

MAYBE WE CAN BUILD OUR WAY OUT: RETHINKING INFRASTRUCTURE SOLUTIONS TO ADDRESS CURRENT TRANSPORTATION PROBLEMS

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ABSTRACT

California, which has been growing faster than other U.S. states for decades, is experiencing the effects of overcrowding on urban and suburban highways. This situation has led to serious congestion, mobility, energy dependence, and air quality problems. These externalities of overcrowding, as well as the resulting inefficient use of land resulting from urban sprawl, create opportunity for social response. The regulatory pressure has been to clean up the air, while political pressure has been to reduce congestion. To address these pressures, economists and hard engineers alike have chanted their mantras supporting their unique solutions. Rarely do we see proposals composed of an array of ideas, with the intent to address simultaneously many of the current transportation problems. This paper first summarizes major transportation problems in the U.S. Then, the paper introduces an infrastructure development plan that incorporates pricing strategies, intelligent vehicle and highway systems (IVHS), and electric vehicle technologies. This plan, dubbed PIE (for pricing, IVHS, and electric vehicles), is just one way in which some of the many promising solutions can be combined to address current transportation dilemmas. It is shown why PIE could be more effective than stand-alone-solutions, and why multi-faceted solutions like PIE should be further analyzed.

INTRODUCTION

California, one of the fastest growing states in the U.S. is now experiencing the effects of rapid growth. Municipalities throughout the state commonly identify lack of auto mobility and poor air quality as primary concerns of the region. This is not surprising, as the highways and arterials surrounding many urban and suburban centers in the state often operate at level of service "D" and often "E" and "F". Secondary impacts of congestion, including degraded air quality and safety impacts, result in billions of dollars per year in health care, loss of productivity,

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crop damage, and accident costs. Moreover, heavy-duty trucks moving goods and providing services on our roadways are experiencing increasing costs performing their duties... these costs being passed to consumers. Americans are also becoming increasingly dependent on foreign oil, increasing petroleum product dependence (Sperling, 1990). Because all indicators suggest that these trends will continue into the future, transportation engineers and planners are left to deal with a very complex and continually worsening situation.

The current regulatory framework has posed additional difficulties for transportation planners. In effect, planners of regions in non-attainment with the ambient air quality standards of the Clean Air Act must provide evidence showing eventual attainment of the standards. This requirement means that planners must be very innovative when designing transportation infrastructure solutions. So, in addition to capacity (mobility) problems, planners are required to deal with air quality problems as well.

The historical approach (through 1970's) of dealing with transportation problems has been to 'build our way out' with additional lane-miles of freeway. This is now largely infeasible as costs of right-of-way acquisition, construction, and constructive use mitigation have become prohibitive. To make more efficient use of existing roadway capacity, strategies aimed at modifying driver behavior, such as flexible work hour programs (peak spreading), car pool and van pool programs, and telecommuting strategies, have been proposed and implemented. These so called 'transportation control measures' (TCMs) have seen varied amounts of success, and in themselves, have not been sufficient to keep up with growing transportation problems. We are now seeing proposals for market driven solutions such as toll roads, gasoline taxes, parking fees, pay at the pump insurance, and registration fees based on VMT and vehicle emission rates. Many economists believe these market approaches have the most potential of any of the available alternatives (in keeping with the opposition to capacity expansion) and that transportation planners should "get the prices right".

It has been argued that increasing system efficiency is necessary because we can no longer 'build our way' out, as we have already experienced. Also, increasing capacity may induce demand for additional travel (latent demand), which in turn may worsen an already bad situation. Clearly, under present constraints, there is a narrow acceptable range of system congestion: we want sufficient congestion to discourage latent demand, but we do not want too much congestion as to stifle economic productivity, degrade personal mobility, and exacerbate poor air quality.

On the forefront of engineering solutions are technologies called Intelligent Vehicle and Highway Systems (IVHS). These technologies aim to increase the capacity and efficiency of existing transportation facilities by utilizing present computing and communications technologies. Examples of these technologies include variable message signs, in vehicle electronic maps, automobile automation, and real-time signal timing and optimization. IVHS solutions however, while still in their infancy, will not necessarily lead to improvements in air quality (Washington, Guensler, Sperling, 1993)

Armed with many proposed solutions to combat growing transportation problems, transportation engineers need a plan that effectively mitigates the many problems while still being implementable,

feasible, and politically acceptable. This paper introduces a conceptual transportation plan that utilizes pricing strategies, IVHS, and electric vehicle technologies (dubbed PIE) into a synergistic infrastructure design. Based upon preliminary examination of the conceptual approach, we do not believe that we should automatically preclude the option of building our way out of the current transportation problems!

We suggest that improved air quality, increased mobility, and economic growth can be provided without exacerbating air quality and energy dependence problems. Moreover, PIE aims to effectively reduce mobility and congestion problems in dense urban areas.

This paper first provides a brief background on current transportation problems and trends in most major U.S. cities. The proposed infrastructure development plan (PIE) is described, followed by a discussion of potential strengths and limitations.

CURRENT TRANSPORTATION PROBLEMS AND TRENDS

Before transportation planners can look at proposed solutions to transportation problems, they must first understand the cause-effect relationships. In some cases problems are interconnected (i.e. congestion and mobility), while others are unrelated. It is critical to understand the relationships, because the solution to one problem often creates another problem. This section of the paper discusses today's pressing transportation problems, including some of those that are not immediately obvious.

Congestion and Mobility

One of the most recognized and apparent transportation problems today is congestion (or lack of mobility) in major urban areas. Congestion is arguably one of the most significant factors 'pushing' the need for change in our cities. Congestion increases air pollution, accident occurrence, and fuel consumption, and decreases economic productivity and quality of life.

In 1987, nearly two-thirds of all interstate urban roads were congested during peak periods (Gordon, 1991). The FHWA estimates that 1.4 billion gallons of fuel are wasted annually due to congestion and is expected to rise to 7.3 billion gallons by 2005 (Gordon, 1991). Also, according to some, the loss of productivity due to time lost in travel is estimated to be \$34 billion in the U.S. According to the California Air Resources Board (1989), the population in California is increasing at 2% per year and the number of vehicle miles driven is increasing by 4-5% per year. These two factors combined result in an estimated 15% increase in congestion per year (assuming zero growth in system capacity).

Even though congestion is pushing the need for change, it can be argued that congestion is beneficial. It is self-limiting, that is, people will limit their trip making according to their individual valuation of time. In this way, people forego trips when their cost of time spent in congestion is too great.

Air Quality

Air quality problems, caused partly by congestion, are receiving increased attention. Although transportation is not entirely responsible for the serious degradation of air quality, it is a major contributor. Similar to congestion, there are many negative impacts or costs of air pollution including negative health effects, crop damage, materials damage, aesthetic impacts, and significant greenhouse gas contributions. According to the California Air Resources Board (1991), "California's air quality problems outrank those from all the remaining 49 states combined". The CARB continues to report that in 1987, personal cars and light-duty trucks accounted for 56% of nitrogen oxide, 43% of hydrocarbon, and 82% of carbon monoxide emissions. Some claim that health care costs are approaching \$100 billion per year nationwide due to the negative effects of air pollution (Gordon, 1991). There is an estimated \$1 billion loss per year due to crop damage caused by air pollution (CARB 1989).

The seriousness of the air quality problem can be seen in the California Clean Air Act enacted in 1988. Recognizing the strong link between transportation and air quality, the Clean Air Act states that "air pollution control districts are required to adopt and enforce reasonably available transportation control measures. The Act also calls for no net increase in vehicle emissions after 1997" (CARB, 1989). California's low emission vehicle and clean fuel program further specifies that vehicle manufacturers offer 2% of their vehicle fleets as zero emissions vehicles by 1998, and 10% by 2003. These stringent requirements set by the State of California are one manifestation of the rising concern over transportation induced air quality problems.

It is also fairly well agreed that the transportation sector is a large contributor to global greenhouse gas 'warming potential'. It is believed that about 49% of manmade greenhouse gas emissions are from carbon dioxide, 18% from methane, 14% from chlorofluorocarbons, 13% from ozone and water vapor, and 6% from nitrous oxide (Gordon, 1991). The relative contribution from transportation to greenhouse gases are significant, 35% for CO₂ and 41% for NO_x. Other emissions from vehicles, although not principal greenhouse gases, contribute to the formation of many of them. Even if the probability of global warming is low, the consequences of being wrong are extreme. According to Sperling (1991) "...it is utter foolishness to proceed as if climate change is not a problem. We are being grossly irresponsible and disrespectful of future generations if we do not at least create the conditions that would allow us to move quickly on to a lower emitting path."

Energy Dependence

The United States presently uses more oil than it drills from domestic supplies. The disparity between domestic oil supplies and oil usage is expected to increase in the years to come. The problem associated with depending on foreign oil is not that foreign oil is scarce, but that the dependence of the U.S. on that foreign oil is increasing (Sperling, 1991). This increasing dependence has political and economic implications for the U.S. (and European Countries). According to Gordon (1991), the American transportation sector consumes about 75% of its petroleum. Furthermore, in 1989, the U.S. transportation sector used 27% more oil than it produced. Considering the projected increases in population growth and vehicle miles of travel, and the lack of alternative fuels, the current trends will likely lead to a crisis. According to the

ancient Chinese Proverb, 'If we do not change the current path we will end up where we are headed'.

Urban Sprawl

The consumption of land in the U.S. has been encouraged by past decades of urban and rural freeway construction. Since the first Federal Highway Act and its subsequent revisions, the proliferation of urban and rural highways from the 1940's to the 1970's has resulted in 165 million cars on U.S. roads in 1987 (Gordon, 1991). Also, in urban areas, about a third of the land is devoted to the automobile or its use. The automobile has become so prevalent in the U.S. that mass transit is experiencing an increasingly smaller share of ridership. According to Gordon (1991), the automobile (and light truck), mass transit, and rail account for 97%, 1%, and 1% of the vehicles miles of travel in the U.S. in 1987 respectively.

Land development in the U.S. can be largely described as 'urban sprawl'. The population densities associated with urban sprawl lend themselves well to the automobile, which makes perfect sense, being that the automobile and highway system has driven this type of development. Unfortunately, though, transit and to some extent rail do not lend themselves well to 'urban' densities, again, explaining the decline of these two modes. The question facing us today is: can we continue to grow and develop without promoting urban sprawl, and perhaps halt or reverse previous trends in the meantime? If we can accomplish this, then maybe we can begin to tackle air quality, energy dependence, and congestion problems. We must at the outset recognize that there is an inseparable link between current transportation problems and current land use patterns.

Other Issues

Congestion, air quality, energy dependence, and urban sprawl are all affected by the transportation system. The transportation system also has other influences. Economic productivity, travel safety, provision of jobs, and quality of life are a few. These are not discussed in great depth here, as it is our opinion that the latter issues are not the salient issues currently driving transportation policy change. Nevertheless, from a perspective of social efficiency, these problems are also critical and must be addressed in any proposed system solution.

A NEW INFRASTRUCTURE: INTRODUCING PIE

Congestion, poor air quality, energy dependence, and urban sprawl are all caused by users of the urban highway system. To address this multitude of problems, planners must devise innovative and flexible plans --- plans that incorporate a wide array of technologies and strategies. An implementation plan (PIE) has been conceptualized that incorporates pricing strategies, IVHS, and electric vehicle technology. PIE also embraces investment in new infrastructure to provide jobs and economic growth. It is believed that if PIE addresses many of the major transportation issues, and provides positive regional economic effects, then the concept will be publicly and politically palatable.

PIE - The Conceptualized Plan

The integral parts of PIE are not unique. The three major components of PIE include: 1) introduction of parking pricing and other market strategies, 2) development of half-width electric vehicles operating on a grade-separated infrastructure, and 3) automation of the electric vehicles. The integral parts of PIE are combined uniquely, and because of this, PIE may offer a unique array of benefits. A description of the infrastructure requirements for PIE is described below.

Parking Pricing

Because a new infrastructure is proposed, parking pricing would be implemented to offset potential latent demand effects. The strategy first ensures that travel on the conventional facilities is made more efficient. Parking pricing would be aimed particularly at large employer sites, but on downtown shopping and business as well. Parking pricing has been shown to be extremely successful in modifying driver behavior (Wachs, 1990). Case studies have shown that average vehicle occupancy rates have risen dramatically after implementation of parking pricing strategies. Other market-based strategies could be implemented concurrently, such as emission-registration fees or congestion pricing. If appropriately implemented, pricing strategies could provide revenues needed for the development and operation of the proposed infrastructure.

Grade Separated Half-Width Electric Vehicles

Half-width electric vehicles (EV's) are grade separated from the existing traffic stream. The light-weight half-width electric vehicles are separated from 'normal' traffic on all high-speed roadways. Garrison and Pritstick (1990) point out the many advantages of half-width vehicles, but also demonstrate their incompatibility with the existing transportation infrastructure. By providing light-weight pre-fabricated structures above existing freeways, these electric vehicles could travel at high speeds with vehicles of their own type. The benefits of exclusive vehicle facilities have been iterated by Janson and Rathi (1991). Access onto and off of these elevated structures could be provided at the midpoint of existing highway overpasses. The elevated infrastructure could consist of one half-width lane in each direction, being approximately 16 feet in width. Occasional turn-out extensions could provide breakdown and maintenance access. The primary purpose of this infrastructure is to accommodate peak period traffic flows.

The network of infrastructure is aimed at carrying commuter traffic from outlying urban and suburban areas into the central business districts. New routes are linked directly to large parking facilities centrally located in the downtown. These parking facilities would be designated as exclusive electric vehicle parking facilities, where electric battery recharge stations would be located. Existing parking facilities could accommodate as many as three times the number of half-width EV's as conventional vehicles. Transit stops and intra-city rail stations could be located near these EV parking structure locations.

EV routes would also connect with conventional roadways in the downtown, or central business districts. This would provide EV's access to conventional roadways.

Automation of Electric Vehicles

The infrastructure designed for half-width electric vehicles is ideally suited for automation. Because all vehicles are of similar size, weight, and operating characteristics, half width electric

vehicles are ideal candidates for automation. In addition, automated lanes would be completely separate from 'conventional' traffic lanes, so mixed mode problems would be avoided. Plus, the downsizing of the vehicle may help to mitigate costs associated with providing in-vehicle advanced technologies.

By reducing headways through automation, flows of up to 6000 vehicles per hour per lane can be accommodated (Johnston et. al., 1988). Since the infrastructure is designed to accommodate peak travel periods, the two elevated lanes could be configured to be uni-directional, as to provide the capacity of up to six conventional lanes of traffic. Two way traffic would be maintained on conventional roadways, and two-way traffic could be resumed on the elevated infrastructure during off-peak travel periods.

The remaining conventional roadway would experience reduced congestion levels due to the potentially doubled or tripled capacity (depending on configuration of the new infrastructure). Reduced congestion would mean higher travel speeds, smoother traffic flows, and reduced travel times on parallel routes. The conventional roadways, with many commuters removed, would consist primarily of non-commuters, heavy duty trucks, and mobile service providers.

POTENTIAL BENEFITS AND LIMITATIONS OF PIE

The following section discusses the expected benefits and limitations of PIE. The areas discussed are congestion and mobility, air quality, energy dependence, urban sprawl, and other problems.

Congestion and Mobility

By placing a significant portion of commuters during peak hours into half width EV's, high throughput could be achieved on elevated lanes while also providing congestion relief on parallel conventional roadways. This would result in smooth flow on automated segments, as well as significantly reduced or relieved congestion on parallel route freeways.

By discouraging 'latent demand' on the existing freeway through effective parking pricing policies in the CBD, new trips into the CBD would be discouraged, leaving the conventional highways un-congested for goods movement and mobile service providers. This would have beneficial regional economic impacts since goods and services could be provided more readily and at cheaper costs to consumers. Also, heavy duty truck traffic would experience cheaper freight hauling costs and increased delivery time flexibility.

When traveling to the CBD, the majority of EV's would drive directly into electric vehicle parking lots where recharge stations are provided. Conventional vehicles would benefit from decreased congestion in the CBD since EV drivers would be on separate roadways. Also, if incentives were given to large employers in the CBD to buy EV fleets, potential EV users could be targeted.

Air Quality

The air quality benefits of electric vehicles have been iterated by Mader (1991) and others. Air quality concerns would be directly addressed by PIE. Since many new vehicles being introduced onto the system would be electric, pollutant levels would be lessened. Fleet turnover of vehicles would occur, replacing high emitters from the fleet with electric vehicles. Granted, the use of EV's shifts the pollution to stationary sources, but it has been shown that there can be substantial air quality benefits, especially if stationary source polluters realize stricter standards. When EV's are powered by non-fossil fuel electric plants, natural gas plants, and current mix U.S. plants, greenhouse gases will be reduced 100%, 18%, and 1% respectively (Deluchi, Johnston, and Sperling, 1988).

By combining automation with electric vehicles, automation becomes an attractive and feasible alternative to improve air quality (Washington et al., 1993). The air quality benefits from reduced hard accelerations, idle, and enrichment events on conventional roadways could potentially result in significant emissions reductions. Also, increased average travel speeds on conventional roadways from below 15 mph to around 35 - 45 mph would also result in reduced emissions.

Energy Dependence

Energy dependence issues are also directly addressed by PIE. The equivalent of two to three lanes of non-automated gasoline powered vehicles could be replaced by one lane of automated EV's. And, if later demand is adequately curtailed, then petroleum use could be significantly reduced. Furthermore, if the conventional roadway could be used more efficiently by its users, i.e. higher average vehicle occupancy rates, then additional reductions in petroleum use could be realized.

Urban Sprawl

PIE does not presently incorporate provisions to directly address the urban sprawl issue. It should be noted however, that urban sprawl is a function of highway development and personal travel times. Recognizing this relationship, an attempt should be made to shape PIE to address urban sprawl. Perhaps a desirable goal would be to discourage additional travel through effective parking pricing and urban redevelopment. The infill would lead to higher population densities which are more compatible with transit and rail use.

Decisions regarding new infrastructure placement will potentially have a large effect on land uses and urban sprawl. Careful planning and placement of the infrastructure will facilitate the desired regional growth. For example, limiting the extent of the service corridor of PIE might discourage re-location of individuals beyond the service corridor, even though individual travel times might be reduced.

Other Issues

As mentioned earlier, there are many transportation issues other than the four mentioned above. Several of these are addressed by PIE and are worthy of discussion here.

General observations regarding the economic impact of PIE can be made. The new infrastructure required to support the half-width EV's would require large capital expenditures. These capital expenditures, however, are likely to be less expensive than conventional multi-level structures due to the light-weight characteristics and reduced size requirements. This is abundantly clear considering that PIE does not require acquisition of additional right of way, whereas conventional freeway expansion does. Thus, on a cost benefit basis, this type of proposal may prove to be very competitive with alternate transportation strategies.

New construction and engineering jobs that accompany major transportation investment may also bolster the economy. The effect of major transportation investment in the past has been shown to proceed significant rises in gross national product.

CONCLUSIONS

A conceptual plan has been introduced that represents a unique mix of highway automation, electric vehicles, and pricing. Illustrations have been provided to show that the plan may be a feasible way to address the current mix of major transportation problems. Although PIE is in the conceptual stages, it plants the seed for further thought, analyses, and perhaps pilot projects. The main point in introducing this plan has been to highlight a key idea: transportation engineers and planners must begin to look at plans that incorporate many different ideas and solutions to address the myriad of problems facing Americans. This plan is an example of how this can be done... it is just one way to suggest a coordination of solutions, and perhaps the foundation of an implementable pilot project.

Perhaps PIE will be investigated further, with the aim to better understand the implications of the given infrastructure. Questions need to be asked of the plan such as: Will consumers accept the limitations of half-width electric vehicles and automation?; What operations specific problems arise from such an infrastructure design? and, Would an infrastructure design such as this be easily modified to accommodate future innovations? These are just some of the questions that need to be asked and critically examined with such a scheme. In addressing these questions, it becomes apparent that the focus of transportation engineers is becoming largely interdisciplinary, which also means we have a lot of work ahead of us.

We have introduced a conceptual approach that would provide new infrastructure and roadway capacity. Historically we have not been able to build our way out of our existing transportation problems, primarily because costs continued to escalate and the externalities of transportation demand resulted in unacceptable side effects, such as air pollution. It was not the increased mobility of new infrastructure that was the problem, but the costs and results of that increased mobility. In a conventional sense, we cannot build our way out of our problems. However, in a non-conventional sense, maybe we can. If we incorporate new technologies and economic and planning approaches into the provision of new infrastructure, we may be able to provide new capacity and increased mobility without the previously experienced side effects. We should not automatically preclude the option of building our way out of the current transportation problems... rather, we must carefully consider and analyze these proposals before we implement them.

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