IDENTIFYING UNCERTAINTIES IN FORECASTS OF TRAVEL DEMAND

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ABSTRACT

Transportation system investments that are costly and have a long intended life are risky if decision-makers shape those investments in response to inaccurate forecasts about the future travel environment. Historically, many forecasts have turned out to be wrong on the basic determinants of future travel patterns, including population, employment, household activity, spatial development, and government policy outcomes.

Uncertainty and risk in forecasting travel demand result from the complexity of the urban system and its evolution. Nevertheless, one can identify and analyze a set of discrete factors that are likely to have a significant effect on mobility in the future. These factors stem from technological invention, product innovation, and marketplace transformation, all primary features of the urban environment. Many of the factors can be thought of as vectors that have both spatial direction and magnitude with respect to changing travel demand. Examples of factors working in different directions are center city revitalization versus affordable homes with backyards, and electronic commerce for online shopping versus e-commerce in support of suburban superstores.

Factors like these are visible in a survey of social and marketplace trends, and are related to the emerging network economy, market and lifestyle shifts, and environmental changes. These changes influence future land use and travel patterns across both personal and commercial transportation. When viewed in aggregate, the factors point to significant uncertainty and risk, and to a need to rethink the methods that are used by most metropolitan planning organizations to forecast the effects of investments and public policies on future travel patterns.

Key Words: uncertainty, risk, complex systems, travel demand modeling, transportation planning, land use planning

INTRODUCTION

Uncertainty, although the object of considerable academic study, is not often a consideration in transportation planning and investment decision-making. Although the urban system is open and dynamic, transportation planners typically use closed, static models to predict discrete values of demand, mode choice, congestion, and transport externalities (e.g., air quality) for a no-action alternative and a limited range of policy interventions. The planning directives in TEA-21 that require a metropolitan transportation plan (MTP) to be updated on a three or five-year cycle imply indirectly that uncertainty requires flexibility in planning. However, major transportation system investment decisions that require long lead times are not likely to be changed based on new information developed when a MTP is updated. Similarly, land use policies in support of major new transit investments are unlikely to be significantly modified once the investment decision is made.

Consequently, uncertainty should be a significant early consideration in metropolitan regions that are being challenged to address growing automobility and its impacts. At a national level, uncertainty should be taken into account when issues such as global warming are addressed in strategic policies. It should also be of interest when planning tools are selected, particularly models used to forecast the outcomes of alternatives policies and strategies.

When actual outcomes are compared with past forecasts, major differences have been noted. This suggests that large uncertainties were present in the analysis. Planning tools have not been improved to the point that uncertainties in predictions made today are less significant. Uncertainties in predictions across any given planning horizon may actually be increasing given the pace of change that is occurring in all quarters of our complex, information technology-based society and economy. Large uncertainties may radically alter the cost-effectiveness of alternative policies and strategies, and may even imply that entirely different planning paradigms are desirable. They may also suggest the need for different decision-support tools that can more effectively account for the complexity of the urban system and the resultant risk and uncertainty in predicted patterns of mobility and travel demand.

In contrast to transportation, uncertainty has long been built into the forecasting used to predict energy demand under alternative supply and demand management scenarios (*1*). In the US Pacific Northwest, where analysis for uncertainty in the energy sector is carried out under a federal law that established the Northwest Power Planning Council, researchers have concluded that analyzing energy demand and transportation are very similar exercises (*2*).

SOURCES OF FORECASTING UNCERTAINTY

There is not sufficient space here for more than a cursory review of the sources of uncertainty in regional models used to forecast travel demand. Other reviewers have addressed uncertainty in modeling in some detail (*3-6*).

Uncertainty in Model Design and Structure

The statistical models of planning agencies assume a time-invariant functional dependence between geographic locations that describes logical travel behavior. Because these functional relationships may change over time, uncertainty is built into the design of the model.

Transportation Network Uncertainty

Models assume that transportation networks will change in predictable ways over the planning and forecasting horizon as population grows and perhaps redistributes. Obviously, the political environment has an inherent level of uncertainty that results from the interaction of political ambition, media reporting, and public opinion. Unpredictable future reallocations of resources between modes and between transportation and other public needs are the result of the interplay of these forces.

Demographic and Behavioral Uncertainty

Transportation models depend on input predictions of population and employment derived from economic models and extrapolations. Models also depend on a number of assumptions about individual and household behavior, the likely actions of commercial owners and investors, technological developments, the general and regional economy, costs of transportation, and the power of government to shape these behaviors, developments, and costs toward beneficial outcomes. Policy interventions can also lead to unintended and unanticipated changes.

These factors may offset one another, resulting in more forecasting accuracy than would otherwise be expected. For example, a regional economic downturn can reduce the number of trips that might have otherwise resulted from a change in the structure of the workforce -- i.e., more woman working outside the home. Nevertheless, this does not reduce the overall uncertainty of the forecast in a statistical sense.

The large number of potential contributors to behavioral uncertainty suggests that this will be a major source of uncertainty in future forecasts as it has been in past forecasts.

Uncertainty Resulting from Social/Political Bias

Planners and modelers are not immune from pressures, whether emanating from their political leadership, or from an inherent urge to produce outcomes that conform with expectations reflected in “preferred” planning scenarios and investment strategies (*7*). Bias introduces a wholly different dimension of uncertainty that cannot be assigned a quantitative value. It also can have an interesting twist when it is transparent as well as purposeful. For example, transit planners sometimes suggest that assumptions introduced to models have been highly constrained to produce “conservative” results, such as ridership projections that are expected to be exceeded when actual riders are counted some years later.

ANALYSIS OF UNCERTAINTY IN TRAVEL DEMAND FORECASTING

There have been relatively few systematic attempts to measure and analyze the uncertainty in predictions related to regional transportation planning. Uncertainty, as reflected in forecast accuracy, is defined here as the difference between forecasted and observed demographic changes and transportation outcomes.

A study by the Institute of Transportation Engineers (*8*) compared actual and forecasted 1975 population, employment, vehicle registrations and trips for five metropolitan areas: Milwaukee, Chicago, Seattle-Tacoma, Spokane, and Washington, DC. These forecasts were relatively short-term, generally 5-10 years, and were based on input values that were current between 1956 and 1961. Differences varied widely depending on factor, region, sub region, and city vs. suburb within a region, and were in some cases quite large. What is important here is not the magnitude of the differences but the apparent reasons. The study attributed the differences to unanticipated large-scale societal and economic changes that occurred after the forecast. These changes are summarized in the Table 1.

TABLE 1 Attributions of Differences Between Forecasted and Actual Demographic and Transportation Values in Five Metro Areas, With 1975 as Forecast Year

Reversal of migration patterns, from into to out of region
Decline in birth rate
Growth of suburbs compared to central cities
Decentralization of population and employment from central city to suburban and rural counties
Higher employment participation rates
Higher trip making propensity
Sudden downturn in key manufacturing industry (in contrast to earlier anticipation of continued high employment growth)

Under ISTEA, and now TEA-21, the FTA and FHWA jointly conduct comprehensive reviews of metropolitan planning practices, including modeling. These reviews do not appear to include an explicit determination of whether and how MPOs address uncertainty (*9, 10*).

UNCERTAINTY OF FORECASTS: PUGET SOUND REGION CASE STUDY

The central Puget Sound region is an example of how uncertainty leads to inaccuracy in forecasting metropolitan travel demand and transportation system performance. The region has a history of applying state-of-the-practice forecasting tools that reaches back to the 1950s. We summarize here forecasts that reflect uncertainty and how uncertainty has been addressed in transportation planning in the region.

Early Forecasts

Population and employment forecasts for the Puget Sound region (Seattle-Tacoma-Everett area) were made beginning in 1964 in support of transportation studies (*11-13*). Table 2 and 3 show percentage differences between forecasted and actual population and employment for 1975 with 1964 as the base year. Also shown are differences for an updated forecast in 1969 that was done to account for a large growth in aircraft manufacturing that occurred in the late 1960s. Differences increased substantially in the updated forecast because it extrapolated from high short-term growth trends and did not predict a sudden downturn in the aircraft industry that occurred in the early 1970s.

As Table 3 indicates, population forecasts for 1990 made at the same time were right on the mark. However, households, employment and vehicles were considerably underestimated. Major changes in the society and economy -- increasing numbers of woman in the work force, decreasing household size, and the shift of population to the suburbs -- were clearly not anticipated.

TABLE 2 Percentage Differences of Forecasted Population and Employment Compared to Actual Population for the Puget Sound Region, 1964 Study and 1969 Update

	1964 Forecast		1969 Update	
County	1975 Population	1975 Employment	1975 Population	1975 Employment
King	-10.0	1.5	-23.3	-11.4
Pierce	1.6	16.1	-8.4	5.1
Snohomish	-1.8	-12.5	-23.2	-40.4
Total	-6.6	2.5	-20.1	-11.5

TABLE 3 Demographic and Vehicle Ownership Forecast of 1967 Puget Sound Transportation Study

	1990 Forecasted	1990 Actual	Difference
Population	2,750,000	2,749,000	0%
Households	820,000	1,071,000	31%
Employment	992,000	1,445,000	46%
Passenger vehicles	1,176,000	1,727,000	47%
Commercial vehicles	153,000	516,000	237%

In 1974, the 1990 performance of a regional transportation plan was forecasted and compared to a no-build alternative. Table 4 shows that despite the plan, which included both highway and transit improvements, the region experienced almost a doubling of per capita VMT compared to the no-build alternative by 1990 which was used as a base year for later forecasts (*14*). Freeway speeds were approximately 10 percent less than had been predicted if no action had been taken.

TABLE 4 Actual Performance of Highway Element Compared to Forecasted No-Action Alternative; 1990 Transportation System Plan for Puget Sound Region as Modeled in 1974

	1972 Existing System	1990 No-Action Plan	1990 Actual
Daily VMT per Capita	12.5	13.8	23.1
Average System Speed - mph	30.1	28.6	26.2
Freeways	53.6	38.2	n.a.
Arterials	23.2	22.2	n.a.

TABLE 5 Change in Freeway/Arterial System Performance for the Puget Sound MTP as Estimated in 1995 and 1998

Performance Indicator	Change 1990-2020 (1995 Forecast)*	Change 1995-2020 (1998 Forecast)*
Daily Vehicle Miles Traveled (millions)	+57.6%	+63.7%
Off peak	+58.6%	+96.4%
AM peak	+61.0%	+53.7%
PM peak	+54.0%	+19.8%
Average speed (mph)		
Off peak	-4.9%	-10.1%
AM peak	-8.4%	-13.2%
PM peak	-17.6%	-10.7%
Hours of delay (thousands)		
Off peak	+221% (+350%)	+1037% (+397%)
AM peak	+160% (+280%)	+292% (+340%)
PM peak	+187% (+367%)	+67% (+357%)
Daily total	+186%	+223%
Total vehicle hours of travel (thousands)	+88.0%	+77.9%
Percent of travel hours lost to delay	+51.4%	+81.0%
Percent of network experiencing congestion		
Freeways	+73.9%	+15.8%
Arterials	+169.1%	+1.2%
Overall	+91.7%	-10.0%
Regional Population	+50.3%	+55.0%

*Numbers in brackets were published; number not in brackets were calculated from more recent data supplied to authors by PSRC.

Recent Travel Demand Forecasts

In 1995, the Puget Sound region adopted a year 2020 Metropolitan Transportation Plan (MTP). Modeling done in support of the MTP predicted travel demand growth from a 1990 base year (*14*).The MTP and the modeling as well were updated in 1998 with a new base year of 1995 (*15*).

Tables 5 and 6 compare the results of the two separate forecasts prepared for the MTP. Since a 30-year planning horizon was used, forecasted values cannot be compared with actuals. However, what is of interest to this discussion of uncertainty are the changes in the forecasted transportation system performance measures made just three years apart.

TABLE 6 Mode Choice in the Puget Sound Metropolitan Transportation Plan

		Mode Choice (Percentage Split)			
		Estimated in 1995		Estimated in 1998	
Trip type	Mode	1990* (Base Year)	2020* (1995 Forecast)	1995 (Base Year)	2020 (1998 Forecast)
Nonwork trips	SOV	61.4	47.3	60.0	56.9
	Carpool	36.1	49.1	38.5	40.3
	Transit	2.5	3.6	1.5	2.8
Work trips	SOV	72.8	71.1	73.7	65.3
	Carpool	19.7	17.3	19.3	23.8
	Transit	7.5	11.6	7.0	10.9
All trips	SOV	67.7	57.9	63.1	58.7
	Carpool	28.3	36.2	34.3	36.8
	Transit	4.0	5.9	2.7	4.5

*Inconsistencies between rows are as reported by the planning agency.

As the tables indicate, the new forecast produced considerable differences in all of the performance parameters. One of the most significant differences – seen in the last row of Table 6 – was the reduction of 2020 transit mode share from 5.9 percent to 4.5 percent, a 24 percent decrease. The differences between the forecasts were attributed to new data for the numerous variables in the models and to improved modeling methodologies (*15*).

Uncertainty Considerations in Modeling Practice

The Puget Sound MPO's travel demand modeling practice is well documented in reports and workshop notes (*16,17*). A review of this documentation and published plans indicates no visible attempt to build uncertainty into the model and forecasts. The methodology was the subject of a federal review (*18*) in the mid 1990s and was subsequently updated with the assistance of a consultant (*19*). Neither effort apparently involved consideration of uncertainty. Discrete values are predicted for essential inputs such as population and employment, and for outputs that describe transportation system performance. In one instance, a consultant to the MPO did suggest methodologies for incorporating uncertainty (*20*), but it is not apparent that any of these have been adopted.

APPLICATION OF THEORIES OF COMPLEX SYSTEMS TO THE URBAN SYSTEM

Uncertainty arises in large part from the complexity of the urban system. This complexity is related to the diversity of activity patterns displayed by individuals and households, and by the

dispersed spatial patterns of the venues where both in and out-of-home activities are carried out (*21*). The complexity encompasses the interaction of known, multiple forces and uncertainty arises out of the continuing introduction of new forces as a result of consumer choice, technological innovation, entrepreneurship, and competition.

We briefly review here the theoretical understanding of complex systems and uncertainty. We then describe the limitations of current urban planning to encompass complexity and uncertainty.

As Richmond (*22*) points out, transportation planners have not faced up to this complexity in their planning: "Recognizing that transportation is inevitably tied into an intricate web of overlaps with all other urban functions and with the rich morass of human life complicates the planning task but makes it more likely to achieve meaningful results." Along the same lines, Innes and Booher (*23*) note that, in the complex metropolitan development system, "simplification results in fundamentally wrong answers, and focus on individual sectors separately will be counterproductive." In addition, Freidman (*24*) argues that we are moving into a non-Euclidean world of many space-time geographies, requiring us to plan with the help of new and more appropriate models.

The Urban System and the Theory of Complex Systems

Complex systems, whether physical, biological, or sociological exhibit behavior that is unexpected. Casti (*25*) suggests that complex systems generate surprises from five distinct mechanisms:

- Paradoxes, leading to inconsistent phenomena
- Instability, leading to large effects from small changes
- Uncomputability, leading to behavior that transcends rules
- Connectivity, leading to behavior that cannot be decomposed into parts
- Emergence, leading to self-organizing patterns

Casti’s typology helps us organize our understanding of the complexity of the urban system. Table 7 indicates some examples of each of these mechanisms that identify the urban system as a complex system.

TABLE 7 Examples of Mechanisms that Characterize the Urban System as a Complex System (After Casti)

Paradox
• Travelers on a congested roadway do not switch from SOV to a bus or carpool to use an uncongested HOV lane.
Instability
• A small additional increase in traffic volume can change a free-flowing traffic stream to one that is unstable and soon stopped.
Uncomputability
• The gravity rule breaks down when people travel beyond the most accessible store to comparison shop, hunt for bargains, or seek a recreational experience beyond the basic purchase. • Latent demand fills new highway capacity.
Connectivity
• People trade off longer commuting distances for affordable housing that meets their needs and lifestyles
Emergence
• Separated-use land patterns were apparent before zoning was regulated. • Mega commercial clusters form around a regional mall as a nucleus.

Forms of Uncertainty

The surprises that come from complexity force planners to grapple with three forms of uncertainty about the future suggested by van der Heijden (*26*):

1. Unknowables, where a future event cannot even be imagined. The existence of unknowables calls for enhanced perception and skill in reacting appropriately.

2. Structural uncertainties, where we can understand how a unique new event can happen, even though there is not enough experience to judge the likelihood.

3. Risk, where the occurrence has historical precedent, and the probability of reoccurrence can at least be estimated.

Although structural uncertainties and unknowables cannot be forecast, the historical frequency of past surprise occurrences indicates their significance to the urban system. Risk can be deduced by looking carefully at trends that have shaped and are currently shaping the urban environment, and on technological developments on the horizon. Numerous trends that organize and describe past events suggest a continuing high level of uncertainly and risk in future urban patterns.

TRENDS LIKELY TO HAVE A SIGNIFICANT EFFECT ON TRAVEL

We have used an online review of national information sources including trade journals and technical forecasts and an ongoing scan of trends and developments in the Puget Sound area to synthesize a cursory list of factors likely to affect the future of urban activity and movement. This review is documented at greater length in reports prepared by the authors for the Mineta Institute (*27*). Because of the large number of sources for this information, we have omitted references except to cite predictions of important measures of change. These factors fall into three broad categories: technology applications, environmental changes, and lifestyle shifts. We note where these factors seem to have been acknowledged by the planning process in the case study area.

Technology Applications

The application of advanced technology is likely to be a significant driver of change over the next several decades. The most consequential categories for transportation planning are information technology (IT), which includes both computers and telecommunications (called telematics in combination), and transportation technology, in which applications of new materials and energy technology count heavily. Other technology categories potentially affecting land use and travel patterns include medical/biology and entertainment/recreation.

Information Technology

Computers and telecommunications are expanding rapidly in capability per unit of cost. The rise of the “network economy” that is exploiting this technology is already a distinctive feature of the present era and will likely be a predominate feature of the future. The ubiquitous presence and use of computers and telecommunications is not yet mentioned in very many MTPs, yet it already is producing impacts on transportation from several directions. Some of the advances widely foreseen are these:

COMPUTERS SMALLER, MORE POWERFUL, AND EVERYWHERE**.** Smaller, faster, more powerful processing, larger storage capacity, less expensive, and ubiquitous computing is a standard forecast from all observers for the decades ahead. Inventor and futurist Ray Kurzweil predicts "that by 2019, a $1,000 computing device will equal the computational ability of the human brain, and by 2029, that same price tag will supply a computer with the computing capacity of 1,000 human brains" (*28*).

Small handheld computers called Personal Digital Assistants (PDAs) are rapidly acquiring more functionality and user acceptance. International Data Corporation, a market research firm covering the computer industry, expects the sales for PDAs to exceed the sales of personal computers by 2005. Miniature, limited-function computers are likely to be widely deployed in the decades ahead. Some of these will simply monitor machinery like elevators and soft drink machines.

Modern automobiles already contain dozens of small computers, and some of them may maintain communication with maintenance facilities. Because of the Internet and Global Positioning Systems (GPS), location-aware information utilities will be possible, for example a capability in PDAs to provide written or verbal directions from anywhere to anywhere else.

VOICE COMMUNICATIONS EVERYWHERE**.** Wireless telephony is on a path to affordable ubiquity. Hands-free, voice-controlled versions will be available for use on the street and in automobiles. The number of wireless voice providers serving the Puget Sound region has risen from two to seven as a result of Federal deregulation and private sector response to surging market demand (*29*).

INTERNET EVERYWHERE**.** A cheap, always-on, wireless Internet device that can be held in one hand is probably coming within a few years. Display devices that simulate paper, or that work through virtual displays based on small attachments to eyeglasses, seem possible. Their use by drivers of cars may be limited, but clearly, passengers could be allowed full functionality. Drivers of cars will be offered hands-free, voice-enabled Internet access built into their new cars, according to recent product development announcements from both GM and Ford (*30*).

Countless options for streaming video will be available at homes, offices, and other fixed locations where large screens are available. In the Puget Sound region, this means that the congestion warnings on the traffic information web site of the Washington State Highway Department could become more accessible to people everywhere.

ELECTRONIC COMMERCE EVERYWHERE**.** A wide and growing variety of consumer and business transactions will take place through the Internet and Internet-like private networks. Online sales volume is doubling annually as of the year 2000, according to electronic commerce industry analysts at Forrester Research (*31*). This includes ordering goods and services for delivery later, and the instant availability of an array of services that earlier required travel to a service-delivery facility such as city hall, a clinic, or a school.

CAMERAS AND SENSORS EVERYWHERE**.** Security from personal assault and property crimes in transit vehicles and cars, at bus stops and park-and-ride lots, and other public spaces are likely to come from video cameras that transmit to public safety services and in many cases to the Internet for general viewing. General visibility through video of the inside of any public transit vehicle is feasible as a way of portraying the status of seating capacity to potential riders.

TELECONFERENCING AND VIRTUAL REALITY**.** While face-to-face meetings and other examples of physical presence will always have unique, attractive characteristics, there will be a wide array of technologies supporting remote interaction between people and machines. The Boeing Company has a professional effort underway to exploit video teleconferencing as a substitute for some daytime in-firm, business meetings.

MOBILE WORKERS AND VIRTUAL WORKPLACES**.** The ability to do office and other kinds of work in many different and varied locations is growing steadily, supported by expanding technology characteristics. The degree to which remote work has limitations trades off directly with the time and expense of travel. A telephone call or videoconference between Tokyo and California trades off against flying to meetings in either place or at an intermediate place.

Transport Technology

Transportation is a more mature technology than IT is, but there are many developments possible in the decades ahead that would certainly improve vehicle functionality and safety.

INTELLIGENT TRANSPORTATION SYSTEMS (ITS) APPLICATIONS**.** ITS is the application of computers and telecommunications to motor vehicle transportation. ITS already provides improvements in both private vehicle transportation and public transit, including faster door-to-door travel times, improved safety, easier inter-modal transfers, support for no-stopping toll collection, and facilitation of HOV usage.

Some results are little known and startling, for example, the six-year research study of the Seattle freeway system that showed a 50 percent drop in travel time over a 7 mile stretch of freeway served by 22 ramps, despite volume increases in excess of sixty percent (*32*). Capacity on some freeways may gradually improve through the advent of automatic braking and lane holding systems in intelligent vehicles that permit higher safe speeds, closer spacing of cars on the road, and a reduced number of accidents. Driver distraction from using in-car ITS information displays and controls is, however, a real issue that must be resolved.

IMPROVEMENTS IN PRIVATE VEHICLES**.** New materials, advanced propulsion systems, and in-vehicle electronics to manage maintenance requirements could lead to dramatic improvements in the performance of cars. Lower energy consumption and emissions, smaller size, higher safety levels, and lower operating costs are the target of manufacturers worldwide. Intense efforts are underway to develop fuel cell technology for a new generation of vehicles. One active research effort is underway at the Pacific Northwest National Laboratory. The Laboratory's public relations magazine declares, "In the next 10 years, environmentally friendly fuel cells may begin replacing conventional combustion engines in consumer automobiles" (*33*).

PUBLIC TRANSIT SERVICE INNOVATIONS**.** Modified regulations, computer-aided dispatching and navigation, and new guideway and vehicle configurations could potentially lead to the offering of new public transportation services. Subscription rental cars at transit stations, variations on airport shuttle vans and jitneys, route-deviation buses, subsidized carpooling, and various fixed-guideway schemes are conceivable (*34*).

NEW OPTIONS FOR THE ONE HOUR TRAVEL RANGE**.** As the 21st century progresses, there may be developed some radically new transportation systems that increase the options for short trips of say, one hour or less, the time range at which people are willing to commute daily or attend an evening entertainment event. One can imagine the possibility of very fast express trains or short takeoff and landing aircraft that serve center city locations. Moving people from their homes and offices to the stations where such systems provide boarding is a challenge of course. Cars that fly --a more ubiquitous form of personal aviation -- is another possibility that is being explored and developed by the National Aeronautics and Space Administration (*35*).

INTERACTION OF INFORMATION TECHNOLOGY AND TRANSPORT**.** International communications and transportation are likely to facilitate a continuing increase in the level of interaction between people across political boundaries as the 21st century progresses. Tourism, business travel, immigration and emigration, importing and exporting of goods, adoption of overseas fashions and customs, and other unforeseen activity and movement effects are likely as result of globalism facilitated by distance spanning technologies.

The routine use of cellular phones in cars is increasing the value of time alone in a moving automobile. The continuing growth in small package delivery services in urban areas is another

example, along with the announcement of billions of dollars in warehouse construction by firms selling goods on the Internet. The growing impacts from online selling on particular categories of retail businesses -- bookstores, automobile dealers, and travel agencies -- is a third illustration.

In addition, many emerging characteristics of freight and goods movement, such as just-in-time delivery of small quantities of parts and supplies, changing load factors in trucks, and more residential delivery of goods, are directly the result of more information technology controlling logistics processes.

Biology and Medical Technology

In the future, people may stay healthier and live longer because of medical and biological technology. Keeping aging people in better health and mobile for a longer portion of their lives is a goal of much research, and healthiness could certainly see breakthroughs or, less probably, reversals. Enhancements could also occur for disabled people who might be provided with more mobility or other health-related incentives to spending more time out in public. There are significant differences in health among regions. For example, despite the fact that Seattle is a regional center for medical care, it has almost 40 percent fewer short-term hospital beds per 1,000 population than the national average" (*36*).

Increasing human life span is a long-term trend that may see a sharp acceleration, or, much less likely, a deceleration or reversal. Acceleration of the trend would result from progress in the conquest of leading killers like heart disease and cancer. A deceleration could result from the emergence of a new disease or condition that cannot be thwarted by the medical community, or from another unexpected development.

New Entertainment and Recreation Options

High-end multimedia electronics and lighting offers exciting new options for place-based entertainment and culture, such as light shows, concerts, environmental simulators, and games, thus creating new places to visit. Materials technology and creativity opens up new sporting and recreation opportunities; snow boarding, roller blading, and mountain biking are three examples from the late 20th century, very much practiced by residents of the Pacific Northwest region.

Environmental Issues

This category includes the potential "big picture" changes that affect the lives of everybody in a society.

The Economy

In the present era of economic strength for most of the United States, one must not forget that this aspect of the urban environment could change. One likely possibility is a downturn in the economy over the next few decades. Another possibility is local recession caused by a problem with regional major employers or another source of economic vitality. In Seattle, for example, a simultaneous collapse in the business performance of Microsoft and Boeing because of

competition and other significant events (a difficult problem discovered in key products, for example) is certainly unlikely, but imaginable.

Other economic issues that entail risk for the future include changes in economic mix and even the structure of particular industries as “creative destruction” occurs. The rapid rise and apparent partial decline of electronic commerce providers is an example for some regions. Changes in the distribution of wealth in national and regional economies, and in communities, is a cause of uncertainty about the future as well

Physical Environment Effects

The effects of energy use and emissions generation on the Earth's climate -- so called global warming -- may lead to significant, policy-driven changes in activity and movement over the course of future decades.

Regional effects in the natural environment, such as air quality, water quality, and species protection, create a dynamic of uncertainty in transportation and land use as well.

Energy Supply

Energy shortages from declining petroleum supplies, for example, or new energy abundance, from exploitation of abundant hydrogen as a fuel, may develop in the decades ahead.

Crime and Terrorism

Personal security at home, at work, or in public places may become either more, or less of a problem in the years ahead. Reality and the perception of reality about crime and terrorism will affect what people do and where they go.

Lifestyle Shifts

In the category of life style shifts we include all the changes in how ordinary people live their lives, in particular, how they use time and how they use geographic space. These may be triggered by combinations of technological shifts, the development of new products, services, and other consumer opportunities, or big picture changes of the type described in the previous section. Potential life style shifts are another way of looking at the effects of technology and other aspects of the environment.

Personal Time Allocation Changes

Over the course of decades, the possibility is open for significant structural shifts across a wide segment of the regional population in the annual shares of work time versus leisure time, indoor versus outdoor time, home-based versus away-from-home time, and nearby versus very-distant activity time. This is because technology, global awareness, and economic circumstances provide new opportunities and perhaps new limits. Furthermore, human behavior can change significantly over a short time period in response to new threats and opportunities.

Spatial Use Changes

In the same way that time allocations can change, people may change their space consumption and movement habits by living in bigger or smaller homes that are closer or farther from workplaces on average, becoming part of family or friend groupings that are more widely or less widely geographically dispersed, or choosing locations for fulfilling their consumer activity preferences that consequently yield more or less travel to get there. The market will likely continue to offer many choices in all ranges of price. Fashions and fads (unforeseeable now, since they are based on future human creations yet uncreated) will be influential, no doubt. In addition, the emerging preferences may be considerably influenced by vehicle traffic congestion, which is predicted by today's transportation planners to grow substantially in the next few decades.

Working at home is growing steadily, but contrary to popular belief, wage and salary workers doing work at home is not growing as fast as the work force as a whole. However, individuals with the technology and organizational flexibility to work in many locations are growing in number, and the level of self-employment rises and falls, all of which yields uncertainty in the future of the journey to work.

The availability of new destinations for new purposes, such as the Gorge Outdoor Amphitheater entertainment venue near George, Washington midway between Spokane and Seattle, or the SuperMall in the suburbs between Seattle and Tacoma, or a new sports stadium in downtown Seattle, also creates new patterns of spatial use and movement.

Of course, there are other well-known forces involved in the change of urban spatial structure that will continue to add a large measure of uncertainty to patterns of metropolitan travel and land use. They include:

- Older central city resurgence
- Growth beyond central cities and counties
- Interregional population shifts
- Redevelopment and infill development
- Government and private initiatives for open space preservation
- Public reaction to density and mixed-use development
- Variety and spatial distribution of retail facilities providing goods or services
- Effects of aging population on preference for residential size, style, and amenities
- Housing costs that decline towards the urban periphery
- Preference for home ownership

Institutional changes

Organizational Rescheduling

Society's institutions are beginning to change their traditional schedules, and this trend could accelerate. More public schools are now operating year round to more fully utilize school classrooms, and there are attempts to make sure that the periods of certain vacations are staggered to avoid overloading travel facilities used by families taking holidays. More use of the

full seven-day week and the full 24-hour day for scheduling work is also a trend, which among other effects serves to spread out the traffic load moving people and goods. The Boeing Company proposed a seven day, 24 hour work week during labor negotiations in 1999. Although rejected by the union, the company plans to offer it as a voluntary work option. Interaction with other geographic regions in the global economy clearly is a driver of this trend as well.

Employer Policy and Practice

The preference and support of employers for part-time, disabled, younger, and older workers has a bearing on transportation requirements. Employer subsidization of alternative modes of transportation is another influence.

Public Policy and Government Spending

What government agencies do, of course, is a significant influence on transportation and land use. Some of what they do is a matter of transportation policy, but sometimes other issues are important, such as the predilection of local governments to stimulate local development in order to generate growing tax revenues. Sometimes the government interest in more revenue leads to competition between jurisdictions within a region to attract development, as opposed to, for example, regional cooperation that would moderate the level of travel demand.

Costs, benefits, and other fiscal factors related to government action include:

- Direct private vehicle costs, including demand pricing
- Opportunity costs from major government spending decisions
- Dramatic changes in the availability of government resources
- Government land sales and purchases

DISCUSSION

Many of the factors just described carry both a weight and spatial direction in their impact on metropolitan form and travel patterns. In other words, they are vectors that effect the choice of travel mode and the compactness and integration of land uses. Some encourage more automobility, e.g., signal timing, while others stimulate transit use, e.g., ITS applications like real-time bus schedules. Some are centripetal, tending to produce lower densities and separation of uses, e.g., the need of families for affordable housing tends to move demand and growth to the periphery of an urban region. Others are centrifugal, tending to cause higher land use densities and an amalgamation of uses. This could be the case for some members of an aging population who seek to downsize their residence and find a location convenient to goods and services. Other examples of factors working in different directions are electronic commerce for at-home shopping and e-commerce in support of suburban superstores.

The factors are complex in themselves, and some are obviously interrelated, which adds additional complexity. Analyzing this complexity, Hibshoosh and Nicosia (*37*) describe how the dynamics of family life, employment, and other social institutions work individually and in combination to influence travel behavior.

In addition to all of the forces mentioned in this paper, there are still other unknowable and structural uncertainties that may change the economy and society, and consequently would

reshape activity and movement. The uncertainties are no more discernible now than was the case three and four decades ago when travel forecasters were impervious to the soon revealed facts of shrinking household size and increasing numbers of women joining the work force.

That uncertainty is neglected in planning and government policy has long been a theme of analysts who track societal trends. A quarter-century ago Zwerling (*38*) suggested that a recognition of immense uncertainty over multi-decade time horizons could yield more emphasis on solutions that are more easily implemented and more flexible in comparison to solutions that appear to be more durable and long-lasting, yet are less effective in terms of public benefits. Twenty years ago Wachs commented that the effectiveness of planning methods will depend far more on our understanding of social trends than on statistical elegance (*39*). Moreover, contemporary forecaster Yehezkel Dror thinks "we are increasingly facing the inconceivable," since all of the deep drivers of history are undergoing radical transformation. Dror advises: "Presuming to foresee the longer-term future should be avoided, open-ended contingent outlooks should be the rule..." (*40*).

CONCLUSIONS AND RECOMMENDATIONS

Many forces are at work shaping the urban system, increasing its complexity and the uncertainty of forecasts of travel within it. Some can be identified but others cannot even be imagined. The rapidly emerging Internet economy adds to the complexity. Many of these forces do not appear to have been acknowledged by regional planners.

The volume curves for several drivers of our society at the end of the century show accelerating rates of growth -- transistors in a microchip, computers attached to the Internet, Internet web sites, volumes of online shopping, business-to-business electronic commerce, and e-mail messages. Since change seems to be accelerating, the uncertainty in making predictions is likely to be increasing.

Given the aggregate uncertainty, planning horizons of 20 or more years may lead to highly problematic estimates of travel demand. The result may be an unnecessary emphasis on capital expenditures, and a variety of lower cost, more short-term options may remain unconsidered.

Much is at stake because local and federal governments are investing large sums based on implicit assumptions that the future will be very much like the present and the recent past. The opportunity costs may be high in acting on these assumptions. Planning for more incremental expenditures may provide a more flexible response to an uncertain future.

Most importantly, a basic accounting of uncertainty and risk needs to be built into the metropolitan planning process at the beginning stages. As many factors as imaginable, whether quantifiable vectors or fuzzy worries, both national and metro-specific, need to be identified and weighed. This requires, for example, an ongoing attempt to come to grips with the emergence of the Internet economy, widely deployed microcomputers, ubiquitous personal communications, and other visible technology developments. The reasons why retail businesses locate where they do needs to be assessed. This is not a recommendation to predict a specific future, but rather to map the many areas where specific predictions are impossible.

With an inventory of the forces causing risk and uncertainty in hand, MPOs will more likely see the need to reconsider the efficacy of current planning tools, including four-step models, and their ability to encompass uncertainty adequately. At both the federal and local level, new planning approaches need to be developed that address uncertainty in the quest for desirable outcomes from major transportation investments.

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