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DYNAMIC LOGISTICS FOR A TURBULENT WORLD: ORGANIZING PRINCIPLES

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Introduction

Companies today are operating in highly stressed and turbulent environments in which even small disturbances to the business system can quickly escalate into major upheavals and headaches. This increasing complexity has highlighted two major risks for companies today. The first risk is that of irrelevance. Unanticipated changes in the external environment, from upheavals in financial markets to explosive political events, can render current strategies and tactics ineffective, rapidly diminishing profitability. The second risk is that of lost opportunity. While the rapid pace of change can destroy a business plan overnight, it also provides new opportunities. Many companies, however, are not prepared to respond to and control fluctuations of asset availability, quality or reliability quickly enough, thereby undermining their ability to exploit these new opportunities.

In previous times, these stresses to the business system were not as critical. Today they can have catastrophic results. Ingrained responses to these stresses are based on an outdated set of behavioral rules that no longer meet the needs of an increasingly dynamic and complex business environment. These rules have functioned well in an era of stability, but are not suited to one dominated by increasing dynamic complexity. The greatest concern for a manager today is not the avoidance of failure costs, but rather the avoidance of opportunity costs associated with not being able to identify, evaluate and exploit higher-value opportunities. Opportunities are triggered by a customer need, made real by its content, place and time. To profit from an opportunity, a successful of transforming activities must be coordinated along the supply chain.

In a dynamically complex business environment, logistics holds the promise of overcoming the spatial and temporal gaps that enable the profitable exploitation of an opportunity. This paper offers a vision of the logistical environment of the future. We begin with an historical perspective of the business and logistics systems that have evolved in response to increasing complexity and dynamism. The organization of these business systems—mass production, lean management and, now, agility—can be viewed as optimal systems for the environments of their day. We then suggest that the central task of companies in today's environment of rapid change and increasing complexity is to manage opportunity. The concept of a dynamic logistical system—a fundamentally new approach to organizing information and material flow in real-time—is presented. Four organizing principles for such a system are described—virtualization, simultaneity, scalability, and autonomy. We conclude with an assessment of current systems, infrastructures and practices vis-a-vis these principles—and a prognosis for their future integration into the logistical systems of tomorrow.

New Rules of the Game

Nearly a decade ago, the front pages of business journals and magazines proclaimed that the customer was king. The proclamation was slightly premature. At that time, deferring to the customer meant providing enhanced customer services, establishing a closer relationship with the customer including more "face-to-face" customer interaction, and accommodating customer whims as much as possible within the constraints of existing manufacturing processes and systems. Although the importance of establishing a relationship with the customer was a new perspective, the manufacturer still maintained the balance of power in the market place.

Only within the last several years has the balance of power truly shifted to the customer. The spread of new technology, especially information technologies such as the internet and on-line yellow pages that made comparison shopping as easy as a push of the button, further diminished customer loyalty. Continuously innovative markets demanded new products, new manufacturing strategies and, at the same time, new success criteria. No longer were quality and price the key market differentiators. Customers wanted responsiveness—fast delivery, customized features and an increasing array of services.

At the same time, trends toward global integration have only enhanced customer power. Falling trade borders, downward pressures on transportation costs, and low factor costs in emerging markets have spurred the integration of world markets. Growing populations developed a hunger for sophisticated products to signal their new prosperity. Regional, ethnic and personal tastes bean to crack the concept of a single market. Globalization, however, is a two-edged sword. Companies are now able to source goods, technology and capital from anywhere is the world. This ability to outsource—to go anywhere to get the best, or the cheapest, or the first available—allowed companies to concentrate on the development of core competencies. Companies specialized in the customer-oriented development of specific know-how or management processes. By virtually integrating, companies are able to compete successfully in a world dominated by rising customer expectations for timeliness and responsiveness, with increasing market "fractalization," rapidly evolving technology, sinking relative prices of energy and transport and, ubiquitous information.

Today, the ability of companies to meet targets of speed and responsiveness in the marketplace depends on their ability to assemble and manage a cast of core competencies—to create the virtually integrated enterprise. Spurred on my globalization and the desire to avoid failure costs, industry has disseminated competence around the world—exported commercial knowledge and technology, developed large international sales and marketing departments, trained people abroad. Business today feels it must be everywhere all the time to succeed in the global marketplace. As nearly everything becomes available everywhere and at any time, the number of commercial actors and the speed of their transactions increases dramatically.

A global business strategy based solely on an assembly of core competencies, however, is not sufficient to maintain a competitive edge in an increasingly complex and dynamic business environment. The source of complexity is the increasing real-time control of the customer delivery process that is needed to produce customized products from parts and components sourced from suppliers around the world. As Lester Thurow has said, "Today everything can be made available everywhere and at any time." By the same token, the time necessary to assemble the supply and transport chain necessary to fulfill customer demand is increasingly more than customers are willing to accept.

Meeting market expectations in a this complex and dynamic environment will require a rethinking of the business systems by which companies interact and products are made. New rules of the game are altering the distinctions between products and services. Nowhere do these changes have more impact than in the arena of logistics—the practices and processes by which information, materials and money circumnavigate the globe to create the products and services for the global marketplace.

Dynamic Complexity: An Historical Perspective

The emerging new rules of today's business environment can be can be viewed as a natural extension of the interplay between the pressures of increasing environmental dynamics or temporal change, and new business strategies such as "customization" that create logistics complexity. It is worthwhile to look at how the interplay of these two dimensions—one characterizing the competitive environment and the other industrial response—have given rise to the business systems of the past one hundred years.

In most tales of industrial history, Henry Ford's Tin-Lizzy is the symbol of the mass production era. Mass production appeared in the early part of this century as a response to the demand for affordable products for a growing middle class. Ford's apochryphal statement that customers could have a Model T in any color so long as it was black reflected the power of the manufacturers to ignore the true or latent demand of the marketplace. New technologies of production and mechanization allowed large volumes of standard products that returned tremendous economies of scale, as well as profits, to the early corporations. The focus on ever increasing economies of scale, combined with a trend toward vertical integration, also led to the formation of ever larger and hierarchically structured companies that ultimately would fall under the weight of their inefficiency.

Mass production remained the predominant business strategy for nearly fifty years. "Taylorism" was a successful strategy for an era of static environments and, since the power to determine what goods were sold resided with the manufacturer, avoided the problem of complexity generated by structural variety. Under Taylorism business systems were dominated by the pressures to reduce unit costs and increase economies of scale. As Figure 1 illustrates, the dynamic between temporal change and complexity can explain the experience of recent years. A simultaneous increase in structural variety—more variants of products to appeal to a "fractalizing" market—and of temporal change characterized by an acceleration in the rate of introduction of these variants, drive sudden and fundamental changes in system behavior. The confounding of these increases in structural variety and temporal change result in an increase in what we call dynamic complexity.

The cascading eras of dynamic complexity are illustrated in Figure 1. The increases in structural and temporal variety triggered by the ascendance of customer power marks the first discontinuity. Economies of scale become insufficient to assure market success. Business systems organized around economies of scope—lean systems—emerged as the dominant form of competition. As shown in Figure 1, lean management is dominated by failure costs—costs that are incurred when fleeting and evanescent market targets are not met. However, as products became increasingly complex, the constellation of core competencies necessary to design, manufacture and deliver a product became more expensive to maintain. At the same time, the increasing pace of technological change made it impossible to develop this core know-how in-house as opportunities arose.

This increase in dynamic complexity is the root of the term "turbulent" that is increasingly being used to describe the business environment today. The analogy, drawn from science of physical systems, has implications from the natural world. Complex and nonlinear physical systems can quickly turn into turbulent or "chaotic" systems. In these systems, predictability of the future is poor or non-existent because even small changes at the edges of the system can have dramatic effects on system's performance and outcome. In turbulent business environments, it becomes difficult to even identify market targets—much less exploit them.

In business systems today, market turbulence is still driven by a global interaction of competitive strategies to penetrate markets with superior goods and services in the face of increasing pretentiousness of customers and fast technological development. What's different today is that new information and communication technologies have rendered obsolete the business processes and responses that worked only a few years ago. Vanishing market demarcations and transaction costs, the progressing predominance of immaterial assets, the substitution of the law of falling marginal costs per unit by the law of the increasing productivity of knowledge and, last but not least, the interfering volatility of global financial markets, have all exacerbated what was already a chaotic environment.

The New Agility: Managing Opportunity

If mass production is dominated by unit costs, and lean management by failure costs, then turbulent environments are dominated by opportunity costs—or the inability to identify and exploit market opportunities in turbulent environments. The challenge in an environment of dynamic complexity is not only to capture market opportunities in real-time, but also to overcome the diseconomies of scale and scope due to market fractalization that constrain profitability.

The concept of opportunity costs is not new, but rather dates to the turn of the last century. According to Green *et al.*, "if a decision for one of at least two opportunities to make use of scarce assets is inferior in terms of costs or utility relatively to the other(s) this relative loss is called an opportunity cost." Until now attempts to integrate opportunity costs into accounting systems has proved difficult for the simple reason that it is difficult to measure the difference between a known inferior and an unknown better or even "best" decision. Firms have focused on cost per unit, or failure costs (e.g. excess inventory, obsolescent products), or even on order-to-delivery cycle times. In a turbulent environment driven by dynamic complexity, the risk is that companies are unable to respond to market opportunities because they lack information to identify the target. The resulting inferior decisions can result in opportunity costs. Alternatively, companies fail because the lead times required to assemble the right set of competencies, or re-deploy existing resources, exceeds the speed of temporal change.

The challenge of hitting the target is especially difficult in today's fast-paced market where windows of opportunity are shrinking continually, as shown in Figure 2. The business system's task is to assemble the necessary assets and supply chain connections that enable the firm to hit the target. First, the necessary assets for assembling a product must be identified and appropriate links for moving parts, components and finished products must be opened. Delays only give opportunities for competitors to steal the opportunity. In some cases, the wrong target may be hit! When this happens, companies must waive a part of their profits due to the costs of re-locating and re-assembling assets, or the costs of increased inventories of unsold goods, or reduced revenues from fire sales.

Companies increasingly face these crucial opportunity risks. They urgently need business systems that enable them to scan for opportunities, to account for opportunity costs in daily operations, and get to the customer before the competition. At the same time, quality and cost must be controlled. Without these systems, companies run the risk of obsolete deployment of physical materials that cannot be reused because they are not fungible. Many production capacities and distribution capacities—for example space in the belly of an air freighter—cannot be stored. To miss the opportunity is to lose it forever.

Maximizing Opportunity

The volatility of today's markets has forced company's to ask themselves important questions about their ability to respond to customers fast and effectively. For example, can supply chains be rearranged efficiently in response to changes in customer demand? Or can asset positions be adjusted quickly in response to exchange rate fluctuations? Ideally, a company's assets should be positioned at their place of maximum value at all times. Of course, this is theoretically impossible given the unpredictable nature of customer demand. In the absence of complete knowledge of customer demand, companies must develop the operational flexibility that will allow assets to be marshaled with the same ease for a variety of market opportunities—regardless of where they surface around the world.

Operational flexibility is expensive and, consequently, Henry Ford's Tin Lizzy tried to get rid of it. Today, the combination of increasing demand for variety and efficiency sharpens the flexibility versus cost debate—and destroys economies of scale at the same time. Recent strategies to increase operational flexibility include delaying product assembly until customer orders are actually received. These postponement strategies, built around common platforms or modules, reconcile variety and efficiency using common standards and interfaces. At the same time, they regain economies of scale by increasing the number of common parts, and achieve variety through the mix of modules. While the personal computer industry is most quickly brought to mind as an example, complex industries like the auto industry are increasingly trying to resolve the efficiency/variety debate through similar strategies.

Dynamic complexity can be tamed by new strategies that maximize opportunity within the organization. Maximizing opportunity means solving the twin problem of information and deployment. The first task is to identify and evaluate effective opportunities. The second task is to deploy materials and capacities close to the opportunity. From the time a product is conceived in response to a perceived market need, actions that the company takes to bring that product to the marketplace reduce opportunity and, at the same time, incur risk. Opportunity is lost because dedicated resources are not available to other market opportunities that may have a higher value. Conversely, risk, or potential opportunity costs, are incurred if that product misses it market target.

This concept of maximizing opportunity and, conversely, minimizing risk, is illustrated in Figure 3. In this graph, opportunity diminishes over time as assets are allocated as part of the total business process of meeting customer demand. The rigidity and risk associated with Henry Ford's Tin Lizzy system of mass production is represented by the lowest curve in the figure. Dedicated machinery, fixed assembly lines, and lots of inventory decrease opportunity rapidly. But, of course, since there was only one model, and the idea of shifting resources to a higher use was not relevant. And, as the dominant manufacturer with total market power, lack of opportunity did not hurt Ford. By contrast, the personal computer manufacturers today are in a very different situation. Through postponement, common parts and components sit on a shelf awaiting receipt of an order. Delaying product assembly (Label 1) or platform strategies (Label 2) increase opportunity. Ideally, decisions to deploy assets should be postponed to coincide with the identification of the opportunity. Business systems need new and different strategies to achieve even greater opportunity.

A significant outcome of strategies such as postponement has been the elevation of logistics as a coordination mechanism for the global enterprise. Fast turnaround for modularized products requires that all parts, components, or modules arrive simultaneously at the point of assembly. Personal computer manufacturers like Dell and Compaq have solved this problem by requiring all suppliers to maintain inventories or parts and components within minutes of the assembly point. Personal computers assembled to specification are air expressed to the customer overnight. Manufacturers dependent upon parts and components located far away from the point of assembly leverage the technology of integrated carriers like FedEx to assure the synchronized arrival of components directly to the point of assembly.

Increasingly, complex industries like the automotive industry are transforming themselves into logistics companies rather than traditional manufacturing companies. One example is Volkswagen's new truck and bus facility in Resende, Brazil. This facility might better be called a "logistics center" than a manufacturing plant. Each vehicle has been broken down into seven modules such as cockpit or chassis. First-tier suppliers assume responsibility for manufacture of each module, assembly into the vehicle at the Resende plant, and manage the module supply chain. Volkswagen provides the assembly facility, and assumes responsibility for the assembly logistics and quality control.

In increasingly turbulent times, however, even these strategies will ultimately fail since they do not address the critical issues of dynamic complexity and market fractalization. In a stable environment, variety can be produced effectively and efficiently. However, as companies increasingly outsource parts, components and modules beyond their core competencies, both the complexities and the potential for failure are exacerbated. Small fluctuations in supply chain reliability can stop the assembly line driving customers to a competitor. Normally, "built-in" lead times or inventory buffers protect against fluctuations. However, these measures run counter to the need to couple the links of the supply chain more and more tightly to avoid time and cost weakness.

Dynamic Logistical Systems

The proliferation of actors, the number of transactions, and the speed with which they must be accomplished is increasingly raising the performance standard for global systems that manage information, communications, transportation, and even finance. A fundamentally new attitude is needed to realize operational flexibility beyond conventional postponement or modularization—and that overcomes the problems of micro-coordination that are endemic in turbulent environments. Such as system, which we term dynamic logistics, must possess the following capabilities:

- *Virtualization* – the ability to acquire the information from the turbulent environment necessary to identify and evaluate opportunity;
- *Simultaneity* – the ability to know the real-time status of all relevant assets and to control them physically by simultaneous access;
- *Scalability* – the ability to arrange capacities and assets to match demand cost effectively; and
- *Autonomy* – the ability to overcome problems of micro-coordination that create a robust, of fail-safe, system

Each of these enablers of dynamic logistics is a response to some characteristic of a turbulent environment that destroys the competence of existing business systems. Virtualization is a response to the rapid destruction of information in a turbulent environment. Scalability is a response to the destruction of economies of scale and scope. Simultaneity is a response to the destruction of accessibility. And finally, autonomy is a response to the destruction of central controllability.

As we have discussed in a previous section, increasing turbulence and the speed of change exceed the lead times needed to respond successfully to market opportunities. In such an environment, any deployment of material assets incurs risk—the risk of having assets deployed at the wrong location at the wrong time. To increase the speed of reaction is a first response. However, the fundamental changes in the environment that result from turbulence do not respond to speed. Rather, the goal of dynamic logistics should be to define products and allocate resources on the basis of the their reduction of opportunity risk—risk that is incurred when assets are no at their location of maximum value.

Wresting Information From Turbulence: The Principle of Virtuality

Virtualization is an organizational strategy to identify and evaluate market opportunities, and to keep these opportunities open as long as possible. Today the half-life of knowledge is about three years. After six years, 75% of knowledge has been devalued, and the devaluation of knowledge is accelerating. In such an environment, it is increasingly difficult to keep in touch with the market, as evidenced by the tremendous surge in companies that provide business intelligence services. For executives today, a crucial question is: "How do you evaluate opportunities which don't exist yet? And, then, how do you allocate resources for opportunities which may exist in the future, but don't exist yet?"

In a dynamic world, companies have to react very exactly and very quickly to changing conditions. Formally, this environment can be described by probabilities of demand at every location and the probabilities of being able to provide exactly the assets needed to respond. To make decisions about asset location, companies must align the probability that a resource will be needed, with the probability that the asset can be provided. A virtual system is one in which it is possible to provide maximum "closeness" of resources to opportunity. What is needed is an operational link between supply and demand that can provide this "closeness" to opportunity. Closeness is typically defined by distance, but does not need to be. 'Real options" are one solution.

Options provide an essential ingredient—information about the future status of an asset. Options are "information-rich" products because they provide critical information about the *future* availability in terms of quantity, quality, price and time. For example, car insurance provides information about future assets in the case of damage or accident. Options provide more—in addition to accounting for down-side risk, they provide an opportunity to achieve up-side gain as in the financial markets.

Figure 4 illustrates a basic pricing system that allocates transport capacities according to the principles of options—virtual capacity allocation. Traditionally, decisions about the allocation of assets are made in advance of the opportunity—for both the shipper and the carrier. A customer of air freight, for example, has a portfolio of assets that are deployed around the world in anticipation of market opportunities (left-hand side). At the same time, the provider of the air freight service has pre-assigned capacities in routes that are based on expected opportunities. For all the reasons mentioned earlier, market demand and opportunities are not aligned due to turbulence in the environment that destroys information.

Consider Figure 4. An 'options' market assigns capacities on a virtual basis—whenever or wherever they are needed. The bell-shaped curve on the left represents perspective of the shipper, providing the probability of demand on, for example, a specific route at a specific time. If the curve were shifted the right, then the shipper should purchase an option to assure that capacity is available when needed. Conversely, when the curve is shifted to the left, then the shipper should sell the option because the expected price reflecting anticipated demand, is too low. To possess a right on such a "virtual capacity" can be very valuable—analogous to insurance against other expected disasters such as floods, hurricanes and other natural disasters.

The right-hand side of the figure provides the perspective of the providers. The premium associated with a tradable option is an evaluation of the "opportunity" associated with the underlying capacity. A high premium indicates the need to increase capacity because many customers perceive a high value for that available capacity. When the premium exceeds a certain amount, the provider should increase capacity; conversely, when it falls below a certain amount, the allocated capacity should be reduced. There is a region between these two prices where no action is possible. In the case of transport management, this situation might result from the technical infeasibility associated with adding "one shipment' to a full plane, or the problem of lead times.

All capacities need not be traded on the basis of options. However, in extremely dynamic environments, a significant portion of those capacities can be allocated through an options-based system. In cases where there are too few market participants, alternative "opportunity-oriented" pricing systems may be applied. The crucial point is not that real options are the answer. Rather, the outcome of virtualization is a virtual capacity allocation system, such as an opportunity-oriented pricing strategy, that allocates resources so that the probability of experiencing an opportunity equals the probability of being able to respond to that opportunity.

In short, "real options" are nothing more than a tool to implement virtuality. In short, we are re-defining the virtual enterprise. Instead of defining the virtual enterprise as a portfolio of real assets, we define it as a portfolio of options pre-configured for expected opportunities. Supply chains are constructed by picking those options from the portfolio which corresponds to the opportunity. The options can be used, if an opportunity arises. If the options are not needed, they can be sold or left to lapse. The price of the real option reflects the value of the opportunity and the underlying assets, as perceived by the market. If the price of the option on transport capacity drops, few players can use the asset. But conversely, a rising price signals a hot asset. Providers of transport services can steer their networks away from "poor" markets to "hot" ones, maximizing opportunity—and profit.

Linking Assets and Opportunities: The Principle of Simultaneity

The identification of opportunities through virtuality is a necessary—but not sufficient—condition for managing in a turbulent environment. Assets must also be continuously visible and physically accessible. A dynamic logistical system must bring together *simultaneously* all of the assets necessary to exploit an opportunity—assets and capabilities necessary to produce goods and services have to be always and everywhere connected to the firm's operational control and dispatch. While strategies such as postponement and mass customization maximize opportunity by leveraging asset flexibility associated with product design and manufacture, they do not address the spatial and temporal distribution of assets—or the inflexible scales of logistical capacities. Assets may be kept too far away from the place and time of need, and there may be insufficient time to reconfigure the system on demand. The success of Dell in the personal computer market can be attributed to their ability to assemble machines to customer specification within minutes from components stored on-site and air express them to the customer overnight. Maintaining inventories of components on-site is not possible always possible. Very complex supply chains require the coordinated transport of hundreds of parts and components from distant corners of the globe—all arriving simultaneously at the point of assembly.

As shown in Figure 5, the ability to postpone resource allocation in the transport chain requires not only asset visibility, but also real-time control. Through the integration of temporal and spatial distribution patterns of moveable assets and transport capacities, the likelihood of demand can be aligned with the likelihood of the transport opportunity. New automatic identification technologies, bar coding techniques and information technologies are solving the problem of asset visibility in the pipeline. When information about routing and carrier schedules linked to information about asset location, real-time control of the pipelines becomes possible. As new opportunities emerge, assets can be reassigned immediately from a point of lower value to a position of higher value. In short, logistical systems that coordinate the deployment of assets in response to market opportunities are becoming central platforms for management of operational risks.

Simultaneity is enabled by information technology that allows all constituencies along the supply chain from customer to raw material supplier to transportation provider. By simultaneous information exchange, order receipts, and exceptions or changes to an order, can be relayed to all the necessary parties immediately. This transaction model represents a significant departure from traditional supply chain processes in which information is passed sequentially along a chain from customer to retailer to supplier to manufacturer, and so forth. The web of transactions that are enabled when all parties are linked in simultaneous information exchange give rise to economies of conjunction. Economies of conjunction occur when opportunities and assets are aligned through information. In the same way that mass production systems were organized around economies of scale, dynamic logistical systems will be organized around economies of conjunction. These economies result not from how production is organized, but rather from how information is managed and exchanged.

Overcoming Scale: The Principle of Scalability

There is an inherent contradiction between the principles of virtualization and simultaneity and the inflexible scales of existing business and logistical systems. Turbulence destroys both economies of scale and scope. For example, fractalizing markets result in smaller and smaller lot sizes and increased product variance. Diseconomies of scale result when production levels that do not match their operational optimum, as illustrated in Figure 6. Diseconomies of scale occur when production lot sizes, and corresponding employment levels, decline below their optimum level—or rise above that level. In a totally scalable system, the costs of producing another unit, or transporting another container, are fully independent of lot size. Not too many years ago, typical production runs were several hundred thousand or more. At this scale, variances of two or three thousand did not matter too much. In fractal markets, however, lot sizes as small as several hundred are often dominated by variance.

Mass customization, modularization, and various "platform" strategies are all attempts to regain economies of scale in a fractal environment. None of these strategies, however, result in a truly scaleable business system. A dimension (i.e. length) is scalable if it can be arbitrarily divided (e.g. into centimeters or millimeters). Physical systems are scalable (and even have fractal dimension). On the other hand, economic scales cannot be arbitrarily divided. Costs or exchange rates are scalable, but the production goods that accompany these costs or rates are not. Lack of scalability in production leads to excessive costs, as well as operational problems. The cost of expediting a single order, especially one that requires a slightly different process, can be extremely high. To make production systems arbitrarily dividable would be too expensive, or even physically impossible. But it does make sense to improve scalability.

Companies are moving towards scalability through a variety of organizational and technological means. Virtual companies can leverage excess capacities of aligned companies, and reduce overhead as well. Consider, for example, a virtual enterprise of 25 mechanical engineering companies in Austria, Germany and Switzerland. Each company is operating at 90% capacity/employment. By sharing excess capacity, the firms can offer, in theory, the operational capacities of the equivalent of an additional 2.5 companies. At the same time, technological developments such as automation de-couple human efforts from the production process, thereby eliminating learning curve effects. Automation also eliminates fixed costs that lead to overlinear cost effects. Inside the factory, new flexible processes and computer-controlled machines enable the production of similar products at no additional cost.

Of course, there is a fundamental difference between the transport industry, on the one hand, and traditional manufacturing industries. Manufacturing, affected by the on-going destruction of economies of scale and scope, have already moved toward agile production systems, embracing technologies and organizational forms that are highly "scaleable." Transport industries, however, are still organized around scale economies. Not that airlines and shipping companies don't focus on individual customer needs—they do that through sophisticated handling and information systems. However, the transportation industry has not focused on the single shipment in the way that the manufacturing industry has. The high costs of purchasing and operating airplanes and ocean freighters, as well as maintaining the transportation network, have forced transport providers to concentrate as much freight as possible on primary trunk routes. At the same time, most pricing structures are mass oriented, offering quantity discounts to larger shipments.

Outsmarting Murphy's Law: The Principle of Autonomy

A fundamental principle of turbulence is that it destroys the central controllability of business systems that rely on top-down or hierarchical structures for managing complexity. Central planning and control systems are dominated by two main effects. The first effect is the disproportionality of cause and effect, or the "butterfly" effect. Traditional forecast-based systems, for example materials planning (MRP) systems for managing the ordering of parts and components, are based on the assumption that small disturbances like butterflies don't cause large system failures. But in highly dynamic systems, there are numerous positive feedback cycles amplified by multiple self-similar systems that interact in complex and nontransparent ways. In these dynamic systems, small inputs to the system can result in major catastrophes.

The bullwhip effect is one example of how information distortion can propagate out of control, leading to tremendous inefficiencies, excessive inventory investment, poor customer service, and lost revenues. The bullwhip, or whiplash, effect has been observed is products as diverse as diapers and personal computers. At Proctor & Gamble, for example, logistics managers noted the broad discrepancy between the variability of diaper sales in retail stores and the variability of raw material orders to suppliers. The amplification of order variabilities as information moved up the supply chain was attributed to rational behavior on the part of managers who wanted to control their supply chains. The same phenomenon was observed by Hewlett Packard executives when comparing sales of their printers with orders from the resellers down the chain. The variability was even more pronounced when they examined orders propagating further upstream to the company's printed circuit division.

The second effect of turbulent environments is the stress of time and the differentiation that results when small, local events cause the system to spin out of control. When this happens, no central system will have both the information and the time necessary to make reasonable decisions. If decisions are made, they may not be the "right' decisions because the decision-makers are so far removed from the local environment. Further, the time it takes to relay the information to the central control location, and back to the local location, may exceed the lead-time of the decision.

Current logistical systems are centralized and optimized to manage the movement of goods in a stable environment. For all the reasons provided above, centralized systems are inappropriate models for tomorrow's logistical systems. In contrast to hierarchical command-and-control systems, dynamic logistical systems must be intelligent, self-organizing and agile. It is essential that authority be distributed locally. Decisions optimized for local information on the basis of global rules can protect against butterfly effects and critical time lags.

Figure 7 illustrates the problem of micro-coordination that can be thrown into a tailspin by a local event such as the failure of a segment of the transport chain, or a change in customer requirement. Figure 6 traces the path a shipment on its way from a supplier's warehouse in Asia to a customer Europe. In mid-route, a message is received from the shipment owner that the priority of a shipment has been reassigned and a new destination in New York has been determined. A query of the interactive tracking system determines that the affected shipment is located in position x-y on pallet 1234. The locally intelligent system reassigns the shipment to a new route, after checking that there are no secondary effects associated with the re-routing. The shipment is de-palletized, the intelligent tag is updated with new routing information, and the shipment is sent on its way to the new destination. The remaining shipments continue unaffected to their original destination. Throughout the entire set of transactions, local intelligence has managed the entire adjustment process, guided by a set of system-wide rules for determining the best route given local information.

Uneven Progress

Progress on the path to dynamic logistics has been uneven so far. As can be seen in Figure 8, none of these four organizing principles have been developed beyond the prototype stage. Virtuality as a concept has been understood, but the application of these concepts to real-world situations has not progressed significantly beyond basic research. The concept of "real options" appears increasingly often in the current business journals, and has been applied to applications ranging from the selection of a research and development portfolio to evaluate investments in new production facilities for products whose life cycle is uncertain. The primary obstacle to further development and application of the concept is the lack of methods for computing and evaluating opportunity costs.

Scalability as a concept has been validated in the factory, but not yet in the design of transport networks. The transportation industry has introduced several innovations over time that improve scalability. The ocean container, for example, created a standard modular unit that could be scaled up to the capacity of the ocean freighter. Future steps toward scalability at the macro-level will be realized in new airport and seaport designs that are modular and portable. At the micro-level, the ability to achieve scalability depends on new information and communications technology that allow shipments from disparate geographic locations and manufacturers to "self-organize" into larger units destined for similar locations. Proven technology exists, but it has not been integrated into a system organized specifically to achieve superior cost economies for "shipments-of-one."

Over the last several years, the principle of simultaneity has advanced the fastest and the farthest. The best example of an integrating infrastructure designed to provide simultaneity is the Global TransPark (GTP) concept. Prototypes of the Global TransPark concept are being built in North Carolina, Thailand, and the Philippines. What does this infrastructure look like? If you could merge an airport with overnight connections to major overseas markets, a multi-modal transportation hub providing regional access, distribution centers capable of consolidating and bundling shipments from all over the globe, and agile manufacturing facilities—all linked together in a universal information environment—you would come close to creating the Global TransPark. These GTPs are being linked into a global network that will bridge the spatial and temporal divide, and serve as an enabling technology for dynamic logistics.

Finally, there is no question that rapid developments in digital technology will soon be leveraged into low cost silicon chips with embedded digital intelligence for controlling shipments moving through an "intelligent" logistics network. In this network, software agents will update shippers and carriers as to the progress of the shipment, negotiating new routes as necessary, and, for all intents and purposes, operating as an advocate for that shipment. The real challenge, of course, is not the isolated development of any of these four dimensions of dynamic logistical systems, but rather their fusion into the logistical systems of the future.

Jack, I have given Guerda a paper copy of the figures. We don't have electronic versions available in a separate file since they are embedded in a bigger Powerpoint presentation from a GLORI meeting.

FIGURE 1

FIGURE 2

FIGURE 3

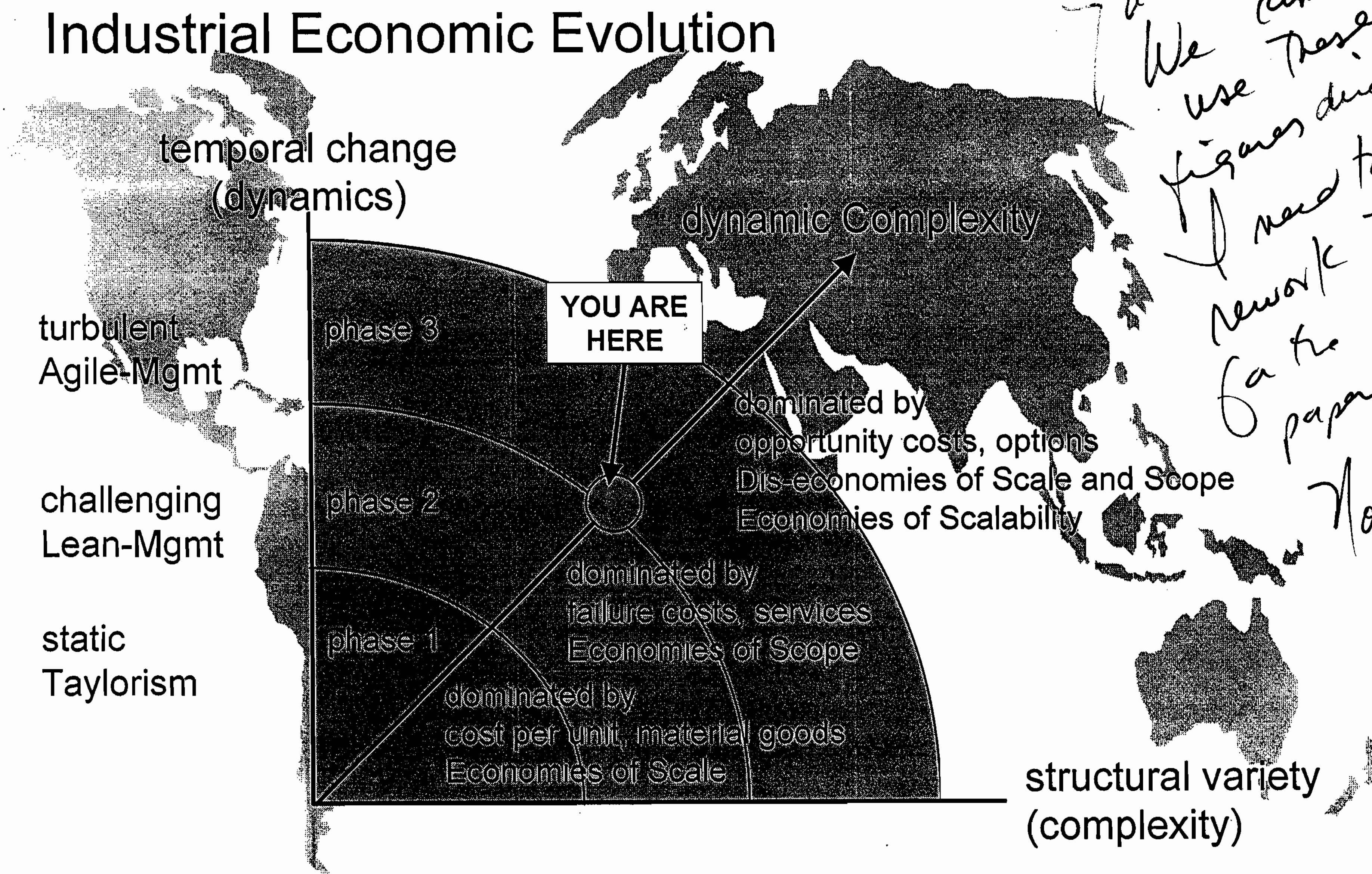
FIGURE 4

FIGURE 5

FIGURE 6

FIGURE 7

FIGURE 1



Jack
We can't use these figures directly. I need to rework them for the paper.
Noel

FIGURE 2

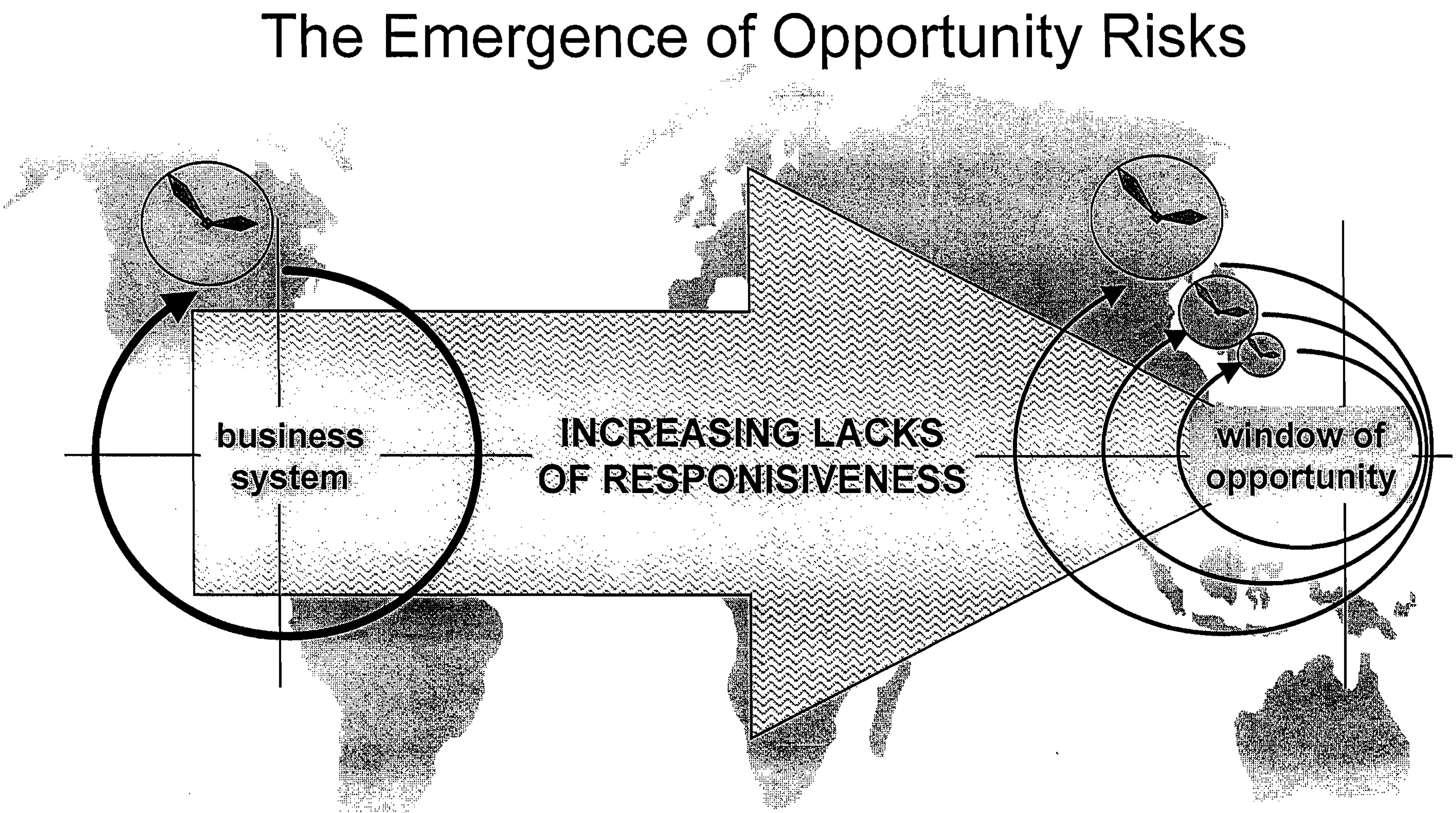

The Emergence of Opportunity Risks
business system
INCREASING LACKS OF RESPONISIVENESS
window of opportunity

FIGURE 3

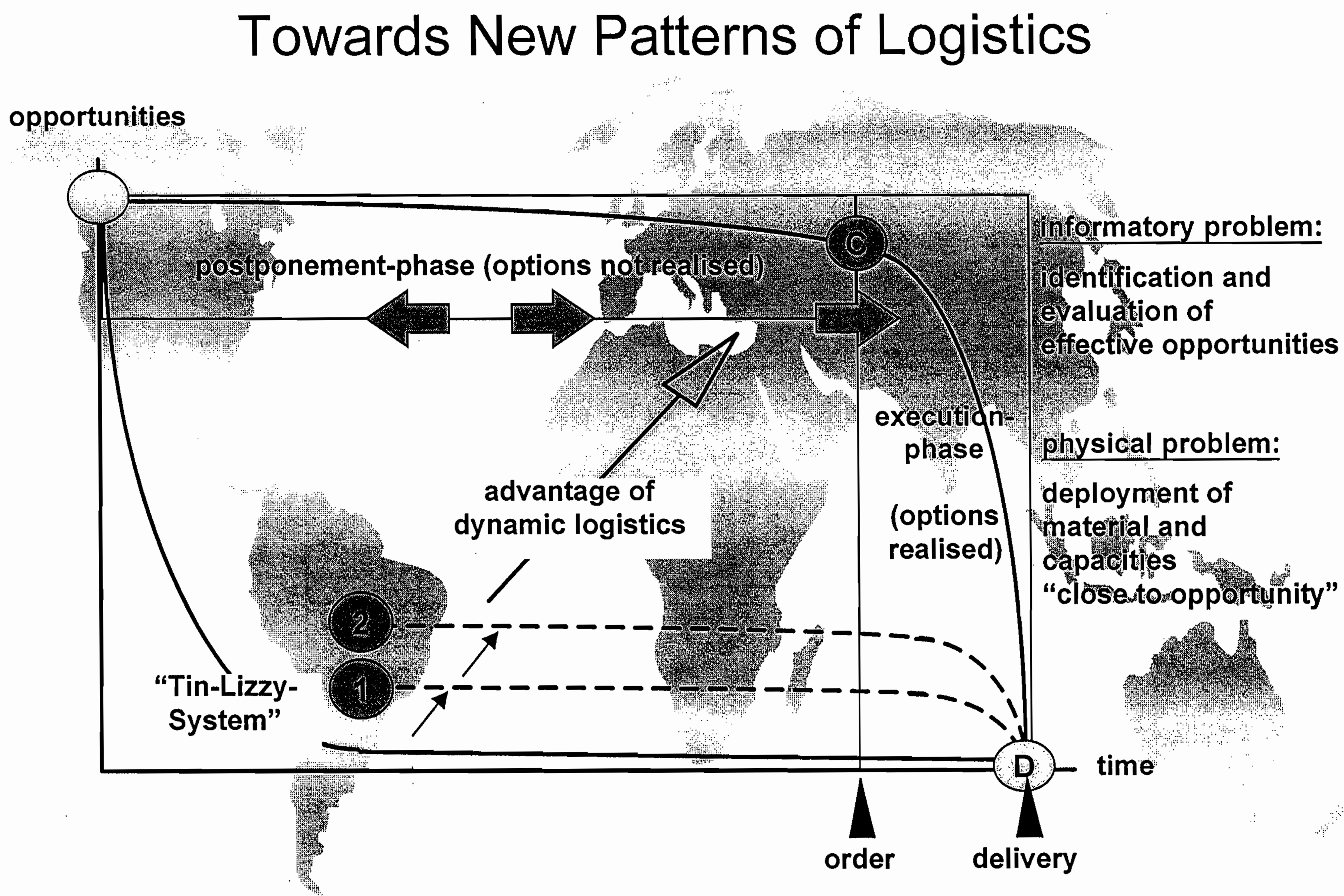

Towards New Patterns of Logistics
opportunities
postponement-phase (options not realised)
C
informatory problem:
identification and evaluation of effective opportunities
execution-phase
(options realised)
physical problem:
deployment of material and capacities "close to opportunity"
advantage of dynamic logistics
2
1
"Tin-Lizzy-System"
D
time
order
delivery

FIGURE 4

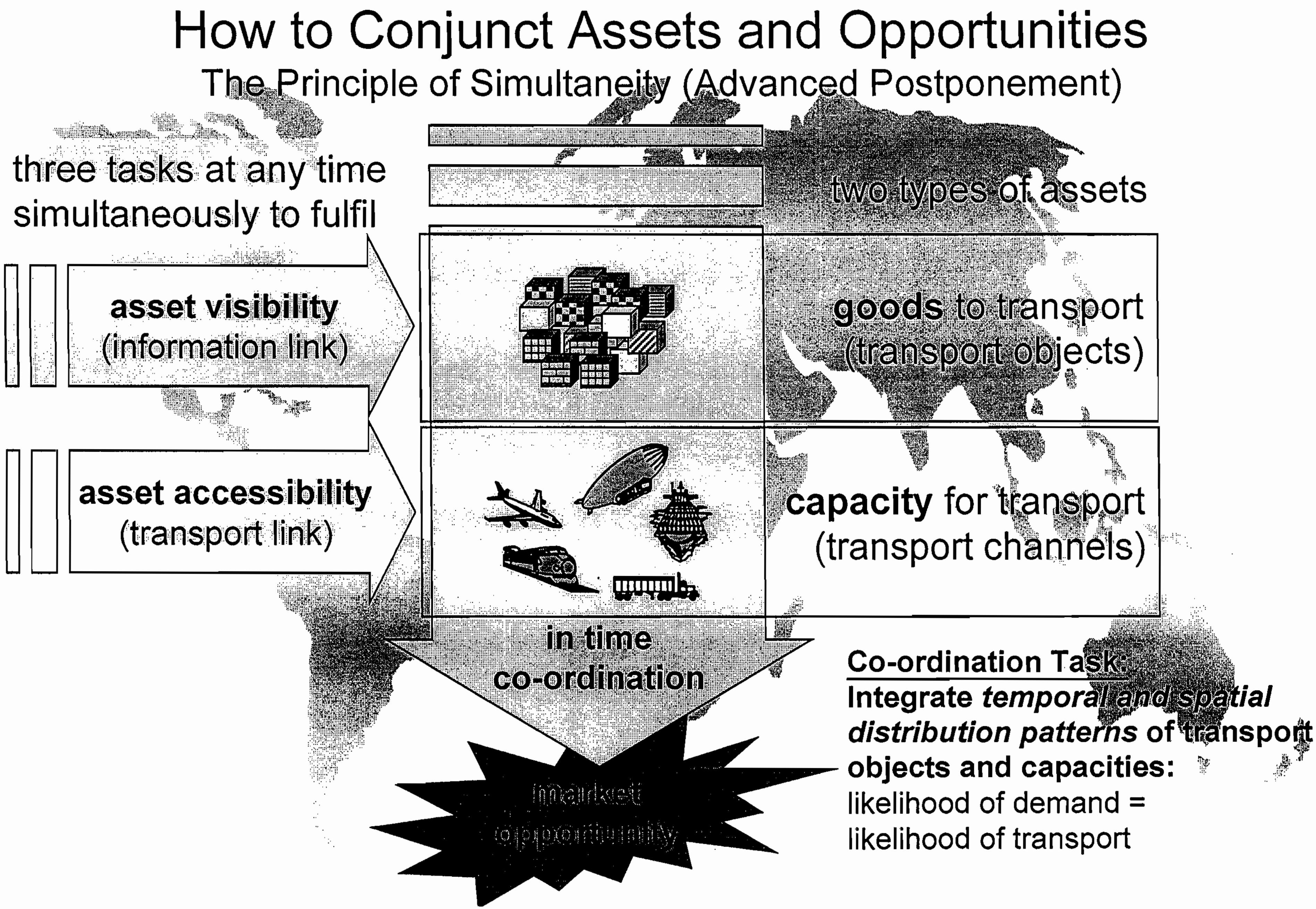
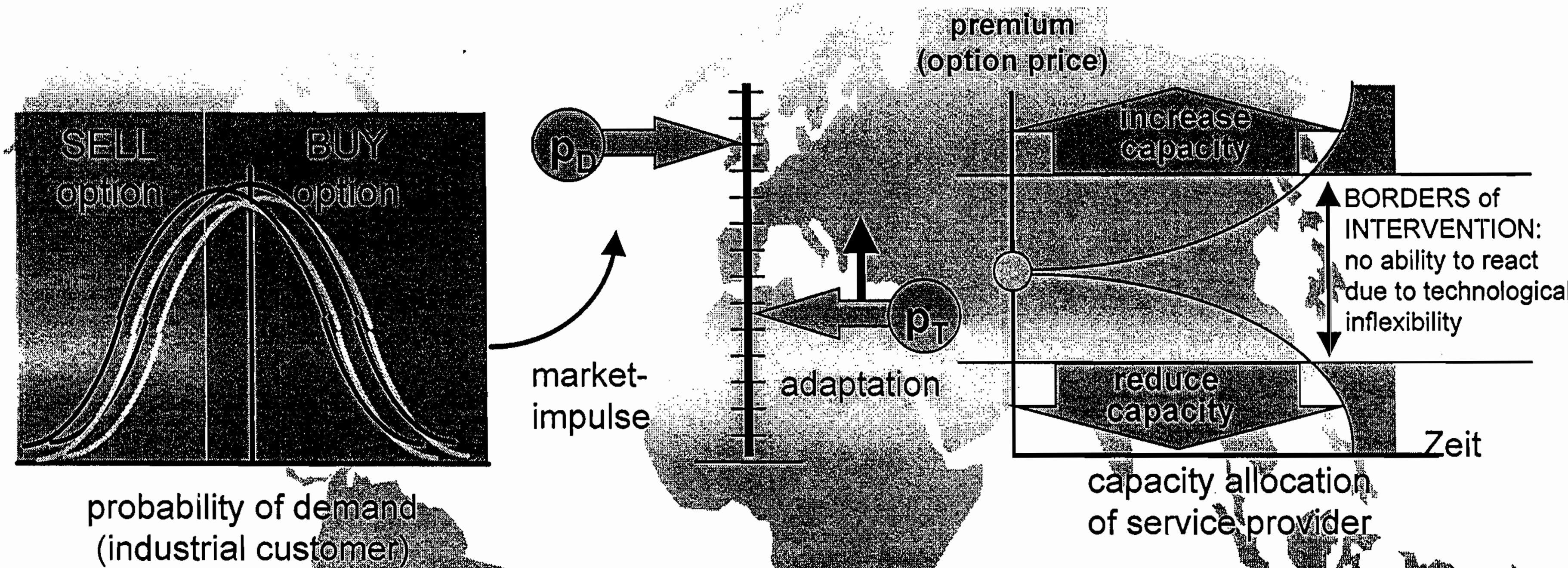

How to Conjunct Assets and Opportunities
The Principle of Simultaneity (Advanced Postponement)
three tasks at any time simultaneously to fulfil
two types of assets
asset visibility (information link)
goods to transport (transport objects)
asset accessibility (transport link)
capacity for transport (transport channels)
in time co-ordination
market opportunity
Co-ordination Task:
Integrate temporal and spatial distribution patterns of transport objects and capacities:
likelihood of demand = likelihood of transport

FIGURE 5

Virtual Capacity Allocation



The virtual layer provides a new source of information:

- Responsiveness to opportunity depends on capacity scaled to demand.
- The probability of response (p_R) has to meet the probability of demand (p_D).
- Idleness of capacities ($p_R > p_D$) has to be avoided
- The price paid for the right to have an asset at disposal (= option) reflects the opportunity perceived in the market

FIGURE 6

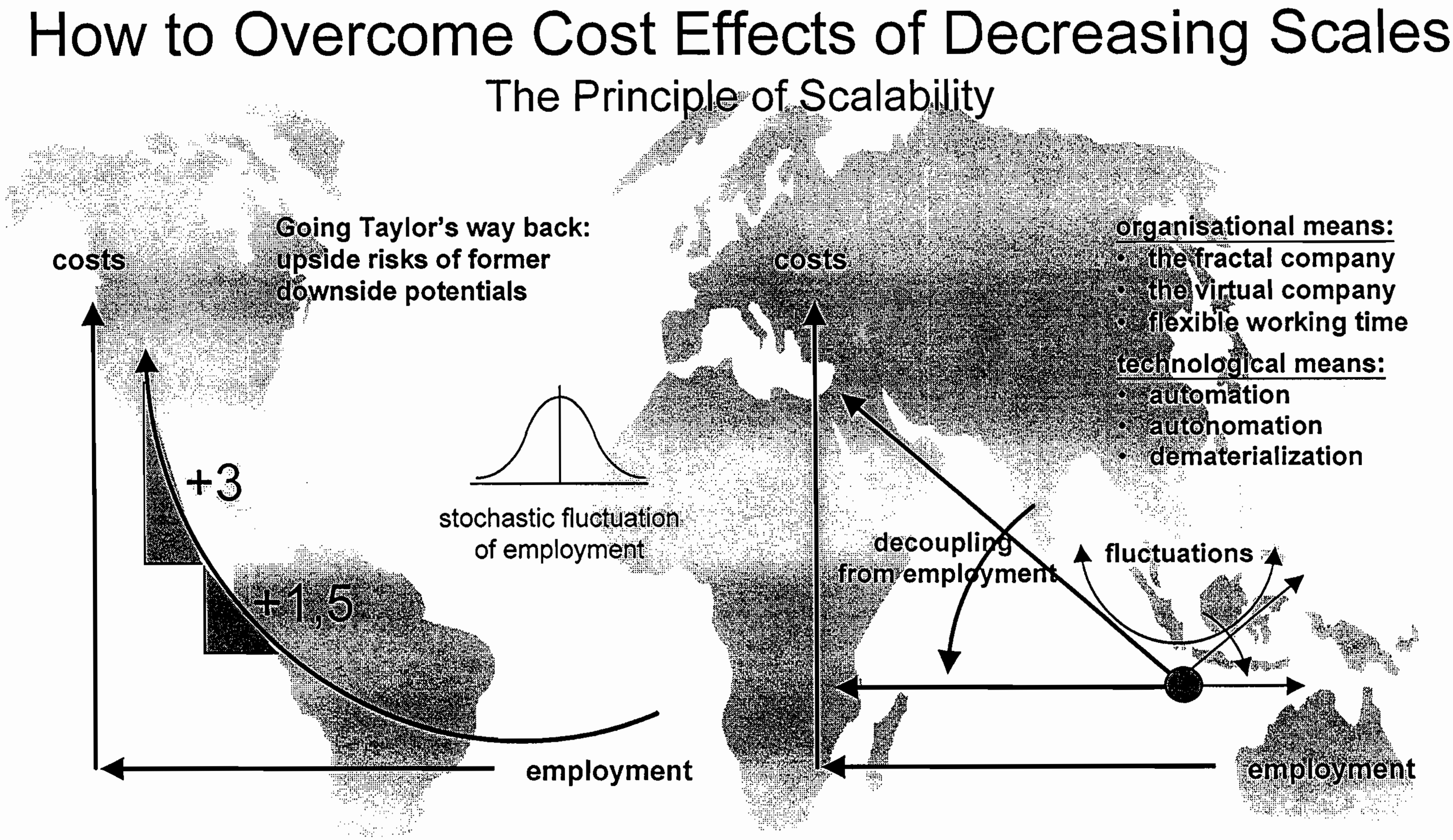
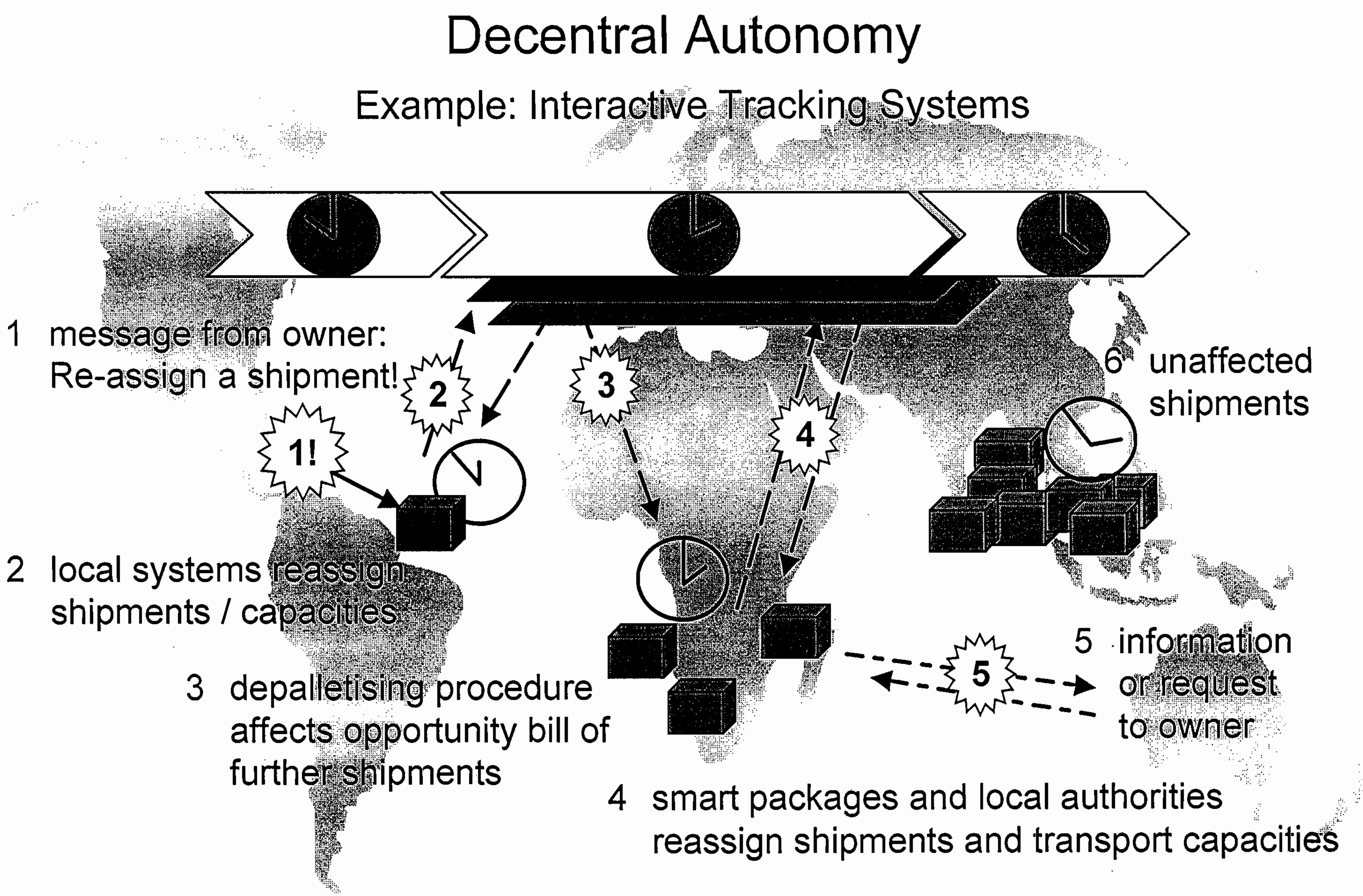

How to Overcome Cost Effects of Decreasing Scales
The Principle of Scalability
Going Taylor's way back:
upside risks of former
downside potentials
costs
+3
+1,5
stochastic fluctuation
of employment
employment
costs
organisational means:
• the fractal company
• the virtual company
• flexible working time
technological means:
• automation
• autonomation
• dematerialization
decoupling
from employment
fluctuations
employment

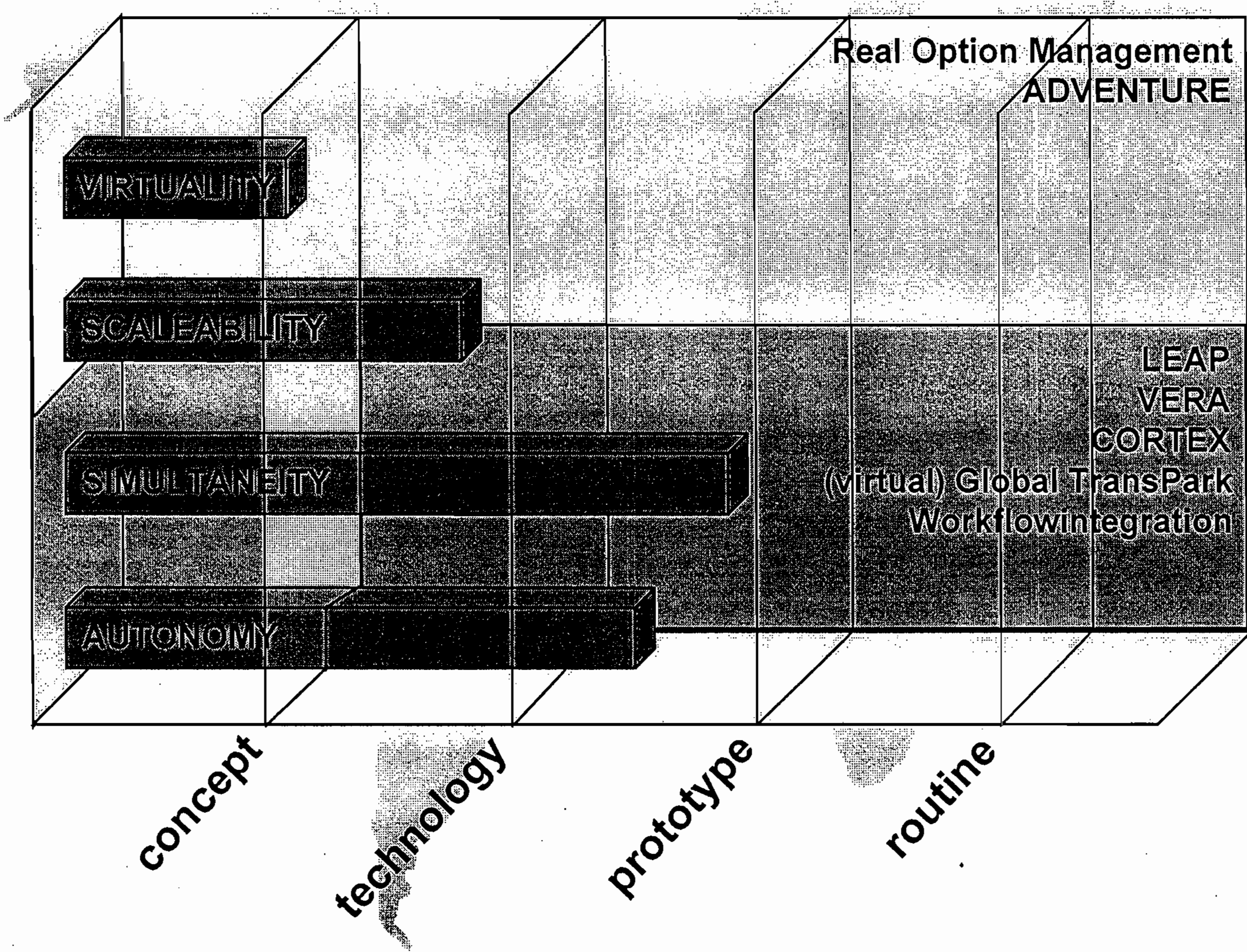
FIGURE 7



Decentral Autonomy
Example: Interactive Tracking Systems
1 message from owner:
Re-assign a shipment!
1!
2
3
4
5
2 local systems reassign
shipments / capacities
3 depalletising procedure
affects opportunity bill of
further shipments
4 smart packages and local authorities
reassign shipments and transport capacities
5 information
or request
to owner
6 unaffected
shipments

FIGURE 8

Degrees of Maturity



concept
understood and major methods available
(basic research)

technology
developed and ready for first implementation
(no standards)

prototype
implemented and proved to be useful
(collaborative development of standards)

routine
in daily operation
(agreed standards)