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FUTURE TRANSPORTATION TRENDS AND TECHNOLOGY

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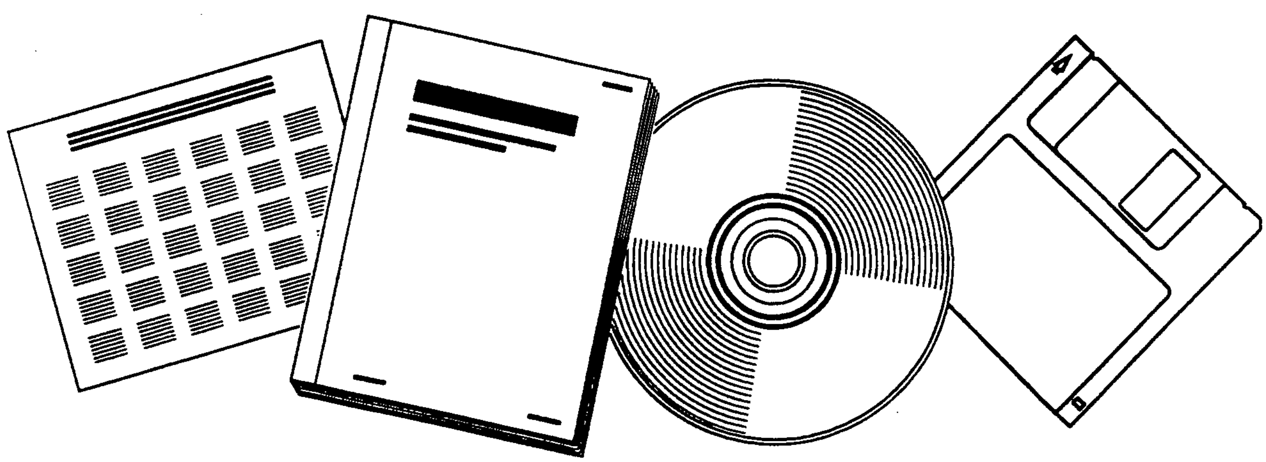

U.S. DEPARTMENT OF COMMERCE
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FUTURE TRANSPORTATION TRENDS AND TECHNOLOGY

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by

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16. Abstract

This document was prepared as a resource for ODOT's 1997 Research Strategic Planning Meeting held in November 1997. Included in the paper are relevant socio-economic trends, including social, environmental, economic, and political. Construction technology, condition assessment and monitoring, transport technologies, information technology, and human factors research are also discussed. Finally, the results of a survey distributed to Department personnel, local transportation agencies, and vendors regarding transportation issues and research needs are presented.

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SI* (MODERN METRIC) CONVERSION FACTORS

APPROXIMATE CONVERSIONS TO SI UNITS

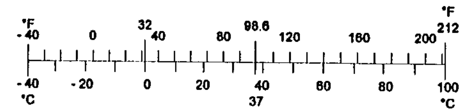
Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
in	inches	25.4	millimeters	mm
ft	feet	0.305	meters	m
yd	yards	0.914	meters	m
mi	miles	1.61	kilometers	km
		AREA		
in^2	square inches	645.2	millimeters squared	mm^2
ft^2	square feet	0.093	meters squared	m^2
yd^2	square yards	0.836	meters squared	m^2
ac	acres	0.405	hectares	ha
mi^2	square miles	2.59	kilometers squared	km^2
		VOLUME		
fl oz	fluid ounces	29.57	milliliters	mL
gal	gallons	3.785	liters	L
ft^3	cubic feet	0.028	meters cubed	m^3
yd^3	cubic yards	0.765	meters cubed	m^3

NOTE: Volumes greater than 1000 L shall be shown in m^3.

Symbol	When You Know	Multiply By	To Find	Symbol
		MASS		
oz	ounces	28.35	grams	g
lb	pounds	0.454	kilograms	kg
T	short tons (2000 lb)	0.907	megagrams	Mg
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5(F-32)/9	Celsius temperature	°C

APPROXIMATE CONVERSIONS FROM SI UNITS

Symbol	When You Know	Multiply By	To Find	Symbol
		LENGTH		
mm	millimeters	0.039	inches	in
m	meters	3.28	feet	ft
m	meters	1.09	yards	yd
km	kilometers	0.621	miles	mi
		AREA		
mm^2	millimeters squared	0.0016	square inches	in^2
m^2	meters squared	10.764	square feet	ft^2
ha	hectares	2.47	acres	ac
km^2	kilometers squared	0.386	square miles	mi^2
		VOLUME		
mL	milliliters	0.034	fluid ounces	fl oz
L	liters	0.264	gallons	gal
m^3	meters cubed	35.315	cubic feet	ft^3
m^3	meters cubed	1.308	cubic yards	yd^3
		MASS		
g	grams	0.035	ounces	oz
kg	kilograms	2.205	pounds	lb
Mg	megagrams	1.102	short tons (2000 lb)	T
		TEMPERATURE (exact)		
°C	Celsius temperature	1.8 + 32	Fahrenheit	°F



* SI is the symbol for the International System of Measurement

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DISCLAIMER

EXECUTIVE SUMMARY

This paper has been prepared as a resource for ODOT's 1997 Research Strategic Planning Meeting. The purpose is to provide a perspective for research goals in order to effectively prioritize future research investment for the next five to 10 years. A brief literature review was conducted, information was gathered from the Internet, and a survey was distributed to determine issues in transportation. The information provided is by no means exhaustive. However, what follows is sufficient to provide current and near-term expectations within the transportation sector.

The first section contains relevant socio-economic trends. These trends are broken-out into four categories: social, environmental, economic, and political. Social trends include population growth, urbanization, and demographic characteristics. Environmental trends include air pollution, water pollution, and noise pollution issues. Economic trends cover infrastructure, industry structure, new business practices, logistics, globalization, and public-private partnerships. Political trends include the changing role of government and the regulatory climate.

The second section contains relevant technologies including: construction, condition assessment and monitoring, transport technologies, information technology, and human factors research. Finally, the survey distributed by the Policy/Research Section is discussed and the results are presented.

As Oregon's population continues to grow, we are faced with balancing a long list of infrastructure needs with limited funding. Complicating the growth issue are the required considerations of all travel modes, of a global economy and of possible environmental impacts. New business practices will change the way we interact with the motoring public. Businesses will depend on ODOT to guarantee a smooth flow of products by providing safe, connected, and intelligent transportation systems. The federal government will assist by allowing more control at the state and local levels.

Fortunately, the technology exists to meet most public expectations. Improved construction technology will reduce time requirements; smart materials will provide continuous condition assessment feedback; composite materials will provide an effective means to rehabilitate our bridges; automobiles, ships, and trains will continue to improve and compete in the global economy; and intelligent transportation systems (ITS) will provide safer travel and improved efficiency within our system. Inherent in these technologies are information and human factors. We must understand how we learn, disseminate, manage, and apply information to the greatest advantage. Also, we must incorporate human factors into our technology to optimize application.

Technology will continue to grow as faster, stronger, and/or better tools are developed. Not all technologies will be appropriate for Oregon. However, we are charged as an agency to determine prudent uses to meet expectations… and to keep up with the changing world.

FUTURE TRANSPORTATION TRENDS AND TECHNOLOGY

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1.0 INTRODUCTION

This paper has been prepared as a resource for ODOT's 1997 Research Strategic Planning Meeting. The purpose is to provide a perspective for research goals in order to effectively prioritize future research investment for the next five to 10 years. A brief literature review was conducted, information was gathered from the Internet, and a survey was distributed to determine issues in transportation. The information provided is by no means exhaustive. However, what follows is sufficient to provide current and near-term expectations within the transportation sector.

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The second section contains relevant technologies including: construction, condition assessment and monitoring, transport technologies, information technology, and human factors research. Finally, the survey distributed by the Policy/Research Section is discussed and the results are presented.

2.0 RELEVANT TRENDS

Social, environmental, economic, and political trends will continue to impact the future of transportation in Oregon. The population will continue to grow, further stressing the environment and deteriorating infrastructure. Shifts in political control, from federal to state and local, will allow us more flexibility in how we respond. Careful consideration of the trends will assist us in providing an integrated system that will last at least through its design life without becoming obsolete.

2.1 SOCIAL

Several social issues affect future transportation including increasing population, population distribution, and specific transportation needs of the elderly and disabled.

2.1.1 Population

2.1.1.1 Growth

Oregon's population and labor force have grown at high rates recently. Population in Oregon is expected to increase 23% between 1995 and 2010 while the labor force is expected to increase 28%. Much of the growth will take place in specific areas. There are nine counties[1] that are expected to have population and labor force growth rates higher than the state average. Three other counties[2] are expected to have labor force growth rates higher than the state average. Most of the growth in population has been driven by in-migration (DAS, 1997). Oregon's natural rate of population growth, i.e., births minus deaths, represented only 29% of growth between 1990 and 1995. This pattern is expected to continue but at slower rates.

2.1.1.2 Urbanization

Over the last few decades there have been major shifts in population and employment distribution. In the Portland-Vancouver area, population and employment in the suburban counties have become a major proportion of the metropolitan region. This has caused an increase in average trip lengths and a decrease in use of alternative modes of transportation. However, growth in these areas is leveling off. These surrounding areas are maturing – population, retail activity, and employment in the suburbs are becoming more balanced. Travel between central cities and suburban areas is expected to continue to increase but at a decreasing rate. (Gregor, 1997)

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[1] Clackamas, Crook, Curry, Deschutes, Jefferson, Marion, Morrow, Washington, and Yamhill

[2] Lane, Polk, and Wheeler

2.1.1.3 Labor Force Participation

In addition to the increasing population and labor force, there has been an increase in the participation rate of women. In 1980, 53.8% of women were in the labor force, while 60.8% were in the labor force in 1995. This has created an increase in household incomes resulting in an increase in automobile ownership and ability to travel. The increase in workers per household has created a larger demand for services that were previously produced in the home, e.g. laundry, housekeeping, dining out, etc. As a result, there has been growth in the service industry and increased number of trips per household (Gregor, 1997).

2.1.1.4 Age

Even though Oregon's population is growing, the number of older Oregonians is expected to stay about the same. Oregon is attracting retirement-age in-migrants, and we have the fifth highest state median age in the U.S. (DAS, 1997). In 1995, 13.8% of Oregon's population was over the age of 65. The proportion of Oregon's population over 65 in 2010 is forecast to be only 14%. Thus, significant changes in transportation demand due to the aging population are not expected until beyond 2010, i.e., beyond the scope of this paper.

2.1.1.5 Disabled Needs

People with disabilities are the nation's largest minority (49 million people). If a person does not currently have a disability, he or she has about a 20% chance of becoming disabled at some point in his or her lifetime (USDOT). The percentage of people with a disability increases with age; for example, five percent of the U.S. population less than age 18, but 84.2% of those 85 years of age or greater are disabled. Therefore, as the baby boom generation advances in age, the number of people with disabilities will also increase. Transportation is key to independence for people with disabilities. Despite important progress in increased accessibility, transportation remains a major obstacle to employment and participation in the community for disabled people. (Coughlin and Lacombe, 1997)

2.1.2 Environmental (USDOT, 1997)

In the next several years, environmental laws and regulations will continue to be a priority with the American public. There is an increasing recognition that multiple sets of regulatory requirements discourage conduct that protects the environment. This awareness is leading to increased coordination and information sharing among government agencies interested in a consistent approach to protection efforts across all pollution sources, including transportation. For example, the nation's water quality issues come from a variety of sources that can only be successfully addressed in a comprehensive, integrated and holistic manner. There is an increasing push from the private sector for intergovernmental, public/private partnerships to address ecosystem issues on a watershed level.

2.1.2.1 Air Pollution

Air pollution causes harm to the health of humans, defoliation of plants, decreased crop yields, acid rain, and decreased visibility. It is also a factor in global warming. Because of their reliance on the burning of fossil fuels, transportation vehicles are a major source of air pollution. Over the past 20 years total national emissions of most air pollutants from transportation sources have decreased due to gains from technology, even with the increases in transportation activity occurring during that time. However, these gains are expected to be overtaken by traffic growth in the next few years.

Mitigation strategies for meeting existing air quality standards require steps that can dramatically affect mobility and access. Increased use of public transportation offers the potential for providing mobility with fewer adverse environmental impacts than automobiles. Automobile manufacturers are already producing electrically powered vehicles with an eye toward assessing the market potential of this product. Promoting research into and use of alternative power and alternative fuel vehicles will be an important factor in reducing transportation's negative air quality impacts.

2.1.2.2 Water Pollution

The public has grown increasingly intolerant of water pollution, especially from industrial transportation sources. Congress has enacted laws to prevent industrial pollution, to remove it when accidents occur and to punish those whose carelessness jeopardizes the health of the resources that are our common heritage. As public awareness increases, the trend will be toward even greater protection of the environment, including, if necessary, more regulation.

2.1.2.3 Noise Pollution

The transportation system is a pervasive source of sound in the U.S. Exposure occurs for those living near busy streets, highways, airports or other transportation centers. Intrusive noise is considered a form of pollution that can degrade the quality of life for those exposed. Noise can interrupt sleep patterns, interfere with speech, or cause continual annoyance to those exposed. With expected increases in congestion, highway noise is expected to increase. Traffic volume at airports is expected to increase, and therefore noise pollution around major airports is also expected to increase despite the introduction of standards to regulate aircraft engine noise.

2.1.2.4 Other Transportation Waste

Transportation is also the source of wastes that require monitoring, control, and disposal. Increasingly numerous and stringent environmental regulations have added new constraints to which transportation design and operation must respond. The primary concern addressed in these regulations is the residuals or waste products of transportation activities that influence air and water quality, energy consumption, and solid waste management (e.g., construction wastes and roadside rubbish). At the same time, transportation plays a role in the management of residuals from other activities, for example when the ash from coal-fired electricity generation processes is used in concrete. (Committee for an Infrastructure Technology Research Agenda, 1994)

2.1.3 Economic

Oregon has an extensive infrastructure that must be incrementally restored, renewed, preserved, strengthened and expanded in capacity if the ever-growing transportation needs of our state are to be served. Within this infrastructure, bridges and pavements command most of our attention. With deregulation came changes in the use of our transportation system. Firms have been utilizing new business practices to remain competitive and profitable. Logistics is a new spin-off industry growing at a phenomenal rate and increasing the efficiency of freight transportation. Transportation firms are now able to take advantage of the trend of globalization of commerce and new public-private partnerships.

2.1.3.1 Infrastructure

The United States is served by what is arguably the most extensive infrastructure in history. The system has developed through the centuries as separate and distinct highways, bridges and other facilities built and operated by numerous government agencies, independent authorities, and private corporations, worth $2.4 trillion. Decisions made in earlier times – when there were fewer people, less intensive land use, and less understanding of the environment – have left us with aging facilities that are often incapable of serving today's demands. When they deteriorate they do so slowly and often in subtle ways that are difficult to observe until substantial damage has occurred. (Committee for an Infrastructure Technology Research Agenda,1994; National Science and Technology Council, 1995)

Two of the major transportation infrastructure components within ODOT are pavements and bridges.

Pavements: ODOT currently maintains about 8,200 lane-miles of roadway and 2,650 bridges. The 1996 pavement management system calculated that only 78% of the state highway jurisdiction roads are in "fair-or-better" condition. Projections based on the 1998-2001 STIP (State Transportation Improvement Program) indicate maintaining the 78% is unlikely even though ODOT has set a goal of achieving 90% "fair-or-better" pavement condition by the year 2010. (Hori, 1996) In fact, the STIP currently allocates only $98 million annually which would result in 71% "fair-or-better" pavement condition. (STIP, 1997) Projected needs are $202 million if all paving projects were constructed to 3R standards. To assist in covering some of the difference, the Department plans to reallocate any hard cash savings to pavement preservation.

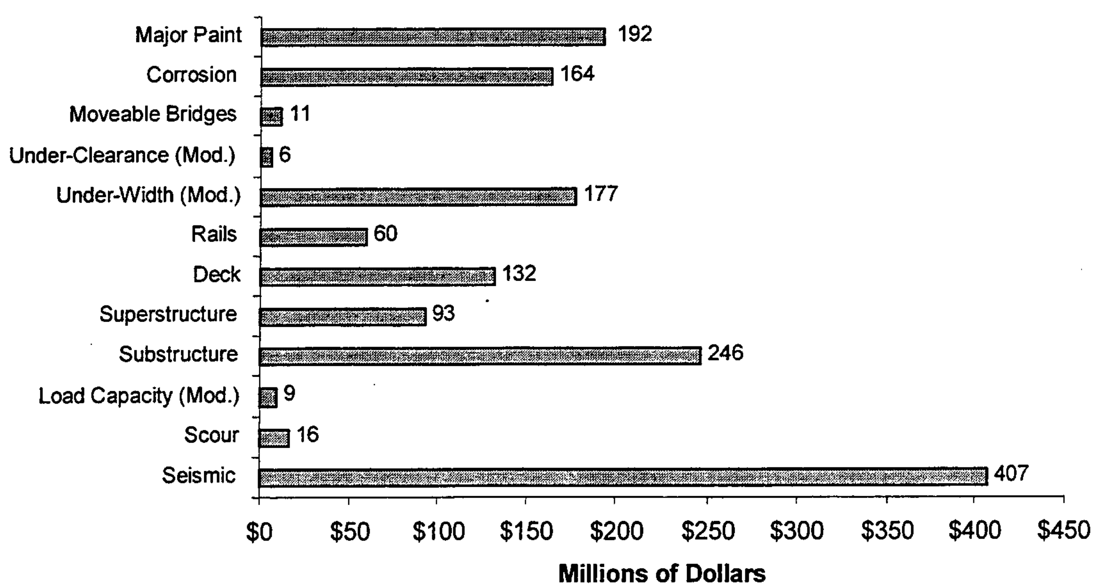
These numbers are approximate as the STIP is a fluid document and the exact federal -authorization (commonly referred to as "NEXTEA") is unknown at this time. If the federal authorization is significantly higher than the department has anticipated, the additional funds will be allocated to preservation activities. (Hamilton, 1997)

Bridges: Based on the bridge highway plan matrix, bridge needs are also significant. (Groff, 1997) Predominant bridge needs identified include:

- seismic retrofits (mitigate unstable bearings and narrow bridge seats, and tie superstructure to substructure to prevent collapse in moderate earthquakes),
- scour mitigation (repair the undermining of bridge pier footings in stream beds),
- load capacity strengthening (required due to deteriorating members),
- load capacity strengthening (required due to need to accommodate heavier legal loads),
- substructure rehabilitation due to deterioration,
- superstructure rehabilitation due to deterioration,
- deck repair or replacement,
- rail repair or replacement,
- under width increases,
- under-clearance improvements (bridge raising to accommodate legal vehicles),
- movable bridge repair,
- corrosion mitigation,
- major paint needs.

The projected needs for the next twenty years, in 1997 dollars, are shown in the following graph.

Figure 2.1 Bridge Needs Summary

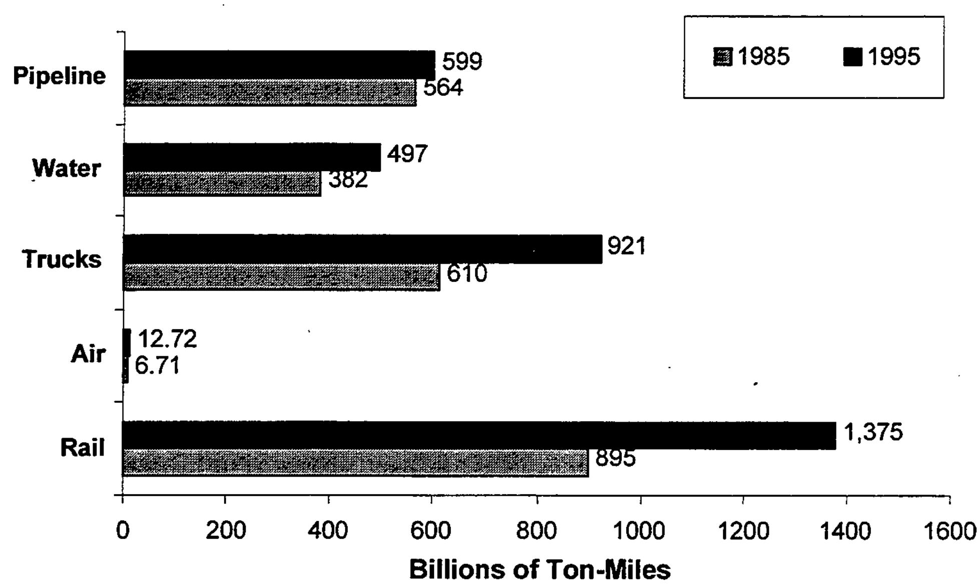


2.1.3.2 Industry Structure

Although the merging of smaller into larger companies has been prominent throughout the U.S. history of transportation, the period since deregulation has been characterized by an acceleration of merger activity. Moreover, the underlying economics of the transportation industry appear to encourage service patterns, which result in a dominant presence in particular areas, if not industry-wide. This phenomenon is illustrated by airline and maritime hub and spoke service patterns. In addition, horizontal integration across modes, in search of an ability to offer more efficient multi-modal service has resulted in another dimension of market concentration. Within this developing industry environment, USDOT will exercise policy and regulatory authority that will influence how the merger pressures are played out and the extent to which new entrants are provided with a reasonable chance to compete.

The following graph illustrates freight movements through the U.S. Between 1985 and 1995, there has been a 38% increase in domestic intercity ton-miles in the U.S. Airfreight has almost doubled, highway and rail freight increased over 50%. Clearly, the industry is growing and growing across modes.

Figure 2.2 Domestic Intercity Ton-Miles by Mode



Source: "Transportaton in America"

2.1.3.3 New Business Practices

Today's markets are dynamic. Competition drives firms to create new ways of doing things in order to increase profit and market share. The transportation industry has seen many such changes, a few are presented below.

Just-in time: This method of managing inventory, i.e., ordering inputs as-needed to keep inventory stock at a minimum, has created a demand for delivery of goods on time and in a predictable and dependable manner. The trucking industry has made operational changes to cater to this need already. The rail industry has also observed the current need for on-time delivery and is working towards increased reliability in their service. (www.interbiznet.com)

Total Quality Management (TQM): A common business practice in the private sector that is beginning to be used in the public arena, including transit. TQM requires employees, including top and line managers, to assume responsibility for product or service quality as defined by the customer. It also emphasizes quality improvements in terms of processes, outputs and inputs. TQM has the potential to increase customer and employee satisfaction. Because of its focus on teamwork and inputs, it also has the potential to increase output and reduce costs. (Obeng and Ugboro, 1996)

Telecommunications: Businesses are using PC's to communicate with suppliers, customers, employees, and to access information. Use of the Internet is becoming a standard tool for companies, government agencies, and the general public. More firms are allowing employees to telecommute. Telecommuting employees spend some proportion of their work-week working someplace other than the traditional workplace. They work from home, in a satellite office, or from a client's office. Advantages to telecommuting include: reduction of sick leave, enhanced productivity, accommodation of employees and customers, reduced office and parking space need, and reduced travel getting to work. (Oregon Office of Energy)

Manufactured products: U.S. manufacturing is moving towards higher-value products, which will continue to drive the trucking industry toward demand-pull distribution systems. Manufacturers won't produce a product until it is ordered by the customer creating a demand for more "less-than-truckload" (LTL) shipments. (Myers, 1996) Prior to deregulation of the trucking industry, goods were delivered in full loads. Since deregulation, firms provide shipments of smaller loads and more often as a means of being competitive.

Supply chains: Alliances between carriers centering on a core-carrier are emerging. Most logistics managers recognize the value and savings that can be realized from a strong partnership with a core carrier. (Meyers, 1996)

2.1.3.4 Logistics

The logistics market covers trucking, warehousing, air, rail, third party contractors as well as other transportation and administrative services. Logistics providers offer a variety of services from dedicated contract carriage to supply chain management to process re-engineering, just to name a few. To compete in this growing field, freight transportation companies have developed separate logistics entities. Contract logistics is a rapidly expanding segment of the industry, expected to grow 15-20% over the next five years. According to the Alex Brown Company, "logistics companies endeavor to satisfy their customers' delivery demands while minimizing the costs of transportation, warehousing, inventory, packaging and labeling, etc. Computer-based models are often used to manage and balance the multitude of variables involved. Experience indicates that overall logistics costs can be reduced by anywhere from 10-40%." Companies are looking at consolidation of supply chain process and better-planned distribution to get the best service for the best price. In addition, the logistics leaders are concerned with increasing customer service and bottom-line contribution. The success of these companies may lie in their ability to become world-class, global players. (American Trucking Association)

The storage and transport of raw materials, parts and output is an increasingly important consideration in decisions on how goods and services will be produced and delivered. The efficient application of logistics in the production process can result in important efficiencies in the production and distribution of goods and ultimately in their cost and competitiveness in the marketplace. The demands that logistics will place on transportation in coming years will have major implications for the system. More direct involvement of transportation considerations in production process decisions will bring a need for a closer relationship between the government and the private sector, which will inevitably raise new issues of fair treatment among competitive private interests. (USDOT, 1997)

2.1.3.5 Globalization

Globalization of commerce will continue to have a significant impact on transportation. Efficient transportation is key to whether U.S. businesses will be competitive in the global marketplace. Greater attention to international trade demands must occur with respect to investment in transportation facilities and the provision of services than has been done in the past. More attention will be devoted to the efficiency of border and port of entry activities in the course of improving the overall effectiveness of international movements. Further, since international movements frequently involve more than one mode, intermodal connections will play a more important role in transportation. Increased commerce with foreign nations will stimulate demand for efficient, international transport for business, leisure and the shipment of high-value goods. Efficient, cost-effective transportation will play a major role in determining whether U.S. businesses can compete in the global market place. (USDOT, 1997)

2.1.3.6 Public – Private Partners

Private sector investment in transportation has generally been greater than that of the public sector. However, public infrastructure investment often provides the essential right-of-way that allows the private investment to function effectively. With the emphasis on smaller, less intrusive government, comes pressure to reduce government spending in all areas and brings into question the outlook for traditional sources of funds for public programs, including transportation. Superimposed on this picture are broader economic considerations such as low and stable inflation and the potential for change in the tax structure, each of which could make the climate for private investment in transportation more positive. With limited resources to address system congestion, capacity, maintenance and the need for improved intermodal connections, DOT's will not only have to manage resources in an effective way and make cost-effective investments, but also create new opportunities for private investment in transportation.

There is a continuing trend towards seeking new relationships among levels of government and the private sector in both the financing and provision of public services. A range of innovations has focussed on revenue sources other than increases in the conventional fuel and vehicle taxes.

In addition to new funding methods, new ways to operate more efficiently are being explored. Washington DOT meets at the end of every construction season with contractors and suppliers to discuss the previous year's projects. While initially met with skepticism on both sides, this new public-private partnership has saved hundreds of thousands of dollars. Information regarding what worked and what failed is exchanged and alternatives are explored, increasing the quality of the roads and saving money in the short and long run. Florida is using contractors for maintenance of some road sections. The contractors not only deliver a new road, they provide the maintenance for that road section too, for an agreed amount of time (10 years or so). This new type of contract is expected to produce superior roads that require less maintenance. (USDOT, 1997)

2.1.4 Political

There is currently a shift towards increased state and local control of transportation decision making. The federal role is moving away from direct involvement. More privatization is expected to take over government functions and services. While there is a demand for the elimination of excessive federal regulations, the public expects increased transportation safety, security, and international standards.

2.1.4.1 Changing Role of the Federal Government

Within the political context of pressure for a more efficient government and a balanced federal budget, clear trends emerge. With respect to the federal role in transportation, there will be a shift away from direct project oversight, centralized, top-down decision-making and prescriptive regulations. There will also be a shift away from one-size-fits-all grant and program specifications. There will be a shift toward increased state and local control of transportation decision making, consensus building, and facilitating. Expect increased use of performance standards and measurement, more program flexibility and a greater demand for information and technical assistance. Also expect counter-terrorism, security issues and disaster relief to become higher priorities than they have been in the past. There will be privatization of certain transportation functions and more focus on infrastructure projects of national or international significance. (USDOT, 1997) Privatization of government functions and services will affect the financing of infrastructure repair and new projects in transportation—private investors will expect a reasonable return within relatively short times. (ASME, 1996)

The virtually instantaneous public knowledge of current events increases expectation of immediate government intervention and remedial action in response to natural disasters and serious transportation incidents. The federal government is expected to respond quickly and help solve problems and restore transportation when these crises occur. (USDOT, 1997)

2.1.4.2 Changing Regulatory Climate

Another political trend is the changing regulatory climate. Amidst a general climate favoring elimination of excessive federal regulations, the public will demand increased transportation safety, security and international standards. This atmosphere highlights the need for sustained and continuing reinvention of regulatory and enforcement processes. In addition, rapid growth in international trade has focused attention on the need for harmonizing international transportation safety standards. For example, growth in international traffic is focusing attention on the fact that foreign carriers are subject to lesser or different safety standards than those applicable to U.S. carriers. Harmonizing these regulations might assist the competitiveness of U.S. carriers but may also result in short term disruptive changes (e.g., forced usage of the metric system). The regulatory process will be more complex but public pressure for quick results will remain. (USDOT, 1997)

3.0 RELEVANT TECHNOLOGIES

Several technologies will continue to impact transportation in the next five to 10 years. Construction, condition assessment and monitoring, composite materials, transport, information, and human factors technology will touch all aspects of our transportation system. Although the list may not be all inclusive, it is intended to provide a discussion of the issues that commonly appear throughout the literature.

3.1 CONSTRUCTION TECHNOLOGY

Infrastructure systems typically require large-scale construction, which involves high-cost, capital-intensive financing and a long time to completion. Effective use of construction technology and management can reduce the time required to build or repair infrastructure, resulting in reduced costs, minimal site disruptions, and improvements in quality and safety. (Committee for an Infrastructure Technology Research Agenda,1994)

Construction technologies requiring further consideration include:

- Use of three-dimensional, spatial data-management systems and simulations for construction site management.
- Adaptation of GPS and laser and radio frequency based systems for construction use.
- Use of trenchless technology including pipe jacking, microtunneling, auger boring, pipe ramming, directional drilling, direction fluid jet cutting, percussive tools, rod pushers, and horizontal slurry drilling.
- Application of robotics, automated guidance and control of heavy equipment to enhance construction safety, especially near hazardous materials or in high-risk sites.
- Investigation of alternative contracting practices.

3.2 CONDITION ASSESSMENT AND MONITORING TECHNOLOGY

New methods of condition assessment and monitoring have become prevalent. Nonintrusive sensing technologies include electromagnetic methods, magnetometers, acoustics, ground penetrating radar, and infrared detection systems used for locating obstructions. Advanced data acquisition and management methods include remote-satellite imagery. High-precision data suitable for describing infrastructure location and condition are being acquired continuously by earth satellites. The systems may provide detailed structure assessment and/or soil and rock conditions following earthquakes, hurricanes, and heavy snow and rainfall. (Committee for an Infrastructure Technology Research Agenda, 1994)

Various materials are also being incorporated into conventional materials to create "smart materials".

3.2.1 Smart Materials

A definition for smart materials is not available in the dictionary - yet. According to James S. Sirkis, head of the Smart Materials and Structures Research Center at the University of Maryland, "(t)he materials themselves are not smart, they just provide a certain function by converting energy from one form to another," like electricity into movement or vice versa, or a chemical bond into a voltage. Smart materials and structures should be considered "a design philosophy" he went on to say, not a research discipline. (Gibbs, 1996)

Self-monitoring concrete was created by adding a small amount of carbon fibers. Electrodes were placed on each end of a bridge and the resistance measured. As cracks developed, the fibers would separate and increase the electrical resistance. With calibration, the extent of cracking could be evaluated. (Gibbs, 1996)

Fiber optic sensors that are based on optical fiber, which is literally as fine as hair, may be used to measure a wide range of effects via changes in light beams propagating through the optical fiber or devices where light is conducted back and forth via optical fibers. For infrastructure applications, important parameters that can be measured include longitudinal and transverse strain, pressure, temperature, and corrosion. (Blue Road Research, 1997)

Specific applications include:

- Measuring the forces on retaining walls to prevent slides. Fiber optic strain sensors could be placed along the length of retaining wall anchors to measure strain gradients. In addition, fiber strain sensors could be placed into the wall face to measure strain field distributions and changes in loading - in order to predict the likelihood of slides.
- Measuring transverse and longitudinal strain using a fiber optic sensor network on tunnel ceilings as well as sidewalls. Because fiber sensors can have both very long or very short gauge lengths that range from millimeters to kilometers, the tunnel designer has a wide choice of strain sensing options for the appropriate fitness monitoring system. Other possible uses for fiber optic sensors in tunnels and other structures include measuring critical points of corrosion on rebar and other reinforcing structures.
- Using fiber optic sensors to measure the amplitude of an acoustic disturbance as well as its location along lengths that may be tens of kilometers long. Systems of this type could be used to measure the location of potholes and the extent of damage to bridges and roads.
- Using arrays of fiber optic pressure sensors to perform critical geotechnical measurements such as water content of soil before, during, and after infrastructure construction operations.
- Monitoring the speed and weight of cars and trucks using an array of strain sensors embedded in roads.
- Monitoring road condition with an ice sensor. This sensor could detect ice on the road and trigger an action, such as a heated bridge deck.

3.3 COMPOSITES

America's commerce and industry depends on highways, bridges, airports, and transit systems. Unfortunately, most of the constructed facilities are deteriorating faster than renovation rates. National bridges, built in the 50's and 60's, face environmental deterioration, wear, and a need for substantial upgrades to accommodate increasing loads. More cost-effective use of the existing infrastructure, such as bridges, is more important than ever in this age of economic constraints. Composite materials offer a competitive solution to rehabilitating and strengthening our aging infrastructure. (Kachlakev, 1997)

Composites consist of high strength fibers bound together with an inert plastic resin. Primarily developed and used in the defense and aerospace industries, composites offer unique advantages in many applications, where conventional materials cannot provide satisfactory service. (Kachlakev, 1997) Stronger, lighter and environmentally friendly advanced composites and materials will revolutionize the construction, maintenance, and repair of transportation facilities, vehicles and systems. For example, the use of improved materials, combined with better vehicle design, will improve the crash-worthiness and fuel efficiency of future vehicles. The application of new materials to transportation barriers will reduce noise and the seriousness of crash damage to vehicles. (USDOT)

Composites are also well suited for bridge restoration applications. Lightweight and natural corrosion resistance are among their main advantages over steel and metal alloys. Their high tensile strength is an excellent complement to concrete properties. The ability to adhere to old concrete and be impermeable are features that make composite systems superior to high-performance concrete. (Kachlakev, 1997)

While the advantages and limitations of conventional materials are well established, the advanced composite science industry has questions to address including: how much will a composite cost and how long will it last. Properly designed and manufactured composite material systems offer superior structural performance, while being compatible with existing construction industry practices. However, consensus standards and design guidelines are necessary for composite materials to enter the construction market on a large scale in the near future. (Kachlakev, 1997)

3.4 TRANSPORT TECHNOLOGIES

There are a number of technological changes anticipated to affect transportation modes within the next five to 10 years. Automobiles are expected to get lighter, safer, more comfortable, more durable, and less polluting. Sea freighters are expected to become faster so that time-sensitive goods can be shipped with more speed and reliability. Trains will get faster and safer. The intelligent transportation systems technologies are using computer and communication technologies to improve mobility, safety, air quality, and productivity. The government role in these issues involves the promotion of integrated and seamless systems of multi-modal services for freight and passengers.

3.4.1 Modes

3.4.1.1 Automobiles

Amory Lovins, speaking on *Hypercars and Negatrips: The Next Transport Revolution,* speculates that ultralight cars are feasible, molded from advanced composites, that are safer, sportier and more comfortable, durable and beautiful than steel cars. The vehicle would be powered by a hybrid electric drive, on board power production using a range of possible technologies. The vehicles would be significantly less polluting. The hypercars would meet the public-policy goals of economy, environment, and fuel efficiency. (Lovins, 1996)

With the use of hypercars, driving could be less expensive (cheaper fuel, cheaper automobiles). The result could be more cars on the road increasing congestion problems. "Making driving nearly a pure capital cost, crashing the world oil price...and making cars seem environmentally benign ...means only that we'll run out of roads and patience rather than air and oil." Other wide-spread implications of hypercars are the likely end of the steel industry as we know it, and an acceleration of commercialization of inexpensive fuel cells that could rapidly displace existing coal-fired and nuclear power plants. (Lovins, 1996)

USDOT projects that there will be a demand for non-traditional fuels as alternative-fueled cars and trucks proliferate. Virtual reality and similar technologies could dramatically reduce automobile crash and injury rates especially among our younger and older drivers. (USDOT, 1997) These technologies are conducive to new methods of driver training and testing.

Safer cars may also provide a sense of false security keeping older drivers on the road. Even though their reflexes may be diminished, they may feel safe from other vehicles, without giving consideration to the possible damage they could cause.

3.4.1.2 Ships

During this century, international trade has become increasingly dependent on several modes of conveyance and on using them in combination. Many farsighted shippers view the coordination of different types of transportation as the last frontier in boosting productivity. They maintain that keeping pace with the burgeoning demands of international commerce will require a more efficient, synchronized pipeline across the planet – one that, like a moving warehouse, can deliver vital goods within hours of when they are needed rather than within days or weeks. (Giles, 1997)

At present, the weakest links in the supply chain are container ships – freighters that haul their cargo stacked in spacious metal containers. As did vessels built at the beginning of this century, they travel at speeds only a little faster than a running man. Although airplanes can also carry freight, sending cargo by air costs up to 10 times more than dispatching it over the water. And because of delays on land, it still takes three to six days for most airfreight to travel door-to-door between Europe and the U.S. Also, airplanes can transport only a minute fraction of all cargo. As a consequence, many perishable and other time-sensitive goods, on average worth $10,000 per ton, waste some of their valuable shelf life in transit. Other concerns, too, argue against a substantial expansion of air transport: jets flying at high altitudes release nitrogen oxides, which can harm the environment.

For these reasons, there is a revitalized interest in improving shipping. An array of new technologies--many borrowed from computer science, the aerospace industry and even America's Cup sailboats--are helping naval architects fashion fleets of faster, more reliable ships. Novel propulsion devices and hull designs may enable some of these craft to travel at twice the speed of current cargo carriers.

3.4.1.3 Trains

Over the past 30 years or so, Japan and Europe have invested heavily in networks of high-speed trains to link major cities. They have turned to fast trains, exceeding 200 kilometers per hour (kph) (roughly 125 miles), in part to relieve congestion on roads and at airports while minimizing operating costs and pollution.

Of course, for trains to live up to their financial and environmental promise, they must draw high numbers of paying passengers. The Japanese and European experience has shown that railways can often meet that demand if the rides are comfortable, competitively priced and able to deposit travelers at their destinations about as quickly as an airplane would. Aircraft still go much faster than trains, often exceeding 600 kph, but long travel times to and from airports often cut significantly into timesavings. (Raoul, 1997)

Reaching these milestones has required innovation in all aspects of railroad engineering, including the design of tracks and signaling systems in addition to the trains themselves. For instance, as speeds rose, roadside signals became useless for the drivers; the cabs went by the signals too fast. The trains are now run with guidance from onboard computers that collate information emitted from monitoring and control equipment in the tracks and in the individual cars and from dispatching stations; the computers can also force the train to stop if critical safety commands go unheeded.

3.4.2 Intelligent Transportation Systems

The goal of the intelligent transportation systems (ITS) movement is to apply modern computer and communications technologies in our transportation systems, resulting in improved mobility, safety, air quality, and productivity. ITS technologies include myriad products and services that can touch many lives in many ways, including:

- **Easier, Safer Travel** - navigation systems in cars and trucks tell drivers exactly how to get to their destination. Intelligent cruise control will automatically adjust a vehicle's speed when in traffic, reducing rear-end collisions and lowering vehicle emissions. ITS technologies can also warn drivers that they are too close to a car in the next lane or that they are in danger of running off the edge of the road. "Mayday" systems inside vehicles that automatically alert police, fire and other emergency personnel of accidents will also become widely available.

- **Quicker Emergency Response** - electronic accident detection allows trained operators to locate and judge the nature of an accident so they can quickly dispatch and guide the right emergency personnel and equipment to the site.

- **Better Travel Information** - information centers provide up-to-date, real-time details on bus, transit and train arrivals and other travel information through various mediums including cable TV, the World Wide Web, kiosks and electronic message boards.

- **Improved Traffic Flow** - drivers with a toll debit card attached to their vehicles can travel through toll plazas without stopping. Toll charges are deducted automatically from a prepaid account. Other travel fare collection systems, such as smart cards, allow subway fares, transfers and other fees to be charged to one card.

- **Fewer Traffic Jams** - traffic management centers reduce traffic jams and speed travel by continuously monitoring current conditions and adjusting speed limits, traffic signals and roadway ramp access.

- **Improved Fleet Management** - bus, freight and emergency vehicle tracking systems allow supervisors to track vehicles and to communicate directly with drivers.

- **Faster and Safer Freight Deliveries** - ITS provides for electronic weighing and inspection of commercial vehicles while in motion, electronic issuing and monitoring of transportation permits and automatic tracking of containers.

Innovations both inside and outside the vehicle will improve safety by checking a driver's vision and motor skills, providing on-board signing and vision enhancements, warning of vehicles and other obstacles in a blind spot and preventing vehicles from hitting other objects on the road through vehicle control and warning systems. (Intelligent Transportation Systems)

3.4.3 Government Role

More and more, governments and other transportation-related organizations are becoming involved in multi-modal issues. They act as a forum to promote an integrated and seamless system of multi-modal services for freight and passengers. Many groups are acting as central guides to improve harmonization of transportation policy among agencies and firms – local, national, and international. For example, the Intermodal Association of North America and the Eno Transportation Foundation jointly publish the *Intermodal Freight Transportation* book (http://emporium.turnpike.net). This 270-page book presents a comprehensive overview of freight intermodalism. It describes many aspects of intermodalism, including terminal operations, transport equipment, containerization, documentation, liability rules, and communications technologies. Interrelationships between modes, shippers, third parties and government agencies are candidly discussed, including an array of trends and changes occurring within the industry.

Canada has organized the Multi-Modal Council that works on intercity, multi-modal and multi-disciplinary transportation issues within Canada and North America. Members of the council include representatives of governments; shippers, motorists, tourists; truck, rail and air carriers; airports and seaports; research and academic communities. (www.tac.atc.ca)

The Georgia Department of Transportation is currently the sponsor for the Multi-Modal Passenger Terminal in Atlanta. This terminal will serve several modes of transportation including Amtrak, commuter rail, intracity passenger rail, rail freight, intercity busses, MARTA rapid rail and bus, taxis, rental cars, and pedestrians. There will be plenty of parking and retail stores in the terminal itself. (www.dot.state.ga)

3.5 INFORMATION

Information technology has dramatically changed over the last 20 years. The availability of databases, amount of information available electronically and power of analysis software has increased tremendously. There is now greater access to more information for more users. Governments are a rich source of data and other information being used by business and the general public.

Information technology is bringing about a "great reversal" in which the dependence of communication and information on transportation is being reversed--leading to a time where transportation will be dependent on information (Alt, et al, 1997). The impacts on businesses and the motoring public are significant. Information technology impacts business operations by lowering costs. Businesses are able to maintain less inventory with just-in-time deliveries, schedule processes better and provide improved customer service with up-to-date freight location information (IBM, 1996).

Information technology also impacts the motoring public. Access through the Internet provides real time information on road and weather conditions by description and visually by camera. In some areas, vehicle computers obtain real time information on traffic congestion and/or construction impacts allowing the driver to make decisions on time-saving routes. The increased use of information technology will make all transportation vehicles (and possibly roads) smarter and potentially safer (ASME, 1996).

3.5.1 Dissemination

Significant changes are taking place in information technology that affect every transportation professional. Efficient and effective access to required information is crucial for transportation professionals to perform their job well. There are a number of sources available to transportation professionals (Rathbone, 1997):

- **Paper sources:** reports, journals, trade magazines: only 2.5% of the available journal articles are read (similar statistics on trade magazines and reports are not available). Since so few articles are read, it is important for a transportation professional to select articles that will be of most use.

- **Conferences:** a 1992 survey indicated that the average number of conferences attended by transportation professionals is 3.2. Considering that 110 national conferences were held in the U.S. in 1995, transportation professionals have access to only 2.9% of available national conferences.

- **Databases:** in 1995 the Bureau of Transportation Statistics reported 37 databases directly related to urban surface transportation. No information is currently available on the usage of the databases.

- **Electronic bulletin boards:** twelve transportation related bulletin boards have been identified in the U.S. and on average 38 people access one a day.

- **Mailing lists:** sixteen transportation related mailing lists have been identified, which have about 290 subscribers.

- **WWW sites:** extensive searching estimates there are 250 transportation related web sites in the U.S. They are accessed an average of 590 times a day from Internet users in and outside the U.S. From this it is estimated that 5.1% of transportation professionals access these web sties on average. Use of this medium is expected to grow in the future.

One strategy proposed for improving information dissemination involves using the Internet to create electronic journals that make it easier for practitioners to publish and get peer review. Monetary incentives, such as charging readers to access papers, could significantly increase the number of papers produced by consultants and government officials.

3.5.2 Management

Another component of information technology is information management. Information collected over the service life of facilities can document current status, simulate future performance, project and evaluate trends in demand and usage. As data acquisition, management, and analysis capabilities increase – in addition to advances in measurement, computation, and communications technology – the amount and quality of data increases. A gap exists, however, between information management and infrastructure development, one that must be narrowed. (Committee for an Infrastructure Technology Research Agenda, 1994)

3.5.3 Government Role

An additional aspect of information dissemination is the role of government. In the era of electronic communication, people expect public information to be available in this new medium. There is increasing pressure for government agencies to have all data and publications available electronically. Some agencies are just getting online and the transition from paper to computer will take time. As demand for this service increases, the task of making information available electronically will become a higher priority. (Rathbone, 1997)

3.6 HUMAN FACTORS RESEARCH

In the blink of an eye, technology can perform literally hundreds of tasks that would take a human operator hours to perform. Often, though, such systems are designed with only scant attention to how the people responsible for their operation interact with them. Systems designed without adequate evaluation of their human interface can lead to operator error and sometimes disastrous consequences. As the use of advanced technologies in transportation becomes more widespread, we also must take into account how the human operator interacts with these systems. The field of human factors research deals with the interaction between people and systems, and attempts to understand how system design can influence operator performance. Also, human factors research can help delineate appropriate functions for humans and machines. It helps designers of machines create products and systems that allow their human operators to achieve the greatest possible benefit with the least risk to their health and safety. This work supports the development of more user-friendly systems and will lead to a reduction in accidents attributable to human error. There are a number of applications of human factors research in the transportation industry. (Volpe Transportation Journal, 1997)

3.6.1 Aeronautics

Flying a plane requires a pilot to continuously monitor information from a number of sources – radioed instructions; cockpit instruments indicating air speed, altitude, and heading; approach charts and local protocols. Human factors research has revealed flaws in communication systems between controllers and pilots and changes have been made to reduce the chance of communication errors.

3.6.2 Rail

Human factors issues facing locomotive engineers and dispatchers in the operation of high-speed trains are somewhat different from those facing pilots and air traffic controllers. The system-operator interface issues for high-speed rail travel stem from the need to keep the engineer actively involved in running the train – even during highly automated operations – to ensure that rapid human intervention is possible in the event of system instability. Rail simulators are currently being used to assess the ideal balance between automation and manual control.

3.6.3 Automobiles

Involvement of human factors issues with respect to automobile accidents has been recognized for years. New ways of collecting accident data will reveal human factors related to accidents that were not previously apparent under traditional data collection methods . Urban areas have higher rates of injury crashes than rural areas on the basis of VMT. Insurance claim frequencies per insured vehicle year for both injuries and vehicle damage increases with urbanization. Traditional databases with crash information provide little detail regarding pre-crash actions necessary for classifying crash events. New methods of data collection will provide the information needed to reduce numbers of accidents. There are five dominant crash types: ran-traffic-control crashes; stopped or stopping; ran-off-of-road; lane-change; and left-turn crashes.

Specific changes can be made to reduce these accidents. As this data is collected and patterns revealed, counter measures will be put in place to reduce motor vehicle crash losses.

4.0 SURVEY

4.1 SURVEY RESPONSE

A brief survey was conducted by the Policy/Research Section in October of 1997. The survey was sent to approximately 2,000 e-mail addresses within ODOT. In addition, over 700 surveys were mailed to regional ODOT personnel, local governments, vendors, and other transportation-related parties. 665 surveys were returned, 463 by e-mail, 190 via mail, and 12 over the phone. The survey asked participants to identify issues they believe would affect Oregon's transportation system over the next five to 10 years. Participants were also asked to identify areas that need research. The survey we sent out follows:

What Do You Think?

We (Policy/Research Section) are trying to identify the critical issues that may affect transportation in the next five to 10 years. We need your help so that all areas are identified. Please take a minute to respond to the questions below. We will use the information to help develop strategic plans for future research. Thanks for your input!

1. The two most important issues affecting Oregon's transportation system in the next five to 10 years will be:

(1)

(2)

2. The single most important thing that needs research is ______________.

3. I have worked for the state of Oregon/ in the transportation field for _____years.

4. The agency/branch I work in is _______

On average, respondents have worked 14.5 years in the transportation field or related industry. The average years of experience by response category does not differ much from the overall average of 14.5 years. Most of the respondents came from ODOT employees, but 28% of the them were from non-ODOT people. Figure 4.1 presents responses by agency. Within ODOT, the largest proportion of respondents came from the regional offices. More detail of ODOT respondents by branch is provided in Figure 4.2. Table 4.1 lists the names of the agencies that participated in this survey.

Figure 4.1 Agencies Represented by Survey Respondents

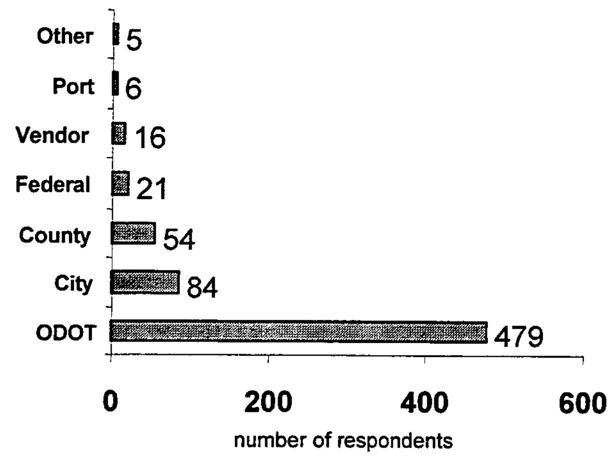
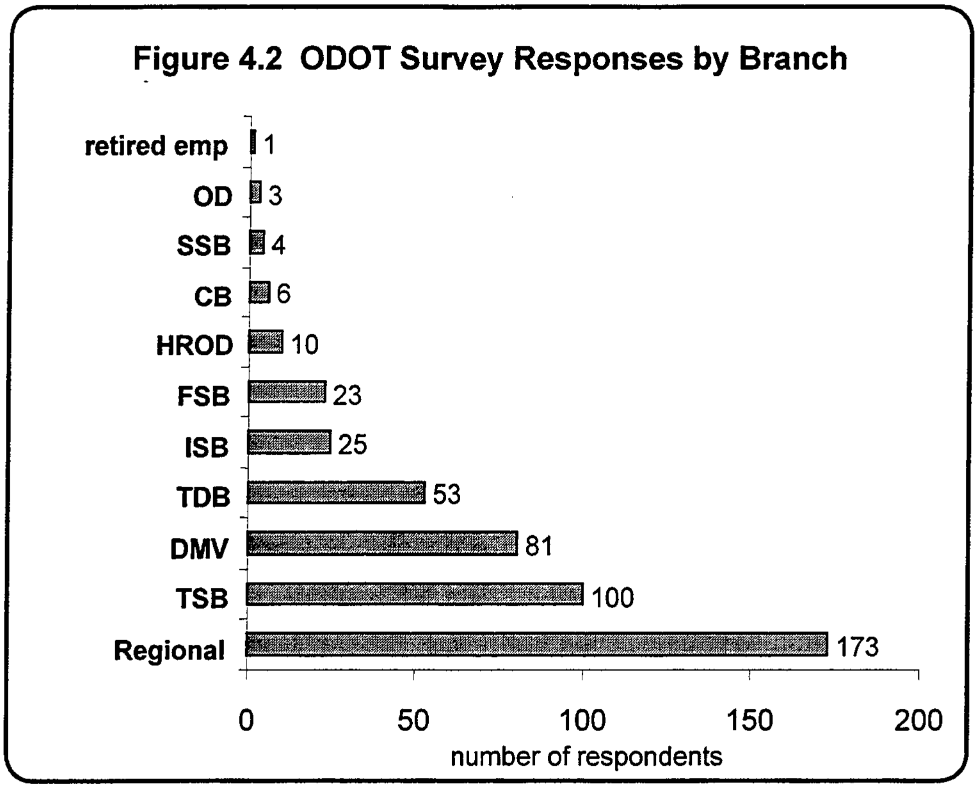
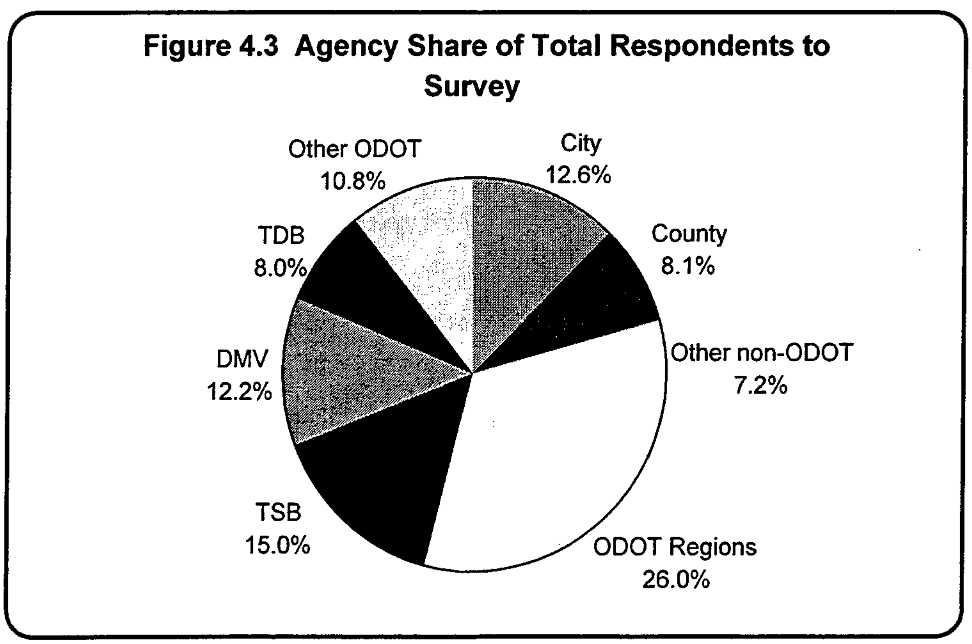


Table 4.1 Agency Branch Names	
OD	Office of the Director
SSB	Support Services Branch
CB	Communications Branch
HROD	Human Resources/Organizational Development
FSB	Financial Services Branch
ISB	Information Services Branch
TDB	Transportation Development Branch
DMV	Department of Motor Vehicles
TSB	Technical Services Branch
Federal	Includes: Bureau of Land Management, US Forest Service, Dept of Environmental Quality, and Federal Highways Administration



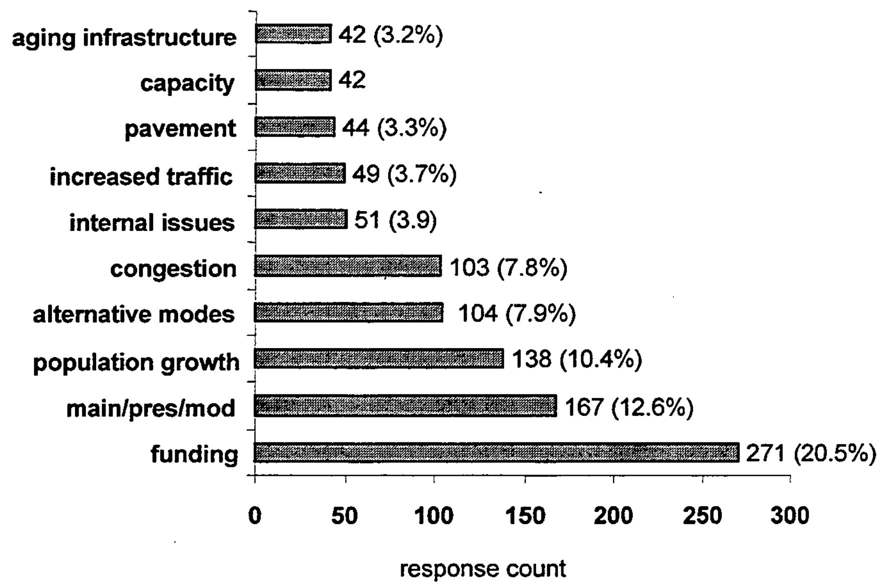
In general, we expect categorical responses to follow the same proportionate mix as respondents by agency in the overall sample. For example, of the respondents listing funding as an issue of concern, about 12.6% are expected to be from cities, 8.1% from counties, 26% from ODOT regional offices, etc. If there is a concern of greater importance to particular agencies, it should be revealed by the distribution of the respondents by agency within that issue category. Figure 4.3 provides a proportional breakout of respondents' agencies illustrated in Figures 4.1 and 4.2. This is useful for the comparison analysis of questions one and two that follows.



4.2 QUESTION ONE

Question One of the survey asks respondents to list two issues considered most important to Oregon's transportation system in the next five to 10 years. Over 75% of the responses fell into 10 categories. These categories are presented in Figure 4.4. A complete list of the response categories is provided in Table 4.2 at the end of this section.

Figure 4.4 Question One Tally: What issues will be important within the next five to ten years?



The variable *funding* refers to respondents stating "funding" or "sources of stable funding" as an issue. Of the people that identified funding as an issue, 58% of them work for ODOT regional offices, 18% for cities, and 13% for counties (covers 89% of responses). Proportionately more respondents from these three groups are concerned with funding. Recall that it was expected that 26% regional offices, 12.6% cities, and 8.1% counties would be the response distribution (see Figure 4.3).

The variable *main/pres/mod* includes responses of "maintenance," "preservation," "modernization," or some combination of the three categories. Of those identifying maintenance/preservation/modernization as important issues, 25% work for TSB or DMV, 24% for ODOT regional offices, 17% for cities, and 9% for counties (covers 75% of responses). Proportionately more respondents from cities are concerned with these issues.

Population growth includes responses "too many people, people moving to Oregon, growth management, and population growth." Thirty-eight percent of respondents choosing population growth as an issue work for TSB or DMV, 28% for ODOT regional offices, and only 8% work for a city or county (covers 74%). Proportionately more respondents working for TSB or DMV are concerned with population growth.

Forty-five percent of respondents choosing *congestion* as an issue work for TSB, DMV, or TDB; 22% for ODOT regional offices, and 15% for cities or counties (covers 83%). Respondents from TSB, DMV, or TDB are proportionately more concerned with congestion.

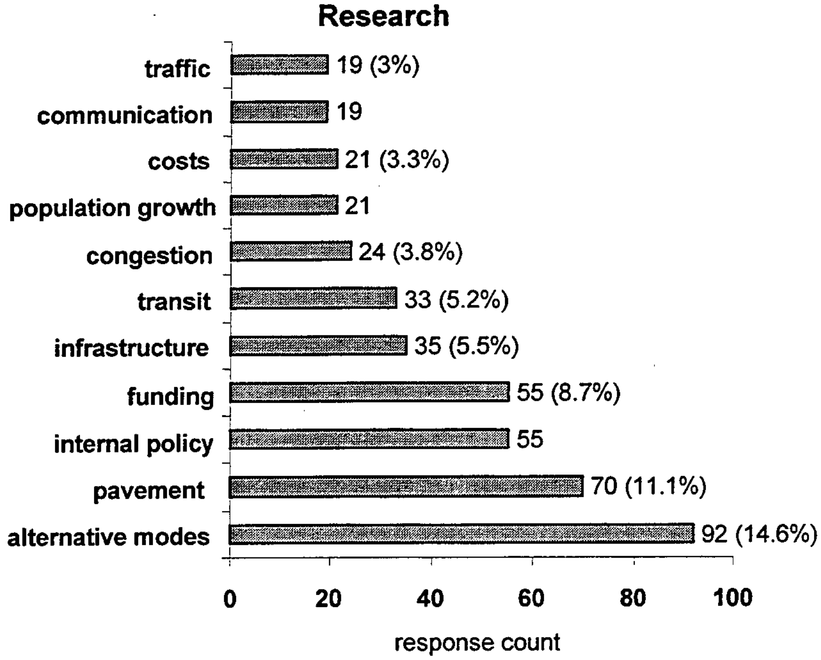
Alternative modes includes responses like "transit, more buses, I-5 corridor transit, high speed rail, increase vehicle occupancy, electric cars, telecommuting, more carpooling, expanded light rail, rural public transit, and creating incentives for people to use modes other than cars." Of the people that identified alternative modes as an issue, 39% work for TSB or DMV, 19% for ODOT regional offices, and 11% for cities or counties (covers 69%). Proportionately more respondents from TSB or DMV are concerned with alternative modes as an issue.

The size of the reporting groups shrinks considerably in the remaining categories, inhibiting analysis. However, there are no obvious patterns in the remaining response groups.

4.3 QUESTION TWO

Question Two of the survey asks respondents to list the most important topic that needs research. Figure 4.5 illustrates the 631 responses received. The 11 categories listed in Figure 4.5 represent over 70% of the research issues identified in this survey. In addition, there were other responses including: safety, environment, capacity, efficiency, ITS (Intelligent Transportation System), tax system, new technology, land use, and access to name a few. A complete list of the response categories is provided in Table 4.2 at the end of this section.

Figure 4.5 Question Two Tally: Issues that Need Research



Variable categorization follows a similar pattern as used in question one. *Internal policy* includes responses: quality of personnel, salary structure, merit pay, contractor incentives, management policy or organization, use of common sense in policy, and professional and courteous service to customers. A number of respondents distinguished between *mass transit* and *alternative modes* so they were separated within the research needs analysis.

Most of the responses to question two follow the same proportional mix as respondents by agency in the overall sample. See figure 4.3 for the distribution of respondents by agency. However, there are a few exceptions. Of the 70 respondents listing *pavement* as an issue, 21% were from cities and 12.8% were from counties. There was also a disproportionately large mention of researching new sources of *funding* by city respondents. County respondents reported a proportionately higher level of *infrastructure* research need. Finally, cities mentioned *congestion* needing research a proportionately greater number of times.

It is worth mentioning a couple of comments provided by respondents. Most survey comments were short but a few provided some interesting detail. One respondent, a contractor who works with Washington DOT, described an annual review process done in cooperation between Washington state and contractors/vendors. At the end of each construction year state representatives and contractors meet and review projects from the preceding year. They discuss what worked and what didn't and devise solutions and strategies to be considered for the next construction year. The respondent reported he was initially pessimistic towards this idea, but admitted it has saved a lot of time and money since being instituted. It has also greatly improved the working relationship between contractors and state representatives. They work more like a team now. He strongly recommended a similar process for Oregon. He also noted that some states, Florida in particular, are starting to include a maintenance provision in their contracts. This is expected to increase the quality of road construction.

A respondent also commented on policies and rules that are impractical and waste money. His example was the allowable number of gravel trucks from out of state working in Oregon. He was on a job near the Washington border where there was a shortage of Oregon gravel trucks but a surplus of Washington trucks. There was something in the regulations that did not allow the contractor to use the Washington supplier which raised the cost of that part of the job significantly and created three days of idleness. He stressed that rules and regulations must relate to minimizing the cost of construction and increasing the quality of the product. It is too expensive to worry about political boundaries.

4.4 RESPONSE COUNTS

We received a rich set of response categories. The following Table 4.2 presents all of the response categories and counts received, for those interested in this much detail.

TABLE 4.2 COMPLETE COUNT OF RESPONSES BY CATEGORY

Question One: Issues	Count		Question Two: Research Need	Count
Funding	271		alternative modes	92
main/pres/mod	167		pavement	70
Population growth	138		internal policy	55
Congestion	103		funding	55
Alternative modes	93		infrastructure	35
internal issues	51		transit	33
increased traffic	49		congestion	24
Pavement	44		population growth	21
Capacity	42		costs	21
aging infrastructure	42		communication	19
access management	33		traffic	19
Safety	30		safety	16
public image	25		environment	15
land use	21		capacity	15
Environmental quality	15		efficiency	15
agency efficiency	15		ITS	12
public education	12		tax system	12
Alternative modes incentives	11		new technology	11
traffic mix	10		land use	10
Coordination between agencies	10		access	10
level of service	8		rapid transit	7
Planning	8		planning	7
Speeding	8		materials	5
Legislative support	8		multimodal	5
Drainage	7		pollution	5
Pollution	7		modes	5
tax system	7		demographics	4
new technology	7		drainage	4
Multimodal interface	7		fuel	3
timely service	6		trips	2
Bridges	5		speeding	2
Livability	5		right of way	2
Community involvement	4		construction	2
natural disasters	4		level of service	2
heavy loads	4		enforcement	2
creative solutions	4		local	2
Prioritization	4		emergency	2
Ports	3		human factors	1
trip making behavior	3		image	1
Nonmotorized vehicles	3		partnerships	1
mass transit	3		response time	1

TABLE 4.2 CONTINUED

Question One: Issues	Count		Question Two: Research Need	Count
public private partnerships	2		morale	1
public communication	2		weight	1
reasonable regulations	2		bids	1
erosion	2		auto misc.	1
ITS	2		trucks	1
weather	2		waterways	1
enforcement	2		Total	631
alternative fuels	1		Missing values	34
sources of aggregate material	1			
right of way	1			
special interest groups	1			
vehicle occupancy	1			
quality of service	1			
driver license restrictions	1			
earthquake retrofits	1			
Port depth	1			
no mass transit	1			
internal policy	1			
demographics	1			
Total	1323			
Missing values	7			

5.0 SUMMARY

As Oregon's population continues to grow, we are faced with balancing a long list of infrastructure needs with limited funding. Complicating the growth issue are the required considerations of all travel modes, of a global economy and of possible environmental impacts. New business practices will change the way we interact with the motoring public. Businesses will depend on ODOT to guarantee a smooth flow of products by providing safe, connected, and intelligent transportation systems. The federal government will assist by allowing more control at the state and local levels.

Fortunately, the technology exists to meet most public expectations. Improved construction technology will reduce time requirements; smart materials will provide continuous condition assessment feedback; composite materials will provide an effective means to rehabilitate our bridges; automobiles, ships, and trains will continue to improve and compete in the global economy; and intelligent transportation systems (ITS) will provide safer travel and improved efficiency within our system. Inherent in these technologies are information and human factors. We must understand how we learn, disseminate, manage, and apply information to the greatest advantage. Also, we must incorporate human factors into our technology to optimize application.

Technology will continue to grow as faster, stronger, and/or better tools are developed. Not all technologies will be appropriate for Oregon. However, we are charged as an agency to determine prudent uses to meet expectations… and to keep up with the changing world.

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