OPTIMUM TRANSPORTATION SYSTEMS TO SERVE THE MINERAL INDUSTRY NORTH OF THE YUKON BASIN IN ALASKA

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ABSTRACT

In 1972 the U.S. Bureau of Mines awarded a grant (No. G 0122096) to the Mineral Industry Research Laboratory, University of Alaska, for a research project to determine optimum transportation systems to serve the mineral industry north of the Yukon River basin in Alaska. The study was conducted during the period May 1 - November 1, 1972.

The study assesses the mineral potential of the region and selects two copper deposits: a known one at Bornite, and a potential one on the upper Koyukuk River. Two possible mining sites within the extensive coal bearing region north of the Brooks Range are also selected. A computer model was developed to perform an economic analysis of technically feasible transportation modes and routes from these four sites to Alaskan ports from which minerals could be shipped to markets. Transport modes considered are highway, rail, cargo aircraft, river barge, winter haul road and air cushion vehicles (A.C.V.). The computer program calculates the present worth of tax benefits from mining and transportation and revenues based on the value of minerals at the port, as well as the auxiliary benefits derived from the anticipated use of the routes by the tourist industry. Annual and fixed costs of mining and transportation of minerals are calculated, and benefit-cost ratios determined for each combination of routes and modes serving the four mineral sites.

The study concludes that the best systems in terms of a high benefit-cost ratio are those utilizing a minimum of new construction of conventional highways or railroads. The optimum system as derived from this study is one linking together existing transportation systems with aircraft or A.C.V. These modes are feasible only for the shipment of a high value product, namely blister copper produced by a smelter at the mining site. Of the several alternatives considered for the shipment of coal, only a slurry pipeline to an as yet undeveloped port on the Arctic coast showed significant promise.

The study recommends that:

1. More government support should be given to mineral exploration in Alaska.
2. Potential mineral industry development should be considered in transportation planning at state and federal levels.
3. Additional research pertinent to mining and processing of minerals in the North should be conducted, and the feasibility of smelting minerals within Alaska explored.
4. Alternatives for providing power to Northwestern Alaska should be investigated.

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CHAPTER 1

INTRODUCTION

Ernest N. Wolff and Nils I. Johansen

Background

Early in 1972 the Mineral Industry Research Laboratory of the University of Alaska was asked by the U.S. Bureau of Mines to submit a proposal to determine "Optimum transportation systems north of the Yukon Basin in Alaska." Such a proposal was submitted and a contract (G 0122096) was awarded by the Bureau of Mines. Work began May 1, 1972, and the contract was terminated November 1, 1972.

Purpose, Scope and Methods

The purpose of the study is quite adequately stated in the title. However, it is not sufficient simply to estimate costs of transportation over various routes and to choose the least expensive. The interaction of routes must be considered, i.e. the addition of a branch route may make a first route competitive where without the branch route it was not. Also it is necessary to estimate some measure of benefits vs. costs, which in a sense is a feasibility measure. For example, a larger tourist industry could ensue from the building of roads and railroads, whereas it might not from other forms of transportation. To this end benefit-cost ratios are computed for each combination of route segments. The method of computing tourist benefits used in this report was developed during the course of the study; a description of the method is being published as M.I.R.L. Report 29A (Solie, 1973).

All benefits from minerals and from tourism are derived by computer. Basically, the only activities of possible economic importance in northern Alaska are mineral production and recreation, chiefly tourism and guiding. In northwestern Alaska, however, a resurgence of reindeer husbandry could increase the use of a surface transportation system. It has been estimated that the area has supported 600,000 to 1,000,000 reindeer and could do this again. No attempt has been made to estimate benefits from this industry, but they could be considerable on Seward Peninsula and vicinity. Also, no attempt has been made to assign positive or negative values to such things as the military or the national benefits of tying the country together with a transportation network, or the disturbing of wilderness, and other social and local economic effects.

When assessing the benefit-cost ratios of minerals and tourism, it is necessary to constantly bear in mind that such a measure is only as good as the data chosen for the computations.

In Chapters 5 and 6 the basic premises and the methods used to arrive at the figures are explained. Many of the figures (costs of mining or smelting for example) are little more than guesses, yet it is believed that the resulting ratios give a comparison that will indicate the best routes.

For some mineral areas it is impossible to calculate benefits and costs because their locations are not now known, e.g. in the Kandik or Galena oil basins. No benefit-cost ratios were estimated for these areas, but in each case, a brief qualitative description and analysis of alternatives is made in the narrative.

Authorship

This report is the work of several people, coordinating with each other. The various chapters have been written separately, and the names of the author or authors chiefly responsible appear on them. Dr. Chris Lambert, Jr., wrote the computer program.

Description of the Area

The portion of Alaska north of the Yukon River encompasses an area slightly larger than the State of Texas. The region has varied topography and climate and may be divided into several physiographic provinces. The following division is based on the one suggested by Fenneman and modified by Woods (1960, Sec. 9). The various provinces are:

1. The Alaskan Coastal Plain.
2. The Alaskan Piedmont.
3. The Brooks Range.
4. The Seward Peninsula.
5. Upland areas, part of the Central Alaska Uplands.
6. Lowlands, part of the central Alaska lowlands and plains.

The general boundaries of these provinces are shown on Figure 1-1. The boundaries are approximate; minor discrepancies between different authors can be found depending on the criteria used to identify unique problems within each province. All the provinces have several features in common; the climate is arctic to subarctic and the whole region is underlain by permafrost of varying thicknesses. Consequently, the entire area is subject to the problems that accompany permafrost.

There are also differences and variations within the region, e.g., the climate varies from continental to arctic, and the topography from interior lowland to countains to coastal plains. The provinces are as follows:

The Alaska Coastal Plain:

This area, encompassing the areas adjacent to the Arctic coast, is a low lying sandy plain covered with tundra and having numerous lakes; permafrost with thicknesses in excess of 1,000 feet underly it. The region has received much public notice because of the Prudhoe Bay oil development and the subsequent plans for building the Trans-Alaska pipeline. It is characterized by an arctic climate and the problems associated with this severe environment. The construction of transportation routes is extremely difficult due to lakes, permafrost and lack of material. The principal settlement in the area is the village of Barrow.

The Alaskan Piedmont

From an elevation of about 2,000 feet on the north side of the Brooks Range, the Alaskan Piedmont extends northward to the coastal plain. The vegetation is of the tundra type. The topography is broken by occasional hogbacks trending in an east-west direction. The region is known to have oil, gas, and coal reserves. The climate is arctic, and this combined with a general lack of construction materials makes development expensive. Permafrost is present to great depths. The construction of east-west transportation routes is probably feasible if full utilization is made of the hogbacks and of alluvium as a potential source of aggregate.

The Brooks Range

The Brooks Range, which crosses Northern Alaska from the Bering Sea to the Canadian Border, is the northernmost and westernmost extension of the Rocky Mountain system. Some peaks reach 8,000 to 9,000 feet in height, but there are few glaciers because of the low precipitation.

The geology of the Brooks Range is complex. Detailed descriptions can be found in several publications (M.I.R.L. Report No. 16, 1968, contains a section on geology and a complete bibliography of U.S. Geological Survey literature). The Range has undergone extensive thrust faulting, and there is widespread mineralization on the southern flank with several known deposits of commercial or near commercial grade. Transportation routes can follow east-west valleys and cross the range at several locations through low passes.

Seward Peninsula

The Seward Peninsula was made famous when gold was discovered at Nome, and it is today considered one of the most highly mineralized parts of Alaska. The topography is rugged and varied, with a soil cover that is in general shallow with sparse vegetation. Ice-rich permafrost and related features, such as solifluction, cover large areas.

Upland Areas

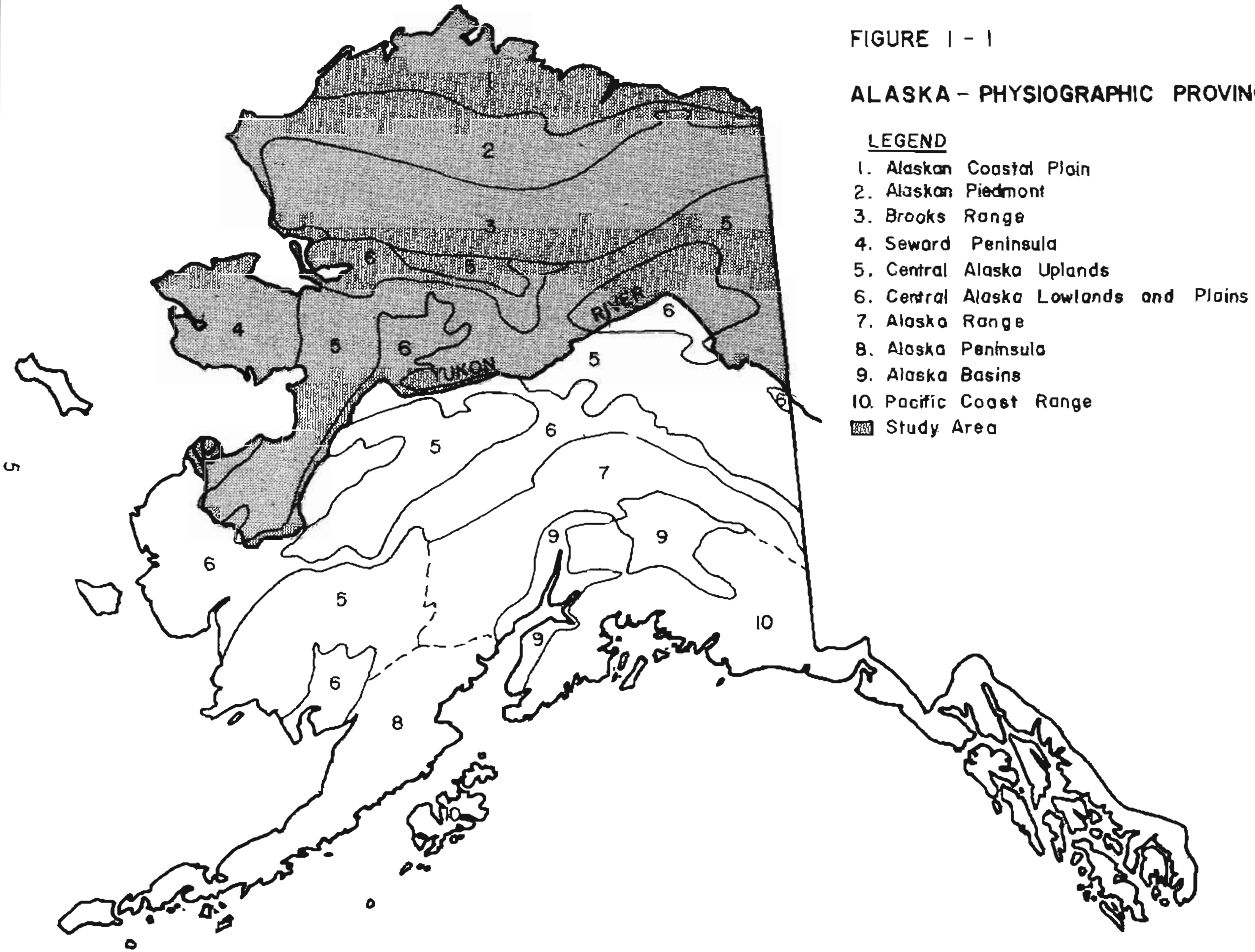
Within the Yukon drainage basin, there are isolated masses of uplands, the northernmost of which are within the area considered in this report. They consist mainly of metamorphic and igneous rocks, and contain several gold mining districts.

Lowlands

The lowlands along the Yukon River and on other rivers encompass large areas. The largest are the Yukon Flats and the delta area, although the Koyukuk, Noatak and Kobuk Rivers also have large lowlands. The areas are underlain by permafrost and are poorly drained and contain numerous lakes. Tundra-type vegetation is common, but some areas support trees. The region is characterized by extreme seasonal variations in temperature, especially toward the east. At Fort Yukon, the maximum recorded summer temperature is 100 degrees F, whereas the record minimum winter temperature is -75 degrees F. The basins may contain oil, and exploratory geophysical investigations are currently being studied by the oil industry. Due to the widespread ice-rich permafrost in these low areas, great care will have to be taken in locating transportation routes across them.

FIGURE 1 - 1

ALASKA - PHYSIOGRAPHIC PROVINCES



CHAPTER 2
MINERAL POTENTIAL

Ernest N. Wolff

A common misconception, especially in Alaska, which is notably lacking in transportation facilities, is to assume that there are many large mineral deposits simply awaiting the arrival of surface transportation in order to be mined. Unfortunately, this is true for only one or two deposits, partially or potentially true for a few more. It is true for the Prudhoe Bay petroleum field, which is awaiting authorization to start the pipeline, and partially true for the Bornite copper deposit, the Lost Fiver fluorite deposit, and especially the Northern Alaskan Coals in that they will become operative with the advent of transportation, if the transportation costs are low enough. It is potentially true for a number of deposits, the existence of which can reasonable be inferred on the basis of geology and surface showings. In this study it has been necessary to include all three categories.

It is not reasonable that a region containing roughly 10% of the area of the United States should not contain much hidden mineral wealth. However, in this study, although there is some speculation, it is kept within strict bounds. This report assumes that known reserves of copper around Bornite will be greatly expanded, and that at least one more copper deposit will be found farther east in the Brooks Range, and that extensive exploration for oil will take place in all sedimentary basins in the area.

Petroleum

Figure 2-1 shows the possible petroleum provinces north of the Yukon. Of these, the Arctic Coastal Plain and the Foothills area are known to contain oil and gas, and of course, the Prudhoe Bay field is too well known to require further mention here. The mode of transportation of oil and gas from the Prudhoe field has already been decided by the oil industry after considering tankers and alternative pipeline routes. The oil will travel by 48-inch pipeline along a fixed route to Valdez and thence by tanker to West Coast ports. As a necessary preliminary for building the pipeline, an all weather road will be constructed from a point on the north bank of the Yukon at the end of the present road system. Likewise, any other oil fields discovered in the Northern basin will probably deliver their oil via branch pipelines, built along roads branching from the main pipeline road.

The other possible petroleum provinces in northern Alaska are the Selawik, Kobuk, Galena, Yukon Flats, and Kandik (see Figure 2-1). At this time, it is not justified to project transportation systems beyond those needed for exploration of these basins, since the locations of potential oil fields are unknown. None of the basins have seen any work, except for some seismic surveys, and a single hole west of Galena. This hole is reported to have penetrated highly faulted rocks having poor reservoir quality.

There appears to be little doubt that exploration in the Selawik Basin would be conducted with equipment and supplies brought by barge to Kotzebue and thence to a near point on the coast or on a river. Tractor train or Nodwell and sleds would be used to reach the desired locality.

The Kobuk province could be serviced by one of three alternative methods: river barge and tractor train, road and tractor train from Fairbanks, or road and tractor train from Lost River or Port Clarence.

The Yukon Flats basin could be reached by barge and tractor train, or road and tractor train. The Kandik area could likewise be serviced by these two alternative methods, although a third method could be a road from Circle to the Porcupine River. (See Figure 4-2.)

Gold

Gold mining has traditionally been the backbone of Alaskan industry, for two reasons: gold was and is widespread in Alaska, and it has high unit value and requires no elaborate transportation system to get it to marker. This consideration is probably less important today, but it does influence the choice of a transportation method; gold mines require essentially only one-way transportation.

Likewise, the placer gold districts of Alaska have traditionally shaped the distribution of population and settlements. All of them had names, and most of them had their own judicial system in the form of a U.S. Commissioner - Recorder (now a State Magistrate).

Figure 2-2 shows the distribution of districts north of the Yukon. The greatest concentration is on Seward Peninsula, where seven such districts are recognized; at one time all of them had recording offices. These are Nome (1), Council (2), Fairhaven (3), Kougarok (4), Koyuk (5), Port Clarence (6), and Serpentine (7). The Ungalik area, south of Norton Bay, may be considered part of the Koyuk district. These districts occupy widely dispersed areas, so that the whole of Seward Peninsula may be considered as one large placer district. At present, freight reaches the mines by several routes. Nome is the principal supply point, although districts at some distance from Nome may be served from other points on the coast. Basically, the routes now available for supplying the gold placer mines of Seward Peninsula from originating ports in the States are these:

1) Ocean-going barge to nearest landing, lighter ashore, tractor from coast, or if roads are available, use trucks,

2) Ocean-going barge to Nome, truck from there to mines or nearest point, then tractor. Alternatively use small barge from Nome to beach, then tractor,

3) Ocean-going barge to Kotzebue for redistribution by barge and tractor.

Gold mineralization is widespread throughout the southern Brooks Range, although commercial exploitation has been possible only at a few centers. The area north of Kiana (8) and around Shungnak (9) have been centers of small operations; both are served by barge or boat from Kotzebue. The Shungnak district most certainly will benefit from the presence of a copper mine at Bornite.

The Koyukuk River system, covering a very large area in northcentral Alaska, contains several gold districts. The Upper Koyukuk district (10) extends from John River and Wild Lake on the west to Gold Beach on the South Fork. The principal production, however, has occurred along the Middle Fork near Wiseman. No lode gold has been produced, only placer. Another district is centered near Hughes (11) on the middle Koyukuk. Hog River (12) to the northwest, has supported a one dredge operation for almost 25 years. It is reached by barge and road, and by air.

The Chandalar gold district (13) has been known since 1906. In pre-airplane times, transportation was extremely difficult, involving an overland trip of 125 miles from Beaver on the Yukon. Production was small and involved hand methods before World War II, but beginning in 1950, heavy equipment was used. This district, unlike the others in the Brooks Range, has extensive gold quartz lodes, some of relatively high tenor, which have barely been developed. The Chandalar district will require greater quantities of freight than other gold districts because of the more complex operation of mining the lodes.

Small centers of placer gold mining occur farther south, close to the north side of the Yukon. Marshall (14) on the lower river, and Melozitna (15) on the central river are the two best known.

Very little prospecting in new areas has been done since the gold rushes. At the time of widespread activity, many prospects were reported but not followed up. It is almost certain that new creeks will be found in the areas south of the north slope, but their importance will be limited to establishing small operations and small centers of seasonal population. Discovery of such placer mines will be speeded up by the establishment of a road network, and this should be borne in mind when routes are laid out to major base metal or nonmetallic mineral areas. However, transportation of supplies to these gold districts must be primarily by air and/or tractor train from the road system.

Copper

Since the early 1950's, the area north of Shungnak, on the Kobuk River in the Baird Mountains, has been under exploration and development for copper. This area probably has the greatest potential for copper at present of any in Alaska, and no doubt would be further advanced towards production if transportation was available. At present, numbers cannot be assigned to grade or reserves, but indications are that it will become a major producer of copper. There is little doubt that the area is a prime target of a transportation system.

Copper mineralization extends eastward from the Bornite area all the way into the Koyukuk and Chandalar districts. For the purposes of this study, it is assumed that there is a 75% chance that a major copper deposit will be discovered somewhere near the headwaters of the eastern Koyukuk or western Chandalar drainage.

In trying to assess the need for power from a dam across the Yukon at Rampart, it was postulated that mines in the Tindir group near the Canadian Border north of Eagle could be producing 3 million tons per year of copper ore by 1995 (U.S.D.I., 1967). There appears to be little justification for this statement. Equipment and supplies for exploration in this area would probably be moved at first by river and tractor train, later by a road north from Eagle.

Coal

Northern Alaska contains very large reserves of coal of sub-bituminous and bituminous rank. Barnes (1967) estimates the region to contain 20 billion tons of bituminous and 110 billion tons of sub-bituminous coal, down to a depth of 3,000 feet. These figures are approximate only, but indicate tremendous reserves. A later estimate (U.S. B.M., 1971) gives 478 million tons of bituminous and 3.4 billions tons of sub-bituminous strippable coal (down to a depth of 120 feet). For purposes of classification, the reserves are listed for six areas: Corwin Bluff - Cape Beaufort, Kukpowruk, Kukolik, Utokok, Meade River and Colville River (Barnes, 1967). The area underlain by coal, therefore, (Figure 2-3) extends from the coast of northwest Alaska half way to the Canadian Border. Almost no detailed information is available on this coal. It has been used for domestic fuel at a few points on the coast, and the U.S. Bureau of Mines has done a small amount of drilling. The U.S. Geological Survey and the University of Alaska have made analyses and some feasibility studies, and the U.S. Bureau of Mines has sponsored a study of transportation economics of these coals at the College of Earth Sciences and Mineral Industry at the University of Alaska, (Clark, 1973). (Note that later in this study, only two fields are considered, one at Kukpowruk and one on the Colville -- called herein "Knifeblade" for Knifeblade Ridge.)

Fluorite

The Lost River area on the Seward Peninsula has long been known to contain tin, but recently other associated minerals have come to the fore. The Lost River Mining Company has announced plans for developing its fluorite deposits at Lost River. According to its annual report (McQuat,1972) they now have 28 million tons of ore with an average grade of 18.6% CaF_2. The Company expects to upgrade this ore to a concentrate containing about 85% CaF_2. The mining rate is expected to be about 4,000 tons per day of ore, producing about 300,000 t.p.y. of concentrates. It is expected that the above reserves will last 20 years. According to the annual report of the Company, there is an excellent chance of increasing reserves. Preliminary plans call for building a port at Lost River and using a 30,000 ton semi-icebreaker ship making one trip per month for up to 10 months. Tin, tungsten and beryllium would be produced as a by-product; tin and tungsten are estimated to make up one half of the value.

Lead-Zinc

There are several gossans near Nome that show strong zinc geochemical anomalies. No quantitative data are available; the gossans are raw prospects. In addition to the gossans, veins of barite and fluorite-galena are reported near Nome (Probst., et al, 1972) indicating potentially large area of mineralization. Drilling any of these areas might develop reserves of zinc and/or lead ore. The present Nome-Teller road could serve for supplying an exploration effort and if a mine was developed, the same road could be upgraded and extended to Lost River or some other port.

Antimony

The history of antimony production in Alaska leads to the conclusion that only small highgrade deposits can be worked. However, antimony mineralization is widespread, and in times of high prices, many small deposits are worked and the ore is hand sorted. A deposit near Wiseman most certainly will benefit from the pipeline road shortly to be constructed. However, only a few tens of tons would be shipped in any one year. Other prospects in northern Alaska could be benefited by a road network.

Industrial Minerals

Industrial minerals generally have value only as a result of being located near a market, hence, those in Northern Alaska have little or no present value. However, some nonmetallics have a high enough value to bear the cost of export, among them asbestos. Asbestos does occur in the Shungnak district, and a small amount has been shipped. Any development of this resource would be tied to a development of the Bornite copper deposit.

Phosphate rock occurs in three general areas (Committee print, p. 141): 1) In a zone about 50 miles long between the Canning and Okpilak River; 2) Between the Chandler and Anuktuvuk Rivers, especially in the Tiglukpuk-Kiruktagiak River area; 3) Near the headwaters of the Colville. These areas are shown in Figure 2-4, as are areas of other industrial minerals. Considering the price of phosphate rock, the remoteness of the region, and the abundance of reserves elsewhere, it is not possible to develop this phosphate in the near future. Hence, phosphate rock is not considered in this report as a potential target for a transportation system.

Graphite and graphitic schist occur near Imuruk Basin on western Seward Peninsula, (Committee print, 1964, p. 133). About 270 tons have been produced, but reserves appear to be limited, although insufficient exploration has been done to establish this. Transportation would probably be by road to Lost River.

Mica occurs in the Bendeleben-Darby Mountains, where sheets as large as 20 inches across have been found; very little is known of reserves.

Noatak Valley Reconnaissance

A more detailed reconnaissance traverse of the Noatak River Valley in the Western Brooks Range was carried out by Dr. Thomas D. Hamilton (1972) of the Geology Department, University of Alaska. Dr. Hamilton accompanied the Alaska Task Force of the National Park Service and his report makes mention of possible mineralized zones in the area, including possible mercury and copper mineralization. His report indicates that the Noatak Valley is similar to other drainage ways in the eastern Brooks range. Permafrost features are common, but it should be possible to establish a transportation system within the valley. Access is also provided to the valley through North-South passes. No attempt is made in this report to speculate on either a possible mining area or transportation corridor through the Noatak Valley area.

Northeastern Alaska

The eastern end of the Brooks Range (Romanzof Mountains) in Alaska is closed to any activities. The area is extremely isolated, and there has been almost no exploration. However, possibly because of this lack of information, the belief persists that the area may contain mineral deposits. A statistical study made some years ago (Harris, 1968) indicates a probability that moderate-sized mineral deposits occur in the region. If this area should be opened to exploration, probably nothing would happen until active work should begin in the Kandik oil basin, when it is possible that a road would be built from Circle northward.

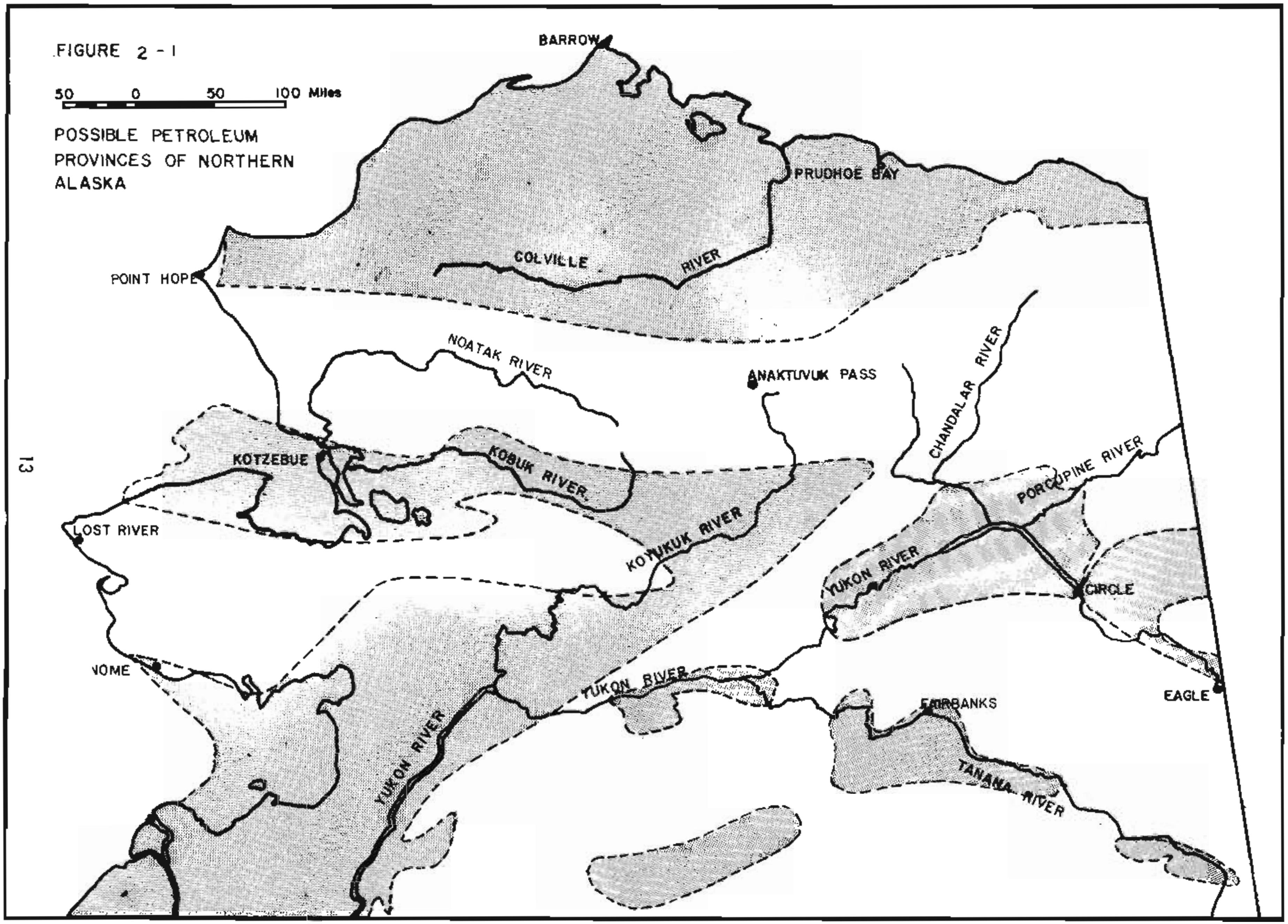


FIGURE 2 - 1
50 0 50 100 Miles
POSSIBLE PETROLEUM PROVINCES OF NORTHERN ALASKA
BARROW
PRUDHOE BAY
COLVILLE RIVER
POINT HOPE
NOATAK RIVER
ANAKTUVUK PASS
CHANDALAR RIVER
KOTZEBUE
KOBUK RIVER
PORCUPINE RIVER
LOST RIVER
KOYUKUK RIVER
YUKON RIVER
CIRCLE
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YUKON RIVER
TANANA RIVER

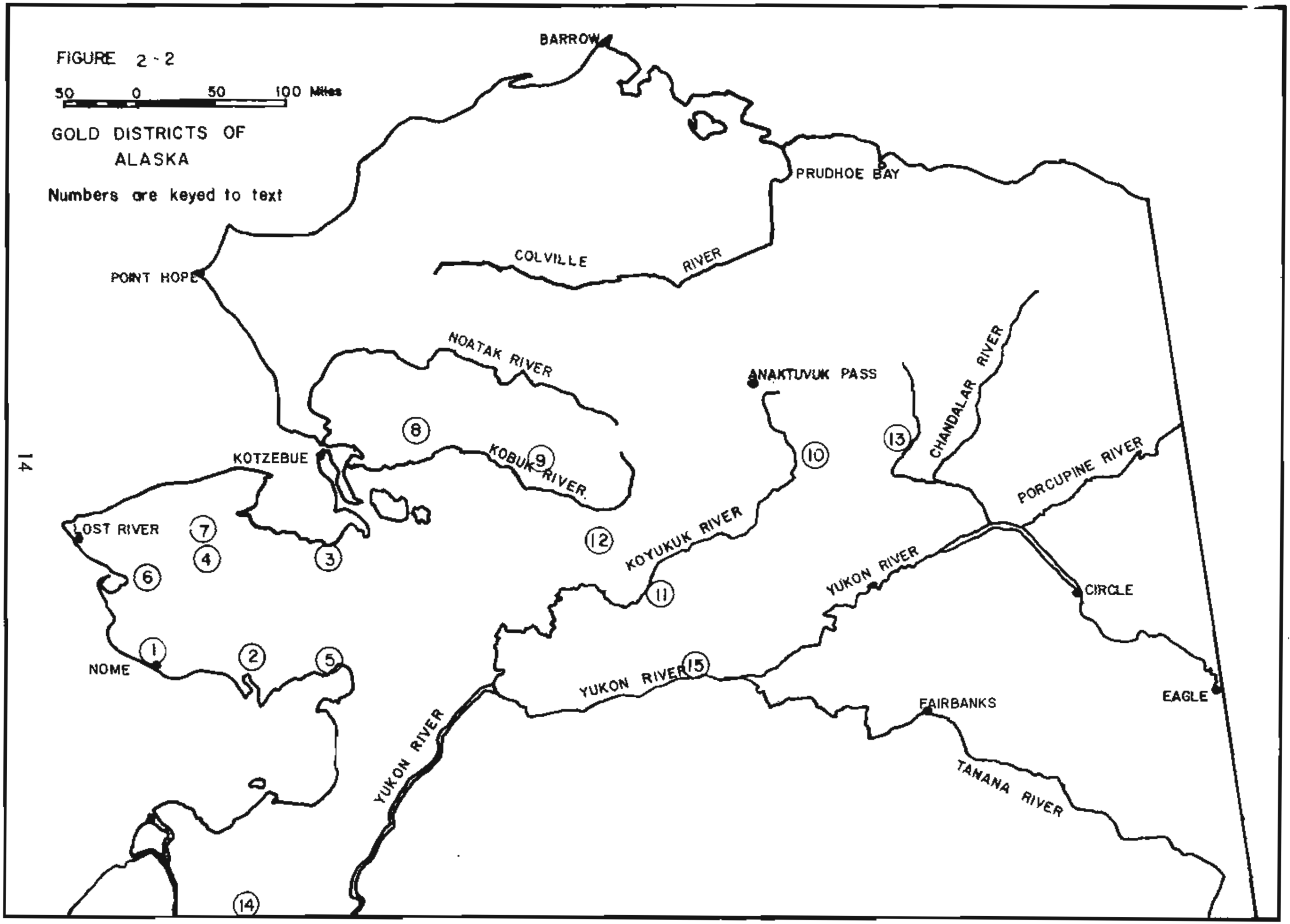
FIGURE 2-2
50 0 50 100 Miles
GOLD DISTRICTS OF ALASKA
Numbers are keyed to text
BARROW
PRUDHOE BAY
COLVILLE RIVER
POINT HOPE
NOATAK RIVER
ANAKTUVUK PASS
CHANDALAR RIVER
KOTZEBUE
KOBUK RIVER
PORCUPINE RIVER
KOYUKUK RIVER
LOST RIVER
YUKON RIVER
CIRCLE
NOME
YUKON RIVER
FAIRBANKS
EAGLE
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11
12
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14
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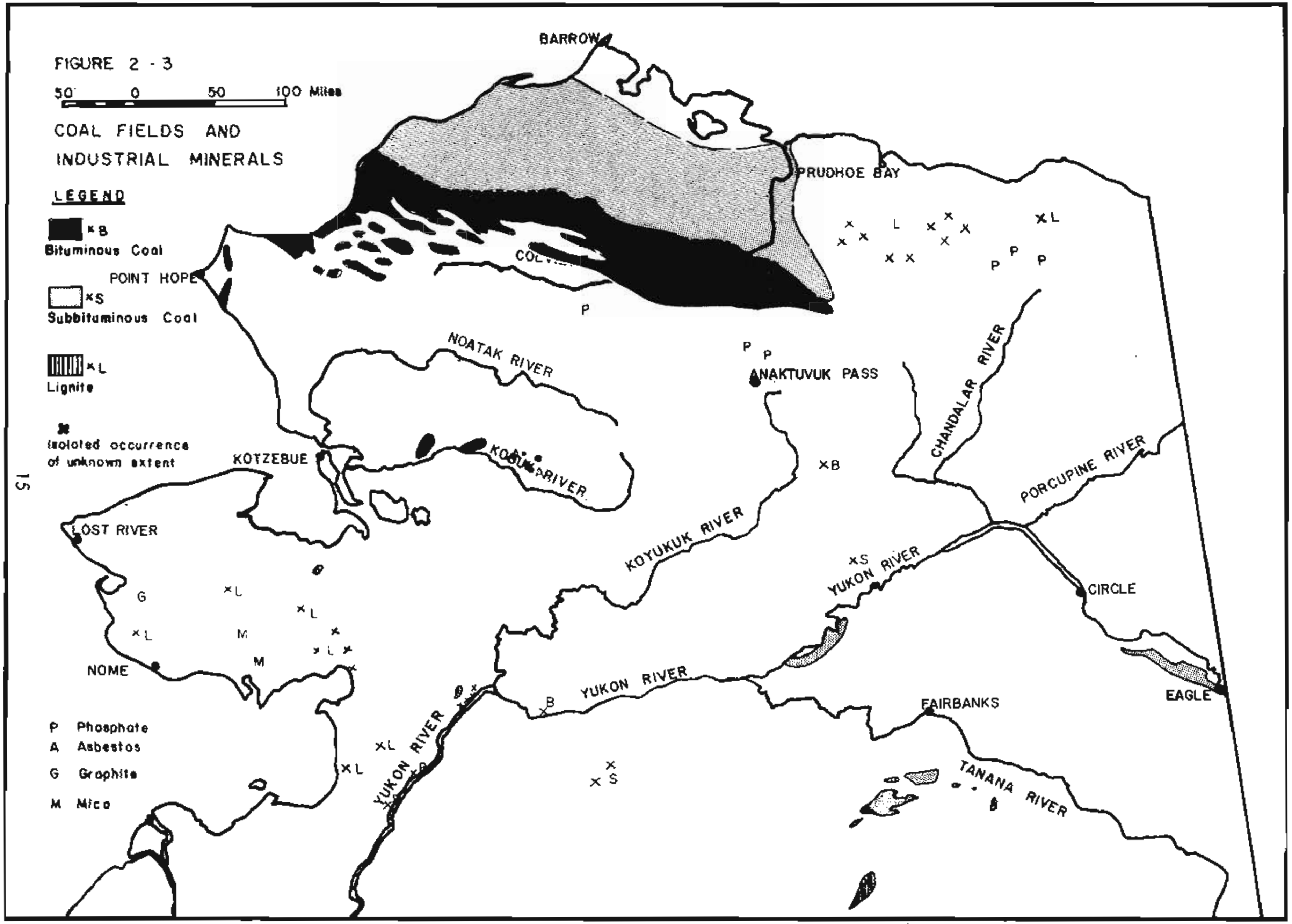
FIGURE 2 - 3
50 0 50 100 Miles
COAL FIELDS AND INDUSTRIAL MINERALS
LEGEND
×B Bituminous Coal
×S Subbituminous Coal
×L Lignite
Isolated occurrence of unknown extent
P Phosphate
A Asbestos
G Graphite
M Mica
BARROW
PRUDHOE BAY
POINT HOPE
NOATAK RIVER
ANAKTUVUK PASS
CHANDALAR RIVER
PORCUPINE RIVER
KOTZEBUE
KOBUK RIVER
LOST RIVER
KOYUKUK RIVER
YUKON RIVER
CIRCLE
NOME
EAGLE
FAIRBANKS
TANANA RIVER

CHAPTER 3

THE TRANSPORTATION MODEL

Richard J. Solie

The model described in this chapter was designed to determine the optimal transportation system for mineral development in the area north of the Yukon River in Alaska. Its basic approach is to estimate benefits and costs for each of the alternative transportation routes, and then to select from among the many possible combinations of routes that system which will yield the highest benefit/cost ratio to government. It is possible that for some of the major areas of mineral concentration, no route will prove to be cost beneficial, and thus the optimal system will not serve those areas. Because of this, a second system is also determined which will be the optimal system serving all of the major areas having valuable known concentrations of minerals.

General Assumptions and Methodology of the Model

A number of assumptions were made in the construction of the model and in the gathering and analysis of the data. The existence of already constructed transportation routes was an obvious assumption. In addition, it was felt that measurement of the costs and benefits for the Trans-Alaska Pipeline and the companion highway would be superfluous since their economic feasibility has already been well established and the commencement of construction currently hinges on environmental, rather than economic considerations. Similarly, it was felt that the feasibility of developing the fluorite mines at Lost River entailing construction of haul roads and the development of adequate port facilities has been sufficiently studied. Thus, the existence of the pipeline and road as well as the Lost River roads and port facilities is assumed in the study. This means that neither the cost of construction and fixed maintenance nor the benefit from mineral extraction in those two locations is considered herein.

A 25-year benefit period is assumed in the study, and further benefits (or costs) beyond the end of that period are ignored. There was no attempt in the study to estimate future inflationary trends in the prices of minerals or in the various pertinent cost factors. Thus, all costs and prices are based on relationships which currently exist, and projections for future years assume stable prices and costs. To compensate for this lack of an inflationary adjustment, a 3% rate of interest is used in discounting future costs and benefit flows. Use of such a rate has the same effect on the present value of future flows as would an assumption tidewater revenues are used rather than market values since transportation could be in foreign ships and mineral sales might be to foreign markets. The size of the multiplier used in the study is 2.5 with the assumption that approximately 60% of the increased gross product occurs in Alaska and 40% occurs elsewhere in the United States.

In estimating benefits for the first concept, it is assumed that 80% of the Alaska employment is filled by unemployed persons or by workers whose former jobs can be filled by unemployed, while for the rest of the nation, 50% are in the same situation at the time of their hiring. Thus, 20% of the changes in Alaska gross product resulting from development of the transportation system and 50% of those occurring elsewhere in the nation are deducted from the total change to account for the "opportunity cost" of the formerly employed workers (i.e., for the reduced output in positions which they vacated. This assumption is in keeping with the continuing very high levels of unemployment in the state and above full-employment levels in the nation as a whole. The 2.5 is in line with common estimates of the national expenditures multiplier while the assumption that 60% of the increased gross product occurs in Alaska is in keeping with an Alaskan multiplier of 1.5 (Tussing, et. al., 1971, p. 115.) Thus, increased gross national product (including varied gross state product) equals 60% x 80% (share of total output produced in Alaska x the % of Alaska output which is increased gross product) + 40% x 50% (share of output produced elsewhere x % elsewhere which is increased gross product) + 68% of the total output change resulting from development of the transportation system.

Taxes and welfare and unemployment insurance costs savings due to the direct revenues from mining, transportation, etc., are calculated separately for each activity. The tax rate applied to the multiplier effect is the same in each case and is an average rate determined by adding: (1) the sum of all federal taxes divided by the GNP (approximately 18.9%, (2) the sum of all state taxes ÷ Alaska gross product (approx. 5.6%) (see Tussing, et. al., 1971, p. 31) and (3) the average rate of welfare-unemployment insurance cost saving per dollar of increase in GNP. The latter is estimated by assuming an average salary of $10,000 per year for each person employed as a result of the increased GNP and dividing this into the average of approximately $2,000 per year in combined unemployment insurance and welfare costs paid to unemployed Alaskans. (Calculated by dividing total Alaskan unemployed into total state welfare and unemployment insurance costs for 1971.) The resulting 20% rate is further multiplied by the approximately 60% of GNP represented by compensation of employees to yield an average of 12% welfare cost savings for increases in GNP. The total tax rate is thus: 18.9% + 5.6% + 12% = 36.5%. Note that: the $10,000 per year income is a reasonable of, for example, a 7% rate of discount along with a 4% inflation factor. Note: Although interest rates and the rate of price increase are not perfectly correlated, it is generally true that because of time preference, high rates of inflation require higher rates of interest in order to maintain the incentive for saving. Furthermore, rates of interest in long-term government bonds of even less than 3% have been experienced in periods as recently as the early 1950's. (Board of Governor's 1965, p. 25.)

It is considered beyond the scope of the study to estimate the impact of Alaskan production on the price structure of the various minerals considered. Thus, mineral prices are assumed to remain constant regardless of the level of Alaskan production. This, of course, could introduce a definite upward bias in the benefit estimates, but it would probably only be significant where Alaskan production would represent a major part of world output.

Transportation routes from a given mine location are considered to be mutually exclusive. Thus, it is assumed that minerals from a given mine location would not concurrently be shipped on more than one route or to more than one port. It is possible in the model, however, for a mineral to be shipped on one route during one portion of a year and on another route during another portion (e.g., by barge during the summer and by winter haul road in the winter months).

Two different concepts are used in calculating the benefits in the model. The first represents benefits to government, a relatively conservative measure of benefits. The second represents the total gross product of the system, and gives an upper limit to benefits at the assumed levels of mineral and business development.

1) The first concept measures the potential benefits to the Federal and State Governments in terms of taxes, reduced welfare, unemployment insurance costs, etc., resulting directly from mining operations, minerals transportation, tourism, and business generated for support services, as well as from the multiplier effect of the increased expenditures (jobs and income created as an indirect effect of the activity). Miscellaneous benefits are calculated which would include such items as savings to an existing population, of reduced costs of transportation, etc. Economic profits (i.e., profits above "normal profits" -- the minimum level required to induce the company to develop and operate the mine) are also included in the benefits since these could be tapped for transportation route construction costs by agreement between government and the mining company, by road tolls, etc.

The multiplier effect is calculated on gross tidewater revenues less reduction in unemployment insurance payments and welfare costs since this is the best estimate of the direct nationwide aggregate demand resulting from development of the transportation system. Gross assumption for employed Alaskans, but is undoubtedly high as an average elsewhere. This, therefore, also introduces a downward bias to the benefits by lowering the welfare unemployment insurance cost savings rate. Also, the use of average tax rate rather than a marginal tax rate creates a downward bias in the estimates because of the graduated tax system.)

The second concept considers benefits from the standpoint of the economy as a whole and includes the total gross product from the transportation system-induced output, without any deduction for costs of production, transportation, etc. This measure reflects the fact that the entire increase in output is a benefit to the economy (or society) as a whole, since it represents an increase in the "size of the pie" available for distribution among the same sized population. In this second approach, no adjustment is made for possible output reductions in other areas of the economy resulting from a shift of resources and, thus, it represents the upper limit of what the benefits could be if measured from the overall economy's view and, if all the labor used in the new production was either unemployed previously or left positions subsequently refilled by unemployed. The ability to effect the labor force transition required to accomplish such a shift, even in an economy with high levels of unemployment, would certainly require a well planned program of recruitment, training, job counseling, etc. Since the result of these programs would be to improve the productivity of the labor force, however, expenditures on them could correctly be viewed as an investment in human capital not chargeable against the new production.

Cost calculations are the same for both approaches and include estimates of both the initial construction costs and the fixed annual maintenance costs of new transportation routes and facilities, (i.e., of those maintenance costs which are unrelated to the volume of traffic). Tax revenues and reduced welfare and unemployment costs resulting from the construction and fixed maintenance expenditures are subtracted from the other costs to obtain the net outlay by government for achieving the benefits estimated. All benefits and costs are discounted from the time when they occur, back to their present value at the beginning of the twenty-five year period.

No explicit account is made of environmental costs of either the transportation system or of the mining or other business activities stimulated by the transportation system's development. The cost estimates in each case, however, include allowances for minimizing adverse environmental effects.

Both the costs and benefits are pro-rated among the various segments of the transportation route so that the individual segments can be assembled in different combinations to create alternative routes. Each route thus consists of a unique set of segments which may involve

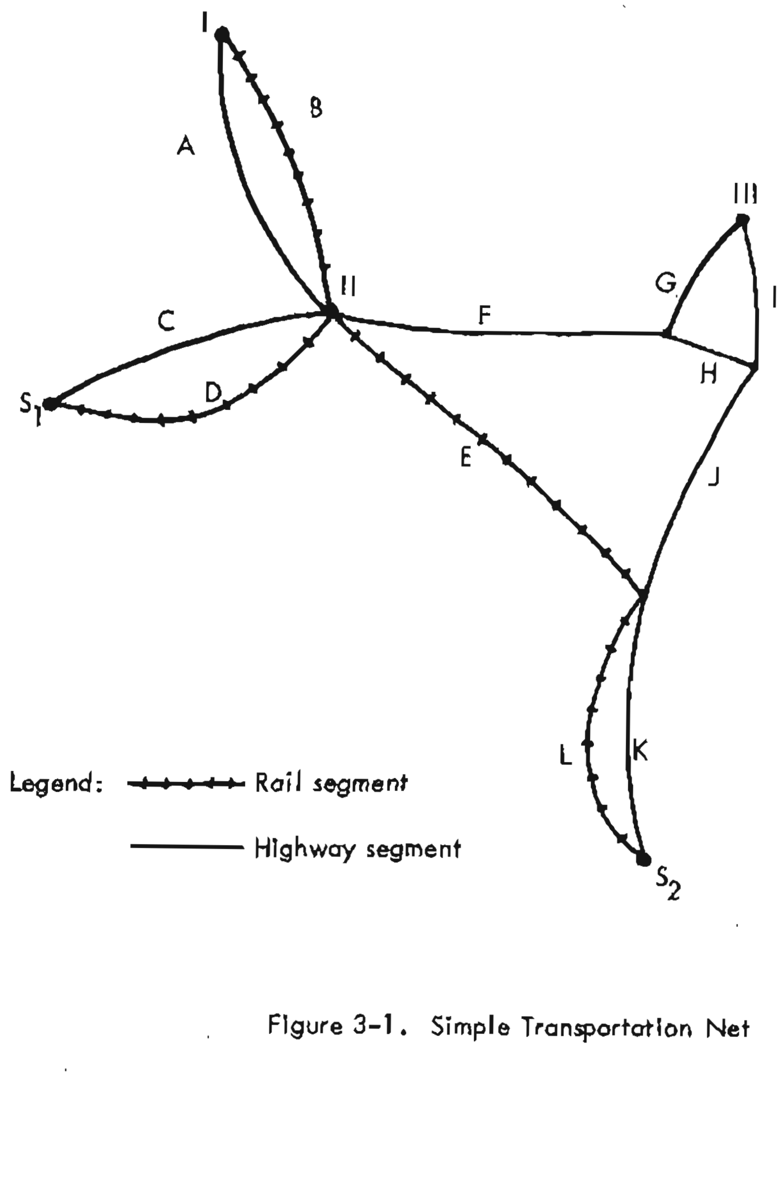

Figure 3-1. Simple Transportation Net

TABLE 3-1

Routes from Location I:

to Seaport S_1:

1) By road to Location II and also to Seaport S_1(AC)
2) By rail to Location II and also to Seaport S_1(BD)
3) By road to Location II and rail to Seaport S_1(AD)
4) By rail to Location II and road to Seaport S_1(BC)

to Seaport S_2:

5)	AEL	11)	BFHJL
6)	AEK	12)	BFHJK
7)	BEL	13)	AFGIJK
8)	BEK	14)	AFGIJL
9)	AFHJL	15)	BFGIJK
10)	AFHJK	16)	BFGIJL

Routes from Location II:

to Seaport S_1:		to Seaport S_2:	
17)	D	19)	EL
18)	C	20)	EK
		21)	FHJK
		22)	FHJL
		23)	FGIJK
		24)	FGIJL

Routes from Location III:

to Seaport S_1:		to Seaport S_2:	
25)	GFC	33)	GHJK
26)	GFD	34)	GHJL
27)	IHFC	35)	IJK
28)	IHFD	36)	IJL
29)	GHJED	37)	GFEL
30)	GHJEC	38)	GFEK
31)	IJED	39)	IHFEL
32)	IJEC	40)	IHFEK

one mode of transportation over the entire route, or two or more modes on different segments (e.g., rail for one portion and highway for the rest). As illustrated in Figure 3-1, a relatively simple model encompassing three different mine locations (I, II, and III), two seaports (S_1 and S_2), two modes of transportation (rail and highway) and twelve different route segments (A through L) could have as many as forty different routes (see Table 3-1) and these could be combined into as many as 2,049 different transportation systems. (Actually, the number of different systems could be even greater if we included systems which served less than all three mine locations.) This extremely large number of unique systems results from the fact that each of the sixteen routes from location I could be combined with any of the eight routes from Location II, yielding 128 combinations of routes from these two locations. Some of these overlap, of course (as in the case of route 1 from Location I, and route 18 from Location II), but the model is designed to prevent double counting of benefits in such a circumstance. Each of the 128 combinations of routes from Locations I and II can be combined with any of the sixteen routes from Location III, thus giving the aforementioned 2,049 possible systems (128 x 16 = 2,048). In the actual model used in this study, there are four major mining locations (or regions) served, six modes of transportation considered (highway, railroad, pipeline, air cushion vehicle, barge, and air), and thirty-eight different route segments thus yielding a truly astronomical number of possible routes and systems. The model, however, provides for selection of only certain specific routes for inclusion in the alternative systems, and this reduces the number of such systems considerably. The final step in operating the model is, therefore, to compare the benefit cost ratios of all these possible systems and to select that one which provides the optimum ratio.

Equations of the Model

First Benefit Concept:

Equation 1: PT = PM - CT

Where:

PT = tidewater price of a given mineral
PM = market price of mineral
CT = transportation costs from port to market

These calculations are made for each mineral, seaport, and market; however, only the market yielding the highest PT for a given mineral and seaport is included in later calculations.

Equation 2: $R = PT \cdot Q$

Where:

R = annual gross tidewater revenues for a given mineral
PT = Tidewater price (Eq. 1)
Q = the annual quantity shipped of a given material

These calculations are made for each mineral, mining location, and route.

Equation 3: $CM = CMF + (CMV \cdot Q) + CMI$

Where:

CM = Total annual cost of mining the output of a given mineral at a particular location. Where several minerals are mined in the same operation, total costs would be shared among the different minerals. Total costs include "normal profit" which is considered to be a % of sales and thus a variable cost.

CMF = Total fixed mining costs

CMV = Average variable mining cost (per ton) of mineral

Q = Tons of mineral mined at the particular location per year

CMI = Indirect costs of mining (e.g., additional state supervisory costs, etc.)

These are calculated for each mineral and mineral location.

Equation 4: $CT = (CTV + CTM) \cdot Q$

Where:

CT = Total variable cost of transporting the particular mineral from a given location via a particular route.

CTV = Variable vehicular costs (per ton) of transporting the mineral from the particular location on a given route segment. These could be trucking charges, airline charges, etc. per ton. In the case of a publicly owned railroad they would include only the variable operating costs per ton for rolling stock (i.e., not variable cost of track or non-moveable facilities maintenance).

CTM = Variable facilities maintenance cost (per ton) on a given route. Includes only the variable cost of maintaining the non-moveable transportation facilities (railroad tracks, loading facilities, depots, highway road beds, etc.)

Q = Quantity of mineral shipped from the particular location on the given route per year.

These costs would be calculated for each mineral, location, and route.

Equation 5: $TR = TPT + TWT + TBT + TPM + TWM + TBM + 1.5\ (R - TWM - TWT)\ T_r\ (.68)$

Where:

TR = Total tax revenues and reduced welfare for state and federal governments from production and transportation of a particular mineral.

TPT = Total taxes paid by workers transporting minerals (including unemployment insurance & S.S. Cont.)

TWT = Reduced welfare costs for transportation

TBT = Total bus. taxes paid by companies transporting a given mineral

TPM)
TWM) Same taxes as above for mining companies and workers
TBM)

R = Annual Gross tidewater revenues (Eq. 2)

T_r = Combined federal and state tax rate on multiplier effect of gross tidewater revenues less welfare and unemployment insurance reductions. (See pp. 14-15)

These tax benefits are calculated for each mineral, location, and transportation route over which the given mineral is shipped.

Equation 6: $PV\ (TFF) = PV\ (TFC) + PV\ (TFM) - PV\ (TFC + TFM)\ T_r$

Where:

PV (TFF) = Present value of total costs of construction and fixed maintenance cost on facilities.

PV (TFC) = Present value of construction costs.

PV (TFM) = Present value of sum of annual fixed maintenance costs

T_r = Tax Rate; and $PV\ (TFC + TFM)\ T_r$ = Present value of taxes and reduced welfare and unemployment cost saving on construction and maintenance expenditures.

These costs are calculated for each route.

Equation 7: $PV\ (RN) = PV\ (R - CM - CT) + PV\ (T_r + M) + PV\ (TR)$

Where:

PV (RN) = Present value of the net revenue flows from the production and shipment of a given mineral, at a particular location, on a specific route.

R = Annual gross tidewater revenues (Eq. 2)

CM = Total annual cost of mining (Eq. 3)

CT = Total annual variable costs of transportation (Eq. 4)

NOTE: (R-CM-CT) = "Economic Profits" (See p. 13)

$PV(T_r + M)$ = Present value of the benefits from tourism, recreation, (increased taxes and reduced welfare) and misc. benefits. Tourism and recreation benefits are calculated separately, and include a multiplier effect.

PV(TR) = Present value of tax revenues (Eq. 5)

The present value of these net revenue flows for all years in the 25-year period is calculated for each mineral, location, and route.

Equation 8: Maximize $\frac{\Sigma PV(RN)}{\Sigma PV(TFF)}$

Where:

$\Sigma PV(RN)$ = Sum of the present value of benefits (See Eq. 7) for all routes in the particular system.

$\Sigma PV(TFF)$ = Sum of the present value of total fixed costs of facilities for all routes in the particular system (See Eq. 6).

Alternate Benefit Concept:

Equation 1: Same as Eq. 1 above.

Equation 2: Same as Eq. 2 above.

Equation 3: Same as Eq. 6 above.

Equation 4: $PV(RN) = PV\left[R + (R - TWM - TWT)\ 1.5 + T_t\right]$

Where:

R = Annual gross tidewater revenues (Eq. 2)

TWM = Reduced welfare costs in mining.

TWT = Reduced welfare costs in transportation.

T_t = Benefits from tourism and recreation based on total resulting increase in GNP plus a multiplier effect.

Equation 5: Same as Eq. 8 above.

CHAPTER 4

THE TRANSPORTATION NETWORK

Nils I. Johansen and Edwin M. Rhoads

Transportation in Alaska

With its great area and diverse climate and topography, Alaska offers challenges to development not found in the other states. Over the years, Alaska's transportation problems have been the subject of numerous studies. The purposes have been as varied as the needs of the transportation systems under investigation. The early studies were concerned with opening up the country and establishing communications. As the country developed, surface and air transportation systems, roads, railroads, and air fields were established. This development is continuing at the present time.

Early development by white men took place along the coast where hunting and fishing were the main sources of revenue. Overland transportation was essentially non-existent, nor was there need for it until gold was discovered in Yukon Territory and later in Interior Alaska. Upon the purchase of Alaska in 1867, three-fourths of Alaska was essentially unknown.

The Klondike gold-rush and subsequent prospecting in the Interior of Alaska helped to develop overland transportation routes. The two principal routes to Dawson were up the Yukon River from the Bering Sea and from Skagway over the Chilkoot Pass. Prospectors came from the Klondike and elsewhere into Alaska and prospected virtually the entire interior. Gold was found near Fairbanks and at Nome, to mention only two of many well known places. In 1900, Nome had a population of 12,000 or fiver to six times the current population.

As a result of the increased activity in the early years of this century, Congress began to appropriate money for roads and trails in Alaska. A Board of Road Commissioners of Alaska was created and this Alaska Road Commission, as it was known, did much to guide the development of transportation routes.

The early history of transportation in Alaska closely followed the development of resources, chiefly minerals. The results of mining activities were trails, roads and railroads, built using the technologies then available.

Mining provided the exclusive economic base for some of the transportation systems and when the mine was worked out, the system disappeared. Two examples are the railroad at Nome and the copper River-Northwestern Railroad to the Kennecott Copper mines.

Until World War II, Alaska had no overland connection with the other states. When the strategic position of Alaska became evident, such a connection was made. The Alaska Highway, built in 1942, from Dawson Creek, B.C., to Big Delta, Alaska, tied the main Alaska Highway network to that of the rest of North America. About the same time, the Glenn Highway between Anchorage and Glenallen on the Richardson Highway was opened to traffic. In 1971, the Fairbanks-Anchorage Highway was completed, thus providing a second shorter road connection between the two largest communities in Alaska. Currently, the State of Alaska has a total of approximately 7600 miles of highways, roads and streets. Further major additions to this network are in the planning stage.

Overland transportation does not tell the whole story of transportation in Alaska. Like many other regions developed within the last 50 years, Alaska has gone directly into the "air age". The state has a well-developed airline network, and transportation by air is a way of life for many communities. People in Alaska are more air-minded than those in other states, as indicated by the high ratio of privately-owned airplanes to the total population.

Modern transportation systems will have to be able to handle several kinds of traffic, even though they were originally intended for a specific use. An example of this is the Alaska Highway, started as a vital factor for the defense of Alaska, but now carrying predominantly civilian (tourist) traffic as well as being an important artery for ore transport in the Yukon Territory.

The portion of Alaska north of the Yukon River (see Fig. 4-2) is sparsely populated, with an estimated population of 19,200 people (1972). The area is currently served by sea and air, but no overland transportation system connects it with the rest of the state, although plans for such connections do exist. Examples are the proposed road to Nome and the proposed pipeline haul road.

The oil discoveries on the North Slope and the future Trans-Alaska Pipeline and the associated haul-road certainly could greatly influence development of Northern Alaska. Across the border, in Yukon Territory, mine development is taking place on a large scale, and access is being provided to speed this development. Northern Alaska is potentially rich in natural resources besides oil and will contribute to both the state and national economies. A modern transportation system in northern Alaska will not only serve the mineral industry of the region, but it will also open access to new land, now closed to the public for lack of adequate transportation. New areas of wilderness will be within reach, a benefit for the whole nation. Development of transportation systems combined with intelligent use of the land may be the incentive needed to develop Arctic and Subarctic Alaska.

Engineering Problems

From an engineering standpoint, it is possible to construct and maintain rail, highway or airport facilities just about anywhere, however, permafrost, remoteness, low population density and severe climate make construction in northern Alaska an expensive challenge. The engineering problems can be broken down into two general categories, namely:

A. Problems primarily related to geology and topography, and

B. Problems primarily related to climate.

Both categories encompass problems related to general location. These problems include a lack of construction materials over large areas, slope stability problems, often magnified by solifluction, avalanches or other unstable conditions, and permafrost. The conditions triggered by the spring thaw, such as floods, must also be considered as well as possible instability of the embankments and foundations resulting from seasonal melting of frost susceptible soil. This is in addition to other problems encountered in a permafrost region.

Permafrost covers about one-fifth of the world's land area and affects four-fifths of the State of Alaska. The word "permafrost" implies simply that the ground is perennially frozen, and does not in any way reflect the soil or rock type. Engineering problems in permafrost are generally related to ground having a high ice content. The organic silts or "mucks" common in many places in the Interior Alaska are typical of such ice rich soils. These soils may contain ice wedges or buried aufeis, especially along waterways, and ice lenses and interstitial ice (Taber ice). Permafrost creates engineering problems when the thermal regime in the ground is altered, generally by removal of cover.

Thawing of permafrost creates two types of problems for the engineer.

1. The thawing of the ice reduces the volume of the soil mass and substantial settlement may results.
2. The melting of the ground ice from the top creates additional water which cannot escape because of frozen ground below. The result is an often large increase in the water content in the soil and a resultant loss of strength of the soil mass.

The melting of permafrost may be a slow process and it may be years before appreciable settlements occurs, however, once the conditions are right to induce melting, the melting will go on. This is especially true when the temperature of the permafrost is close to the melting point.

There are several construction methods, available which will minimize some of the problems related to ice-rich permafrost. The most obvious one is to relocate to better ground whenever possible. Other methods are to excavate the ice-rich permafrost and replace it with a non frost-susceptible soil, or to apply insulation either alone or in combination with a heat sink.

In late August, 1973, a reconnaissance flight was made over most of the area considered in this study. The flight was carried out at a low altitude when practical, so that some assessment could be made of the ground conditions along the proposed transportation corridors. As expected, there is evidence of permafrost along all the proposed corridors, but the flight also showed that by careful location of the transportation route, most of the problems related to unstable ground could be minimized. A reconnaissance report submitted by Dr. Thomas D. Hamilton (1972) Associate Professor of Geology, University of Alaska, indicates the complexity of the geology and terrain of the central Noatak Valley. The routes of the reconnaissance flight and the Noatak River field trip are shown in Figure 4-1.

Development of the Transportation Network

Based on a survey of previous transportation studies, and an analysis of the topography and geology of the area north of the Yukon, a network of feasible ground, air and water routes have been plotted connecting mineral sources with tidewater outlets (Fig. 4-2). Proposed routes are linked with the established transportation facilities within the state and those expected to be a certainty in the near future, i.e. the highway along the proposed trans-Alaska pipeline route from Prudhoe Bay to Livengood (Alyeska Pipeline Service Company, 1971) and the city and port of Lost River on the Seward Peninsula (Lost River Mining Corp., Ltd. 1971). The resulting network offers a number of possible alternatives for the transport of mineral products from four principal locations selected for the purpose of this study. Two sites in the Brooks Range coal region, Kukpowruk and Knifeblade, represent possible coal mine locations selected for their geographic relation to previously considered transportation routes (Alaska Department of Highways, 1970). The other two locations are the copper deposits in the Bornite-Kobuk area, and a potential copper-bearing area north of Wiseman designated as Koyukuk in this study. The potential oil-bearing areas designated as the Galena Basin and Kandik are not included; however, the possible transportation routes to these areas are shown in Figure 4-2 for future consideration.

The network consists of numbered segments, each segment signifying a specific transport mode between junctions, transfer points or terminals, so that any geographical route from a mine location to a point on tidewater can be defined by a succession of discrete segments. This permits the precist identification and description of all possible routes, and tabulation of combinations of routes and modes available within the network for manipulation in the computer model discussed in the preceding chapter. A total of 19 designated routes comprising 38 segments selected for the computer program are identified and described in Tables 4-1 and 4-2.

Transportation Modes and Cost Factors

The transportation modes selected for the study include both the common methods already in use in the State (railroad, highway, winter trails, river barge, air and petroleum pipelines), and also less conventional systems: slurry pipelines for coal, large air cushion vehicles, and transmission of coal energy in the form of electrical power. A brief description of each mode and the derivation of its associated cost factors are contained in the following paragraphs, and a tabulation of the cost and benefit factors for the routes and segments analyzed in the computer model are shown in Tables 4-3 and 4-4. Intermodal transfer costs are assessed separately only when a major installation is required such as a barge landing and loading facility. Costs for transferring between truck, rail car, aircraft and ACV is on the order of a few cents per ton, insignificant in comparison with the lack of precision of estimating single mode transportation costs. Therefore, the variable cost per ton for these is assumed to absorb transfer costs.

a. Railroad. There have been a number of recommendations for extension of the Alaska Railroad system since its completion in 1923. The latest of these, the Tudor-Kelly-Shannon (TKS) Alaska Transportation Corridor Study (Tudor-Kelly-Shannon, 1972) was selected as the basis for estimating construction and right-of-way maintenance costs for the selected rail routes. The alignment and the costs for the segments between Nenana on the existing railroad and Kobuk (segments 3, 4, and 5) are as given in the TKS study. The construction cost of the lines from Kobuk to Kukpowruk (segment 24), and to Lost River (segments 25 and 26) is estimated at $1,750,000 per mile, derived from an average of the TKS estimate for the Nenana-Deadhorse route, exclusive of the Yukon River bridge and the Dietrich Pass tunnel. Construction cost of the Kokpowruk-Cape Thompson (segment 37) route is estimated at $2,542,594 per mile, based on the TKS estimate for railroad construction on the North Slope. An operating cost of $0.05 per ton mile, approximately that of the existing Alaska railroad is used in this study, though the TKS study estimated an operating cost of $0.042 per ton mile for new railroad. Maintenance costs were computed on a 60%/40% ratio of annual fixed maintenance of right-of-way to variable maintenance resulting from tonnage moved over the rails. For the Nenana-Kobuk segments (3, 4 and 5), the maintenance costs as stated om TKS were used. For the other segments of new track, the unit maintenance cost

Table 4-1

Route Identification

Route	Commodity	Distance Miles	Mode*	From	To	Segment No.'s
1	Copper Concentrate	821	Hwy-RR	Bornite	Seward	12,4,3,1
2	Copper Concentrate	895	Hwy-RR	Bornite	Seward	12,11,10,7,6,2,1
3	Copper Concentrate	417	Hwy	Bornite	Lost River	12,13,14
4	Copper Concentrate	240	Hwy-Barge	Bornite	Kotzebue	15,22
5	Copper Concentrate	419	Hwy-RR	Bornite	Lost River	12,25,26
6	Blister Copper	530	Air	Kobuk	Anchorage	29
7	Blister Copper	808	ACV-RR	Kobuk	Seward	30,1
8	Blister Copper	262	ACV	Kobuk	Kotzebue	31
9	Coal	931	RR	Kukpowruk	Lost River	24,25,26
10	Coal	848	Hwy	Kukpowruk	Lost River	20,21,15,12,13,14
11	Coal	1146	Hwy-RR	Kukpowruk	Seward	20,21,15,12,4,3,1
12	Coal	1220	Hwy-RR	Kukpowruk	Seward	20,21,15,12,11,10,7,6,2,1
13	Coal	500	P/L	Kukpowruk	Lost River	36
14	Coal	150	RR	Kukpowruk	C. Thompson	37
15	Coal	150	P/L	Kukpowruk	C. Thompson	38
16	Copper Concentrate	775	Hwy-RR	Koyukuk	Seward	27,7,6,2,1
17	Blister Copper	530	Air	Koyukuk	Anchorage	32
18	Coal	966	Hwy-RR	Knifeblade	Seward	16,5,3,1
19	Coal	951	Hwy-RR	Knifeblade	Seward	16,10,7,6,2,1

*Hwy = Highway
RR = Railroad
Air = Airplane
ACV = Air Cushion Vehicle
P/L = Slurry Pipeline

Note: This table is reproduced in Chapter 7 as Table 7-1a for the convenience in reading that Chapter.

Table 4-2

Segment Identification

Segment	Mode*	Distance Miles	From	To
1	RR	416	Nenana	Seward
2	RR	54	Fairbanks	Nenana
3	RR	253	Alatna	Nenana
4	RR	139	Kobuk	Alatna
5	RR	41	Bettles	Alatna
6	Hwy	81	Livengood	Fairbanks
7	Hwy	144	Prospect	Livengood
8	Hwy	218	Sagwon	Prospect
9	Hwy	62	Prudhoe	Sagwon
10	Hwy	30	Bettles	Prospect
11	Hwy	157	Kobuk	Bettles
12	Hwy	13	Bornite	Kobuk
13	Hwy	320	Kobuk	Bunker Hill
14	Hwy	84	Bunker Hill	Lost River
15	Hwy	45	Kobuk	Onion Portage
16	Hwy	226	Knifeblade	Bettles
17	Hwy	168	Knifeblade	Sagwon
18	Hwy	248	Kukpowruk	Knifeblade
19	Hwy	150	Cape Lisburne	Utukok River

Table 4-2 Continued

Segment Identification

Segment	Mode*	Distance Miles	From	To
20	Hwy	96	Kukpowruk	Utukok River
21	Hwy	184	Utukok River	Onion Portage
22	River	195	Onion Portage	Kotzebue
23	Hwy	162	Circle	Fairbanks
24	RR	421	Kukpowruk	Kobuk
25	RR	322	Kobuk	Bunker Hill
26	RR	84	Bunker Hill	Lost River
27	Hwy	80	Koyukuk	Prospect
28	WRD	52	Bornite	Onion Portage
29	Air	530	Kobuk	Anchorage
30	ACV	392	Kobuk	Nenana
31	ACV	262	Kobuk	Kotzebue
32	Air	530	Koyukuk	Anchorage
33	River	440	Nulato	Nenana
34	River	674	Burnt Paw	Nenana
35	WRD	40	Galena Basin	Nulato
36	P/L	500	Kukpowruk	Lost River
37	RR	150	Kukpowruk	Cape Thompson
38	R/L	150	Kukpowruk	Cape Thompson

*RR = Rail Road
Hwy = Highway
WRD = Winter Road
ACV = Air Cushion Vehicle
Air = Airplane
P/L = Pipeline

Table 4-3

Benefit and Cost Factors for Each Route

Route	Personal Income Tax Benefit ($)	Price ($)	Quantity (ton)	Total Mining Cost ($)	Vehicle Benefits ($)	Welfare Benefits ($)
1	$9,197,000	$218.00	200,000	15×10^6	$ 16,000	$ 243,000
2	1,253,000	218.00	200,000	15×10^6	369,000	470,000
3	1,984,000	218.00	200,000	15×10^6	359,000	726,000
4	226,000	213.00	200,000	15×10^6	59,000	83,000
5	509,000	218.00	200,000	15×10^6	40,000	187,000
6	411,000	870.00	60,000	19×10^6	838,000	110,000
7	321,000	880.00	60,000	19×10^6	656,000	118,000
8	208,000	860.00	60,000	19×10^6	544,000	76,000
9	18,155,000	18.00	5,000,000	25×10^6	0	6,647,000
10	80,409,000	18.00	5,000,000	25×10^6	18,150,000	29,442,000
11	39,780,000	19.40	5,000,000	25×10^6	6,238,000	14,566,000
12	62,095,000	19.40	5,000,000	25×10^6	16,048,000	22,736,000
13	1,420,000	18.00	5,000,000	25×10^6	0	520,000
14	2,925,000	17.00	5,000,000	25×10^6	0	1,069,000
15	130,000	17.00	5,000,000	25×10^6	0	48,000
16	774,000	218.00	200,000	15×10^6	265,000	160,000
17	411,000	870.00	60,000	19×10^6	838,000	110,000
18	27,830,000	19.40	5,000,000	25×10^6	4,838,000	10,190,000
19	26,708,000	19.40	5,000,000	25×10^6	10,295,000	9,776,000

Table 4-4

Benefit and Cost Factors for Individual Segments

Segment	Variable Transportation Cost $/ton	Tourist Benefits*	Gross Tourist Benefits*	First Right-of-Way Cost	Annual Right-of-Way Cost
1	$22.05	$ 0	$ 0	$ 0	$ 0
2	2.85	0	0	0	0
3	13.74	8,995,000	36,250,000	558,279,000	1,649,000
4	7.36	5,570,000	22,446,000	258,980,000	407,040
5	2.27	1,464,000	5,900,000	99,285,250	229,000
6	9.35	0	0	0	0
7	16.62	0	0	0	0
8	31.70	0	0	0	0
9	9.01	0	0	0	0
10	3.46	1,551,000	6,251,000	9,000,000	81,000
11	22.84	6,159,000	24,821,000	47,000,000	424,000
12	1.89	14,000	56,000	3,900,000	35,000
13	72.13	0	0	96,000,000	864,000
14	18.93	0	0	25,200,000	227,000
15	6.54	30,000	121,000	13,500,000	122,000
16	32.86	366,000	1,475,000	67,800,000	610,000
17	37.87	0	0	50,400,000	454,000
18	55.90	0	0	74,400,000	670,000
19	33.81	0	0	45,000,000	405,000

Table 4 (Continued)

Benefit and Cost Factors for Individual Segments

Segment	Variable Transportation Cost $/ton	Tourist Benefits*	Gross Tourist Benefits*	First Right-of-Way Cost	Annual Right-of-Way Cost
20	21.64	3,000	$ 12,000	$28,800,000	$259,000
21	41.47	32,000	129,000	55,200,000	497,000
22	25.89	0	0	4,000,000	250,000
23	18.69	0	0	0	0
24	22.65	2,474,000	9,970,000	736,750,000	2,400,000
25	16.10	0	0	563,500,000	1,835,000
26	4.52	0	0	147,000,000	478,000
27	11.63	0	0	0	0
28	23.22	0	0	62,400	78,000
29	103.35	0	0	4,000,000	300,000
30	76.08	0	0	7,940,000	196,000
31	54.63	0	0	5,340,000	131,000
32	103.35	0	0	4,000,000	300,000
33	54.12	0	0	0	0
34	82.90	0	0	0	0
35	17.54	0	0	48,000	112,000
36	11.89	0	0	199,562,000	3,520,000
37	7.84	0	0	346,636,000	2,560,000
38	1.81	0	0	79,639,000	813,000

* See comments pages 50-51; Tables 6-1 and 6-2, pages 52-55.

of the TKS Dietrich-Deadhorse route ($9,500 per mile) was used.

b. Highway. Estimates from various sources of construction costs for roads in Northern Alaska show a wide variation due in part to a variety of terrain conditions considered and differences in the road standards used. The TKS study estimated a cost of $186,000,000 for the construction of 187 miles of highway from the Trans-Alaska Pipeline road to Kobuk, nearly a million dollars per mile. Their cost was based on a design standard for a 60 mph, 200-300 vehicle-per-hour road with maximum grades of 3% in flat terrain to 6% in mountainous terrain. Estimates by the Alaska Department of Highways for roads of a lower standard, but adequate for heavy tractor-trailer traffic vary from $277,000 to $283,000 per mile in the area considered (Alaska Dept. of Highways, 1970). For this study, a road with a width of 28 feet, a minimum of 5 feet of fill in permafrost areas, grades not exceeding 11%, average bridging, culvert and drainage in conformance with acceptable practice for Alaskan terrain and climatic conditions is estimated to cost $300,000 per mile, exclusive of bridging exceeding 1500 feet in length. Maintenance costs are separated into (1) fixed annual maintenance and repair of the roadbed and structures necessitated by seasonal effects of erosion, permafrost, snowfall and degradation of stream crossings and drainage structures, estimated at $2700 per mile, and (2) the additional variable maintenance required due to degradation of the road surface from vehicle traffic. A variable maintenance cost of $0.0054 per ton mile per year was derived from an annual average daily traffic maintenance factor developed by the Alaska Department of Highways (Greek and Geidel, 1972), adjusted for heavy truck traffic and increase in operational costs in remote regions of the state. Freight rates for commercial trucking used in this study are based on the current rate quoted by Alaskan trucking firms of $0.11 per ton mile for class 50 loads in the Alaskan interior. Also, off-the-shelf combination of a 3-axle heavy duty diesel-powered truck-tractor and a 25-ton payload 2-axle end-dump semi-trailer was selected as an over-the-road ore and coal carrier. This combination will meet the state highway maximum gross vehicle weight limit of 90,000 lb. It is assumed that each combination unit will travel 150,000 miles per year and that the useful life will be 2 years because of excessive wear and tear incurred by continuous travel over gravel roads (U.S. Coast Guard, 1968 and oral communications with independent truckers). To compensate for additional operation costs in the more remote areas, rates were determined by using a cost escalation factor based on relative prices of construction (Civil Engineer, Oct. 1971). Truck freight rates used in the study are:

(1) segments between Fairbanks-Prospect, Bettles and Circle, $0.11/ton mile,

(2) between Prospect/Bettles-Sagwon, Knifeblade and Kobuk-Onion Portage, $0.14/ton-mi, and

(3) between Kobuk/Onion Portage-Kukpowruk and Lost River, $0.22/ton mile.

c. Winter Trail. The capability of ice and frozen soil to support vehicular traffic across terrain impossible during warmer seasons has long been exploited in northern countries. The most widely used equipment for heavy cargo are sleds drawn by crawler tractors, and heavy duty wheeled vehicles operating on prepared winter roads. The tractor-sled combination is expensive in terms of tonnage hauled ($1.00 to more than $2.00 per ton-mile, depending on terrain conditions) and slow (around 5 mph using standard crawler tractors to 10-20 mph using more recently developed tracked prime movers). The primary advantage of this method is that little route preparation is required, permitting great freedom of choice of access and destination. This would apply to resource exploration and to the development of production sites for commodities which will not depend on vehicle transport, e.g., crude oil for pipeline delivery. The preparation of winter roads, while more costly than tractor trails, permits the sustained use of standard heavy-duty highway equipment during the frozen period, and can be considered for the transport of minerals. Based on reports of winter road operation in Alaska and Canada (Dalton, 1964; FAA, 1969; Christofferson, 1971) and estimates of maintenance costs, a figure of $1200 per mile for winter-route preparation and $2800 per mile for maintenance during an average 6-month operational season may be considered normal. Due to the additional maintenance and operating personnel required under these conditions, truck rates will be around $.40 per ton-mile on winter haul roads. Deletion of several oil field locations from the program, as discussed in subparagraph f below made it unnecessary to include data on winter trails in the computer model. The above information is included in this report for information only.

d. River Barge. The possibility of transporting ore mined in the Kobuk region by river barge down the Kobuk River to Kotzebue for transfer to ocean shipping has been investigated and discussed in a number of reports (Brown and Jones, 1968). The most practical plan for using river transportation is to dredge the Kobuk River Channel from Hotham Inlet to a point near Onion Portage, a distance of about 175 miles, and establish a barge landing and transfer facility there to receive the ore from tractor-trailers hauling from the mine at Bornite (Swan, Wooster, 1972). The freighting season on the Kobuk is from mid-June to late September, an average of 90-100 days, therefore, it will be necessary to stockpile ore at Onion Portage during the closed season. The initial cost for this route is made up of $800,000 to dredge the channel to achieve a 200-foot channel width and five foot depth, and $3,137,500 to construct the barge landing and ore hauling facility. The $800,000 figure is a Corps of Engineers estimate, and the $3,137,500 figure was arrived at by scaling up a smaller proposed facility (Swan, Wooster 1972). With this expenditure, 200,000 tons of copper concentrate can be handled by 750-ton barge propelled two at a time with 500 hp tugs. Freight cost is estimated at $24.00/ton for barge delivery (Brown and Jones, 1968) plus $1.89/ton for operation of the facility at Onion Portage. Annual maintenance of the river channel was estimated by the Corps of Engineers at $250,000 per year.

e. Air Transportation. The use of aircraft for transportation of cargo is feasible only if either the urgency of delivery or the unit value of the cargo is great enough to warrant the transportation cost. Substantial tonnages of equipment and supplies have been moved to the Prudhoe Bay area at a cost between $.23 and $.27 per ton mile, actually cheaper than truck transportation over the short-lived winter haul road, (FAA, 1969). In order to assess the potential of aircraft, the possibilities of transporting blister copper, smelted at the mine site, by Boeing 747F aircraft to Anchorage for transfer to ocean shipping was investigated. Assuming 60,000 tons per year of blister copper smelted from the annual concentrate output of 200,000 tons at the Bornite and Upper Koyukuk mine locations, it was determined that one 747F flying to each location could haul the annual output of blister copper, and deliver equipment and supplies, including diesel fuel, to support each location. A cost analysis for this operation kindly provided by Boeing, to which was added a capital recovery cost, indicates that the ton-mile rate for this transportation means would be around $0.195. Construction of the air field and associated facilities at each smelter area is estimated at $4,000,000.

f. Petroleum Pipelines. An attempt was made to determine cost factors for crude oil pipeline delivery from oil fields in the Galena Basin and Yukon-Kandik Basin areas. Possible routes from the Galena Basin field are: 1) to the trans-Alaska pipeline, or 2) a refinery in the Fairbanks area, or 3) to a tanker transfer facility at the port of Lost River, and from the Yukon-Kandik field to the Fairbanks area or to Canada. Lack of information as to the possible extent of reserves and well capacity precludes a realistic estimate of pipeline costs, therefore, these routes are not included in the computer model, nor are the Eagle-Porcupine River road or the winter trail and river routes which would provide practical access for the development of these oil fields. Possible pipeline and access routes are shown in Figure 4-2 for future consideration.

g. Slurry Pipeline. The transport of pulverized minerals by a fluid medium through pipelines is a successful technique in many parts of the world. With adequate control of heat transfer, it is within the realm of engineering practicality to use this method in cold climates. Paul Clark, a graduate student at the University of Alaska, has contributed the results of his investigation of slurry pipelines for transporting coal from the Alaskan Arctic as input to this study. Based on his calculations, (Clark, 1972) it is estimated that the initial construction cost of the preparation facility at the mine site, including the water supply system would be $12,250,000, and the receiving facility at the pipeline terminal $10,000,000. Average construction cost of the pipeline and intermediate pumping stations total $394,500 per mile. The annual operating cost including capital cost recovery is estimated at $0.0233 per ton-mile plus $0.02 per ton delivered for water supply. Maintenance costs are calculated to be $7040 per mile for annual fixed maintenance and $0.004 per ton-mile annually due to the variable rate of wear, depending on the tonnage delivered.

h. Air Cushion Vehicles. Considerable interest has been generated over the possible applications of air cushion vehicles (ACV), also called hovercraft, or surface effect vehicles, for northern countries. For the transportating of cargo or passengers, current experience indicates that economies of scale apply to ACV's, i.e., the larger the vehicle, the lower the cost per ton-mile or passenger-mile (Rhoads, 1972). A preliminary design concept by the Boeing Company for a 100-ton payload ACV was selected for evaluation in this study. A direct operating cost estimate by Boeing of $0.15 per ton-mile plus an assumed annual capital and overhead cost were used to derive the freight costs used in the model, which average around $0.20 per ton-mile. ACV's have several inherent characteristics that limit their usefulness. Some of these are: limited climbing and side-slope ability (5-10%), great width in proportion to payload capacity (100 t. ACV is 52 ft. wide), low obstacle clearance, and aerodynamic steering requiring a wide turning radius. These factors necessitate careful route selection and some route preparation. A cost of $20,000 per mile for initial ACV route preparation was derived from an Alaska Highway Department preliminary study of ACV guideways, and an annual maintenance cost of $500 per mile is assumed.

i. Electrical Power Transmission. Although transmission of electrical power usually is not thought of as a transportation system per se, it was felt worthwhile to compare the possible cost of delivering coal energy from mine to consumer by wire with that of truck and rail delivery. The parameters involved in this analysis do not lend themselves to the computer model, therefore, a synopsis of the analysis is presented in this subparagraph. To provide a basis for the comparison, it is assumed that blister copper is being produced at Kobuk from ore mined and concentrated at Bornite. The industry is supported by a town of 5,000 population, 70,000 kw of continuous power are required for this complex, and one source for this energy is the coal beds at Kukpowruk. With a 3% transmission loss over a 300-mile power line (segment 50), a power plant of 72,000 kw output is required at Kukpowruk. Assuming an average thermal heating value of 10,000 BTU per pound for the coal of less than coking grade, and a plant efficiency of 40%, 269,000 tons of coal per year will be consumed. If this quantity of coal is mined in conjunction with large-scale production for export at a cost of $5.00 per ton, it was calculated from information provided by the Golden Valley Electric Association that the required electrical power could be provided by the powerline to Kobuk at a rate of $.048 per kilowatt hour, which includes amortization of the power plant and transmission line. If a power plant is installed at Kobuk, consuming coal at the rate of 261,000 tons per year and coal is delivered from Kukpowruk by an established rail line, the cost per kwh would be $.029. If delivered by highway, the cost would be $.049 per kwh (costs would be essentially the same if the coal is delivered to Kobuk from the existing mine at Healy on the Alaska Railroad.) This brief analysis places the transmission of electrical power produced by coal in perspective vis-a-vis transportation of coal, and indicates that it should be considered in more depth. Further study should be devoted to other possible fuel sources, including known fields of natural gas and smaller, but closer deposits of coal.

Estimation of Transportation Benefits

The benefits derived from transportation as used in the computer model consist of personal income tax and welfare benefits based on employee salaries as described in Chapter 3 above, and the taxes on the vehicles used to move mineral products (Tables 4-3 and 4-4). Annual salaries are computed for the vehicular modes (RR, truck, aircraft and ACV) by applying a payroll factor to the operating cost (variable cost/ton x annual tonnage hauled). The payroll factors used are shown in Table 4-5.

TABLE 4-5

Payroll Factors (Percentage of Operating Cost)

Mode	Payroll Factor (%)	Source
RR	30%	Canadian Inst. of Ground Transp. (1972)
Truck	34%	Bureau of the Census (1968)
Aircraft	36%	Bureau of the Census (1971)
ACV	36%	Assumed same as aircraft

Payroll for barge and pipeline transportation are computed from estimated of the number of employees engaged. Both of these operations involve a relatively small payroll in proportion to operation expenses. The shorter of the two coal slurry pipelines was designed to be highly automated, accounting for the very low payroll-derived benefits for that route.

Vehicle tax benefits are computed from current tax rates on fuel, lubricating oil and tires, excise and use taxes, and registration fees.

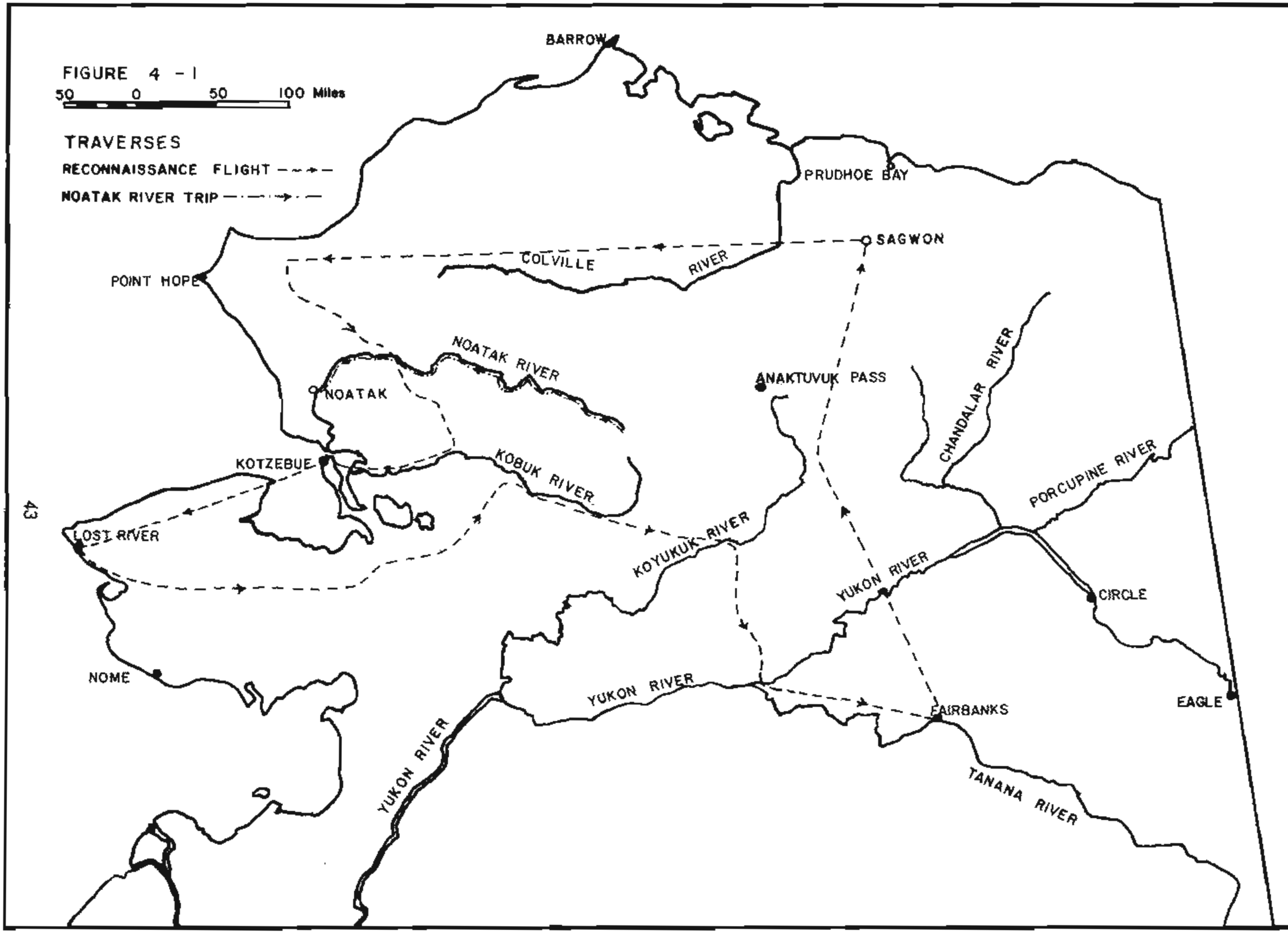
FIGURE 4 - 1
50 0 50 100 Miles
TRAVERSES
RECONNAISSANCE FLIGHT
NOATAK RIVER TRIP
BARROW
PRUDHOE BAY
SAGWON
COLVILLE RIVER
POINT HOPE
NOATAK RIVER
NOATAK
ANAKTUVUK PASS
CHANDALAR RIVER
PORCUPINE RIVER
KOTZEBUE
KOBUK RIVER
LOST RIVER
KOYUKUK RIVER
YUKON RIVER
CIRCLE
NOME
YUKON RIVER
FAIRBANKS
EAGLE
YUKON RIVER
TANANA RIVER

CHAPTER 5

ESTIMATING THE BENEFITS OF MINING

Ernest N. Wolff and Chris Lambert, Jr.

Note on Markets

At the present time, the number of custom smelters that are available to shippers of concentrates is limited. The ASR copper smelter at Tacoma is not accepting concentrates from new customers. This leaves Anaconda, Montana as the only northwestern market open to Alaskan copper producers, and this may be only temporary. The Bunker hill lead smelter in Kellogg, Idaho still accepts lead as does the Cominco smelter in Trail, B.C., but no zinc, and the Anaconda lead-zinc smelter is phasing out. The principal reason for this shortage of smelter capacity is pollution control.

This study seeks to define a transportation system for a potential minerals industry in Northern Alaska. It presupposes that to be feasible, such an industry would be producing minerals in large quantities, large enough, in fact, (along with Yukon and B.C. mines) to alter the traditional patterns of transportation and smelter locations. Japan, too, is feeling the effects of industrial pollution, and it is probable that their smelters may be rebuilt to cut pollution.

We can summarize these and other factors as follows:

1) smelters must reduce their pollution,

2) a technological breakthrough to new pyrometallurgical and hydrometallurgical processes which will provide smelter capacity with much less pollution is coming, and

3) new sources of minerals will make it desirable to relocate smelters.

For these reasons, this study assumes that when Alaska is ready to produce minerals, smelters will be available to process them. The question of whether to build smelters in Alaska should be explored thoroughly before that time, because it is within the realm of possibility, even probability, that within the next few decades the combination of abundant hydrocarbon fuel and large copper mines will make it desirable to build one or more smelters in Alaska. If this should happen, Alaska will become something more than a producer of raw materials, but also an exporter of semi-processed materials. Such a development would greatly enlarge the benefits derived as a result of building a transportation network now. However, in this study, benefits are computed chiefly on the basis of shipping concentrates and coal, but the potential benefits of smelting blister copper at the mines are also explored.

Another assumption, based on geography, seems well justified. Alaska, on the rim of the Pacific basin, has access to many regions of high population. It is as a supplier of Japan and other Asian markets that Alaska has one of its few location advantages. Alaska may look to the Orient as a market for almost anything that it can produce.

Calculations of Benefits

Chapters 3 and 4 of this report deal with the model used to arrive at benefit-cost ratios for the proposed transportation system, and Chapter 7 deals with the results. It is one of the aims of this chapter to describe how the costs and benefits for mining were calculated. Again, as it has been in many other places in this report, it is cautioned that there are no empirical guides to cost of mining in the Arctic, and estimates of such costs must be based upon rough estimates or even guesses. The following pages show how the various parameters in the study were determined.

Copper

One basic assumption has been made for all mineral developments: no company will operate a mine in the Arctic unless it will make a profit of at least 15% of revenue. An attempt has been made in all cases to determine a tidewater value for the concentrate or other commodity. This price is established as the value at the market (smelter or stockpile) minus cost of ocean shipping, overland shipping and smelting costs. For copper in concentrates, this cost has been assumed at twelve cents per pound, three cents each for ocean shipping, overland shipping, smelting, and refining/marketing.

Based on published accounts and also as a reasonable, though fairly high figure, it has been assumed that 200,000 tons per year of concentrates containing 30% copper would be shipped from each location. This is equivalent to 60,000 tons of copper. The following analysis is then made:

60,000 tons copper at \$0.50/lb. = \$60,000,000

Minus \$14.4 million cost after leaving Alaska, (\$0.12/lb. x 120,000,000 lbs.)

Revenue at tidewater	45,600,000
Minus cost of mining	15,000,000
Minus business tax	
Equals	Gross profit
Minus State income tax	
Minus Federal income tax*	
Equals	Available for profit and economic profit

Minus 15% of revenue for profit $6,840,000

Equals Economic profit

$$\text{Benefit cost ratio} = \frac{\text{Present Worth of (All Taxes + Welfare Reductions + Econ. profit)}}{\text{Present Worth of (First Cost of Construction + Fixed Maintenance)}}$$

(*) State income tax deductible prior to application of Federal income tax.

Each one of the above items is necessarily only an approximation. Transportation costs have been estimated as closely as possible, but mining and milling cost, at $15,000,000, is a guess. Implicit in the assumption of this mining cost is the idea that the tenor of ore mined will be adjusted until $15,000,000 will cover the cost of mining and milling 200,000 tons of concentrate. If the ore contains 1% copper, or 20 lbs. per ton, 200,000 tons of concentrate containing 30% copper would represent 6,000,000 tons of ore mined and milled per year. This ore would be worth $10 per ton, and cost $2.50 per ton to mine and mill. These figures are probably too low to allow mining; in other words, the tenor of the ore must be higher than 1%. However, if a smaller tonnage of higher grade ore was mined, the amount of money available for mining and milling would be proportionally higher, until for 30% ore, it would be $75/ton, with the ore having a value of $300 per ton. When considering smelting at the mine site, the following assumptions about costs were made: although smelting was estimated to cost three cents per pound in the northwestern states, it was assumed to be somewhat higher in Alaska to take care of the differential in cost. The cost of producing 60,000 tons of blister was thus estimated at $19,000,000 for mining, milling and smelting. At the same time, the revenue at tidewater could be increased by 7¢ per lb., (three cents for smelting, plus four cents saved on transportation from Alaskan ports to refiners). Revenues at tidewater than is $54,000,000.

Coal

Revenue derived from coal is computed from a price of $23 per ton for coking coal in Japan, and various costs for shipping. Mining costs for 5,000,000 tons per year are assumed at $5.00/ton, and ocean shipping costs at $5.00 per ton from Cape Thompson (by large ship). The use of such a route presupposes that the technology is available for slurry loading of a ship lying several miles offshore in an ice-environment. It would also be necessary to stockpile for nine months and then assemble a fleet of large ships for a three month season, finding employment elsewhere for them for the other nine months. Such assumptions may be unjustified at present but they must be made if the exporting of the coal is to be considered feasible at all. The cost of an overland trip to some other port would be prohibitive. A source of error is the fact that the special 7% state income tax on profits from mine production (mining license tax) has not been figured into the analysis. However, while this would decrease the economic profits left after mining profit, it would not effect total benefits, since it would simply go to the state via a different route.

Gold

Benefits from gold production have not been calculated. Three major gold areas are postulated: Seward Peninsula, Chandalar, and the Koyukuk Region. None of these will be big producers unless the price of gold continues upward. Any gold mining generated by the proposed transportation system would provide benefits over and above those calculated.

Oil

Likewise, benefits from oil production are not calculated. Suggestions for routes contained in this report apply only to exploration. Almost certainly new oil fields would be exploited by pipeline, since past experience has shown that pipeline transportation of oil is more efficient than other overland routes.

All other minerals which may have a potential value in the future have been disregarded for the purposes of this study. They are described in Chapter 2. Undoubtedly, benefits will accrue from these deposits as a result of building the transportation net.

CHAPTER 6

ESTIMATING THE BENEFITS OF TOURISM AND RECREATION

Richard J. Solie

The Potential of Tourism

Alaskan tourism has been called the industry which "can most rapidly provide jobs to the widest spectrum of educational and age levels." (U.S. Federal Field Committee, 1971, p. 199.) From 59,000 visitors in 1964, the number of tourists in the state had grown to 120,000 by 1970 and is expected to reach 186,000 by 1975 and 300,000 by 1980. Tourist expenditures, which amounted to approximately $37 million in 1970, are projected to rise to nearly $60 million by 1975. (U.S. Federal Field Committee, 1971, pp. 212-213.)

To anyone familiar with the magnificent beauty of the State, the potential of tourism can be seen to be great. A number of factors have limited the growth rate, however, and among these factors three of the most important are: 1) remoteness, both in time and distance, from the "lower forty-eight," 2) the lack of sufficient road systems and facilities within the State, and 3) the short seasons and severe weather. Nothing significant can be done to change the impact of the weather or the physical distance of Alaska from the "lower forty-eight", but distance, in terms of time, and road systems and facilities within the State, are certainly factors subject to change. The paving of the Alaska Highway would be a significant factor in accomplishing the former, while construction of major segments of the transportation system considered in this study would do much toward eliminating the latter problem.

The large area which would be served by the alternative transportation systems considered herein, certainly has great potential for tourism as well as for resident recreational use. Included in the area, much of which lies north of the Arctic Circle, are magnificent mountains, including the world famous Brooks Range, vast areas of tundra and northern forest, several large river systems, wildlife of many varieties, and the opportunity for hunting, fishing, camping, and sightseeing. Also within this region lies the proposed "Gates of the Arctic Park."

As recommended by the National Park Service in 1968, the park would consist of two units, "one containing the Alatna River drainage and the headwaters of the

Kobuk and Nootuk Rivers, the other straddling the Arctic Divide at the headwaters of the North Fork of the Koyukuk River....the archeological sites and values at Anaktuvuk Pass are also of interest to the Service....it is possible that this area could become one of the outlying sites of interest in the Alaska Cultural Complex.." (U.S. Field Committee, 1971, p. 228.) Development of the proposed park would certainly have a significant impact on tourism and recreational benefits resulting from the transportation systems considered in this study.

Some Problems and Assumptions

Under the best of circumstances, estimating future demand is a difficult task, and this task is made especially formidable in the case of a previously undeveloped tourist area. In such a case, any estimates must be considered more as "educated guesses" than scientific projections, and this applies to the estimates of tourism and recreational benefits described in this chapter. Techniques were designed, however, to make the estimates in this study as realistic as possible, and they are described in some detail later in this chapter and in a companion report (Procedure for Estimating Tourism Benefits, M.I.R.L. Report No. 29A.)

A further problem in estimating the future demand or usage of a new recreation area is a measure of the extent to which the opening up of the new area merely draws away people from existing facilities. (This problem differs from that resulting from the drawing away of resources from other "opportunities" -- see p. 3-4.) In this study, the assumption is made that an insignificant portion of the tourist and recreational demand is drawn away from existing facilities, and, thus, no adjustment is made for such a reduction elsewhere. Although this may seem to be an unrealistic assumption, it is probably reasonable since, as a number of studies have pointed out, one of the principal factors limiting growth of tourism and recreational use in Alaska is the lack of roads and facilities within the State. (U.S. Field Committee, 1971), pp. 214-216). Thus, the opening up of the transportation system in this area, especially that serving the proposed Gates of the Arctic Park region, can stimulate an increase in total tourist traffic into the State, and it is likely that the benefits from the time which these additional tourists spend elsewhere in the State (benefits not included in this study) will more than offset the effect of any shift of tourists and recreationists from present facilities.

Two principal types of tourism and recreational usage are distinguished in this study: destination-oriented and non-destinated-oriented. The first is defined as consisting of those individuals who set out on a trip with a particular destination in mind, a destination with unique characteristics not readily substituted for by alternative locations. (e.g., Mt. McKinley Park.) In contrast, the non-destination -oriented traffic may set out with no particular destination in mind (e.g., they are just sightseeing) or the destination may be just a location where they expect to fulfill the primary purpose of their trip, e.g., hunting, fishing, camping, etc., a purpose which may be fulfilled satisfactorily by other locations or sites along the route.

It is assumed in this study, that the "Gates of the Arctic Park" is developed as proposed, and it will represent the primary area for which destination-oriented traffic is projected. Estimates of this traffic are developed by comparisions with highway and rail traffic to Mt. McKinley Park. Non-destination-oriented traffic is estimated along all of the highway segments interconnected with existing highway routes, and the technique used for developing those estimates is to extrapolate from traffic flowing to the closest "jumping off point" on the existing highway system.

Two classes of tourists and recreationists are considered in developing tourism benefits: resident and non-resident. In projecting their numbers into the future, increased resident usage of the transportation system is based on projected changes in resident population, whereas, future growth in non-resident tourist usage of the system is tied to estimates of overall growth in tourist traffic in the State.

Estimated Benefits by Route Segment

Table 6-1 presents a summary of present values of direct expenditure by both destination and non-destination-oriented recreational visitors. These estimates are derived from data projections based on an analysis of tourist traffic in Mt. McKinley National Park (Solie, 1973). Alternative figures for some routes (e.g., 3A, B, C, and D) reflect two factors: 1) the possibility of a fork in a road segment, thus resulting in decreases in non-destination-oriented traffic on each fork; 2) where there are routes (either rail or highway) serving both units of the proposed Gates of the Arctic Park, total revenues are assumed to be increased by 50%. Each unit of the Park and the road segments leading to it would thus serve 75% of the destination-oriented visitors that if only one unit were served.

A "multiplier" of 2.5 is applied to the direct expenditures of Table 6-1, adjusted for reductions in welfare payments, to reflect the effect of subsequent recirculation of the tourism expenditures. (The actual rate used is thus: [Direct Revenue + (Direct Revenue x 88%) x (1.5)] (.68) (.365)=57.6% x Direct Revenue. See Ch.3 for a discussion of the multiplier, tax rates, welfare savings rates, and the "opportunity cost" of the resources.)

Of the tax and welfare benefits generated by destination-oriented visitors to the proposed Gates of the Arction region, 25% are assumed to be required to pay for other public facilities needed for opening up the Park (feeder roads, camp sites, etc., but not hotels, restaurants, etc., which, it is assumed, would pay for themselves). (Where routes to both units of the proposed park exist in a system, and destination-oriented revenues are increased by 50%, revenues for route segments to each unit would be only 75% of what they would have been had there been a route to only one unit. Thus, the charge for "other" facilities is assumed to be 33-1/3% rather than 25%). The balance is considered a benefit to the newly-constructed transportation routes considered here. These benefits are pro-rated to the segments of the basis of mileage, and the present value of the future flows for a 25-year period is determined. These amounts are the benefits from tourism and recreation and they are added to the other benefits determined in the model to provide the estimate of total benefits.

In calculating benefits for the second concept (total increase in GNP, assuming no "opportunity cost" of resources) the direct revenues from tourism are multiplied by 2.32 (a multiplier of 2.5 adjusted for reduction in welfare costs) to reflect the multiplier effect, and the present value of these future flows becomes the estimate of recreational benefits. Table 6-2 shows the present value of these recreational benefits for both concepts. As can be seen, the recreational benefits can be substantial, and, thus, although they would probably be insufficient to justify construction of many (possibly most) routes by themselves, they are certainly a factor to consider in planning the location of a given route or in determining an optimal system.

Table 6-1

Estimates of Present Value of Direct Expenditures
For Destination and Non-Destination-Oriented Recreational Visits: By Segment

Segment	Destination-Oriented Resident	Destination-Oriented Non-Res.	Non-Dest. Oriented Resident	Non-Dest. Oriented Non-Res.	Total Direct Expenditures
1	N.A.	N.A.	N.A.	N.A.	N.A.
2	N.A.	N.A.	N.A.	N.A.	N.A.
3A[2]	825	11,376	0	0	12,201
B	1,154	16,415	0	0	17,569
C	513	7,296	0	0	7,809
D	1,026	14,591	0	0	15,617
4A[2]	454	6,261	0	0	6,715
B	635	9,035	0	0	9,670
5A[2]	86	1,188	0	0	1,274
B	167	2,375	0	0	2,542
6	N.A.	N.A.	N.A.	N.A.	N.A.
7	N.A.	N.A.	N.A.	N.A.	N.A.
8	N.A.	N.A.	N.A.	N.A.	N.A.
9	N.A.	N.A.	N.A.	N.A.	N.A.
10A[2]	774	2,155	59	301	3,289
B	529	1,438	59	301	2,327
C	396	1,159	59	301	1,915
D	595	1,738	59	301	2,693
11A[2]	1,982	5,232	30	153	7,397
B	2,775	7,550	60	307	10,692
12A[2]	0	0	0	0	0
B	0	0	0	0	12
C	0	0	2	10	24
13	0	0	4	20	0
14	0	0	0	0	0
15A[2]	0	0	0	0	0
B	0	0	5	22	27
C	0	0	9	43	52
16A[2]	0	0	0	0	0
B	1,491	4,360	59	318	6,228
C	2,237	6,539	117	636	9,529
17	0	0	0	0	0
18	0	0	0	0	0
19	0	0	0	0	0
20A[2]	0	0	0	0	0
B	0	0	1	3	4
C	0	0	2	6	8
21A[2]	0	0	0	0	0
B	0	0	5	28	33
C	0	0	10	55	65
22	0	0	0	0	0
23	0	0	0	0	0
24	0	0	881	4,295	5,176
25-60	0	0	0	0	0

1. Source: Present values of future recreational expenditures based on data in M.I.R.L. Companion Report 29A.

2. For a discussion of the reason for alternate sets of data for given segments, see the discussion on page 50. Selection of the appropriate set of data is determined as follows:

For Segment 3:

A: If segments 4 <u>and</u> 10 <u>and</u> 16 coexist in system, use "A" data.

B: If segment 4 exists, but either 10 or 16 does not, use "B".

C: If segment 4 does not exist, but 5 <u>and</u> 10 <u>and</u> 11 coexist, use "C."

D: Otherwise, use "D".

For Segment 4:

A: If segments 10 <u>and</u> 16 coexist in system, use "A".

B: Otherwise, use "B."

For Segment 5:

A: If segments 4 <u>or</u> 10 <u>and</u> 11 also exist in system, use "A" data.

B: Otherwise, use "B."

For Segment 10:

A: If segments 11 and 16 coexist in system, use "A" data.

B: If segment 11 exists, but 16 does not, use "B."

C: If segment 11 does not exist, but 16 and 4 coexist, use "C."

D: Otherwise, Use "D."

For Segment 11:

A: If segment 16 also exists in system, use "A" data.

B: Otherwise, use "C."

For Segment 12:

A: If segment 10 does not exist in system, use "A" data.

B: If both segments 10 and 16 coexist in system, use "B".

C: Otherise, use "C."

For Segment 15:

A: If segment 10 and 11 and 12 do not exist, use "A" data.
B: If segment 10 and 11 and 12 and 16 coexist, use "B."
C: Otherwise, use "C".

For Segment 16:

A: If segment 10 does not exist in system, use "A" data.
B: If segment 10 and 11 or 4 also exists use "B" data.
C: Otherwise, use "C."

For Segment 20:

A: If segment 10 and 11 and 12 and 15 exist, but 16 does not exist, use "A" data.
B: If segment 10 and 11 and 12 and 15 and 16 all exist, use "B" data.
C: Otherwise, use "C" data.

For Segment 21:

A: If segments 10, 11, 12, 15, and 20 all exist, but 16 does not, use "A" benefits.
B: If 10, 11, 12, 15, 20 and 16 all exist, use "B."
C: Otherwise, use "C" data.

Table 6-2
PRESENT VALUE OF ESTIMATED BENEFITS FROM TOURISM BY ROUTE SEGMENT FOR TWO CONCEPTS[1]
(Thousand of $)

Route Segment	Est. State & Fed. Tax Benefit[2]	Est. Total GNP Benefit
1	0	0
2	0	0
3A	7,028	28,323
B	10,120	40,784
C	4,498	18,127
D	8,995	36,250
4A	3,868	15,588
B	5,570	22,447
5A	734	2,958
B	1,464	5,900
6	0	0
7	0	0
8	0	0
9	0	0
10A	1,894	7,633
B	1,340	5,400
C	1,103	4,445
D	1,551	6,251
11A	4,261	17,172
B	6,159	24,821
12A	0	0
B	7	28
C	14	56
13	0	0
14	0	0
15A	0	0
B	16	64
C	30	121
16A	0	0
B	183	737
C	366	1,475
17	0	0
18	0	0
19	0	0
20A	0	0
B	2	8
C	3	12
21A	0	0
B	16	64
C	32	129
22	0	0
23	0	0
24	2,474	9,970
25-60	0	0

[1]For a discussion of the two concepts, see Pages 18-19. For determination of appropriate route segments (i.e. A, B, C, or D) see Fn. 2, Table 6-1.

[2]Estimated tax benefits are determined by multiplying direct expenditures of Table 1 by 57.6%. See discussion on page 51.

[3]Estimated total change in GNP determined by multiplying direct expenditures of Table 1 by 2.32. For discussion see page 51.

CHAPTER 7

RESULTS AND CONCLUSIONS

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Benefit-Cost Ratios

The benefit-cost ratio concept is discussed in Chapter 3, and is defined there: "The benefits are benefits to the state and federal governments in terms of taxes, reduced welfare and unemployment insurance costs, etc., resulting directly from mining operations, minerals transportation, tourism and business generated for support services as well as from the multiplier effect of the increased expenditures." Profits to the mining companies over and above those stipulated (economic profit) are also included in the benefits. The costs include estimates of both initial construction cost and the fixed annual maintenance costs of new transportation routes and facilities. The fixed costs are independent of the tonnage hauled. The ratio between present worth benefits and the costs is then the benefit-cost ratio used to evaluate the various routes and route combinations (route system). Each system involves one route from each postulated mining location. The system with the most favorable benefit-cost ratio is theone where the total cost of all the routes (one from each location) was weighed against the total benefits generated by all the routes and found to be the highest. The minimum profit to the company operating at each location was assumed to be 15% of the revenue at tide water. This minimum profit is considered to be adequate to encourage the development of a mining venture. Benefit-cost ratios have been determined by computer, using a program developed by Chris A. Lambert, Jr., during this study. The program is on file at the Mineral Industry Research Laboratory.

The results obtained for the individual routes are summarized in Table 7-1. In addition to the benefit-cost ratio, a net benefit (benefit less cost) is shown for each route. It must be emphasized that the dollar values presented are derived from assumptions and computations developed for this study and should be considered in terms of relative, rather than absolute value. The routes can be divided into several categories:

Table 7-1a
Route Identification

Route	Commodity	Distance Miles	Mode*	From	To	Segment Numbers
1	Copper Concentrate	821	Hwy-RR	Bornite	Seward	12, 4,3,1
2	Copper Concentrate	895	Hwy-RR	Bornite	Seward	12,11,10,7,6,2,1
3	Copper Concentrate	417	Hwy	Bornite	Lost River	12,13,14
4	Copper Concentrate	240	Hwy-Barge	Bornite	Kotzebue	15,22
5	Copper Concentrate	419	Hwy-RR	Bornite	Lost River	12,25,26
6	Blister Copper	530	Air	Kobuk	Anchorage	29
7	Blister Copper	808	ACV-RR	Kobuk	Seward	30,1
8	Blister Copper	262	ACV	Kobuk	Kotzebue	31
9	Coal	931	RR	Kukpowruk	Lost River	24,25,26
10	Coal	848	Hwy	Kukpowruk	Lost River	20,21,15,12,13,14
11	Coal	1146	Hwy-RR	Kukpowruk	Seward	20,21,15,12,4,3,1
12	Coal	1220	Hwy-RR	Kukpowruk	Seward	20,21,15,12,11,10,7,6,2,1
13	Coal	500	P/L	Kukpowruk	Lost River	36
14	Coal	150	RR	Kukpowruk	C. Thompson	37
15	Coal	150	P/L	Kukpowruk	C. Thompson	38
16	Copper Concentrate	775	Hwy-RR	Koyukuk	Seward	27,7,6,2,1
17	Blister Copper	530	Air	Koyukuk	Anchorage	32
18	Coal	966	Hwy-RR	Knifeblade	Seward	16,5,3,1
19	Coal	951	Hwy-RR	Knifeblade	Seward	16,10,7,6,2,1

*Hwy=Highway
RR=Railroad
Air=Airplane
ACV=Air Cushion Vehicle
P/L=Slurry Pipeline

Note: This table is reproduced in Chapter 4 as Table 4-1 for the convenience in reading that chapter.

Table 7-Ib
Summary of Results, Individual Routes,
All Dollar Values are Present Worth Values

Route Number	Benefit to the State ($\$10^3$)	Rank	Cost to the State ($\$10^3$)	Rank	Net Benefit Benefit-Cost ($\$10^3$)	Rank	Benefit-Cost Ratio	Rank	Remarks
1	481,485	5	758,226	2	-276,741	12	0.635	12	
2	307,672	10	60,616	7	247,056	7	5.075	8	Subsidized*
3	232,033	12	126,995	5	105,038	9	1.827	9	Subsidized*
4	384,183	7	20,637	8	363,545	5	18.616	6	
5	398,757	6	718,183	1	-319,426	13	0.555	13	
6	495,700	4	7,663	10	488,037	4	64.687	3	
7	504,393	3	9,739	9	494,654	3	51,791	5	
8	513,924	2	6,539	11	507,385	2	78.593	2	
9	(								
10	(No								Mining cost
11	(Benefit								+ transportation cost
12	(								exceeds revenue
13	252,973	11	186,835	4	66,138	11	1.353	10	Subsidized*
14	376,715	8	290,312	3	86,403	10	1.297	11	Subsidized*
15	580,087	1	68,863	6	511,224	1	8.423	7	
16	229,260	13	0	13	229,260	8	High	1	Subsidized*
17	337,394	9	5,954	12	331,440	6	56.666	4	
18	(No Benefit								Mining cost +
19	(No Benefit								transportation cost exceeds revenue

*Company needs a tax reduction to meet minimum company profit, page

1. No benefit

As shown in Table 7-1b, routes 9, 10, 11, 12, 18 and 19 show no for benefits. This is because, for the data used, the tidewater revenue (selling price times quantity) is exceeded by the sum of the cost of mining and cost of transporting the commodity from the mine to the port. These routes are summarized as follows:

Route	9	Coal	Railroad	Kukpowruk/Lost River	931 Miles
	10	Coal	Highway	Kukpowruk/Lost River	848 Miles
	11	Coal	Hwy/RR	Kukpowruk/Seward	1146 Miles
	12	Coal	Hwy/RR	Kukpowruk/Seward	1220 Miles
	18	Coal	Hwy/RR	Knifeblade/Seward	966 Miles
	19	Coal	Hwy/RR	Knifeblade/Seward	951 Miles

As the summary shows, these routes involve shipping a low value commodity great distances using conventional transportation systems. Even with subsidies, these ventures would not be able to show a benefit to the State.

2. Subsidized Routes

Routes 2, 3, 13, 14 and 16 do show a benefit, but by using these routes, the companies would fail to make a 15% minimum profit as outlined in the assumptions. The routes do, however, generate benefits of such magnitude that it would be to the State's advantage to subsidize the ventures. The subsidy would allow the company to operate and obtain the minimum profit. The benefits generated from these operations considerably exceed the required subsidy and the net result would be a positive benefit to the State. These routes are also listed separately.

Route	2	Copper Concentrates - Hwy/RR - Bornite/Seward	895 mi.
	3	Copper Concentrate - Hwy - Bornite/Lost River	417 mi.
	13	Coal - Pipeline - Kukpowruk/Lost River	500 mi.
	14	Coal - RR - Kukpowruk/Cape Thompson	150 mi.
	16	Copper Concentrate - Hwy/RR - Koyukuk/Seward	775 mi.

To summarize, these routes would not be developed unless the company is given some tax reduction to operate over them. If such an incentive is offered, the net result is a benefit to the state.

3. Costs exceed benefits

The table also shows that for routes 1 and 5, which involve the building of a railroad to Kobuk from Nenana and Lost River, respectively, the benefit to the state is exceeded by the cost to the state. The table shows the benefit to have a substantial value, but the cost is also much greater. The company could operate and make the minimum profit if the routes were constructed, but the state would not realize a sufficient return on the investment necessary to provide a railroad transportation system to serve the mine. This, of course, does not take into account any additional benefits from other sources or non-monetary advantages not considered in this study.

4. Self-sustaining routes

The remaining routes are self-sustaining. They will serve the mine and also generate benefits to the state in excess of the costs. These routes are:

4 - Copper Concentrate	From Bornite to Kotzebue by Hwy/Barge
6 - Blister Copper	From Kobuk to Anchorage by Airplane
7 - Blister Copper	From Kobuk to Seward by Air Cushion Vehicle /RR
8 - Blister Copper	From Kobuk to Kotzebue by Air Cushion Vehicle
15 - Coal	From Kukpowruk to Cape Thompson by Slurry Pipeline
17 - Blister Copper	From Koyukuk to Anchorage by Airplane

From the foregoing, it is evident that the routes that should be investigated further are the self-sustaining routes and the subsidized routes. For these routes, the state will realize benefits in excess of its costs. The results as shown in Table 71b, also show that the routes having the largest difference between benefit and costs are those with a small total transportation cost. The model heavily favors these transportation routes. The table shows the best route using the difference as a criterion to be Route 16. This is because the pipeline road is assumed to be in existence and no additional initial cost to the State is considered for using this already existing road. The next routes showing a favorable difference are the routes with a minimum of new, conventional construction. The results show the air-cushion vehicle routes, the airplane routes, barge routes and slurry pipeline routes to be more beneficial to the state than conventional roads and railroads. It should be kept in mind, however, that this study is constrained to consider the best way to transport minerals. Considerations as to serving the few settlements in the area and opening up the country to tourism may favor more conventional transportation routes, although they show less identifiable net benefit.

Transportation System

The computer model analyzed the transportation routes in terms of a transportation system. The transportation system is a combination of routes, one from each of the four mining location. Routes 1 through 8 serve the copper at Bornite, Routes 9 through 15 serve the coal in Northwest Alaska, Routes 16 and 17 serve the potential copper industry in the Koyukuk area and Routes 18 and 19 serve the coal deposits at the north central area of the Brooks Range (Knifeblade).

The results show that a combination of routes 8, 15, 17 and 19 would be the best system and that the benefit-cost ratio for the combination was 10.284. It should be noted, however, that this combination includes the coal from Knifeblade, and this particular location is a losing proposition as shown in Table 7-lb. Excluding Knifeblade, the combination of routes 8-15 and 17 yield a benefit-cost ratio of 17.594. The difference between these two numbers is due to the fact that the other routes in effect subsidize the Knifeblade transportation system. Excluding the routes from Knifeblade from the analysis, the following combination of routes yielded the best transportation system in terms of high benefit-cost ratios.

Table 7-2a
Summary of Systems Excluding Knifeblade Coal

System (Routes)	Benefit ($\$10^3$)	Cost ($\$10^3$)	Ratio	Benefit-Cost (Net Benefit)($\$10^3$)
8 - 15 - 17	1,431,405	81,356	17.594	1,350,049
8 - 15 - 16	1,323,271	75,375	17.555	1,247,896
6 - 15 - 17	1,413,181	82,480	17.133	1,330,701
6 - 15 - 16	1,305,047	76,526	17.053	1,228,521
7 - 15 - 17	1,421,875	84,556	16.815	1,337,319
7 - 15 - 16	1,313,741	78,602	16.713	1,235,139

Table 7-2b
Best System Using Highway & Railroad Combinations, Excluding Knifeblade Coal

System (Routes)	Benefit ($\$10^3$)	Cost ($\$10^3$)	Ratio	Benefit-Cost (Net Benefit)($\$10^3$)
2 - 14 - 16	913,646	350,928	2.603	562,718

If blister copper production is excluded from consideration, the following network emerges.

Table 7-2c
Summary of Systems, Excluding Blister Copper and Knifeblade Coal

System (Routes)	Benefit ($10^3)	Cost ($10^3)	Ratio	Benefit-Cost (Net Benefit)($10^3)
4 - 15 - 16	1,193,530	89,500	13.336	1,104,030
2 - 15 - 16	1,117,019	129,479	8.627	987,539
3 - 15 - 16	1,041,381	195,858	5.317	845,523
1 - 15 - 16	1,290,833	827,089	1.560	463,744
5 - 15 - 16	1,208,104	786,946	1.535	421,158

The low ratios for the systems containing routes 1 or 5 result because these routes have a benefit-cost ratio less than unity (Table 7-1b) and, in effect, the other routes are supporting the system. Table 7-1b also shows that transport by barge has a favorable benefit-cost ratio, 18.617. The highest ratios for new transportation, however, are those involving air-cushion vehicles and airplanes. This kind of transportation favors the movement of a high-value per ton commodity such as blister copper. For these routes to exist, the assumption is made that blister copper is produced at or near the mine. The additional cost of the smelting is considered as part of the mining cost.

Tourist Benefits

The contribution of tourist benefits was also investigated separately (Chapter 6 and M.I.R.L. Report No. 29A). As already stated, the system 8, 15, 17, 19 has a benefit-cost ratio of 10.284. Without tourist benefits, the ratio is 10.281. The tourist benefits would be generated mainly by providing access to the proposed "Gates of the Arctic Park." The optimum network of systems does not provide many segments of conventional transportation modes that are amenable to tourism.

When the relative importance of tourism on the more favorable (to tourism) access routes to "Gates of the Arctic" was investigated, it was found that tourism contributed 3% or less to the total benefit value. The conclusion to be drawn from this study is that tourism alone will have a minimum influence on the development of Arctic Alaska. However, tourist benefits, although small compared to the benefits generated from the mineral industry, are significant, and the values in terms of intangible benefits such as breathtaking scenery and the area's wild nature cannot always be put in terms of dollars. In addition, benefits of a true multi-purpose regional transportation system were not investigated in this study; for example, tourist benefits might be used as an initial justification to build a road, which may then provide benefits as a development road or a road to explore potential mineral deposits. The benefits from exploration alone may not justify the road, but combined with the potential tourist benefits, such a road may become feasible.

Gross Benefits

The model also makes an assessment of the gross benefits and the corresponding gross benefit-cost ratio. The gross benefit concept is described in Chapter 3. This concept considers "benefits from the standpoint of the economy as a whole and includes the total gross product from the transportation system-induced output, without any deduction for cost of production, transportation, etc. This measure reflects the fact that the entire increase in output is a benefit to the economy (or society) as a whole." Using this concept, the two best systems (including the coal from Knife-blade), are the following:

1) 8 - 15 - 16 - 19 with a gross benefit/cost ratio of 32.182
2) 6 - 15 - 16 - 19 with a gross benefit/cost ratio of 32.051

Note: Again it must be stated that excluding the Knifeblade route, much higher benefits would be derived from the system.

The major difference between the systems obtained by using gross benefits rather than benefits is that the system favors Route 16. It can be seen from Table 7-2a that systems 8 - 15 - 16 and 6 - 15 - 16 have the lowest cost, Route 16 being in part the assumed pipeline road. Thus, by increasing the benefits figure (gross benefits) the system having the lower cost is naturally favored.

Discussion of Results

The foregoing analysis suggests that those modes of transportation requiring the least initial outlay by the State will provide the greatest benefit/cost ratio. Thus, if a route can use a segment of already constructed road or railroad, or a river, the relatively low "cost" will allow a high benefit-cost ratio to be attained. Next in economy of investment for the State are airplane and A.C.V. terminals and routes, and these modes show a high benefit-cost ratio.

It would be a misapprehension to assume from this that freight can be moved over present roads cheaper per ton than over new, shorter roads, or that airplanes and A.C.V.'s will move freight cheaper than roads or railroads. Any mining company would rather ship via railroad than airplane, if it is not asked to pay - exclusively - for the railroad. Because the results of this study very clearly depend upon assumptions and attitudes, and economic dogmas, it is perhaps wise at this time to recapitulate some of these that are pertinent.

1) The company is assured of its minimum profit by defining it as a function of revenue, not profits. Thus, it is immaterial whether transportation costs are high or low; a certain minimum profit is assured or there will be no operation. It will be noted that in the second category of routes (pages 58 and 59) it would pay the State to forego some of its taxes to stimulate an operation, and, thus assure 15% of revenue for profit to the mining company, because the benefits to the State are still considerable.

2) It could be argued that the use of a method that has an excessively high operating cost is an economic waste which might reduce calculated benefits. It has already been pointed out that roads provide tourist benefits not provided by, e.g. A.C.V.'s.

3) There is an intangible benefit connected with a labor intensive mode of transportation. If extra benefits accrue from a low labor intensive method, these benefits may flow back to the local populace as welfare, whereas the recipient of the welfare might otherwise be a truck driver or brakeman if a labor intensive route is used.

4) Is it feasible to ask an industry to invest heavily in a region without conventional surface transportation? Would or should industry demand such transportation from government?

5) Should this area, one sixth of the U.S., if Alaska is considered as a whole, be tied together by a conventional network as a manifestation of national will and policy?

6) It can be argued that if government has faith that the Brooks Range will be a major producer of metals, and that more oil fields will be discovered, it would be to its advantage to establish roads now, since at some volume of production,

conventional transportation modes will produce greater benefits than air or A.C.V. service.

7) The western U.S. was "opened up" by railroads, that is, when transportation became available, cattle ranching, wheat farming, logging and other industries based upon surface products (renewable resources) were established. Also, the railroads connected two rich and well populated areas -- the east and west coasts. It is not to be expected that this will happen in Alaska. In fact, where railroads were established to isolated mining regions in the West, they were spur lines, abandoned at the close of mining.

8) Tourism, the only major "surface industry" in the study area, is best served by roads, not railroads.

9) In connection with several of these points, conflicts may be resolved with the following arguments: The mineral deposits now known or reasonably inferred will not, by themselves, justify building surface transportation systems. If the State decides that the mining industry must bear the cost of building such systems, they will not be built now. If industry says it must have roads before mines can start, they never will start. If discovered reserves, as at Bornite, lie idle too long, companies will become discouraged and cease exploration, and the chance to develop sufficient reserves to justify the construction of surface systems, through exploration and discovery, will be lost. Hence, there will never be enough mineral reserves to justify surface transportation, and the roads never will be built. The use of airplane or A.C.V. at the start may be the best that industry or the State can hope for, and actually serve to "open up the country". A road system will follow.

10) Whatever system is built, it will depend upon minerals and the discovery of new minerals to support it. It will detract from the network's effectiveness to institute new transportation without actively encouraging mining and exploration with every means at the State's disposal.

11) It should be noted that this study is aimed toward providing transportation for mineral industry as it could be established with known or reasonably inferred mineral deposits. It may be that the aggregate of benefits not considered, e.g. gold mining, reindeer husbandry, increased tourism, residential passenger service and minerals not included in the model, will make a conventional transportation system feasible.

12) This report contains numbers indicating, within the limits of the accuracy of the data and assumptions, the relative benefits to be drawn from different transportation systems. In the final analysis, however, the type of transportation system built will be the result of political, economic, geographical and other factors. Roads and railroads have been built before on less justification than offered here. If it is the national will to build a railroad, it will be built in preference to, for example, an A.C.V. route.

13) The results listed herein may be suggesting that we are on the verge of a new era in transportation, and should be studied in depth. Alaska is in a unique position. It has persisted almost into the last quarter of the twentieth century with an extremely sparse settlement and transportation network. Technology has placed at our disposal methods that may make unnecessary the building of conventional systems, ones that might have been used to service mining areas of the West, had they been available.

Conclusions

Due to the high cost of construction and the price of manpower in the north, the best systems in terms of a high benefit-cost ratio are those utilizing a minimum of new, conventional construction, such as building of highways or railroads. The optimum transportation system obtained by this study is one linking together existing transportation facilities with aircraft operations or air-cushion vehicles.

This particular transportation system also favors products with a high dollar-to-weight ratio. This is indicated by the great increase in the benefit-cost ratio from shipping blister copper rather than copper concentrate. This kind of a transportation system does not generate any significant tourist benefits, nor provide surface transportation for local residents, nor, more importantly, provide transportation in support of exploration efforts.

Of the several possible alternatives for shipment of North Slope coal, only a slurry pipeline to an as yet undeveloped port on the Arctic coast shows promise. Such a route does not extend any other transportation network, and does not offer any of the side benefits such as tourism or backhaul capability.

Although not directly assessed in the study, it should be noted that the optimum systems should result in the least degree of environmental disturbance.

Recommendations

While the magnitude of the numerical values produced by the mathematical model must be qualified by the necessity for using assumptions and estimates in place of valid data, the indicated overall potential benefits to the state and nation derived from tapping the mineral resources north of the Yukon Basin warrant an urgent recommendation for placing increased emphasis on developing the mineral industry and a viable transportation system in Alaska as a matter of national and state policy. This matter should be given a high priority by all responsible federal and state agencies. Specific areas for implementation include, but are not limited to, the following:

1. Support of Mineral Exploration. The present government effort to survey the coal resources of Alaska should be intensified to determine the potential of coal both as a marketable product and a source of energy for use within the state. Federal and state policy should be expanded to provide more encouragement for exploration of all other economic minerals in Alaska.

2. Include potential mineral industry development in transportation planning at state and federal levels. Research aimed at establishing factors influencing the cost of mining should be pursued. Mining operations will have to be opened in Northern Alaska and elsewhere in the State if the State's economic base is to expand. The feasibility of smelting the minerals mined within Alaska should be studied in considerable depth. The results of this report favor smelting of the mineral and transporting the near-finished product rather than moving ore or concentrates. The transport of refined minerals would bring greater revenue to the state and also minimizes the transport of waste materials.

Further research is also needed in the general area of mining in permafrost. New methods of thawing frozen ground as well as utilizing the permafrost to advantage in a mining operation should be considered. Such research will also help to create an understanding of the ecological impact of a mining operation in the Arctic. By developing mining methods suitable to the arctic environment and by understanding the often delicate nature of permafrost, mining operations could be carried out without undue disturbance of the surface.

4. Investigate alternatives for providing power in northwestern Alaska. Economic and engineering studies should be conducted to determine the best sources of

energy and most efficient means of transferring energy from source to consumer in quantities required for various levels of urban and commercial activities in northwestern Alaska.

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