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URBAN GOODS DISTRIBUTION BY SHORT-DISTANCE COMBINED TRANSPORT

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Abstract

Urban distribution centres will become the main interaction points between intra-city and inter-city goods transport. These transfer-centres create the opportunity to use the most appropriate transport modes within and outside cities. By introducing short-distance combined transport goods distribution systems, the deliveries of goods to cities can be made more efficient (economically and environmentally). The centralised, consolidated supply of goods in intermodal urban terminals makes it more convenient to operate specially designed urban logistic systems.

INTRODUCTION

Goods distribution in urban areas is essential for the prosperity of these areas, but meanwhile goods transport generates problems as congestion, noise, emissions, energy-use and a degree in traffic safety (Ogden, 1992; Van Binsbergen *et al*, 1995). Next to that, freight traffic experiences much hindrance: delays occur and time schedules can not be met with. Accessibility problems and (subsequent) edge-city developments, as in the United States, weaken the key-role of urban centres in the society. Therefore, the distribution processes within, towards and from urban areas must be made more efficient and the negative side-effects of goods traffic must be reduced.

For inner city goods distribution relative small, highly manoeuvrable low emission vehicles should be used, for efficiency reasons outside cities relative large, low cost transportation systems will be necessary. These contradictory requirements ask for either compromises in vehicle choice or for an intermodal goods distribution system. Such a system would function at short distances and would need newly developed logistic systems. From a technological perspective the development of appropriate transport systems, the development and use of small load units and transfer systems is needed. Next to that, organisational changes in companies and appropriate legislation are necessary to implement the intermodal system. The feasibility of such an intermodal system depends on the willingness to implement it by companies and governments, but also at the user quality, the performance and the prospects of the system. These relate to the system design, which is discussed in depth in this paper.

LOGISTIC DEVELOPMENTS IN URBAN DISTRIBUTION

Changing logistic concepts

A logistic chain is a series of subsequent activities that form a product and deliver it in the required quantities at the desired place. Basic activities of all logistic chains are production (modifications in form), transport (modification of place), storage (modification in time), assortment composition and consumption (McKinnon, 1989). These interdependent basic activities occur repeatedly within a logistic chain. In the end-distribution, the part of the logistic chain often seen in urban areas, important players are manufacturers (producers), wholesalers, retailers and, in fact, consumers. Leaving this last group aside, end-distribution typically follows the patterns as shown in figure 1 (derived from Visser *et al* 1998). Consolidation is hard to achieve (direct distribution) or is bound to individual companies. In that case, distribution centres are located somewhere in between origins and destinations of shipments.

Important developments in logistics (will) change these patterns profoundly:

- tendency to eliminate logistic activities that does not generate any clear added value (storage);
- tendency to centralise production and warehousing, developments that are triggered by the creation of the single European Market, the relative low transportation costs and the fierce competition;
- highly advanced stock- and supply management systems that eventually can be directly driven by sales (automatically registered at check-out counters).

Developments in the logistic processes of food-retails, making up an important share in total urban goods distribution, show how main future logistic chains will look like (see figure 2).

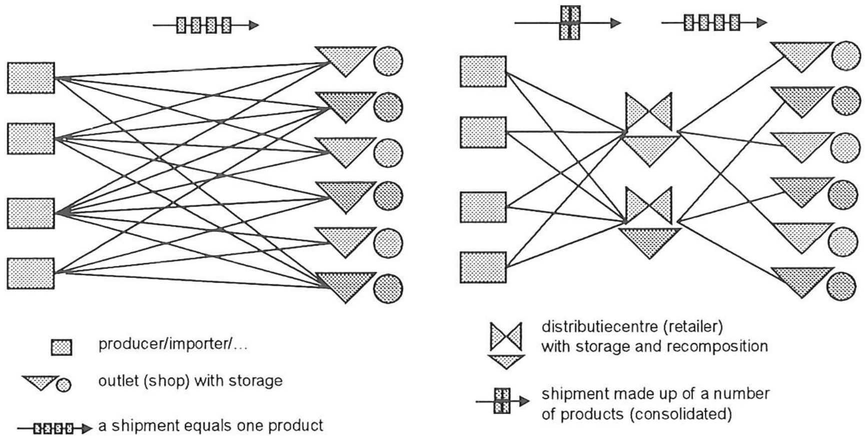

Figure 1 - Traditional logistic concepts in goods distribution

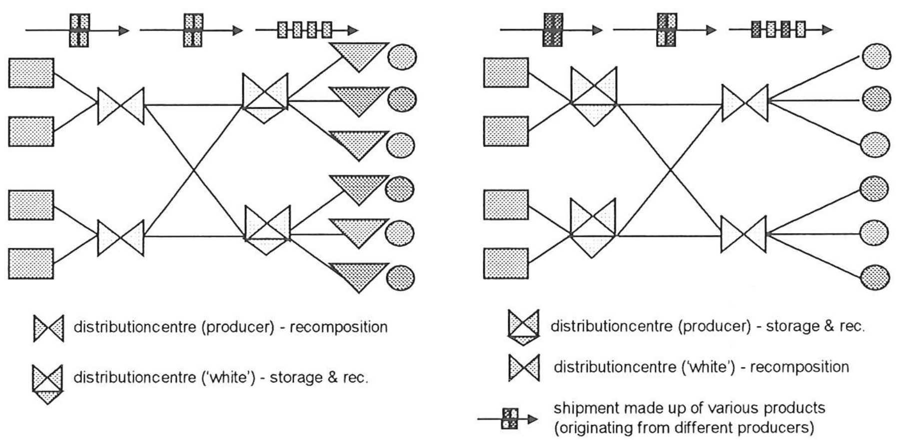

Figure 2 - Logistic concept for fast movers (left) and slow movers (right)

In those modern logistic systems the share of consolidated transport is increased and use is made of distribution centres close to producers and centres close to market areas. A clear distinction is made between 'fast movers' (commodities, low net margin products) and 'slow movers' (specialities, high net margin products). These flows can theoretically be dispatched along different routes: fast movers are stored near market areas (in the future maybe in 'grey' distribution centres), slow movers are, if at all, stored near the sources.

In designing systems for urban goods distribution, attention must be paid to these main developments in logistics. Not only to design new systems based on the requirements resulting from these developments, but also to make use of the opportunities these developments pose: forming of urban 'land-ports'.

Changing locations for logistic activities

The location of logistic activities changes in time, for different types of activities at a different pace. Once a logistic activity is located somewhere, normally this activity will stay there for a certain period. The locations of consumer areas and related retailers (urban areas) are more or less fixed for decades if not centuries, left alone urban sprawl and the building of new cities. The location of large production facilities is fixed for one to a number of decades, dependent of the type of facility and the economic development. Physical distribution concepts have life cycles of about seven years. As the location and function of distribution centres is strongly related to physical distribution concepts, the locations and functions may also change in this pace.

A reduced lifecycle for logistic activities enhances the flexibility of a company; therefore companies try to reduce the length of those life cycles. This can be done by 'leasing' property, hiring (in stead of buying) distribution centres and outsourcing transport and logistic activities.

Though consumers change their homes also in a pace of about once every decade, the site of residential areas does not change a lot. In fact, most cities today were established centuries ago (in Europe that is). Ofcourse there are exceptions and next to that, the average population density tends to decrease - so the location of consumers should not be regarded as unchangeable, but the pace of the changes is slower than that of (other) logistic activities. Residential areas generally attract shopping facilities, though mass motorization makes that locations of shopping malls are less bound to residential areas nowadays than they were in the past.

For planners it is important to know that the location of production and especially consumption 'facilities' is more or less fixed in time, while the location of logistic centres is not strongly bound to specific locations (foot-loose) and can be relocated swiftly. So, the location choice for these facilities offers the largest degree of freedom.

Looking to logistic activities, the most appropriate places to plan distribution centres are near (large) production facilities, near unavoidable interchange points (harbours, airports) or near large market areas (cities).

The need for interchanging goods

For physical (technical, infrastructural), operational or legislative reasons, transfer of goods from one vehicle into another can be necessary, as is the case in sea and airports. Due to vehicle dimension restrictions imposed in most western cities, somewhere in the chain goods must be transferred to small vehicles. To date, these transfers are regarded as additional cost factors, but due to the changing logistic processes these transfers may in future come in handy. Not only for legal or physical reasons, but also for logistical reasons transfers near the market areas will become common practice. These urban distribution parks can be regarded as 'urban ports'.

As stock keeping should be minimised as much as possible, the transfer procedures largely come down to cross docking, in some cases combined with recomposing sendings. New freight flow management and information systems will help to reduce delays or will help to overcome the negative aspects of delays by giving appropriate information.

Consolidation

Consolidation concentrates flows of goods by bringing together shipments or loads. To handle these large flows efficiently, relative expensive transport systems can be used because the costs of these systems per transported ton stay low. Consolidation therefore leads to higher efficiency and lower, overall, transport costs (see also Bovy *et al*, 1994). These are partly necessary to overcome aversive effects of the act of transhipping goods. Consolidation can take place on infrastructure, in vehicles, in load-units and in packages. For each situation the most appropriate form of consolidation must be found.

System requirements

Different stakeholders have different requirements with respect to urban distribution. The main task for system-design is to tune these sometimes seemingly unmatchable requirements (Visser *et al*, 1996). Shippers and transport companies wish to reduce the costs and the total transport time of goods in a chain and wish to enhance reliability. By reducing the 'lead time', interest costs of goods in the chain can be reduced. Faster transport processes allow a more efficient use of personnel and vehicles. Imnproved transportation requires high(er)-speed transport systems, the reduction of the number of unplanned stops (traffic signs, giving way, congestion, ...), advanced tracking, tracing and control systems, automated transfer procedures and optimised load/unload procedures.
Transport companies can use largely the same vehicles in and outside all urban areas, there are only rare exceptions. This results in low investments costs. If multimodal transport systems are proposed, the flexibility and interoperability may be endangered. Using standard load or transport-units, standardised information technology and if possible single-standard vehicles for all cities, will help to overcome this problem. Furthermore mutual attunement of legislation of local governments with respect to entrance requirements would be very useful.

NEW TECHNOLOGIES FOR URBAN DISTRIBUTION

Decoupling intra city from outside city physical distribution activities allows optimising both activities 'independently' within the frame of the integrated logistic concept. The intra city movement of goods can be fine-tuned to urban circumstances, without worrying about the longer-distance leg of the movements. Reverse, optimal technological solutions for inter-city distribution can be used without causing hindrance in urban areas (see Van Binsbergen et al, 1995).

Intra city systems

Within urban areas there is not much space to create new infrastructures, except if solutions are found by going underground. In most other circumstances one has to work with the infrastructure that is available, with several options.
The accessibility of urban areas for goods vehicles can be *limited to a certain time frame*. In that time frame goods vehicles have the exclusive right to use the infrastructure and can thus enter the city and deliver the goods without being hindered by other traffic. The time frames are generally fixed and often non co-ordinated in a region. The principle can be made more efficient by co-ordinating the entrance time frames for different cities in a region and making the access times more flexible.
Although in most cities there isn't enough space to create new infrastructure, in some cases it will be possible to *assign certain 'routes'* to certain user-groups. If transport flows are large, the assignment can be permanent, but if transport flows are small, one can think of timed assignment of routes.
Information systems, very look a like parking routing information systems, can be used to guide goods transport vehicles through the city. In the future such systems can process information about the actual traffic situation, can make predictions and can inform drivers to take the most efficient route. It may be even useful to combine the assignment and information systems to allocate a particular path in space and time to a particular vehicle.
Advanced *co-operative fleet management systems* allow to use the most appropriate vehicle (size, carrying capacity, emission-requirements) for each sending: there will be less need for compromises (compromises in vehicle choice always lead to overcapacity and low load-factors). In general, small vehicles will increase traffic and environmental problems, but will at the same time enhance the

overall performance and decrease lead-times in sendings as more 'direct deliveries' will be done. These advantages and disadvantages must be balanced in designing an urban distribution system.
Within urban areas use can be made of underground connections, for example between distribution centres at the borders of the urban area and the central area (bypassing heavily congested areas within the cities). In these (automated) underground logistic systems, the use of small vehicles will hardly have any negative side effects. Calculations show that underground systems require very high investment cost but would not require excessive tariffs to be cost-effective. The estimated costs are about twice the end-distribution costs of today (Visser *et al*, 1998). Knowing that today's distribution costs certainly will increase in future, the tariff-gap isn't insuperable. The concepts can be combined in urban distribution systems; goods are collected in urban distribution centres or urban logistic parks ('ports') at the frames of a city and from these centres distributed within the urban area. The centres act as a reconsolidating point in which goods are only stored for a very short period (if at all).

Road-based inter-city systems

In the opinion of Dutch policy makers the main transport links between Port of Rotterdam, Amsterdam-Schiphol Airport and the 'Hinterland' should be almost congestion free. Therefore plans are developed, and partly executed, to give free way to goods transport at certain links. At some known bottlenecks, reserved lanes for goods vehicles have been built. These free or reserved lanes could be extended for short-distance goods transport for urban areas, forming *free or reserved networks* (see Van Binsbergen & Schoemaker, 1996). With some modifications, such systems can be the start of a fully independent goods transport network, aimed at the Hinterland transport and also at short(er) distance, regional goods transport, which accounts for more than half of total goods transport by road.
Pilot projects have been done to check the usability and safety of extended road vehicles called '4 TEU trucks'. The pilots took place in the Port of Rotterdam and was aimed at improving the efficiency of container transport within the harbour area, but the principle can also be used in (intermodal) short distance transport. The European Commission has proposed legislation that allows member states to use 25 metre trucks within their borders. This seems to be the first step in accepting longer trucks on certain routes. In the United States, Australia and to a lesser extend Scandinavia, long trucks are well known. The main advantages of these vehicles are a higher cost-efficiency (less drivers and less fuel per transported tonne-kilometre) and some environmental advantages. If braking distances can be limited, there will also be some 'capacity advantages'.
By automating the guidance systems of trucks, less drivers will be needed and this will probably lead to cost reductions. Additional advantages of vehicles running on dedicated infrastructure may be increased reliability in time, full-continue transport systems and night-time-distribution (see: Projectteam CombiRoad 1994; Evers, 1995). Even at relative low track-speeds, some 50 kilometres an hour, about the same average operational speeds can be achieved as in traditional transport because no traffic induced intermediate stops or speed reductions occur. Automated guided road trains are a logical follow-up of automated guided vehicles and road trains. The net gains will be somewhat less as road trains are efficient transport modes already. Maybe some additional gains can be achieved by optimising the actual manoeuvring control. It may be a difficult task for the driver to keep the long truck combinations in the right track (the combination will 'sweep its tail' because it magnifies steering-corrections of the pulling vehicle). By improving the driving skills, technical adaptations and automatic steering corrections, this effect can be diminished, which makes it possible to use narrower infrastructures.

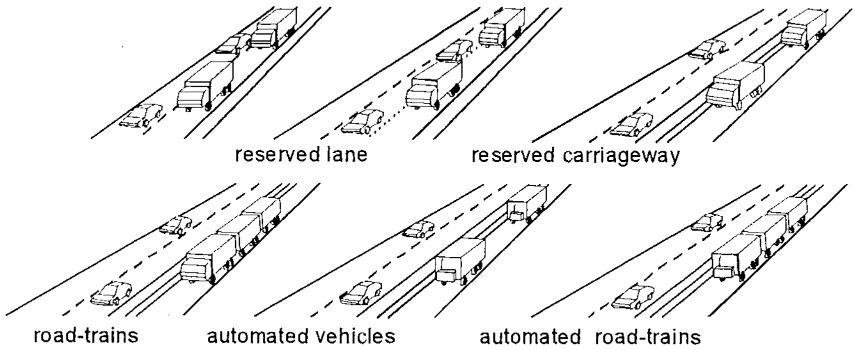

Figure 3 - Different options to improve road-capacity for goods transport

Today road infrastructure is, largely, free accessible. Infrastructure use is not planned or regulated by government bodies or other 'regulators'. Everybody may at any time start with a journey, only risking congestion once being on the road. This is in contrast with railway systems in which a journey may start only when a free path is guaranteed. This leads to a more efficient use of infrastructure and eventually also to predictable delays. Road infrastructure management should copy some of the ideas of 'rail-like' management: advanced systems regulate the inflow of traffic on a certain part of the infrastructure. Only if the quality is guaranteed, access is permitted. Other options limit the accessibility of infrastructure to those who use the infrastructure most effective.

Rail-based systems for inter-city transport

The characteristics of traditional rail systems do not match with the requirements for short distance distribution transport. In traditional rail transport the level of consolidation is of an order too large and the processes of train forming, reordering (shunting) and splitting take too much time. For short distance transport, short trains are more appropriate. Trains consisting of about five or six wagons offer scale advantages with respect to road transport but do not ask for the far-too-large scale of consolidation of traditional trains.

Making trains short is fiddling with the base consolidation principle of rail transport. Shorter trains will mean a decrease of advantages of scale, a decrease of efficiency in productivity (more train drivers should be needed), infrastructure use (the fixed safety systems are optimised on long trains) and energy use (as traction equipment is also optimised for long, heavy trains). Therefore a complete redesign of rolling stock, the safety system and even the train control system is needed. This could let to a full-automated train running in a flexible (adapted) moving block safety system propelled by motors in every wagon (like in most short distance passenger trains).

The lower speeds of traditional freight trains are not compatible with those of passenger transport trains, resulting in a very limited number of 'paths' in the train schedule (Rutten, 1995). If the short freight trains could operate at speeds of about 120 - 160 kms/hour, mixing with intercity trains would be possible, thus offering more flexibility in creating train-paths in the schedules. Because the higher speed conflicts with the 'environmentally sound' image of railway operations, newly developed advanced engines should be used. The trains are used in the distribution process and will usually transport lightweight goods, so wagons can be made lightweight. This also reduces energy use.

The process of loading and unloading trains must be speeded up. In the end sendings (colli) must be stowed in a train but loading and unloading colli in train wagons takes too much time for the train itself (the wagons cannot be used during the loading process). Furthermore, the handling of individual colli is not attractive from a logistic perspective. Therefore the use of transport-units (containers of some sort) is required. The train itself is only loaded and unloaded with those transport-units, the units itself can be stuffed or stripped elsewhere (Van Binsbergen *et al*, 1997).

Several developments take place in practice, which makes the short trains for intermodal short distance transport more science than fiction. In Germany the Cargo Sprinter serves as a test project. The train consists of multiple platforms, the end ones are powered by a small diesel motor and can carry up to two 20 feet containers. The intermediate platforms are non-powered. The end platforms have a control cab, in addition to the cargo space. At the test phase, the CargoSprinters are manned, but this will probably change in future .

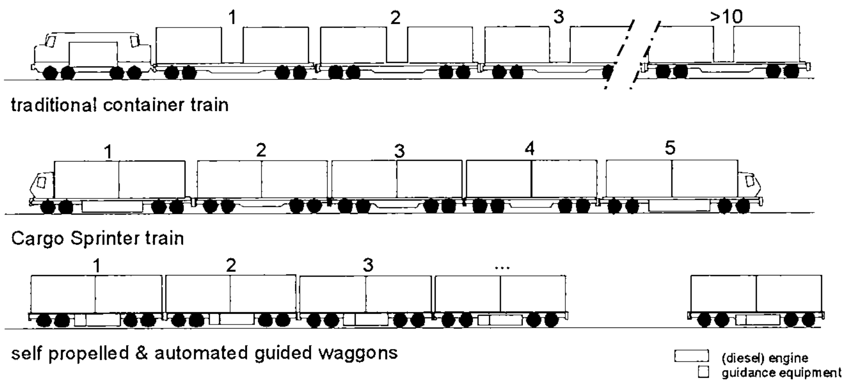

Figure 4 - Options to adapt rail transport systems to urban distribution

In Germany and France developments take place to automate the transhipment of containers between trains and, in a later stage, between trains and other transport modes (trucks). Although these projects do not directly correspondent to short-distance goods transport, some results can be used for future developments.

Underground systems

There are lots of ideas for interlocal, regional or even national and international underground systems for goods transport (see Lievense *et al*, 1995; Van der Geijn Partners, 1996; Heidemij/TRAIL 1996). Advantages of underground systems are the autonomous traffic flows, weather-independence, efficient space-utilisation and less or no local environmental effects like noise, air pollution, physical hindrance and separation.
Well-known disadvantages are investment costs and system-safety. In essence, all known transport systems can be used in tunnels. In practice, there are some restrictions on propulsion and guidance which are related to tunnel characteristics (DHV/TRAIL, 1996).
In underground systems zero-emission vehicles are preferred as this reduces the need for air-cleaning and conditioning devices. Nowadays, all specially designed underground systems (metro) are equipped with electric engines or external propulsion systems (air pressure, cables etc.). As lateral movements of vehicles require larger tunnel diameters, most specially designed underground systems make use of guided systems. In these systems the lateral freedom of movement is restricted (compared to human-steered vehicles). For safety reasons rigid, physical guidance systems (rail) are preferable to electronic guidance systems.
The consequences of accidents in tunnels can be enormous: the accessibility to tunnels for rescue workers is limited, as is the manoeuvrability of helping appliances. Therefore, much attention is given to prevent accidents happening at all. This requires fail-safe safety systems, comparable to that of railway systems.

Investment costs for tunnelling are high, but the advantages of underground transport are obvious. For heavily congested urban areas (such as the Tokyo metropolitan area) extensive studies have been done, but the economic perspectives in Japan do not allow enormous investments in the near future. For other large urban areas also ideas for underground systems have been developed. Also for conurbations as the Randstad in The Netherlands, underground distribution could solve congestion and environmental problems, though the 'inside out' spatial structure of the conurbation (there is no high-density central area) asks for specific solutions.
One of them is creating a connection-network between the main cities, commercial and logistic areas in (and in a latter phase outside) the Randstad area. Preliminary study results show that some 28,3 million up to 58 million tonnes of a total of 195 million tonnes annually could be transported by such an underground system. The network length would vary from about 320 up to 1300 kilometres and would require 12 to 30 large (intermodal) terminals.
If most important 'logistic activities' would be connected to such a network, including inside urban areas, quite revolutionary new logistic concepts could be used. For example batch-processing in transport could be limited drastically as in a well designed underground transportation system sendings can be handled on an almost individual basis (thus far a pallet-size is regarded as minimum shipment size).
Such systems sound like science fiction and maybe they stay just that. On the other hand, increasing problems regarding accessibility and environment may change our attitude in future - the systems pose serious possibilities. They also make us think about re-arranging our logistic processes and this may in the end have an important spin-off on the operations of 'traditional' transport services.

NETWORKS

Elements of networks and network design

Networks exist of links, access points, consolidation points and other nodes (crossings, interchange points). By using *access points* or transfer points goods can enter or exit the network. In internal *consolidation points* goods are consolidated or deconsolidated and for that goal sometimes temporarily stored. On *crossings* one can change direction within the network. The *links* make a connection between the various nodes.
The general objective in network design is to consolidate most transport activities using least resources. If network design includes the design of infrastructures, this means limiting the number of nodes and links (or the total length of the links) as much as possible given some preconditions. If network design deals with routing and vehicle allocation, the design is aimed at limiting the vehicle use and route-length. Consolidation means making detours and/or taking into account the transhipment of goods. The gains of consolidation vehicles on infrastructure or goods in vehicles must be bigger than the costs.
If consolidation turns out to be an effective option to optimise the transport process, the *number and location of consolidation points* must be determined. Consolidation points that act as transfer points must be spread over the area. Each centre has its own servicing area (market-area). The average distance between the centres depends from transport system characteristics (minimum distance between centres) and the maximum access-distances allowed (maximum distance between centres if an area must be fully covered). The transport characteristics determine the 'stopping-distance' and this will be an input to find the minimum distance between centres. The quality of the transport system will also determine which access distances (and times) will be acceptable for customers. If the transport system can operate at a high operational speed, a limited number of consolidation centres can be used. If the operational speed is low, multiple regional consolidation points must be used.

Different types of service network-layouts have different characteristics for the users.
Full networks (see figure 5) offer direct connections between all points. This type of network can only be operated in an efficient way if the transport volume matches with the resources used (i.e.: very large quantities on dedicated infrastructure with large dedicated vehicles, or small quantities in small vehicles using existing infrastructures). Note that direct networks do not automatically offer a higher quality: in direct networks with low volumes frequencies of delivery (or delivery rates) may be lower and transport speed may be less than in other networks.
Consolidation - deconsolidation networks use multiple transfer points. In the downstream centres, near the origins, load from different suppliers is put together and is transported to the upstream centres where deconsolidation takes place. Wagonload railway services are based on this principle. The number of interchanges requires an efficient transfer system or high speed at the consolidated transport leg of the chain.
Hub and spoke (star or radial shaped) networks depend strongly on their central point of consolidation. Flows for different origins or destinations are consolidated on the spokes and rearranged in the hub. Hub and spoke systems are useful for high-speed transport systems transporting relative high volumes of goods.
Ring networks combine a limited capability of consolidation with a most effective use of available resources (notably infrastructure-length). Non-closed *line* networks are very look-a-like ring networks, but do not offer the possibility of circular movements (and the possibility of incident evading by taking another branch of the network). In line-networks high intensities at the central part of the network can be expected.
These forms of networks are in fact 'logistical' networks which can be expressed in (dedicated) infrastructure or which can use already existing infrastructure.

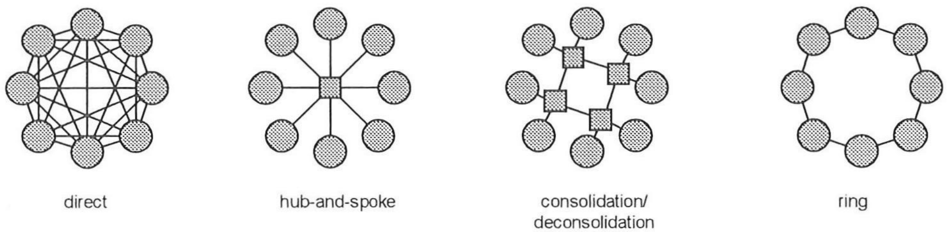

Figure 5 - Different shapes for service networks

Note that different types of service networks can be combined. The centres in the consolidation/deconsolidation networks can act as lower-level hubs. Suppliers can transport goods for different receivers in consolidated flows to the downstream hub, while goods originating from different suppliers and intended for a single receiver can be consolidated from the upstream hub.
The infrastructure networks come in some additional shapes.
Grid or triangular infrastructure networks offer a high degree of flexibility if links are bi-directional. Especially in urban areas, networks often come in an *organic form*, they 'grew' from the historic city-centre without a master plan.
From the perspective of urban areas, transversal ('going through') and tangential ('passing by') infrastructures are distinguished. Due to urban developments, railway-links nowadays often *transverse* cities while new-built highways *encircle* the main built-up areas. Transfer points can be found in the midst of an urban area (like stations for passenger trains - central locations) or at the frames of a city (like most distribution centres - peripheral locations). When taking into account the process of bringing goods to urban areas by using large-scale vehicles, locations of transfer points at the edges of a city are preferred. Then there will be fewer accessibility problems and there will be less hindrance.

Different networks for different systems

Often it will be impossible to create fully new infrastructure dedicated for goods transport. Than already existing infrastructure (road or rail) should be used. The goods distribution service network, can be seen as a serivice layer over a physical infrastructure-network. In some cases the infrastructure network does not match with the distribution network. Additional infrastructure must be built or the distribution network has to be adapted. In other cases creating extra lanes or tracks can increase infrastructure capacity.
If new transport modes are used, a new network must be built. Clearly, this will be the case if we want to make use of an underground distribution system in an urban area with no such infrastructure in place. The same goes if we want to operate fully automated road vehicles.
In one way or another, often use is made of existing infrastructure. Even for underground systems, mostly the pattern of surface infrastructure is followed. Infrastructure for automated vehicles will be built alongside existing infrastructures. This way the space utilisation, separation effects and costs will be limited.

Choosing an appropriate network configuration

Characteristics of the market and the transport system determine which network configuration is optimal. The most important *cost factors* are investment and exploitation costs for terminals or consolidation points, vehicles and infrastructure. Additional important characteristics of the transport system are operational *speed* and *reliability* in time. Important characteristics of the service-area and the market are the size and therefore the average transport-distances, the geological characteristics (rivers, mountain ranges etc.), the dispersion of addressees the average drop size and the total transport flow.
Further more, the typical shipment size determines the logistical network configuration.
Sendings at package-level ('collo') or pallet-level require multiple steps in consolidation to obtain an efficient logistical structure - as is the case with specialities as mentioned earlier.
Multiple-pallet (less than truckload - LTL) sendings ask also for consolidation, but only at the main legs of the network and full truckload-sendings can be transported using direct networks.
Often combinations of service network types will be necessary. With respect to rail transport, hierarchical consolidation takes place, resulting in a *mix of a hub-and-spoke and consolidation-deconsolidation network*. Also the Cargo Sprinter system uses such a combined network, but trucks may do access and egress transport, and consolidation is easier due to the limited number of wagons. Also in road transport this type of combination networks is used, for example for postal and express services.
Downscaling rail transport and upscaling road-transport (on the main routes) makes it possible to use the efficient hierarchical ring-network structures. Such a ring (or multiple rings) connects urban or regional distribution centres, while these centres act as regional hubs.

IMPLEMENTING NEW SYSTEMS

On the short-term (up to ten years) only modifications of existing infrastructures, technologies and concepts can take place. The short-term time frame is too short to offer fully operational and reliable alternatives for road-transport. Feasible developments will be extended-length and multi-trailer trucks, optimised internal combustion diesel engines, free truck-lanes on most congested highways near cities and urban or regional distribution centres. On short term new logistic systems, 'advanced legislation' and enforcement techniques and forms of private-public-partnerships will be designed and tested and pilots with short rail trains at 50 - 150 km distances will be performed.
On medium term, up to twenty years, some fundamental changes can be achieved:

- autonomous goods transport links, equipped for automated vehicles;
- pilots with fuel-cell/electric engine operated trains;
- fully operational specially designed railway trains for inter-urban transport;
- fully operational road based city distribution systems;
- fully operational regional intermodal (rail/road) distribution centres;
- fully operational new logistic systems which incorporate urban and regional distribution centres;
- pilots with urban and regional, automated underground distribution systems.

At the long-term, options seem sometimes to be unlimited. Still, also in the end there will be restrictions in investment funds, available space and useful technology. Developments in consumer behaviour (good flows, traffic flows) are hard to predict at this long term. On the other hand, if no radical changes take place, much of the existing infrastructures will still exist. On the long term autonomous goods distribution networks for automated transport, automated rail transport of goods and underground distribution systems in some large cities and at some specific locations can be developed.

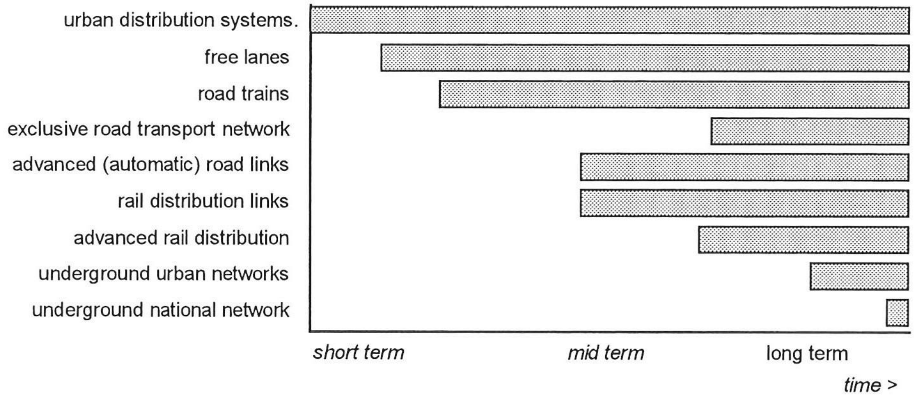

Figure 6 - Developments in urban goods distribution in time

CONCLUSIONS

Developments in vehicle technology, logistics management and the management of infrastructure-use can decrease the negative side effects of goods transport and can enhance efficiency. The required developments are often too expensive or too complex to implement by individual transport companies. The shared interest of society and companies must create the preconditions to develop new logistic and transport systems together. Physical, legal and logistical reasons determine the need for transferring goods. Up till now, in most cities only legislation was an incentive to make use of a multi modal transport system. In (near) future these incentives will shift towards physical and even logistic reasons. We envisage a balanced inter modal goods transport system which is fine-tuned to the needs of intra and inter city goods movement. One key feature of that system is the necessity of transfer points near urban areas. In the concept as described, this is no additional transfer point, but a consolidation/deconsolidation point that is an essential part of future logistic chains. Creating such transfer points is required to optimise intra-urban transport systems as well as inter-city transport systems.

In inter-city transport, developments in road and rail transport can be expected (and partly take place already). Medium distance road transport will be made more cost-effective. This means an enlargement of scale by using longer road-vehicles (road trains) and an improvement in quality by automating the guidance systems. In the heavily congested conurbation of the Randstad, the use of road-trains will be only acceptable at certain main roads, preferably using free lanes. The development of free lanes takes place for the so-called 'Hinterland-connections', but should also be constructed for interregional (but national) movements of goods. One can envisage a path of development starting as free lanes and resulting in a completely separated, autonomous road-infrastructure network. Such a network will be essential to operate automated guided vehicles. Rail transport systems must be adapted to operate for regional distances. In fact, downscaling is required and developments in that direction already take place. Also in rail transport automation of movements can enhance quality and probably reduce operational costs. The development and use of load-units are essential for both systems.

Underground systems will maybe in the long term be operational. Most advantages of these systems for regional and interregional can also be achieved by using automated road or train systems, which only partially will run underground.

The principle of consolidation is essential in network design. Ring-shaped networks will probably be the most efficient solution: the shape makes best use of available infrastructure and fits well to the urban structure of the Randstad. An important precondition is that the process transferring goods between vehicles is cheap and fast.

Implementing those systems takes much time. On short term appealing results may not be expected. The short-term period can be used to test some of the new concepts and to prepare medium-term developments. Urban or regional distribution centres will be developed, as will new forms of co-operation between transport companies, receivers and governmental institutions. Most developments can take place in the medium term. In such period changes in logistic chains can be realised, new infrastructure can be built and most new technologies can be made fully operational. In the long term further developments can take place in the field of automated guidance and underground transport systems.

Advanced inter-urban goods transport systems will enhance the efficiency of medium distance goods transport. New promising developments take place that can be used to implement these new systems in the twenty years to come.

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