Evolution of Light-Rail Transit

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Social, economic, and governmental needs frequently dictate changes in the use of urban transport technology. It is the evolution of public belief and policy that most influences the development of any technology. Overdependence on petroleum fuels for transport and industrial growth has cast doubt on long-term options for continued urban life-styles and mobility. There is a need now for planning and deployment of new light-rail transit (LRT) systems. LRT, like all forms of transport, must be judged on its benefits and social costs to both users and nonusers. A look at Ghent, Hannover, Mannheim, Zurich, and Utrecht can show the transit planner how five cities have developed and used their LRT services in a manner that provides greater accessibility for all citizens as well as less direct pollution and easier adaptability to the existing urban setting. The technology of LRT is simple when innovative planning and engineering are used.

The evolution of a technology is too often erroneously viewed as the change in the equipment and the size of the machinery used. Frequently the observer does not comprehend important underlying conceptual and organizational aspects.

For the first time in three decades numerous questions are being raised, in both Canada and the United States, about the continued development of all sectors of our economy. Urban passenger transport activities and the reasonableness of uninhibited private mobility are subjects of great concern. Since April 1977, strong interest has been shown in the general area of transport and energy. On April 18, President Carter stated, "The energy crisis has not yet overwhelmed us, but it will if we do not act quickly.... [The United States] is the most wasteful nation on earth.... With about the same standard of living, we use twice as much energy per person as do other countries like Germany, Japan, and Sweden." On April 20 he said further, "Transportation consumes 26 percent of all our energy—and as much as half of that is wasted.... I will propose a variety of measures to make our transportation systems more efficient." On April 22 he stated, "I think there will be a substantial shift toward increasing use of the public transport systems."

In the National Energy Plan, released on April 29, Carter wrote, "In the long run, mass transit by bus and rail must play a significant role in reducing energy consumption in the transportation sector. Reliable, inexpensive mass transit is needed to serve existing, spread-out metropolitan areas. New development patterns based on public transportation can bring homes and offices, churches and schools, shops, and other community buildings together and, at the same time, conserve energy."

Like many evolutionary events, these particular comments by President Carter were not underscored and projected by the media into the public forum because other portions of his speeches and plans had more momentary interest.

How does a society improve the quality of its well-being while nurturing the conservation of its environment and globally limited resources? What can be done with transport, a major factor in our life-style? Actually, in light of the critical warnings concerning our dwindling resources, transport must be reevaluated in two ways. First, it must be able to adequately meet society's needs and, second, it must make the most efficient use of the energy required in its performance. This is where light-rail transit (LRT) offers its most effective appeal.

Looking back over the last five centuries, rather than the last five decades, we find that conurbanation developed for a variety of reasons. Worldwide, a primary reason was to facilitate communication and interrelationships among people. When this urban concentration occurred, there was a noticeable reduction in the need for time-consuming and costly transport. During the last five decades, as it became easier for urban citizens to use private conveyances, the need for efficient movement seemed to languish. This phenomenon of private mobility looked good at the time, particularly within those short spans that planners and officials must often deal with.

The potential for redirecting transportation during the decline of energy sources is being realized. The U.S. Department of Transportation recently indicated that the total transportation activities of this nation accounted for 19.5 EJ (18.5 quadrillion Btu) of energy, or 53.4 percent of all the petroleum and liquid petroleum gas energy produced domestically or imported during 1972. Of this monstrous amount, the portion required for passenger transport was 12.5 EJ (11.8 quadrillion Btu) or 64 percent of the total. It was estimated that private automobiles used solely for urban trips consumed 36 percent of petroleum fuels. In other words, more than 1 out of every 3 L of gasoline was consumed for trips originating and terminating solely within an urban area; by comparison, only 7.2 percent was used for military purposes and 5.7 percent for all domestic commercial aviation. Statistics from 243 major cities confirm that much of this 36 percent of petroleum energy is expended along major corridors in which millions of private vehicles operate only in peak hours at suboptimal speeds with less than 25 percent occupancy. It should be evident that, within this vast flow of transportation, there are numerous corridors within our cities that would handle more than 4000 person trips/h in a peak period in one direction and 500 trips/h during the base period. Such patterns suggest a major market for the use of LRT systems.

Unfortunately, during the past 3 years the enlightened talk on future petroleum availability has argued about whether depletion will occur by 1985 or 2020. Such talk is a bit unsettling. Debaters seem to argue over the termination year rather than providing insight on the economy's options. This sounds like a cavalier economic attitude—that we need not worry about the disaster until it has befallen us. As prudent planners and citizens, we should examine and implement alternatives before events overtake us. Given the new limits of resource availabilities and the current rate of urban expansion, the need for development and deployment of new and more effective urban transport is upon us now. Every community and planning agency should give consideration to LRT now.

Since October 1973, the relevant factors in the management of urban development and regional transport have undergone a major metamorphosis. The criteria for project feasibility have changed. They are different because we can no longer depend on permanent, unrestricted, low-cost use of petroleum and the continued dispersion of urbanized development. Transport problems reflect but one aspect of this change. We have sewer moratoriums, water rationing, zoning restrictions, and citizen opposition to expanding development. We must reassess how urban areas will operate in the coming decades.

LRT AROUND THE WORLD

Nearly 26 months have passed since the first TRB conference on LRT. During that time, more than 300 cities around the world have successfully continued to operate and expand their LRT and tramway systems. These cities prove that LRT systems are a strong option for moving people and that they are acceptable to the community. There have been 2800 new light-rail vehicles (LRVs) put into service. A totally new LRT system is being constructed in Edmonton. Edmonton is the first North American city to actively embrace the development of LRT in an area that has no vestige of streetcar operation. Buffalo and Calgary are in the final stages of design and engineering for new LRT installations. An increasing number of cities has shown interest in the use of LRT systems, including Denver, Dayton, Detroit, San Diego, Cincinnati, Vancouver, and Portland, Oregon. The United States and Canada are not alone among nations that are reevaluating LRT technology. Designs for new LRT systems have been developed in Mexico, the Netherlands, France, Belgium, Colombia, and Brazil.

We do hear from many people about battery-operated automobiles, steam propulsion, and many other technologies that have been conceptualized but not very successfully tested in the recent past. The pragmatist must look at the options currently available to find the ones that will meet the traffic demands, budget constraints, and social objectives, while providing reliable service but minimal maintenance and operating costs.

Unlike some of the proposed alternatives offered by new and unproven technologies, the ability of the LRT system to perform successfully, efficiently, and economically is supported by nine decades of evolutionary development. Statistics abound—in West Germany during the last 2 years, the 35 cities that have LRT have handled more than 3.3 billion passenger trips over 503 million vehicle km (314 million vehicle miles).

This kind of performance shows why many urban transport specialists believe LRT technology is proven and reliable. It may be true, in some instances, that various models of new equipment may demonstrate some shortcomings in their performance. This does not detract from the overall merit of the technology. Although LRT technology is not a proprietary concept of one company or one government, it is not immune from the problems found within all other types of urban transport technology. All transport systems are sensitive to misguided overdesign and the constraints of funding requirements. Within LRT technology, one aspect of overdesign is the extensive use of tunneling. From the standpoint of operation and capacities, LRT can operate without long underground sections.

Opponents of LRT cite the fact that generating electricity incurs a sizable loss of energy in the combustion process. But, since this is true of all energy-generating technologies, the source of the energy needed to maintain the major flows of urban passengers should be evaluated along with other criteria. LRT systems can provide needed urban transport without total reliance on petroleum. Sixty-eight percent of centralized electrical generation uses coal, hydroelectric power, or fission. Whatever pollution is caused by this process is concentrated in one area, and the vehicles propelled by this electrical energy do not carry pollutants into the central business district (CBD) or the residential neighborhoods.

Advocates of LRT should not be downplaying the capital and operating costs of the mode. The merit of LRT is found in cost comparisons based on the projected traffic demand and needed capacity. While the operator's financial costs for a system are important, they are no longer the sole criterion for determining the financial, economic, and social benefits to society for the development of such systems.

In alternatives analysis it is necessary to be sure that comparable costs and service standards are used. The best comparison of costs is that between busways and LRT. LRT, like the busway, possesses the proven ability to branch into major transport corridors. However, LRT provides better access to activity centers and stronger civic commitment to service. The investment differences between LRT and other types of transit equipment have remained similar through our inflationary years, but LRT equipment offers longer service life, larger carrying capacity, and stronger productivity. During subway construction in Amsterdam, a city with soil conditions similar to those in New Orleans, it was found that the cost of 1 km (0.6 mile) of subway was the same as that of 3 km (1.8 miles) of aerial structure or 30 km (18 miles) of LRT installation. In costing, the planner should not be timid. Right-of-way investments escalate in relation to width and, on this basis, LRT can be very economic.

The attractiveness of this concept and technology lies particularly in the word light. It does not mean shoddy. It does not mean second class. It means creative design and engineering that require the economist, engineer, planner, and operator to use their training to develop the best system for the least cost. As the railway engineer Wellington indicated some 80 years ago, any fool can solve his problem given enough money (1). Today we must get the greatest amount of urban transport capacity into location and operation with the amounts of investment money available, since the treasuries at all government levels are not limitless in their bountiful giving to urban transport projects. We must continually monitor the worldwide development and use of LRT. Only through better understanding of the great flexibility of LRT can we best utilize its benefits.

The impact of any urban transport technology on the society within which it is used must be carefully evaluated for its merits and its liabilities. The private automobile, as used within the urban area, has not been immune from such review. In all forms of transport and urban activity, there continually arise questions about the equitable sharing of benefits and social costs between users and nonusers. This is true of airplanes, automobiles, buses, and LRVs. Questions of this type are not related solely to transport; they have been raised throughout the centuries of urbanization. Sixteenth century Parisian neighborhoods bristle when new types of buildings and developments, like the Pompidou Center, are forced on them. However, these neighborhoods and the citizens thereof forget that the accepted landmarks of today (such as the Eiffel Tower) were the objects of strong criticism during their construction. Further social and political conflict arises when the negative aspects of modern life-styles degrade the urban setting, as is the case with increasing levels of air pollution. Although the life-styles within the city may differ throughout the world, the impact of all types of development must be weighed. The effect of change and development on residents must be compared with the needs and desires of the whole community and its interests; this is how LRT technology and operation should be judged.

GHENT

The city of Ghent, Belgium, provides an example of the relative impact that various forms of urban transport infrastructure have. Ghent has retained its LRT and

tramway systems at a time when major national highway construction was going on within the city. Today, some LRT lines still run within residential streets that have low traffic volumes. However, during the last decade, the city has upgraded many of the lines to reserved lanes. This has been done not simply to improve the physical separation of vehicles and services but also to improve the urban landscape through the placement of trees, shrubs, and small parks.

In the late 1960s, a major European expressway (E-3) was constructed through the southwest portion of Ghent. While the city did not argue about the national need for the highway, there was some dispute about the selection of its right-of-way. The compromise reached might not be the same if the issue were raised today, but this major highway was constructed on a huge elevated structure through the southwest neighborhoods of the city. Part of the compromise was that, to the southern side of the expressway, a grade-level LRT line was to be built. Within the community and neighborhoods, the six-lane expressway provides no capacity for local movement. However, the LRT services are currently scheduled to provide 200 seats/h in each direction during the off peak and to carry 1200 passengers/h during the peak hour. New community service buildings have been located near the LRT line. Overall, the cost of this 1-km (0.6-mile) extension of double-track route was less than $300 000. The city had ordered new LRVs for the entire network, so that the added cost of this line was not specifically considered.

Along the other four LRT routes operated by the city, there has been a noticeable attempt to combine the provision of fixed-guideway public transportation with an attractively landscaped setting. Through the use of modest investment (and at low annual operating and maintenance costs), a program of traffic engineering and landscaping has been undertaken in the last 6 years to beautify the streets and neighborhoods and to encourage use of a quiet, pollution-free system of urban transit—LRT.

HANNOVER

In West Germany, the city of Hannover has retained and improved its network of LRT and tram operations. One benefit of this policy has been that the community's activities are concentrated in specific areas that promote resource efficiency within the urban economy. The use of this transit mode has permitted the redesign of the inner city and its activities and the retention of LRT services to give direct access to the attraction centers. Private automobiles and buses have been channeled out of the major activity areas and commercial streets of the city.

By using an innovative program of right-of-way development, the public transit authority has handled 83 million passenger trips/year without total reliance on exclusive rights-of-way. In the portions of the city where existing and projected traffic capacity permits, LRT mixes freely with other vehicles. In the intermediate areas, street lanes that have LRT guideways are sometimes emphasized by the use of rougher textured pavements designed to encourage a semiexclusive operation by the high-capacity transit vehicles. The city has begun the actual conversion of some mixed-use streets to reserved LRT routes. Within residential neighborhoods, these changes are increasing the capacity of passenger transport while reducing the throughput capacity for private vehicles. Such measures have reduced the noise level in the neighborhoods and improved the community's appearance.

The LRT lines operate easily through the median of tree-lined streets and traverse major public parks without causing disruption of the public's use of such areas or causing harm to the vegetation of the parkland. At intersections and other important street locations, LRT services have priority. This is handled through the use of overhead contactors that preempt traffic signals and initiate electric commands that permit greater reliability and performance for public transit vehicles.

The LRT system does not require expensive and complex station locations. It functions easily with low-cost passenger loading sites for both the CBD and the periphery. LRT is flexible in the route pathways it can use in residential areas. This mode permits the closer spacing of stops than does rapid transit or subway. The compromises that are possible between speed and flexibility of location cannot be obtained with other forms of fixed guideways. There is strong backing within the community based on the fact that the greater use of LRT on private rights-of-way provides a transit infrastructure that will not promote a greater use of private vehicles; it provides greater capacity for mobility of the population without encouraging the use of private vehicles.

At interchange points where feeder bus services terminate, off-street transfers are made. Passengers find these services attractive because of their strictly timed meets and short cross-platform boarding distances between vehicles. The new communities that are developing as satellites to Hannover are being connected to the center city by LRT services. To avoid conflicts at certain locations, LRT is routed into short tunnels and exclusive alignments to link the center of the satellite areas to the center of the city.

In 1976 two LRT lines to the CBD were relocated underground. The subway portions of this alignment are at shallow depths directly under the roadway and do not require complex and costly mezzanines and escalator installations. The transition from underground to the surface is made effectively and simply. In the southern portion of the CBD, this transition from underground to surface operation takes place just south of the university campus. Since, even underground, overhead electric wires are used, the operation can safely ascend within a built-up residential community.

This results in very direct routing of LRT services and permits it to enter any area where users want to go. The LRVs in use can operate over routes that have a mixture of design standards and still provide increased carrying capacity. The vehicles daily operate safely through areas that have high levels of pedestrian activity, and they operate easily in mix with other vehicles, including automobiles, through many of the city streets. These LRT vehicles provide ample seating for off-peak services and plenty of standing space for peak-hour loadings. On some lines there is a mixture of high-step and low-step operation to facilitate the entry of patrons of all ages.

MANNHEIM

Mannheim in West Germany provides an outstanding example of low-investment LRT development. This city of 400 000 people has shown no desire by passengers, merchants, officials, or the operator to convert major portions of any of the 18 LRT lines to underground operation. In 1973 the city closed two principal commercial streets to vehicular traffic and upgraded their use to an exclusive pedestrian mall and LRT corridor. This project has been very successful, and the business community has experienced continued expansion and increased sales. The main corridors of the LRT lines in and around the center of the city handle more than 9000 patrons in peak hours. Although there is one automobile

for every three inhabitants, the people use LRT services for 40 percent of their local trips; this amounts to 48 million trips/year.

Rather than relying on aerial structures or subterranean levels, the LRT lines use a variety of surface locations to achieve their functional operation. LRT is found in reserved medians of several of the principal streets. It operates in exclusive and mixed configurations on conventional streets. At points of moderate congestion, track structure has textured pavement that permits automobiles and trucks to use the linear path but discourages them from extended operation over such pavements. The conflict with cross traffic is minimized through proper traffic engineering measures.

The impact of the LRT system on the city's activities and land use are minimized because of the strong comprehensive planning discipline of the city. In this city and other German cities, it has been found that the new large-capacity LRVs have attracted better patronage during weekdays. On some lines patronage is up 25 percent, while off-peak use has risen by more than 30 percent. These increases in patronage have occurred without official use of legal restraints on the use of automobiles.

The center of Mannheim is something like a new town because it was totally planned in the late seventeenth century. This total approach to comprehensive urban planning has continued even through the late 1960s when outlying satellite communities were developed. The satellite of Vogelstang is connected to the center of Mannheim by a new LRT line. Since the LRT uses its own right-of-way, the line has been able to penetrate to the very center of the new community without having the impact that would normally be made by a major highway. The major loading points on this line are in the lower level of a shopping center. The activity and design layouts would be similar to those of portions of LRT lines in Cleveland's Shaker Heights or Philadelphia's Media and Sharon Hill operations.

Of outstanding interest is the pedestrian and transit mall of the center city of Mannheim. In 1973, with a budget of about $2.3 million, the city and transit authority successfully converted more than 15 blocks to this new format. The result is that real estate prices within the center city are stable and the cost of public utilities (water, gas, and electricity) and telephone services have remained lower because of the greater concentration of activities. Several sidewalk cafes have been developed in the area and the LRT system passes within a few meters of social gatherings at such cafes. This shows that the necessary public movement of thousands of people through the central core of a city does not have to be disruptive to the life experience of the residents and workers of the center city.

ZURICH

In Switzerland, the voters in Zurich 5 years ago rejected a bond issue for construction of a heavy-rail transit system as the solution to their urban transport deficiencies. Since that time improvements have been made through various modest investment measures to strengthen the LRT lines and provide new LRVs. In Zurich, public transport handles the bulk of weekday trips, and the LRT lines accounted for 140 million annual trips (68 percent of the total). The city government has realized that the option of increasing automobile capacity throughout the street network would never solve the problem of mobility of people within the city. As a result, the city invested in public transport for peak-hour capacity requirements. LRT has given the city the ability to provide peak-hour capacity for 65 000 people without major negative impact on the city's beauty. On service lines 2 and 4, direct connection to a suburban railway is achieved at grade level. With cross-platform boarding, very modest investment is necessary for the linkage of these two service modes.

To the southeast of Zurich, an LRT line is provided to some medium- and high-income communities. The Forchbahn Railway shares trackage with the city system but then has its own separate right-of-way outside the city limits. New, attractive vehicles with seating for 86 patrons have been placed in service. The line provides a peak-hour capacity of 3000 spaces. This LRT service terminates in a very modest center-city area with a loop track arrangement around the perimeter of a scenic central park. The park's primary objective of enhancing the visual and physical ambience of the historic portions of the city has not been degraded by the LRT operation. This shows that city parks and public transport may not require separate locations.

In the western portion of the primary commercial street of Zurich, the Paradeplatz is being upgraded to an area reserved exclusively for pedestrians and LRT service. Seven LRT lines will converge at this intersection. The area is currently being reconstructed to exclude private vehicles after 3 years of experimental closure.

With such a variety of proven measures and designs, the LRT system has been able to provide both high capacity and reliable service while retaining its surface location within the heart of the city. The pedestrian and transitway development along Bahnhof Street in the center of Zurich is strongly supported by the business community, partly because of its wide acceptance by pedestrians. LRT brings thousands of people into a historic area of the city in a way that no other existing technology can. The pedestrian and LRT zone has been in use since 1972. During this time there have been no major accidents related to conflicts between the LRVs and pedestrians. As a result, thousands of commuters are transported through the center city daily in a manner that enables the city to retain the social amenities that encourage a pleasant urban life-style.

UTRECHT

Opponents of LRT technology frequently concede that such a system is fine but only works in cities that currently have some degree of conventional street railway operations. They indicate that the investment now required for the establishment of a totally new system makes it impossible to undertake. The best refutation is found in places like Utrecht in the Netherlands, which terminated all tramway services in 1938. Currently the metropolitan region around Utrecht is experiencing major suburbanized growth. It is now necessary to connect two satellite communities to the CBD and the railway station of the historic city. The authorities have therefore approved the construction of 11 km (7 miles) of totally new LRT line.

This project will create an LRT line that is not placed in an existing, abandoned railroad right-of-way. It will be placed in highway medians and along arterial roadways in a manner designed to minimize conflict and promote movement by this mode. It will connect the satellite communities with commercial and employment centers and with intermediate neighborhoods. In April 1977, construction of the maintenance base and administrative offices for this LRT system were begun. The line is being established as part of a comprehensive urban development in which the community provides new housing of mixed densities so that families and senior citizens can share more open surroundings. Alternatives analysis

was undertaken to compare the costs and benefits of conventional railroads, busways, paratransit, and LRT. The technology that best satisfied the policies and goals of the region was a modern LRT system that promoted the development of houses and apartments in a manner that provided balance between green space and urbanization, while linking these new communities with the older city.

SUMMARY

The five cities reviewed here are by no means unique in their use of LRT technology. Unlike new systems, such as monorails or people movers, the operation and technical successes of LRT are not restricted to a few sites. In more than 300 cities in about 30 nations, the significance of LRT is shown daily. There are different options and objectives for the world's various societies, but there is a question as to whether we can continue to rely so much on the automobile. We need a combination of urban transport technologies in which each contributes positively. When we consider costs, accessibility, pollution, and adaptability to setting, there are many strong arguments for the use of LRT technology. LRT services can be combined with the use of private vehicles through peripheral parking lots.

However, it must be remembered that the choices available to urban planners and officials must be based on what the community and nation will permit the technology to do. One clear example of this relates to the amount of peak-hour capacity that is desired. If the transport capacity is to be provided by elevated expressway, the amount of land required and the impact of the structure will be several times greater than those for an LRT structure. In Cologne and Rotterdam, LRT installations exist and provide high-capacity transport with minimal impact on the residential and historic areas of the cities.

The materials, equipment and vehicles required for LRT use are available worldwide. New rolling stock is being supplied for Helsinki and for LRT operations in Fort Worth. The Boeing Vertol LRV is being built in Philadelphia for revenue service in Boston. This vehicle has been in revenue service since December 1976. The Pullman-Standard Car Manufacturing Company of Chicago has designed a new four-axle vehicle. In Ontario, there are in production both four-axle and six-axle vehicles currently slated for use in Toronto. An indication of the versatility of LRT technology for adapting to new social objectives is seen in Boeing Vertol's proposal for handling wheelchair patrons by providing a hydraulic lift within the vehicle.

When innovative planning in urban transport is encouraged, the difference between the design and cost of LRT equipment and those of heavy-rail equipment becomes very apparent. LRT technology combines design and equipment that adjust easily within the existing urban fabric and operate through the historic, recreational, residential, governmental, and business communities with ease. The idea that a railbound vehicle, operating in its own reserved or private right-of-way, must be expensive and overbearing on its surroundings is found not to be true in light of existing applications.

The planners and engineers interested in the use of this technology should review the methods used in other nations. However, such interest should not envision total and strict importation of another city's operation but rather should examine innovation in the urban transport planning process. In this manner, LRT will be feasible for expanded installation within many cities of North America.

REFERENCE

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Current Trends: Problems and Prospects of Light-Rail Transit

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The difficult task of rescuing our urban transit systems from several decades of neglect has only started. Among the obstacles to transit improvements is our deeply rooted double standard for different types of expenditures: Purchase of wasteful items by consumers is considered to move the economy but the use of public funds, even for the construction of very useful projects, is often criticized as wasteful. Another serious obstacle to the development of rail transit in our country has been a lack of expertise in the planning, technology, and operation of these modes. We have virtually invented a new mode: unreliable rail transit. A concerted effort must be made to apply the technical skills that this technology requires to fully realize its great potential. A major step toward that goal would be made if the Urban Mass Transportation Administration would redirect some of its efforts from the development of exotic modes (some of which have little potential) toward the modernization of standard rail and bus technologies. In spite of these obstacles, light-rail transit (LRT) has recorded significant advances. It is now broadly recognized as a serious contender for major transit improvements in many medium-sized and large cities. Its modernization in Europe is continuing, new LRT systems are under construction in Canada, and several U.S. cities are actively planning or designing new LRT systems. There is also a major potential for extensive deployment of LRT in the large cities of developing countries that has not been fully recognized yet. President Carter has promised to pursue three important goals: to revitalize cities, to decrease unemployment, and to increase energy efficiency; if he takes a correct path toward these goals, we should see construction of LRT in a number of our cities in the near future.

Few areas incorporate and symbolize as many of the problems, conflicts, and challenges of modern society as urban transportation does. Among the most complex problems of our society is finding the right balance between the interests of individuals and society—the dilemma of where, how much, and in what manner to introduce public control over planning, development, and operation of systems that consist of private and public