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A literature review, surveys, and data analyses indicate that paving gravel roads may raise property values and vehicle speed. Paving has little effect on traffic volume, economic development, employment, tourism and recreation. Evidence from testing an empirical model suggests that paving may reduce fatal accident rates. However, this finding may also be attributable to safety improvements which often accompany paving rather than the paving itself. Because there are a number of plausible explanations for this finding, the issue should receive further study.

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Socioeconomic and Environmental Impacts of Paving Gravel Roads

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April 26, 2002

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Socioeconomic and Environmental Impacts of Paving Gravel Roads

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ABSTRACT

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A literature review, surveys, and data analyses indicate that paving gravel roads may raise property values and vehicle speed. Paving has little effect on traffic volume, economic development, employment, tourism and recreation. Evidence from testing an empirical model suggests that paving may reduce fatal accident rates. However, this finding may also be attributable to safety improvements which often accompany paving rather than the paving itself. Because there are a number of plausible explanations for this finding, the issue should receive further study.

SUMMARY OF FINDINGS

Environmental Impacts

The primary impacts of the environmental factors discussed in this report are summarized below.

- Unpaved roads are a significant source of dust. Dust impacts affect air quality, water quality, aquatic habitat, and aesthetics. Dust suppression treatments can be very effective in reducing road dust, but they may also have impacts. Paving an unpaved road can reduce dust generation up to 99 percent.
- Stormwater runoff is a primary source of contamination to waterbodies and waterways. Contaminants include sediment, road surface treatments, substances added by vehicles, and applications and treatments to control pests and fertilize vegetation. There is a large volume of runoff data for both unpaved and paved roads, but only one of the studies reviewed compared pollutants in stormwater runoff from gravel and paved surfaces.
- Factors affecting road noise include road surface, pavement age, tire type, vehicle speed, vehicle type, and traffic volume. No studies were located that compared noise generated from paved surfaces with noise generated from unpaved or gravel road surfaces, and no studies relating specifically to noise and gravel or unpaved roads were found.
- Most animals appear to be susceptible to the dangers of roads and many are killed annually on roads. Most studies reviewed compared road kill generated by roads with the lack of road kill generated by no roads. Few studies compared road kill of paved roads with gravel roads, however these few studies did suggest that road kill is a factor for both paved and unpaved roads. Paved roads generally have greater speeds, which decrease driver response time and result in greater vehicle to animal collisions. However, gravel roads with lower average speeds tend to have smaller rights-of-way, which decrease visibility for drivers and animals alike.
- Loss of habitat, road aversion by certain species, and roadside barriers are some of the factors that create habitat fragmentation for many species. Most studies compared habitat fragmentation generated by roads with the lack of habitat fragmentation generated by no roads. Few studies compared habitat fragmentation of paved roads with gravel roads. These few studies did suggest that habitat fragmentation is species specific, and the wider the road (generally paved roads) the greater the habitat fragmentation.
- Roads constructed on permafrost are susceptible to frost action and thaw settlement during freeze and thaw cycles. Some studies suggest that paved surfaces tend to be warmer than unpaved surfaces, and that paved roads require thicker embankments to counter thaw settlement.
- No studies were located that compared project footprints from paved roads with project footprints from unpaved or gravel roads, and no studies relating specifically to project footprints and gravel or unpaved roads were found. Most

studies compared the effects of the project footprint of areas with roads to areas without roads.

- A paved road may require more fill material than an unpaved road, depending on terrain and the embankment material quality. Surfacing and subsurface materials in Alaska are generally considered to be of poorer quality and tend to degrade more quickly.

- Improving access to areas increases the potential for habitat modification and destruction. The studies reviewed focused on impacts from off-road-vehicles (ORV's). ORV's can be environmentally damaging to vegetation, and permafrost soil and there is a growing body of literature documenting their negative effects.

Socioeconomic Impacts

A literature review, analysis of survey responses, and the results from estimating empirical models of traffic accidents and volume yield six conclusions on the impact of paving gravel roads.

- Several versions of an empirical model of traffic fatalities indicate that fatality rates are significantly higher on unpaved roads (gravel and dirt) than on paved roads in the Central Region of the Alaska Department of Transportation and Public Facilities (ADOT&PF). The same finding occurs for the Northern Region for one version of the empirical model. This result may indicate that paved roads are safer, due to better vehicle control perhaps, but it may also be attributable to the fact that paved roads are generally straighter, flatter, wider, and have better guardrail, signing, and lighting than gravel roads. Thus the result ought to be regarded as suggestive of the need for further investigation rather than definitive.
- Evidence from a sample of roads in the Central Region of the ADOT&PF suggests that paving roads does not generally result in increased traffic volume.
- Although no 'before and after paving' speed studies have been conducted in Alaska, the belief among most Department of Transportation officials contacted in Alaska and other states is that vehicle speeds tend to increase after a gravel road is paved even in the absence of road design changes.
- Tax assessors and property appraisers estimate that the value of an undeveloped acre of land bordering a gravel road would increase by between 0 and 15 percent in the Southeast and between 5 and 17 percent in the Central Region of the state. Appraisers in Fairbanks were less forthcoming with numerical estimates but generally suggested that paving caused only a slight, if any, increase in property values.
- Paving of gravel roads has no measurable effect on economic development in a community.
- Low cost methods of benefit-cost analysis could be used to prioritize potential paving projects and to evaluate program effectiveness.

CHAPTER 1 – INTRODUCTION AND RESEARCH APPROACH

Problem Statement and Research Objective

The ADOT&PF is continually seeking ways to reduce the cost of constructing and maintaining roads and highways in Alaska and reducing the environmental impacts of these facilities. The Department prefers to pave gravel roads to meet these objectives but there are limited data on the socioeconomic and environmental impacts of paving gravel roads. The absence of such data makes it difficult to respond to comments regarding the potential impacts of paving on traffic volumes, land use, tourism, wildlife, community character and capacity, and similar topics. The inability to adequately respond to these comments results in delays in implementing projects that would reduce maintenance costs and improve roadways.

The objective of the research is to develop information that will allow ADOT&PF to respond to questions and comments from the affected public about the effects of paving gravel roads. The relevant information includes air, water, and wildlife impacts; effects on property values and local economic development; and the implication for traffic safety and volume.

Scope of Work

In order to document project needs and impacts during the development of gravel road paving projects, ADOT&PF wishes to have qualitative and quantitative information on the socioeconomic and environmental impacts and the cost effectiveness of paving gravel roads in Alaska. This information is to be provided in a format to facilitate incorporation into the project environmental documents.

Research Approach

Three general methodologies are employed in assessing the environmental and socioeconomic aspects of gravel road paving projects:

- Data collection and reporting
- Empirical analysis
- Literature review

For many of the issues of interest to ADOT&PF there is a paucity of data. Very few studies directly address either the environmental or economic impacts of paving. The following subsections describe the methods pursued to assess the environmental and socioeconomic impacts of paving gravel roads.

Environmental Impacts

The primary method for locating information about the environmental impacts of paving gravel roads was on-line data searches and, where accessible and available, obtaining a full copy of the citation. The initial focus of the search was on obtaining quantitative, comparative data. However, virtually no studies comparing environmental impacts of unpaved or gravel roads and paved roads were located, and no before- and after- research was located. The search was widened to any information about the differential environmental impacts associated with gravel/unpaved roads and paved roads. This yielded more information; however, the applicability of much of it to the low traffic volume, public roads that are typical of Alaska is questionable.

The subject that yielded the largest amount of information was dust, followed by water quality-related issues. At the other end of the scale, no useful information on noise associated with gravel/unpaved roads was found.

Databases searched included the following:

- ADOT&PF's web site: http://www1.dot.state.ak.us
- Alaska Resources Library and Information Services (ARLIS) database: http://lexicon.ci.anchorage.ak.us
- EPA's Office of Air and Radiation web site: http://www.epa.gov/oar
- UAA/APU Consortium Library
- USDA Forest Service web site: http://www.fs.fed.us/news/roads
- US Department of Transportation's National Transportation Library – TRIS Online
- Washington State Department of Transportation web site: http://www.wsdot.wa.gov

Federal agencies' web sites with databases that could have yielded potentially useful information but were not in operation at the time of the study included the Bureau of Land Management, the National Park Service, and the US Fish and Wildlife Service (US Department of Interior agencies).

Social and Economic Impacts

In order to assess the socioeconomic impacts of paving, data were collected from online databases such as the Fatality Analysis Reporting System (FARS) and ADOT&PF sources such as the records for completed paving projects and the Highway Analysis System (HAS). The HAS is the internal accident records database for ADOT&PF. The FARS data on traffic fatalities and accident data from a sample of ADOT&PF Central Region roads are analyzed for differences in accident and fatality rates and traffic volume flows attributable to the paving of gravel roads.[1] In addition, surveys of Department of Transportation (DOT) officials in other states and surveys of property appraisers and tax assessors in Alaska were conducted to generate quantitative and qualitative information. These data are summarized and reported in tables and figures in the text. Finally, relevant

[1] The Alaska Department of Transportation and Public Facilities has divided the state into three regions: Southeast, Central, and Northern which loosely correspond to the geographic areas of the state. The Southeast region includes the Alaska 'panhandle,' the southeastern coastal area bordering Canada. The Central Region includes the city of Anchorage, part of south central and much of southwestern Alaska, and the Aleutian chain. The Northern Region encompasses everything else including Fairbanks, central Alaska, and eastern Alaska except for the panhandle.

published and unpublished studies from state, national, and international sources were located through online search tools such as Ingenta (http://www.ingenta.com/) and EBSCOhost (available through the Loussac Library in Anchorage, http://lexicon.ci.anchorage.ak.us/aml/onlinedatabases.shtml) as well as more general online search engines.

CHAPTER 2 – FINDINGS

State-of-the-Art Summary

The overwhelming picture that has emerged from our search of the databases managed or maintained by ADOT&PF, USDOT, EPA, USDA, and UAA is that very few studies have been done that provide comparative research into the environmental impacts of paved and gravel roads.

The case studies located for Alaska were limited to several studies along roads in Prudhoe Bay developed in support of the Trans-Alaska Pipeline and several reports that considered the economics of gravel roads and the effectiveness of different types of dust palliatives. None of these studies provided comparisons between unpaved and paved roads, but they did provide information on the effects of dust from unpaved roads. This was true for studies at both the national and international level. By far the most well documented impact of gravel or unpaved roads that could be compared with paved surfaces were the effects of dust. There were numerous studies that looked at the environmental impacts of roads versus non-roads, but little was found comparing unpaved and paved roads. Factors for which little or no comparative information was found included noise, project footprint and material sources, improved access, and habitat loss from secondary impacts. Vehicle emissions were not considered as part of this study.

Very few studies have been conducted on the socioeconomic effects of paving gravel roads in other parts of the United States. There are several studies on traffic safety and low volume roads. Most of the studies on gravel or dirt roads financed by state departments of transportation, the US Department of Transportation and other agencies, however, have focused on design and maintenance issues.

State DOT officials who responded to the survey on socioeconomic aspects of paving gravel roads generally regard paving as either a low priority or not a priority for their departments. Just one respondent thought that such paving was a moderately important objective. These responses probably reflect the small amount of unpaved, state-maintained road mileage in these states. None of the states has an extensive network of unpaved, state-maintained roads. One state has somewhat more than 200 miles of unpaved, state-maintained roads. The others have less than 100 miles of such roads. It is not surprising that the Departments of Transportation in other states have little interest in the environmental and socioeconomic consequences of paving when they have so few miles of state-maintained, unpaved roads. In the states from which survey responses were received, almost all unpaved road mileage is maintained locally. Individuals from five of the responding states indicated that there are between 15,000 and 80,000 miles of unpaved, locally maintained roads in their states.

As a consequence many of the findings of this research are based upon inferences that are drawn from studies which either address the effects of road projects, generally, or address unpaved roads but were conducted in other countries. In a few areas, notably traffic accidents and traffic volume, there are data available for Alaska and these data are analyzed to determine the possible effects of paving on accident rates and traffic volume. Finally, survey responses from Alaskan appraisers and borough tax assessors provide information on property value changes associated with paving gravel roads.

More detail on the study findings is presented in the following sections. Findings from the environmental assessment are present first. Those from the socioeconomic portion of the study follow.

Environmental Findings

The environmental factors discussed below include dust-related air quality impacts, water quality, noise, road kill, habitat fragmentation, permafrost, project footprint, material sources, and secondary environmental pressures attributable to improved access.

Dust-Related Air Quality Impacts

Dust on unpaved roads is generated when vehicles travel across the surface and also when the wind is blowing. Vehicle wheels pulverize the road surface material into a suspendable particle size. The wheels lift particles off the surface, and the wake of the vehicle continues to influence the suspended particles after the vehicle has passed. Dust on paved roads comes from unpaved shoulders and from materials deposited on the paved surface.

Gucinski et al's list of dust impacts includes a reduction in visibility and the suspension of airborne particles that can be hazardous to health. Smaller particle dust can remain airborne for a long time and be transported long distances by the wind. Inhalable particulate matter can accumulate in the respiratory system. Particles less than 2 microns in diameter have been found to contribute to human health problems, increased mortality especially in the young and old, and in people with respiratory problems. Reduced visibility can also have negative impacts on aesthetics and recreational values. The report noted that the effects of the amount of road maintenance on unpaved roads on dust emissions were not well understood.

The US Environmental Protection Agency (EPA) has established air quality standards for particulate matter less than 10 microns in size (PM-10) generated from unpaved roads. The EPA's *Compilation of Air Pollutant Emission Factors* for unpaved roads (AP-42, Section 13.2.2) indicates that dust emissions from unpaved roads vary linearly with the volume of traffic traveling along the road (EPA 1998). Other factors include road condition, road length, traffic characteristics (volume, type, weight, number of wheels, speed, tires width etc.) number of vehicle passes, the silt and moisture content of the road surface material being disturbed, particle size distribution, and climatic conditions (Reckard, 1983, Succarieh 1992, Bennett 1994).

AP-42, Section 13.2.2 (EPA) provides an equation for estimating an emissions factor for unpaved roads. The report discusses emission control technologies for controlling and reducing particulate emissions. Source reductions, surface treatments, and surface improvements are described. Paving is listed as a highly effective surface improvement, with an estimated control efficiency of 99 percent for coarse air particles (PM-10).

Paved roads still have dust generation potential. A study of particulate emission rates for unpaved shoulders conducted by Hoosmuller et al (1998) looked at developing an empirical estimate of particle emissions. The study focused on developing a measurement methodology, identifying the mechanisms that suspend dust, and quantifying PM(10) emissions in an emission rate. Observations indicated that large vehicles (traveling over 50 mph) generated significant dust entrainment. In another study that looked at highway runoff in Washington State (Wick et al), the authors theorized that solids adhering to vehicles traveling on unpaved roads can be released on highways, providing a source of dust.

An Alaskan study (Auerbach et al, 1997) suggests soils with a low pH are more susceptible to road construction and dust impacts than soils with higher pH. The effects of roads on snow pack include increased drifting in the lee of the road and earlier melt-out near the road due to a dust induced change in albedo.

Few studies reviewed looked at dust dispersal. Several reports authored by Miller and Alexander looked at the effects of road development and operations associated with construction of the Trans-Alaska Pipeline. Road dust was one of the three main impacts observed. Using dust captured in traps and dust deposited on Sphagnum, they found that dust decreased as distance from the road increased. Dust settlement was greatest in the downwind areas of the road alignment. The results showed that the dust also exerted a noticeable affect on Sphagnum near road areas, where large patches of dead and dying moss were observed.

As part of a study to identify the major impacts of the West Road at Prudhoe Bay, Klinger et al (1983) conducted a dust study to measure the quantity and quality of dust falling on experimental plots. The study found that the main dust impact occurred within 100 feet of the road. Total dust volumes were considered too low to have much effect on vegetation, but it was theorized that the carbonates in the dust could cause changes in acidic tundra over the lifetime of the road.

Another report (Zachel, 1986) summarizing dust data collected as part of ongoing annual monitoring activities along the West Road at Prudhoe Bay showed similar dispersal results to earlier studies. Fallout decreased rapidly as distance from the road increased. The report noted that daily average fallout was substantially greater in summer than winter, and that winter fallout patterns were different to those in summer, however no reasons were given.

Road dust can be controlled with the application of dust suppressants. Dust suppressants fall into four main categories: water absorbing, organic petroleum, organic nonpetroleum, and synthetic polymer emulsions. Suppressants are effective at controlling dust, but little information is available about their environmental impacts (Las Vegas Stormwater Quality Committee 2001). The interim findings from an ongoing research project undertaken to collect quantitative water quality and dust data from unpaved roads suggested that runoff from treated road surfaces was impacted (Sanders et al 1993).

A report on controlling dust emissions (Succarieh 1992) looked at different methods for suppressing dust on unpaved roads. Suppression alternatives discussed included paving, traffic control, and chemical stabilization (water and wetting agents, hygroscopic and deliquescent chemicals, organic binders, petroleum based suppressants, and waste products). In his report, Succarieh (1992) summarized potential environmental impacts for a number of chemical suppression agents. These are shown in Table 1.

Table 1. Potential Environmental Impacts of Selected Dust Suppressants

Chemical Stabilization Agent	**Potential Environmental Impact**
Water (Fresh or Salt)	Salt water impacts similar to calcium chloride
Calcium chloride Sodium chloride Natural brines	Generally non-toxic due to rapid dissolution in the environment Toxic to some plants (such as fruit trees)
Calcium lignosulfonate Sodium lignosulfonate Magnesium lignosulfonate Pead chemicals lignosulfonate Ammonium	Biodegradation slow-persistent Moderately toxic to rainbow trout and aquatic plants
Used oil, waste oil	May contain heavy metals (leads), PNA's and PCB's Potential of hydrocarbons and contaminants entering surface water or groundwater in high water table areas
Bunker oil	Potential hydrocarbon contamination of waterbodies and groundwater Contains hydrocarbons that may be toxic

Source: Succarieh, May 1992

A more recent report prepared for the ADOT&PF (Bennett 1994) reviewed different surface treatments that could improve the surface characteristics of gravel roads in Alaska. The author noted that roads in Interior Alaska experienced major dust problems in dry summertime conditions. Concern over the performance of gravel surfaces and the control of "fugitive dust" was an issue because excessive dust production leads to road surface deterioration, environmental degradation, and visibility problems, as well as other road surface effects.

A report examining the design standards, maintenance needs and performance levels of high-speed gravel roads compared with paved roads was prepared in 1983 for ADOT&PF (Reckard, 1983). The report focused on different costs associated with constructing and maintaining each type of road, but provided some information on the application of dust palliatives. Products discussed included calcium chloride, waste oil, cutback asphalt, asphalt emulsions, and lignin. Calcium chloride is the most widely used dust suppressant agent on roads in Alaska. The benefits of calcium chloride included a smoother, harder surface, and reduction or elimination of dust. Primary disadvantages cited were corrosive action on vehicles and slipperiness of the road surface when wet.

An unpublished report (Jones 1998) on the development of a risk-based methodology for determining the toxicity of additives to surface water, groundwater, and vegetation noted that all the dust palliative products tested were toxic to aquatic life in an undiluted form. However, testing of leachate from soils where the products had been applied at the recommended rate showed no negative impacts on terrestrial or aquatic organisms. No additional information was available on the products tested or the frequency of application.

Water Quality

Road runoff contains contaminants that can ultimately reach waterbodies and waterways. The primary sources of contaminants are:

- Road surface treatments (materials that contain chloride, sodium and calcium)
- Substances added by vehicles (asbestos from brake linings, oil, grease, rust, rubber particles, and hydrocarbons from accidental spills)
- Applications and treatments to control pests and fertilize vegetation.

Substances reach streams and waterbodies by drift, runoff, leaching, or adsorption on soil particles. Chemicals applied to the road surface perform various functions, including dust abatement, road surface stabilization, and deicing. Runoff also includes metals from gasoline and vehicle tires. Roadside sources include fertilizer applied along road edges and cuts and fills, and herbicides used for weed control and the control of non-weedy plants. The affect on water quality of land applications is a function of how much chemical is applied, proximity of the road to a waterbody, and rain, snowmelt and wind events that drive chemical and sediment movement. The effects of increased nutrients include modification of aquatic biota composition (Gucinski et al 2001).

A study on the effects of different shoulder treatments on the quality and quantity of highway storm water runoff compared pollutant loads from shoulders paved with conventional asphalt, porous asphalt, and gravel materials (St John et al 1997). The results indicated that porous asphalt shoulders were significantly more effective than conventional asphalt and gravel in reducing runoff volumes, peak discharge rates, and pollutant loads. Gravel was more effective in reducing runoff volumes and pollutant loads than conventional asphalt.

In their report on the effects of Road Construction on Lakes and Ponds of Arctic Alaska, Miller and Alexander (undated) reported that road dust affects waterbodies in several ways: surface tension results in a dust scum coating the water surface, the natural seston of the water is diluted with dust particles potentially reducing food ingestion by filter feeding crustaceans, dissolved nutrients and cations are released by leaching, siltation occurs on submerged plants in waterbody margins, and light penetration is reduced. The results from their study indicated that ponds in contact with a roadbed were two to three times more productive with respect to $^{14}CO_2$ than ponds not in direct road contact. This was attributed to nutrients leaching from the roadbed, from dust in the ponds, and from fertilizers used for revegetation.

The deposition of fine sediments can seal redds and suffocate eggs and young and fill intergravel crannies that young fish and invertebrates use for cover from predators. Road erosion can create channel aggradation, in-fill ponds, and smother benthic macroinvertebrates that are a food source for young fish. Fine sediments may also cement spawning gravels, decreasing permeability of the substrate thereby restricting oxygen supply, and impede construction of reds. Decreased pore size may also allow only the smallest, least fit fry to escape. High suspended sediment loads can cause physiological damage to salmonids. Feeding efficiency can be impaired by decreasing the visibility of food, as well as decreasing the population of fauna.

In addition to the above, Gucinski et al (2001) noted that increased fine-sediment in stream gravel has been linked to decreased fry emergence, decreased juvenile densities, loss of winter carrying capacity, reduced benthic populations, and algal production. Poorly planned, designed, built, or maintained roads can lead to degradation of fish habitat. The report noted that channelized road-stream crossings were susceptible to sediment input from side casting, snow plowing, and road grading and that these activities can trigger fill-slope erosion and failures.

Gucinski et al (2001) noted that few studies have looked at the hydrologic effects of roads on areas dominated by snow hydrology, permafrost, and wetlands.

<u>Noise</u>

Road noise is a function of the road surface, pavement age, tire type, and speed. On highways, it is also a function of traffic volume, and the number of trucks in the traffic flow (Washington State DOT). Databases were searched using keywords “road noise”, “noise and unpaved roads”, “noise and gravel roads”, “noise and unpaved or gravel roads”. Numerous citations were found that reported on the noise levels associated with different types of paved road surface and tire type, including mud and snow tires. No studies were located that compared noise generated on unpaved or gravel road surfaces, and no citations relating to noise and gravel or unpaved roads were found. The report by Gucinski et al that considered a broad range of environmental and socioeconomic factors did not consider noise.

Noise was a variable in several of the citations that considered effects on wildlife and birds, however other variables in these studies, such as high road density and large traffic volumes, are not typical of Alaska. Noise impacts to wildlife are discussed under habitat fragmentation.

Road Kill

According to Noss (1999), animals are attracted to roads for a variety of reasons. Some of these reasons include:

- Birds use roadside gravel to aid their digestion of seeds
- Browsing herbivores are attracted to the dense roadside vegetation
- Rodents proliferate in the artificial grasslands of road verges
- Large mammals use roads as efficient travelways
- Scavengers seek out road kill for food.

One study suggests (Ruediger, 2000) that there is a predictable development cycle for roads and highways. Most started as gravel roads and eventually are paved. Then they are often improved by widening, straightening, and adding pullout zones and passing lanes. Eventually, as traffic volumes increase 2-lane roads are upgraded to 4-lane roads and may then evolve into large multi-lane Interstate Highways. As the implementation of road standards increases, the impact on carnivore populations also increases. When gravel roads are paved, vehicle speeds increase, loss of animal habitat increases, and the potential for car-animal collisions increases.

It was indicated by the Wyoming Department of Transportation that when a road is rebuilt to today's standards, providing 3.6-meter lanes, at least 1.8-meter shoulders, clear safety zones and improved horizontal and vertical alignment, wildlife mortalities will decrease. Even though vehicle speeds may increase, providing the additional width and improved alignment should mitigate the potential effects by providing the driver more sight distance and width to react to wildlife on the road (Bonds, 1996).

Road kill is an issue for both paved and unpaved or gravel roads. A large number of animals are killed annually on roads. The speed of the vehicle is the primary factor contributing to vehicle-wildlife collisions (Gunther, 1998). According to Noss, vehicles on high–speed highways pose the greatest threat to wildlife.

Unpaved roads, particularly when "unimproved", force reduced vehicle speeds and increase response time from the vehicle driver, therefore can be less dangerous (Noss, 1999). However, gravel roads usually have narrower right-of ways, which decrease visibility and reaction time for drivers and animals alike.

The volume of traffic usually contributes to the increase in road kill. However, in one Texas study, mortality was greatest on roads with intermediate volumes, presumably because higher-volume roads had wider right-of-way that allowed better visibility for both animals and drivers alike (Noss, 1999).

Habitat Fragmentation
According to Gucinski et al (2000), habitat fragmentation occurs when natural populations of animal species are affected by habitat loss caused by road building, thus splitting areas of similar habitat, and by the animals' avoidance of areas near roads. According to Noss (1999), some species of animals refuse to cross barriers as wide as roads. Each new road cuts these species populations, and a network of roads fragments a population further. These species' then become vulnerable to the problems associated with population isolation, including inbreeding.

Highways are habitat fragmentation factors for bears. Highway impacts include vehicle collisions and avoidance of vehicle noise by bears. Bear movement is inhibited by changes along highways, including loss of vegetation, fencing and other barriers along or between highway lanes, as well as the human developments that occur along our highways. (Servheen, 1998).

Habitat fragmentation can also be caused by road avoidance. One report suggests that it may be characteristic of large animals such as elk (*Cervus canadensis*), bighorn sheep (*Ovis canadensis*), grizzly (*Ursus arctos horribilis*), caribou (*Rangifer tarandrius*), and wolf (*Canis lupus*) to exhibit road avoidance behavior. It appears that the larger the road the greater the avoidance by these animals; whereas the animal will be more likely to cross a smaller road with less frequent traffic. In a telemetry study of movement of black bears (*Ursus americanus*), bears almost never crossed interstate highways, and they crossed roads with little traffic more frequently than those with high traffic volumes (Gucinski, 2001).

Road building introduces new edge habitat in the forest. The continuity of the road system also creates a corridor by which edge dwelling species of birds and animals can penetrate the previously closed environment. Road edges can increase species diversity by increasing the habitat for edge dwelling species (Gucinski, 2001).

Edge habitats may be considered ecological traps for breeding birds because apparently favorable nesting conditions may have higher nest predation levels than interior habitats. Predators are more abundant on edges than in forest interior and forage along travel lanes (linear geographical features) such as edges.

Permafrost
Roads constructed on permafrost are susceptible to frost action and thaw settlement during freeze and thaw cycles. Frost action, thermal contraction, and traffic initiate cracks in pavement. Additional distortion and cracking occurs when water penetrates the surface and ice forms (Phukan 1980).

On paved roads, thaw occurs faster under dark pavement while shoulders (protected by snow) remain frozen. Bearing capacity is reduced in the spring when materials thaw, resulting in potholes and cracking of the surface.

The rate of thaw was the primary difference noted between gravel and paved surfaces in frost susceptible or permafrost areas, although it is not clear that this constitutes a difference in environmental impact. The side slopes of roads built in frost susceptible soils tend to be more vulnerable to sloughing and erosion, and likely have greater potential to generate sediment-laden runoff.

A study looking at the economic aspects of high-speed gravel roads (Reckard, 1983) suggested that heat transfer calculations indicated road embankments with unpaved surfaces could be up to two feet shallower than paved embankments and still provide equal performance regarding thaw settlement. Reckard noted that gravel surfaces are, on average, cooler in summer than paved surfaces and that this has implications for embankment thickness. Shallower embankment depth would require less material. The study listed the following factors affecting thaw in permafrost: permafrost temperature, conductivity, density and moisture of embankment materials, temperature, thaw season, wind, cloud cover, precipitation, shading, and surface type. The report also suggested that dust palliatives (calcium chloride and lignins) may reduce frost heave in soils.

Project Footprint

In general, paved roads need greater project footprints than gravel roads. The project footprint directly effects habitat fragmentation (see habitat fragmentation section). The greater the project footprint is, the greater the potential for habitat fragmentation, and vice versa. Databases were searched using keywords “project footprints”, “project footprints and unpaved roads”, “project footprints and gravel roads”, “project footprints and unpaved or gravel roads”. Numerous citations were found that reported on project footprints associated with constructing roads versus not constructing roads. No studies were located that compared project footprints on unpaved or gravel roads and paved roads. Also see the habitat fragmentation section.

Material Sources

No literature relating directly to the environmental impacts of material sources was located during the review. Embankment and surface course material quality and availability was a consideration in studies looking at the costs associated with paving gravel roads, but no discussion was found on the environmental impacts of developing new material sources, expanding existing sources, stockpiling materials or operating asphalt batch plants etc.

From reading the literature related to embankment material requirements, particularly in permafrost areas, a thicker embankment (and larger footprint) may be required for a paved road than an unpaved road to counter the effects of heat transfer. This translates to greater material needs for paved roads, particularly in areas where permafrost cannot be avoided.

Improved access translating to increased environmental pressures

Improvements in access may lead to changes in recreation use and tourist use. For forest roads Gucinski et al (2001) noted that the amount, placement, and class of road is positively correlated with the amount and concentration of recreational use. Based on this statement, an unpaved road might experience increased use after paving where it provides access for different types of recreation, both active (e.g. hunting, fishing, and snowmachining) and passive (e.g. sightseeing and photography).

Gucinski et al's (2001) report noted that the majority of physical impacts from recreational use were concentrated on near-road areas. This may be location and activity dependent in Alaska. Activities such as snowmachining and 4-wheeling allow users to travel substantial distances away from roads. Off-road vehicle use is very popular in the state, both as a primary means of transportation in many communities, and increasingly for recreation. Snow machines are used extensively in winter and all terrain vehicles (ATV's) are used year-round. Collectively referred to as off-road vehicles (ORV's), they can have undesirable effects on vegetation, soils, and ecosystems of permafrost-related landscapes. Adverse impacts of ORV traffic can include vegetation damage or destruction, changes in vegetation community composition, permafrost thaw, soil erosion, and terrain degradation. Noise and exhaust emissions are additional impacts. Such impacts may affect aesthetic or visual values and can have consequences for biological productivity and later use of affected landscapes (1990:70). Improving access to areas increases the potential for habitat destruction from ORV's. By improving road conditions, areas that were once inaccessible to recreational ORV's are now accessible.

Soil exposure, vegetation destruction and microtopographical depressions (ruts) are concerns of off-road travel. In arctic and taiga settings, ORV traffic affects vegetation and not the underlying soil (Slaughter et al. 1990:65). Poorly drained soils underlain by permafrost are often most heavily damaged by ORV traffic. Many trails used by small ORV's in central Alaska traverse poorly drained terrain underlain by ice-rich permafrost-terrain susceptible to thaw, consolidation and erosion if the thermal balance is disturbed (1990:69).
Services that are developed to support recreational use may also impact the environment. Provision of lodging and food service businesses, fuel supplies, sanitary waste disposal facilities, camping areas (including facilities able to accommodate RV's and trailers), may ultimately develop in response to actual or perceived increased use.

Gucinski (2001) in their review of resource-based outdoor recreation data and literature for forest roads noted that most existing information did not directly address issues specifically related to the relations between roads and recreation, including soil erosion, habitat fragmentation, wildlife disturbance, and riparian vegetation.

Socioeconomic Findings

This section of the study presents findings in five different topic areas: Traffic accidents and volume, traffic speed, property values, economic development and related issues, and benefit-cost considerations.

Traffic Accidents and Traffic Volume

Zegeer et. al. (1994) is the only study located which directly assesses the differences in accident rates on paved and unpaved roads. Using data from Michigan, Utah, and North

Carolina they found that accident rates were not significantly different on paved relative to unpaved roads at annual average daily traffic (AADT) of less than 250 vehicles per day (VPD). Accident rates on unpaved roads, however, were significantly higher when the ADT exceeded 250 VPD. Similarly, the authors found that accident rates were much higher on unpaved roads when they studied a different data set for North Carolina. They obtained different results, however, when using a dataset for Minnesota. For that state, there was no statistically significant difference in accident rates for paved and unpaved roads.

The National Highway Traffic Safety Administration collates data on traffic fatalities (the FARS data) in the United States. The data are available by state. Using these data for the Northern and Central ADOT&PF regions of Alaska an empirical model was developed relating the annual fatality rate per million vehicle miles traveled to various roadway characteristics.[2] A more detailed discussion of the methodology is presented in Appendix A. Analysis of the FARS data reveals two interesting findings.

- Estimation of several different specifications of the model indicates that fatality rates are significantly higher on unpaved roads and rural roads. These results are very similar and consistently significant for different specifications of the model. There was no evidence that roadway alignment and profile have significant effects on fatality rates in the Central Region.
- The effect of unpaved roads on fatal accident rates is much weaker in the Northern Region. Just one version of the model suggests that rates on unpaved road are significantly higher than those on paved roads. As with the Central Region, roadway alignment and profile do not significantly affect the fatality rates. Unlike the Central Region, however, fatality rates on rural roads are not significantly higher in the Northern Region.

With the assistance of Central Region staff, a second data set of all recorded accidents was developed from the HAS data for a sample of gravel roads that had been paved in the 1990s. This data set is less complete than the one drawn from the FARS data because there is no information on roadway alignment and profile. But the data do allow a comparison of the same roads before and after paving. These data are analyzed for two purposes. First, an empirical model that relates accident rates per million vehicle miles traveled to roadway characteristics is developed. Second, a similar model is used relating traffic volume, as measured by vehicle miles traveled, to roadway characteristics. Two results are noteworthy.

- The results show no statistically significant differences in overall accident rates among roads that are paved, unpaved, and being paved.
- There is no significant difference in traffic volume between paved and unpaved roads. Not surprisingly, however, traffic volume is significantly lower on roads during the year that paving occurs.

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[2] Data on average annual daily traffic were not available before 2000 for the Southeastern region so the accident data from that area of the state could not be analyzed.

Traffic Speed

It is commonly perceived that average vehicular speed increases once a gravel road is paved. Indeed, this sentiment was expressed by several of the transportation officials outside of Alaska who responded to the survey (see Appendix D) and by ADOT&PF officials with whom this issue was discussed. ADOT&PF officials cite instances where overall speed limits and those on curves specifically were raised after paving gravel roads. Better friction factors on pavement allow higher speeds on road curves. However, the evidence for higher overall vehicle speeds is anecdotal; there are no studies which provide any indication of the average magnitude of the change.[3]

Property Values

No studies that address the effects of paving on property values could be located despite extensive reviews of various on-line sources. The dearth of relevant literature lead Northern Economics staff to conduct a survey of tax assessors and property appraisers in the Fairbanks North Star Borough, the Matanuska Susitna Borough, the Municipality of Anchorage, the City and Borough of Juneau, and the Ketchikan Gateway Borough. DOT officials from other states were also queried about the effects on property values. The appraisers and assessors were asked about the effects of paving a gravel road on the value of an acre of undeveloped land bordering the road. The respondents in the Central and Southeast regions had similar comments. Those in Fairbanks were more reluctant to offer opinions but did so in a few cases. The results of the survey and the questionnaire are in Appendix B of this document. The following results emerged from the survey.

- In the Southeast and Central Regions the respondents estimated that paving would increase the value of the hypothetical acre by between 0 percent and 17 percent. The median increase was about 8.6 percent.[4]
- In the Northern Region, several respondents commented that paving would have little effect because roads were snow-covered for so many months. Most were reluctant to suggest a specific percentage change.
- Just two respondents from the departments of transportation in other states indicated that property values were affected by paving. Both responded that property values increased but neither suggested a specific quantity.

Economic Development and Related Issues

Most of the findings in this section are inferences drawn from studies of highway projects and the academic literature on the relation between public capital and economic growth. The survey of transportation officials in other states asked about the effects of paving but just one respondent provided an opinion. Appendix C contains a review of representative literature on public infrastructure and growth.

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[3] A speed study, before and after paving, is planned for some Central Region roads in 2002-2003. DOT officials from other states who responded to the survey sometimes cited an absence of speed studies as a reason for answering 'don't know/can't answer' to the inquiry about post-paving travel speeds.

[4] One individual in Juneau expressed a contrarian view. That respondent thought that privacy considerations led people to pay more for property on gravel roads.

- A single study [Canning (undated)] relating paved roads and economic growth was located. The author did not find any significant effect of paved roads on the growth of per capita Gross Domestic Product (GDP) for a cross-section of countries. This study suggests that the paving program in Alaska will probably have little effect on economic development and employment near the newly paved roads.
- An ECONorthwest and Portland State University study (2001) conducted for the Oregon Department of Transportation found that highway projects had an ambiguous effect on land use. In some cases highway projects appeared to encourage economic development in the area, in others development seemed to have been discouraged by the project, and in still others no effect could be discerned from the transportation project.
- Department of Transportation officials who responded to the survey generally did not regard economic development as either an important reason for paving or an outcome of paving. Just one respondent felt otherwise.
- If a gravel road leads to a particular tourist destination, then paving that road may generate additional trips for recreational and tourism purposes. In 1999 Northern Economics conducted a study of traffic on the McCarthy Road.[5] That study found that recreational vehicle (RV) rental companies wanted the road paved. The owner of one such company thought that paving the road would lead to more RV traffic because the companies would promote travel in the area.

Benefit-Cost Considerations

No benefit-cost studies for paving gravel roads could be located although there is some related literature. In addition, the survey questionnaire of DOT officials in other states included questions about costs and benefits of paving projects. The survey instrument and responses to the DOT survey are summarized in Appendix D. The survey respondents cited three important benefits of paving.

- All but one DOT official cited the desire to reduce maintenance costs as either the most important or the second most important reason for paving a gravel road.
- All the survey respondents thought that lower maintenance costs were a result of paving. Reduced air (including dust) and water pollution were the next most cited benefits.
- Half the survey respondents thought paving lowered road user costs.

Blanchard (1996) reviewed benefit-cost studies of transportation projects in Canada and concluded that "Gravel road paving projects were almost consistently not cost-beneficial, only 2 out of 18 such projects being cost-beneficial."[6] However, ADOT&PF has adopted a policy of paving unpaved roads in the state. Given Alaska's budget deficit and the prospects of tax increases or permanent fund dividend decreases, it is likely that closer scrutiny will be given to each agency's expenditures. ADOT&PF may wish to prepare for

[5] The McCarthy Road leads to Wrangell-St. Elias National Park. At present much of the road is gravel and parts of the road are in poor condition.

[6] This appears to be the only published document which reviews the benefits and costs of gravel road paving projects.

the possibility of increased budgetary scrutiny by conducting its own analysis of such projects.

The following discussion provides a brief overview of the types of items which might be considered in the assessment of a basic, 'gravel to black' job. In this context the phrase 'gravel to black' means the paving of a gravel road but without making any significant design or other changes. The appropriate time horizon for a cost-benefit study should be the expected life of the pavement, a factor which may vary with climatic conditions in the region and road use (quantity and types of vehicles). Naturally, future costs and benefits would be discounted appropriately. A simple example of the process can be found in "Case Study 1" in Adler (1987).

Benefits:

- **Maintenance cost savings for ADOT&PF**.[7] There at least two reasons to anticipate a reduction in road maintenance costs after paving. First, grading costs are eliminated. Among other problems, gravel roads are prone to washboarding and the loss of fines over time. Exactly how quickly such problems occur depends on traffic and weather. But, to be maintained in reasonably good condition gravel roads must be graded periodically and the expense can be significant. Repaving a road is more expensive than grading but occurs less frequently so that often there is a net cost savings according to ADOT&PF officials. Second, the time required for snow removal is reduced.[8] Graders are used to plow gravel roads. In order to minimize gravel removal during plowing frequent blade adjustments are required. On paved roads trucks with floating blades that automatically adjust to the contours of the road can be operated at higher speeds, thus can plow more miles per day, than graders.

  ADOT&PF officials emphasize the importance of the maintenance benefit not only because it is thought to be less costly to maintain a paved road but also because the maintenance budget tends to be much tighter than the capital budget and funds from one budget generally cannot be used for the other purpose. Most paving jobs are financed through the capital budget in Alaska. From the ADOT&PF perspective, then, a dollar saved from the maintenance budget has more 'value' than a dollar saved from the capital budget even though, from a benefit-cost perspective, there is no difference.

  It should be noted that there is not universal agreement that paved roads have lower maintenance costs than gravel roads. According to the Kentucky Transportation Center (2000, p. D2) "Gravel roads have the advantage of lower construction and sometimes lower maintenance costs." Reckard (1983) found that

[7] In this category the analyst conducting the benefit-cost study would estimate the difference in maintenance costs between a gravel road and a paved road. If there is an estimated cost savings, as anticipated, then the savings is a benefit. If the paved road, for some reason, has higher maintenance costs then this difference would be included in the cost category.

[8] The ADOT&PF website indicates that the time needed for snow removal is halved. See the Gravel to Pavement Projects category on the agency's website at http://www.dot.state.ak.us/, accessed April 5, 2002.

maintenance expenditures were substantially higher for paved roads in the Interior and South Central Regions of Alaska and lower in the Central Region. Higher costs on paved roads occurred where thaw settlement and frost heaving were problems.

- **Reduced road user cost**. Costs borne by the user of the road, greater wear and tear on vehicles, may be significantly reduced once a road is paved. The manual of the American Association of State Highway and Transportation Officials (AASHTO) (1977, p. 62) suggests, for example, that the cost of operating a passenger vehicle at forty miles per hour on a gravel road is approximately 40 percent greater than on a paved road.

- **Travel time savings**. ADOT&PF officials and those from other states generally indicated that average vehicle speed increases after paving. Faster travel speeds imply travel time savings but this benefit is probably minor due to the relatively low traffic volumes (VMTs) on roads of the type under consideration in this study.

- **Environmental Benefits**. Determining dollar values for environmental benefits of paving is a problematic exercise. Difficulties notwithstanding, some benefits are likely to occur. For example, paving reduces dust levels which may reduce respiratory problems in humans and animals and permit more efficient photosynthesis in plants. Even if such gains are not monetized, they could be included as non-quantified benefits of paving in any benefit-cost study.

Costs:

- **Costs of paving**. Paving costs are a relatively straightforward consideration. Included as costs would be the road surfacing material, labor, and an allowance for the cost of the machinery and equipment for the duration of the project. Since the project is a basic gravel to pavement one, neither design change nor right-of-way costs are incurred. Striping and other pavement markings or features could be included here or could be factored into the maintenance benefit discussed earlier.

- **Environmental**. Again, environmental costs are difficult to quantify; but, at the least, should be listed so that they are not overlooked factors. Possible environmental costs are likely to differ substantially depending on the location of the road. A list of such costs might include, but not be limited to, additional wildlife mortalities due to higher travel speeds and more stream contamination due to runoff from standing oil and antifreeze on paved surfaces.[9] On low-volume roads, these environmental costs are likely to be small.

[9] These considerations are complex. See the earlier discussion on road kill in this section, for example. Oil and antifreeze on gravel roads may contaminate groundwater.

Sufficient evidence does not exist to state unequivocally how/if accident or fatality rates will change once a gravel road is paved. For this reason, consideration of the effects of paving on accident rates is omitted from the list of benefits and costs. However, the evidence presented in Appendix A indicates that fatality rates may decline when gravel roads are paved. If this result is supported by further studies, a decline in fatality rates would represent a significant benefit to consider in conducting benefit-cost studies on such projects. Estimation of the empirical model in Appendix A suggests that paving has no effect on overall accident rates. However, it is possible that higher traffic speeds on pavement lead to increased accident severity, greater property damage and more severe injuries, when accidents do occur. If so, such costs should be accounted for in a benefit-cost analysis.

Measurement of the costs and benefits associated with paving should not be difficult in most cases, except for environmental considerations. ADOT&PF should have good information on maintenance cost savings of paved over unpaved roads and the cost of paving. Indeed, some ‘rules of thumb’ could be developed from a few studies and used to provide inexpensive estimates of travel time savings. These rules might take into account the distance paved and the road attributes as well as traffic volume. National studies such as one prepared by The Road Information Program (TRIP) (2001) could provide estimates of user cost savings. The effects of paving on accident rates and severity could be generalized based on studies using available data on accidents. The primary measurement problems involve the pollution and wildlife impacts.

CHAPTER 3 – INTERPRETATION, APPRAISAL, AND APPLICATIONS

This chapter provides an overview of the findings and outlines recommendations arising from the interpretation and appraisal of the findings presented in the previous chapter. There are three specific recommendations from the empirical study of traffic accidents and one each on the traffic speed and benefit-cost issues. None of the other areas studied provided findings that would suggest policy or procedural changes.

Overview of the Environmental Issues

Many of the studies reviewed in the process of locating relevant and applicable information for this study provided comparisons between unroaded and roaded areas, or looked at areas with much heavier traffic density than is typical of many roads in Alaska. Much of the information reviewed did not directly address relationships or provide comparisons between unpaved and paved roads. This applies to all the environmental factors considered in this report. For several of the factors, no information was found for unpaved roads and only limited information was found for paved roads. The factors that we feel "safe" in saying we obtained comparative information on are those related to dust and, to a lesser extent, water quality and aquatic habitat.

This study considered the air quality impact of dust and did not look at emissions. Although few comparative studies of dust impacts were reviewed, studies overwhelmingly indicated that the benefits of paving far outweigh any negative impacts to air and water quality. It is reasonable to assume that paving a road effectively reduces the majority of air and water quality impacts associated with dust generation, including the potential impacts of long-term use of dust palliatives. The environmental impacts of dust palliatives have not been well documented, and at least two of the studies reviewed were progress reports into the effects of dust palliatives.

Paved and unpaved surfaces have different absorption characteristics, and a paved surface may generate more runoff. Studies indicated that the character of storm water runoff from a paved surface is different than that from an unpaved surface, with less sediment and more vehicle-related contaminants, however little quantitative data was located. No studies documenting the impacts of sand, which is used on both paved and unpaved roads in Alaska during the winter, to air and water quality impacts were located and reviewed.

Virtually no studies looked at wildlife and habitat issues in the context of paved versus unpaved roads. The habitat fragmentation studies reviewed generally compared roaded and unroaded areas or looked at road width as a variable, but did not consider differences in the effects of paved and unpaved surfaces.

The effects of paving on road kill were unclear. Average speeds on paved roads were reported to be generally higher than those on unpaved roads and there is evidence to suggest that animal mortality numbers are positively correlated with higher speeds. Paved roads with higher average speeds tend to have better alignments and additional width that provides drivers with more sight distance and width to react. Unpaved roads tend to have lower average speeds but narrower rights-of-way, so drivers have less distance to react when they see an animal. This information suggests that if paving was the only improvement made to an unpaved road, then road kill may increase because vehicles could potentially travel at greater speeds. Additional variables that would be important in Alaska include seasonal impacts on driving conditions and time-of-day. Snow and ice increase the breaking distance required to stop and shorter days translates to more driving during the hours of darkness when visibility is greatly reduced.

Comparative impacts for noise, project footprint and material sources were not addressed in the literature. Impacts of permafrost were discussed but the focus was economic rather than environmental.

Overview and General Recommendations on Socioeconomic Issues

Traffic Accidents and Traffic Volume

Analysis of data on fatal accidents in Alaska from 1994 to 2000 indicates that fatal accidents are significantly higher on unpaved roads. However, we have not been able to isolate the impact of surface type from all of the other improvements that typically are found on paved roads and that are typically missing from gravel roads.

Despite an extensive search, no other studies of the relation between fatality rates and unpaved roads could be located in published literature. The afore-mentioned study by Zegeer et. al. found that the road surface had an ambiguous effect on accident rates. Using data from three states, there was some indication that accident rates were higher on unpaved roads with average annual daily traffic (AADT) in excess of 250 vehicles per day. With other data there was no significant difference in accident rates between paved and unpaved roads.

Estimates from an empirical model applied to a sample of recently paved roads in the ADOT&PF Central Region indicate no statistically significant relation between traffic accidents and gravel roads. The data set used to generate this result provided little information on characteristics other than roadway surface so this result must be considered tentative.

The empirical estimations revealed no statistically significant increase in traffic volume after paving gravel roads. Because this result is based on a small sample of roads from the ADOT&PF Central Region, further research could be conducted on this matter.

These findings give rise to three recommendations:

- Too few studies on accident rates and roadway surface have been conducted to establish a basis for specific policy recommendations on paving gravel roads. The empirical findings discussed in detail in Appendix A suggest that more research is needed on the relation of roadway surface with accident rates. This additional research is recommended.

- There are insufficient data on Alaskan fatalities to study the relationship between roadway surface and traffic fatality rates in enough detail. Such a study would best be carried out using national data. It may be possible to secure the funding for this work from the US Department of Transportation. The pursuit of such funding from USDOT and the conduct of such a study is strongly recommended. A more definitive answer to this important issue is needed.
- Sufficient ADOT&PF data are available on roadway traffic volumes to conduct an expanded study of the effects of paving gravel roads on traffic volume. If it can be carried out at a reasonable cost, additional research on this matter should be undertaken. In particular, the relationship in other ADOT&PF regions should be assessed.

Traffic Speed

Generally, Department of Transportation officials who were queried on the matter thought that average vehicle speed increases after paving. This belief is based on the experiences of the officials who responded, no studies comparing vehicle speeds on gravel and paved roads could be located. Speed studies are planned in the ADOT&PF Central Region in 2002-2003. These studies should provide useful guidance to ADOT&PF and it is recommended that these studies be carried out.

Property Values

The survey findings indicate that some increases in property values are likely when gravel roads are paved. Although property owners may regard these increases as gains when the property is sold, the increases represent higher costs to the buyers. Thus, there is no net gain or loss to society as a result of the property value effects.[10] Because the effects essentially cancel it is recommended that there be no additional study of this issue.

Economic Development and Related Issues

Again, there are few studies that directly link economic development or growth to paved roads. In the one study uncovered that did examine this relationship, the author did not find any significant effect of paved roads on economic growth in a cross-section of countries. More general studies on public infrastructure and economic growth give ambiguous results. Thus, it appears that the paving program in Alaska will have little effect on economic development and employment near the newly paved roads. No recommendations arise from this finding.

Benefit-Cost Considerations

Only one study, conducted by Transport Canada, was located that reviewed the benefits and costs of paving gravel roads. The Canadian study examined the costs and benefits of eighteen gravel road paving jobs and found that only two of the projects had benefits which exceeded costs. Thus 90 percent of the Canadian paving projects examined for the study cost more than the benefits they provided. Given the number of projects studied, this is a large percentage that were not cost-beneficial.

[10] Changes in property values are regarded as transfers between buyers and sellers. For this reason, they are not considered in benefit-cost studies of federally-funded transportation projects. See Office of Management and Budget, Circular No. A-94, Revised, pp. 5.

The measurable benefits of paving unpaved roads include lower maintenance costs, travel time savings for road users, and, most likely, lower user costs. More difficult to quantify, but benefits nonetheless, are factors such as the reductions in air and water pollution caused by gravel road dust. The empirical results on fatal accidents indicate that fatality rates may decline if gravel roads are paved. If confirmed by further study, this would be an important benefit as well, albeit an unanticipated one prior to this study.[11] A measurable cost is the paving work. Faster traffic speeds may result in more road-killed wildlife, a cost for which measurement is more problematic.

Benefit-cost analysis is a data-intensive and costly process for transportation projects. For low cost projects such as paving low-volume gravel roads there are two relatively inexpensive alternatives for developing useful information on costs and benefits. First, ADOT&PF could conduct a few case studies on selected roads in each transportation region. The results from these benefit-cost studies could be used to develop general 'rules-of-thumb' for assessing paving operations on similar roads. These rules might vary with such items as area climatic conditions, presence of permafrost, and other factors which might influence the costs or benefits. Second, benefits and costs could be estimated with a generalized model such as the World Bank's Roads Economic Decision (RED) model, which was designed specifically for low volume roads. See Archondo-Callao (1999a, 1999b, 2001) for descriptions of the RED model. Alternatively, it may be possible to adapt Cambridge Systematics' (1998) Sketch-Planning Analysis Spreadsheet Model (SPASM) for use in the analysis.

Benefit-cost analysis is a familiar tool for assessing many transportation projects. The need to apply the technique to paving gravel roads can be inferred from Connor and McHattie (1999) who write that gravel roads should be paved "When it makes economic sense." This article appeared in the ADOT&PF Local Transportation Assistance Program newsletter, *Technology for Alaskan Transportation*. The use of a benefit-cost analysis with either a spreadsheet model or using rules developed from other studies would allow ADOT&PF to set paving priorities with roads having the greatest net benefits being paved soonest. It is recommended that ADOT&PF conduct benefit-cost studies of 'gravel to black' paving projects.

[11] See the traffic accident analysis in Appendix A and elsewhere in this document. One possibility is that paved roads reduce fatal accident rates by permitting better driver-control of vehicles.

CHAPTER 4 – CONCLUSIONS AND SUGGESTED RESEARCH

This chapter presents a summary of the findings and the study conclusions arising from the findings. Conclusions from the environmental impacts are presented first followed by those from the socioeconomic impacts. Suggestions for further research conclude the study.

Summary and Conclusions

Environmental Impacts

Truly comparative research appears to be limited. No before and after studies that looked at road segments before they were paved and again after they were paved were located nor were any studies that compared paved and unpaved roads in environments with similar physical, climatological, biological, and traffic characteristics. Unpaved roads in Alaska occur in a diverse range of physical and climatic environments. Most are low volume roads and many are seasonal.

The relative impacts of different environmental factors will vary on a case-by-case basis. The primary benefits of paving indicated by the literature and responses to interviews conducted by Northern Economics are the reduction in dust related impacts to air quality and water quality. The secondary environmental impacts of paving a road are going to vary depending on the location and function of the road. The effects of improvements to roads that serve a traditionally residential area are likely to be different to the effects of improvements to roads that access or link tourist destinations and popular recreation areas.

Existing studies focused on the positive outcomes of paving roads and did not identify any direct negative environmental impacts of paving roads. It is likely that paving a road may, in some cases, result in some temporary negative environmental impacts.

None of the literature reviewed included longitudinal studies or looked at short-term versus long-term environmental impacts. There may be some historical interest to chronicling the life of a road, from gravel to pavement, to document what actually happens and to be able to compare roads in different physical environments and regions. For instance, when a road is paved, what other construction typically occurs (e.g. increasing the road bed footprint, changes in drainage structures, vegetation clearing, construction of pullouts, and access points). A longitudinal study would also include gathering post-construction data, including positive and negative impacts on a range of environmental factors.

Environmental data are often collected in response to a regulatory need and this appears to be a factor in the availability of information on dust emissions and water quality. The overall lack of studies may be an indication that the direct environmental impacts of paving alone, where there are no other improvements or construction, are relatively minor, with documented benefits outweighing negative impacts.

Secondary and indirect environmental impacts may be important for some roads where paving could result in changes in the type of traveling public and vehicle use (e.g. an increase in the number of tour buses, cyclists, and recreation vehicles.) resulting from reductions in travel time, a more comfortable road surface to travel on, improved air quality, and reduced wear and tear on vehicles. Changes in vehicle and user type may also lead to the development or expansion of traveler or tourist support facilities, with related energy, water, sewer, and solid waste requirements. Impacts may be very localized. Increased use may also result in negative impacts from illicit discharges from recreation vehicle waste tanks and increased littering.

Suggested Environmental Research

Economic issues were the primary focus of most of the Alaskan studies reviewed that considered gravel and paved roads. There appears to be limited local information available where environmental factors are the primary variables of interest.

Dust is considered a problem on many unpaved roads in Alaska. Responses to Northern Economics' survey of transportation officials rated reducing air and water pollution as an important reason for paving. However, no data that quantifies and compares air and water quality impacts of gravel and paved roads was located which suggests there is a gap in the information available, particularly for rural roads.

Studies reviewed indicate that the environmental impacts of dust palliatives are not well known or documented. Research that look at the effects of dust palliatives in cold climates would provide valuable data on the impacts of products used in Alaska.
Many transportation improvement projects in the state gather valuable anecdotal information on issues and concerns through the public process and informal contacts, such as discussions with local residents and businesses. This wealth of information resides in an unorganized manner in project files. DOT&PF personnel have suggested that, for certain projects, this information be better tracked and that follow-up interviews or surveys be conducted after a project has been completed to see where problems were resolved or new ones created. This would provide valuable feedback on the perceived success of a project and identify areas of dissatisfaction or concern. A project of this type should not be restricted to environmental issues, but cover a wide range of topics.

Socioeconomic Impacts

Traffic Accidents and Traffic Volume

Additional study is needed to verify whether higher fatality rates are associated with unpaved roads; but if, indeed, such is the case then the paving of gravel roads would provide the previously unanticipated benefit of reducing traffic fatalities. A drawback of the empirical model used to uncover this relationship is that it cannot be used to estimate the reduction in fatalities that would have occurred if unpaved roads were paved. Again it should be emphasized that the finding of lower accident rates on paved roads is tentative and deserving of further study.

A simple empirical model of traffic volume failed to reveal any relation between vehicle miles traveled (VMT) and roadway surface. This result suggests that paving a gravel road will not generate a significant increase in vehicular traffic. The finding arose from a sample of roads that had been paved in the 1990s, thus there were data on traffic volumes for the same roads for several years before and after paving. Although this model may be misspecified, how such misspecification might affect the results is not clear; our conjecture is that any effects from misspecification are minor.[12] Therefore, it is probably appropriate to cite this result when residents along a to-be-paved road express concern about possible adverse effects of paving on traffic volume. This conclusion should be qualified in situations involving unpaved roads leading to tourist or recreational areas. In such cases, paving the road may lead to much higher traffic volumes since rental vehicles could use the road.[13] McCarthy Road leading to the Wrangell-St. Elias National Park is an example of a situation where paving is likely to cause a substantial increase in traffic.

Traffic Speed

Although many transportation officials believe that traffic speeds increase after paving a gravel road, there have been no specific studies of this issue. The findings from estimating the empirical model for traffic accidents do not indicate an increase in the accident rate after paving as one might expect if average vehicle speed rises.

Property Values

The responses to the survey of tax assessors and appraisers in Alaska suggest that paving could add as much as 17 percent to the value of property bordering the road. Although this finding may help create a consensus in favor of paving among local residents, the rise in value represents only potential transfers from buyers to sellers. The buyers pay higher prices if the road is paved. Such transfers net to zero when considering societal benefits and costs. Gains in property values do not provide a justification for paving a gravel road.

Economic Development and Other Considerations

The literature on highway infrastructure and economic growth, and public capital and economic growth provide conflicting conclusions on the effects of transportation projects on economic activity. There is evidence that suggests that the benefits, if any, are not large, but estimates vary widely. For transportation projects such as paving gravel roads, the effects are probably small for at least two reasons. First, the projects are relatively low-cost. Thus there is only a small infusion of funds into rural areas where many of these projects occur. Second, regional economic models show that public (or private) spending has a significant effect on an area only if much of the spending remains in the community rather than leaking out through spending on goods produced outside the community. Even if a local contractor is hired to perform the paving work, most spending quickly leaks out of the community since most goods purchased by the residents are produced elsewhere. Because business location decisions and employment effects arise from economic development, and paving gravel roads will have little effect on economic development, few business location or employment effects are anticipated.

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[12] For example, roadway characteristics such as roadway profile and alignment are not included in the model but it is not clear how such factors would influence traffic volume.

[13] Some rental companies prohibit the use of their vehicles on unpaved roads.

Benefit-Cost Studies
No benefit-cost studies on paving gravel roads could be located either in Alaska or the rest of the United States. A review of eighteen benefit-cost studies conducted by Transport Canada found that only two gravel road-paving projects produced benefits in excess of costs. The other sixteen projects produced net losses to Canada. This conclusion for Canadian projects suggests that an evaluation of the gravel road-paving program in Alaska ought to be undertaken in order to determine whether such projects represent the best use of taxpayer funds. However, benefit-cost studies can also serve a useful function for ADOT&PF by providing information which could be used to set paving priorities.

Rather than expensive detailed benefit-cost analyses as would be required of a major highway improvement, the studies for gravel roads could be undertaken with low cost methods. These low cost methods include the use of spreadsheet models to evaluate road paving and the development of generalized rules for evaluating benefits and costs.

Suggested Socioeconomic Research
The need for additional research on the relation between fatality rates and roadway surface cannot be overstressed. The empirical model that uncovered this result for the Central Region is simplistic. Some presumably relevant variables such as weather and road condition at the time of the accident could not be included in the model. Thus the finding of a significantly higher fatality rate on unpaved roads may have arisen because some important explanatory variables were omitted from the model. Additional research ought to be undertaken to develop better data and an improved model for investigation of this issue.

ADOT&PF ought to investigate the use of low cost approaches to benefit-cost analysis of gravel road paving projects. The use of benefit-cost studies would help ADOT&PF officials evaluate the effectiveness of the gravel road paving program relative to other department projects and would assist the department in prioritizing paving projects.

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APPENDIX A – ACCIDENTS AND TRAFFIC VOLUME ON ALASKAN ROADS

Introduction

This appendix describes in detail the literature on traffic accidents and unpaved roads, the available data on accidents and traffic volume, and the analyses conducted using the data. The purpose of the data analyses is to estimate the extent to which paving a gravel or dirt road affects accident rates.

The literature review is presented first, followed by a discussion of the two data sets. The basic model and the estimation results for various versions of the model are presented. Details from the two data sets are presented in tabular form at the end of the appendix.

Literature Review

Only one study addressing accident rates on gravel and paved roads could be located despite an extensive search. Zegeer et. al. (1994) undertook a careful comparison of the possible differences in accident frequency and severity between paved and unpaved roads. Using data from Michigan, Utah, and North Carolina they found that accident rates were not significantly different on paved vs. unpaved roads having an average daily traffic (ADT) of less than 250 vehicles per day (VPD). Accident rates on unpaved roads, however, were significantly higher when the ADT exceeded 250 VPD.

Similarly, the authors found that accident rates were much higher on unpaved roads when they studied a different road data set for North Carolina. However, because they were unable to control for other factors that affect accident rates, particularly shoulder width, the results may be misleading.

Finally, Zegeer et. al. obtained different results when using a dataset for Minnesota. For that state, there was no statistically significant difference in accident rates for paved and unpaved roads. Thus their results do not provide unqualified support for paving justified by safety considerations.

Data Development

In light of the paucity of information on the effects of road surface, paved vs. unpaved, on accident rates; we examine evidence from two data sets developed for Alaska. One data set is for fatalities on Alaska roads between 1994 and 2000. The other has accident information for sixteen roads paved in the 1990s in the ADOT&PF Central District.[14] Due to missing entries and other problems many observations had to be eliminated from each data set.

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[14] This data set could not have been developed without the assistance of many individuals in the ADOT&PF Central Region office, particularly the Safety section. We are very grateful for their assistance.

Using the FARS data, fatality rates are computed for Alaska roads. A series of empirical models relating fatality rates per million vehicle miles traveled (VMT) are estimated for the ADOT&PF Northern and Central Regions.[15] For the Central Region, the empirical results suggest that unpaved roads are associated with significantly higher fatality rates per million VMT even when allowing for roadway profile and alignment factors (see Table A1). This finding may arise because vehicle control is more difficult on unpaved roads and these roads are often in areas of steep terrain. It may also arise because paved roads are generally straighter, flatter, wider, and have better guardrail, signing, and lighting than gravel roads. The variables used to weigh the effects of profile and alignment cannot capture the effects of many safety improvements which often accompany paving. Data limitations prevent the development of additional explanatory variables. The model results also suggest that fatality rates are higher on rural collectors (major and minor), rural local roads, and other (unknown classification) rural roads.

Higher fatality rates are associated with unpaved roads in the Northern Region for some, but not all of the model specifications (see Table A2). The effect of unpaved roads on fatality rates does not appear to be nearly so strong for the Northern Region. This may be because the roads are under snow for much longer, in some places, than in the Central Region. Once packed under snow, roadway surface probably matters little. However, there appears to be no significant effect of rural collectors, rural local roads, and other rural roads on fatality rates; contrary to the finding for the Central Region.

The results should be considered tentative primarily because the methodology employed did not permit controlling for lane and shoulder width, adequacy of traffic signs and guardrail, traffic law enforcement by police, emergency service response time, weather, road condition, terrain, and driver characteristics among other factors. However, the finding that paved roads seem to have lower fatality rates suggests the need to study this issue further in order to isolate the reasons that unpaved road appear to increase fatality rates.

Traffic Fatality Data Set

Information on traffic fatalities in Alaska for 1994-2000 is obtained from the Fatality Analysis Reporting System (FARS) of the National Highway Transportation Safety Administration of the US Department of Transportation. The availability of the data determined the period of the study, 1994 and 2000 data are the earliest and latest data, respectively, that are available. The FARS data set contains information on every accident in which a traffic-related fatality was reported in the United States. Each accident includes a wide variety of information on the general characteristics of the accident as well as roadway, climatic, driver, and passenger characteristics. Characteristics of most interest to this study are the various roadway characteristics: surface type (gravel, dirt, concrete, etc.), roadway alignment (straight or curve), roadway profile (level, grade, etc.), and roadway function class (rural principal arterial-interstate, rural minor collector, urban local etc.).

[15] The models could not be estimated for the Southeast region because the requisite data were not available.

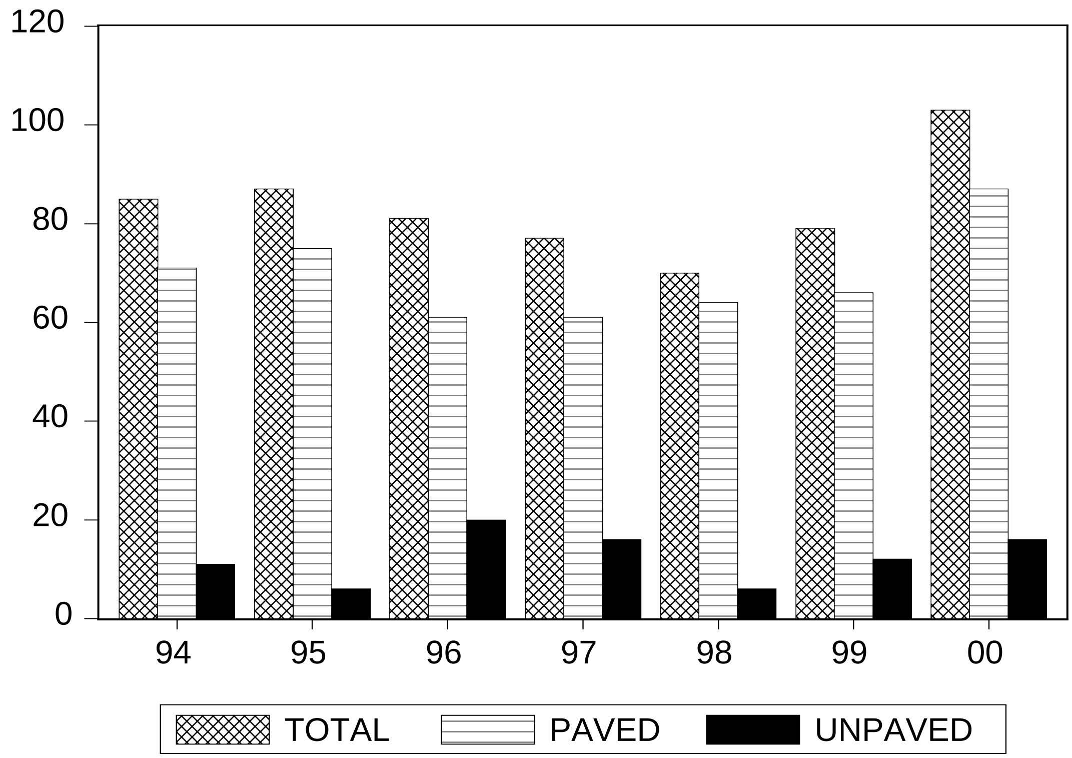
The FARS data were used to develop Table A1. The same information is shown in the bar graph, Figure A1, immediately following the table. The total number of traffic fatalities in Alaska ranged from 70 to 103 annually for the seven year study period. Although seven years is much too short a period to provide much guidance on tendencies, it appears that traffic fatalities were generally declining in the state between 1994 and 1999, despite gains in Alaska's population. The substantial increase in fatalities in 2000 may be an anomaly.

Table A1-Traffic Fatalities in Alaska, 1994-2000

Year	Fatalities-Paved Roads	Fatalities-Unpaved Roads	Fatalities-Total
1994	71	11	85
1995	75	6	87
1996	61	20	81
1997	61	16	77
1998	64	6	70
1999	66	12	79
2000	87	16	103

Figure A1

Traffic Fatalities on Alaskan Roads, 1994-2000



The distribution of fatalities between paved and unpaved roads varies sharply. In 1995, fatalities on unpaved roads were just 7 percent of the total while the next year they accounted for almost 27 percent of all fatalities. Although they do provide an overview of the traffic fatality picture in Alaska, the data do not provide any insight into the accident or fatality risk of paved relative to unpaved roads. Table A6 shows the distribution of fatalities by year for each road identified in the FARS data.

FARS data required extensive manipulation prior to use in the empirical model. For example, the FARS data set identifies the location of the accident by the name of the road as it is locally known, but the local name can differ from the name used in the ADOT&PF road logs. For example, Willow-Fishhook Road in the Central Region was referred to as Hatcher Pass in several fatality reports in the FARS. Although in this instance the ADOT name of the road could be identified, many observations were undoubtedly lost for this reason. It is also possible that observations were lost because the accident occurred on a locally maintained road; hence the road does not appear in the ADOT&PF road logs. In addition, all fatal accidents that occurred in Anchorage were eliminated because few gravel roads remain in the municipality.

For the remaining roads, route numbers were entered into the data set. The route numbers along with the date and milepoint of the accident allowed the entry of average annual daily traffic (AADT) for the year of the accident and section length appropriate to the location of the accident. These variables were obtained from various issues of the ADOT&PF *Annual Traffic Volume Report*. Using these numbers we calculated the vehicle miles traveled (VMT) for each section of the road on which an accident occurred. Equation A1 displays the formula for computing the fatal accident rate. Note that the rate is for annual fatal accidents per million vehicle miles traveled.

$$\text{Rate}_{it} = \frac{\text{Fatalities}_{it} * 1{,}000{,}000}{\text{AADT}_{it} * \text{Length}_{i} * \text{Days}_{t}} \quad \text{(A1)}$$

The ‘i’ subscript indexes the section of road and the ‘t’ subscript indexes the year. Fatalities is the number of deaths in traffic accidents, AADT is average annual daily traffic, and length is the mileage of the section in which the fatalities occurred. Fatalities and AADT vary across section and year. Length is the same for all years but differs across sections of the same road. Days, of the year, has a subscript because 1996 was a leap year; thus the number of days in the formula is 366 for the 1996 rates. Note that this method produces a fatality rate for each section of the road in which one or more fatal accidents occurred. It would be possible for a particular road to have different accident rates across different sections of the road.

Another difficulty encountered is that the milepoint of the accident, a FARS variable, was not always consistent with the total length of the road determined from ADOT&PF route logs. Specifically, in some cases the accident allegedly occurred at a milepoint beyond the end of the road. For example, this inconsistency happened with the three fatal accidents on Rezanof Drive, Kodiak Island. In these cases we computed an average VMT based on the number of road sections for which the AADTs were available. We substituted this average VMT for the section VMT in calculating fatality rates for roads characterized by this inconsistency. An additional difficulty was that we were able to obtain AADT and other information on roads in the Southeast region only for 2000. As a result the observations for the Southeast region were not included in the data analysis.

Model and Analysis

For each fatal accident, FARS provides a wealth of information on road characteristics at the site of the accident. The officer who prepared the accident report can select from seven different roadway surface types and fifteen roadway function class types for example. For this study, however, there are too many different types for many of the variables, given that the usable fatal accident observations numbered 153. In order to assess the effects of road characteristics, dummy variables are created to capture the general characteristics of interest. These include:

- **DUMUNPAVE** has a value of 1 if the accident occurred on an unpaved (gravel or dirt) road and a value of zero if it occurred on a paved road (regardless of pavement type).
- **DUMR** has a value of 1 if the accident occurred on a road identified as a rural major collector, a rural minor collector, a rural local road, or unknown rural road and a value of zero if the road was in an urban area or was a rural principal

arterial (interstate or other) or a rural minor arterial. Thus the major rural roads are grouped with urban roads.[16]

- **DUMCURVE** has a value of 1 if the accident occurred at a curve and zero otherwise.
- **DUMNOLEVEL** has a value of 1 if the accident occurred at a grade, hillcrest, or sag and zero otherwise.

The fatality rate is regressed on a constant and different combinations of the dummy variables, equation A2 shows the general form of the regressions.

$$\text{Rate}_{it} = \beta_0 + \sum_j \beta_j \text{DUM}_j + \varepsilon_{it} \qquad \text{(A2)}$$

In the formulation of A2, the i and t subscripts remain as identified earlier and j indexes the different dummy variables. Three versions of equation A2 are estimated for the Northern and Central ADOT&PF regions. Version (a) includes all four dummy variables, version (b) contains three of the dummies and omits DIMCURVE, and version (c) includes three of the dummies with DUMLEVEL omitted. The output displayed in Tables A2 and A3. The a priori expectation is for curves and road alignments other than straight to be associated with higher fatality accident rates thus the coefficients (βs) on these two dummies are expected to be zero.

Table A2-Fatality Rate Model Estimated Coefficients, Central Region

	(a)		(b)		(c)	
	coefficient	**std. error**	**coefficient**	**std. error**	**coefficient**	**std. error**
constant	.04	.28	.10	.25	.27	.23
DUMUNPAVE	1.83**	.56	1.80**	.56	1.94**	.56
DUMR	1.34**	.33	1.34**	.33	1.24**	.33
DUMNOLEVEL	.44	.30	.45	.29		
DUMCURVE	.15	.29			.19	.29

Note: std. error is the standard error for the estimated coefficient.
**Significant at the 1% level

[16] It was assumed that most unpaved roads would have a classification no higher than rural major collectors. Thus the inclusion of this dummy variable in the estimations would capture the effects of rural characteristics which might otherwise be erroneously attributed to the absence of pavement.

Table A3-Fatality Rate Model Estimated Coefficients, Northern Region

	(a)		(b)		(c)	
	coefficient	std. error	coefficient	std. error	coefficient	std. error
constant	3.55	7.45	.37	6.95	2.13	7.23
DUMUNPAVE	20.52	11.11	19.21*	11.11	17.02	10.27
DUMR	6.82	9.83	6.17	9.86	8.36	9.62
DUMNOLEVEL	-9.56	11.31	-12.29	11.11		
DUMCURVE	-11.06	9.57			-12.74	9.32

*Significant at the 10% level

The estimation results suggest that the effects of roadway characteristics on fatality rates differ between the Central and Northern Regions. These differences are obvious for the unpaved and rural dummies. For the Central Region, the results from all three model specifications indicate that fatality rates are significantly higher on unpaved and rural roads (major collector or lower).[17] The roadway alignment and profile variables have no significant effects on fatality rates when the model is estimated with Central Region data. However, these results are probably attributable to the simplistic nature of these variables in this model since other studies indicate that alignment and profile characteristics affect safety. The effect of unpaved roads on accident rates is much weaker in the Northern Region. The marginal significance of the coefficients on the unpaved road dummy is just slightly greater than .10 for specifications (a) and (c) and just below .10 for specification (b). As with the Central Region, roadway alignment and profile do not significantly affect the fatality rates. Unlike the Central Region, however, fatality rates on rural roads are not significantly higher in the Northern Region.

Although the model indicates that fatal accident rates are higher on unpaved roads, it is not clear that changes in surface type cause changes in fatal accident rates. The methodology used to examine road characteristics precludes consideration of lane and shoulder width, adequacy of traffic signs and guardrail, weather, driver, terrain, and other factors that could affect fatality rates. If some of these variables are relevant then their omission from the models can bias the estimated coefficients. For example, if unpaved roads are more common in the mountainous areas of the Central Region and fatal accidents are more likely in areas of steep terrain and sharp drop offs, then the model is misspecified and will incorrectly attribute higher fatality rates to the absence of pavement. Further investigation of this issue with more completely specified models could better identify the impact of road surface on fatality rates.

<u>Traffic Accident Data Set-Central Region</u>

The traffic accident data set for the ADOT&PF Central Region contains accident data for 1990-2000 on sections of sixteen Central Region roads, originally gravel, which were paved in the 1990s. AADT and the section length for the road at the site of the accident were added to the data set in order to compute accident rates per 1,000,000 vehicle miles (see equation A1). Two dummy variables were created with these data. As before,

[17] There are ten unpaved rural roads and thirty-two paved rural roads in the Central Region data. Thus the difference in the coefficients on the two dummy variables is not attributable to just a few observations.

DUMUNPAVE has a value of one for the year of the accident if the road section was unpaved and zero otherwise. DUMPROG has a value of one if the road was being paved during the year the accident occurred and zero otherwise.

A version of the model (equation A2) was estimated with the accident rate regressed on a constant and the two dummies. The estimated version of the model is not, by any means, an explanatory model for traffic accidents. The raw data contain little information on road characteristics and other factors. The purpose of the estimation is to uncover whether the absence of pavement or the process of paving is associated with accident rates different from those on paved roads. For this particular data set, the results show no statistically significant differences in accident rates among roads that are paved, unpaved, and roads being paved. Once again, however, due to data limitations we regard this conclusion as tentative.

Summary data, including the average AADT for the entire road, are shown in Table A4. For the period when the road was unpaved, the average AADT shown in the table is for the year immediately preceding the paving.

Table A4-Summary Data for Selected Central Region Roads

Road Name	Route Number	Year Paved[a]	Ave. AADT Unpaved	Ave. AADT[b] Paving in Progress	AADT, 2000 Paved
Cohoe Loop Rd.	114700	1998/99	668	701	567
Tote Road	116650	1998	513	506	510
Big Eddy Road	117100	1998/99	800	840	850
Forest Lane	118200	1997	200	153	215
Scout Lake Road	118700	1999	388	427	430
Knik River Road	136035	1999	187	188	190
Clark/Wolverine	136075	1996	908	1100	1535
Scott Road	137500	1999	350	350	370
Hyer Road	170020	1995	281	285	740
Church Road	170056	1998	523	620	673
Pittman Road	170066	1994	1060	1346	2658
South Big Lake	170073	1998	3099	3318	2921
Edlund Road	170076	1997	na	na	850
Hollywood Rd.	170077	1997	na	na	981
Beaver Lake Rd.	170081	1993	na	na	940
Long Lake Road	170086	1998	280	404	430

[a] The exact year of paving could not be determined from available ADOT&PF documents.
[b] For Cohoe Loop and Big Eddy Roads the year of paving is assumed to be 1999 in order to determine the average AADT.
na = not available

Traffic Volume
The Central Region data set discussed in the previous section can also be used to assess differences in traffic volume (as measured by VMT) between paved roads, unpaved roads, and roads that are being paved. Coefficients from the estimation of equation A3 are shown in Table A9 and provide an indication of the sensitivity of traffic volume to the road surface.

$$VMT_{it} = \beta_0 + \beta_1 DUMUNPAVE_{it} + \beta_2 DUMPROG_{it} + \varepsilon_{it} \quad \text{(A3)}$$

Table A5-Traffic Volume Model Estimated Coefficients, Central Region

	Equation A3	
	coefficient	**std. error**
constant	1314.60*	170.43
DUMUNPAVE	45.78	270.30
DUMPROG	-734.09*	192.52

*Significant at the 1% level

The significant, negative coefficient on DUMPROG indicates that VMT tends to fall on roads that are being paved. This result is expected. The finding is useful, however, because it suggests that differences in traffic volume attributable to the road surface can be uncovered even with an incompletely specified model of driving behavior and with a small sample of roads. Thus, a bit more confidence may be placed upon the finding that a significant coefficient is absent from the unpaved road dummy. This result suggests that paving an unpaved road does not increase traffic volume significantly, a noteworthy result given the common perception that traffic flows increase after paving. Once again, however, various limitations on the data and formulation of the model make this conclusion tentative but worth further exploration.

Additional Information

As discussed above, many observations in the fatality accident data set were lost because the it was impossible to determine the route numbers of the roads upon which the accidents were located. In addition, all fatal accidents that occurred in Anchorage were removed from the data. For the remaining observations, Table A6 shows the number of fatal accidents annually by road and route number for the study period. Not surprisingly, a large share of fatal accidents happened on the state's major highways.

Although the number of observations in the fatality data set was insufficient to estimate the model for each roadway characteristic and for weather and light conditions, the number of fatalities associated with these factors is shown in Tables A7, A8, and A9 for the three regions. Again, these data exclude roads in Anchorage and those roads for which route numbers could not be determined.

Table A6-Alaska Traffic Fatalities by Road, 1994-2000

CENTRAL REGION										
#	**ROAD NAME**	**RD #**	**1994**	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**TOTAL**
1	CHINIAK HWY	67400	0	0	2	0	0	0	0	2
2	REZANOF DRIVE	68000	0	5	0	0	0	0	0	5
3	MILL BAY RD LOWER	68525	2	0	0	0	0	0	0	2
4	LAKEVIEW DRIVE	68554	0	1	0	0	0	0	0	1
5	BALLYHOO	70810	0	0	0	1	2	0	1	4
6	STERLING HWY	110000	3	5	1	0	2	1	4	16
7	EAST END RD	110300	0	2	1	0	0	0	0	3
8	KALIFORNSKY	115400	0	0	1	0	0	0	0	1
9	KENAI SPUR RD	117600	1	2	1	2	2	1	3	12
10	ROBINSON LOOP RD	118500	0	0	1	0	0	1	0	2
11	SCOUT LAKE RD	118700	1	0	0	0	0	0	0	1
12	SEWARD HWY	130000	1	0	0	10	4	6	7	28
13	4TH AVENUE	134450	0	0	2	0	0	0	0	2
14	FUNNY RIVER RD	134530	0	0	0	0	1	0	0	1
15	E STREET	134557	2	0	0	0	0	0	0	2
16	AERO	134745	0	0	0	1	0	0	0	1
17	GLENN HWY	135000	0	0	0	3	2	0	1	6
18	OLD GLENN HWY	136000	2	2	1	0	0	0	0	5
19	BODENBURG LOOP	136045	0	0	1	0	1	0	0	2
20	PLUMLEY RD	136046	0	0	0	0	0	1	0	1
21	CLARK/WOLVERINE	136075	0	1	0	0	0	0	0	1
22	PALMER/WASILLA HWY	136800	4	0	0	0	1	2	1	8
23	SPRINGER LOOP INNER	136900	0	1	0	0	0	0	0	1
24	PALMER/FISHHOOK RD	137000	1	0	0	0	0	0	0	1
25	WILLOW/FISHHOOK RD	137700	0	1	3	0	0	0	0	4
26	PARKS HWY	170000	0	0	1	8	8	7	6	30
27	TRUNK RD	170006	0	0	0	0	0	0	1	1
28	KNIK-GOOSE BAY RD	170044	1	2	2	0	0	1	2	8
29	WASILLA/FISHHOOK RD	170047	0	1	0	1	0	0	0	2
30	LUCILLE RD	170059	0	0	0	1	0	0	0	1
31	PECK	170060	0	0	0	0	0	0	1	1
32	SCHROCK RD	170064	0	0	0	0	0	3	1	4
33	SELDON AVENUE	170065	0	0	0	0	1	0	0	1
34	PITTMAN RD	170066	0	0	0	0	0	2	0	2
35	BIG LAKE RD	170073	2	0	0	0	0	1	0	3
36	HOLLYWOOD BLVD	170077	0	0	0	0	0	0	1	1
37	BOGARD RD	170700	0	0	0	0	2	1	0	3
38	TALKEETNA RD	171000	2	0	0	0	0	0	0	2

NORTHERN REGION										
#	ROAD NAME	RD #	1994	1995	1996	1997	1998	1999	2000	TOTAL
40	DALTON HWY	150000	0	0	0	1	0	0	2	3
41	BENTLEY DRIVE	150049	0	0	0	0	0	0	1	1
42	OLD STEESE HWY (FOX)	150105	0	0	1	0	0	0	1	2
43	FARMERS LOOP RD	150200	0	0	0	0	1	2	0	3
44	CHENA HOT SPRINGS RD	151000	0	1	0	0	0	0	6	7
45	SUMMIT DRIVE	151510	0	0	0	0	0	1	0	1
46	GOLDSTREAM RD	151600	0	0	0	0	0	0	1	1
47	STEESE HWY	152000	1	0	0	0	0	1	1	3
48	FISH CREEK RD	152011	0	0	0	0	1	0	0	1
49	SOURDOUGH CREEK RD	152030	0	0	1	0	0	0	0	1
50	ELLIOT HWY	153000	0	2	0	1	0	0	2	5
51	MINTO RD	153030	0	0	1	0	0	0	0	1
52	STEVENSON ST	154000	0	0	0	0	0	1	0	1
53	AGVIK STREET	154020	0	0	0	0	0	0	1	1
54	PISOKAK	154055	0	0	0	0	0	0	1	1
55	WESTERN ACCESS RD	160000	1	0	0	0	0	0	0	1
56	COUNCIL RD	166500	0	0	1	0	1	0	0	2
57	NOME/TELLER HWY	167000	0	0	0	0	0	1	0	1
58	PROSPECT	168135	0	0	1	0	0	0	0	1
59	FRONT ST	168600	1	1	2	2	0	0	0	6
60	VILLAGE RD	174829	0	0	0	1	0	0	0	1
61	CHENA RIDGE/PUMP RD	175500	0	0	0	0	0	1	1	2
62	AIRPORT WAY	175700	1	0	1	0	0	0	1	3
63	GEIST RD	175800	0	0	0	1	0	1	0	2
64	UNIVERSITY AVE	175900	0	0	0	0	1	2	0	3
65	PEGER RD	176120	0	0	0	0	1	0	0	1
66	JOHANSEN EXPRESSWAY	177200	0	0	1	0	1	0	0	2
67	NORTHWAY RD	180800	0	1	0	0	0	0	0	1
68	DIKE RD	188610	1	0	0	0	0	0	0	1
69	BADGER LOOP RD	188800	1	1	0	1	0	0	2	5
70	HOLMES RD	188850	0	0	0	1	0	0	0	1
71	RICHARDSON HWY	190000	2	2	0	8	5	7	6	30
72	EGAN DR	190525	0	0	1	0	0	0	0	1
73	VALDEZ AIRPORT RD	191000	1	0	0	0	0	0	1	2
74	DAYVILLE RD	191600	0	0	0	1	0	0	0	1
75	EDGERTON HWY	198000	0	2	0	0	0	0	0	2
76	OLD EDGERTON LOOP RD	198500	0	0	1	0	0	0	0	1
77	TOK CUTOFF HWY	230000	0	0	0	0	0	0	1	1
78	NABESNA RD	237000	0	0	0	0	1	0	0	1
79	TAYLOR HWY	250000	0	0	1	1	0	1	0	3

SOUTHEASTERN REGION										
#	ROAD NAME	RD #	1994	1995	1996	1997	1998	1999	2000	TOTAL
80	MADISON	291406	0	0	0	1	0	0	0	1
81	NORTH TONGASS HWY	291500	2	0	1	0	0	1	1	5
82	HOLLIS	292000	0	0	0	1	0	0	0	1
83	HYDABURG RD	292100	0	0	0	0	0	1	0	1
84	MITKOF HWY	294000	0	0	0	0	0	0	1	1
85	THREE LAKES LOOP RD	294067	0	0	0	0	0	0	1	1
86	GUSTAVUS	295308	1	0	0	0	0	0	0	1
87	HALIBUT POINT RD	295400	0	0	0	0	1	0	0	1
88	KATLIAN	295439	0	0	1	0	0	0	0	1
89	DOUGLAS HWY	296000	1	0	0	2	3	1	0	7
90	THANE ROAD	296011	0	0	0	0	0	0	1	1
91	N DOUGLAS	296150	0	2	0	0	0	0	0	2
92	MENDENHALL LOOP RD	296400	0	0	0	0	0	1	1	2
93	RIVERSIDE	296500	0	0	1	0	0	0	0	1
94	HAINES HWY	298000	0	0	1	0	0	0	1	2

Table A7-Traffic Fatalities by Road Characteristic, 1994-2000

NORTHERN REGION				
ROAD CHARACTERISTIC		**UNPAVED**	**PAVED**	**TOTAL**
Atmospheric Conditions				
	Adverse or Unknown	5	7	12
	Not Adverse	27	68	95
	Total			107
Light				
	Daylight	20	46	66
	Not Daylight or Unknown	12	29	41
	Total			107
Road Alignment				
	Straight	19	37	56
	Curve	13	38	51
	Total			107
Roadway Function Class				
	Rural Arterial	12	27	39
	Rural Collector	8	30	38
	Rural Local & Rural Unknown	4	10	14
	Urban Arterial	4	5	9
	Urban Collector	0	3	3
	Urban Local & Urban Unknown	4	0	4
	Total			107
Roadway Profile				
	Flat	20	54	74
	Not Flat	12	21	33
	Total			107
Roadway Surface Condition				
	Dry	19	45	64
	Wet	3	13	16
	Snow, Slush, Ice	6	17	23
	Sand, Dirt, Oil, Other	4	0	4
	Total			107

Table A8-Traffic Fatalities by Road Characteristic, 1994-2000

CENTRAL REGION			
ROAD CHARACTERISTIC	**UNPAVED**	**PAVED**	**TOTAL**
Atmospheric Conditions			
Adverse or Unknown	0	27	27
Not Adverse	16	126	142
Total			169
Light			
Daylight	13	82	95
Not Daylight or Unknown	3	71	74
Total			169
Road Alignment			
Straight	7	78	85
Curve	9	75	84
Total			169
Roadway Function Class			
Rural Arterial	10	87	97
Rural Collector	2	43	45
Rural Local & Rural Unknown	2	18	20
Urban Arterial	2	3	5
Urban Collector	0	1	1
Urban Local & Urban Unknown	0	1	1
Total			169
Roadway Profile			
Flat	10	79	89
Not Flat	6	74	80
Total			169
Roadway Surface Condition			
Dry	7	78	85
Wet	3	24	27
Snow, Slush, Ice	6	49	55
Sand, Dirt, Oil, Other	0	2	2
Total			169

Table A9-Traffic Fatalities by Road Characteristic, 1994-2000

SOUTHEAST REGION			
ROAD CHARACTERISTIC	**UNPAVED**	**PAVED**	**TOTAL**
Atmospheric Conditions			
Adverse or Unknown	3	6	9
Not Adverse	2	17	19
Total			28
Light			
Daylight	2	8	10
Not Daylight or Unknown	3	15	18
Total			28
Road Alignment			
Straight	3	12	15
Curve	2	11	13
Total			28
Roadway Function Class			
Rural Arterial	1	2	3
Rural Collector	0	3	3
Rural Local & Rural Unknown	2	1	3
Urban Arterial	0	11	11
Urban Collector	2	6	8
Urban Local & Urban Unknown	0	0	0
Total			28
Roadway Profile			
Flat	2	10	12
Not Flat	3	13	16
Total			28
Roadway Surface Condition			
Dry	3	9	12
Wet	0	10	10
Snow, Slush, Ice	0	4	4
Sand, Dirt, Oil, Other	2	0	2
Total			28

APPENDIX B – PROPERTY VALUE SURVEY OF TAX ASSESSORS AND PROPERTY APPRAISERS

Introduction

The absence of studies and other information on property values and road paving led Northern Economics staff to conduct a short telephone survey of tax assessors and property appraisers in Fairbanks, the Matanuska Susitna Borough, Anchorage, Juneau, Ketchikan, and Sitka. The appraisers and assessors were asked about the effects of paving a gravel road on the value of an acre of undeveloped land bordering the road. Fifteen usable responses were received. The respondents in the Central and Southeast regions had similar comments. For reasons that are unclear, those in Fairbanks were more reluctant to offer opinions but did so in a few cases. A copy of the survey is located at the end of this appendix.

Survey Responses

Persons surveyed were first asked the to state the average value of an undeveloped acre of residential property having gravel road frontage in the rural areas of their region.[18] The responses varied widely, from $6,000 to $50,000 in the Central Region and from $11,000 to $100,000 in the Southeast. The two Northern Region respondents who provided numerical values indicated $7,500 and $20,000.

Each was then asked what the effect on the property value would be if gravel road fronting the hypothetical acre were paved. The dollar value of the responses again varied widely; but when converted to percentages the effects were more similar. In the Southeast region, with one exception, respondents thought that the value would increase between 0 percent and 15 percent. The exception thought that the privacy afforded by a gravel road was an important concern for many people and that they would pay more for an acre of land on an unpaved road. Respondents in the Central Region thought that residential property with gravel road frontage would rise by between 5 percent and 16.7 percent in value if the road were paved.

Only one respondent in the Northern Region was willing to provide a specific number for the change in the value of the hypothetical acre. That person's response indicated an increase of 153.3 percent in the value of the acre if the road were paved. However, this respondent insisted that gravel roads are not paved unless utilities are provided and refused to separate the amount attributable to the paving from the provision of utilities. Thus we consider the response invalid. Other Northern Region respondents refused to provide specific values but commented that paving would have little effect because roads were snow-covered for so many months.

Respondents were then asked to estimate the price of an average acre of undeveloped commercial property with gravel road frontage. Only three respondents were willing to

[18] One person specialized in commercial property appraisal and was unwilling to provide information on residential property values.

offer opinions, most stated that they were much more familiar with residential property or specialized only in residential property. Of the three who answered the questions, the value of the acre on an unpaved road ranged from $20,000 to $120,000.[19] If the road were paved one respondent from the Southeast region thought that commercial property would increase 2.5 percent in value while the other stated a 33.3 percent increase. The Northern Region respondent did not believe that paving a gravel road would have any effect on the values of adjacent commercial properties.

[19] The sole respondent from the Northern Region stated the lower value. The second of the two respondents from the Southeast said that $43,000 was the average price.

Questionnaire for Assessors, Appraisers

Hello, my name is_____________. I work for Northern Economics, a consulting firm in Anchorage. We are conducting a study on the effects of paving gravel roads for the Alaska Department of Transportation and Public Facilities. If you have a couple of minutes I would like to ask your opinion about the effects of paving gravel roads on land values in your area.

Name of firm or assessor's office.____

Name of person providing the information. ____

Location of the office ____

RESIDENTIAL

1. What is the average price of an acre of undeveloped **residential** land with gravel road frontage in the rural areas of your region? ____________________ TRY TO GET ONE NUMBER, NOT A RANGE.

2. Suppose that the road fronting the acre of undeveloped **residential** land is now paved but every other property characteristic is unchanged. As a result of the paving, the value of the land increases/decreases/remains unchanged (Circle one) by ____________________ . TRY TO GET ONE NUMBER AND NOT A PERCENTAGE OR A RANGE. ACCEPT THE PERCENTAGE IF NECESSARY.

COMMERCIAL

3. What is the average price of an acre of undeveloped **commercial** land with gravel road frontage in the rural areas of your region? ____________________ TRY TO GET ONE NUMBER, NOT A RANGE.

4. Suppose that road fronting the acre of undeveloped **commercial** land is now paved but every other property characteristic is unchanged. As a result of the paving, the value of the land increases/decreases/remains unchanged (Circle one) by ____________________ . TRY TO GET ONE NUMBER AND NOT A PERCENTAGE OR A RANGE. ACCEPT THE PERCENTAGE IF NECESSARY.

APPENDIX C – ECONOMIC DEVELOPMENT, LAND USE, AND RELATED ISSUES

Introduction

The effects of paving on business location decisions, employment, and economic development in general involves two, somewhat unrelated, questions. To what extent does road paving stimulate economic development that would not have otherwise occurred? To what extent does road paving cause shifts in economic development amongst different areas? Both questions are part of the overall debate about the role of public infrastructure, including transportation infrastructure, in economic growth. Unfortunately, neither question has been directly addressed in academic studies or research by transportation organizations and agencies. Thus the discussion which follows is based upon insight drawn from work addressing the more general issue of transportation infrastructure, particularly highways, and growth and from studies of road benefits across countries.

Literature Review

Public Infrastructure and Growth

The literature on the effect of public infrastructure on US economic growth is large and growing.[20] No consensus has yet been achieved about the nature of this relationship. The results of different studies are often contradictory. Aschauer (1989) was the first researcher to address this issue formally. He found that the contribution of public infrastructure to American economic growth was relatively large. Aschauer (1998, 2000) obtains the same conclusion in studies of the Mexican economy and for a sample of forty-six countries.

Other authors find that the contribution of public capital is more modest. Batina (1999) finds that the inclusion of a variable for oil shocks reduces the measured effects of public capital on output. Tatom (1993) disputes the conclusion that additional public capital increases productivity in the private sector. Tatom argues that methodological flaws of studies such as those of Aschauer generate the erroneous conclusion. Garcia-Milà, McGuire, and Porter (1996) reach a conclusion similar to Tatom’s for highways as well as other public capital.

In a study for the Federal Highway Administration (FHWA) Nadiri and Mamuneas (1998) find that public highway capital reduces the costs of production in thirty-two of thirty-five US industries from 1950 to 1991. For the thirty-five industry sectors, they estimated that each $1 net increase in the stock of highway capital generated almost thirty

[20] A comprehensive survey of this extensive literature is beyond the scope of this study. The studies cited should be viewed as representative of those which have been undertaken. Again, most of these studies deal with public capital, including transportation infrastructure. The few which address the role of paved road mileage are typically cross-section empirical studies which include data from less developed countries with a significant portion of unpaved roads.

cents in aggregate cost savings to producers. Furthermore they find that highway and private capital were complementary during the study period. In other words, additional highway infrastructure encouraged rather than supplanted private investment. However, they also note that the cost savings have declined over time and were much smaller in the 1981-1991 period than earlier. This last result implies that the most productive highway infrastructure investments have already been made.

Rephann and Isserman (undated) examine the economic effects of interstate highways upon counties through which the interstate passes or that are close to the interstate. Their results indicate that the economic benefits (post-construction) of an interstate highway vary with the nature of the county. Counties that contained cities of 25,000 or more residents and counties close to large cities had significantly higher growth rates as a result of the interstates. The higher rates of growth are particularly pronounced in retail trade and state and local government. Rural counties through which the interstate passed incur much smaller economic benefits but the pattern is similar to the urban counties. However, rural counties close to but not containing are harmed by the nearby interstate. The authors interpret this result as reflecting the increased competition faced by businesses in these areas; residents can travel at lower cost to urban areas for shopping. The Rephann and Isserman results suggests that highway projects can have significant distributional effects by encouraging changes in consumer behavior. Aldrich and Kusmin (1997) find that the location of an interstate highway interchange within a rural county is associated with higher growth in the county; a conclusion consistent with the findings of Rephann and Isserman.

More directly related to the issue of road paving, Canning (undated) does not find any significant effect of paved roads on the growth of per capita Gross Domestic Product (GDP) for a cross-section of countries. However, he regards this result as preliminary. Canning's result should not be considered as contradictory to those of Nadiri and Mamuneas. Canning uses paved road mileage as an explanatory variable in his study while Nadiri and Mamuneas examine highway mileage. Typically highway improvements reduce transportation costs for goods and this benefit could be expected to show up clearly in econometric studies. By contrast, paved road mileage should be substantially greater in most countries than highway mileage. Since much of the paved road mileage is not much used for the transport of goods, thus provides less-measurable benefits, the effects on output are more difficult to discern.

It is unclear whether the effects of highway and other transportation projects in Alaska would be greater or smaller than studies suggest for the remainder of the United States . Because the geographic area is so large and the road network so small there is probably more scope for productive transportation investment in Alaska than is true in the remainder of the nation if the state's population continues to grow. However, this conclusion is purely speculative; the contribution of transportation infrastructure to the economy of Alaska has not been addressed in any published studies.

Rather than a cause of income or output growth, paved roads can and perhaps ought to be viewed as a good which people demand more of as society's income grows. This is the perspective taken in a series of papers by Ingram and Liu (1997, 1998, 1999). They find that paved road length (meters of paved road per capita) increases at roughly the same rate as per capita income. The Ingram and Liu results, taken together with Canning's finding that paved road mileage does not have a statistically significant effect on per capita output growth, seem to suggest that paving roads would have little if any effect on economic development which would not have otherwise occurred.

Land Use

An ECONorthwest and Portland State University study (2001) conducted for the Oregon Department of Transportation found that highway projects had an ambiguous effect on land use. Their empirical model used data from sixteen Oregon communities that had highway projects completed in the 1970-1990 period. The model included a variable indicating whether new development occurred within an urban grid cell (approximately 2.3 hectares in size), and a number of explanatory variables. The model was estimated separately for the communities in the data set.

The explanatory variable of most interest is the distance of the grid cell from the highway project. If accessibility (i.e. distance) to a highway project encourages economic growth then the expected coefficient on the distance variable should be negative. However, they found the expected significant, negative coefficient in just four instances. For the other communities, the distance variable had significant, positive coefficients in five cases and insignificant coefficients in the other seven instances. Thus, the effects of the highway improvements on land use were ambiguous for the communities included in the Oregon study. Neither the Albany nor the La Grande/Island City case studies conducted by ECONorthwest and Portland State University (1999, 2001) showed evidence of development or land use changes that could be attributed to the highway improvements.

As already mentioned, studies seem to indicate that paving has almost no effect on economic growth. The land use studies in Oregon suggest that the paving of gravel roads will do little to shift economic development from one area to another. Together the studies imply the tentative conclusion that there will be little if any commercial development along newly paved roads.

APPENDIX D – SURVEY OF STATE AND PROVINCIAL TRANSPORTATION OFFICIALS

Introduction

Many of the issues that Northern Economics and HDR, Alaska wanted to address with this study have not been examined elsewhere. For example there is no publicly available literature on the effects of paving gravel roads on economic development and just one study has of water pollution comparing gravel and paved roadway surfaces. In order to obtain such information on paving operations and consequences and in order to assess practices in other areas, a survey was sent to Department of Transportation officials in the states of Washington, Oregon, Idaho, Montana, Wyoming, South Dakota, North Dakota, and Minnesota. The survey was also modified appropriately and sent to DOT officials in five Canadian provinces; British Columbia, Yukon Territory, Alberta, Northwest Territories, and Saskatchewan. Copies of the surveys are located at the end of this appendix. Completed surveys were received from one or more respondents in six of states. Ten completed surveys were returned. A single response was received from a Canadian respondent but too late to be incorporated into the document. Although this represents a very low response rate, it is quite likely that some who received the survey simply agreed to let one person in their office return a completed survey. Indeed, the Department of Transportation in one state aggregated the responses of a number of officials in that state and returned a single survey. Several of the respondents indicated a wish to keep their responses confidential. Consequently, none of the summary information discussed below identifies the locations of the responding officials.

Survey Findings

General results

The conclusions and opinions of transportation officials in other states concerning the results from paving gravel roads are consistent with those of officials in ADOT&PF with whom this issue has been discussed. However, the respondents considered the paving of unpaved roads to be a low priority for their departments probably because the mileage of state-maintained unpaved roads is so low elsewhere. The most oft-mentioned responses from officials in other states were the following:

- The amount of unpaved local roads mileage far exceeds that of unpaved state roads.
- Most respondents felt that average annual daily traffic volume and the desire to reduce maintenance costs were the two most important reasons for paving an unpaved road.
- Respondents generally indicated that paving a gravel road leads to lower maintenance costs, reduced air and water pollution, and an increase in average annual daily traffic.

Overview

DOT officials who responded to the survey generally regard paving gravel roads as either a low priority or not a priority for their departments. One respondent thought that such paving was a moderately important objective. These responses probably reflect the small amount of unpaved, state-maintained road mileage in these states. None of the states have an extensive network of unpaved, state-maintained roads. One state has somewhat more than 200 miles of unpaved, state-maintained roads. The others have less than 100 miles of such roads. In these states, almost all unpaved road mileage is in local hands. Individuals from five of the responding states indicated that there are between 15,000 and 80,000 miles of unpaved, locally-maintained roads.

The Departments of Transportation do not aggressively seek to pave the remaining unpaved roads. Some respondents did not know how many miles of unpaved roads had been paved in the last five years. Of those that responded several indicated zero miles. Others gave answers ranging from four to fifteen miles, except for individuals from one state who declared that slightly more than fifty-five miles had been paved.

Reasons

The survey listed nine possible reasons for paving and provided space for adding reasons that were not included in the survey. The survey included instructions that participants not rank any reason considered to be unimportant. Among respondents who ranked the listed reasons for paving an unpaved road, all but one considered the most important reasons to be annual average daily traffic volume and a desire to reduce road maintenance costs. All respondents except one rated these reasons with a 1 (most important) or a 2 (next most important).

Of the six respondents who ranked ‘political reasons’, four gave this reason a 2, 3, or 4 rating. In the minds of these four respondents, then, political reasons appear to be an important determinant of paving. The survey also included ‘local wishes’ as a reason. All but one respondent who provided rankings considered political reasons to be more important than local wishes in making the paving decision. Two of the three respondents who ranked all of the listed reasons considered local wishes to be the least important, relatively. Three other respondents considered local wishes to be unimportant.

Question 7 of the survey listed seven possible effects of paving an unpaved road. The respondents were asked to indicate which of the effects were commonly observed during the first year after the paving and which could be directly attributable to the paving. All who responded to this question thought lower road maintenance costs were a result of the paving. Reduced air pollution, including dust, was the next most cited effect followed by reduced water pollution and higher annual average daily traffic. Half the respondents thought that the paving lowered costs to road users. None of the respondents thought that the paving made the road safer for travel and reduced traffic accidents. No one believed that the paving stimulated economic development along the road during the first year after the paving but one respondent indicated that economic development resulted within five years of paving.

The final six questions in the survey addressed the results of paving in more detail. These questions dealt with the effects of the paving on accident rates, average severity of traffic accidents, average vehicle speed, property values, and usage by commercial and recreational vehicles. Each question indicated that the answer should be based on the respondent's experiences. However most of the respondents generally answered 'don't know/can't answer' for most of these questions. Two of the respondents who supplied this answer to most or all of the questions indicated that there were no data or studies available upon which they could base an answer. This type of response suggests that other departments of transportation have not formally studied the effects of paving gravel roads.

Among those who provided answers other than don't know/can't answer, there was a consensus that average vehicle speed increases once a road is paved. Two respondents provided estimates of the average percentage increase in speed, 10 percent and 25 percent. Two respondents thought that a paved road increased property values along the road although none offered an estimate of the magnitude of the increase.

In the opinion of one respondent, the number of commercial and recreational vehicles using a road increases after the road is paved. However, this respondent indicated that the magnitude of the increases would depend on development and local activities.

Conclusions

For the states represented by the returned surveys, the amount of state-maintained, unpaved road mileage is very low especially relative to the number of miles of unpaved, locally maintained roads. This probably explains why most of the officials indicated that paving unpaved roads was either a low priority or not a priority. It is likely that many of the respondents have been working many years for their states' departments of transportation and were employed when their states had many more miles of unpaved roads in the states' networks. Thus respondents generally were not hesitant to rank the reasons for paving and indicate some of the consequences of paving. However, they appear to have been reluctant to elaborate upon some of the effects of paving on accident rates and other factors. This reluctance probably arose because the data were unavailable and because the states had not conducted studies of the paving effects.

Road Paving Survey of State DOT Officials

IMPORTANT: If you prefer that the information you report be treated as confidential please so indicate by placing an X on the line by yes in the following statement. If you mark yes, any information you provide will be used only to compile aggregated data.

_______YES, I prefer that the information which I report be kept confidential.

SURVEY

PLEASE PROVIDE THE FOLLOWING GENERAL INFORMATION.

1. In what state do you work? ________________

2. How many miles of state-maintained unpaved roads are there in your state? _____________

a. How many miles of state-maintained gravel roads? ___________

b. How many miles of state-maintained dirt roads? ____________

3. How many miles of locally-maintained unpaved roads? ____________

4. How many miles of previously unpaved roads have been paved in the last 5 years? ________

5. In your state, what factors influence the decision to pave an unpaved road? Indicate the importance of the factor by placing a 1 next to the most important, 2 for the next most important, etc. For any unimportant factors leave the space blank .

Annual average daily traffic volume ______
Desire to reduce road maintenance costs ______
Desire to reduce road user costs ______
Desire to stimulate local economic development _____
Political reasons ______
Wishes of the local residents _____
Improve safety/reduce traffic accidents _____
Reduce air pollution (including dust) _____
Reduce water pollution _____
Other ______ Please indicate all that apply
____

For the following, please place an X in the space next to your answer except when a specific response is requested.

6. As an objective of your state's DOT, paving gravel or other unpaved roads is

highest need/priority _____
very important _____
moderately important _____
low need/priority _____
not an objective ____

7. Based on your experiences with your state's Department of Transportation which effects are commonly observed in the first year following the paving of an unpaved road? Please mark only those effects which you feel are attributable to the paved road.

Increased annual average daily traffic _____
Lower road maintenance costs _____
Lower road user costs ______
Economic development along the newly paved road_____
Safer travel/fewer traffic accidents _____
Reduced air pollution (including dust) _____
Reduced water pollution _____
Other ______ Please indicate all that apply
____

8. Based on your experiences with your state's Department of Transportation, in the first year after paving an unpaved road accident rates on the newly paved road generally

increase _____ (go to 8a) do not change_____
decrease _____ (go to 8b) increase sometimes and decrease sometimes _____
don't know/can't answer _____

8a. If accident rates generally increased, what was the average percentage increase? _____

8b. If accident rates generally decreased, what was the average percentage decrease? _____

9. Based on your experiences with your state's Department of Transportation, in the first year after paving an unpaved road the average severity of traffic accidents on the newly paved road generally

increases _____ (go to 9a) does not change_____
decreases _____ (go to 9b) increases sometimes and decreases sometimes _____
don't know/can't answer _____

9a. If accident severity generally increased how would you characterize the increase?
very large increase ____ large increase ____ moderate increase ____
small increase ____

9b. If accident severity generally decreased how would you characterize the decrease?
very large decrease ____ large decrease ____ moderate decrease ____
small decrease ____

10. Based on your experiences with your state's Department of Transportation, in the first year after paving an unpaved road average vehicle speed on the newly paved road generally

increases _____(go to 10a) does not change_____
decreases _____ (go to 10b) increases sometimes and decreases sometimes _____
don't know/can't answer _____

10a. If average speed generally increased, what was the average percentage increase? _____

10b. If average speed generally decreased, what was the average percentage decrease? _____

11. Based on your experiences with your state's Department of Transportation, in the first year after paving an unpaved road the value of property bordering the newly paved road generally

increases _____(go to 11a) does not change_____
decreases _____(go to 11b) increases sometimes and decreases sometimes _____
don't know/can't answer _____

11a. If property values generally increased, what was the average percentage increase? _____

11b. If property values generally decreased, what was the average percentage decrease? _____

12. Based on your experiences with your state's Department of Transportation, in the first year after paving an unpaved road the number of commercial vehicles using the newly paved road generally

increases _____(go to 12a) does not change_____
decreases _____(go to 12b) increases sometimes and decreases sometimes _____
don't know/can't answer _____

12a. If the number of commercial vehicles generally increased, what was the average percentage increase? _____

12b. If the number of commercial vehicles generally decreased, what was the average percentage decrease? _____

13. Based on your experiences with your state's Department of Transportation, in the first year after paving an unpaved road the number recreational vehicles using the newly paved road generally

increases _____ (go to 13a) does not change_____
decreases _____ (go to 13b) increases sometimes and decreases sometimes _____
don't know/can't answer _____

13a. If the number of recreational vehicles generally increased, what was the average percentage increase? _____

13b. If the number of recreational vehicles generally decreased, what was the average percentage decrease? _____

Road Paving Survey of Provincial DOT Officials

IMPORTANT: If you prefer that the information you report be treated as confidential please so indicate by placing an X on the line by yes in the following statement. If you mark yes, any information you provide will be used only to compile aggregated data.

_______YES, I prefer that the information that I report be kept confidential.

SURVEY

PLEASE PROVIDE THE FOLLOWING GENERAL INFORMATION.

1. In what province do you work? ___________________________

2. How many kilometers of province-maintained unpaved roads are there in your province? ___________

a. How many kilometers of province-maintained gravel roads? ___________

b. How many kilometers of province-maintained dirt roads? ____________

3. How many kilometers of locally-maintained unpaved roads? ____________

4. How many kilometers of previously unpaved roads have been paved in the last 5 years? ________

5. In your province, what factors influence the decision to pave an unpaved road? Indicate the importance of the factor by placing a 1 next to the most important, 2 for the next most important, etc. For any unimportant factors, leave the space blank.

Annual average daily traffic volume ______
Desire to reduce road maintenance costs ______
Desire to reduce road user costs ______
Desire to stimulate local economic development _____
Political reasons ______
Wishes of the local residents _____
Improve safety/reduce traffic accidents _____
Reduce air pollution (including dust) _____
Reduce water pollution _____
Other ______ Please indicate all that apply
____

For the following, please place an X in the space next to your answer except when a specific response is requested.

6. As an objective of your province's Ministry of Transportation, paving gravel or other unpaved roads is

highest need/priority _____
very important _____
moderately important _____
low need/priority _____
not an objective ____

7. Based on your experiences with your province's Ministry of Transportation, which effects are commonly observed in the first year following the paving of an unpaved road? Please mark only those effects that you feel are attributable to the paved road.

Increased annual average daily traffic _____
Lower road maintenance costs _____
Lower road user costs ______
Economic development along the newly paved road_____
Safer travel/fewer traffic accidents _____
Reduced air pollution (including dust) _____
Reduced water pollution _____
Other ______ Please indicate all that apply
____

8. Based on your experiences with your province's Ministry of Transportation, in the first year after paving an unpaved road accident rates on the newly paved road generally

increase _____ (go to 8a)   do not change_____
decrease _____ (go to 8b)   increase sometimes and decrease sometimes _____
don't know/can't answer _____

8a. If accident rates generally increased, what was the average percentage increase? _____

8b. If accident rates generally decreased, what was the average percentage decrease? _____

9. Based on your experiences with your province's Ministry of Transportation, in the first year after paving an unpaved road the average severity of traffic accidents on the newly paved road generally

increases _____ (go to 9a)   does not change_____
decreases _____ (go to 9b)   increases sometimes and decreases sometimes _____
don't know/can't answer _____

9a. If accident severity generally increased how would you characterize the increase?
very large increase ____ large increase ____ moderate increase ____ small increase ____

9b. If accident severity generally decreased how would you characterize the decrease?
very large decrease ____ large decrease ____ moderate decrease ____ small decrease ____

10. Based on your experiences with your province's Ministry of Transportation, in the first year after paving an unpaved road average vehicle speed on the newly paved road generally
increases _____(go to 10a) does not change_____
decreases _____ (go to 10b) increases sometimes and decreases sometimes _____
don't know/can't answer _____

10a. If average speed generally increased, what was the average percentage increase? _____

10b. If average speed generally decreased, what was the average percentage decrease? _____

11. Based on your experiences with your province's Ministry of Transportation, in the first year after paving an unpaved road the value of property bordering the newly paved road generally
increases _____(go to 11a) does not change_____
decreases _____(go to 11b) increases sometimes and decreases sometimes _____
don't know/can't answer _____

11a. If property values generally increased, what was the average percentage increase? _____

11b. If property values generally decreased, what was the average percentage decrease? _____

12. Based on your experiences with your province's Ministry of Transportation, in the first year after paving an unpaved road the number of commercial vehicles using the newly paved road generally
increases _____(go to 12a) does not change_____
decreases _____(go to 12b) increases sometimes and decreases sometimes _____
don't know/can't answer _____

12a. If the number of commercial vehicles generally increased, what was the average percentage increase? _____

12b. If the number of commercial vehicles generally decreased, what was the average percentage decrease? _____

13. Based on your experiences with your province's Ministry of Transportation, in the first year after paving an unpaved road the number recreational vehicles using the newly paved road generally

increases _____ (go to 13a)   does not change_____

decreases _____ (go to 13b)   increases sometimes and decreases sometimes _____

don't know/can't answer _____

13a. If the number of recreational vehicles generally increased, what was the average percentage increase? _____

13b. If the number of recreational vehicles generally decreased, what was the average percentage decrease? _____