WORKING PAPER

LOGISTIC CHANGES TO PRODUCTION AND SOME IMPACTS ON TRANSPORTATION AND MATERIALS HANDLING

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June 1988
WP-88-069

IIASA
International Institute
for Applied Systems Analysis

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FOREWORD

The Technology, Economy and Society (TES) Program focuses its research on technological evolution and diffusion, appropriate management strategies, and social and economic impacts. In particular, the objective is to identify those economic and social conditions under which new technologies and associated institutional and social innovations can evolve and how they will affect economic and social structures.

This report first analyzes the driving forces behind the evolution of the new logistic technologies and concepts such as Electronic Data Interchange between firms along the logistic chain and Just-In-Time transport. Then it discusses plausible impacts of introducing these new logistic systems on the organization of transport and the evolution of material handling technologies considering a simultaneous introduction of computer-integrated and automated manufacturing technologies in industry. Hence, the study integrates some of the results from the two TES projects, New Logistic Technologies (NLT) and Computer Integrated Manufacturing (CIM).

F. Schmidt Bleek
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ABSTRACT

There is presently a trend to "internalize" external transport links within the framework of large production system networks. This is made possible by the rapidly increasing capability to swiftly exchange huge masses of data within such networks and the availability of a deregulated transport sector, where the highly competitive trucking industry sets the rules. The result is new forms of logistics systems, designed to meet a set of service requirements which go beyond low cost. The impact of such systems on the evolution of material handling technologies is discussed. Details of one operational Just in Time system and one hypothetical JIT transport system connecting two production plants with particularly unmanned operations are included for the purpose of illustration.

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SUMMARY

Freight transportation has traditionally been predominantly production oriented. Common carriers have offered services based on preestablished networks and timetables. These services were used by a great number of manufacturers, each purchasing their materials and components in one market and selling their products in another market.

The explosive development of computerized data interchange is now changing the situation rapidly. Instead of purchasing and selling in open markets, individual manufacturers are now linked together into networks within the frame of large production systems. The transport between any two manufacturers in the network becomes internalized within the frame of a joint logistic system.

This internalization of external transport will change the perspective of transport in industry and have profound impacts on the way transport should be organized and performed as well as on the choice of packaging and material handling technologies. Instead of looking for a suitable physical connection within the existing service offer, a tailor-made link will be set up to fit into the network. Simultaneously the necessary information links will be identified and set up. This will be accomplished while simultaneously adopting a range of new logistics technologies, which stress other service parameters in addition to low transport cost. Since for many reasons stocks at both ends of the transport link will be kept to a minimum just in time (or JIT) delivery capability will often be requested.

The external transport link will be identified as one of the least punctual and in other respects weakest links in the production network. Major industries are already putting in large efforts to rationalize and upgrade their transport operations. This threatens to shrink the market for open common carrier based transportation systems, which base their services on highly standardized production resources. A lot of the goods will disappear into dedicated semi-closed systems with no or limited access to shippers not belonging to the network being served, unless new technology and organizational solutions are used to radically improve the performance of the common carriers and give their systems the needed flexibility.

Internalization of the external transport links will also pinpoint the current interfaces between internal and external transport as the place where a lot of change has to come. The interfacing shall not only cover the external and internal physical links but also the data processing structure by appropriate information links. External transport and internal material handling will have to use compatible technologies involving new forms of load platforms and new approaches to packaging the goods. New concepts such as amodal and transternal transport will evolve.

Since each semi-closed transport system is only requested to be able to handle a limited assortment of goods, which is known beforehand and whose packaging may be influenced, the incentives to apply automated material handling will be much higher than in traditional external transport systems, which are required to handle all sorts of goods on unknown dimensions packed in a variety of ways.

Packaging machinery and materials are usually designed to permit highly automated packaging. They are much less suited for automated unpacking. In networks the party at the receiving end will have as much influence on the choice of packaging technology as the party at the sending end. The result will often be a choice of recirculated specially adapted containers, which use little or no traditional non-returnable packaging material. Instead they will house jigs which keep parts in geometrically fixed positions to serve the dual purpose of protecting the goods mechanically and facilitating automated handling. To compete the packaging industry will have to come up with technologies and materials which work equally good at both ends of a transport chain.

The paper is concluded by giving a brief account of two transport systems which make use of some of the principles touched upon above. The first is a real case describing the evolution of a system for moving seats to a passenger car assembly plant from a subcontractor. The second is a scenario of a system set up to serve two plants partially operating with fully automated shifts. It is designed to permit safe loading and unloading of goods during unmanned hours.

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FROM PRODUCTION-ORIENTED TO MARKET-ORIENTED TRANSPORT

Manufacturing companies have in the past generally paid little interest to transportation problems and logistics. One reason is the tradition in all industrialized nations that responsibility for transport is external to the firm. It has been assumed that it is the responsibility of the government to provide and control the use of an infrastructure which makes it possible to overcome natural geographic barriers in a country. This view goes back to the time when rail was the preeminent land transport mode. As a consequence, policy towards transport as well as the transport industry proper has until recently been dominated by supply- or production-oriented thinking.

Another way of thinking is now emerging. We are in the midst of a paradigm shift which represents a transition to market-oriented thinking and is most openly manifest in the wave of deregulation, which hit the USA a couple of years ago and is currently sweeping across Europe.

A strong reason for this fundamental change has been the growing importance of highway transportation. Highway transport, as the dominant mode, now sets the rules. In terms of competition, trucking is the exact opposite of traditional rail operation: it fulfills the requirements for an ideal market - low entry costs, insignificant economies of scale, etc.

Since railways now face competition in virtually every market segment, there is no longer any need for government to exercise close controls. It may even be argued that modern technologies make it perfectly possible for several transportation companies to operate their own trains on the same track. As a first step towards this solution the Swedish government has recently decided to split the National Railways into two halves; a National Rail Track Administration and a Rail Transportation Company.

The paradigm shift can be expressed as follows:

Old paradigm: <u>first</u> set up a stiff supply of standardized transport service opportunities, <u>then</u> every time transport is needed, choose between the existing opportunities.

New paradigm: <u>first</u> define the transport requirements for the logistic link, <u>then</u> set up a transport service that meets those requirements.

This paradigm shift is the equivalent of the move to just-in-time and flexible manufacturing:

Old paradigm: first design and produce a set of standardized products and distribute to local warehouses, then sell and deliver.

New paradigm: first receive the customer's product specification, then produce to this exact specification.

THE EVOLUTION OF LOGISTICS SYSTEMSW

What underlies these new attitudes in industry and government? Clearly deregulation and the increasing flexibility of truck transport provide only part of the answer. To exploit the advantages of deregulation and flexibility it must be possible swiftly to exchange large amounts of information between many parties. This can only be done with modern data collection and transmission techniques. Just as large computer-based information systems are the keys to flexible manufacturing systems, Electronic Data Interfaces (EDI) is a necessary prerequisite and the single most important force behind the rapid market-orientation of transport.

Actually, EDI has a much wider influence, since it changes the character of the production system. Instead of purchasing raw materials and components in one market and selling products in another market, individual manufacturers are now linked together into networks within the frame of large production systems. The transports between any two of them will become part of this larger system. The manufacturing and transport industries will share a number of logistics systems[1], each of which are engineered to provide highly specialized services. These will go far beyond simply providing the physical transport. It is significant that in negotiations between shippers and transport operators low transport cost is far from being the only important service variable. Figure 1, which originates from Volvo Transport, shows the diminishing importance of direct transport costs relative to service elements that ifluence costs and benefits along the whole logistic chain.

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[1] This is a term which has many synonyms; industrial logistics, logistics management, physical distribution management, materials management, integral logistics. They have different origins and thus slightly different meanings which, however, with the widening scope of logistics tend to converge, A short description of the significance of a logistics system as compared with a transportation system is given in Appendix 1.

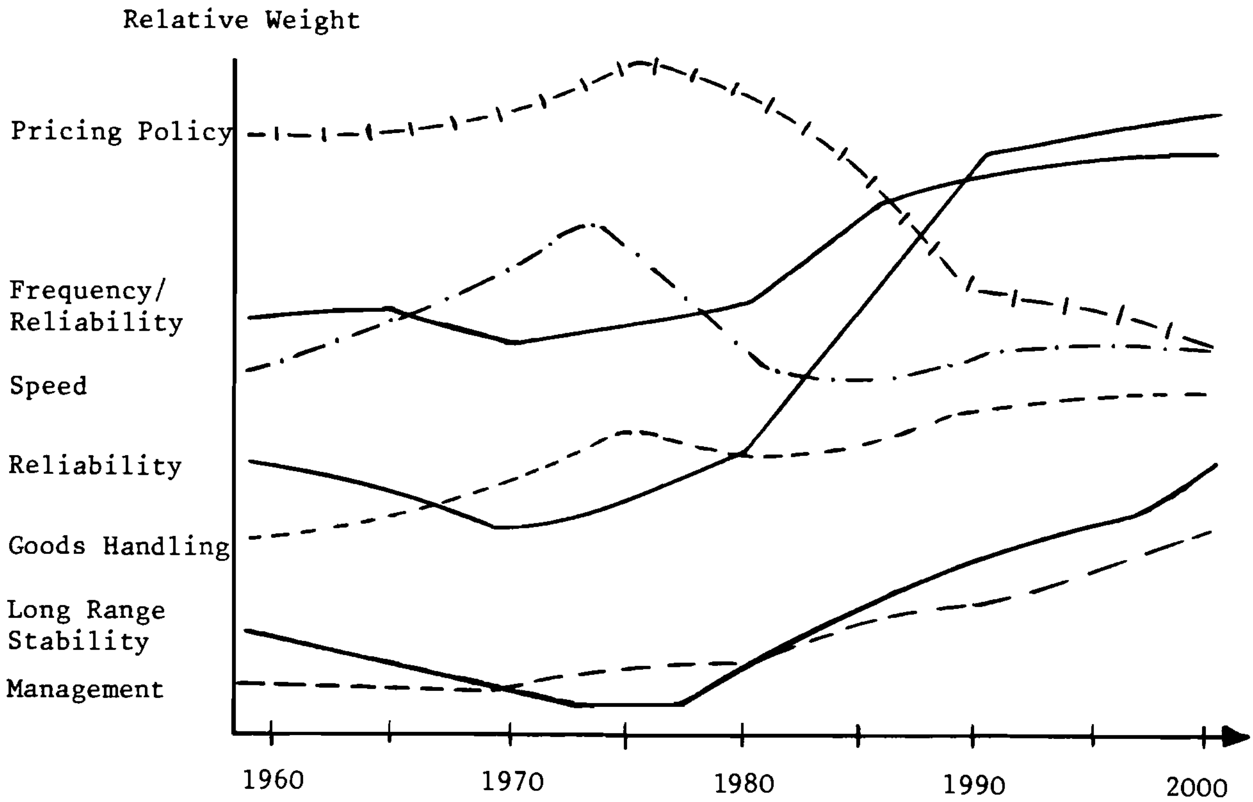

Figure 1: Relative Weight of Various Parameters for Judging the Quality of a Transport System

(Source: R. Svensson, Volvo Transport AB)

THE CRITICAL EXTERNAL TRANSPORT LINK

The eagerness with which industry is now pursuing the idea of reducing lead times is not surprising. As long as a plant manager is content only to worry about times needed for the operations he is himself supervising, there is pressure for increasing lead times instead of the contrary. Once the perspective is changed to looking at accumulated lead times in logistics chains, the results become almost shocking: the average time from raw material source to final production in Sweden is about one year, calculated from the triangle

$$\frac{TIME * SALES}{2} = INVENTORY$$

For a steel product[2] [ref 1], typically, only some 2% of the time is spent in manufacturing and some 5% in transportation. The rest of the time the material is resting in storage. This contrasts drastically with fresh groceries, where perishability of the product limits total time spent in the logistics chain to a couple of days.

As long as lead times in industry remain at several months and storage buffers are kept at numerous points in the logistics chains, plants can be operated reasonably independently. Since external transports always were from one storage point to another, minor disruptions could be tolerated and the industry manager took little interest in the quality of the transport service. But in a situation, where inventories are drastically cut, storage points removed and lead times in manufacturing reduced by almost one order of magnitude, the attitude towards external transportation radically changes. The transport is suddenly regarded as an integral part of the production system. The external transport link is internalized. This has several immediate consequences:

* Industrial leaders experience deficiencies in the existing transport infrastructure as a major barrier against further development of their industrial systems.[3]

* The professional interest in transport links moves from primarily providing capacity to providing a reliable and constantly high level of service.[4]

* Present shop layouts and technologies for receiving or sending goods stand up as a second barrier for the smooth integration of external transport and manufacturing operations.

* The information structures of business logistics systems and

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[2] These numbers refer to a much quoted case of the flow of crank shafts for Volvo engines from input to assembly.

[3] The main message of the report "Missing Links", published by the Round Table of European Industrialists [ref.2] is that the transport infrastructure in Europe must be considerably strengthened to allow European industry to effectively compete with that of North America, Japan and South-East Asia.

[4] The reason for the current interest in building bridges and tunnels is that while ferries can easily provide an equivalent level of capacity, their service level is thought of as much inferior to that made possible by fixed infrastructure.

transport logistics systems must be strongly integrated[5] in order to allow JIT systems to include complex transport solutions.[6]

A word of warning should be inserted here. It is becoming increasingly common that simplified doctrines are spread across the industrialized world as a kind of salvation recipe which solves all the problems for those who adopt it. JIT based trucking is not the sword which cuts through all Gordic knots. The demand for new road infrastructure, which at an incredible cost would provide marginal improvements of the service level, is often quite unrealistic. And the idea that electronic aids and perfect winter maintenance would allow the potentials of road systems to operate at the regularity equal or better than railways is long into the future.[7]

The demand trends, however, signify that existing infrastructure will soon be inadequate. Maybe the time has come to discuss radically new forms of infrastructure, such as city-wide pipeline distribution systems, which connect stores, offices and apartments through logistics centers. When discussing transport options, one often routinely refers to the four modes: rail, road, air and sea, forgetting that the fifth mode - pipelines - has already the largest share of transport work in Europe.

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[5] Because of the strategic importance of being able to control the design of the information processing structure of logistics systems there is presently intense competition between logistics departments of large shippers and forwarding agencies about who is getting the largest stake in the computerized data exchange systems which are emerging. Telecommunication companies, port authorities, banks, insurance companies, and independent Value-Added Network operators also see large business opportunities.

[6] Currently most JIT systems are based on direct transportation over short links using exclusive equipment. As a rule of thumb for these first generation JIT systems it was often quoted that external transport links should not be longer than 50 km, which obviously does not fit well with the industrial structures in most countries. Exceptions are of course those production systems set up with short transport links as important design criterion, such as Toyota City in Japan and Buick City in the United States.

[7] It is quite a different story that many railway administrations experience a severe management crisis, caused by the fact that they are still in the production era, while they should, long ago, have passed on to the marketing and later logistics eras. This has little to do with the inherent qualities of rail technologies.

IMPACTS ON MATERIAL HANDLING TECHNOLOGY

The efforts to reduce friction between manufacturing operations and external transport will require new approaches to packing the goods and new forms of standardized load carrying units.[5] The attempts which have been made so far to automate the handling operations of general cargo in freight terminals have not been very successful. The reason is that the transportation system is open, which means there are no possibilities for the terminal operator to influence what kind of goods will pass through his terminal, nor prescribe what packing materials and methods should be used. He may have some control over the load carrying units which are used, but even this is far from absolute. Consequently, automation of material handling in external transportation systems has lagged behind relative to technologies that are now finding their way into many internal material handling systems, such as handling robots in flexible machining cells and fully automatic guided vehicles, sorting facilities and warehouses.

The speed by which JIT systems are introduced may change the situation, directly or indirectly. The direct effect is that JIT systems themselves will likely sharply raise the demand for dedicated automated material handling. The limited space next to the manufacturing operation makes it desirable to keep the load module in a buffer from where it is automatically brought forward in the exact moment when it is needed. The indirect effect is that once JIT principles have been accepted, they seem to force transport companies and forwarding agencies to considerably improve their general cargo operations. An obvious way of doing that is to offer a very high level of service to those shippers who are willing to make a choice among a number of highly standardized combinations of load module and unit load concepts and then adapt their own operations to the use of these. This would make the transport operator perceive the system as closed and facilitate automation of his material handling.

JIT has already become a widely used term. However, many of the JIT systems reported on in the literature do not stand up to a rigorous definition of the JIT concept; they are just ordinary transport systems with sharpened demands for a level of service and very small buffers. Extreme requirements for transport regularity may cause traffic problems, e.g. in Japan there is a growing problem with trucks parked on the highways waiting for the exact delivery time before making the final approach to their destination.

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[5] Some new definitions or more precise versions of existing ones seem to be needed to facilitate discussions of such approaches. Some suggestions are given in Appendix 2.

The load module is an important concept in JIT transportation. The parts in it are often packed in the exact sequence they are needed. The module must be designed to give good protection to the goods, and it must be easy to handle. Since a true JIT transport terminates at the location of a manufacturing operation, it must be possible to break the load module in a limited space without generating waste which is difficult to dispose of. In many applications it should be attractive to use an industrial robot to break the load module and pick up the goods in the prescribed sequence. To facilitate this it might be desirable to use some kind of fixtures for the goods in the load module.

All these factors makes the use of ordinary disposable cardboard boxes less attractive. These are designed for automatic packing and sealing but not for automatic unpacking. The waste they produce is bulky and therefore not easy to get rid of. Thus, there are several incentives for using standard returnable containers or some form of durable special purpose-built load platforms when creating a load module.

In this context it must be seriously questioned whether the standard European 800 mm x 1200 mm pallet - the EUR pallet - is a suitable starting point for future standardized load modules. The combination of an EUR pallet and cardboard boxes modularized to fit on the EUR pallet is an ideal module for handling by one man and his manually powered fork-lift carrier. Since the outer dimensions are not well defined - especially when the pallet is loaded with goods not packed in cardboard boxes, it is far from ideal in fully automated material handling systems. Thus there is a need for standardizing carrying units with a size similar to the EUR pallet, but with walls keeping the goods in place and with standardized height (Figure 2). These units will be sufficiently expensive also when unloaded to motivate that they are given identity as individuals. To facilitate tracking them in the information processing structure, all material handling equipment used in moving them should automatically read their identity. If an escort memory is used, it is also possible to read and update its quality status, ownership, arrival time, billing instructions, etc.

The standardization issue, however, is more important than that. The extent to which existing global standards may be modified and extended to form a harmonized set of standards on load module and unit load-platforms will, to a large extent, be a decisive factor in the competition between common carrier systems and purpose- built systems for specified products. Ideally these standards should cover the whole spectrum of sizes from small boxes to the largest containers of 48 feet length or more. They should be accompanied by a set of handling standards, which to the extent possible must allow a flexible choice between lifting, rolling and sliding techniques.

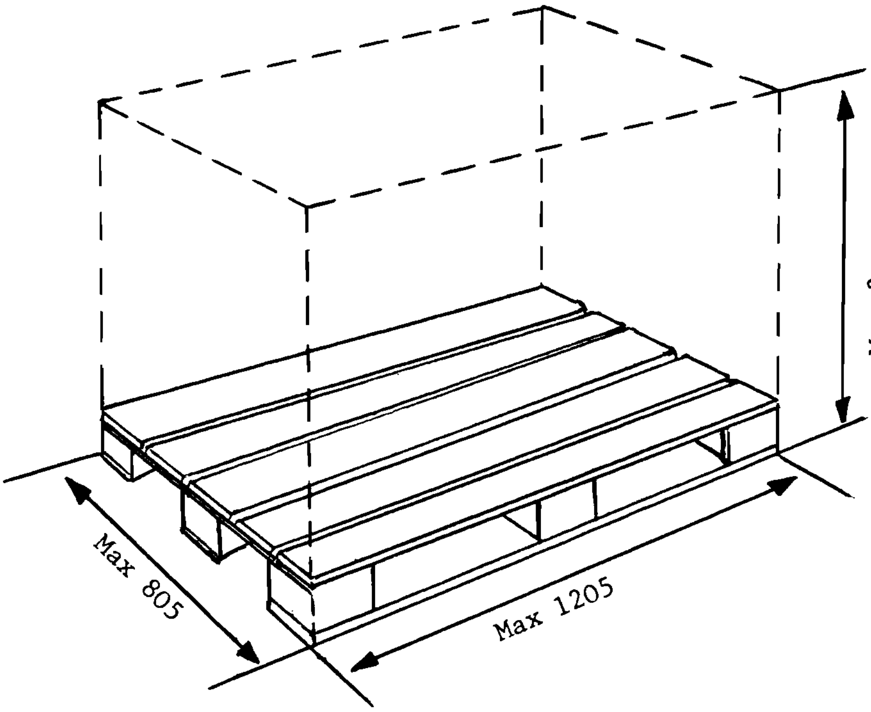

Figure 2: Standard EUR Pallet and Load Module Based on the Same Measures

THE VOLVO EUROPE HANDLING SYSTEMS FOR SEATS - A JIT CASE

In order to illustrate how some of the concepts discussed above have been applied in a real case, some details will be given about a Belgian JIT system [ref.3]. Volvo Gent in Gent has a contractor by the name of ECA (Etablissementen Christian Assende). ECA has been making upholsteries for car seats since 1965. Before that the upholsteries were delivered from Bengtsfors in Sweden, which gave unacceptably high transport costs. When the change of contractor took place, the logistics cost for foam was reduced from 16% to 1.5% of the price of a seat. In the beginning the manufacturing of upholsteries at ECA was based on delivery plans for six weeks. ECA normally kept a stock which would allow two weeks of supplies. In spite of this, shortages sometimes occurred, e.g., when disturbances in the paint shop forced production of cars in other colors than was originally planned.

This led to a first project, when Volvo and ECA together created a system to provide the upholsteries in a faster and safer way. Five weeks in advance a preliminary production program was established. Two weeks later a new but still preliminary order was issued. Using this, ECA could give their own orders and start making the upholsteries. Finally an order arrived, which was definitive for the next day and preliminary with 95% precision for the two days thereafter. Thanks to these measures the two weeks of stock could be shrunk to 1.5 days and the shortage problems eliminated.

Already in the first project the need for storage space for upholsteries was significantly reduced. When the decision was taken to manufacture the 700 series in Gent, an investigation was initiated at Volvo about the possibilities to out-source complete seats. In the end ECA was transformed into a sequence controlled supplier of complete seats to Volvo. The advantages by using sequence control are evident against the background of the following numbers. The front and back seats together contain 900 details from 100 subcontractors. Together they provide for 1,071 variants of complete seats. As later the five door version of the 700 series was brought into production, the total number of variants increased to around 3,000.

Figure 3 shows the principal production layout. The sequence in the final assembly becomes final only when the ready painted body is placed on the driven line for final assembly. The required data about the seats of the prospective automobile are then brought by a data link to ECA where they are automatically printed. The lead time for seat assembly is approximately 8 hours. The production runs over two shifts at a pace of 22 cars per hour. ECA has no buffers. The production is based on the following information:

5 weeks in advance forecast with 75% precision

3 weeks in advance forecast with 83-84% precision

Daily forecast with 96% precision

8 hours before assembly final order

ECA is located approximately 20 km from Volvo. For the transportation of complete seats a transport system has been created, where the unit load provides the necessary buffering function. Four specially built semitrailers are used as the load carrying part of the unit load. In addition the contracted transport company always has one truck reserved for these transports. In principle there are always two semitrailers at Volvo, one at ECA and one on the road between the two plants. Each semitrailer loads 40 complete sets of seats, which means that one shipment is sufficient for close to two hours of production. The load modules are formed by loading the seats in specially designed racks. The semitrailers are parked indoors at Volvo, from where the

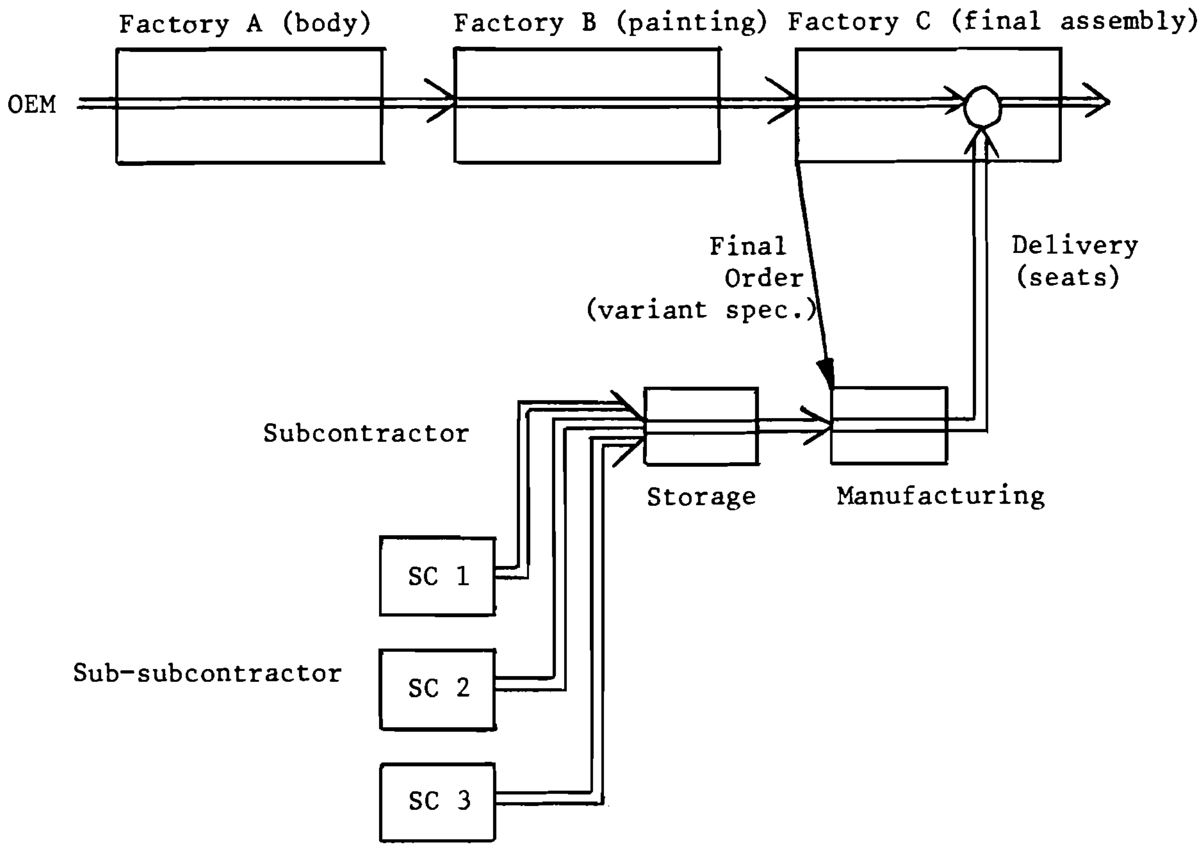

Figure 3: Sketch of Principles for Sequence Controlled Component Production by a Subcontractor. The Contractor takes over Responsibility for Variant Adaptation and Final Assembly of the Component for each Customer.

racks are successively unloaded with a fork-lift truck and taken directly to the assembly line. One rack is loaded with right front seats, one with left front seats and one with back seats. The seats are placed according to the sequence of assembly orders. The specification of each particular seat which was transferred to ECA together with the final order is placed on that seat.

In connection with the introduction of the system, the responsibility for quality of the chairs was transferred from Volvo to ECA. Accordingly there is no arrival check at Volvo. The quality has increased significantly. The frequency of faulty seats has dropped from 2% to .25%.

The economic benefits from the system are considerable. The cost reduction of the chairs related to the price from the contractor is 8%. The decrease of capital cost for inventories of upholsteries and complete seats is 3% of the price of the product. Thus the total savings effect is 11% of the total supply cost.

The logistics chain for upholsteries and seats is shown in Figure 4. For comparison the equivalent logistics chain for the Torslanda plant in Gothenborg is shown in Figure 5. Plans have been made to introduce similar changes at this plant. The distance of 175 km to the subcontractor in Bengtsfors is however too long to be incorporated in a lead time of only 8 hours. The scheme will therefore have to be suitably modified.

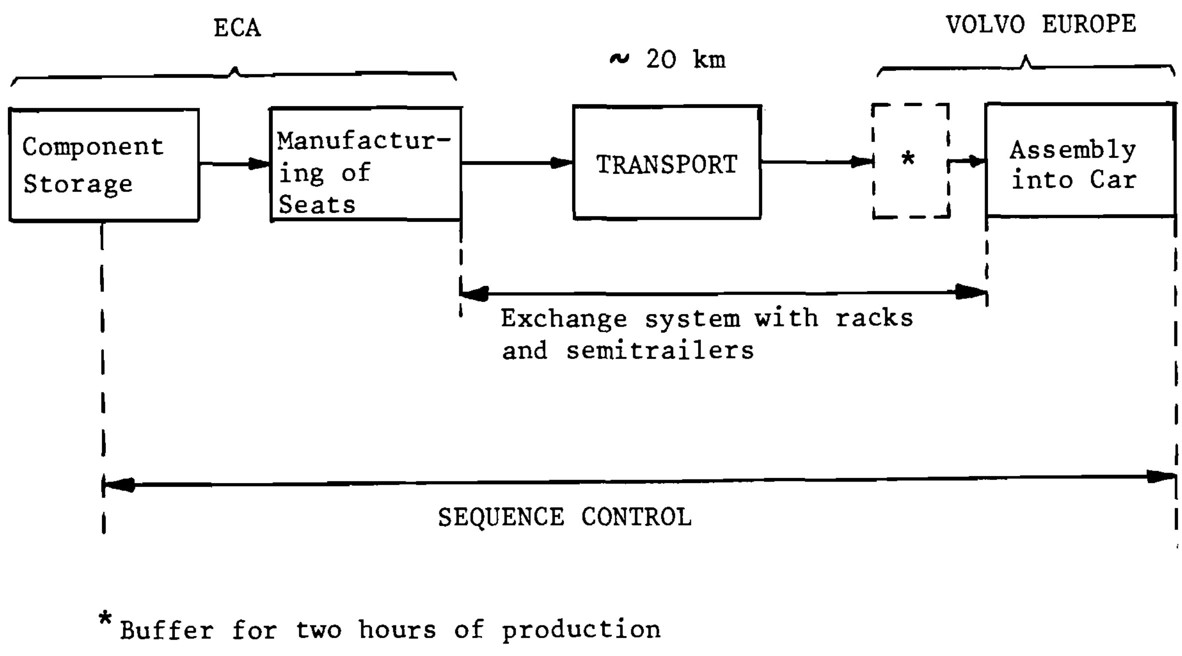

Figure 4: Production Layout for Passenger Car Seats in Ghent (Source: Ref.3)

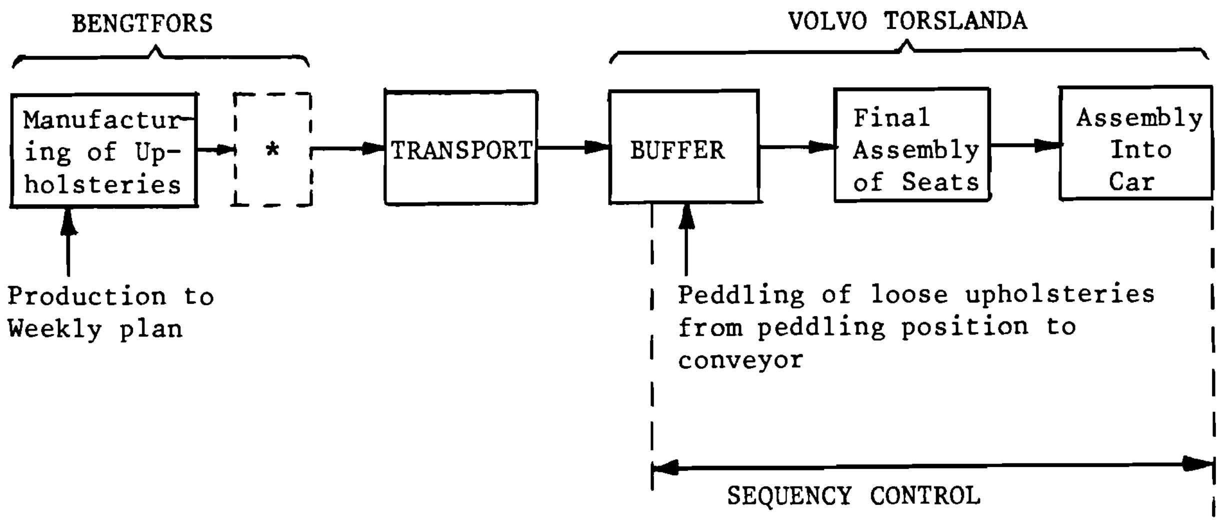

Figure 5: The Existing Volvo Production Layout for Passenger Car Seats in Sweden (Source: ref. 3)

AUTOMATED LOADING AND UNLOADING - A SCENARIO

In rail as well as in highway transportation long distances are traditionally covered by night. The ability to carry out all transport chain operations[9] during times outside normal working hours is particularly important in JIT applications. The possibilities of finding attractive transport schedules would be greatly increased if not only the actual movement of the goods but also loading and unloading at the plants could take place out-side normal working hours.

The following highly hypothetical case will illustrate this. Figure 6 shows a time diagram for the operation of two plants which are connected by a JIT system. Both plants are operated in two shifts with one shift manned and one unmanned. Plant A starts with an unmanned shift at midnight and continues with manned shift during the day. Plant B also operates with a manned shift during the day and finishes with an unmanned shift in the evening.

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[9] This includes not only long-haul transport, but also terminal operation for consolidation or change of transport mode as well as customs and other document handling.

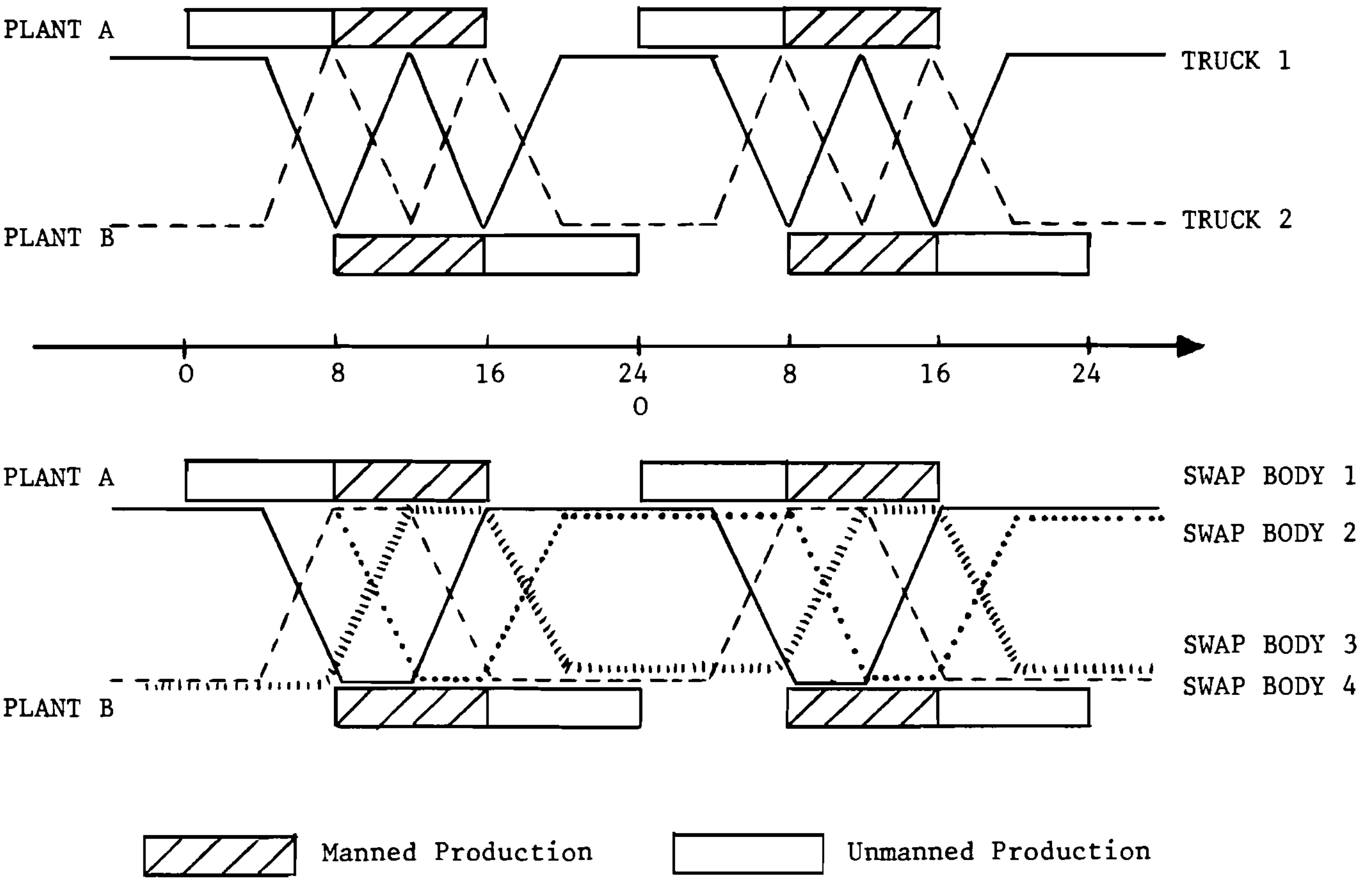

Figure 6: Hypothetical and Idealistic JIT System Connecting Two Plants with Staggered Production Hours. Cycles are shown for 2 hours and 4 Swap Bodies. Lead Time is 8 Hours.

The lead time is eight hours. The JIT system is operated by four drivers, two trucks and four swap bodies. The cycles for swap bodies and trucks are shown in the diagram. The total time disposable for making a single trip between the plants is four hours. At one out of four times when a driver arrives to deliver or pick up a swap body the plant is unmanned. One out of two times the manned shift is just about to close. Since the plant must then be locked for security reasons, the docking cells for the swap bodies are designed in such a way that neither the truck driver nor anyone else can enter the plant through them.

When the driver arrives he backs up to an empty docking cell, while doing that he slightly raises the swap body by increasing the pressure of the air suspension systems. A vertical guide rail on either side steers the swap body into position. The driver then lowers the body by letting air out of the suspension system. The swap body drops onto two horizontal guide rails and is now in its final position. The driver can now move to the next cell to pick up another body or go home.

From here the automatic material handling system of the plant takes over. First the identity of the swap body is read and checked. Then it is secured so that it cannot move. After that the doors of the building and the swap body are both opened (as in a lift). The inside of the swap body is now a part of the building and the load modules inside it can, at any time, be automatically picked up by an automatic guided vehicle for transport to a manufacturing operation.

The same logic steps are taken when the swap body is loaded and picked up by the driver. The only difference is that it is now the driver who must prove his identity by inserting a card in a slot or by some other action. Only then is the swap body mechanically released by the material handling system.

Figure 7 is a sketch indicating how such a docking cell could be designed.

CONCLUSION

The external transport links are more and more internalized as an integral part of production. This often results in smaller and frequent shipment of reusable unit load platforms designed for fully automated in-plant handling. General cargo operators are forced to make their Less-Than-Truckload operation more flexible in order to handle a variety of platforms and faster terminal operation or they will lose business to dedicated systems. For this purpose a new spectrum of standardized unit load platforms and modules and fully automated loading and unloading equipment are suggested in order to integrate external and internal transport chains to truly transternal and amodal logistic chains.

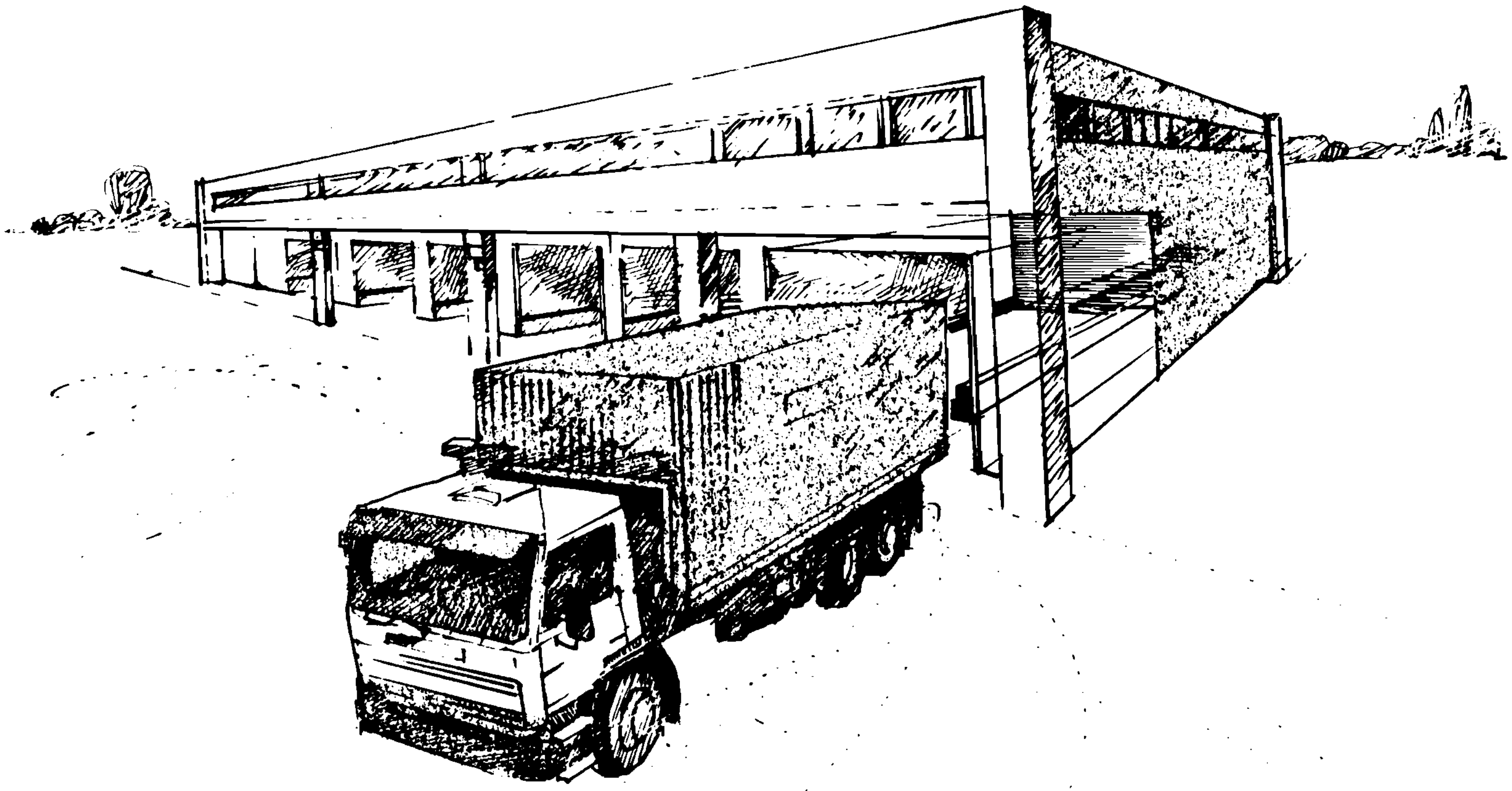

Figure 7 : Illustration of Plant with Facilities for Docking of External Transport Unit Loads and Automatic Loading and Unloading During Unmanned Hours.

APPENDIX 1
CHARACTERISTICS OF A LOGISTICS SYSTEM AS COMPARED WITH A TRANSPORT SYSTEM

A transportation system is traditionally set up to handle many individual and independent shipments. It focuses on physical movement. Timetables are planned on the basis of demand forecasts rather than actual demand. Services are offered at times when demand is estimated to be high, subject to conditions of rational use of fleets and manpower. Most customers remain anonymous to the system designers, as marketing takes place after the system is in place and operational.

A logistics system is specifically set up to handle recurrent material flows. Thus it is the flow of materials through several intermediate steps of packaging, handling, transport and storage (i.e., the material flow) rather than occasional shipments, which is the center of interest. The emphasis is as much on the associated information flow as on the actual physical flows of goods and materials.

This dual character of a logistics system is represented in Figure A1:1. The information processing structure and the physical structure of the system are interrelated by observations which provide the necessary data about the current state of the materials flow and by decisions taken in the information processing structure which give rise to actions in the physical structure. This provides the system control.

Using control theory concepts a traditional transportation may be thought of as an open system with little feedback regarding the objectives of its activities, whereas the logistics system is a closed system with carefully engineered feedback about its current state[10].

As in any application of control theory the performance of a logistics system is very sensitive to the qualities both of the sensors used to provide the necessary observations and of the equipment to exercise the required control action. This is particularly true for sensors.

10From a theoretical viewpoint it is ambiguous whether the special elements which perform the observation and control tasks belong to either of the structures or a separate. For practical purposes it is customary to include these elements in the physical structure. This means that the arrows marked observation and control in Figure A1:1 may be thought of as providing information flow.

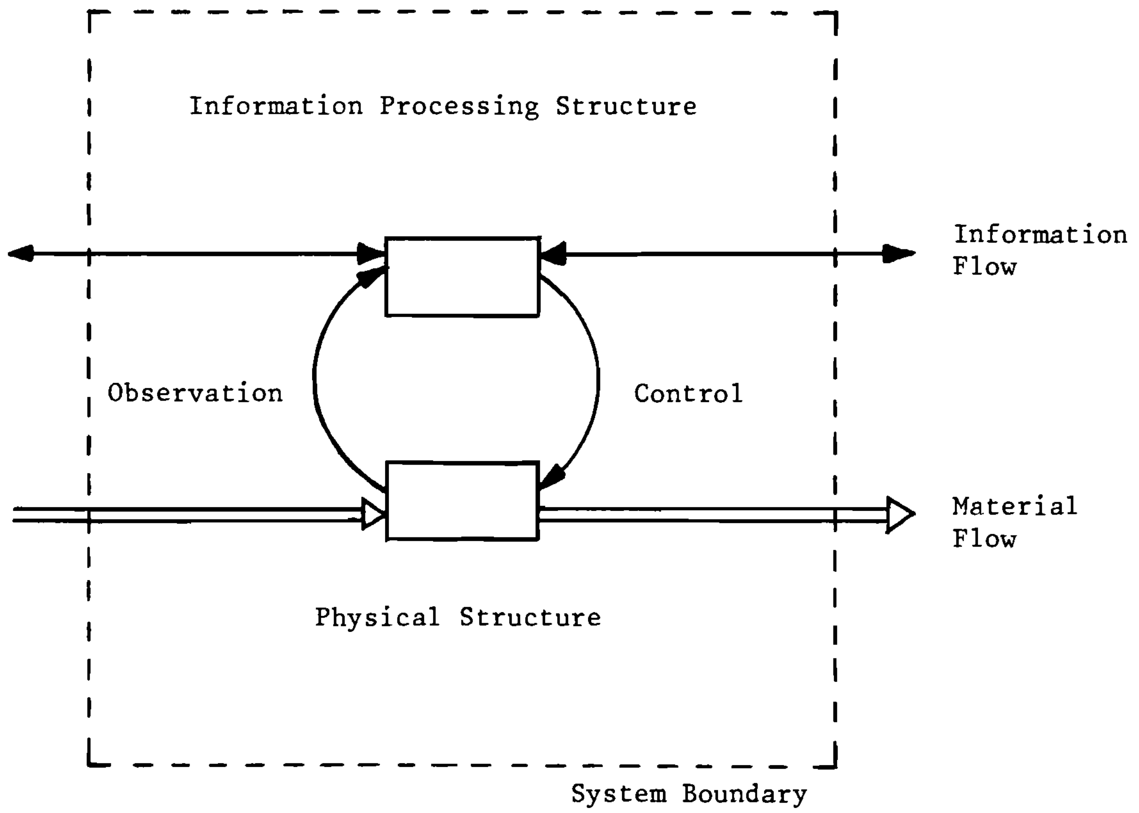

Figure A1.1: General Features of a Logsitics System

Observation and control in logistics systems have until now largely been performed manually. There is, however, rapid on-going technological innovation in this field. Bar-code technologies are being internationally standardized and adapted for use in rugged environments. Compact escort memories are being developed, which may be fixed either to goods, their casings, or to their platforms. These contain information about the individual shipment and may be read in motion at specific check points. Vision and voice systems, originally developed for use in robots on the workshop floor, are also being adapted to rugged environments and put to use in logistics systems.

The logistic system connecting a specific supplier-user pair could be called a logistic chain, as shown in Figure A1:2. An amodal transport operation can then be contracted to take care of several logistic chains in part or in full. The chains connect many companies, but cover similar geographic relations. Thereby, economies of scope can be achieved. Since an amodal operator does not own any means of transport, he subcontracts and controls modal operators and terminals to perform transport services, and frequently other services as well, such as: container pools to supply load platforms and value added networks (VAN) to take care of telecommunication and some data processing.

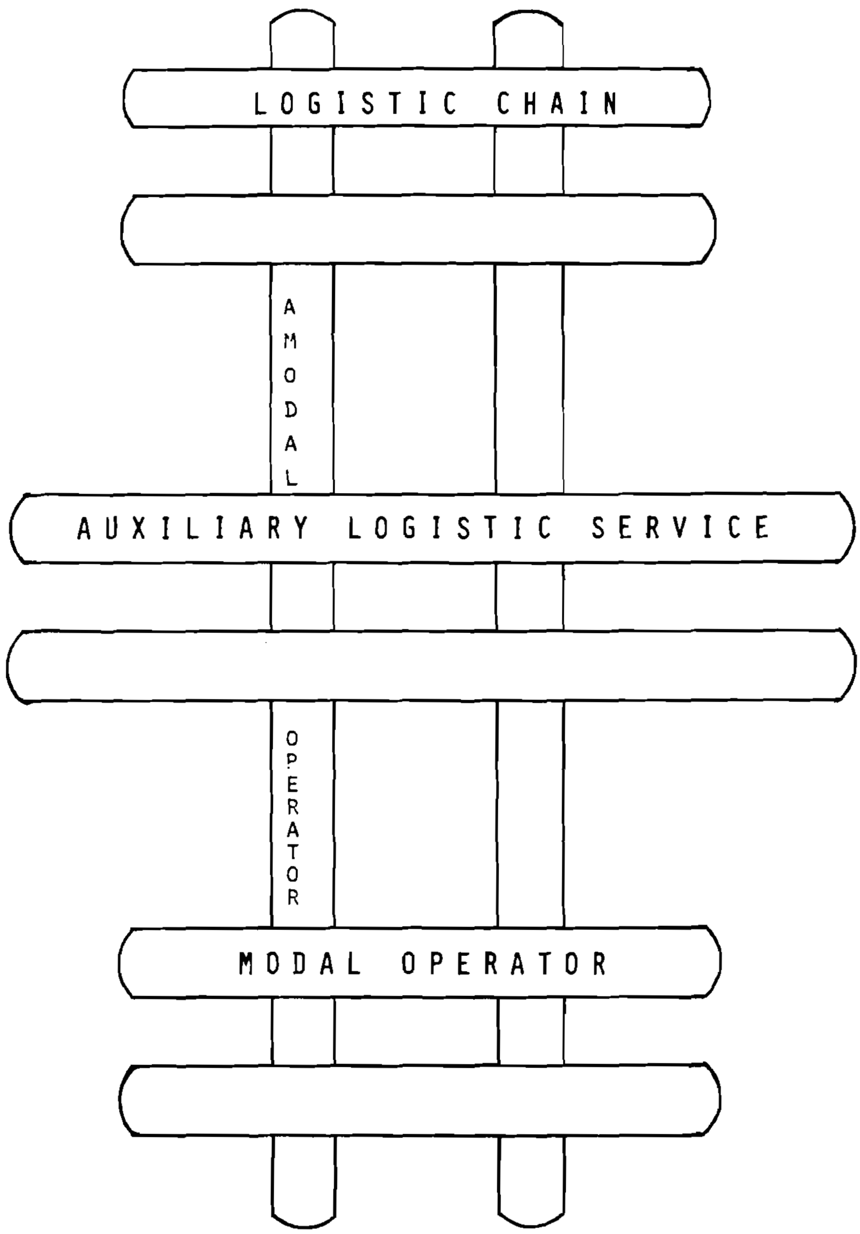

Figure A1.2: The Logistics Chain and its Subsystems

APPENDIX 2
SUGGESTED DEFINITIONS

Amodal Transport Operator	Transport chain organizer-manager, who is independent of specific transport modes, and who brings in and controls special mode operators when needed [ref.4].
Transmodal Transport Operator	Firm engaged in several modes which it operates simultaneously [ref.4].
Combi Transport	Transport chain which involves several transport modes.
Intermodal	Ability to move from one mode to another [ref.4]. Refers to operators as well as load platforms.
Transternal	Ability to engage in transport links both internal and external to the walls of the plant. Refers to load platforms as well as operators.
Load Platform	Platform intended to support and keep the goods or materials together during transport, handling and storage. A load platform can be fixed or detachable.
Fixed Load Platform	Load platform fixed to the means of transport, handling or storage.
Detachable Load Platform	Load platform intended to follow the goods through part or whole of the logistics chain. It can be reusable such as slip sheet, pallet, container and swap body or disposable such as cardboard box.
Unitization	Aggregating many smaller load platforms into a single, larger load platform. Several larger can be aggregating into an even larger, etc., like Russian dolls, e.g., from cardboard box to unit train.

Unit Load Platform	Standardized detachable load platform, e.g. ISO-container, EUR-pallet and some swap bodies.
Unit Load	Load of goods or material on a unit load platform physically handled as a single unit during part or whole of the transport chain. Unit loads can be unimodal, intermodal, transmodal or transternal.
Load Module	Transternal unit load handled as a single unit from one manufacturing operation to the next, i.e. the smallest unit load of the transport chain.
JIT Transport	A transport fulfilling all of the following requirements: - The amount of parts in transit is exactly what is needed for the next production cycle; - Delivery to the point-of-use must occur at scheduled time; - All parts must be usable.

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