Published as: Zou, Xi and David Levinson (2005) Financing and Deploying Automated Freight Systems in The Future of Automated Freight Transport: Concepts, Design and Implementation. (ed. Rob Konings, Peter Nijkamp, Hugo Peimus) Edward Elgar pp. 227-242.

Financing And Deploying Automated Freight Systems

David Levinson and Xi Zou

University of Minnesota Department of Civil Engineering

500 Pillsbury Drive SE

Minneapolis, MN 55455 USA

+01 612 625 6354

levin031@umn.edu

DRAFT: July 1, 2003 For Comment Only

Abstract

New technologies are bringing Automated Freight Systems (AFS), which aim to reduce congestion, mitigate environmental impacts and enhance public safety, to fruition. The financing and deployment issues of AFS differ from other Intelligent Transport System applications. This chapter briefly introduces major concepts of AFS. The financing strategies for these concepts are discussed, in which the government subsidies play an important role through the use of public-private partnership. Economies of scale and externalities of the current and new systems are discussed. In the discussion of the deployment of AFS, it is suggested that deployment schemes are highly correlated with financing strategies.

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Introduction

Efficient and flexible transport services advance economic growth and enhance competitiveness in the international market. Currently, however, traffic is growing faster than capacity (FHWA 2002). Increasing congestion prevents traditional transport modes from meeting the growing demand from shippers for reliable, inexpensive, fast, and flexible transport services. Moreover, heavily congested roadways are a major source of pollution. New technologies, such as advanced traffic management and traveler information systems, are developing slowly, and lag the pressing needs for transport improvements. Systematic innovation, developing new compatible but advanced transport modes, provides an alternative solution.

Typically, 15% to 25% of product cost reflects the expense of transport, inventory, warehousing, packaging, and material handling (Bowersox et al., 1992). Major automobile manufacturers, such as Ford and General Motors, spend more than $3 billion per year in freight transport (Coyle 1994).

Time compression, customer satisfaction, asset productivity, organizational re-engineering, and outsourcing all affect the demand for transport (Coyle 1994). Further, e-business has created new demand for freight transport. It has been said that more than 150,000 people are running their home-based business using the online auction site EBay (Reuter 2003). Transactions and the accompanying shipments are generated every second. These developments rely on timely shipment and delivery service.

The increasing demand for effective freight transport is both a challenge and an opportunity for transport service providers. More and more small packages swarm to

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carriers, while the demand from conventional bulk shippers remains. The resolution of this challenge stems not only from the innovation of operating strategies, but also from the application of new technologies. Automated freight systems (AFS), which apply advanced technologies in computing, sensing, and communications to construct a highly efficient and safe transport system, include following major components (FTAM 2002):

- New terminal technology for multi-modal freight transport;
- Modularized vehicle and traffic control;
- Intelligent vehicle and control system;
- Intelligent infrastructure;
- New logistic strategies for matching service and transport capacity.

Compared with conventional freight systems, the development of each of these components needs to change both hardware (the physical infrastructure and vehicles) and software (the policies, rules, and controls that govern transport). But the whole new system must remain compatible with existing networks because

- The configuration of packages from shippers will not change significantly;
- The international standard container – sizes that we input to the new AFS will remain, otherwise an increase in repackaging costs will be required;
- The conventional transport system will continue to exist.

Based on these concerns, the deployment of any AFS concept should be examined carefully to verify its feasibility and economic efficiency.

AFS heralds Intelligent Transport Systems. But compared to advanced passenger transport systems, AFS has some advantages. Passenger comfort is not an issue in freight transport. The allocation of travel time and delay in transport will not annoy package shippers in the same way that travelers get irritated. There are fewer safety issues among packages. Thus the carriers are freer to handle the system.

It is believed that, compared with conventional freight transport, AFS will improve cost effectiveness, enhance system reliability, reduce energy consumption, reduce delivery times, ensure all-weather delivery and around-the-clock service, ensure cargo security, reduce air and noise pollution, and consume less land (Roop et al. 2000). The issue is whether those benefits outweigh the cost, and who receives the benefits and costs. This paper explores sources of financing for deploying AFS.

While there are many ideas about the future of freight transport system, few of them are original. Many are just innovations or reinventions of old or even obsolete ideas. In this paper we address three types of AFS: Pipeline, Rail, and Truck.

Automated Pipeline Systems (APS)

> *"I suppose so," said Edith, "but of course we have never known any other way. But, Mr. West, you must not fail to ask father to take you to the central warehouse some day, where they receive the orders from the different sample houses all over the city and parcel out and send the goods to their destinations. He took me there not long ago, and it was a wonderful sight. The system is certainly perfect; for example, over yonder in that sort of cage is the dispatching clerk. The orders, as they are taken by the different departments in the store, are sent by transmitters to him. His assistants sort them and enclose each class in a carrier-box by itself.*

The dispatching clerk has a dozen pneumatic transmitters before him answering to the general classes of goods, each communicating with the corresponding department at the warehouse. He drops the box of orders into the tube it calls for, and in a few moments later it drops on the proper desk in the warehouse, together with all the orders of the same sort from the other sample stores. The orders are read over, recorded, and sent to be filled, like lightning. The filling I thought the most interesting part. Bales of cloth are placed on spindles and turned by machinery, and the cutter, who also has a machine, works right through one bale after another till exhausted, when another man takes his place; and it is the same with those who fill the orders in any other staple. The packages are then delivered by larger tubes to the city districts, and thence distributed to the houses. You may understand how quickly it is all done when I tell you that my order will probably be at home sooner than I could have carried it from here." **Edward Bellamy (1887) *Looking Backward: 2000-1887* (chapter 10, p.106)**

As suggested by Bellamy (1887), pipeline transport has long been the technology of the future. Each type of pipeline: slurry, pneumatic and capsule pipeline, has a different history, characteristic, and status (Liu 2002). The slurry pipeline transmits liquefied oil, coal and other mining products; the pneumatic pipeline is mainly used to transport city waste; the pneumatic capsule pipeline is widely used in transporting parcel and bank documents over a short range (Liu 2002). APS originates with ideas dated from as early as the 1st century. Modern APS are still based on capsule pipelines. The major differences are in the propulsion system. Many advanced technologies have been proposed, from renovated pneumatic propulsion to the linear induction motor. Pipelines powered by linear-synchronous machines can carry freight capsules with higher efficiency and lower noise and pollution than trucking and rail systems. Meanwhile, tunneling technology has matured enough to build underground pipelines in an efficient and economical way. All these achievements make the automated pipeline systems technically feasible. Companies, such as Capsule Pipelines, CargoCap, Evacuated Tube Transport (ET3 Tube), Frog Cargo, Magplane Pipeline Transport, Pipenet, and TubeXpress have proposed or begun to implement initial systems.

Pipelines can be built underground in most places (at less cost than underground highways or railroads), which minimizes environmental impacts. The size of vehicles is physically limited by the diameter of pipeline. Pipelines are a textbook example of economies of scale, because when the diameter of pipe increases, the pipe cost increases less than proportionally, the construction cost increases proportionally, and the capacity increases exponentially (Braeutigam 1999).

Automated Rail Systems (ARS)

Self-propelled rail cars have been around almost as long as the railroad itself, and are in wide use in passenger travel. Combining this with automation gives ARS. In automated rail systems, containers or vehicles are loaded onto carrier vehicles that, powered by their own electric motors, can move with a high speed along a fixed guideway. Companies like Autran, MagneMotion's MagneTrak and MegaRail have proposed systems. While the AFS of this kind looks like a light rail system, unlike conventional rail where a fleet of trains operate according to schedule, ARS provides one vehicle for each load and can respond quickly to changing demands.

Automated Truck Systems (ATS)

> *"....nothing seems more certain then that many special highways will be constructed for motor trucking."* Editorial, **Roads and Streets**, 1928

Automated truck systems can be seen as a special version of automated highway systems (AHS) for commercial vehicles. Separating trucks and cars is hardly a new idea, yet despite being suggested over 75 years ago, there must be difficulties or it would already be done. An increasing number of trucks worsens traffic and generates serious accidents. Therefore screening trucks out of passenger traffic seems a reasonable solution. However, it is far easier to realize an automated system on rail tracks than roads, as control (steering) is simplified.

Trucking companies want to increase fleet safety and reliability of shipments. The cost of automated equipment is a smaller share of the cost of a truck than of a passenger vehicle. In this AFS concept, trucks operating in the dedicated lane are equipped with advanced control systems that cause trucks to follow the roadway and keep a safe spacing between each other, while running at a high speed. The intelligence in the infrastructure communicates with trucks to maintain the safe operation and implement control strategies.

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Overview

By comparing these concepts, it is obvious that the framework of Automated Freight Systems contains innovations in many transport modes. To study its deployment, we must not only investigate the characteristics of each single mode, but also understand their roles and impacts for inter-modal transport systems. The rest of this chapter will concentrate on the financing and deployment issues of AFS. However, it should be noted that these two issues are highly correlated. Every deployment scheme can only be configured if financial resources are organized for capital and operating expenditures; while every financing scheme depends on the relationship of actors responsible for deployment.

Financing

Current funding systems for general transport systems may serve as models for AHS and AFS, though there are differences in the proportion of contributions from public and private sectors.

Roadway systems are traditionally funded by general funds from federal and local government and the Highway Trust Fund. The revenue from tolls, user fees, and gas taxes are direct financing resources, as are the direct investment from private enterprises. For roadway improvement systems like ATS, automobile users' taxes and public transport subsidies could remain dominant sources for capital investment. However, the funds from the private sector may become more and more important in that the operation of ATS entails higher expenses than traditional systems.

Funds for traditional freight railway systems are mainly private, though government often contributes right-of-way in the form of land, whose increase in value provides revenue to the railroad as land developer. Local government often contributes in urban railway improvements, especially for consolidation of rail yards in return for the redevelopment of the reclaimed area. For ARS, similar resources will be available, though cross-subsidies from automobile user's taxes contained in public subsidies for urban transit are less likely to be available. There is no fixed scheme that determines the allocation of burdens of public and private financing resources in ATS and ARS. But private investment or private-public partnership for managing mixed financing resources are more and more recognized as promising approaches in face of the constrained availability of public funding.

Current pipeline systems are mainly financed by the private sector because most of them are just for freight transport. This situation may make the transition to the APS smoother than other two AFS systems. For APS, the allocation of burdens will lean toward the private sector because less land is required. Subsides from federal and local government may be in forms of favorable tax policies and other indirect instruments.

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Financing depends on beneficiaries. It is an accepted practice to associate costs with beneficiaries. It seems obvious the companies who use AFS benefit from it; otherwise they would not use it. Users of conventional transport modes may benefit from reduced traffic. Society benefits from reduced negative externalities.

Rationales for Government Support

Garrison and Levinson (2002) summarized reasons for government intervention in the transport sector. Some of those reasons apply to financing AFS.

First, existing technologies have a large advantage in that they have already achieved economies of scale. A new technology may eventually be more cost effective, but isn't initially due to high fixed costs (network construction, new technology development) and low demand. A new industry requires maturation before the economies of scale are realized, and thus requires subsidy (from patient capitalists or the government) in its early years. While this argument is certainly true to some extent, the degree depends on circumstances, and on the appropriate response depends on the confidence that one has for the industry. Further, government support here should be seen more as a loan than a grant.

Second, government support can be seen to fit the requirements of upfront investment of Social Overhead Capital (SOC). The government may act as a "door-opener" to support the industrial development of the economy. (Baum and Schulz 2000) The potential of AFS for increasing productivity in both the newly developed freight system and the conventional transport systems may justify government support.

This economic development argument is often used in transportation, yet is even harder to quantify than the economies of scale argument.

Third, is the externality argument of Pigou. Negative externalities should be internalized by taxes and positive externalities should be internalized by subsidies. Government subsidies, as instruments of intervention, can improve the optimal use of resources when there are market failures. To achieve the reduction in externalities, we have several options: (a) properly internalize those external costs everywhere in the transport sector, (b) subsidize the reduction of those negative externalities, or (c) some combination of the two. Ideally, in a first-best world, we would do (a). But since we haven't done (a), we can conclude that we live in a second-best world, and our next best option is (c), or failing that, (b). This justifies subsidies on an externality argument. But we must be careful not to double count and both tax the externality and subsidize its removal. We choose the subsidy only when the first best choice, tax the externality, is politically infeasible.

We have a social demand curve higher than private demand because the new technologies will presumably reduce negative externalities produced by conventional technology. (Rothengatter 2001) Without subsides, the social demand curve *D**, which is higher than the market demand curve *D*, is not achieved.

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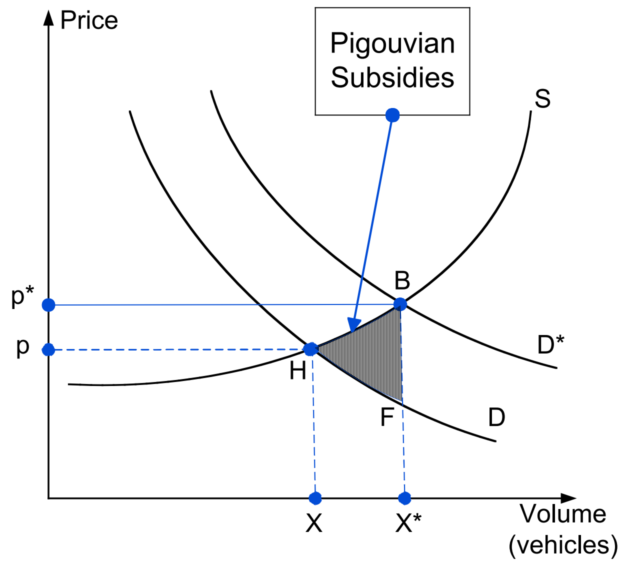

Figure 1.

The tool to create incentives for the private sector is the subsidy *BF*. So a welfare increase is generated. Thus subsidies should go to the transport modes that produce positive external benefits or reduce negative external costs from other transport modes. Nevertheless, it would be better if the conventional transport modes that produced high negative external costs were taxed instead. We find this argument theoretically convincing, but question the magnitude of externalities that will be reduced through use of automated freight systems.

A fourth reason used to justify government support is that the involvement of private resources is not as large as required (i.e. the private sector can't build it alone, yet it "must" be built). This failure of the private sector may be due to: (1) the limited resource of private capital; (2) the difficulties in obtaining credit from national and international banks by private investors; (3) the limited portion of cost coverage provided by bank credits (Burnewicz and Bak 2000); and (4) the perception that the government will provide support. When the market risks are very high, private investors will hesitate to enter the market. We don't find this rationale convincing, it simply explains why the private sector won't get involved, not why the public should.

The realization of AFS is such a complex issue that the market failures resulting from organizational and policy dysfunction are almost inevitable. It is normally recognized as a function of government to remedy the failure when the process of technology evolution deviates too far from efficiency, equity, or environmental goals. The systematic intervention required for fixing the failures often can only be obtained from governments. Furthermore, the technology change embedded in AFS may need new institutional and societal arrangements that only governments can implement.

The Triad Structure

In general transportation systems can be divided into a triad structure: vehicles, track, and operations. In AFS, the ownership of vehicles may be conjoint with the ownership of infrastructure, which is not the case in general transport systems. A clarified understanding of this issue may help us allocate the financing burden.

(a) Vehicles

ATS highlights the intelligence of vehicles because the vehicles have fewer physical constraints imposed by the infrastructure (e.g. from pipeline, guideway and rail). Most dedicated truck lane systems require that vehicles can run on both intelligent roadways and conventional highways, i.e. they operate with a dual-mode operation. This means an additional cost for vehicle operators or truck-drivers.

In ATS, the cost of automated trucks should be separated from the infrastructure investment and be covered by truck owners. Users, trucking companies, ideally cover the investment in automated trucks or truck modification. But in the initial stage, it will be difficult to prove to truckers that the investment in automated equipment is worthwhile and will be recouped from the use of ATS. Besides other instruments of promotion, the government can directly subsidize truck modification to ensure a minimum demand for ATS. Without this demand, the new system may not have a chance to survive. Also the benefit of participation should encourage more trucking companies to enter the system. As a stimulating tool, the need for this subsidy should decrease when the demand increases and reaches the capacity of the system.

In APS, the design of the vehicle (or capsule) is a part of total system design, and the vehicles will be highly standardized and used exclusively within the APS. It is likely that the system operator owns every vehicle so it can manage operations effectively. Alternatively, it is possible that the system may be divided into vehicle (capsule) operators and pipeline operators, like the train-track separation in the British rail system. This can generate a totally different financing scenario, but it is more likely to happen when the pipeline-like systems become universal and are networked (as in Bellamy's *Looking Backward*).

ARS is a hybrid of the two; vehicles may or may not be owned separately from the track. Some intelligence lies in the vehicle, though tracks and switches minimize the need for this. When ARS vehicles operated on a mixed network, track costs have already been paid for. Thus in contrast with ATS and APS, the network itself may not need to be financed, rather only a small per-use charge will be paid.

In the APS and the ARS, the financing schemes differ because of the ownership of vehicles (capsules, railcars) is different from ATS. If APS or ARS operators own the vehicles, their cost should be counted in the initial investment, though compared to the cost of construction and land use. If owners of vehicles are dedicated shipping companies, we find a similar case to the British railway system. The door of the new market is opened to the private sector. But to make the system run in the first place, the investment from them should be well organized before the system begins operation.

(b) Track

Track refers to the road, rails, or pipelines themselves. Track is characterized by a high fixed capital cost and relatively low variable maintenance cost. Because of this cost structure, it is often the case that competitive markets cannot recover the costs for the network backbone. (And the more competition, the harder it is to recover costs, which is why monopolies emerge so often in network businesses). User fees charged to shippers and carriers, the groups that benefit most directly, likely will be unable to cover the total system cost of the new networks. It is here that subsidy is most likely needed if AFS are to emerge.

For the reasons describe above, subsidies from central or local government are the one of major components of transport financing. Traditionally new transport infrastructure (highways, ports, railroads, airports) have been partially subsidized by government. There is a trend to transform transport financing to a situation in which private resources or private-public partnerships are encouraged to enter the business. In financing AFS, an innovative financing scheme may fit the characteristics of the new configuration of transport modes in which the private sector plays an important role. In these advanced systems, the capital investment may cover not only the cost of infrastructure but also the cost of the advanced equipment for both infrastructure and vehicles.

The instruments of subsidies vary. Subsidies are usually in the forms of direct financial supports, research incentives, tax reductions, or tax exemptions. The investment in the public transport infrastructure and other funding for regional and local public transport can also been seen as means of subsidies. Rothengatter (2001) suggested indirect subsidies could exist in (1) the overhead cost of public administration and political insurance and (2) the external costs of transport infrastructure and infrastructure use. In deploying AFS, both direct and indirect subsidies are necessary, though their realization is contingent on case particulars.

(c) Operations

The third component of transportation systems are operations, the management, communications, control, administration, and maintenance of the facility. Higher capital costs can be used to construct more automated facilities that have lower operating costs, so we would expect in AFS this to take place. Still there are ongoing costs of business after the network has been laid down. An important source for financing AFS infrastructure is the vehicle-related revenue from tolls.

Collecting tolls is the transport economists' favorite because it represents the basic idea that users of the system should pay for it. There will not be argument on whether or not to collect fees in such an expensive system. The argument will concentrate on who should determine the level of the fee and how much of the cost should be recouped.

An economically efficient AFS should yield enough revenue to cover the debt for construction and operating costs. Furthermore, it should generate funds for improving the system and for the construction of extensions. The general model is that the infrastructure owner invests in track and operations. These costs can be recovered in part or whole by user fees, the remainder from public subsidy (especially for the track). These sources may either pay for the costs directly, or may be used to pay down debt if the operator raised money from capital markets.

In the financing of AFS, though there are several possible financing resources available, government holds a vital role. Carefully organized and operated public-private partnerships will be necessary to dispatch financial resources, if such systems are to come to fruition in a widespread way.

Deployment

Traffic in areas where AFS will be deployed should be significantly higher than other areas. It is obvious that investors will try to find the market niche and route where the system will attract enough users to cover the capital and operating costs. However, this problem is not as simple as it appears on first sight. For instance, to maximize reduction in externalities, ATS should be located in places where truck volume affects traffic greatly and total traffic is large. There are also network effects, so that the link that is most valuable for future extensions may differ from the single most efficient link in an isolated system.

The foremost concern of investors should be on how much demand will eventually use the new system. We can image that both induced and diverted traffic will be there. Induced traffic refers to traffic that is generated only because of the new capacity (Lakshmanan and Anderson 2001, Levinson and Kanchi 2002). The diverted traffic refers to the traffic moving from the old system to the newly developed system. We expect the diverted traffic will dominate because the saving from the new network is only a small component of total cost.

The performance of dispatch in the intakes and outlets affects demand for AFS. This problem can be solved by advanced terminal and warehouse systems. The terminals and warehouses can act as buffer between the high capacity advanced system and low capacity conventional systems. In ATS, the buffer area may not function as well as expected, as shown in Figure 2(a). This is not only because of the limited space of the buffer area, but also because of the variability of the truck fleet. When a high volume of trucks reach the buffer area, the operator can make some of them wait for a while to limit the truck flow feeding to conventional transport systems – other freeway or highway systems. However, the buffering time suffered by truckers will reduce the total efficiency of the system and may eliminate the truckers' incentive to use the system. So there should be a special design of truck dispatching system and buffer areas, which provide enough exits for trucks and do not seriously affect the related transport systems. One possible answer is to mandate trucks exit in a dispersed manner, as shown in Figure 2(b). It is possible because

(1) The customers of the new system may differ in their destinations and can exit separately;

(2) The trucking fleets can be encouraged to cooperate by toll differentials;

(3) The truck fleets that use the system may be relatively static and few in number so that they can negotiate a mutually beneficial arrangement. This is analogous to an indefinitely repeated Prisoners Dilemma (Fudenberg and Tirole 1995).

We have discussed various financing schemes that should be considered for different AFS modes. Although the spatial deployment of AFS should respond to demand, a national AFS deployment policy will direct the financial support and regulate market behavior. Government aid forms an important tool of regulation because it is vital for projects with large infrastructure construction to have controls imposed by their financiers.

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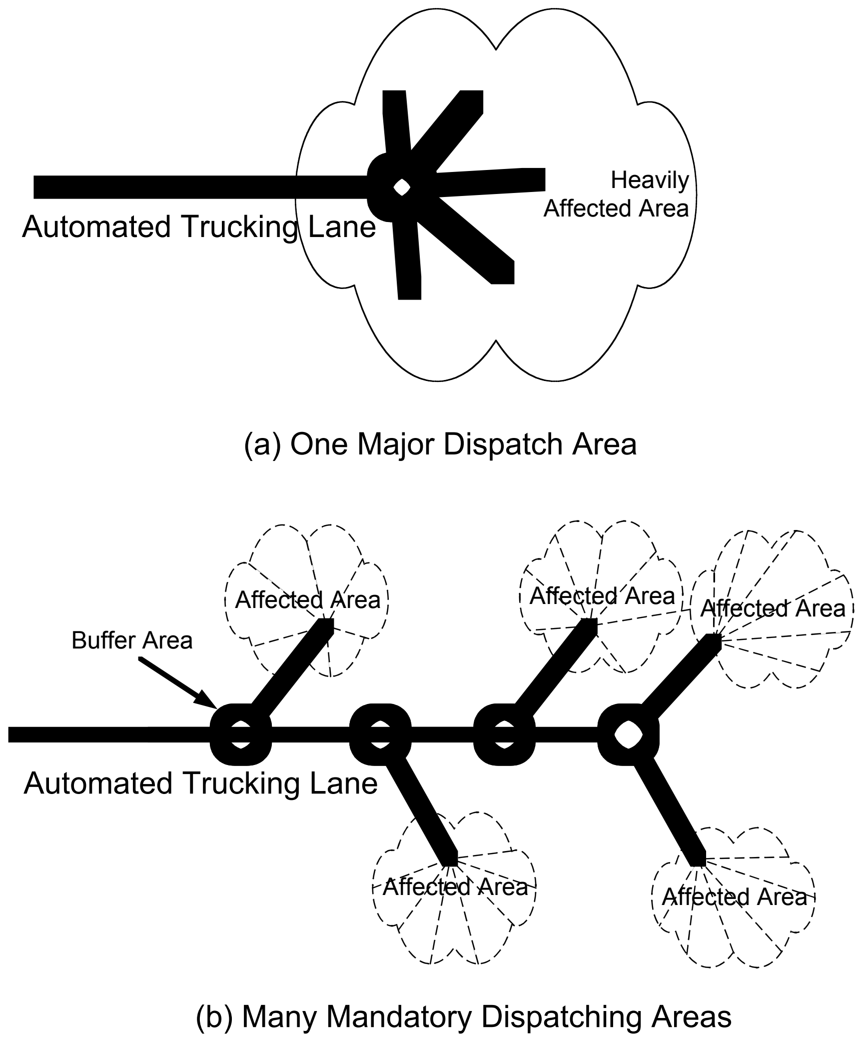

Figure 2.

Vance and Mills (1994) suggested three approaches to deploy APS, which may also apply to the deployment of other AFS. The first approach is "to build the most needed and financially viable segments in congested areas". Vance and Mills pointed out that its disadvantage is the requirement of standardization after some segments have already been built and in operation. However, the standardization process exists in every other technology deployment and can be accomplished in a step-by-step manner. Yet many technologies have failed due to incompatibilities. AFS embraces innovations in both infrastructure and vehicle technologies, in both hardware and software (control and operation strategies). The standard for each of these aspects cannot be set up overnight. Fortunately, unlike other surface transport systems, the compatibility issue accompanied with the standard revision can be mitigated by the flexible multi-modal terminal technology.

The second approach is like the development of the U.S. interstate highway system, in which a national plan establishes standards in advance. It can be expected that the enactment process faces indifference from the legislature. The freight transport system draws less public attention. The need for a renovated or additional freight system may not be seen as important as safety-related issues. The time to pass the related act may be long.

In facing these difficulties, a third approach assumes that APS would only provide niche services. This type of deployment will "allow totally private planning with limited enabling legislation and, perhaps, access to federal right-of-way." (Vance and Mills 1994) This is an approach with minimal steps and reduces the danger of delaying the problem to the future. The niche-scale deployment does not necessarily lead to public recognition. It is an approach to support the innovation when technologies are immature. Successful technologies in niche markets may then be extended, as happened with railroads in the 1830s.

For a location with a high probability of deploying AFS, there is still an issue of choosing among the AFS concepts. This choice-making process will be as complex as problems we mentioned before, because of the conflict among interest groups with different opinions.

Environmentalists will likely object to ATS, which they view as like highway expansion. APS could be their favorite. Besides the merits we discussed so far, as the innovation of the conventional pipeline system, APS can learn from the experience of conventional systems. Furthermore, it will benefit from the old system in the implementation because the new system can either take advantage of the old rights-of-way or even directly use a part of the old infrastructure. These advantages are less significant when the pipeline is deployed in an urban area to meet the high traffic demand, because the old system usually runs across rural areas and goes directly to suburban destinations. Though we will not go deeply into the technical issues, it should be noted that the propulsion mode would strongly affect the performance of the tube system. The energy efficiency, operating cost, maintenance cost, environmental impacts and system reliability of the system will largely depend on the propulsion technique used.

There is also a drawback for the APS and ARS: the size of vehicles is physically limited. As noted, some goods that fit conventional containers will face problems. The market share of the new system will be affected. For example, if the pipe is 1.83m in diameter, some packages that currently fit the size of standard container will be screened out of the APS shipment list.

Conclusions

Increasing traffic congestion argues for innovations that either enhance the capacity of current infrastructure or divert traffic to newly constructed infrastructure. The concern of the public in environmental conservation, community integrity and

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sustainable development makes the simple expansion of conventional highways more difficult than ever. The innovations in automated freight systems provide opportunities to mitigate congestion, enhance transport productivity, and reduce vehicle pollution without a large amount of land consumption. The number of alternatives for the technology of AFS is large and each results in different scenarios for their deployment and financing.

Financing strategies for the three concepts of AFS discussed in this chapter possess different characteristics in terms of monetary resources, private participation, cost sharing and management. Specific financing schemes should be designed according to these factors.

Government subsidies in the form of loans, grants, or tax breaks may be vital during the early years of AFS to construct infrastructure. The reduced negative externalities of AFS make them good candidates for public investments. However, the instruments of the government subsidies vary according to the deployment scheme of AFS. A comprehensive AFS deployment strategy will prompt the market penetration process, but until a clearer picture of technology and financing emerges, the path of deployment remains murky.

The analysis we conducted before is mainly on a basis of the practice in developed counties. Developing countries, in which the government has relatively concentrated but limited economic power, may also have the ardor for deploying advanced transport systems, though most of them are still struggling for financing resourced for general transport systems. For instance, the world's longest MAGLEV may be built in China between two of its biggest cities in the near future. It is common

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that the constrained financing resources from either public or private sectors in these countries will limit the demand for advanced transport systems and the capability to build them. The financing issue then becomes less important than the decision-making procedures, which may depend arbitrarily on non-market factors.

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