price control is not yet a reality in the pharmaceutical industry, it is not totally wrong to think that sales prices can be decided on the basis of cost and if the greater the cost, the higher the sales price If this is the case, one can question the utility of a study of integrated logistics in the pharmaceutical industry In other words, why should one care about cost optimization if any costs can be passed down to the consumer and by extension, to governments ? However, as stated earlier, the business environment is changing and cost management becomes of increasing relevance for pharmaceutical companies at a time where social programs are suffering from huge deficits Therefore, the absence of a total cost approach at the French subsidiary, either due to its structure of the multinational parent company or to the historical freedom of pharmaceutical companies for price fixing should be revised since it represents a barrier for the development of more cost effective organizations

4.5 Definition of Customer Service

At XYZ Ltd , the concept of customer service depends on the type of products and customers to consider As mentioned earlier, for new products or leading products or hospitals, good customer service is a 100% on time delivery of quality conformed pharmaceuticals Given the nature of the products, it could be very critical to disrupt the chain between the company and customers since some person's life can be the issue In the case of hospitals, the company does not hesitate to use express courier for immediate delivery

For leading products, the challenge is of a different nature Any shortages at the point of sales or point of use would cause the sales of a competitor's products As it is easily understandable, purchasing a medicine is a question of immediate satisfaction of a need, not of a desire Under these conditions, postponement of purchase by the customer is very seldom feasible, except for ethical drugs having no direct competitors Nevertheless, stockouts would cause the pharmacist or the hospital to look for other supply sources and eventualy, if it exists, for other medicines

For new products, it is a question of wise marketing Given the size of promotional budgets that go with the introduction of a new product, it would be a major mistake not to secure product availability to meet demand in the same way as for any other type of product

As it can be presumed, in this industry quality of fabrication is either 100% or it is not No one could tolerate a single defect and the quality inspection are so numerous both on and off the production lines that the only damages could come from transportation As mentioned earlier, XYZ is actively working to achieve at least a 95% service level throughout their distribution network The 5% defects include both packaging damages and late delivery

Concerning this service level, XYZ should make sure that what they call a 95% service level is from the customer perspective and not from their own perspective Some customers might be very difficult to service either due to the nature of the products they order or to their geographical situations Even if each transporter achieves below 5% defects, it does not necessarily mean that each customer has not suffered from more that this percentage It is therefore the company's responsibility to ensure that each customer, regardless of their order or location, is served according to the company's standards

Therefore, given that the company applies the latter analysis of customer service, it appears that XYZ meets the corresponding requirements to integrate its logistics activities

4.6 Analysis of Shipment Methods and Delivery

As it has been shown in section 3 5, shipments and delivery in general has been the object of a careful redefinition over the last years and the company is about to install a very efficient and effective delivery system

Shipments are done differently depending on their size and emergency For small or urgent parcels, mail or express courier are used For 'long' (relative to the size of the home country) distances, regional carriers use a combination of rails and roads so that their cost is minimized while they meet XYZ's requirements in terms of lead-time

Finally, the selection of integrated carriers to make sure that a single company is responsible from the DC to customers is another sign of logistics integration Therefore, from a distribution perspective, XYZ already achieved supply-chain integration

4.7 Efficiency of Information Systems (IS)

The nature of information systems at XYZ has already been partially discussed. Information on AMAPS/Q relative to production management includes some lot tractability features which are compulsory to provide data needed should product recall occur Apart from this particularity, the rest of the system is somehow old. At the distribution center, the Electronic Data Interchange (EDI) between the company and large customers and the one between the company and the carriers allows, as stated earlier, a very efficient and instantaneous exchange of information

The efficiency of the system from the production perspective can be criticized since it consists in planning tools but not in real-time controlling tools In addition, the lack of decision support systems weakens the overall value of the information system in the context of integrated logistics Explanations have been given on the reasons why the company does not possess these tools and the objective of this paper is not to design the proper IS but rather to highlight the potential barrier to integration Since the absence of good IS is a major cause of failure among the industries which have adopted integrated supply-chain management, the least one can say is that the company would have to redesign its IS in the perspective of a future evolution of their logistics management

4.8 Relationships with Internal Customers and Coordination

The concept of supply-chain also expresses that the different actors in the logistics chain have a supplier-customer relationship If this concept is obvious in the case of the relationships between suppliers of material and the purchasing company, it is less understood in the case of two consecutive functions within the same company

At XYZ, for example, the department responsible for receiving and preparing raw materials for production acts as a supplier for the different manufacturing departments In turn, bulk production is a supplier for the packaging activities Since the concept can be extended to the latest echelon in the chain, it is important to consider that internal customers have to be serviced with as much quality as for external customers Observation of the relationships between successive echelons at XYZ leads to a mixed impression some links are the objects of very high service level whereas others are not The objective of the paper is not to highlight specifically the departments between which the relationships are of lower quality Nevertheless, some general observations are summarized by the following

On the one hand, when the internal supplier-customer relationship is obvious with respect to the nature of the material flow (e g between bulk production and bottling), the coordination is excellent Quality inspection is done in such a way that the chances of a transfer of non-conforming materials are extremely small and planners act as coordinators between functions The balancing of flows might not be perfect but the supply-chain is rarely disrupted Similarly, planners coordinate the relationships between production and the distribution center so that finished-goods availability is disclosed as soon as possible to allow a continuous flow of materials and information

On the other hand, when the internal supplier-customer relationship is not obvious and is not related to material flows but rather to information flow, there is a kind of discrimination and coordination is poor. A typical example happened when a bulk had been rejected by quality inspection The rejection, which was not the first one in a small period of time for the same product, highlighted some non-conformity of the production process At the same time, the bottling line was waiting for the bulk to be released from inspection and had been set-up, according to planning, for the particular product, causing some bulk of other specialities to wait for the bottling line It took three-days for the information to be communicated to planners whereas the problem was instantaneously communicated to people responsible for the production of liquids Poor communication or retention of information ? It is hazardous to conclude but as a result, the bottling line had to be re-setup for another speciality thus delaying the material flow

Another example is the delay that exist between the moment when a bulk is released from quality inspection and the moment when the information appears on AMAPS/Q Data release is usually done either a the end of the day or at the beginning of the next so that, for example, if quality inspection releases a bulk around noon, the availability is known by planners the next day in the morning This increases the supply-chain leadtime unnecessarily and even if it's only for a few hours, it can be very critical in case of stock-outs of finished products In addition, when one knows that at the group level, one minute reduction of leadtime would generate a US$ 10,000 saving, can the company really afford some data release delay ?

The communication problems that have just been highlighted might only be sporadic or just the results of incomplete internal communication procedures which can be fixed relatively quickly However, should they persist, they could be the sign of divergent functional objectives and would represent a substantial barrier for integration

4.9 Confidentiality of Information and Potential for Opportunism

The last but not least potential barrier for integration of the supply-chain is the potential for opportunism by external agents who would be integrated into the logistics chain Total integration would mean developing partnerships with a set of external companies which could eventually take advantage of confidential information, should they be relative to the products or to the organization itself

Since pharmaceutical products are especially profitable when they are exclusive to the company and patented, the confidentiality is very important At XYZ, confidential information such as active ingredients composition are maintained within the group boundaries and integration of suppliers for example would not represent a threat since confidential supplies are provided by internal agents In other words, integrating suppliers of materials having no confidential value would not represent a danger

Another positive action is the control exercised by distribution managers on wholesalers As for many other products, there exists a parallel market for pharmaceuticals, especially in regards to exports Wholesalers could sell some pharmaceutical products to unauthorized clients or to authorized ones but at a price lower than what the particular client should pay for it This is possible since prices can differ depending on the countries and the type of agreements existing either between the company and the customers or between governments In order to prevent wholesalers from getting involved into this parallel activity, their ordering pattern and volume are monitored and in case of abnormal deviations, orders are blocked automatically the same way that they are blocked for customers having reached their credit limits The order is then the object of a specific investigation

Another threat could come from the development of partnerships with 'losers' or low quality standards organizations The development of programs such as supplier qualification should minimize this risk As it is successfully implemented for distribution, a close monitoring of partners' performance would decrease the potential for opportunism.

Therefore, given the existing integration for confidential activities and the care demonstrated by some parts of the supply-chain to develop and maintain high quality integrated partners, there exists little risk for the integration to be jeopardized

4.10 Summary of Potential Barriers

As the preceding analysis demonstrates, there exist some potential barriers at XYZ on the way to total integration of the supply-chain Principally, they appear in the form of a lack of coordination between some functions, a certain inadequacy of the performance measures, the absence of effective decision support systems and some weaknesses in the existing information system They should become the object of particular care at the time of further integration of the logistics chain In antithesis, some factors will act as catalysts for integration such as ESN, the planning efforts, the existing integration downstream the distribution center and the concern for high quality partnerships

Is it then possible to classify XYZ into some pre-defined categories of organization having good or average or low chances for integration ? The present study is only an illustration of the company's position with respect to integration and overall, the chances depend more on the ability and willingness of company's members to overcome the barriers than on the nature of the barriers themselves.

5. BUILDING INTEGRATION WITH EXISTING TOOLS

Once the existing supply-chain is screened and the potential barriers to integration highlighted, one should concentrate on the key operational blocks on which successful integration could be built It is therefore the object of this section to review, according to the main managerial functions, how integration could benefit from certain operational tools The following analysis has not for objective to review the way each planning or managing tool works but rather how it can help building integration It is interesting to mention that, despite its innovative character, supply-chain integration does not condemn existing operational tools to obsolescence Rather, it highlights some of their capabilities that had not been utilized so far and represents what could be achieved if these tools were used at their full potential

5.1 Demand Management

Demand management consists of the set of activites related to sales ranging from accurate forcasts to reliable and efficient deliveries While their importance for superior marketing strategies is largely accepted, their contribution to a successful integration is also obvious as it will be demonstrated below

5 1 1 Sales Forecasting

Accuracy of forecasts allows not only marketers to improve customer service but also production managers to reduce the volume of inventory Since integration has as objective a reduction in inventories and supply-chain leadtime, there can be no succesfull integration without superior forecasting Therefore, integration can be built on the basis of better forecasts since they result in reduced the volume of hedging inventory against unreliable forecasts As a result, this inventory reduction shortens total supply-chain leadtimes and enhances the company's ability to be more flexible At XYZ, this issue is key since inventories are expensive and finished-goods perishable

5 1 2 Order Management

Superior order management plays an important role both in service level and supply-chain leadtime issues If orders are collected faster, processed faster and with greater accuracy, the total leadtime for downstream production is highly reduced At

XYZ, the existing EDI between clients and the company is an excellent illustration of both increased efficiency and integration efforts In addition, as seen, the automation level at the DC makes the processing time very competitive Therefore, it appears that XYZ's order management methods are totally in accordance with integration requirements and it is on such a basis that the rest of the company should identify opportunities for leadtime reduction by means of integration

5 1 3 Distribution Resource Planning (DRP)

DRP consists of two principal tasks, finished-goods stockpile management and transportation The former, at XYZ, is related to the management of replenishment orders As a rule of thumb, the DC keps the equivalent of two weeks of demand for each product This means, logically, that two weeks is the average leadtime for replenishment, once the reorder point has been reached Given DC's proximity to the production plant, it appears that these two weeks represent a hedging inventory for production planning deviations since there is no reason for hedging against delay in transfers from Pharmatown to Distritown. This approximate analysis demonstrates how demand management is totally dependent on production planning horizon and accuracy This brings another interesting aspect of integration Could this lead-time and corresponding inventory level be reduced by, let say, one week ? Assuming it is feasible, this would necessitate either more flexibility of production lines or more accurate anticipation by order managers for replenishment decisions Since it is reasonnable to believe that such a reduction in inventory would come from both increased flexibiltiy and anticipated replenishment orders, it highlights how integration takes some of its building elements in existing working policies, i e more efficient cooperation between production and distribution

In the case of transportation, it has already been shown how XYZ is gradually building integration of carriers in its supply-chain and how this integration can increase the service-level to customers as well as decrease transportation costs

5.2 Supply Management

The two principal objective of supply management are to plan supply acquisition and to make them available for production in order to link supply capacity to demand for finished-goods The first objective is achieved through materials requirements planning whereas the second is the rationale behind the Master Schedule

5.2 1 Material Requirement Planning (MRP)

At XYZ, MRP is already in place Bills of materials are organized in such a way that the input of a fabrication request in the system automatically places orders for the required materials and planners just have to confirm the orders in the system

Obviously, there is nothing new in the way MRP is used at XYZ The objectives behind the use of MRP are, mainly, to launch orders at the right time, to help production planning and scheduling and to anticipate shortages However some factors such as suppliers' leadtime or lot size could be better adapted to XYZ's needs through suppliers' inetgration as it will be shown in section 7 In addition, the use of MRP can help integration since it offers visibiltiy in supply needs and it is not excluded to observe, one day, some EDI between suppliers and customers It could help suppliers plan their own manufacturing activities on the basis of clients demands for materials

5 2 2 Master Scheduling

The objectives of the Master Schedule are the followings (adapted from the APICS (American Production and Inventory Control Society) reference guide) First, it must be consistent with the business plan and stick to the production rate defined by the production plan Second, it must provide visible data and responses to inquiries so that customers can be better informed of what can be done and when Third, it must be stable and offer simulation capabilities to measure the impact of changes on the feasibility of the overall plan Finally, it must be managed with specific policies and some specific job assignments and procedures In fact, the master schedule is a part of a set of operational tools that leads to efficient manufacturing resource planning

The objective of this section is not to describe how a Master Schedule operates but rather to show how it can help building integration, in view of the four principles listed above First, making sure that it respects both the business plan and the production rate should prevent deviations at the manufacturing level that could be caused either by temporarily idle capacity or changes in demand Any deviations from the master schedule would cause activities upstream and downstream the production to observe some unanticipated variation in material flows Such a variation would obviously cause some shortages or excesses at certain points in the supply-chain whereas the master schedule provides, if correctly done, supply-chain balancing

Second, by providing data visibility, it plays the role of a decision support system by quantifying planning decisions This visibility, shared with the rest of the organization, represents a common ground on which decisions can be made and implemented It can support quantitative decision making at any points in the supply-chain and therefore allows integration of activities Since this visibility can be communicated to customers, it helps informing clients on the feasibility and required lead-time of a specific order and assuming that the schedule is realistic, it helps obtainign realistic forecasts and improved customer service.

Third, its stability and simulation capabilities allow some 'what-if' analysis on the entire supply-chain and allow managers to measure the impact of a specific change and therefore, to make corrective decisions at other echelons of the chain to maintain balance and coordination

Finally, by recognizing the need for specific job assignments for the master schedule, it automatically builds some organizational positions responsible for supply-chain coordination acting as catalysts for the integration process assignments and procedures In fact, the master schedule is a part of a set of operational tools that leads to efficient manufacturing resource planning

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5.3 Resource Management

5.3.1 Capacity Requirements Planning

A key factor leading to supply-chain leadtime and total cost is the total capacity on which materials processing depends In case of shortages of capacity, a bottleneck is created and total leadtime increases On the other hand, excess of capacity leads to wastes of equipment and increases the total logistics cost of products Therefore, the right balance should be created in order to utilize capacity as much as possible in full without creating bottlenecks in the system Once again, there can be no integration without such an analysis since integration requires a perfect knowledge of supply-chain's capacity Whereas, if total capacity is known, it allows the planning and scheduling of smooth material flows with a minimization of idle capacity on the one hand and of bottlenecks on the other This is why integration is also built on a perfect knowledge of the company's supply-chain capacity For example, for the production of syrup, if 12,000 liters is the total production capacity for a given period of time, lets say 6 hours, there is no point in requesting raw materials preparation for 36,000 liters for a 12-hour period. This example may sound obvious, but can the company say that it never happened to have raw materials preparers busy with weighing some materials for a process that is to be launched after another one for which materials are not ready ? In addition, the same capacity analysis should be done on each equipment, including machine breakdowns frequency and duration, machine clean-down time requirements in order to come up with an accurate figure In fact, integration requires a perfect knowledge of operational capacities since it requires very exact planning and scheduling

5.3.2 Schedule Optimization

Whereas planning optimization is a notion commonly shared by production planners (although not always done), the concept of schedule optimization seems to be more often neglected Especially in the case of batch production requiring long change-

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5.3 2 Schedule Optimization

Whereas planning optimization is a notion commonly shared by production planners (although not always done), the concept of schedule optimization seems to be more often neglected Especially in the case of batch production requiring long change-over times, good scheduling is as important as good planning At XYZ, the scheduling rule is fairly simple and logical since the most time-consuming activity is to clean-down equipment between products, same products are scheduled consecutively Althoughthis makes sense with respect to a certain frozen planning period, say a week, it is not necessarily optimal with respect to a longer planning horizon Operational researchers have been interested in such an issue for years and examples of apparently illogical but really optimal schedules are numerous In fact, optimal scheduling is tied to planning methods and in general to overall production policies If customers are asked to wait for three-months for a certain order and this lead-time includes a one-month production leadtime, then the schedule will depend on the given planning horizon However, if the company tries to reduce production leadtime to 2 weeks, the scheduling of activities under this new planning horizon will be different

Therefore, by imposing on clients some leadtimes that are longer than what is really needed to process materials, a company can afford the scheduling The objective here is not to criticise the type of scheduling that has been done but rather to raise an issue are the total production leadtimes really incompressible or are they the result of a delibarate attempt of management to keep planning and scheduling simple ?

6. EVALUATING THE TRADE-OFFS OF INTEGRATION

One of the key elements of the concept of integrated supply-chain management comes from the many trade-offs to take into account when deciding for a global logistics strategy. Some trade-offs occur between functions whereas others affect global operational decisions These trade-offs have been presented in the first part of the study and will be applied to XYZ in the present section over times, good scheduling is as important as good planning. At XYZ, the scheduling rule is fairly simple and logical: since the most time-consuming activity is to clean-down equipment between products, same products are scheduled consecutively. Althoughthis makes sense with respect to a certain frozen planning period, say a week, it is not necessarily optimal with respect to a longer planning horizon. Operational researchers have been interested in such an issue for years and examples of apparently illogical but really optimal schedules are numerous. In fact, optimal scheduling is tied to planning methods and in general to overall production policies. If customers are asked to wait for three-months for a certain order and this lead-time includes a one-month production leadtime, then the schedule will depend on the given planning horizon. However, if the company tries to reduce production leadtime to 2 weeks, the scheduling of activities under this new planning horizon will be different.

Therefore, by imposing on clients some leadtimes that are longer than what is really needed to process materials, a company can afford the scheduling. The objective here is not to criticise the type of scheduling that has been done but rather to raise an issue: are the total production leadtimes really incompressible or are they the result of a delibarate attempt of management to keep planning and scheduling simple ?

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6.1 Cross-functional Trade-offs

Since organizations are systems, any decisions made at a certain stage will affect decisions at some subsequent stage The following trade-offs are not new to production and operations managers However, once the concept of integration and collaboration is present in a company, these trade-offs would be more apparent and understanding their challenge would be a critical factor for a successful integration

For example, product design will affect production processes At XYZ, this notion can take two forms First, product and packaging design complexity It could be tempting to differentiate some OTC drugs from those of competitors by innovative packaging designs as it is done in other industries On the one hand, very complex packaging formats would cause complex production processes On the other hand, very simple formats could weaken product marketability and be the result of costly development efforts since it is not always easier to make thing simple rather than complicated

Second, the same trade-off exists in the attempt of designing standardized packaging It would increase flexibility of packaging lines and thus reduce change-over time between products However, trying to standardize packaging of pharmaceuticals is not easy as it has been stated earlier in the paper and it could require costly development efforts It is therefore important to weigh both aspects at the time of product design and it involves the collaboration and coordination of both R&D and production people.

Another aspect of product design and feasibility is the relationships that exist with the time to market For example, the development of a new pharmaceutical product might take a variable time depending on the degree of features added to the core active ingredients Taste-test or packaging studies can postpone the introduction of a pharmaceutical even if the active ingredients are already effective It is a common decisions between R&D and marketing as to decide how much longer can a product's

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A third trade-off exists between purchasing and manufacturing and is related to some economical ordering quantities At XYZ, given the current fixed campaign size for bulk production, purchasing is fairly stable However, what would happen in case of variable batch sizes or if the organization could take advantage of suppliers' discounts and change production rate to reduce combined procurement and production cost? While the transfer of supply requirements from production planning to purchasing is a traditional practice, how many organizations have attempted the reverse communication flow to inform planners of suppliers' discount opportunities ? This is one of the challenges of integration and trade-off measurements

A last but probably most well-known trade-off exists between the desire of marketers to have ample product availability and diversity and the manufacturing objectives for low inventory of standardized products How many times have consumers heard from salespersons that 'manufacturing is not able to meet exploding demand' ? In order to reduce the opportunity for such a poor-service-related comment to occur, it is necessary that marketing and manufacturing define, in collaboration even if not in direct link, the production rate required to meet forecasted market shares and the level of inventory to maintain to hedge against fluctuating demand This might sound very elementary, looks like a business common-sense but is not always done At XYZ, this trade-off is all the more important as demand for some products is unstable or cyclical, as supply-chain leadtimes are long, as stockouts are not desirable at all and as inventory costs are very high introduction be delayed in order not to loose some niches Once again, collaboration is needed

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6.2 Operational Trade-offs

The differentiation between cross-functional and operational trade-offs simply implies that either more than two related functions within the organization are affected by the decisions or that it is specific to one function

Globally, raw materials, work-in-process and finished-goods inventory levels affect the ability of the company to respond, without involving suppliers, to both forecasted and changing demand As a result, customer-service can be maintained at a certain target level The balancing of inventory levels and service-level is probably the most visible cost issue of all trade-offs and it represents one of the key issue of supply-chain integration, stock minimization while achieving service-level maximization At XYZ, given the cost of inventory, the issue is one of the company's challenges

In case of rush orders to be satisfied either by rush delivery or rush production or both, one factor to measure is the relation between the cost of such an expedited order, the value of the order to customers and the value of the customer for the organization This concept has been understood at XYZ for a long time since hospitals, which are responsible for providing the most urgent health care, are the object of specific rush order acceptance policies and zero stockout is the name of the game

Another interesting trade-off occurs at the time of balancing forecasting cost and inventory cost There exist many different forecasting techniques requiring different kind of data collection and analysis The cost of forecasting is non-negligible and often requires considerable mobilization of assets such as technicians and information systems. It is therefore necessary to balance the savings in inventory level that would result from more accurate forecasting and the cost of forecasting At XYZ, once again, this analysis is important even if one needs to differentiate the cost of inventory that is maintained to hedge against demand variability and the cost of inventory that is needed given supply-chain lead-time

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Forecasting can also affect the process rate since it ties sales forecasts to some planning horizon The ability to forecast, with accuracy, over longer time fences would enable production to reduce the opportunity for unanticipated orders and therefore stabilize the process rate This should be included in an analysis of the cost of better forecasting methods

A trade-off that concerns marketing, production and R&D is the commonalities of parts that can be created between different product varieties and the variety of customer needs At XYZ, this analysis has been done for Alpha when one export variety, although similar to the one for the home country in terms of active ingredients, has been differentiated by some additional flavors This was done in response to some marketing studies and the cost-benefit analysis of such a differentiation has been done As the market base increases geographically, such analysis will be more and more frequent and its impact on supply-chain leadtime, inventory levels and flexibility will need to be carefully measured

A last trade-off of this non-exhaustive list concerns the balancing of inventory costs and distribution costs that is of interest not only to XYZ but also to the customers Generally speaking, by increasing the volume ordered and shipped, customers should have access to additional discounts resulting from XYZ's reduced frozen capital and occupied storage room If it is impossible for some customers (pharmacists) to increase the volume of orders, some arrangements could be passed between pharmacists and regional distributors to store greater quantities in their self-operated warehouses

7. ACHIEVING EFFECTIVE INTEGRATION

As any other ambitious objective, total integration of the supply-chain does not happen all of a sudden and its realization is a gradual process As Towill, Naim and Whikner (1992) recommended for the simplification of supply-chain, integration is a "top-down" objective

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7.1 Functional

At the functional level, two actions have to be taken in order to prepare the company for supply-chain integration First, it is necessary to achieve excellence within each function At this point, excellence is not measured according to functional (independent) performance measures but rather according to the way work is done Since integration has for objectives the reduction of the total cost of the system, the reduction of supply-chain leadtimes and the increase in service level, it is necessary that each function be in control of its tasks For example, production processes have to be fully qualified and operated with total satisfaction in terms of output quality and reliability Flexibility of equipment should be maximum and operators fully trained In other words, assets such as working capital and people should be operational at their optimal level

Second, the impact of a future integration on the working procedures has to be understood It is more a behavioural than technical issue and successful integration depends heavily on the ability of people to accept that the 'good old ways' could one day be obsolete Since resistance to change is one of the principal factor of failure in today's fast moving organizations, people should be trained to accept different working procedures For example, integration of logistics could lead the company to change its make-to-stock operational strategy to a package-to-order strategy requiring a shift in the decoupling point from finished products to work-in-process. This suddenly growing bulk inventory and decreasing end-product inventory could destabilize people who feel that security lies in a massive ready-to-be-shipped inventory while implementation is "bottom-up" In the present case, the bottom represents each organizational function whereas the top is the top-management responsible for strategic decision-making

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At XYZ, despite the existing quality of production processes and apparent mentality that is ready to accept integration, some efforts still have to be made, particularly with respects to changes in planning and control methods

7.2 Operational

A second step should be taken at the operational level and it concerns the initiation of cross-functional coordination and common performance measures Depending on the stage of integration already present in the company, this coordination could be more or less present As it is easily understood, there cannot be efficient integration in the absence of cross-functional coordination This coordination can be initiated by policies and procedures directly related to internal communication In order for the communication to be effective, positions should be created for coordinators and catalysts of the integration process Cross-functional meetings should be organized in order to discuss the future challenges of integration

In the case of XYZ, increased cooperation between purchasers and planners and between production managers and planners should be implemented Another decisive issue would be a redefinition of the position of quality control and inspection in the supply-chain As seen, this function greatly influences the total supply-chain lead-time by its ability to release materials Today, it seems that this service-function for the rest of the supply-chain operates in some type of isolation form the pharmaceutical division In fact, what could be perceived as a parallel activity in the manufacturing cycle is in fact directly in line with production processes It would therefore be desirable that the constraints imposed to quality inspection and control be openly discussed and communicated to the rest of the company. For example, some people directly affected by the delays of quality inspection still believe that a 30-day leadtime for control is a sign of low productivity whereas it is, in fact, the required time for incubation Such an attitude is not desirable and leads to silent conflicts As well, the fact that raw materials management takes place

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Another key factor for integration is the notion of common performance measures As stated, integrated logistics favours a total cost approach to the system and functional optimization makes little sense if it is against supply-chain performance optimization Total cost has been defined as the sum of highly visible costs, usually known such as materials, production or distribution costs and less visible such as information systems maintenance costs or handling costs Once all costs are determined, the challenge of integration lies not so much in knowing the sum of the cost but rather in knowing the shape of the cost function and the impact of any functional decision on the total cost of the system For example, it matters less to know that the existing cost for a product is X dollars (although fairly valuable for company's financial issues !) than to be able to foresee that a variation in batch sizes would affect the total cost by Y dollars The first measure, total cost, is static whereas the other, impact on total cost, is dynamic and reflects the true challenges of supply-chain integration With this in mind, a common and absolute performance measure is needed in place of functional measures and total logistics cost could represent an excellent organizational objective The apparent absence of functional performance measures would in fact represent a shift from quantitative measures (that could incline departmental managers to behave in a non-integrated way) to qualitative measures (percentages of delays, defects, shortages, etc) At XYZ, these measures could be the number and duration of stockouts of raw materials, work-in-process (bulk) or finished goods, the number of machine minor and major breakdowns, the number of material-rejecting quality inspections, the variation between actual and projected sales and production volumes In fact, the cost issue would be at the corporate level at the time of defining the true total logistics cost of the product This would necessitate some modifications of the accounting systems that are not discussed here and relative to underground is not a reason for some production people to have a 'dark' idea of what is going on there

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7.3 Tactical

Once the components of the organization are ready to cooperate and to pursue a common performance measure, it is time for tactical integration to happen By tactical, reference is made to the set of short-to-medium term decisions able to provide the company with competitive advantages in terms of cost, supply-chain leadtime and customer service level

The first step to take is to achieve total internal integration Now that functional groups have been trained to understand the challenges of integration, that cross-functional coordination has been initiated, that coordinating positions exist and that common performance measures have been defined, total internal integration can be achieved Of course, it does not mean that the functions disappear but rather that they are combined In a first time, purchasing, raw material management, incoming materials inspection, material requirement planning and production could be grouped in a Materials Management function The objective of this new aggregate function will be to provide production with the right supply at the right price and at the right time and to process materials Such a combined approach would have for principal advantage that once the planning decided, each component will be able to work 'just-in-time' for the next partner so that total supply-chain leadtime upstream production will be optimal The difference with the existing system comes first from the participation of all agents in planning decisions given capacity and budget and second, as a result of participative planning, the assurance that bottlenecks would be reduced either at materials preparation or at materials inspection Another important factor would be the ability to plan capacity utilization at the quality inspection the same way as it is done for manufacturing equipment Today, it seems that production planning drives the operations upstream and downstream and that each overheads allocation and non-quantifiable benefits of new technologies and logistics strategies

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At the other extreme of the internal supply-chain, sales forecasting, finished-goods stockpile management and physical distribution management would be combined into a Demand Management function responsible for servicing customers It would include all activities from replenishment order scheduling to physical distribution, on the basis of sales forecasting and orders processing Once again, this form of distribution requirement planning coupled with order management would ensure a continuous and expected flow of materials within the function It would avoid such things as finished-goods stockouts and ineffective shipments policies (size, frequencies, consolidation)

Next, the need would now be to link both materials management and demand management This key function would take into account capacity planning and scheduling optimization given the constraints imposed to the organization (budget) It represents the core of the organization since it is supposed to achieve balancing of flows, optimal capacity utilization and reach the objectives of minimum cost, shortest lead-time and highest service level It is believed that this activity would be supported by the utilisation of some decision support system with simulation and optimization capabilities It would drive the operational policies implemented by materials management and demand management by communicating the desired batch sizes, inventory levels and production rate In fact, it would link pure strategic decisions at the top-management level to pure operational ones implemented by the two existing aggregated management functions

A last action to take would be to decide where to position the main inventory level in the supply-chain, the decoupling point As theory indicates, the objective of supply-chain integration is to reduce inventory as much as possible and eventually to achieve 'zero stock' under just-in-time operational policies However, as explained earlier, true JIT will be difficult to achieve at XYZ, first due to the structure of the competitive environment and its regulations, second due to process leadtimes and cost relative to the synthesis of active ingredients, third due to high change-over time and fourth due to demand variability In these conditions, inventories will still play a strategic role and the key issues reside in determining both their positions and levels in the supply-chain In the case of fully integrated supply-chain management, the principle is a very deep penetration of customers orders in the chain In other words, orders would be satisfied as far upstream as possible, leading to a decoupling point at the raw materials inventory The major problem with the pharmaceutical industry comes from the long change-over times between products Thsrefore, apart from the case of fully-dedicated production equipment, it is not conceivable to place the decoupling point so far upstream In addition, the position of the decoupling point will depend on the total system capacity to satisfy demand As one can observe, there are no specific rules for positionning the decoupling point and it requires a case by case analysis In addition, its position will affect the total effectiveness of the supply-chain with respect to inventory cost and service level This is why this particular aspect of integration will be the object of a study in the third part of the paper where simulation will help measure the impact of supply-chain integration on the decoupling point At the same time, a qualitative analysis of the factors influencing the positioning of the decoupling point will be done

7.4 Strategic

Behind operational policies hide many strategic considerations relative to supply-chain integration First, integration should be analyzed as a substitute for either vertical integration (company-owned partners) or obligational contracts (sporadic partnership with limited control). At XYZ, the analysis has been made at different levels such as the decision to operate a distribution center, to close down regional warehouses and to pass responsibility for delivery to regional carriers. Upstream production, the same analysis still has to be done for external suppliers Should XYZ keep the same contractual relationships with suppliers or should they integrate them ? The need for integration has been discussed earlier and there is little doubt that it is a necessary step to reduce supply-chain leadtime and to increase quality standards It belongs to the top-management to decide and it will not be discussed here any longer However, one can recall that in the case of recurrent transactions as is the case for high volume supplies and when moderately to highly specialised materials are required, supply-chain integration fits, especially if the company operates under a substantial degree of uncertainty as it is the case for pharmaceuticals

Should the company decide to integrate suppliers, the necessary steps could come from a supplier qualification program It would necessitate the commitment of suppliers to respect some internal policies and procedures, to share information with XYZ, to bring their production equipment and processes to some quality level determined by XYZ As a return, XYZ would be committed to long-term relationships for these controlled and qualified supply sources. It would take substantial time and effort to achieve such a qualification program but the results would certainly make it worthwhile The reduced burden for quality inspection as well as the reduction of chances for unanticipated delay, combined to the commitment for prices and volume would decrease hedging inventoryand consequently a portion of supply-chain leadtime

Once suppliers are integrated, since carriers are in the process of being integrated, XYZ's supply-chain would be totally integrated The implementation of such an integration would still represent an important challenge, requiring modifications in some operational procedures but it would increase the company's ability to respond in a more competitive way to its growing customer base and variety.

CONCLUSIONS

Two activities of research were pulled together in this study The first objective was to review the literature dealing with integrated logistics form both a qualitative approach and a quantitative modeling standpoint The review led to the building of an analytical framework to evaluate the potential for logistics integration of an organization The second objective was the application of the framework on a pharmaceutical company and the identification of some industry-related environmental and operational constraints

The concept of integrated logistics has recently emerged from both the academic and corporate world The increasing competition and the new technologies have forced a redefinition of product cost so that it is now more relevant to focus on the logistics cost, or total cost, of the goods sold This is possible only if a company is willing to move from the traditional fragmented view of functional optimality to the evolved integrated approach, understanding by this matter that integration is principally a process of trade-offs This evolution has captured a lot of attention from researchers and models dealing with integration are becoming more and more reliable and complex These models, either optimization or simulation models are expected to become key decision-making tools for the redesign of more effective and efficient supply-chain as integral part of a company's decision support system

At the pharmaceutical company XYZ Ltd, the heavy environmental and operational constraints common to many multi-national pharmaceutical company, the analysis of the supply-chain for one product category revealed some inequalities with respect to the degree of integration achieved Whereas the activities downstream production demonstrate a heavy concern for and substantial achievement toward integration, the lack of integration of external suppliers as well as a recurrent tendency for functionality represent the areas where major improvements can be made

The principal limitation of the study is the timeframe in which the observation at XYZ Ltd has been done It would have been interesting to observe the evolution of the logistics activity for at least six months and to back up the analysis with a second evaluation, six months after the first one As an example, three months after the end of the observation, the company started a suppliers qualification program. The lack of such a program has been considered as being one of the principal barrier to total integration at the time of observation It would be interesting to evaluate how well this program has been implemented and what are the main consequences on supply-chain efficiency.

As one future direction, the study of integrated logistics could be accompanied by a simulation model. As it has been exposed earlier in the literature review, integration of the supply-chain can only be effective and efficient if a certain number of criteria are met Therefore, the first task is to justify how and why simulation is capable of representing the mechanism of integration with the required criteria

The representation of a company's supply-chain leads to a serial multi-echelon system in which parameters such as inventories dynamically vary as time elapses. This global and dynamic approach being one of the major requirement for successful logistics management, it is encouraging to observe that simulation suits this approach The global approach is possible since nothing prevent the analyst from building different routine relative to each different echelon of the chain and from linking them by using sequential output-input The dynamic alteration of parameters is implied by the linkage since any change at one echelon influences the calculation of the other parameters, downstream the chain by the proper nature of the model, upstream by some feedback features

In addition, it is almost always under uncertainty that activities (variation in demand, supply, delivery capabilities, breakdowns,) happen and the combination of both the dynamic and the stochastic elements would lead, for optimization modeling, to very difficult tractability and long solving time As opposed, randomness is one basic element on which simulation is based and a large variety of stochastic parameters and events can be modeled easily

Therefore, the use of simulation greatly reduces these two barriers and allow very flexible changes in input data and parameters Obviously, it cannot be compared to optimization since it does not serve the same purpose but in the present case, the objective is to measure supply-chain performance and compare alternative designs, both tasks being easily done with simulation

The relative facility to model dynamic and stochastic operating systems allow simulation to represent situations that are very close to reality in terms of uncertainties such as leadtime and demand variations By definition, a model is an artificial representation of reality which enables to study multiple scenario without actually altering existing systems Therefore, it is of great interest to logistics managers to evaluate the potential benefits and drawbacks of a specific policy without incurring the cost of a real application

The concept of integrated logistics, as defined in the first part of the thesis, is essentially a trade-off issue, a right balancing of inventory costs and production or distribution costs In other words, monitoring the supply-chain requires some "what-if" analysis and it is specifically the nature of simulation, i e. to evaluate the impact of different scenario on the total cost and leadtime of the system in the present case, the facility with which one can run the simulation for different scenario without changing the structure of the program makes this modeling tool a very valuable decision-making tool to highlight the impact of integration at XYZ Ltd..

The location of the decoupling is an activity that fits well into simulation models It consists in determining the point of the supply-chain where demand management based on sales forecasts and downstream cost-related activities is separated from the activities based on capacity and materials planning From a modeling point of view, it consists in separating the activities that will use re-order point based replenishment routines from those which will use periodic replenishment routines.

In order to make a meaningful model, the operating policies used in the model would be those applied at XYZ Ltd A five-echelon system would be designed These echelons, a distribution center, a finished-good stockpile, a packaging line, two blending tanks and four storage tanks and a raw material stockpile are linked together so that the output of one stage becomes the input for the next, minus the loses in between due to materials rejection for insufficient quality

There are 44 raw materials and packaging materials, 3 types of bulk syrups and 6 varieties of finished products The bill of materials used in the simulation will correspond in quality and quantity to the real one so that inventory depletion rate, reorder size and cost will be monitored by the simulation

Demand for products is stochastic and the data distribution is based on existing sales data. Two types of orders arrive fragmented orders (F O) requiring manual manipulations for picking products in cartons and packing the order and entire orders (E.O) for which the lot size is a multiple of the stored packed volume In the latter case, orders are prepared entirely by robots The time to prepare orders depends on the number of items and the type of orders

The DC is replenished by a shuffle from the production site and stocks are transferred from end-of-quarantine inventories to DC inventories ready to be shipped In order to measure the performance for service level, any order which cannot be filled due to stockouts is registered as entirely lost for the company

There is one packaging line used for all the finished products and one can distinguished minor setups (same bulk, different labeling) from major setups (different bulk or different product). The packaging campaign will be organized according to the production planning and the company's policy to launch a few large campaigns rather than more campaigns of smaller size will be respected at the beginning in the model Some variations will be done in order to measure the supply-chain performance with different lot sizes. Two blending tanks exist and the activity is totally automated At the end of the blending process, bulk of syrups is transferred to the storage tanks (4)

The problem of quality control and inspections would be the object of a specific echelon, parallel in the material flow to the manufacturing activities and the problem of capacity and leadtime in this department will be the object of a different "What-if " analysis

In the present study, the decoupling point would be placed at the finished-goods stockpile The underlying reason comes from the practices of the company and can be explained by the specific constraints placed on pharmaceutical companies Since it is not allowed to mix several different bulk of products for a single packaging campaign, and since set-ups and cleaning times are very high, sales data collected from marketing are aggregated so that production launches blending and packaging campaigns for a set of non-distinguished customer orders. Therefore, the earliest time the products become earmarked for a specific customer is at the distribution center, except in very seldom cases of special orders

The simulation could be programmed using the General Purpose Simulation Software (GPSS/H) Data used for the model would be gathered at the company and the output of the simulation should enable logistics people to evaluate the performance and responsiveness of the existing operating policies. On this basis, some changes to the traditional policies could later be tested.

In fact, integrated logistics is an on-going research topic that is far from being exhausted The study of its application in certain industries where regulations and practices represent an unexpected handicap for improvements should be encouraged since it is probably there that integration of the supply-chain could offer interesting alternatives to traditional production and operations management programs aiming at inventory , leadtime and waste reduction

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