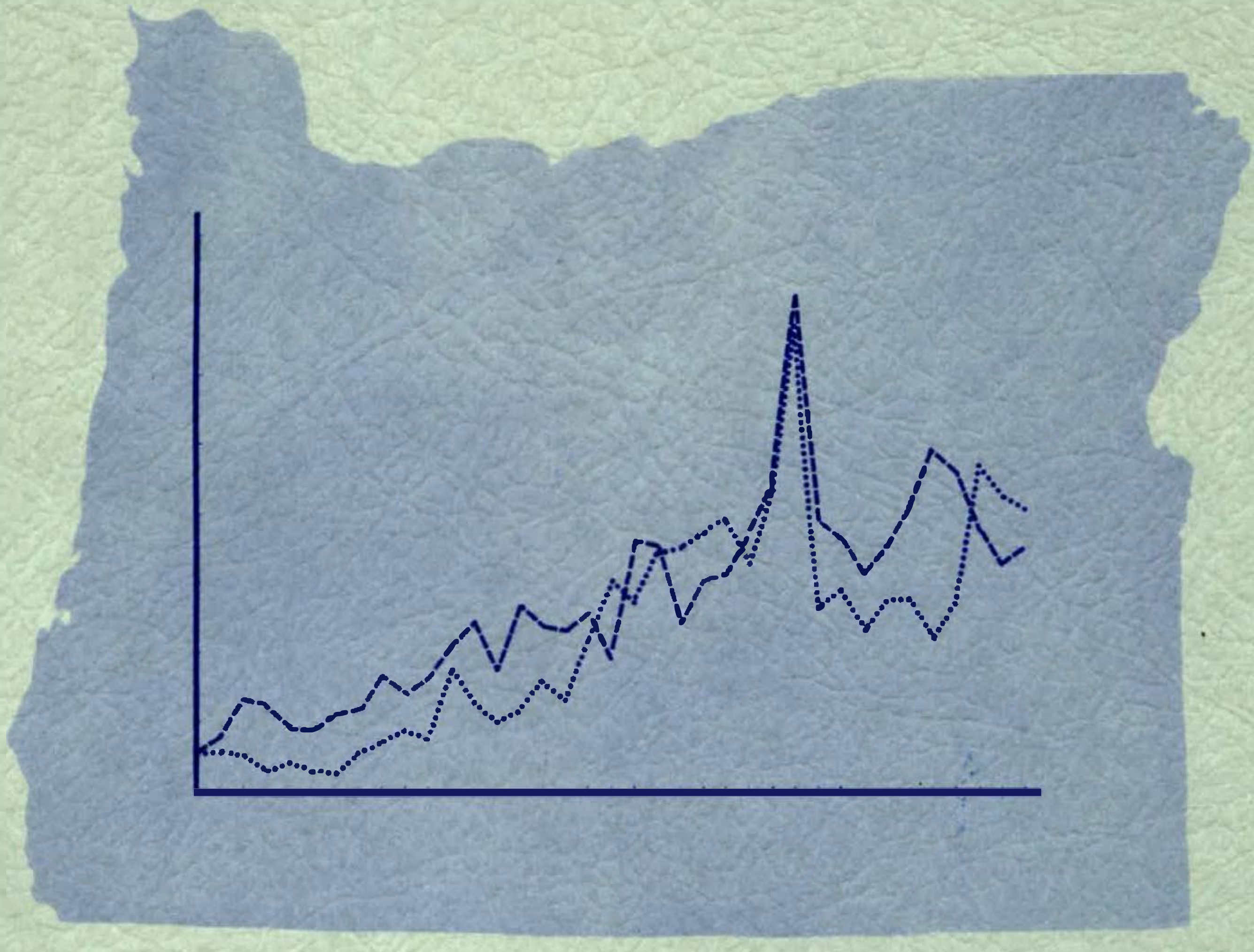
SPECIAL PAPER 5

ANALYSIS and FORECASTS of the DEMAND for ROCK MATERIALS in OREGON



1979

STATE OF OREGON
DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES
DONALD A. HULL, STATE GEOLOGIST

STATE OF OREGON

DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES

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SPECIAL PAPER 5

ANALYSIS and FORECASTS of the DEMAND for ROCK MATERIALS in OREGON

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Under Contract To
Oregon Department of Geology and Mineral Industries

With the assistance of
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Oregon Department of Geology and Mineral Industries

1979

PREFACE

In November, 1978, the Oregon Department of Geology and Mineral Industries (DOGAMI) contracted Economic Consultants Oregon, Ltd. (ECO) to conduct an economic analysis of Oregon's demand for rock materials and to forecast future demand. We analyzed the demand for the state as a whole and for four substate areas: the Portland metropolitan area; Jackson County; Lincoln County; and Umatilla County. For each area, we forecast the demand in 1985, 1990, and 2030. This report presents the complete results of our study.

In conducting the study, we received extensive and valuable assistance from many individuals and agencies. John Beaulieu and Jerry Gray of DOGAMI in particular provided indispensable information. They also generously offered constructive criticism of various interim reports. Tom Maresh, of the Department of Geography at Oregon State University, also helped us with his critiques and advice. ECO, of course, assumes full responsibility for the views and any remaining errors in the report.

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General

In this report, we develop and present a set of economic tools with which planners and others can analyze and forecast the demand for sand and gravel and for crushed stone in Oregon. Then we use these tools to describe and forecast demand in the state as a whole and in four substate areas: the Portland metropolitan area; Jackson County; Lincoln County; and Umatilla County. Additionally, we develop descriptive models of the statewide demand for lightweight aggregates and of the demand for crushed stone in the Willamette National Forest. Appended to the report are the major models we used in developing demand forecasts, analytic test statistics for these models, and listings of all the original data that are the foundation of the study.

Our objective is to help planners and others anticipate with greater accuracy the likely future growth of the rock-materials industry. Such information should help communities, counties, and state and federal agencies make sufficient rock resources available in the future while minimizing land-use and environmental conflicts.

Understanding thoroughly the probable future characteristics of the rock materials industry requires analyzing both the demand and the supply sides of the market. This report addresses the demand side only. Here we investigate the economic forces which generate the demand for rock materials and provide a methodology for forecasting future demand. By combining this methodology with existing and forthcoming studies of rock supplies, both private and public participants in the market for rock materials can anticipate and plan with greater effectiveness.

The key findings of the report concern (a) the erratic and the predictable components of the demand for rock materials in any market area, (b) the reliability of econometric analysis in describing the non-erratic components of demand, (c) the general historic absence of statistically adequate trends in the compound growth rates for the demand for rock materials in Oregon, and (d) the usefulness of econometric simulation analysis to forecast demand when other, more direct forecasting methods are inappropriate.

Econometric planning tools offer an analytical and empirical description of current demand and forecasts of future non-erratic demand such as the demand in well-integrated markets. Erratic, even volatile, demand--especially in rural areas--along with cyclical fluctuations in the predictable components inhibit the ability of trend analysis to account for current and past demand. Of course, no descriptive approach can forecast erratic demand directly. However, planners and others may estimate some of the volatile elements by anticipating major public works projects.

In addition to this introduction the Executive Summary contains five other parts. In Part II we describe briefly current demand for rock materials in Oregon. In the next two parts we present the economic variables underlying demand and describe the production areas for which we study demand closely. In the fifth part we explain the econometric models which examine demand. The simulation technique we use to forecast future demand is presented in the last part of this summary.

The Demand for Rock Materials in Oregon

As a measure of historic demand we used estimates of past production of rock materials.[1] The production data come from the U.S. Bureau of Mines; we refined these data with information from the Oregon Department of Geology and Mineral Industries and from industry sources.

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[1]Demand may exceed actual production if, at current prices, output is lagging behind orders.

With only minor exceptions, all the demand in Oregon for sand and gravel and for crushed stone stems from these materials' use in construction and related activities. Road construction historically has consumed about 50 percent of the state's total production of sand and gravel and about 75 percent of the crushed stone. Other major categories of use have included building construction and landfills.

For most uses, consumers of rock products prefer either sand and gravel or crushed stone. These preferences stem from differences between the two commodities in their physical properties or their price. Because of the strong preferences, we analyzed the demand for the two commodities separately. Despite users' preferences related to physical properties, for many uses the two commodities can be substitutes. In some areas of Oregon the supplies of sand and gravel are very limited and in these areas complete substitution occurs. This real scarcity, especially of sand and gravel, likely will increase in the future, causing higher prices for the more scarce commodity and a shift of demand to the less scarce commodity. Users of this report should take such supply effects into account.

Although construction constitutes the immediate source of demand for rock materials, the level of construction and the demand for rock derive more fundamentally from the size and vigor of the overall economy. The geographic distribution of rock production illustrates this relationship. Between 1970 and 1976, Oregon annually produced averages of 19,671,000 tons of sand and gravel and 16,648,000 tons of crushed stone, according to data from the U.S. Bureau of Mines.[2] For 5 percent of the sand and gravel and 21 percent of the crushed stone--primarily rock used on roads in the national forests--the Bureau cannot identify the county of origin. But the ten counties in the Willamette Valley produced the bulk of the remaining production. The Willamette Valley, with most of Oregon's population and economic activity, produced about 71 percent of the state's sand and gravel and 43 percent of its crushed stone.

Economic Variables

The historic relationships between specific characteristics of Oregon's economy and its rock production form the basis for analyzing and forecasting the demand for rock materials. Accurately measuring these relationships reveals the extent to which various economic variables individually and jointly influence the level of demand for rock materials.

In developing our analytical techniques and our forecasting methodology, we relied on regularly collected and readily available data. Thus, planners and other users can update our results and apply our techniques to areas throughout Oregon using these same data. Two data series are likely to be more useful in the future than they have been in the past. The Bureau of Mines' data for rock-materials production are increasingly accurate and comprehensive in recent years, and the Department of Revenue compiles adjusted gross income data by county. In the future, when these agencies have accumulated long-term series of accurate production and income statistics, the revision and application of the tools derived in this report will yield even more reliable analyses and forecasts.

Adequate historic records of reliable data exist for only a few economic variables. We examined the relationships between the annual production of sand and gravel and of crushed stone and four economic variables:

1. the estimated average price of the commodity;
2. total population;
3. total employment; and
4. total state and federal expenditures for highway construction.

Total personal income likely also influences the market, but lack of data permitted only a cursory analysis of income's influence on rock production.

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[2] These averages underestimate actual production because of incomplete reporting by some producers to the Bureau of Mines.

Using various techniques, we developed econometric models of the relationships. The models show the strength of the relationship between production and each economic variable. The models also show the ability of the economic variables jointly to explain variation in the level of production for each rock commodity.

Study Areas

We developed econometric models for five areas:

1. the Portland metropolitan area (Clackamas, Columbia, Multnomah, and Washington Counties);
2. Jackson County;
3. Lincoln County;
4. Umatilla County; and
5. the state as a whole.

We chose the four substate areas to represent an expected range of demand characteristics related to, respectively, major urbanized, urbanizing, coastal and eastern Oregon economies.

In principle, the analycial techniques we developed apply primarily to local market areas, where a single set of demand, supply, and economic considerations interact. However, the availability of critical data only on a countywide basis dictated our use of counties or groups of counties to approximate local market areas. These approximations do not hamper the techniques substantially because each study area encompasses virtually all the characteristics of its local markets. For Lincoln County, some rock moves across the study area's boundaries, but we acknowledge this activity in the analysis. When adapting our techniques to other areas, one must continue to define study areas which are reasonably consistent with the boundaries of local markets.

Econometric Models of Demand

Theoretically, the relationships between the production of each rock commodity and the four economic variables should be strong and systematic. The econometric models for the Portland metropolitan area support the theory. The economic variables explain 93 percent of the historic variation in the area's annual production of sand and gravel. They explain 70 percent of the variation in the area's production of crushed stone. By nearly all indicators, the econometric models for this area, given reliable forecasts of the area's future economy, should yield highly reliable forecasts of the future demand for rock materials.

The econometric models perform substantially less well for the other areas. The economic variables explain less of the variation in rock production. Furthermore, in most instances the models indicate a nonsensical relationship between production and at least one economic variable.

Three factors seem to cause the econometric models to perform less well in the areas other than Portland. One factor is the erratic or lumpy nature of the demand for rock materials in the smaller economies. This erratic behavior obscures and distorts the relationships between rock production and the economic variables in areas like Jackson, Lincoln and Umatilla Counties. Because production in rural areas contributes to the statewide totals, the effects of the erratic behavior also exists, but to a lesser extent, in the statewide data.

The other two factors causing problems for the model stem from statistical complications. In the production data, which producers supply to the Bureau of Mines voluntarily, inconsistencies and underreporting seem to exacerbate the fundamentally erratic nature of rock production in the smaller economies. This problem likely will diminish over time as producers learn the value of reporting comprehensively and accurately. The other complicating factor involves complex relationships among the economic variables, especially between population and employment. These relationships, reflecting what is called multicollinearity, are especially troublesome for areas other than Portland, and they compound the problems caused by the other factors.

By inhibiting the models' ability to describe accurately the forces which determine demand in smaller markets, these factors cause the models for areas outside Portland to yield unreliable forecasts of future demand. In the Portland metropolitan area, demand for rock materials derives from the area's general economic forces and the econometric models explain variation in demand satisfactorily. In the other areas, the erratic component of demand is relatively more prevalent (in some areas it prevails almost exclusively) and the econometric models establish the relationships between production and the economic variables less conclusively. Consequently, in all areas other than Portland, the econometric models offer insights into the demand for sand and gravel and for stone but they cannot support demand forecasting adequately. Inconsistencies in the data for rock production appear to compound the difficulties with the econometric models and produce artificially high (and, usually, statistically inadequate) rates of growth in production. In general, the demand for crushed stone is more erratic and unpredictable than the demand for sand and gravel.

Simulating Future Demand

In the absence of local-area forecasting models, and because Portland's econometric models most clearly identify the well-behaved relationships between production and general economic characteristics, we use these models to forecast future demand for the Portland area and also to simulate the predictable component of demand elsewhere. Adapting the Portland-area models to simulate demand in the other areas requires careful consideration of the models' applicability to market conditions elsewhere. This technique treats only the component of demand deriving from general economic forecasts. In the absence of better data, forecasting the erratic components of demand for a particular production area must rely on anticipating the public construction of highways, power facilities, dams, jetties, and the like.

Using the simulation techniques derived from the Portland-area's econometric modelling, we forecast high, medium, and low estimates of the level of predictable annual demand statewide and in the four substate areas for 1985 and for 1990. These demand forecasts likely have a downward bias, of unknown magnitude, arising from producers' incomplete reporting of production to the Bureau of Mines. Since historical production has been underreported, the econometric simulations derived from these production data also are likely to underestimate production.

Forecasting demand fifty years hence is a very tenuous task. Fifty years ago, for example, few highways were paved and the proportions of rock materials consumed in building construction varied from those in 1979. Thus, projecting the current demand structure onto an economy a half century away is at best questionable. However, the simulation model still offers the best estimate of what we have called the predictable elements in demand. To give a range of estimates of demand in 2030, we used the simulation procedure to derive a growth rate of demand in the several markets and projected demand based on these growth rates.

ANALYSIS and FORECASTS of the DEMAND for ROCK MATERIALS in OREGON

CHAPTER 1

INTRODUCTION

Construction activities, including road building and landfills, are fundamental characteristics of a growing economy. Oregon's economy has been growing at an exceptionally rapid pace. Statewide population and employment grew more rapidly in the 1960s than they did in the 1950s, and both have grown more rapidly in the 1970s than they did in the 1960s. Since 1970, the compound annual growth rate of employment in the Willamette Valley, for example, has been about 4 percent and the Valley contains over 70 percent of Oregon's employment and population. The accompanying expansion in construction activity has increased the demand for rock materials--sand and gravel, crushed stone, and lightweight aggregates such as cinders.[1] This increase causes special and serious problems for the rock material industries, for the construction industries, and for state and local land-use and economic planners.

Construction of roads, houses, and other facilities requires large amounts of rock materials, primarily sand and gravel and crushed stone. Because these materials have a low value relative to their bulk and weight, transportation costs constitute an unusually large portion--typically about 35-50 percent--of their total costs. Thus, producers of rock materials invariably seek to minimize transportation costs by locating their facilities near those rock resources that are closest to the consumption areas.

However, the basic characteristics of rock mining are not compatible with most urban land uses and with many state and local planning goals. Growing urban areas create a planning paradox: they require larger amounts of rock materials, yet they typically have surrounded previously established mining operations with residential and other land uses that threaten to force the operations further from the urban center. Furthermore, moving the mining operations to other resource deposits may be precluded either because the alternative deposits themselves are surrounded by incompatible land uses or because such movements would conflict with state and local goals to preserve open spaces, scenic areas or water quality.

The comprehensive planning requirements under the provisions of Oregon's 1973 Land Use Act (ORS, Chapter 197) focus attention on the need to balance these land-useconflicts with the demand for rock materials. Specifically, Oregon's Statewide Planning Goals, as adopted by the Land Conservation and Development Commission (LCDC), require local governments to inventory their resources and assess their economic needs before preparing their comprehensive plans for satisfying the goals.

To help local and state officials evaluate future requirements for rock materials, this report presents a methodology for estimating the future demand for sand and gravel and for crushed stone. The report describes the state's major markets for these

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[1]The term, sand and gravel refers to water-worn rock deposited by flowing water. The term crushed stone refers to rock material taken from bed rock in a quarry or natural outcrop.

commodities, develops economic models of demand and uses these models to forecast the demand in 1985, 1990, and 2030 for the state as a whole and for four substate areas. The substate areas are: The Portland Metropolitan Area (Clackamas, Columbia, Multnomah, and Washington Counties); the Medford-Ashland area (Jackson County); Lincoln County; and Umatilla County. These areas are representative of most local markets in the state, and analysts can adapt the basic methodology and the results for these areas to estimate the future demand in other areas. We also examine the demand statewide for lightweight aggregates and the demand within the Willamette National Forest for crushed stone.

In addition to this introductory chapter, this report contains five chapters (Chapters 2-6) and an Appendix. CHAPTER 2: METHODOLOGICAL SUMMARY presents an overview of Oregon's rock-material markets and outlines the structure and logic of the analytical models. It also describes the data underlying the analysis and explains how uncertainties in the data affect the analytical results. CHAPTER 3: THE STATEWIDE ANALYSIS analyzes the statewide historical production of sand and gravel and of stone and introduces the models for explaining the demand for these commodities. CHAPTER 4: THE SUBSTATE MARKETS describes the historical demand for sand and gravel and for stone in each of the four substate areas: the Portland area; Jackson County; Lincoln County; and Umatilla County. CHAPTER 5: FORECASTS OF DEMAND extends the contents of the previous two chapters and forecasts the 1985, 1990, and 2030 demand for sand and gravel and for stone in the state as a whole and in each of the four substate areas.

The demand characteristics discussed in Chapters 3-5 differ considerably from the demand for lightweight aggregates and for rock used for construction related to timber harvests. Although only limited data exist for these two commodities, CHAPTER 6: DEMAND FOR LIGHTWEIGHT AGGREGATES AND DEMAND IN THE WILLAMETTE NATIONAL FOREST examines the demand for them briefly.

Using This Report

In the study areas

Planners and other persons interested in the demand for sand and gravel and for stone in the areas we studied can use this report directly. For each area, we forecast the future levels of the predictable component of the demand for each commodity. These forecasts have three dimensions:

1. they represent the portion of demand identified by the Bureau of Mines' production data;
2. they explain only the segment of demand which is determined directly by each area's economic characteristics; and
3. they derive from the particular estimates we used for the future values of the economic variables.

Users in the study areas can either adopt our forecasts as they stand or develop alternative forecasts. Developing alternatives will require altering one or more of the three dimensions of our forecasts. If one anticipates components of demand not incorporated by the first two dimensions, developing new forecasts will require adding these components to our forecasts. Possible additional components include, for example, the rock required for a new dam and the production missed by the Bureau's data.[1]

Altering our forecasts along the third dimension, changing the estimation parameters, will require repeating parts of our analysis. Specifically, one will have to retrace the steps outlined in Chapter 5 using alternative estimates for the future values of the economic variables.

On a larger scale, we encourage users in the study areas to repeat the entire analysis as additional data become available in the coming years. As we explain throughout the report, the data for production and some of the economic variables likely will become more reliable and useful in the future. These improved data undoubtedly will lead to a greater

[1]DOGAMI estimates for this component that Bureau of Mines statistics report 80 percent of production.

understanding of the demand for rock materials and, hence, improved forecasts.

In other areas

We based our forecasts of the demand for rock materials in the study areas on the underlying economic forces which determine the demand. These forces are not identical for all areas in Oregon, but they probably show considerable similarities. For the Portland area, we modelled the determinants of demand quite precisely and, consequently, forecast future demand directly from the models. For the other study areas, several difficulties explained in Chapter 5 prevented our developing a full set of forecasts directly. Instead, we developed forecasts for these areas through simulations using the Portland-area's models.

Users of this report can forecast the demand in areas outside the study areas by following similar procedures. In areas very similar to the Portland area--Lane County, for example--there is a high likelihood that the data for these areas will produce acceptable models. Users in these areas should test this possibility by gathering the data we describe in Chapter 2 and then following the analytical steps we used in Chapters 4 and 5 for the Portland area.

Users in an area where the data will not support adequate models should follow the process we used to develop the forecasts for Jackson, Lincoln, and Umatilla Counties. In summary, this process involves the following steps:

1. determine the appropriate boundaries of the market area;
2. acquire the data for the area's historic levels of production of each type of rock material (from the Appendix of this report or from DOGAMI);
3. determine the historical long- and short-term growth rates for production, as we do in Chapter 4;
4. analyze the availability of rock supplies to determine if supply constraints will alter future market conditions and preclude the continuation of any of the historical growth rates;
5. project the appropriate historical growth rates to estimate future levels of annual rock production, as we do in Chapter 5;
6. acquire data for the historical values and estimates of the future values of the explanatory variables (real price, population, total employment, and state highway expenditures) for the area;
7. follow the procedures outlined in Chapter 5 to simulate and forecast the area's demand; and
8. compare the forecasts from steps 5 and 7 with anticipated market conditions to determine a reasonable range of estimates for future demand.

By following this procedure, one can develop and evaluate forecasts of demand for virtually any market area in Oregon. For many, perhaps most, of these areas this process will provide the most feasible forecasts of demand given the constraints posed by data and unforeseen events.

CHAPTER 2

METHODOLOGICAL SUMMARY

Abstract

This study's primary objective was to develop the best possible models for explaining and forecasting the demand for Oregon's rock materials, particularly for sand and gravel and for crushed stone. We analyzed two types of models, econometric models and growth-rate models, for the state as a whole, and for four substate areas. The demand in any area for rock resources derives directly from construction, and related projects. Indirectly, the demand stems from the strength of the area's overall economy. The econometric models estimate the direct and indirect influences on demand by examining the relationships between the levels of annual rock production in each area and four explanatory variables: the average price of the rock; the area's population; its total employment; and the level of state and federal expenditures for highway construction in the area. The growth-rate models determine trends in each area's level of production and thereby summarize the effects of all influences on demand.

Production Areas for Rock Materials

A preliminary objective of this project was to identify and analyze the various major characteristics of the different rock-material markets in the state. An obvious, but not straightforward, step toward this objective involved analyzing the spectrum of market activities in the state and delineating the major market areas that encompass these characteristics. We then selected five specific areas, representing a range of market characteristics, for in-depth study.

Fundamentally, a market area for a rock product is the geographic area in which a producer sells the output from a production site (e.g., a gravel pit). Consequently, the number of market areas in the state, using this fundamental definition, would equal the number of rock-material mining sites.

With the vast number of mining sites in the state, this fundamental definition is neither manageable nor analytically useful. To facilitate the analysis of public policies that affect the rock-material industry, it is more meaningful to take a broader perspective. We used a perspective that defines a market area as a geographic area where a group of producers sells a relatively large amount of rock-material to a concentrated, common group of consumers.[2]

Because of the extremely wide distribution of rock supplies throughout the state, supply constraints generally have not been absolute. Thus, supply characteristics, except for their impacts on transportation costs, generally have been secondary to demand characteristics as determinants of a market area's character. Consequently, in delineating existing market areas, we focused first on concentrations of demand.

Except for large construction projects in rural areas, the state's major urban areas comprise the major centers of demand for sand and gravel and for crushed stone. In general, the urban-services boundary around each of these areas encompasses most of the local demand for rock materials and thus, this boundary generally approximates the boundary of the market area quite closely. However, in many instances, major production sites serving the urban area lie nearby but outside the urban-services boundary. Hence, establishing a boundary satisfying the definition of a market area and encompassing both major

[2] A "group" may consist of only one producer or consumer if it sells or buys a sufficiently large volume.

producers and major consumers frequently requires extending beyond the urban-services boundary outward.

Unfortunately, the primary data on rock production (described in detail below) exist only for counties and for the state as a whole. Consequently, rather than focus our analysis directly on delineated urban markets, we were restricted by the data to county-wide approximations.

The data in Table 1 show the mean annual level of production during 1970-1976 of sand and gravel and of crushed stone in each of Oregon's 36 counties. The data illustrate the wide disparity in production levels among the counties, with the greatest production--especially for sand and gravel--occurring in counties containing the largest urban areas. The 17 counties listed in Table 2 form the foundation for identifying the major markets. These counties have the largest levels of production and clearly enclose the vast bulk of the state's production allocable to counties.

In selecting sub-state areas for in-depth analysis, we chose areas that are economically important and representative of the range of major market characteristics. These characteristics include:

1. the general geographical/political/economic region (e.g., Eastern Oregon, Willamette Valley, Coast);
2. the extent to which demand stems from a single industry or from a diverse economy;
3. the size of the urban area;
4. the mode of transportation used to move rock materials from producers to consumers; and
5. the potential for future land use controversy over rock-material production.

Based on these characteristics, we selected four urbanized areas (seven counties) to illustrate markets for sand and gravel and for crushed stone. Clackamas, Columbia, Multnomah, and Washington Counties represent the Portland metropolitan area, Oregon's largest and most diverse urban center. This market area contains considerable potential for future land-use conflict. It shares most of the characteristics exhibited by other urban market areas in the Willamette Valley. However, its size and proximity to the Columbia River give it some unique characteristics, such as the extensive use of barges to transport rock materials long distances. Although Clark County, Washington, is part of the metropolitan economy, we excluded it from the analysis because the study focused on the demand for Oregon's rock resources and because Clark County consumers have demanded and probably will continue to demand little rock from Oregon.

The Medford-Ashland metropolitan area represents smaller, rapidly growing metropolitan areas in the western valleys. It differs from market conditions in the Willamette Valley, in the greater usage of crushed stone, relative to sand and gravel. The data in Table 2 show that, during 1970-1976, Jackson County produced nearly three times as much crushed stone as sand and gravel. The ten counties in the Willamette Valley produced considerable amounts of crushed stone--5,714,000 tons per year, or 43.2 percent of the statewide total allocable to counties. However, they produced more than twice as much sand and gravel, 13,251,000 tons per year, or 70.7 percent of the statewide amount allocable to counties.

Umatilla County is representative of market conditions in Eastern Oregon and in small urban areas (mainly Pendleton and Umatilla). It also has the potential for project-related growth due to the proposed nuclear power generators in a nearby county.

Lincoln County represents coastal-zone markets, which generally have unique supply and demand characteristics. Very little market analysis exists for the coastal markets, primarily because supply patterns are very disorderly. For example, Lincoln County contains little exploitable sand and gravel and must import this commodity from other counties. However, because the markets on the coast are so unusual, it was important to include a representative county in the study.

Besides rock consumption in uses related to urban economic activities, substantial amounts of rock material, especially crushed stone, are used in roads on private and public timberlands. Little is known about the forest-related demand for rock. Differences in ownership, management, geology, and climate for Oregon's timberlands must create diverse

Table 1. Average annual production of sand and gravel and stone, by county: 1970-1976

County	Sand and Gravel (1,000 S/Ton)	Stone (1,000 S/Ton)
Baker	355	673
Benton	333	142
Clackamas	2,611	610
Clatsop	136	359
Columbia	1,161	307
Coos	111	316
Crook	32	66
Curry	95	165
Deschutes	138	18
Douglas	1,347	547
Gilliam	56	53
Grant	96	168
Harney	42	135
Hood River	22	233
Jackson	596	1,670
Jefferson	42	92
Josephine	650	109
Klamath	336	420
Lake	46	200
Lane	2,531	1,287
Lincoln	223	361
Linn	744	413
Malheur	221	193
Marion	1,326	82
Morrow	31	98
Multnomah	3,371	632
Polk	326	161
Sherman	2	205
Tillamook	286	203
Umatilla	233	448
Union	188	257
Wallowa	73	106
Wasco	94	107
Washington	593	1,695
Wheeler	45	45
Yamhill	255	385
Subtotal Allocated to Counties	18,731	13,204
Various Counties[a]	940	3,444
State Total	19,671	16,648

SOURCE: U.S. Bureau of Mines, unpublished annual production statistics, provided by DOGAMI. See page 15 for explanation.

[a]Includes production, primarily by the U.S. Forest Service, which is reported only on a statewide basis, and not allocated to individual counties.

Table 2. Average annual rock resource production in 7 major counties: 1970-1976

County	Sand and Gravel Production (1,000 S/Ton)	Sand and Gravel % of State Total[a]	Stone Production (1,000 S/Ton)	Stone % of State Total[a]
Metropolitan Portland				
Clackamas	2,611	13.9	610	4.6
Columbia	1,161	6.2	307	2.3
Multnomah	3,371	18.0	632	4.8
Washington	593	3.2	1,695	12.8
Total	7,736	41.3	3,244	24.6
Metropolitan Salem				
Marion	1,326	7.1	82	0.6
Polk	326	1.7	161	1.2
Total	1,652	8.8	243	1.8
Albany/ Corvallis				
Linn	744	4.0	413	3.1
Benton	333	1.8	142	1.1
Total	1,077	5.7	555	4.2
Lane	2,531	13.5	1,287	9.7
Jackson	596	3.2	1,670	12.6
Douglas	1,347	7.2	547	4.1
Baker	355	1.9	673	5.1
Klamath	336	1.8	420	3.2
Josephine	650	3.5	109	0.8
Umatilla	233	1.2	448	3.4
Yamhill	255	1.4	385	2.9
Lincoln	233	1.2	361	2.7
Total	17,004	90.8	9,942	75.3

DATA SOURCE: U.S. Bureau of Mines, unpublished annual production statistics, provided by DOGAMI. See page 15 for explanation.

[a]Refers to percent of total statewide production allocated to counties.

patterns in this demand. As a starting point for learning more about the timber-related demand for rock, we used the Willamette National Forest (WNF) as our fifth substate production area, because some data exist for the Forest Service's production of crushed stone in the Forest. Road construction or reconstruction accompanying timber sales to private harvesters accounts for almost all the demand for rock in the WNF. This usage technically does not indicate demand operating through a market. However, this situation characterizes most of the public and private timber-related demand for rock and, thus, the WNF is representative of this segment of the industry.

The six analyses mentioned above (statewide, four urbanized markets, and WNF) examine the demand for sand and gravel and/or crushed stone. In addition to these commodities, producers also mine lightweight aggregates--cinders, pumice and shale. Only scant data exist regarding the markets for these commodities. Consequently, we analyzed only the historical trends in the production levels of the lightweight aggregates.

The Models

In general, changes in the level of demand for rock materials occur because of previous or concurrent changes in characteristics of the overall economy. For example, a growing economy entails land-development activities with land fills, building construction and road construction--all major consumers of rock materials. Thus, one would expect to find relationships between trends in the level of rock production and various indicators of general economic activity.

However, levels of rock production can vary quite erratically over time, especially in nonintegrated local economies or integrated economies of small size. This unpredictability arises from three sources. First, many projects using rock materials are so large they create lumpiness in the demand for rock. Consequently, demand[1] jumps during the project and then falls upon its completion. The pattern of total annual statewide production shown in Figure 1 provides dramatic evidence of lumpy demand stemming from large projects. Several dam construction projects during the mid-1960s, especially the John Day Dam, pushed the production of both sand and gravel and crushed stone rapidly upward, but when the projects finished, production fell sharply. For substate areas, even projects much smaller than dams can be substantial enough to distort local production patterns.

Second, even small local economies are complex. Any given set of economic conditions creates variable impacts on different economic sectors and, hence, variable impacts on the demand for rock materials. For example, the housing construction sector exhibits distinctively different patterns of behavior over time than do the services and manufacturing sectors, creating a mixture of underlying trends within the overall demand for rock materials. As one consequence, these different trends reduce the likelihood of finding systematic, strong relationships between total demand and any single industrial sector.

Third, some of the demand for rock materials comes from construction projects, primarily governmental public works, which occur for reasons bearing little or no relationship to local economic conditions. Instead, the scheduling of these projects depends on such diverse and unpredictable factors as politics and the weather. These projects can constitute major components of the overall demand for rock, especially in rural counties. For example, according to the analysis in Chapter 3, uses related to road construction have accounted for about 50 percent of the statewide demand for sand and gravel and about 75 percent of the statewide stone production. This construction occurs on two types of road, interurban and intraurban. In most cases, decisions to build, expand or rehabilitate the interurban roads in a county rest primarily on statewide, or even national, concerns, rather than on the characteristics of the county's cities and their local

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[1]Technically, the level of rock produced in a year is not the same as the demand for rock. The demand for rock during any given year is not a single number, but a continuous range of values that are price-specific; the quantity which consumers demand is less at higher prices than at lower prices. The amount of rock produced in a given year is the unique level of demand at the prevailing prices during the year plus any adjustments due to changes in inventories.

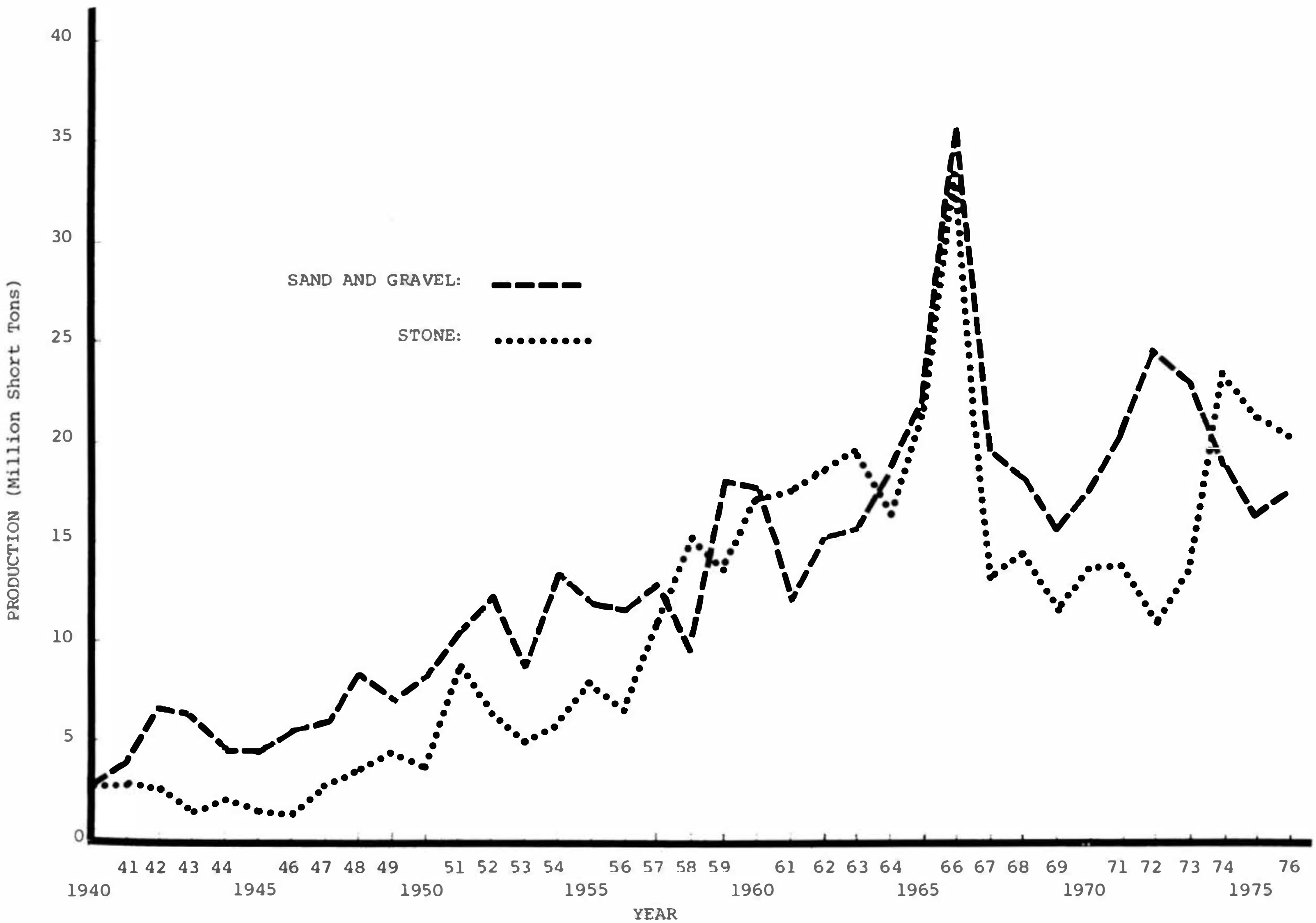

FIGURE 1: Annual Statewide Production of Sand and Gravel and of Crushed Stone, 1940-1976

economies. The development of intraurban roads generally stems more from local conditions and, consequently, parallels the development of local economies to a greater degree. One can expect highly urbanized counties to have a high proportion of intraurban roads. Consequently, the demand for rock stemming from road construction in highly urbanized counties should show a close relationship with the counties' economic conditions. The typically high proportion of interurban roads in rural counties, though, makes the road-related demand for rock in these counties only loosely related to local economic conditions.

Two types of models

Because several forces tend to make demand erratic, and because of substantial inadequacies in the available data, we have developed two types of models. A summary model, called the growth-rate model, describes historic trends in total rock production within a market, but provides little explanation of why the trends have occurred. It summarizes the patterns of growth (positive or negative) in historic production levels and determines the apparent trends (to the extent that trends have occurred) in the mean compound annual growth rate. To apply the growth-rate model as a planning tool, we evaluate the general economic forces behind the trends in production growth and predict which forces and trends likely will continue. We amend the growth rate models, through a simulation procedure, to adjust for changes in general economic forces. Then we forecast future production levels based on the amended growth-rate trends.

The second model, termed the econometric model, is an explanatory model. It first determines the historic relationships between the levels of rock production and specific characteristics of the general economy. Then it predicts future values for these explanatory characteristics and combines these values with the historic relationships to forecast the corresponding future production levels for rock materials.

The combination of the two models yields the most comprehensive analysis of demand possible, given the data limitations described below. Theoretically, if sufficient valid information about production levels and economic conditions were available, the econometric model would identify the economic forces determining demand and would predict future demand. However, for most markets, insufficient data exist. Consequently, we used the econometric model as extensively as the data allowed to explain and forecast demand, but relied on the growth-rate model to give an overview of past and anticipated production trends.

The Growth-Rate Model

When an economy grows, the trends of many economic characteristics, such as an industry's total production, approximate the straightforward trend of compound growth, similar to the growth of monetary principal under a compound rate of interest. In a given year, new activity in a sector, from new firms and the expansion of existing firms, enlarges the sector's total size. In the following year, this expanded base generates even more growth and an even larger base for the succeeding year. Of course, as general economic conditions change, the size of the compound growth rate can change also.

Well-integrated economies typically exhibit fairly smooth growth over time. Although total output may vary cyclically, one firm's successes and failures generally offset the failures and successes of other firms, causing the overall growth rate to vary only moderately from one year to the next.

Smaller, less diverse economies, such as most substate economies in Oregon, generally do not behave nearly so smoothly, because they do not contain enough firms to have an overall balance. Consequently, growth rates in any industry such as the rock-materials industry can vary widely from year to year. Except for the Portland metropolitan area, all of the markets for sand and gravel and for crushed stone which we examined are insufficiently large and diverse to have smooth, balanced growth in production. The small substate markets exhibit large, irregular fluctuations in rock production. Only the Portland area (Clackamas, Columbia, Multnomah and Washington Counties) exhibits smooth growth resulting from its large, integrated, urban economy. Statewide production trends, being composites of all the local trends, lie between the two extremes.

Forecasting future levels of production for substate markets using growth rates is an inexact process. Experience has shown that past trends generally will continue, at least briefly, into the future. Forecasting using past growth rates consequently involves first identifying an area's fundamental, long-range historical trends in demand. We based the long-range trends on the period, 1950-1976. Data for years previous or subsequent to this period either do not exist or they are inappropriate because of the unusual economic perturbations of World War II.

The second step in using growth rates to forecast an area's future levels of demand involves identifying any recent, short-term trends in production which differ from the long-term trends. Growth rates can change because of changes in economic, political and other factors. But, most changes in the rate of growth which persist for more than a few years likely stem from underlying changes in the structure of the area's total economy. In most of the areas we examined, only one noticeable shift in production trends seems to have occurred, in 1964. The 1964-1976 growth rates generally were lower than the growth rates for 1950-1976.

The third step in forecasting involves projecting the long-term and the short-term historical growth rates into the future and interpreting the reasonableness of the resulting forecasts. To judge the forecasts' reasonableness, we examined the extent to which they were consistent with general expectations for the area's total economy. In general, one can expect most of Oregon's local economies to experience overall growth in, say, employment at average annual rates of between 2.5 and 4.5 percent through the end of this century. The rate of growth in the demand for rock materials may differ substantially from these rates over periods of rapid expansion in the local economy, but not indefinitely. For most of the areas we examined, the production data show short- or long-term growth rates, or both, greater than 4.5 percent. To develop growth rates more consistent with expectations for these areas' general economies, we used the econometric models to simulate the growth rates for the component of demand related directly and predictably to general economic conditions. Then, for each commodity in each area, we used the simulated growth rate and the short-term or the long-term rates, or both, in forecasting upper and lower bounds for the future demand in 1985, 1990 and 2030.

The Econometric Model

As the graph (Figure 1) of annual, statewide rock production illustrates, the demand for sand and gravel and for crushed stone fluctuates considerably. Most characteristics of the economy as a whole also fluctuate. This variation is the key for developing econometric models that explain the demand for each type of rock material. By comparing the fluctuations in rock production with the fluctuations in various economic characteristics, we can qualify the extent to which the economic characteristics explain, or determine, rock production.

In developing the econometric models one first must identify all the measurable economic variables which theoretically determine the level of demand for each rock material. These economic variables include, for example, the price of the rock material and the miles of roadway constructed annually.

In the second step, one then compares the rock-materials' historic production levels with the values of the economic variables to determine the extent to which each variable has fluctuated in conjunction with production. Completing this step requires using a computerized technique called multiple regression.[2] The degree of correspondence in the joint variation of production and the economic variables indicates the extent to which each economic variable actually explains the level of rock production. Making these determinations produces the econometric models--mathematical equations which show the relationships between rock production and the explanatory variables.

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[2] For further discussion of multiple regression techniques, see any econometric text, for example, Ralph E. Beals, STATISTICS FOR ECONOMISTS: AN INTRODUCTION (Chicago: Rand McNally & Co., 1972).

The econometric models have the following, generalized form:

$$Y = b_o + b_1X_1 + b_2X_2 + \ldots + b_nX_n;$$

where Y = the dependent variable (the variable to be explained, e.g., annual production of crushed stone); b_o = the intercept term (a constant); X_1, X_2, X_n = explanatory variables; and b_1, b_2, b_n = the coefficients of X_1, X_2, and X_n.

The intercept, b_o, shows the estimated base value of the dependent variable. The value of Y would equal b_o if all the explanatory variables equalled zero. If the explanatory variables were not zero, then the estimated average value of Y would equal the sum of b_o plus the products of each explanatory variable times its coefficient. Each coefficient estimates the average relationship between the respective explanatory variable and the dependent variable. The coefficient shows the amount Y will change, on average, given a one-unit change in the value of the explanatory variable, assuming that all other explanatory variables remain constant.

For each model, we provide the following information: a definition of the dependent and the explanatory variable; the value of the intercept; and the value of the coefficient for each explanatory variable. In addition, we report several statistics describing the model's strength and reliability.

The first of these statistics is the coefficient of determination, commonly called R^2 (R-squared). It measures the proportion of the total historical variation in the dependent variable explained jointly by all the explanatory variables. For example, in a model with stone production as the dependent variable and an R^2 of 0.60, the explanatory variables jointly explain sixty percent of the total variation in the historical production of stone. All other considerations remaining equal, a model which explains a greater proportion of the dependent variable's variation is generally preferred to a model which explains a lesser proportion.

Each model really only estimates the true relationships between the dependent and the explanatory variables. Because the model is an estimate, it is always possible that the explanatory variables really do not explain any of the dependent variable's variation, even though the model has a positive R^2. To indicate the likelihood of this occurrence, we report the F-ratio for each model. By comparing the F-ratio with an F-distribution table (found in most econometrics texts and in compilations of standard statistical tables) one can determine the statistical probability that the model actually explains none of the variation in the dependent variable. Models where this probability is low--that is, models with large F-ratios--are desirable.

Besides uncertainties about the model as a whole, similar uncertainty also exists for the estimated values of the intercept and of the coefficient for each explanatory variable. Multiple regression analyses almost always yield a non-zero value for each of these parameters. However, these values are only estimates of the true values. For each parameter, it is necessary to determine the probability that the true value is zero. Consequently, in addition to reporting the estimated value of the intercept and each coefficient, we also report the t-statistic for each parameter. These statistics, together with a t-distribution table (found in most econometrics texts and in compilations of standard statistical tables), indicate the probability of error in the model's estimated values for the intercept and each coefficient.

To forecast the future demand for rock materials using the econometric models requires first forecasting likely values of the explanatory values, then inserting these values into the model and calculating the consequent value of the dependent variable. Several uncertainties obviously are inherent in such forecasts. One cannot know for certain if relationships based on past data will apply in the future. Also, the forecast future values of the explanatory variables contain some uncertainty. However, if an econometric model has identified strong, systematic relationships between the dependent and explanatory variables, and if drastic changes in these relationships are not foreseen, then the model should yield the most reliable forecasts possible.

The Data

Developing sound growth-rate and econometric models of the demand for rock materials requires accurate data, over a long period of time, for past rock production and for the economic variables which affect demand. Although the analysis and models presented in the subsequent chapters clearly demonstrate the fundamental forces which determine the demand for rock materials, some inadequacies are present in the data upon which the models rest. Interpreting the models requires understanding these inadequacies.

Explanatory variables

Our search for meaningful econometric models revolved around four explanatory variables. They were: the estimated average annual price of each rock commodity in an area; the area's estimated annual population; its estimated annual total employment; and the annual expenditures for road construction and maintenance in the area by the Oregon Department of Transportation (ODOT). These are the only appropriate variables for which sufficient, accurate, historical data are readily available and for which annual updates are available in a timely manner. However, additional explanatory variables should become useful to the analysis as data on their values accrue over the next few years.

Price: Theoretically, a commodity's price and the prices of substitutes should have considerable influence on the demand for the commodity. Price data for rock materials are not directly available. Consequently, we estimated the average annual price of each commodity in each area from data collected by the U.S. Bureau of Mines. The Bureau annually asks producers to report the tonnage and the value of each commodity they either sold or used themselves. The Bureau then summarizes the producers' reports for each county and for the state as a whole. We calculated the average prices by dividing the values by the corresponding tonnage figures.

Because of reporting errors in the data for tonnages and values, the accuracy of the price estimates is uncertain. Many producers, especially in distant years, did not respond to the Bureau's requests for production data. Furthermore, some producers have reported their tonnage figures, but not the value of their production. Nevertheless, calculating prices from the Bureau's data yields the best estimates available. The estimates seem more valid for large metropolitan areas. Also, in recent years, producers have been reporting to the Bureau more comprehensively; a continuation of this trend should improve the accuracy of price calculations in future years.

Each commodity's price includes the effects of inflation, which interferes with the ability of price to explain demand. Accordingly, we converted all prices to "real" prices, that is, prices in constant dollars, by dividing the actual prices by the national wholesale price index (1967 = 100) for sand, gravel and crushed stone as reported by the U.S. Department of Commerce.[3] This index is readily available back to 1956. The real prices give a better indication of the effects of changes in market conditions, and thus give a better measure of how these changes affect demand.

In Chapter 4 we analyze the competitive relationships between the price of sand and gravel and the price of crushed stone. In Chapter 6 we discuss forecasting future levels of the real price for each commodity.

Population: Increases in an area's population should stimulate greater economic activity, more construction, and increased demand for rock materials. Estimates of past total population for the state and for counties came from the U.S. Census for decennial years and from Portland State University's Center for Population Research and Census for the intervening years. Each year the Center publishes estimates of the previous year's population in the state and in local areas, thus making current data readily available. The Center also has published estimates of future population by county, and it updates these forecasts periodically.[4]

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[3]U.S. Department of Commerce, Domestic and International Business Administration/ Bureau of Domestic Commerce, CONSTRUCTION REVIEW (Washington, D.C.: U.S. Government Printing Office, various years).

[4]Center for Population Research and Census, Portland State University, STATE OF OREGON: POPULATION PROJECTIONS FOR OREGON AND ITS COUNTIES 1975-2000 (February, 1976).

Employment: The demand for rock materials in an area should rise or fall along with the level of employment. An increase in employment usually signifies growth in the economy and economic growth usually entails a greater use of rock for construction and related activities. Conversely, when an economy slows down, both the level of employment and the demand for rock should drop.

The State Employment Division estimates annual total employment, by county of residence, through periodic surveys. These data include employees not covered by unemployment insurance. Although estimates of employment by industrial sector perhaps could have refined the econometric models, such data based on consistent definitions do not extend back many years. Consequently, we relied on the data for total employment. We derived our projections of future employment from forecasts prepared in 1976 by The Bonneville Power Administration.[5]

Population and employment are the only appropriate indicators of general economic conditions for which adequate data exist. Each of these variables theoretically should explain a substantial, unique portion of the variation in the demand for rock materials. Demand should increase if an area's population grows, even if its total employment does not, and vice versa. Population and employment, though, also are closely related. This interaction, termed multicollinearity, sometimes reduces the econometric models' ability to isolate each variable's unique impact on demand. But, we retained both variables in the models for all areas because the models for areas where multicollinearity is small confirm their theoretical importance.

Highway expenditures: Road construction and maintenance account for most of the rock consumed in Oregon. Consequently, highway construction and maintenance activities should bear a close positive relationship to the demand for rock materials. As an indicator of the level of these activities, we used ODOT's total direct expenditures (in constant dollars) for road construction and maintenance. The data for this variable for the years 1963-1976 came from the Policy and Program Development Section of ODOT. They include ODOT's direct expenditure of state and federal funds on state and federal highways. They do not include funds ODOT passed through to cities and counties.

To rid the expenditure data of the effects of inflation, we adjusted the data to constant dollars. We used a road-construction cost index (1967 = 100) provided by ODOT's Policy and Program Development Section.

The Section also provided forecasts of future expenditures, by county, for 1979-1984.[6] We extended these forecasts to estimate the levels of expenditures in 1985 and 1990. For our lower-bound estimates, we extended the Transportation Commission's average annual expenditures for 1979-1984 under the "Basic Program." For our upper-bound estimates, we extended the average expenditures under the "Program with Additional Revenues."

Other explanatory variables: Sufficient, appropriate data for other explanatory variables do not exist. One potentially useful variable is the level of personal income. We hypothesize that the demand for rock materials in a market depends partially on the level of affluence (income) in the market. A limited amount of data on income do exist, and as we show in Chapter 4, they support this hypothesis, especially in Jackson and Umatilla Counties. The data are for the total, adjusted gross income, by county, as published by the Oregon Department of Revenue.[7] Unfortunately, the data exist only for the years 1969-1976, an insufficient amount of time for this variable to contribute fully to the analysis. However, we have reported a limited analysis because this variable may become an important explanatory variable in the future as the Department extends the series.

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[5] U.S. Department of the Interior, Bonneville Power Administration, OREGON POPULATION, EMPLOYMENT AND HOUSING UNITS PROJECTED TO 1995 (Portland, Oregon: 1976).

[6] Oregon Transportation Commission, HIGHWAY IMPROVEMENT PROGRAM: 1979-1984 (Salem: Oregon Department of Transportation, 1978).

[7] Oregon Department of Revenue, PERSONAL INCOME TAX ANALYSIS, various years.

The demand for rock materials

Data directly measuring the demand for rock materials do not exist, so we relied on data for the levels of production. The level of production for a year approximates the level of demand, at the prevailing prices, except for any changes in producers' or consumers' inventories. Inventories change only slightly from year to year, except when they build up in advance of very large construction projects such as major dams. Consequently, data for production levels provide a reasonable estimate for the levels of demand.

Production data: The most comprehensive set of production data is the Bureau of Mines' estimates of annual production, by county, from 1940 to 1976. The Bureau acquires these statistics annually by mailing a questionnaire to producers. This procedure creates two gaps in the resulting data. First, the Bureau has requested data on a site-specific basis and the list of specific sites, especially in earlier years, has been incomplete. Second, producers have complied with the Bureau's questionnaire on a voluntary basis, and their compliance has been neither comprehensive nor consistent. Thus, the Bureau's data unavoidably underestimate actual production.

Errors of measurement: We attempted to determine the extent of the error in the Bureau's data by examining three other sources of production data, but these data gave only a rough notion of the size of the error. We first asked producers in the seven counties we studied to complete a mail-questionnaire and report their past levels of production. Despite our efforts and the efforts of industry representatives, however, too few producers responded to yield meaningful results. We next looked at the data DOGAMI collects under the provisions of the 1971 Mined Land Reclamation Act. These data roughly indicate the amount of rock sold or used by the producers covered by the Act, and in future years they may provide an independent assessment of the Bureau's data. At present, however, they are insufficient. Finally, we relied on the results of DOGAMI's surveys of mining sites. For mining sites in the four Portland-area counties, Curry County and for Benton County, DOGAMI has compared the total reported production with the size of the excavation.[8] The results indicate that the Bureau's data underestimate total production by about 20 percent.

Although this figure gives the rough order of magnitude of the error, it does not provide some detail which would be very useful (for example, the extent to which the error applies to different counties; the extent to which the degree of error is consistent from one year to the next; and whether the error has been increasing, decreasing, or remaining steady).

These aspects of the error in the Bureau's data are important to any attempts to use them for understanding and forecasting the demand for rock products. We suspect the errors are greater in rural counties, fluctuating from year to year but generally decreasing recently. These characteristics interfere with the performance of both the growth-rate and the econometric models. The decreasing error in measurement in recent years causes production to appear to have grown faster than it actually has. The large, very erratic variation in reported production for the rural counties interferes substantially with the ability of the econometric models to explain the variation in actual production.

Nevertheless, the Bureau's data are the best available, and in some areas, especially the Portland area, they are quite good. Through the use of simulations and other techniques, they yield reasonable forecasts of demand. Producers likely will improve their reports to the Bureau in future years, and as this occurs, the data will provide even better results.

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[8] Gray, J. J., G. R. Allen, and G. S. Mack, ROCK MATERIAL RESOURCES OF CLACKAMAS, COLUMBIA, MULTNOMAH, AND WASHINGTON COUNTIES, OREGON, Special Paper 3, in cooperation with the Columbia Region Association of Governments, 1979; Ramp, L., Schlicker, H. G., and Gray, J. J., GEOLOGY, MINERAL RESOURCES, AND ROCK MATERIAL OF CURRY COUNTY, OREGON, Bulletin 93, 1977; and Schlicker, H. G., Gray, J. J., and Bela, J. L. ROCK MATERIAL RESOURCES OF BENTON COUNTY, OREGON, Short Paper 27, in cooperation with Benton County Board of County Commissioners, 1979, (Portland: Oregon Department of Geology and Mineral Industries).

CHAPTER 3

THE STATEWIDE ANALYSIS

Abstract

There is no statewide market for rock materials. Rather, there are many diverse markets throughout the state and the statewide data for rock production constitute a weighted average of the characteristics of all these markets. Consequently, analyzing the demand for rock materials from the statewide perspective summarizes and offers insight to all the substate markets. Road construction has been the largest single use of sand and gravel and of crushed stone. Although the current price for each commodity has increased over time, real prices have been erratic and they generally have decreased since 1965. Sand and gravel have exhibited lower prices and higher levels of production than crushed stone. However, these differences have been decreasing and the production of crushed stone has grown much more rapidly than the production of sand and gravel. The econometric models for the state as a whole show promise, but currently the erratic nature of demand in non-metropolitan areas and problems with the existing data confound the models. Better data over the coming years should improve the models' performance.

Overview of Statewide Characteristics

Production characteristics

Although the data in Figure 1 show considerable fluctuation in production over the period 1940-1976, a long-term trend of rising production emerges for each category of resource. With two exceptions, these trends apparently stem directly from the state's general economic and population growth rather than from any particular governmental or industrial activity. The two exceptions are production arising from the construction of several major dams and from the construction and maintenance of roads in the state's national forests.

The construction of Green Peter, Foster and John Day dams, especially the latter, caused the unusually large bulge in the production of sand and gravel and of crushed stone from 1960 through 1966. Since this production bears only distant, indirect relationships with the postulated explanatory variables for demand, we removed it from the statewide production statistics. Using estimates provided by DOGAMI and the U.S. Army Corps of Engineers, we adjusted the statewide statistics by subtracting the amount and the value of the sand and gravel and of the crushed stone used in these dam projects.

The Bureau of Mines compiles most of its production data on a countywide basis. The U.S. Forest Service, however, reports the amount of rock extracted from the mining sites within the national forests on a statewide basis rather than by county. These amounts account for virtually all the production shown for the Various Counties category in Table 1. Almost all the rock from the national forests, mostly crushed stone, is used in constructing the roads that support timber-harvest activities. Harvest levels in the national forests have derived more from national economic conditions and from declining supplies on other timberlands than from state and local economic conditions. Consequently, the production levels of rock in the Various Counties category have been quite unrelated to the economic variables we used to explain production, and we subtracted this category from the statewide totals for all years.

The adjustments for the dams and the national forests yield the production patterns illustrated in Figure 2. For the remainder of the report, the terms statewide production and demand will refer to the adjusted statistics.

In general, the production of sand and gravel has exceeded and has been less erratic than the production of crushed stone. In addition, price, population, employment and

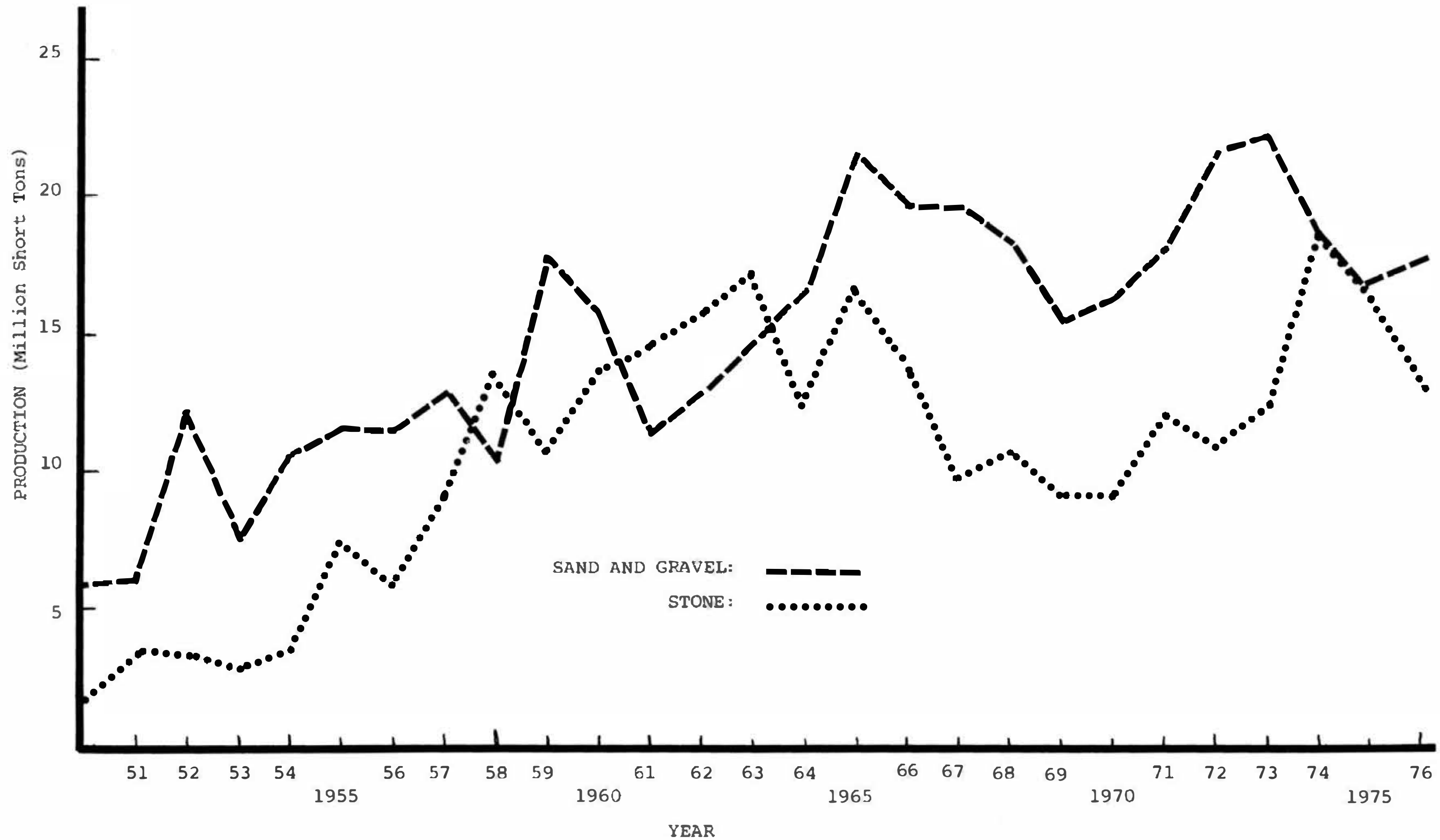

FIGURE 2: Adjusted Total Statewide Production of Sand and Gravel and of Crushed Stone

expenditures on highways--the indicators of general economic conditions--perform much better as explanatory variables for sand and gravel production than for crushed stone production.

Not incidentally, the production of sand and gravel has been more concentrated than stone production in the counties which are highly urbanized and have widely integrated economies. The data in Table 2 show Clackamas, Columbia, Multnomah, Washington, Marion, Polk, Yamhill, Linn, Benton, and Lane Counties--the Willamette Valley--together account for 70.7 percent of Oregon's annual average sand and gravel production between 1970 and 1976. The same counties account for only 43.2 percent of the state's stone production. The Willamette Valley, of course, also contains the bulk of Oregon's population, employment, and urbanized area. By all indications, the demand for rock materials is more regular and more closely related to economic variables in large, diverse, urban areas.

Characteristics of use

Road construction has been the largest, single use of the state's sand and gravel and stone. Tables 3 and 4 show the rough distribution by use of the state's annual consumption of sand and gravel and of stone, respectively, from 1960 through 1974. The data come from publications of the U.S. Bureau of Mines and, unfortunately, the classifications of consumption are neither precise nor consistent. The data in Table 3 show that for the years between 1960 and 1973, Road Material or Paving averaged about 58 percent of the state's total use of sand and gravel. The more detailed data for 1974 show that more than half of the road-related use of sand and gravel was for roadbase and subbase. The only other consistently major use of sand and gravel has been the construction of concrete buildings and products. Throughout all the years for which data are shown, usage for buildings has averaged about one-quarter of the total.

The data in Table 4 show similar, but more exaggerated, consumption patterns for crushed stone. For the years 1971-1974, the data clearly identify the extent to which stone has been used for road construction and maintenance. In previous years the single category, Concrete & Roadstone, contains all road-related consumption. However, virtually all the consumption in this category probably was road-related since crushed stone generally is not preferred for making concrete. Thus, according to the data for this category during 1960-1968 and the disaggregated data for 1971-1974, road construction and maintenance used about 71 percent, on average, of total statewide stone production. The second largest general use of stone has been for riprap and fill.

Prices

The prices of sand and gravel and of stone in Oregon generally have increased. However, price inflation accounts for much of the increasing trend. When the effects of inflation are removed through the use of a wholesale price index, the resulting real prices vary considerably from year-to-year, but exhibit no strong long-term trends.

Nominal (or unadjusted) prices: Figure 3 shows the estimated, mean annual prices (unadjusted for inflation) for sand and gravel and for crushed stone from 1950 to 1976. Throughout this period, the estimated price of crushed stone generally exceeded the estimated price of sand and gravel. The price of sand and gravel was larger only in 1964 and 1965, and we could discern no reliable justification for the reversal of the general pattern during these two years. Although the price of each commodity varies, their overall trends have been upward, especially in the latter years.

Real prices: The graphs in Figure 4 of the real prices, look quite different, however. Removing the effects of inflation seems to take away the upward movement present in actual prices. Indeed, since the mid-1960s, the real price of each commodity, though very erratic, generally has declined.

Figure 4 also compares the estimated real prices in Oregon to the estimated average real prices for the entire U.S. The national prices clearly behaved much differently, declining steadily until about 1970, then moving upward. The U.S. price for crushed stone has exceeded the price of sand and gravel throughout the period.

Fluctuation in prices: As the graphs in Figures 3 and 4 illustrate, the statewide

Table 3. Sand and gravel sold or used statewide by producers, by class of operations or use[a]
(thousand short tons and percent of total)

Use	1960 %	1961 %	1962 %	1963 %	1964 %	1965 %	1966 %	1967 %	1968 %	1969 %
Building	6,047(34)	2,760(22)	2,992(20)	3,371(21)	3,478(19)	3,761(17)	3,174 (9)	3,862(20)	4,663(26)	4,658(30)
Road Material	8,434(48)	8,811(72)	9,989(67)	11,199(71)	13,502(74)	16,118(74)	12,757(36)	11,675(59)	9,203(50)	8,785(56)
Fill	--	--	--	--	--	1,027 (5)	18,476(52)	965 (5)	1,303 (7)	1,110 (7)
Railroad Ballast	--	--	--	51(--)	117 (1)	80(--)	145(--)	--	--	--
Other Uses[b]	3,191(18)	727 (6)	1,888(13)	1,095 (7)	1,156 (6)	814 (4)	775 (2)	3,128(16)	3,091(17)	1,187 (8)
Total[c]	17,673	12,299	14,869	15,715	18,253	21,800	35,327	19,630	18,260	15,740

Use	1970 %	1971 %	1972 %	1973 %
Building	4,319(25)	6,938(34)	8,612(35)	6,089(27)
Paving	10,765(61)	10,726(53)	12,520(51)	11,607(51)
Fill	1,286 (7)	1,796 (9)	2,393(10)	3,223(14)
Railroad Ballast	--	--	159 (1)	17(--)
Miscellaneous	90 (1)	246 (1)	337 (1)	707 (3)
Other Uses	1,121 (6)	525 (3)	417 (2)	1,158 (5)
Total[c]	17,581	20,231	24,478	22,801

Use	1974	%
Construction Aggregate		
Nonresident & Resident Const.	3,410	(18)
Highway & Bridge Const.	1,251	(7)
Other (Dams, Airports, etc.)	313	(2)
Concrete Products (Blocks, etc.)	813	(4)
Bituminous Paving	3,683	(20)
Roadbase and Subbase	5,317	(29)
Unprocessed Aggregate	2,497	(14)
Fill	917	(5)
Other Uses	357	(2)
Total[c]	18,558	

DATA SOURCE: U.S. Bureau of Mines, THE MINERAL INDUSTRIES OF OREGON, various years.

[a]Includes commercial and publicly funded projects.

[b]Includes miscellaneous uses and, in some years, uses for fill and/or railroad ballast.

[c]Data may not add to equal the totals due to rounding.

Table 4. Stone sold or used statewide by producers, by use[a] (thousand short tons and percent of total)

Use	1960 %	1961 %	1962 %	1963 %	1964 %	1965 %	1966 %	1967 %	1968 %
Dimension Stone	4(--)	3(--)	2(--)	3(--)	1(--)	--	--	--	--
Concrete & Roadstone	12,102(72)	11,183(64)	9,403(52)	13,656(69)	11,882(74)	13,293(62)	14,277(43)	10,992(83)	12,434(87)
Railroad Ballast	309 (2)	--	--	446 (2)	220 (1)	263 (1)	244 (1)	237 (2)	174 (1)
Riprap	2,879(17)	4,717(27)	7,737(42)	4,661(24)	2,550(16)	2,364(11)	1,380 (4)	1,234 (9)	813 (6)
Other Uses[b]	1,619(10)	1,552 (9)	1,116 (6)	927 (5)	1,527 (9)	5,292(25)	17,387(52)	737 (6)	891 (6)
Total[c]	16,912	17,455	18,258	19,692	16,120	21,212	33,288	13,201	14,312

Use	1969 %	1970 %	1971 %	1972 %	1973 %	1974 %
Bituminous Aggregate	500 (4)	1,290(10)	1,185 (9)	1,273(12)	1,406(10)	1,554 (7)
Concrete Aggregate	--	688 (5)	1,658(12)	--	675 (5)	1,395 (6)
Dense Graded Road Base Stone	2,625(23)	3,794(28)	4,529(33)	3,328(30)	4,311(32)	7,586(32)
Macadam Aggregate	366 (3)	381 (3)	439 (3)	57 (1)	369 (3)	288 (1)
Surface Treatment Aggregate	3,597(31)	3,820(28)	1,402(10)	1,350(12)	1,221 (9)	1,152 (5)
Unspecified Aggregate & Roadstone	2,569(22)	2,472(18)	2,992(22)	2,015(18)	2,585(19)	4,727(20)
Fill	26(--)	23(--)	94 (1)	120 (1)	363 (3)	62(--)
Railroad Ballast	25(--)	10(--)	375 (3)	432 (4)	525 (4)	820 (4)
Riprap & Jetty Stone	574 (5)	307 (2)	500 (4)	973 (9)	1,037 (8)	4,805(21)
Other Uses[b]	1,380(12)	655 (5)	621 (5)	1,367(13)	918 (7)	692 (4)
Total[c]	11,662	13,439	13,794	10,915	13,410	23,351

DATA SOURCE: U.S. Bureau of Mines, THE MINERAL INDUSTRIES OF OREGON, various years.

[a]Includes commercial and publicly funded projects.

[b]Miscellaneous uses, including dam embankment, and industrial stone.

[c]Data may not add to the totals due to rounding.

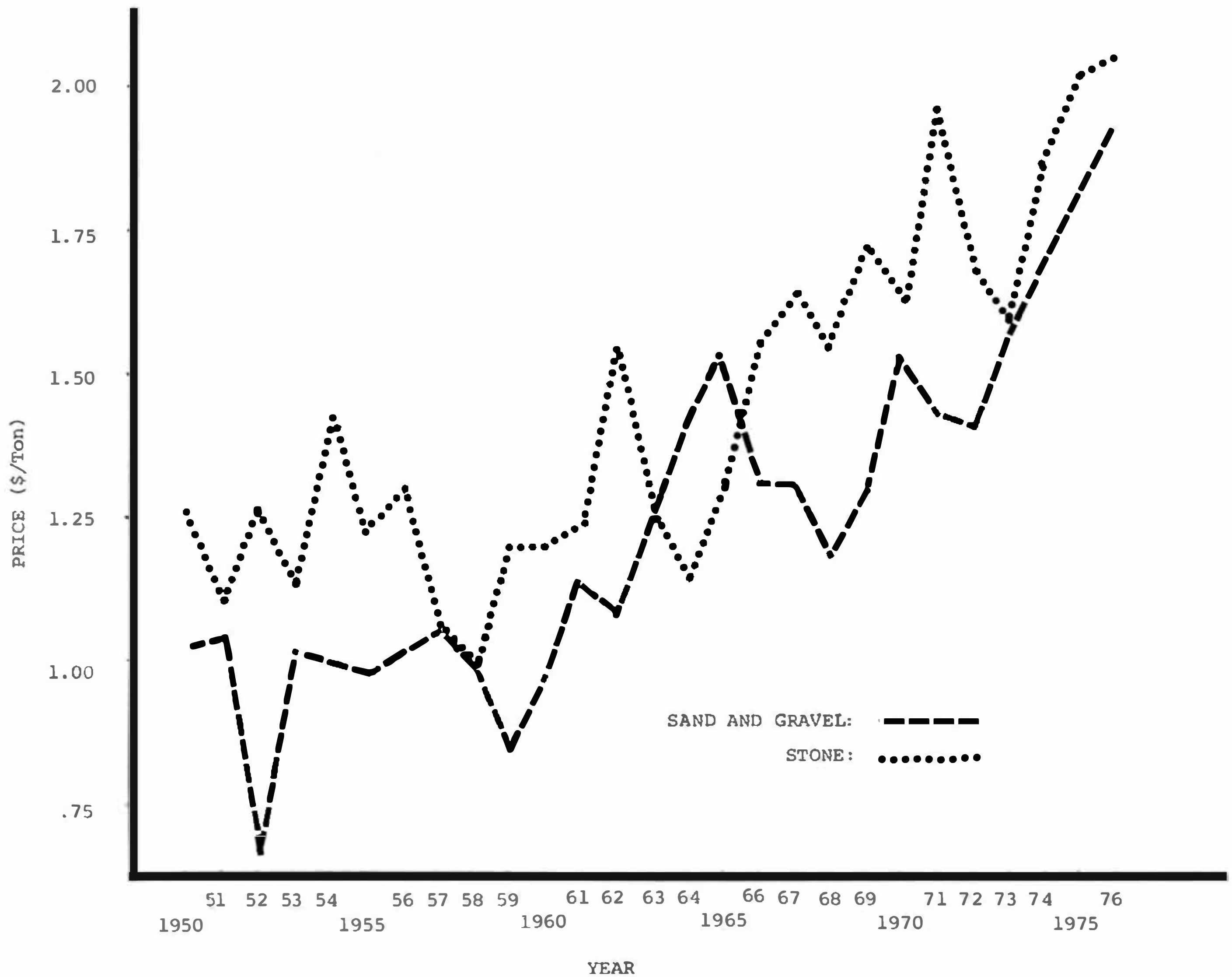

FIGURE 3: Average Annual Current Statewide Prices for Sand and Gravel and for Crushed Stone

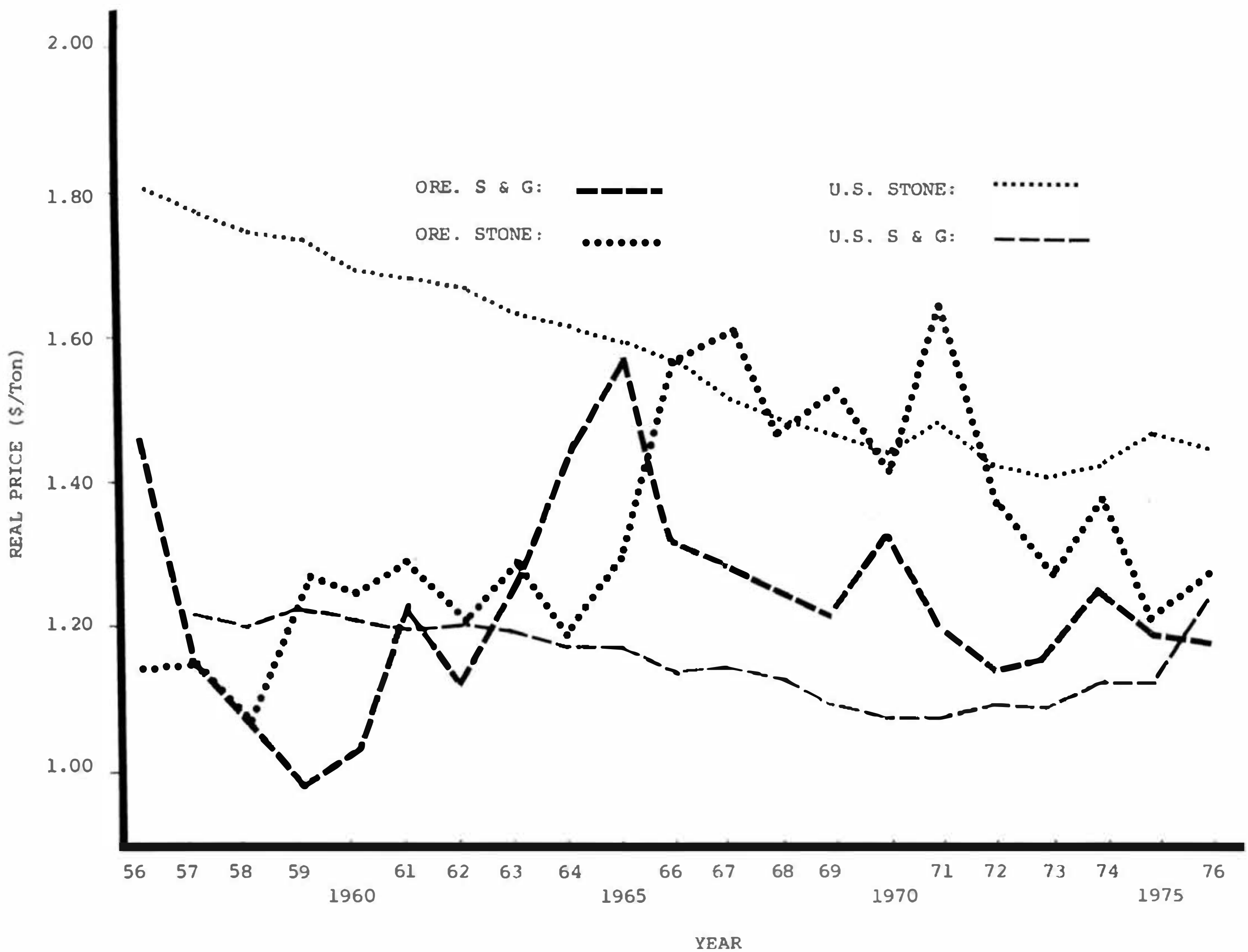

FIGURE 4: Average Annual Statewide and National Prices, adjusted for inflation (1967=100), for Sand and Gravel and for Crushed Stone, 1956-1976

prices of sand and gravel and of crushed stone have fluctuated quite erratically. The extent to which the fluctuation reflects actual market conditions instead of errors in the Bureau of Mines' process for collecting data is unknown. We believe both factors contribute substantially.

We calculated the mean annual price of each type of commodity for each year by dividing the amount of production reported to the Bureau into the value of the production. The reported data for the value and level of production seem to be less consistent from year-to-year for rural counties and more consistent for urbanized counties. Similarly, the greatest fluctuations in prices occur in the rural counties. Reporting errors certainly have caused part of the fluctuation. Rural counties generally contain fewer producers than urbanized counties and non- or mis-reporting by a few producers consequently could have a greater effect on the Bureau's production data for the rural counties.

However, part of the fluctuation also may stem from lumpiness in the demand for rock materials. Most demand comes from construction-related projects of considerable size. In large urban areas and integrated economies, as one project finishes another begins, thus producing a fairly consistent total demand. In smaller economies, though, projects occur less frequently. The resulting irregular demand could create variation in the price estimates either by periodically straining productive capacity or by requiring irregular production of rock materials having different prices.

Whatever the cause of the greater fluctuation in rural prices, the statewide prices constitute a weighted average of the prices calculated for all areas from the Bureau's data. Consequently, the fluctuations also show up in the statewide data.

Components of price: The prices derived from the Bureau of Mines' data constitute only part of the total delivered cost of rock products. The total delivered price is the sum of the value of the rock at the point of production plus the transportation costs for delivering the material to the point of consumption. The prices derived from the Bureau's data represent essentially the productionvalue of the rock. The Bureau asks producers to report only production value, but evidence suggests they also include some--less than 10 percent--of their transportation costs.[9]

Ideally, an analysis of demand should consider the total delivered price of rock materials, since this is the price facing consumers. However, if the relative sizes of the two components of total cost remain fairly constant, then one can use the production prices derived from the Bureau's data as analytic proxies for total prices. In 1968 the Bureau estimated that transportation costs constituted about 45 percent of the delivered price of rock materials in the Pacific Northwest.[10] Producers informally estimate that transportation costs average between one-third and one-half of the total price currently. Apparently, transportation costs, on average, have remained a fairly constant proportion of total cost.

However, as producers deplete resource deposits near centers of demand, they must relocate to more distant deposits. Such relocations likely will occur more frequently in the future than they have in the past. In some places, these moves will increase transportation costs dramatically. To forecast demand in these places, analysts should adjust upward the anticipated prices corresponding to the Bureau's data, to reflect anticipated market prices more accurately.

Growth Rates

On average, the statewide demand for crushed stone grew more rapidly during the period, 1950-1976, than did the demand for sand and gravel. As the data in Table 5 show, stone production grew an estimated mean annual rate of 5.2 percent, while the production of sand and gravel grew about 3.7 percent per year. The total demand for all rock

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[9] Jerry J. Gray, N. S. Petersen, and G. A. Kingston, MINERAL TRANSPORTATION COSTS IN THE PACIFIC NORTHWEST, Bureau of Mines Information Circular 8381 (Washington, D.C.: U.S. Government Printing Office, 1968), pp. 14-17.

[10] Ibid., pp. 16-17.

Table 5. Estimated historical statewide growth rates

	Mean Annual Growth Rate		
Time Period	Sand & Gravel	Crushed Stone	All Rock
1950 - 1976	3.74% (0.0001)[a]	5.24% (0.0001)[a]	4.18% (0.0001)[a]
1964 - 1976	-0.15% (0.8742)[a]	1.34% (0.4526)[a]	0.53% (0.6022)[a]
1967 - 1976	0.17% (0.9049)[a]	6.08% (0.0080)[a]	1.53% (0.2095)[a]

[a]Probability that, within the production data, the mean growth rate actually equals zero.

(sand and gravel plus crushed stone) grew at an intermediate rate, 4.18 percent, compounded annually.

The growth rates in Table 5 are only estimates, based on the Bureau's data, of the true rates of growth in demand. There is some probability that the estimated rate incorrectly measures the true rate. One possible source of this error is that the variation in the data, if severe, can cloud the actual rate and produce an incorrect estimate. In Table 5 we report a common indicator of the likelihood of this type of error: the probability that the true growth rate within the data could equal zero. A high probability means the data contain much variation and the estimate is unreliable; a low probability shows little variation and high reliability.

Another possible source of error is that the reporting or recording of the data changed systematically over time. If each year the degree of underreporting by producers has diminished, then the Bureau's data will reflect not only the actual growth in demand, but also the increasing completeness of the data. Measuring the extent of this type of error is not possible without a statistically reliable survey of producers' past production.

In most instances, the growth rates for production in the substate areas seemed to change about 1964, and therefore we examined the 1964-1976 statewide rates. Both commodities show slower rates of growth for this period than for 1950-1976; sand and gravel even shows a negative rate. However, the tests of the models, especially for sand and gravel, indicate rather high probabilities that the true rates equal zero. Thus, we can be quite certain that the growth rates for 1964-1976 are lower than for 1950-1976, but we can't measure them precisely. The situation changes somewhat for the 1967-1976 period. Crushed stone had a mean growth rate of 6.08 percent during this period, higher than the long-term rate and with a high level of statistical reliability. The growth rate for sand and gravel, however, effectively equalled zero.

Econometric Models of Statewide Demand

The econometric models offer an overview of the various markets in Oregon for sand and gravel and for crushed stone. They reveal the major characteristics of the historic demand statewide for these rock materials, and they provide the basis for a more detailed examination of these characteristics in Chapter 4. However, some difficulties arise in the statewide models, apparently caused by the erratic production data from the rural counties. These difficulties reduce the models' applicability for forecasting changes in demand over long time periods.

Models for sand and gravel

The econometric models of the statewide demand for sand and gravel confirm the importance of the influence which price, population, employment and highway expenditures have on the demand for rock materials. These variables jointly explain most of the historic variation in annual production. But, some characteristics of the state's local markets and some statistical problems in the data prevent the models from specifying each explanatory variable's underlying, long-term effect on demand.

The models: Table 6 summarizes five econometric models of the annual statewide production of sand and gravel. The explanatory variables in each model are:

Model 1: real price, population, employment, state highway expenditures;
Model 2: real price, population, employment;
Model 3: real price, population;
Model 4: real price, employment; and
Model 5: real income.

The data in the table show the years for which each model applies, the value of the intercept (b_o), the value of the coefficient (b_{1-4}) for each explanatory variable, and the model's coefficient of determination (R^2). As an indicator of each model's statistical reliability, the table also lists the probability that there really is no relationship in the data between the dependent variable and the explanatory variables.

The Appendix presents additional information about these five models and discusses other models which we developed but decided were not important to the central arguments of this study.

Model 1: Model 1 is the theoretically preferred model because it contains all four explanatory variables. Thus, it should identify the independent relationship between each explanatory variable and the dependent variable. However, data for state highway expenditures, the fourth explanatory variable in Model 1, extend back only to 1963, thus constraining the model's ability to explain production. Consequently, for a longer term perspective it is important to begin by considering all the models jointly.

For the statewide production of sand and gravel, Model 1 performs reasonably well by some measures, but less well by others. The model explains 75 percent of the variation in the data for historical, annual production. This figure is quite respectable. However, the intercept term and the coefficients for price and population have signs different than expected. Each of these results affects the model's usefulness.

The intercept: At first glance, the model's intercept indicates that the Bureau's data for the statewide production of sand and gravel would be -8,282,846 tons if the values of all the explanatory variables equalled zero. Of course, such an implication is meaningless. Thus, the negative intercept indicates that the model is not valid when the explanatory variables have low values. However, it does not impair the model's validity when the explanatory variables have values similar to those experienced during 1963-1976.

Price and population: The coefficients for price and population present more difficult problems for interpreting the model. The coefficient for price implies that, during 1963-1976, the quantity of sand and gravel demanded would have risen by over 4 million tons if the real price had increased by $1.00 per ton. The coefficient for population shows that the quantity demanded would have fallen by about 12 tons, if the other variables remained unchanged, for each increase of one person in the state's population. Clearly, these coefficients are inconsistent with general notions of how price and population affect demand.

Effect of erratic demand: There are three potential explanations for the wrong-signed estimates of the coefficients. One is the erratic nature of the production data, especially for rural counties. We suspect the erratic data contribute to the incorrect coefficients either simply by obscuring the true relationships between production and the variables or by containing some unknown systematic relationship between errors in the data and the explanatory variables.

Price and demand: A second possible explanation, applying directly to the coefficient for price, stems from producers' general inability to respond quickly to changes in demand. Typically, producers maintain enough productive capacity to accommodate the

Table 6. Statewide econometric models of annual production of sand and gravel[a]

Model No.	Dependent Variable[c]	Intercept	Coefficients of Explanatory Variables					R^2 (Prob.)[d]
			Price	Population	Employment	Highway Expenditures	Income	
(1)	Production (1963-1976)	-8,282,846	4,146,131	-11.99	45.39	0.086	--	0.75 (.0090)
(2)	Production (1956-1976)	3,174,190	4,328,572	-17.44	54.58	--	--	0.55 (.0031)
(3)	Production (1956-1966)	-8,973,755	3,856,321	10.52	--	--	--	0.44 (.0054)
(4)	Production (1956-1966)	-5,240,266	3,805,631	--	21.95	--	--	0.51 (.0017)
(5)	Production (1969-1976)	15,670,553	--	--	--	--	--	0.23 (.2326)

[a] For a complete description of the models, including additional test statistics, see the Appendix.

[b] See text for the definition of the variables.

[c] Production is measured in short tons per year.

[d] Probability that the model actually explains none of the variation in the data for the dependent variable.

average level of demand plus a small increment. In small local markets, though, demand can surge dramatically and exceed producers' capacities. When producers respond by raising their prices, they create a positive relationship between price and demand. This relationship applies only as a short-term phenomenon, however. Over time periods long enough for producers to adjust their capacities, the normal, negative relationship applies.

The Bureau of Mines' data for sand and gravel (and for crushed stone) apparently contain the short-term, positive relationship between price and production. The analysis in Chapter 4 shows the effect is more prevalent in the data for the rural counties. In an attempt to avoid the phenomenon's presence in the annual statewide data, we studied the relationships between production and the three-year, moving-average values of the explanatory variables. The results of this procedure, illustrated in the Appendix, generally were unsuccessful. (They also were unsuccessful for the rural substate areas.)

Multicollinearity: The third possible explanation stems from complex relationships among the explanatory variables themselves. The correlation statistics in the Appendix show that the data for price, population, and employment are closely related. These relationships, called multicollinearity, are statistical, as opposed to causative, and they reduce the model's ability to estimate the actual relationships between the explanatory variables and demand.

Population and employment are closely and directly related. Factors such as increasing participation in the labor force, though, make the relationship complex. In addition, the short-term positive response of price to increases in demand tend to confuse the relationships between production and the three explanatory variables even further.

Comparing Model 1 with Models 2, 3, and 4 offers a better understanding of multicollinearity. Model 2 differs from Model 1 by excluding highway expenditures as an explanatory variable and extending the time period of observation. Although the magnitudes of the coefficients for the remaining variables are a little different, their signs are unchanged. However, the coefficients change considerably in Models 3 and 4. In Model 3, with only price and population as explanatory variables, population has a positive coefficient. In Model 4, with only price and employment as explanatory variables, the coefficient for employment is much smaller than in Models 1 and 2. Clearly, the data for population and employment are related in some complex way with production. As a consequence, when both explanatory variables are included in the model the complex relationship forces the employment coefficient to increase and gives population a negative coefficient.

Multicollinearity among the explanatory variables diminishes the utility of Model 1 and the other models somewhat, but, by itself, it does not render them invalid. Rather, it makes identifying production's unique relationship with population or with employment impossible. Nevertheless, in most instances, the models identify production's joint relationship with the two variables. These distinctions are important because the study's basic focus was to quantify the joint theoretical effects of several explanatory variables on the demand for each category of rock materials. To this end, the compensating effects of a negative coefficient for population and an inflated positive coefficient for employment are not impediments.

Using Model 1: The problems with the coefficients interfere primarily with the model's usefulness for forecasting future levels of demand. By its very nature, and because of its relatively high R^2 (0.75), Model 1 provides a reasonably good explanation of the interactions between the explanatory variables and annual changes in demand. However, the effects of erratic demand, the short-term relationship of price and production, and of multicollinearity reduce the model's validity for predicting changes in demand over several years. In Chapter 5, on forecasting demand, we illustrate how to compensate for these problems.

Production and income: We explained earlier that it would have been desirable to use an indicator of income as an additional explanatory variable, but no existing data extend back far enough to be truly useful. However, we used the available 1969-1976 data for aggregate adjusted gross income to determine if sufficient meaningful relationships exist between this variable and production to warrant future analysis after more data are produced. For Jackson and Umatilla Counties we found some very significant relationships, and we report them in Chapter 4. The relationships within the statewide data are not as noticeable. Nevertheless, we include Model 5 in Table 6 for comparison.

Interpreting the coefficients: One should be certain to interpret cautiously the coefficients of the explanatory variables. For example, in Model 3, the coefficient for population suggests that, during 1963-1976, as Oregon's population increased by one person, the statewide production of sand and gravel--as measured by the Bureau's data--increased on average 10.52 tons, if the other explanatory variables remained constant. The coefficient does not imply an average statewide production per person of 10.52 tons. The coefficient only indicates how much production is associated with just changes in population, independent of changes in other variables.

Models for crushed stone

In general, the statewide econometric models for crushed stone, presented in Table 7, resemble the models for sand and gravel. However, because the demand for stone is less regular and more erratic than the demand for sand and gravel, the models explain less of the annual variation in the demand for stone. Nevertheless, the models provide useful insights into Oregon's markets for stone.

The models: Model 1 has a positive intercept and correct signs on the coefficients for price and population, but incorrect signs for employment and highway expenditures. According to the coefficient of determination (R^2), the model explains only 25 percent of the variation in production between 1963 and 1976. The probability that the model, in fact, explains none of the variation is 0.59.

Model 2, without highway expenditures but with more years of observation, explains a greater percentage of the variation in production. However, it includes a negative coefficient for population. The other models, including Model 5 with income as the only explanatory variable, have very little explanatory power.

The models' characteristics indicate that the problems present in the data for sand and gravel also exist in the data for crushed stone. Their effects are more severe with the models for crushed stone, however, primarily because the demand for crushed stone varies more erratically than the demand for sand and gravel. Most crushed stone is produced and used outside the Willamette Valley in areas where markets typically are too small to provide smooth, balanced demand. Consequently, the statewide demand for stone bears weaker relationships with the explanatory variables than does the demand for sand and gravel.

Using the models: Although the models directly explain only little of the variation in demand for crushed stone, they indirectly reveal important characteristics of Oregon's markets for stone. On a year-to-year basis, the erratic variation in the demand for stone obscures the influence of the general economic characteristics (i.e., the underlying determinants of demand). Planners and other interested persons should anticipate unpredictable surges in the demand for stone, rather than expect smooth growth patterns, when planning for the future.

Total Statewide Demand for Rock Materials

For most uses, consumers of rock materials prefer either sand and gravel or crushed stone. These preferences come from differences between the two commodities either in their physical properties or in their price. These strong preferences prevail in most of Oregon and, consequently, we analyzed the demand for the two commodities separately. Some areas, though, do not contain readily available supplies of one or the other commodity. Additional areas likely will experience shortages in the future as they exhaust readily accessible resource deposits.

For market areas which are facing or will face scarcity in one of the commodities, one should analyze the total demand for the two commodities combined as well as separately. In Chapter 4, we analyze the total demand for rock materials in several substate areas, especially Jackson and Lincoln Counties.

Table 7. Statewide econometric models of annual production of crushed stone[a]

Model No.	Dependent Variable[c]	Intercept	Coefficients of Explanatory Variables[b]: Price	Population	Employment	Highway Expenditures	Income	R^2 (Prob.)[d]
(1)	Production (1963-1976)	29,836,530	-9,335,489	2.20	-7.34	-0.023	--	0.25 (.5883)
(2)	Production (1956-1976)	13,603,374	-9,161,208	-2.05	6.53	--	--	0.56 (.2143)
(3)	Production (1956-1976)	14,151,846	-9,249,957	5.51	--	--	--	0.23 (.0998)
(4)	Production (1956-1976)	17,350,597	-9,600,645	--	10.47	--	--	0.22 (.1069)
(5)	Production (1969-1976)	9,862,784	--	--	--	--	0.22	0.15 (.3458)

[a] For a complete description of the models, including additional test statistics, see the Appendix.

[b] See text for the definition of variables.

[c] Production is measured in short tons per year.

[d] Probability that the model actually explains none of the variation in the dependent variable.

Shortages of one of the commodities have not typified conditions for the state as a whole. Hence, we focused on the separate statewide demand each commodity. However, to compare statewide results with substate results, we also examined growth-rate and econometric models of the total demand statewide. These models explain little of the variation in statewide production and have high probabilities that, in fact, they explain none of the variation. We present the results in the Appendix.

CHAPTER 4

THE SUBSTATE MARKETS

Abstract

In any market area, two components comprise the demand for rock materials. One component arises from the area's general economic forces in a well-behaved, straightforward manner. The other component also stems from overall economic conditions, but in an erratic, unpredictable manner. In the Portland metropolitan area, the first component predominates and, consequently, the econometric models explain variation in demand satisfactorily. In the other areas, the second component is more prevalent and the econometric models establish the relationships between productionand the economic variables less conclusively. Inconsistencies in the data for rock production appear to compound the difficulties with the econometric models and produce artificially high rates of growth in production. In general, the demand for crushed stone is more erratic and unpredictable than the demand for sand and gravel.

The Portland Metropolitan Area

The four counties comprising this area--Clackamas, Columbia, Multnomah and Washington--contain Oregon's largest and most complex market for rock materials. According to Table 2 in Chapter 2, these counties produced an average of 7,736,000 tons of sand and gravel and 3,244,000 tons of crushed stone per year during the period 1970-1976. These amounts represented 41.3 percent and 24.6 percent of the respective statewide demand. The size of this market and the diversity and strength of the economy which supports it combine to make the demand for each type of rock commodity grow rapidly and with well-defined past trends. These combined factors also clearly define the relationships between the demand for sand and gravel and the underlying economic forces which help determine the demand. The relationships for the demand for crushed stone, while reasonably strong, are not so apparent as for sand and gravel.

Growth rates

The Bureau of Mines' production data indicate that the demand for rock materials in the Portland area has grown very steadily and very rapidly. Each of these characteristics, in general, coincides with theoretical expectations for such a large, integrated, metropolitan market. However, the growth rates apparent from the data are so large, they raise questions about the data's reliability.

Long-term rates: Table 8 contains the estimated average growth rates during 1950-1976 for the Portland area as well as for the other three substate areas. Over the period, 1950-1976, stone production in the four counties grew with a mean rate of 9.1 percent per year, almost three times the mean growth rate for sand and gravel, 3.2 percent per year. The total demand for all rock grew at 4.4 percent. All three rates have very low probabilities for statistical error, based on the amount of variation in the data.

In the context of general economic behavior, the long-term growth in the demand for sand and gravel is quite large; the rate for crushed stone is phenomenal. At this rate, the production of stone doubled every seven years. Few reliably determined economic indicators, if any, have ever sustained a mean growth rate of this magnitude for over 21 years. Thus, the size of the growth rate for stone raises the possibility of distortions in the production data. For example, some of this huge growth rate may reflect severe underreporting in 1950, and gradually less severe underreporting during the 1951-1976 period.

Short-term rates: In most of the substate areas, production activity seemed to change about 1964. In the Portland area, the production of sand and gravel accelerated,

Table 8. Estimated historical growth rates for demand in substate areas

	Mean Annual Growth Rate		
Time Period	Sand and Gravel	Crushed Stone	All Rock
<u>Portland Region</u>			
1950-1976	3.23% (0.0001)[a]	9.11% (0.0001)[a]	4.36% (0.0001)[a]
1964-1976	6.41% (0.0007)[a]	5.66% (0.0109)[a]	6.15% (0.0005)[a]
<u>Jackson County</u>			
1950-1976	2.85% (0.0534)[a]	7.49% (0.0012)[a]	5.88% (0.0009)[a]
1964-1976	3.21% (0.3923)[a]	13.68% (0.0891)[a]	11.24% (0.0485)[a]
<u>Lincoln County</u>			
1950-1976	--	5.27% (0.0001)[a]	5.27% (0.0001)[a]
1964-1976	--	1.83% (0.5415)[a]	1.83% (0.5415)[a]
<u>Umatilla County</u>			
1950-1976	0.74% (0.6401)[a]	2.96% (0.0528)[a]	1.79% (0.1863)[a]
1964-1976	0.46% (0.0376)[a]	2.01% (0.6014)[a]	1.15% (0.7999)[a]

[a]Probability that, within the production data, the mean growth rate actually equals zero.

while the production of stone slowed. From 1964 until 1976, the production of sand and gravel grew at an average rate of 6.4 percent per year, and stone production grew at 5.7 percent per year. These rates indicate a doubling in the annual production of each commodity during the 1964-1976 period.

Although these rates are significantly less than the estimated long-term growth rate for stone, they too seem inflated. They are especially excessive for use in long-term forecasting. Given the rapid, general expansion of the Portland area during 1964-1976, the build-up of metropolitan infrastructure may explain such large growth rates in rock production. However, even a rapidly growing area eventually slows its development of roads, bridges, and buildings. As a consequence, the high rates of growth in the demand for rock materials also subside.

<u>Econometric models of demand</u>

The econometric models of the demand for rock materials in the Portland area confirm the theoretical expectations of the underlying, predictable relationships between demand and the explanatory variables. The fundamental model of the demand for sand and gravel has very high explanatory power and all of the coefficients have the expected sign. The models of the demand for crushed stone and for all rock materials also perform very well, though not to the same degree as the models for sand and gravel. This result shows that the demand for stone is more erratic than the demand for sand and gravel, even in a metropolitan area.

Sand and gravel: Table 9 summarizes the models. The most preferred model is Model 1, which includes all the explanatory variables: real price, population, employment, and state highway expenditures. Model 1 explains 93 percent of the variation in the area's production of sand and gravel between 1963 and 1976. Each of the coefficients for the explanatory variables has its anticipated sign.

Each coefficient explains the direction and the magnitude of the relationship between the demand for sand and gravel in the area and the respective explanatory variable during 1963-1976. Price and production are negatively related. Increases in the real price of sand and gravel, independent of changes in the other variables, are related to decreases in demand. This relationship does not imply that a price increase causes a drop in total rock production, though, because demand could shift between sand and gravel and crushed stone. The other explanatory variables are related positively to demand.

To interpret the magnitudes of the coefficients, one should consider simultaneously the values of both the coefficients and the explanatory variables, themselves. The absolute magnitude of the coefficient for price in Model 1 is very large, indicating a drop in production of 4,616,027 tons for a price increase of $1 per ton. Independent increases of one unit in population, employment, and highway expenditures, were associated, respectively, with production increases of only 5.50, 8.61 and 0.03 tons per year. One should not conclude from the vast differences in these magnitudes, though, that price had a greater impact than the other variables on production. The data in the Appendix for the variables show that the real price of sand and gravel was small and very steady during 1963-1976, while the values of the other variables were large and they changed considerably during the period. Overall, population, employment, and highway expenditures had more impact than price on production.

Although Model 1 is the preferred econometric model for sand and gravel, we also include other models having fewer explanatory variables in Table 9. Models, 2, 3 and 4 examine production during the period, 1956-1976. They all have quite high coefficients of determination (R^2) and the anticipated signs on the coefficients for the explanatory variables. In contrast, Model 5, which relates production to income, basically indicates only the absence of any true relationship. All the models are presented in greater detail in the Appendix.

Crushed stone: The econometric models of the demand for crushed stone in the Portland metropolitan area, shown in Table 10, perform quite well, but not as favorably as th- models for sand and gravel. Model 1 explains 70 percent of the 1963-1976 variation in production, much higher than the comparative statewide model. The coefficient for population has a theoretically incorrect sign, however. All the coefficients in Models 2, 3, and 4 have the correct sign, but they account only for about one-half, or less, of the variation in production. In Model 5, the level of income coincides very little with the variation in stone production; in this integrated economy, total income apparently does not drive the demand for stone.

The characteristics of the models for stone stem from the nature of the market for this commodity in the Portland area and from the characteristics of the data incorporated in the models. Of all the areas we studied, the Portland area had the smoothest pattern of stone production. But, even here, the production of stone was more erratic than the production of sand and gravel. This greater volatility apparently caused Models 1-4 for stone production to have lower explanatory power than did the corresponding models for sand and gravel. The unexpected sign on the coefficient for population and the unusually large coefficient for employment in Model 1 reveal multicollinearity within the data for these two variables. The relatively high R^2 for Model 1, though, suggests that multicollinearity does not seriously hamper the model's explanatory power.

Table 9. Econometric models of the annual production of sand and gravel in the Portland Metropolitan Area[a]

Model No.	Dependent Variable[c]	Intercept	Coefficients of Explanatory Variables[b]					R^2 (Prob.)[d]
			Price	Population	Employment	Highway Expenditures	Income	
(1)	Production (1963-1976)	3,572,790	-4,616,027	5.50	8.61	0.03	--	0.93 (.0001)
(2)	Production (1956-1976)	-4,187,145	-2,133,241	13.60	3.82	--	--	0.85 (.0001)
(3)	Production (1956-1976)	-6,026,188	-1,348,390	16.17	--	--	--	0.84 (.0001)
(4)	Production (1956-1976)	7,673,086	-5,467,529	--	14.70	--	--	0.63 (.0003)
(5)	Production (1969-1976)	7,006,693	--	--	--	--	0.08	0.01 (.8248)

[a]For a complete description of the models, including additional test statistics, see the Appendix.

[b]See text for the definition of variables.

[c]Production is measured in short tons per year.

[d]Probability that the model actually explains none of the variation in the data for the dependent variable.

Table 10. Econometric models of the annual production of crushed stone in the Portland Metropolitan Area[a]

Model No.	Dependent Variable[c]	Intercept	Coefficients of Explanatory Variables[b]: Price	Population	Employment	Highway Expenditures	Income	R^2 (Prob.)[d]
(1)	Production (1963-1976)	1,601,970	-2,502,933	-5.52	31.9	0.0144	--	0.70 (.0180)
(2)	Production (1956-1976)	-898,184	-1,455,246	5.52	2.16	--	--	0.53 (.0088)
(3)	Production (1956-1976)	-2,374,016	-1,269,100	7.75	--	--	--	0.51 (.0016)
(4)	Production (1956-1976)	3,231,120	-2,256,424	--	6.20	--	--	0.36 (.0283)
(5)	Production (1969-1976)	1,337,536	--	--	--	--	0.29	0.23 (.2269)

[a] For a complete description of the models, including additional test statistics, see the Appendix.

[b] See text for the definition of the variables.

[c] Production is measured in short tons per year.

[d] Probability that the model actually explains none of the variation in the dependent variable.

Responsiveness of demand

The demand for sand and gravel in the Portland area has dominated the demand for crushed stone. The historically greater production levels for sand and gravel summarize consumers' preference for this commodity. The speed with which the demand for each commodity has responded to changes in the explanatory variables also indicates this preference.

According to the theory underlying the econometric models, changes in the explanatory variables stimulate change in the demand for rock materials. These events usually do not occur simultaneously, however; changes in demand follow the changes in the explanatory variables.

The models previously described used annual data, for concurrent years, for all variables. Thus they measured the extent to which the demand for each commodity responded within the same year to changes in the explanatory variables. Clearly, the demand for sand and gravel responded better on an annual basis.

We also tested the responsiveness over longer time periods. For each commodity, we developed an econometric model with annual values for production and three-year, moving-average values for the explanatory variables. These models compared the average values of the explanatory variables during each three-year period with the level of demand during the third year of each period. For example, we compared the production in 1976 with each explanatory variable's average value for 1974, 1975, and 1976.

The three-year averages reduce the number of observations in the data, leaving too few observations--only 12--when we applied the technique to Model 1. So, we applied it to Model 2, which has price, population, and employment as explanatory variables over the period, 1956-1976.

The resulting model (Model 7) for each commodity is described fully in the Appendix. Model 7 for sand and gravel performs much worse than the corresponding Model 2. This result implies that the demand for sand and gravel responds essentially just to recent economic events, as described previously, but not to more distant events.

Conversely, Model 7 for crushed stone is an improvement over the corresponding Model 2. Both models explain about 65 percent of the variation in annual stone production. However, Model 7 is free of some of the problems of multicollinearity found in Model 2; the coefficients of all three explanatory variables have the anticipated sign. This outcome indicates that the demand for stone responds in both an immediate and in a delayed manner to changes in the econometric variables. Each type of response, by itself, appears weaker than the very strong, almost immediate response by the demand for sand and gravel to economic changes. However, the two types of response by the demand for stone appear to have an impressive, combined effect which is greater. This combined effect seems to explain why the demand for stone in the Portland area has been growing more rapidly than the demand for sand and gravel.

Planning for anticipated supply constraints

Anticipated market conditions: The Portland area is one of Oregon's markets which soon may experience a major curtailment in readily available supplies of sand and gravel. More distant supplies exist, but transporting them to the area's centers of demand likely will increase the average delivered price.

Because the modelling results of the demand for each rock commodity in the Portland area are so consistent with theoretical expectations, one can use the models to estimate the effects of the supply constraint. Several extensions of the models will enhance their utility.

The econometric model (Model 1) of the demand for sand and gravel shows how demand will respond, based on historical relationships, to future price increases for this commodity. However, the model does not address all the factors which will determine how the market will adjust to reduced supplies of sand and gravel. For example, it does not show how readily demand will shift to crushed stone if the price of sand and gravel rises substantially. Clearly, this shift will depend not just on the rise in the price for sand and gravel, but also whether or not producers also raise the price of stone.

Total demand for rock: To provide some additional insight to what may occur, we examined the historical total demand for all rock materials in the Portland area. The resulting growth rates and econometric model are shown in the Appendix. In general, the all-rock results are weighted averages of the growth rates and models for each commodity. One can use them to describe and forecast future levels of demand for rock, regardless of the proportional split in demand between the two commodities. These forecasts--combined with the forecasts from the separate models for each commodity and supplemented with information about consumers' preferences and producers' likely reactions--should provide a sound foundation for planning.

Relative-price relationships: To provide further insight, we also analyzed how changes in the price of one commodity historically affected the demand for the other commodity. The complete analytical results are described in the Appendix ("Econometric Model 8: Ln Production (1956-1976)"). In summary, the results suggest that the demand for sand and gravel is less sensitive than the demand for stone to changes in the relative prices of the two commodities. For example, the model indicates that a 10 percent increase in the price of sand and gravel relative to the price of stone, occurring in the absence of changes in the other explanatory variables, would produce a 3 percent decrease in the quantity of sand and gravel demanded and an 11 percent increase in the quantity of stone demanded. This result apparently stems from consumers' preference for sand and gravel.

It is important to remember that this model, like all the other models, is based on historical data. During the period, 1956-1976, the prices of sand and gravel and of stone were quite steady and usually nearly equal in the Portland area. If these characteristics apply in the future, then one can expect stone producers to raise their prices to match any future increases in the delivered price of sand and gravel caused by greater transportation costs. In this case, the two commodities will maintain approximately equal relative prices, and the results of Model 8 will continue to apply. If the relative prices differ markedly in the future, then one should reevaluate Model 8's applicability.

The Other Substate Areas

The analytical results for the remaining three substate areas we examined--Jackson, Lincoln, and Umatilla Counties--are not as conclusive as the results for the Portland area. The historic production of rock materials in these counties has been generally too erratic for the models to identify trends and relationships precisely. Nevertheless, the analysis provides useful information about the market characteristics of these areas.

Jackson County

Growth rates: The data in Table 8 show the estimated, historical growth rates in Jackson County. From 1956 to 1976, the production of sand and gravel grew with a mean annual rate of 2.85 percent. The production of crushed stone grew at a mean rate of 7.49 percent per year. During the period, 1964-1976, both rates increased: to 3.21 and 13.68 percent per year, respectively.

As was the case for the Portland area, the estimated growth rates for crushed stone seem unreasonably high. Without additional information about the accuracy of producers' reports to the Bureau of Mines, one cannot measure the extent to which these rates reflect actual historical market conditions or reporting errors. However, one can conclude that the rates implied by the historical data probably will not represent long-term future growth in demand. At 13.68 percent per year, for example, demand would double in less than 5 years, and Jackson County's economy is unlikely to increase fast enough to support such growth for long.

Econometric models: Table 11 outlines the most important econometric models for Jackson, Lincoln, and Umatilla Counties. In particular, Table 11 reports the results for Model 1 in each county. The Appendix contains a more detailed analysis of the models.

For Jackson County, Model 1 explains 72 percent of the variation in the production of crushed stone between 1963 and1976. Although this model has a high explanatory power, some of the coefficients of the explanatory variables cast doubt onthe model's validity. The coefficients for population and employment are excessively large, and the latter is

Table 11. Econometric models for Jackson, Lincoln and Umatilla Counties[a]

Model No.	Dependent Variable[c]	Intercept	Coefficients of Explanatory Variables: Price	Population	Employment	Highway Expenditures	Income	R^2 (Prob.)[d]
Jackson County								
(1)	S&G Production (1963-1976)	-1,130,726	1,004,474	-14.12	39.17	0.054	--	0.35 (.3741)
(1)	Stone Production (1963-1976)	-12,089,332	-943,763	269.61	-315.54	-0.014	--	0.72 (.0133)
(5)	S&G Production (1969-1976)	171,490	--	--	--	--	0.85	0.34 (.0967)
(5)	Stone Production (1969-1976)	-1,363,166	--	--	--	--	6.36	0.15 (.0469)
Lincoln County								
(1)	Stone Production (1963-1976)	3,658,683	-154,776	-212.6	269.2	-0.008	--	0.40 (.2878)
Umatilla County								
(1)	S&G Production (1963-1976)	2,841,029	727,544	-180.29	247.12	-0.006	--	0.52 (.1260)
(1)	Stone Production (1963-1976)	668,788	93,564	-14.72	16.96	-0.008	--	0.04 (.9824)
(5)	S&G Production (1969-1976)	91,152	--	--	--	--	0.62	0.51 (.0568)
(5)	Stone Production (1969-1976)	295,722	--	--	--	--	0.58	0.05 (.5947)

[a]For a complete description of the models, including additional test statistics, see the Appendix.

[b]See text for the definition of variables.

[c]Production is measured in short tons per year.

[d]Probability that the model actually explains none of the variation in the dependent variable.

negative. The coefficient for highway expenditures also is negative. These results indicate extreme multicollinearity within the data for these variables, which confuses their relationships with the levels of production.

Model 1 explains only 35 percent of the variation in the production of sand and gravel during the 1963-1976 period. It has rather large probabilities that any single coefficient, or all coefficients, may actually be zero. Thus, there is substantial uncertainty about the model's having any meaningful descriptive powers.

All-rock model: The all-rock model is described in the Appendix. It has a high coefficient of determination (R^2), but, like the explanatory model for crushed stone, it exhibits the effects of severe multicollinearity. If future data can reduce these effects, this model appears to hold substantial explanatory potential.

Production and income: Table 11 also shows the short-term historical relationship between the production of each commodity and income (Model 5). The suggested relationship, especially in the case of stone, imply that production and income move together in a less diversified economy. Income, thus, potentially will be useful as an explanatory variable for demand in rural areas when data for longer time periods become available.

Lincoln County

Production data: As Tables 1 and 2 showed, the Bureau of Mines' data report historic production in Lincoln County of substantial quantities of both sand and gravel and crushed stone. However, Lincoln County--and much of the coastal area--contains very limited deposits of usable sand and gravel. Producers of sand and gravel in Lincoln County produce only small amounts. According to estimates by DOGAMI, producers in other counties, especially Benton and--just recently--Douglas Counties, have transported about 20,000 tons of sand and gravel into Lincoln County each year to meet demand. Apparently, the Bureau misclassifies some of the stone produced in Lincoln County as sand and gravel.

Although we cannot measure the extent of misclassification precisely, it appears that virtually all the reported amounts of sand and gravel actually are stone. Consequently, we incorporated all the county's production data for sand and gravel with the data for crushed stone. Using these combined data, we then analyzed the historical total demand for stone which essentially has equalled the demand for all rock.

Growth rates: Table 8 shows a 1950-1976 estimated annual growth rate of 5.27 percent for the combined data. As in the cases of the Portland area and Jackson County, this long-term rate seems exaggerated and likely reflects a greater incidence of underreporting in early years than in later ones. The estimated growth rate for 1964 to 1976 is lower but it has a high probability of being zero.

Econometric model: Table 11 shows only one econometric model, Model 1, for the combined Lincoln County data. This model explains only 40 percent of the variation in production. The coefficients for population, employment, and highway expenditures either have incorrect signs or they are unreasonably large. Thus, this model, which is the best possible model given the available data, provides few descriptive insights into the characteristics of demand and is invalid for forecasting future demand.

Umatilla County

The data for Umatilla County exhibit many characteristics already made familiar by Jackson and Lincoln Counties. Both commodities show long-term (0.7 percent for sand and gravel and 3.0 percent for stone) and short-term (0.5 percent and 2.0 percent, respectively) estimated growth rates which have very high probabilities of actually being zero. Thus, reported production has not grown in any technical sense of the term; it has simply varied. Variation in the data is too great to enable determination of a valid mean growth rate.

Applying the econometric model, Model 1, to Umatilla County's data produces indecisive results. For each commodity, the model contains coefficients for the explanatory variables which have perverse signs and high probabilities of actually being zero.

Model 5 suggests a strong correlation between the reported levels of production of sand and gravel and total income. The R^2 for this model is 0.51. Given the small number of observations upon which this model is based, this result is encouraging. With better, long-term income data, one perhaps will be able to use income to explain more of the demand for rock in Umatilla and other rural counties.

CHAPTER 5

FORECASTS OF FUTURE DEMAND

Abstract

Of all the models, the econometric models for the Portland metropolitan area yield the most reliable forecasts for future demand. These models most clearly identify the predictable, well-behaved relationships between production and general economic characteristics. The Portland-area's estimated demand in 1990 for sand and gravel and for stone--10.8, and 8.0 million short tons, respectively--are about one and one-half times their respective levels of production in 1976. These expected increases in demand result from expected growth in the area's population, employment, and real highway expenditures, while real prices remain constant.

While the econometric and growth-rate models offer insights into the demand characteristics of the other areas, the models are inadequate to support demand forecasting. Consequently, we used the Portland-area models to simulate the predictable components of the demand in these areas. Adapting the Portland-area models and performing the simulations require careful consideration of the models' applicability to market conditions in other areas.

Using simulation techniques, we forecast high, medium, and low estimates of the level of annual demand statewide and in the substate areas for 1985 and for 1990. Forecasting demand fifty years hence is a much more formidable task. To estimate a range of demand in 2030, we extended the simulations and projected the historical growth rates. For the state as a whole, moderate projections show the demand for sand and gravel growing by about 2.0 percent annually and the demand for stone increasing at 3.6 percent annually. These rates imply statewide production levels in 2030 of 63 and 114 million short tons per year for the two commodities, respectively.

The forecasts we present address only the predictable components of the demand for rock materials. We based the projections on the Bureau of Mines' data, from which we removed some highly erratic components of production. These "cleaned" data underreport actual historical production levels and probably underestimate future levels. One should account for the excluded components of demand in developing forecasts of total demand.

Forecasts of Demand in 1985 and 1990

Forecasting future levels of the annual demand for rock materials requires focusing on the predictable components of demand. These components, as we demonstrated in the previous chapters, stem from the underlying influence of general economic characteristics. The fundamental econometric model, Model 1, provides the most valid and widespread measurements of the historical relationships between economic variables and levels of demand. Consequently, we relied on Model 1 to forecast demand in 1985 and in 1990.

Model 1 estimates the level of the predictable component of demand, based on historical relationships with a given set of particular values for the explanatory variables. Consequently, to forecast future levels of production with this model, one must have two things:

1. the expected future values of the explanatory variables; and
2. sound reasons to expect that the historical relationships between the explanatory variable, and production will continue to apply in the future.

We address each of these points below.

Estimated future values of the explanatory variables

Table 12 presents the high, medium, and low estimated values of the explanatory variables in 1985 and in 1990 for each area. The population estimates, by county, were developed by the Portland State University Center for Population Research and Census. The Center has determined a basic population estimate by a standard cohort-survival demographic model. The range then depends upon additional assumptions about the net rate of in-migration.

We derived the employment estimates from the Bonneville Power Administration's forecasts of household employment by county. The BPA derived these forecasts by applying employment/population ratios to its population forecasts. The resulting employment forecasts are low and currently under revision by BPA. We revised the BPA estimates upward by applying the BPA's employment/population ratios to PSU's somewhat greater population forecasts.

The estimates of expenditures by the state on highway construction and maintenance are derived from the Transportation Commission's Highway Improvement Program for 1979 through 1984. The low estimates of annual expenditures are one-sixth of the anticipated, total "Basic Program" expenditures for fiscal years 1979 to 1984 on Maintenance, Minor Betterment, Non-Interstate and Interstate Improvements. Where maintenance expenditures are not reported, we assumed them to be 50 percent of other expenditures. The high estimates of future annual expenditures are one-sixth of the total expenditures anticipated under the "Program with Additional Revenues." This program includes substantially more expenditures on non-interstate highway improvements than the "Basic Program." We adjusted all expenditure levels to "real" levels (1967 = 100) by adjusting for anticipated inflation in construction costs.

We derived estimates of the future real prices of the two rock commodities from the price trends in the Portland area from 1958 to 1976. The real price of each type of rock in this area varied only slightly during this period, reflecting the stable developed market for rock materials in an active diversified economy. When we projected the trends forward, the real price of sand and gravel declined from an average of $1.30 in 1963-1976 to $1.28 in 1990. For the same years, the real price of stone fell from $1.30 to $1.27.

These prices reflect essentially just production costs, not transportation costs. Consequently, they underestimate delivered prices. However, they are consistent with the data used to develop the econometric models and, hence, valid for forecasting, unless changing market conditions radically alter the relationship between production cost and delivered price. The impending scarcity of sand and gravel in Portland may effect such changes, but at this time the continuation of past trends seems reasonable.

Price levels in the other markets and in the state as a whole have been more erratic, and price forecasts based on them show substantial growth rates (some positive and others negative). But, they are not very reliable. As the several markets grow, pricing activity should converge toward the Portland-area's experience of the last twenty years. Hence, forecasting in other areas with Portland's prices is not unreasonable.

Forecasts for the Portland metropolitan area

Table 12 shows the estimated demand for all areas in 1985 and in 1990. With the mid-range value of the explanatory variables, Model 1 predicts that the demand for sand and gravel in the Portland area will equal 9.5 million tons per year in 1985 and 10.8 million tons per year in 1990. These values imply the area's demand for sand and gravel will grow at a mean annual rate of 2.0 percent per year between 1963 and 1990.

For crushed stone, the mid-range values yield estimates of 6.6 (1985), and 8.0 (1990) million tons per year. These values indicate the demand for this commodity will grow about 6.0 percent per year.

These forecasts for demand are quite reasonable, given anticipated market conditions. All of the area's explanatory variables are expected essentially to continue their historic trends. During the 1963-1990 period, population and employment are expected to grow with mean annual rates of 1.9 and 2.3, respectively; annual real highway expenditures will approximately double. These three variables will drive demand, since we assume real prices will remain essentially unchanged. As in the past, the demand for sand and gravel

Table 12. High, medium and low estimates for 1985 and 1990

Area	Population (millions)	Employment (millions)	Highway Expenditures ($ millions)	Annual Production (million tons/year) Sand and Gravel	Stone
PORTLAND:					
1985:					
High	1.17	.555	35.2	10.0	7.0
Mid	1.13	.539	31.7	9.5	6.6
Low	1.11	.527	31.7	9.3	6.4
1990:					
High	1.31	.634	40.4	11.7	8.8
Mid	1.24	.598	36.4	10.8	8.0
Low	1.19	.575	36.4	10.4	7.5
STATEWIDE[a]					
1985:					
High	2.82	1.28	87.9	25.4	21.3
Mid	2.74	1.24	67.7	24.0	20.2
Low	2.70	1.22	67.7	23.6	19.7
1990:					
High	3.13	1.45	101.0	26.1	23.9
Mid	2.95	1.37	77.7	26.6	23.1
Low	2.84	1.31	77.7	25.5	22.0
JACKSON[a]					
1985:					
High	.142	.065	0.79	.98	1.81
Mid	.139	.063	0.45	.94	1.76
Low	.136	.062	0.45	.91	1.74
1990:					
High	.158	.073	0.91	1.19	1.98
Mid	.149	.069	0.52	1.09	1.90
Low	.143	.066	0.52	1.03	1.83
LINCOLN[a]				All Rock	
1985:					
High	.033	.015	1.17	.74	
Mid	.032	.015	0.56	.73	
Low	.031	.014	0.56	.72	
1990:					
High	.036	.017	1.34	.79	
Mid	.039	.016	0.65	.75	
Low	.033	.015	0.65	.74	
UMATILLA[a]					
1985:					
High	.057	.026	1.99	.42	.68
Mid	.055	.025	0.90	.40	.64
Low	.054	.024	0.90	.38	.62
1990:					
High	.062	.029	2.25	.56	.75
Mid	.059	.027	1.04	.49	.69
Low	.057	.026	1.04	.47	.67

[a]Estimates of future production derive from a simulation using Portland-area econometric models with appropriately adjusted intercepts.

Note: These projections are based on Bureau of Mines data and also represent only the predictable component of total demand. Refer to pages 15 and 16.

will grow with the explanatory variables. The growth in the demand for stone, meanwhile, will show the larger, combined effect of immediate and delayed responsiveness to changes in the explanatory variables. (See the discussion in Chapter 4.)

Statewide forecasts

Using the statewide models: The statewide econometric models lack sufficient explanatory power and theoretical consistency to yield acceptable forecasts of future statewide demand. Applying these models to the expected future values of statewide prices, population, employment, and highway expenditures gives forecasts that contradict Oregon's present and expected economic characteristics. For example, the statewide Model 1 for crushed stone forecasts the level of demand statewide for stone in 1990 will equal 14.6 million tons per year--less than the average annual production during 1970-1976. Given the anticipated growth in the state's economy, this result seems unlikely. Because of this and similar incongruities, the statewide models are unsuitable for forecasting, and we did not use them to develop any of the forecasts we report.

The problems within the statewide models stem from the general characteristics of the demand for rock. The total demand for each rock commodity in the state as a whole, as well as in each substate area, consists of a predictable component and an erratic component. The predictable component, related directly to an area's economic characteristics, forms the fundamental, long-term behavior of total demand. The erratic component primarily determines the short-term characteristics. Unfortunately, in areas where the erratic component is sizable, even though not prevalent, it can conceal the predictable component. As a consequence, the erratic component can prevent the econometric models from measuring and forecasting the predictable component.

This type of situation exists within the statewide demand for sand and gravel and for stone. It also exists in Jackson, Lincoln, and Umatilla Counties. In each of these areas, the models based on the area's historical production data fail to provide acceptable forecasts.

The predictable component of demand: In all rock-material markets, economic conditions influence the predictable component of the demand for rock in essentially the same ways. For example, an increase in population in any area will lead to the use of rock in the construction of new houses, schools, and roads. Consequently, the relationships between economic conditions and rock production in one area should be similar to the relationships in other areas.

This similarity persuaded us to use the Portland area's econometric models as a tool for estimating future demand, not just in the Portland area, but also in other areas. From the analysis in previous chapters, it is clear that the predictable component dominates the demand for sand and gravel and for stone in the Portland area. The econometric model (Model 1) of the demand for each commodity in this area measures the economic forces which determine the predictable component of demand quite clearly. The model for sand and gravel measures the forces especially well. In the absence of more direct alternatives, one therefore can use the measurements for the Portland area to simulate the predictable component elsewhere.

Simulating demand: Simulating the predictable component of demand in another area essentially involves combining the area's values for the explanatory variables with the coefficients from the Portland-area's models. However, before doing this, one must perform two preliminary steps. First, one must determine if the area's market conditions impair the validity of the simulation. Completing this step involves examining demand and supply factors to ascertain if the forces determining the predictable component of demand in the area differ radically from the forces present in the Portland area.

Using the simulation technique to forecast statewide demand seems very reasonable. The Portland area and the rest of the Willamette Valley, which has similar economic characteristics, comprise the bulk of the statewide demand for sand and gravel and for stone. Consequently, the predictable components of demand for the state should resemble those for the Portland area.

The second step is to alter the intercept in the model so it fits the area. An essential element of each econometric equation is the value of the intercept. In the simulations, the value of the intercept will be unique for each area and each type of rock material. One cannot merely transfer the Portland-area intercepts to the other areas in the same manner as one transfers the coefficients.

Calculating the appropriate intercept for an area requires first multiplying the Portland-area coefficients by the mean historical values of the explanatory variables--population, employment and highway expenditures--for the area during 1963-1976. After adding all the results to the mean price effect calculated for the Portland area, the total is subtracted from the area's mean level of production during 1963-1976. The difference is the value of the area's intercept.

For example, the average values of the explanatory variables and of production for the statewide stone market during 1963-1976 are:

real price	$1.30 per ton;
production	13 million tons;
population	2.1 million tons;
employment	395,300; and
highway expenditures	$94,440,000.

The intercept term is estimated to be -2,000,000 tons so that the simulation equation becomes:

$$\text{stone} = -2{,}000{,}000 - (2{,}502{,}933 \text{ price}) - (5.52 \text{ population}) + (31.9 \text{ employment}) + (0.014 \text{ highway}).$$

The intercept for the comparable simulation model for statewide sand and gravel production, using the Portland area's estimated coefficients, is 2,000,000. The estimated future levels of rock production in 1985 and 1990 are reported in Table 12 for the high, medium, and low estimated values of future statewide population, employment, and highway expenditures.

The simulation model also can be used to estimate an area's underlying growth rate of demand. This is accomplished by using the model, and an area's values--both historic and expected--for the explanatory variables to simulate the fundamental characteristics of the area's demand for a type of rock material. This process involves developing consistent estimates of production for several years, past and future, for example 1963 and 1990. Then we can derive the estimated underlying compound annual growth rate of the model directly from the 1963 and 1990 estimated values. For these years and the mid-level simulations of statewide demand, these rates are 2.0 percent and 3.6 percent for sand and gravel and for stone, respectively. Given the state's anticipated population and general economic growth, these rates seem plausible.

Forecasts for Jackson County

We also used the Portland-area models to simulate and forecast the demand in Jackson County for sand and gravel and for stone. Even in a moderately short period of time, Jackson County's economy likely will acquire more diversified characteristics. As it evolves, the predictable component of the demand for sand and gravel and for stone should become increasingly similar to the comparable components in the Portland area.

Using the same technique described for the statewide simulations we derived new intercepts for the simulation models. The new intercepts are 5,600,000 for sand and gravel, and 3,700,000 for crushed stone.

The high, medium, and low values of the estimated future demand for rock materials in Jackson County are reported in Table 12. The mid-level, long-term, simulated growth rates for 1963-1990 implied by these equations are 2.4 percent per year for sand and gravel and 2.6 percent per year for stone.

Forecasts for Lincoln County

Like Jackson County, Lincoln County likely will experience substantial economic growth and diversification during coming years. This development likely will not be as extensive as in Jackson County or in the Portland area. But the fundamental economic forces determining the predictable component of demand in Lincoln County should approximate the forces in the Portland area. Therefore, simulating the future predictable demand for rock materials using a model derived from the large urban market in the Portland area is not unreasonable. Only one set of forecasts is required for Lincoln County since the county produces virtually no sand and gravel.

We forecast the demand in 1985 and in 1990 for rock materials in Lincoln County through a simulation using the Portland area's model of stone production. Applying the model to the mean values of production and the explanatory variables produced an intercept of 3,600,000 tons per year. The model simulated predictable production levels of 440,000 tons in 1963 and 640,000 tons in 1976 as compared to actual production of 530,000 and 600,000 in the respective years. It estimated medium-range future production levels of 730,000 tons in 1985 and 750,000 tons in 1990. These figures indicate a mean annual growth rate between 1963 and 1990 of 1.9 percent. This rate seems in line with the expected growth in population of 1.1 percent per year and in employment of 1.8 percent per year.

Forecasts for Umatilla County

We use the Portland-based simulation model to forecast demand in Umatilla County, but we do so with reservations. The Umatilla economy bears little resemblance to the Portland area and using a simulation model derived from Portland suggests that demand will become more orderly and more urban-oriented than is, in fact, likely. However, to the extent that orderly expansion will occur, the subsequent demand is reflected in these simulations and, especially, in the growth rates estimated from the simulations.

The simulation models for sand and gravel and for stone have intercepts of 5,800,000 and 3,300,000 tons, respectively. The model estimates a predictable demand for sand and gravel in 1963 and 1976 of 255,000 tons and 363,000 tons, respectively, as compared to reported levels of 333,000 tons and 248,000 tons. The forecasts from the simulation for 1985 and 1990 are 397,000 tons and 487,000 tons, respectively, with a consequent 1963-1990 growth rate of 2.3 percent. For stone, the 1963 and 1976 simulated values are 346,000 tons and 558,000 tons, compared with respective actual values of 712,000 tons and 294,000 tons. The projected demands of 644,000 tons and 687,000 tons for 1985 and 1990 reflect a 1963-1990 annual growth rate of 2.5 percent. These growth rates seem somewhat large compared to the corresponding expected growth rates of 1.1 percent for population and 1.8 percent for employment. However, the erratic component of the demand for rock in Umatilla County so obscures the predictable component that it is difficult to compare the actual and the simulated rates.

Forecasts of Demand in 2030

Projecting the demand for rock materials, or any other economic event, fifty years into the future is inexact at best and fraught with the likelihood of large errors. In general, one can forecast demand this far ahead only by simplified techniques such as projecting growth rates. The forecast should project a range of values which will bound the most probable levels of demand.

We forecast the demand for sand and gravel and for crushed stone by projecting the growth rates arising both from the Bureau of Mines' production data and from the forecasts for 1985 and 1990. The growth rates coming from the data tend to be larger than the growth rates indicated by the forecasts based on the Portland-area models. The two sets of growth rates generally seem to encompass the likely long-term trends and patterns expected for Oregon's fundamental economic characteristics.

Some compound growth arithmetic is useful. At a 1 percent annual rate, the level of production of rock in 2030 will be 71 percent greater than the level of production in 1976. With a 3.5 percent rate, production will be 641 percent larger in 2030 than 1976. A 6 percent annual rate implies 2,326 percent more production in 2030 than in 1976. Six percent annual rates of growth in real value are extremely unlikely to occur across a 50-year period.

The forecast levels of annual demand in 2030 for sand and gravel and for crushed stone are presented in Table 13. One should regard these forecasts as only rough indicators of the expected long-term trends in demand for each area.

Table 13. Projections of annual demand for 2030

Model	Growth Rate		Annual Production[a]	
	Sand/Gravel	Stone	Sand/Gravel	Stone
STATEWIDE				
Growth Rate (1950-1976)	3.7%	5.2%	157.4	269.1
Simulation[b] (1963-1990)	2.0%	3.6%	62.8	114.4
PORTLAND				
Growth Rate (1950-1976)	3.2%	9.1%	38.9	439.0
Growth Rate (1964-1976)	6.4%	5.7%	48.7	83.8
Simulation[b] (1963-1990)	2.0%	6.0%	20.9	96.8
JACKSON				
Growth Rate (1950-1976)	2.9%	7.5%	2.9	51.7
Simulation[b] (1963-1990)	2.4%	2.6%	2.5	6.3
UMATILLA				
Growth Rate (1950-1976)	c	3.0%	c	2.4
Simulation[b] (1963-1990)	2.3%	2.5%	1.3	2.0
LINCOLN	All Rock		All Rock	
Growth Rate (1950-1976)	5.3%		10.6	
Simulation[b] (1963-1990)	1.9%		1.7	

[a] Millions of short tons per year in 2030.

[b] Based on mid-range values of the explanatory variables.

[c] Estimated coefficient has no statistical validity.

Note: These projections are based on Bureau of Mines data and also represent only the predictable component of total demand. Refer to pages 15 and 16.

The projected demand for stone in Portland exemplifies the hazardous complexities in very long range forecasts. Using production data growth trends to forecast, the suggested demand for stone in Portland in 2030 is 439 million short tons, more than one and one-half times the statewide demand for stone (269.1 million short tons) predicted with the comparable statewide production data. Early-year reporting errors in the data, along with other factors, have so inflated the estimated growth rate for stone in the Portland area that very long term projections become nonsensical.

CHAPTER 6

DEMAND FOR LIGHTWEIGHT AGGREGATES AND DEMAND IN THE WILLAMETTE NATIONAL FOREST

Abstract

In the other chapters our analysis focused on the demand for sand and gravel and for crushed stone arising from general economic forces. The analysis excluded lightweight aggregates--cinders, pumice, and shale used for concrete--and the U.S. Forest Service's use of sand and gravel and crushed stone on roads in the state's national forests. Our analysis of the statewide production of lightweight aggregates and of the Willamette National Forest's use of crushed stone found insufficient information readily available to support meaningful models.

Lightweight Aggregates

Basically, three specific commodities--cinders, expanded shale and pumice--comprise the category broadly labelled lightweight aggregates. They are used as the rock material in concrete. Except for expanded shale, which was produced until 1977 in Washington County, these commodities have come primarily from counties in eastern Oregon. The total quantity of lightweight aggregates produced in Oregon is small. The Bureau's data show only about 298,000 tons per year between 1970 and 1976.

Essentially no quantitative analysis exists regarding the small and dispersed demand for lightweight aggregates. Further, the demand for these materials likely is highly dependent upon the market conditions for substitute building materials, as well as on general economic conditions. Thus complex analysis of the demand for lightweight materials would require extensive analysis of the markets for many construction materials and the expected utility of this analysis is quite low. Consequently, our analysis of the demand for the lightweight materials is based only on a simple, growth-rate model.

For the period 1957-1976, the combined production of these materials grew with a mean annual rate of 2.67 percent. This rate is quite reliable; the probability that the true rate of growth equals zero is 0.0001. The mean level of annual production for this period was 250,000 tons. Extending the growth rate into the future indicates production of 400,000 tons in 1985 and 460,000 tons in 1990.

The Willamette National Forest

Large amounts of rock material, especially crushed stone, are used for road construction and maintenance on forested lands. Almost totally, these roads serve to give logging vehicles access to timber stands. The mining sites producing the rock for logging roads generally are away from populated areas and use of the material seldom requires market transactions. For example, on national forest lands logging companies undertake most road building as incidental requirements within timber-sales contracts. As a consequence, very little is known about the amount of rock used on timberlands or about the forces determining demand.

To begin expanding the knowledge in these areas, we examined the production of rock (crushed stone) in the Willamette National Forest (WNF). The U.S. Forest Service does not maintain records on the amounts of rock extracted from the WNF, except in only the past few years. However, the Forest Service's records do show the miles of road constructed and reconstructed from 1956 through 1977. Also, the Forest Service estimates that road construction consumes 4,800 tons of rock per mile while reconstruction uses 1,800 tons per mile. Finally, the Forest Service estimates that maintenance efforts presently cover about 4,000 miles of road per year and use a fairly constant amount of rock--about 150,000 tons annually. By combining all these figures, one can estimate the amount of rock produced in the WNF annually.

Historically, the number of miles of new construction generally has decreased over time, but in an erratic pattern. The miles of reconstruction, though, have increased at a fairly constant rate of about 16.8 percent per year. For the future, the Forest Service estimates it will build 3,000 miles of new road over the next 30 years.[12] Reconstruction efforts should continue at about 250 miles per year.

We tried two approaches to analyze the demand for rock in the WNF. First, we looked at the historical trends in growth rates. Although the amount of rock used in reconstruction grew quite steadily at 16.8 percent annually, the amount used for new construction was very erratic and no clear trend was identifiable for total production. In the second approach, we reasoned that a primary determinant of rock production in the WNF would be the amount of timber harvested. Thus, we examined an econometric model using the amount of harvest as the explanatory variable. Again, however, the model showed no relationship.

In an attempt to gain some insight into the problem, we repeated the analysis using the Bureau's data for "various counties," comprised almost entirely of production from all the state's national forest lands. Neither sand and gravel nor crushed stone showed any consistent growth trends between 1950 and 1976. However, when we modelled production against total timber harvest from all national forests, we found results explaining 40 to 46 percent of the variation in rock usage. The stone model showed that production increased 3.43 tons as total harvest increased by one million board feet. The intercept for this model was -5,093,741 tons and the R^2 was 0.46. For sand and gravel, the model's parameters were: intercept, 3,361,701 tons; coefficient for harvest, -1.07 tons per million board feet; and R^2, 0.40.

By themselves, these results do not explain timber-related demand for rock with any reliability. However, they do indicate possible explanatory relationships between production and harvest which might be identified with more reliable data or alternative modelling techniques, or both.

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[12] Interview with Bill Vischer, Willamette National Forest.

APPENDIX

The purpose of this technical appendix is to provide supplementary data analysis to complement and more fully substantiate the arguments in the main report. All the information reported in this appendix adds supporting evidence to the choice of models for describing and forecasting demand. We examined many models which are not reported either here or elsewhere. While these other models were constructed from sound theoretical premises, problems such as the available data and/or the choice of modelling technique interferred with the derivation of useful information. Thus, only the models which we feel add insight to the major models (those used in the argument of the main report) are included in the tables of this appendix.

The tables record test statistics which are not included in the main report. The t-statistic for each intercept and estimated coefficient is contained in the appended tables along with the F-ratio and the standard error for each regression equation. In the spirit of maintaining readability for a general audience, these statistics were intentionally omitted in the main document. Some information interpretive of these test statistics--for example a statement of the probability that an estimated coefficient is zero--is contained in the body of the report.

Specifically, Tables 14 through 24 report statistical modelling results of growth-rate and econometric analyses in the statewide and the four substate market areas. The growth-rate analyses reported include those for historic data from 1950-1976, 1964-1976, and 1967-1976 (in only the statewide market).

The tables of econometric results list 8 different models for the state and Portland. The first 6 of these include the full model (price, population, employment, and highway expenditures) for 1963-1976 which is used in the main report. A model without highway expenditures developed with the 1963-1976 data is presented (this model indicates most directly the explanatory power lost by excluding highways from the analysis) along with the comparable model derived from 1956-1976. Also the regressions of production against only price and population, price and employment, and income are included.

The econometric models reported for Jackson, Lincoln, and Umatilla Counties correspond to the first six modelling forms for the state and Portland areas. Many regressions for the smaller areas had no descriptive power; these are omitted from the appended tables.

The final two econometric models reported for the state and Portland evaluate specific additional relationships related to the major arguments of the study. These models are numbers 7 and 8 in the tables of econometric models for sand and gravel and for stone in the Portland and statewide market areas. Model 7 is a three-year moving average regression which hypothesizes that demand in year 3 results from price in year 3 and the cumulative average effects in employment and population over the past 3 years. The purpose in using a moving average model is to account for the time lags between independent events--like increases in service related employment--and the direct impact on rock material demand. Also these models may sometimes reduce time correlation between independent variables by accounting for lags in their co-relationship. Employment and population are highly correlated; the moving average model was neither able to reduce that correlation nor to improve the t-statistic on these two variables. The variation in production is better explained with a moving average model only in the case of stone production in Portland. Model 7 verifies a time lag from the year of measurement of economic indicators, which affect sand and gravel demand immediately, and the subsequent impact on stone demand.

Econometric Model 8 for Portland and the statewide market estimates the natural logarithm, or percentage growth, in demand as a function of the natural logarithms of employment, population, and the ratio of the price of sand and gravel to the price of stone. The model corresponds to an hypothesis that the variation in growth of demand for rock materials over time is explained by the growth in population, employment, and the price ratio.

Our objective in formulating Model 8 was to test the historic responsiveness of the demand for sand and gravel or for stone to changes in the relative prices of the two goods. The statewide result for sand and gravel is a nearly zero coefficient for the price ratio--0.009--with a nearly zero t-statistic of 0.03. Relative prices have virtually no effect on the demand for sand and gravel. For the statewide demand for stone, the logarithmic coefficient of the relative price is 0.904 which is significant at the 5 percent level. Model 8 estimates that if the price ratio increases by 10 percent then the statewide demand for stone will increase by about 9 percent while the demand for sand and gravel will not change. The change in relative prices may occur, for instance, because population and employment grow and increase the demand for and the price of sand and gravel. The increased price of sand and gravel relative to stone does not affect demand for sand and gravel but does increase the demand for the substitute good, stone.

For the Portland area, Model 8 demonstrates that in a developed economy the substitution of the cheaper good for the more expensive one is more likely to take place. The coefficients on the price ratio terms suggest that a 10 percent increase in the ratio of the price of sand and gravel to the price of stone, occurring in isolation, will produce: (1) a three percent decrease in the demand for sand and gravel; and (2) an 11 percent increase in the demand for stone. The market for both commodities is tested to be much more responsive to relative price effects than the statewide market.

One conclusion from Models 7 and 8 is that the sand and gravel market is more highly developed and more fully integrated into the overall economy. Model 7 verifies that especially in the well developed urban economy where public works projects do not weigh so heavily in demand, the demand for stone occurs through a lagged process, likely as a result of changing relative prices due to excess demand for sand and gravel. The demand for sand and gravel, on the other hand, is better explained by the value of same-year variables.

In addition to the full descriptions of the models, this appendix also contains other information. Table 25 shows, for the major econometric models, the correlation coefficients for the "b values" of the explanatory variables. The correlation coefficients measure the degree of multicollinearity within the data for the variables.

The subsequent tables provide the data for the explanatory variables we used and production data for the state as a whole and for groupings of all the counties in the state. Grouping the data was necessary to protect producers' confidential information. One can replicate our models for the Portland area using the production data from Table 32. Reproducing the production data we used to develop the statewide models will require subtracting from the total statewide production (Table 31) both the production unallotted to counties (Table 45) and the production used in major dam projects (Table 46).

Table 14. Growth-rate models for sand and gravel

Model No.	Dependent Variable	Intercept	(t-statistic)	Coefficient of time[a]	(t-statistic)	R^2	F-Ratio	Se[b]
Statewide								
(1)	1950-76 Ln Production	15.94	(185.81)	.0374	(6.98)	0.66	48.75	0.216
(2)	1964-76 Ln Production	16.74	(230.98)	-.0015	(-0.16)	0.00	0.03	0.123
(3)	1967-76 Ln Production	16.71	(194.28)	.0017	(0.12)	0.00	0.02	0.126
Portland								
(4)	1950-76 Ln Production	14.93	(153.41)	.032	(5.31)	0.53	28.20	0.248
(5)	1964-76 Ln Production	15.18	(138.37)	.064	(4.64)	0.66	21.49	0.186
Jackson								
(6)	1950-76 Ln Production	12.63	(56.01)	.029	(2.03)	0.14	4.11	0.570
(7)	1964-76 Ln Production	12.84	(44.84)	.032	(0.89)	0.07	0.79	0.487
Umatilla								
(8)	1950-76 Ln Production	12.27	(49.19)	.007	(0.47)	0.22	0.22	0.630
(9)	1964-76 Ln Production	12.34	(26.95)	.005	(0.08)	0.00	0.01	0.777

[a]Coefficient of time is the growth rate.

[b]Standard error.

Table 15. Growth-rate models for crushed stone

Model No.	Dependent Variable	Intercept	(t-statistic)	Coefficient[a] of Time	(t-statistic)	R^2	F-Ratio	Se[b]
Statewide								
(1)	1950-76 Ln Production	15.32	(88.79)	.052	(4.87)	0.49	23.69	0.436
(2)	1964-76 Ln Production	16.37	(119.22)	.013	(0.78)	0.05	0.61	0.232
(3)	1967-76 Ln Production	15.96	(148.35)	.061	(3.51)	0.61	12.32	0.157
Portland								
(4)	1950-76 Ln Production	12.93	(65.49)	.091	(7.40)	0.69	54.70	0.499
(5)	1964-76 Ln Production	14.44	(98.35)	.057	(3.06)	0.46	9.36	0.250
Jackson								
(6)	1950-76 Ln Production	11.98	(36.35)	.075	(3.64)	0.35	13.26	0.833
(7)	1964-76 Ln Production	12.41	(21.31)	.137	(1.86)	0.24	3.48	0.990
Umatilla								
(8)	1950-76 Ln Production	12.36	(53.01)	.030	(2.03)	0.14	4.13	0.589
(9)	1964-76 Ln Production	12.72	(42.91)	.020	(0.54)	0.03	0.29	0.504
Lincoln								
(10)	1950-76 Ln All Rock[c]	12.07	(69.65)	.052	(4.87)	0.49	23.71	0.438
(11)	1964-76 Ln All Rock[c]	12.75	(22.57)	.018	(0.63)	0.04	0.40	0.392

[a]Coefficient of time is the growth rate.

[b]Standard error.

[c]All rock material production in Lincoln County is stone.

Table 16. Growth-rate models for all rock material

Model No.	Dependent Variable	Intercept	(t-statistic)	Coefficient[a] of Time	(t-statistic)	R^2	F-Ratio	Se[b]
Statewide								
	1950-76 Ln Production	16.41	(168.81)	.0418	(6.89)	0.65	47.42	0.25
	1964-76 Ln Production	17.21	(219.40)	.0053	(0.54)	0.03	0.29	0.13
	1967-76 Ln Production	17.15	(223.76)	.0153	(1.35)	0.17	1.83	0.12
Portland								
	1950-76 Ln Production	15.08	(175.82)	.0436	(8.14)	0.72	66.25	0.22
	1964-76 Ln Production	17.58	(156.65)	.0615	(4.91)	0.69	24.07	0.17
Jackson								
	1950-76 Ln Production	12.99	(52.10)	.0588	(3.78)	0.36	14.26	0.62
	1964-76 Ln Production	13.24	(32.92)	.1124	(2.22)	0.31	4.92	0.68
Lincoln								
	1950-76 Ln Production	12.07	(69.65)	.0527	(4.87)	0.49	23.71	0.438
	1964-76 Ln Production	12.75	(22.57)	.0183	(0.63)	0.04	0.40	0.392
Umatilla								
	1950-76 Ln Production	13.09	(62.02)	.0179	(1.36)	0.07	1.85	0.53
	1964-76 Ln Production	13.28	(37.78)	.0115	(0.26)	0.01	0.07	0.60

[a] Coefficient of time is the growth rate.

[b] Standard error.

Table 17. Econometric models of the statewide demand for sand and gravel

Model No.	Dependent Variable	Coefficients of Explanatory Variables (t-statistic) Intercept	Price	Population	Employment	Highway Expenditures	Income	R^2	F-Ratio	Se[a]
(1)[b]	Production (1963-1976)	-8,282,846 (-0.77)	4,146,131 (0.96)	-11.99 (-1.41)	45.39 (2.55)	0.086 (4.03)		0.75	6.6	1,451,100
(2)	Production (1963-1976)	16,221 (0.00)	8,217,281 (1.23)	-15.73 (-1.18)	48.46 (1.72)			0.29	1.34	2,306,600
(3)	Production (1956-1976)	3,174,190 (0.35)	4,328,572 (1.05)	-17.44 (-1.23)	54.58 (2.01)			0.55	6.85	2,537,617
(4)	Production (1956-1976	-8,973,755 (-1.24)	3,856,321 (0.86)	10.52 (3.36)				0.44	7.1	2,743,046
(5)	Production (1956-1976)	-5,240,266 (-0.88)	3,805,631 (0.91)		29.95 (3.91)			0.51	9.26	2,572,897
(6)	Production (1969-1976)	15,670,553 (7.22)					0.21 (1.33)	0.23	1.76	2,372,700
(7)	Production[c,d] (1956-1976)	-20,663,736 (-1.55)	11,830,941[d] (3.19)	30.78[e] (1.36)	-47.84[e] (-1.11)			0.59	6.15	2,173,600
(8)	Ln Production (1956-1976)	9.697 (1.03)	0.009[f] (0.03)	-2.092[g] (-1.06)	2.745[g] 1.85			0.56	7.07	0.160

[a]Standard error.
[b]For correlation coefficients on this model see Table 25.
[c]This is a moving-average model.
[d]Production and price in the third year of each three-year period.
[e]Coefficient for the three-year average value of the variable.
[f]Coefficient for ln (price of sand and gravel ÷ price of stone).
[g]Coefficient for ln of the variable.

Table 18. Econometric models for the statewide demand for stone

Model No.	Dependent Variable	Coefficients of Explanatory Variables (t-statistic): Intercept	Price	Population	Employment	Highway Expenditures	Income	R^2	F-Ratio	Se[a]
(1)[b]	Production (1963-1976)	29,836,530 (1.48)	-9,335,489 (-1.54)	2.2 (0.11)	-7.34 (-0.19)	-0.023 (-0.49)		0.25	0.74	3,229,900
(2)	Production (1963-1976)	25,490,651 (1.45)	-9,384,795 (-1.61)	2.92 (0.16)	-6.49 (-0.18)			0.23	0.98	3,106,000
(3)	Production (1956-1976)	13,603,374 (1.10)	-9,161,208 (-1.89)	-2.05 (-0.06)	6.53 (0.36)			0.56	7.07	3,109,276
(4)	Production (1956-1976)	14,151,846 (1.83)	-9,247,957 (-2.07)	5.51 (1.56)				0.23	2.63	3,021,986
(5)	Production (1956-1976)	17,350,597 (2.62)	-9,600,645 (-2.10)		10.47 (1.51)			0.22	2.54	3,033,480
(6)	Production (1969-1976)	9,862,784 (3.28)					0.22 (1.02)	0.15	1.05	3,286,200
(7)	Production[c,d] (1956-1976)	18,012,809 (1.04)	-10,673,088[d] (-1.97)	10.18[e] (0.34)	-13.25[e] (-0.23)			0.28	1.71	2,764,700
(8)	Ln Production (1956-1976)	4,552 (0.30)	0.904[c] (2.13)	1.117[g] (0.35)	-0.319[g] (-0.132)			0.28	2.15	0.259

[a]Standard error.
[b]For correlation coefficients on this model, see Table 25.
[c]This is a moving-average model.
[d]Production and price in the third year of each three-year period.
[e]Coefficient for the three-year average value of the variable.
[f]Coefficient for ln (price of sand and gravel ÷ price of stone).
[g]Coefficient for ln of the variable.

Table 19. Econometric models of the demand for sand and gravel in the Portland Metropolitan Area

Model No.	Dependent Variable	Coefficients of Explanatory Variables (t-statistic)						R^2	F-Ratio	Se[a]
		Intercept	Price	Population	Employment	Highway Expenditures	Income			
(1)[b]	Production (1963-1976)	3,572,790 (0.73)	-4,616,027 (-2.83)	5.50 (1.44)	8.61 (0.93)	0.033 (1.73)		0.93	30.52	597,240
(2)	Production (1963-1976)	7,928,651 (1.72)	-5,954,574 (-3.78)	6.17 (1.48)	2.82 (0.30)			0.91	33.03	654,740
(3)	Production (1956-1976)	-4,187,145 (-1.41)	-2,133,241 (-1.67)	13.60 (4.57)	3.82 (1.18)			0.85	27.39	848,400
(4)	Production (1956-1976)	-6,026,188 (-2.72)	-1,348,390 (-1.36)	16.17 (8.84)				0.84	46.16	809,790
(5)	Production (1956-1976)	7,673,086 (3.54)	-5,467,529 (-3.47)		14.70 (4.50)			0.63	13.68	1,270,181
(6)	Production (1956-1976)	7,006,693 (3.20)					0.08 (0.23)	0.01	0.05	1,295,400
(7)	Production[c,d] (1956-1976)	-14,036,142 (-3.73)	2,869,535[d] (1.68)	23.91[e] (4.19)	-10.45[e] (-1.07)			0.79	16.51	1,013,900
(8)	Ln Production (1956-1976)	-17.66 (-3.96)	-.304[f] (-1.135)	2.41[g] (7.03)	.027[g] (0.60)			0.83	23.89	0.161

[a] Standard error.
[b] For correlation coefficients on this model, see Table 25.
[c] This is a moving-average model.
[d] Production and price in the third year of each three-year period.
[e] Coefficient for the three-year average value of the variable.
[f] Coefficient for ln (price of sand and gravel ÷ price of stone).
[g] Coefficient for ln of the variable.

Table 20. Econometric models of the demand for stone in the Portland Metropolitan Area

Model No.	Dependent Variable	Coefficients of Explanatory Variables (t-statistic): Intercept	Price	Population	Employment	Highway Expenditures	Income	R^2	F-Ratio	Se[a]
(1)[b]	Production	-1,601,970	-2,502,933	-5.52	31.9	.014		0.70	5.29	658,710
	(1963-1976)	(-0.53)	(-1.69)	(-1.42)	(3.13)	(.076)				
(2)	Production	-1,253,424	-2,513,233	-4.34	29.37			0.68	7.15	644,980
	(1963-1976)	(-0.43)	(-1.74)	(-1.25)	(3.11)					
(3)	Production	-898,184	-1,455,246	5.52	2.16			0.53	5.25	795,560
	(1956-1976)	(-0.36)	(-1.12)	(2.32)	(0.81)					
(4)	Production	-2,374,016	-1,269,100	7.75				0.51	9.41	864,234
	(1956-1976)	(-0.94)	(-0.94)	(4.07)						
(5)	Production	3,231,120	-2,256,424		6.20			0.36	4.49	897,870
	(1956-1976)	(1.71)	(-1.59)		(2.71)					
(6)	Production	1,337,536					0.29	0.23	1.81	832,470
	(1969-1976)	(0.95)					(1.35)			
(7)	Production[c,d]	-5,747,212	1,944,956[d]	4.70[e]	5.51[e]			0.62	7.22	697,430
	(1956-1976)	(-2.72)	(1.72)	(1.58)	(1.07)					
(8)	Ln Production	-25.30	1.11[f]	3.01[g]	-0.08[g]			0.67	10.21	0.269
	(1956-1976)	(-3.40)	(2.49)	(5.26)	(-1.05)					

[a] Standard error.
[b] For correlation coefficients on this model, see Table 25.
[c] This is a moving-average model.
[d] Production and price in the third year of each three-year period.
[e] Coefficient for the three-year average value of the variable.
[f] Coefficient for ln (price of sand and gravel ÷ price of stone).
[g] Coefficient for ln of the variable.

Table 21. Econometric models of the demand for sand and gravel and for stone in Jackson County

Model No.	Dependent Variable	Coefficients of Explanatory Variables (t-statistic) Intercept	Price	Population	Employment	Highway Expenditures	Income	R^2	F-Ratio	Se[a]
(1)[b]	Production Sand & Gravel (1963-1976)	-1,130,726 (-0.68)	1,004,474 (0.99)	-14.12 (-0.36)	39.17 (0.65)	.054 (1.65)		0.35	1.20	310,550
(2)	Production Sand & Gravel (196301976)	-716,881 (-0.40)	1,218,495 (1.12)	-4.10 (-0.10)	-0.07 (-0.00)			0.16	0.62	335,260
(3)	Production Sand & Gravel (1956-1976)	422,147 (0.36)	-256,956 (-0. 33)	30.86 (1.15)	-67.22 (-1.44)			0.16	0.94	413,870
(4)	Production Sand & Gravel (1969-1976)	171,490 (0.82)					0.85 (1.97)	0.34	3.87	224,880
(5)[b]	Production Stone (1963-1976)	-12,089,322 (-2.32)	-943,763 (-2.09)	269.61 (2.90)	-315.54 (-2.06)	-.014 (-0.14)		0.72	5.86	878,070
(6)	Production Stone (1963-1976)	-12,261,980 (-2.54)	-934,903 (-2.20)	266.09 (3.12)	-303.60 (-2.47)			0.72	8.65	834.420
(7)	Production Stone (1956-1976)	-1,971,398 (-0.92)	-1,249,999 (-3.38)	102.90 (1.82)	-131.13 (-1.28)			0.56	6.45	873,570
(8)	Production Stone (1969-1976)	-1,363,166 (-1.10)					6.36 (2.49)	0.51	6.22	1,330,700

[a] Standard error.
[b] For correlation coefficients on this model, see Table 25.

Table 22. Econometric models of the demand for sand and gravel and for stone in Umatilla County

Model No.	Dependent Variable	Coefficients of Explanatory Variables (t-statistic) Intercept	Price	Population	Employment	Highway Expenditures	Income	R^2	F-Ratio	Se[a]
(1)[b]	Production									
	Sand & Gravel	2,841,029	727,545	-180.29	247.12	-.006		0.52	2.41	319,370
	(1963-1976)	(0.60)	(2.39)	(-1.07)	(1.38)	(-0.12)				
(2)	Production									
	Sand & Gravel	3,137,925	715,417	-191.32	257.87			0.52	3.55	303,320
	(1963-1976)	(0.81)	(2.61)	(-1.40)	(1.73)					
(3)	Production									
	Sand & Gravel	-427,006	577,833	-19.30	42.60			0.33	2.34	303,430
	(1956-1976)	(-0.13)	(2.18)	(-0.21)	(0.53)					
(4)	Production									
	Sand & Gravel	91,152					0.62	0.51	6.23	62,798
	(1969-1976)	(1.61)					(2.49)			
(5)[b]	Production									
	Stone	688,788	93,564	-14.72	16.96	-.008		0.04	0.09	307,250
	(1963-1976	(0.15)	(0.42)	(-0.09)	(0.09)	(-0.18)				
(6)	Production									
	Stone	1,009,928	91,247	-28.32	31.53			0.04	0.13	292,060
	(1956-1976)	(0.25)	(0.43)	(-0.20)	(0.20)					
(7)	Production									
	Stone	235,022	72,619	15.75	-31.57			0.03	0.13	276,960
	(1956-1976)	(0.09)	(0.38)	(0.19)	(-0.41)					
(8)	Production									
	Stone	295,722					0.58	0.05	0.32	263,400
	(1969-1976)	(1.25)					(0.56)			

[a]Standard error.

[b]For correlation coefficients on this model, see Table 25.

Table 23. Econometric models of the demand for rock in Lincoln County

Model No.	Dependent Variable	Coefficients of Explanatory Variables (t-statistic) Intercept	Price	Population	Employment	Highway Expenditures	Income	R^2	F-Ratio	Se[a]
(1)[b]	Total Rock Production (1963-1976)	3,658,683 (1.97)	-154,776 (-1.10)	-212.6 (-1.71)	269.2 (1.84)	-.008 (-0.10)		0.40	1.48	170,950
(2)	Total Rock Production (1963-1976)	3,556,203 (2.38)	-157,021 (-1.19)	-206.62 (-1.99)	263.15 (2.07)			0.40	2.18	162,170
(3)	Total Rock Production (1956-1976)	91,753 (1.75)	53,637 (0.94)	4.93 (1.54)	22.16 (2.19)			0.61	17.2	149,330

[a]Standard error.

[b]For correlation coefficients on this model, see Table 25.

Table 24. Econometric models of the demand for all rock material in the statewide, Portland, Jackson County, and Umatilla County areas

Model No.	Dependent Variable	Coefficients of Explanatory Variables (t-statistic) Intercept	Price	Population	Employment	Highway Expenditures	Income	R^2	F-Ratio	Se[a]
Statewide										
	1963-76	1,272,446	5,473,334	-0.80	21.93	0.064		0.17	0.45	4,221,800
	Production	(0.03)	(0.33)	(-0.03)	(0.45)	(1.04)				
Portland										
	1963-76	1,440,651	-6,667,195	0.39	39.54	0.046		0.91	22.12	961,120
	Production	(0.20)	(-2.41)	(0.06)	(2.70)	(1.52)				
Jackson										
	1963-76	-7,889,165	-2,826,862	259.09	-326.19	0.063		0.82	10.36	735,390
	Production	(-1.64)	(-3.50)	(3.32)	(-2.55)	(0.81)				
Umatilla										
	1963-76	3,724,365	612,817	-165.57	193.05	0.008		0.20	0.57	636,080
	Production	(0.35)	(0.96)	(-0.44)	(0.49)	(0.09)				

[a] Standard error.

Table 25. Correlation of b values for major econometric models

Model No.	Dependent Variable (Table No.)*	Explanatory Variable	Correlation Coefficient Intercept	Price	Highway Expenditure	Population
Statewide						
(1)	Production	Price	-.73			
	Sand & Gravel	Highway Expenditures	-.19	-.23		
	(1963-76)	Population	-.32	-.13	.11	
	(Table 16)*	Employment	-.05	-.35	-.04	-.92
Statewide						
(1)	Production	Price	-.57			
	Stone	Highway Expenditures	-.43	-.02		
	(1963-76)	Population	-.63	.25	.07	
	(Table 17)*	Employment	.38	-.22	.05	-.94
Portland						
(1)	Production	Price	-.93			
	Sand & Gravel	Highway Expenditures	-.51	.47		
	(1963-76)	Population	-.39	.47	-.10	
	(Table 18)*	Employment	-.37	.16	.36	-.68
Portland						
(1)	Production	Price	-.76			
	Stone	Highway Expenditures	-.15	.01		
	(1963-76)	Population	-.12	.30	-.40	
	(Table 19)*	Employment	-.27	-.17	.32	-.87
Jackson						
(1)	Production	Price	-.21			
	Sand & Gravel	Highway Expenditures	-.15	-.13		
	(1963-76)	Population	-.58	-.54	-.16	
	(Table 20)*	Employment	.39	.45	.40	-.94
Jackson						
(5)	Production	Price	-.47			
	Stone	Highway Expenditures	-.23	.13		
	(1963-76)	Population	-.78	.09	-.26	
	(Table 20)*	Employment	.42	.15	.53	-.83
Umatilla						
(1)	Production	Price	-.49			
	Sand & Gravel	Highway Expenditures	.50	-.32		
	(1963-76)	Population	-.96	.33	-.52	
	(Table 21)*	Employment	.84	-.18	.48	-.95
Umatilla						
(5)	Production	Price	-.50			
	Stone	Highway Expenditures	.39	-.06		
	(1963-76)	Population	-.98	.43	-.45	
	(Table 21)*	Employment	.90	-.41	.44	-.97
Lincoln						
	Production	Price	.00			
	All Rock	Highway Expenditures	-.54	-.16		
	(1963-76)	Population	-.97	-.15	.47	
	(Table 22)*	Employment	.91	.18	-.40	-.98

*The table containing the parameters of the model.

Table 26. Estimated average population for each study area: 1950-1976

Year	Oregon	Portland Area	Jackson County	Lincoln County	Umatilla County
1950	1,521,341	271,478	58,510	21,308	41,703
1951	1,568,000	275,200	61,300	23,200	43,300
1952	1,602,100	282,200	63,000	23,200	47,500
1953	1,636,800	294,600	63,000	23,200	47,600
1954	1,662,680	303,840	64,740	23,390	43,320
1955	1,690,840	314,930	65,790	23,440	43,550
1956	1,734,650	736,590	70,840	24,000	45,320
1957	1,737,470	750,450	71,750	25,300	43,840
1958	1,726,630	716,960	68,660	24,480	42,350
1959	1,777,000	720,950	71,300	24,900	44,750
1960	1,768,687	750,467	73,962	24,635	44,352
1961	1,816,345	762,567	76,523	24,252	44,726
1962	1,825,138	711,424	80,346	23,275	43,643
1963	1,851,690	720,902	83,647	22,487	43,193
1964	1,906,000	733,840	87,473	22,425	42,917
1965	1,972,150	756,400	92,100	23,200	43,100
1966	1,999,780	765,200	95,000	23,400	43,500
1967	2,006,360	766,500	95,000	23,550	43,800
1968	2,050,900	788,745	95,000	25,065	44,590
1969	2,081,640	799,810	93,700	25,130	45,370
1970	2,091,385	909,465	94,533	25,755	44,923
1971	2,143,010	934,130	97,620	25,840	45,120
1972	2,183,270	955,770	100,100	26,100	45,450
1973	2,224,900	954,300	105,000	27,000	46,400
1974	2,266,000	962,360	108,100	27,300	47,250
1975	2,299,000	973,500	110,700	27,650	48,200
1976	2,341,750	987,200	113,000	28,100	50,000

SOURCE: Center for Population Research and Census, Portland State University.

Table 27. Estimated average total employment for each study area: 1950-1976

Year	Oregon	Portland Area	Jackson County	Lincoln County	Umatilla County
1950	607,500	--	--	--	--
1951	629,100	--	--	--	--
1952	631,100	--	--	--	--
1953	631,500	--	--	--	--
1954	623,700	--	--	--	--
1955	644,900	--	--	--	--
1956	662,000	--	--	--	--
1957	646,500	--	--	--	--
1958	644,300	6,470	24,340	7,480	--
1959	672,200	291,250	24,530	7,320	15,590
1960	682,300	298,120	24,590	7,540	15,630
1961	679,300	296,390	24,210	6,940	15,950
1962	695,000	305,980	25,440	7,040	16,400
1963	712,700	315,570	26,290	6,960	16,160
1964	738,300	326,240	29,500	7,320	16,550
1965	775,800	341,310	30,990	7,880	16,770
1966	807,300	355,170	32,440	7,990	17,350
1967	817,500	362,850	33,330	8,320	17,970
1968	843,500	378,000	34,920	8,580	17,820
1969	872,200	397,710	35,820	8,570	17,380
1970	802,800	364,243	34,200	9,560	17,630
1971	834,600	373,590	37,960	9,850	18,860
1972	893,700	398,593	41,610	10,550	19,600
1973	939,000	419,138	44,050	11,180	19,610
1974	939,000	423,294	43,150	10,970	19,890
1975	929,000	416,196	42,910	11,060	20,920
1976	929,000	428,286	44,500	11,770	22,900

SOURCE: Oregon Employment Division, Research and Statistics Section.

Table 28. Estimated annual real expenditures for road construction and maintenance by the Oregon Department of Transportation in each study area: 1963-1976

Year	Oregon	Portland Area	Jackson County	Lincoln County	Umatilla County
1963	83,876,776	17,268,000	9,017,643	901,391	2,276,637
1964	110,810,992	22,753,184	9,860,800	1,456,894	1,742,624
1965	127,004,896	24,546,224	14,134,075	2,433,407	1,097,336
1966	112,946,896	18,550,848	7,997,081	2,089,227	1,256,760
1967	98,996,640	20,751,296	3,269,281	2,805,529	4,279,912
1968	85,626,880	28,494,928	2,690,447	2,154,106	8,025,987
1969	75,233,248	32,653,312	3,176,832	1,416,594	8,749,262
1970	77,209,504	38,448,368	2,641,788	455,004	4,119,925
1971	110,579,600	51,449,760	2,405,396	1,055,754	3,101,396
1972	108,895,296	36,851,840	2,166,263	2,341,577	3,185,785
1973	113,293,392	37,138,400	3,068,601	1,895,701	4,559,171
1974	54,833,648	15,139,662	1,320,764	629,260	3,194,749
1975	71,303,312	16,980,080	1,369,887	1,062,208	2,556,017
1976	90,171,792	19,502,928	3,582,871	919,567	2,962,520

SOURCE: Oregon Department of Transportation, Policy and Program Development Section.

Table 29. Estimated average real price of crushed stone for each study area: 1956-1976

Year	Oregon	Portland Area	Jackson County	Lincoln County	Umatilla County
1956	1.47	1.26	1.77	1.57	1.42
1957	1.15	1.40	1.75	1.60	1.30
1958	1.08	1.19	1.76	1.56	1.01
1959	1.27	1.60	1.49	1.48	1.26
1960	1.25	1.22	0.85	1.46	1.33
1961	1.29	1.34	1.97	1.72	1.31
1962	1.21	1.05	1.64	1.52	1.20
1963	1.29	1.29	1.47	1.31	1.27
1964	1.19	1.28	1.69	1.52	1.41
1965	1.31	1.25	2.01	1.48	1.43
1966	1.58	1.58	2.78	2.91	1.92
1967	1.62	1.42	2.34	1.84	1.88
1968	1.48	1.26	1.62	1.71	1.28
1969	1.54	1.47	2.01	1.93	1.44
1970	1.42	1.26	1.87	1.79	1.47
1971	1.65	1.44	2.79	1.96	2.85
1972	1.38	1.19	1.11	1.46	1.54
1973	1.27	1.09	1.22	1.81	1.21
1974	1.38	1.45	0.97	1.60	1.37
1975	1.21	1.25	0.71	1.75	1.34
1976	1.27	1.22	0.96	1.70	1.37

Table 30. Estimated average real price of sand and gravel for each study area: 1956-1976

Year	Oregon	Portland Area	Jackson County	Lincoln County	Umatilla County
1956	1.14	1.11	1.33	0.00	1.14
1957	1.15	1.30	1.22	1.82	1.21
1958	1.07	1.09	1.40	1.34	1.12
1959	0.92	1.12	1.37	1.51	1.06
1960	1.02	1.12	1.08	1.25	1.46
1961	1.22	1.23	1.29	1.09	1.33
1962	1.13	1.22	1.03	1.10	1.58
1963	1.26	1.49	1.45	1.41	1.45
1964	1.45	1.54	1.37	1.33	1.38
1965	1.57	1.67	1.47	1.54	1.53
1966	1.33	1.65	1.33	1.43	2.12
1967	1.29	1.50	1.57	2.11	2.19
1968	1.13	1.36	1.39	4.82	1.74
1969	1.21	1.36	1.32	1.20	1.61
1970	1.34	1.30	1.30	1.50	1.70
1971	1.20	1.24	1.32	1.36	0.87
1972	1.14	0.97	1.31	1.05	1.42
1973	1.16	1.18	1.32	1.45	1.39
1974	1.26	1.40	1.40	1.38	1.33
1975	1.19	1.23	1.34	1.21	1.18
1976	1.18	1.18	1.64	1.25	1.18

Table 31. Annual production and value, 1940-1976, for sand and gravel, and crushed stone (including road metal cinders): Oregon

Year	Sand and Gravel Production (tons)	Sand and Gravel Value ($)	Crushed Stone Production (tons)	Crushed Stone Value ($)	Total Production (tons)	Total Value ($)
1940	2,939,132	1,337,389	2,787,140	2,249,365	5,726,272	3,586,754
1941	3,968,395	2,159.470	2,836,390	2,436,783	6,804,785	4,596,253
1942	6,660,311	4,497,514	2,596,030	2,635,086	9,256,341	7,132,600
1943	6,063,028	5,425,814	1,535,490	1,834,271	7,598,518	7,260,085
1944	4,601,163	3,752,671	1,947,230	2,378,142	6,548,393	6,130,813
1945	4,476,504	3,681,255	1,547,960	1,924,873	6,024,464	5,606,128
1946	5,419,183	4,578,672	1,474,570	2,022,434	6,893,753	6,601,106
1947	6,020,440	5,541,373	3,002,000	4,425,847	9,022,440	9,967,220
1948	8,384,755	10,628,889	3,682,420	5,733,658	12,067,175	16,362,547
1949	7,134,751	7,682,272	4,397,420	6,483,839	11,532,171	14,166,111
Total	55,667,662	49,285,319	25,806,650	32,124,298	81,474,312	81,409,617
1950	8,199,900	8,168,293	3,841,840	5,593,435	12,041,740	13,761,728
1951	10,504,339	9,117,343	8,721,799	10,831,483	19,226,138	19,948,826
1952	12,219,486	8,556,218	6,250,849	8,893,368	18,470,335	17,449,586
1953	8,763,078	8,629,632	4,941,460	6,346,989	13,704,538	14,976,621
1954	13,157,239	14,149,380	5,872,353	8,617,795	19,029,592	22,767,175
1955	11,953,878	11,832,344	7,741,937	9,417,834	19,695,815	21,250,178
1956	11,637,183	11,646,367	6,097,965	7,890,197	17,735,148	19,536,564
1957	12,842,941	13,481,263	10,601,664	11,763,564	23,444,605	25,244,827
1958	10,463,884	10,264,933	15,103,872	15,644,263	25,567,756	25,909,196
1959	18,086,651	15,506,379	13,355,532	16,138,870	31,442,183	31,645,249
Total	117,828,579	111,352,152	82,529,271	101,137,798	200,357,850	212,489,950
1960	17,673,052	16,170,083	16,924,554	19,731,392	34,597,606	35,901,495
1961	12,298,573	13,679,872	17,537,869	21,338,557	29,836,442	35,018,429
1962	14,868,629	14,556,382	18,271,466	21,006,935	33,140,095	35,563,317
1963	15,715,230	18,849,779	19,987,643	24,522,341	35,702,873	43,372,120
1964	18,253,000	25,158,000	16,542,223	19,721,430	34,795,223	44,879,430
1965	21,800,000	32,849,000	21,680,634	27,768,830	43,480,634	60,617,830
1966	35,327,000	34,986,000	33,822,881	48,915,115	69,149,881	83,901,115
1967	19,630,000	25,250,000	13,858,981	20,960,582	33,488,981	46,210,582
1968	18,260,000	21,457,000	14,835,489	21,597,180	33,095,489	43,054,180
1969	15,740,000	20,491,000	12,327,559	19,457,431	28,067,559	39,948,431
Total	189,565,484	223,447,116	185,789,299	245,019,793	375,354,783	468,466,909
1970	17,532,000	25,978,000	14,299,449	21,648,283	31,831,449	47,626,283
1971	20,230,000	28,707,000	14,401,739	27,240,675	34,631,739	55,947,675
1972	24,489,000	34,981,000	11,536,389	19,050,919	36,025,389	54,031,919
1973	22,802,000	32,751,000	14,104,751	22,555,285	36,906,751	55,306,285
1974	18,557,755	30,947,585	23,927,831	44,029,722	42,485,586	74,977,307
1975	16,527,524	29,595,902	22,468,793	43,199,163	38,996,317	72,795,065
1976	17,556,455	33,474,912	21,165,337	44,010,518	38,721,792	77,485,430
Total	137,694,734	216,435,399	121,904,289	221,734,565	259,599,023	438,169,964

DATA SOURCE: U.S. Bureau of Mines, unpublished data, provided by DOGAMI.

Table 32. Annual production and value, 1940-1976, for sand and gravel, and crushed stone (including road metal cinders): Clackamas, Columbia, Multnomah and Washington Counties

Year	Sand and Gravel Production (tons)	Sand and Gravel Value ($)	Crushed Stone Production (tons)	Crushed Stone Value ($)	Total Production (tons)	Total Value ($)
1940	859,457	445,731	196,930	182,828	1,056,387	628,559
1941	1,355,162	776,111	325,708	312,060	1,680,870	1,088,171
1942	1,659,374	1,016,664	372,910	409,571	2,032,284	1,426,235
1943	1,889,848	1,791,791	251,267	272,089	2,141,115	2,063,880
1944	1,626,318	1,274,584	227,648	273,351	1,853,966	1,547,935
1945	1,363,485	1,247,007	265,132	571,952	1,628,617	1,818,959
1946	1,941,829	1,905,944	165,688	226,101	2,107,517	2,132,045
1947	1,909,684	2,103,135	195,903	268,254	2,105,587	2,371,389
1948	2,874,210	3,068,681	253,823	348,277	3,128,033	3,416,958
1949	2,673,399	2,958,226	384,353	508,514	3,057,752	3,466,740
Total	18,152,766	16,587,874	2,639,362	3,372,997	20,792,128	19,960,871
1950	2,873,526	3,167,283	374,858	482,578	3,248,384	3,649,861
1951	3,428,373	3,456,073	366,907	373,550	3,795,280	3,829,623
1952	6,958,099	3,852,840	1,462,832	1,861,974	8,420,931	5,714,814
1953	3,231,045	3,130,361	329,920	397,530	3,560,965	3,527,891
1954	3,721,841	3,859,696	288,330	389,128	4,010,171	4,248,824
1955	3,643,673	3,986,479	1,809,927	1,844,457	5,453,600	5,830,936
1956	4,410,939	4,285,927	643,685	710,585	5,054,624	4,996,512
1957	4,382,006	5,205,217	316,228	403,491	4,698,234	5,608,708
1958	3,571,224	3,595,905	1,976,173	2,168,179	5,547,397	5,764,084
1959	4,459,931	4,617,546	831,613	1,233,970	5,291,544	5,851,516
Total	40,680,657	39,157,327	8,400,473	9,865,442	49,081,130	49,022,769
1960	4,562,976	4,772,210	1,528,741	1,734,842	6,091,717	6,507,052
1961	3,348,843	3,854,708	1,773,116	2,225,163	5,121,959	6,079,871
1962	2,959,804	3,427,537	1,212,087	1,509,559	4,171,891	4,937,096
1963	3,814,258	5,460,828	1,696,284	2,106,056	5,510,542	7,566,884
1964	4,208,000	6,213,000	1,683,380	2,061,012	5,891,380	8,274,012
1965	4,290,000	6,918,000	1,766,747	2,136,692	6,056,747	9,054,692
1966	3,454,000	5,580,000	2,261,871	3,486,648	5,715,871	9,066,648
1967	4,727,000	7,105,000	2,418,295	3,437,706	7,145,295	10,542,706
1968	6,008,000	8,483,000	4,360,577	5,712,653	10,368,577	14,195,653
1969	5,859,000	8,570,000	2,535,488	4,022,494	8,394,488	12,592,494
Total	43,231,881	60,384,283	21,236,586	28,432,825	64,468,467	88,817,108
1970	6,709,000	9,868,000	2,496,793	3,576,351	9,205,793	13,444,351
1971	7,727,000	11,393,000	2,386,054	4,090,206	10,113,054	15,483,206
1972	9,834,000	14,262,000	2,967,471	4,396,098	12,801,471	18,658,098
1973	8,264,000	12,175,000	5,024,432	6,854,451	13,288,432	19,029,451
1974	7,560,459	14,011,210	3,746,589	7,204,816	11,307,048	21,216,026
1975	6,634,916	12,344,393	2,971,602	5,623,306	9,606,518	17,967,699
1976	7,424,033	14,103,319	3,439,347	6,764,554	10,863,380	20,867,873
Total	54,153,408	88,156,922	23,032,288	38,509,782	77,185,696	126,666,704

DATA SOURCE: U.S. Bureau of Mines, unpublished data, provided by DOGAMI.

Table 33. Annual production and value, 1940-1976, for sand and gravel, and crushed stone (including road metal cinders): Coos, Curry, Douglas, Jackson, and Josephine Counties

Year	Sand and Gravel Production (tons)	Sand and Gravel Value ($)	Crushed Stone Production (tons)	Crushed Stone Value ($)	Total Production (tons)	Total Value ($)
1940	161,705	97,017	89,748	81,761	251,453	178,778
1941	197,739	152,865	189,515	231,515	387,254	384,380
1942	944,884	912,739	152,613	160,846	1,097,497	1,073,585
1943	303,641	239,203	197,969	290,985	501,610	530,188
1944	209,664	179,862	360,846	388,802	570,510	568,664
1945	179,285	149,657	65,849	92,316	245,134	241,973
1946	138,069	120,108	173,642	210,800	311,711	330,908
1947	323,093	311,787	264,113	337,291	587,206	649,078
1948	355,608	381,127	507,931	563,735	863,539	944,862
1949	691,162	622,496	572,793	782,189	1,263,955	1,404,685
Total	3,504,850	3,166,861	2,575,019	3,140,240	6,079,869	6,307,101
1950	704,086	781,306	212,214	276,630	916,300	1,507,936
1951	879,634	983,472	447,451	557,068	1,327,085	1,540,540
1952	1,018,139	988,904	406,849	511,337	1,424,988	1,500,241
1953	1,120,620	1,202,826	476,095	559,005	1,596,715	1,761,831
1954	1,273,985	1,480,723	1,236,801	1,688,376	2,510,786	3,169,099
1955	1,450,397	1,702,141	972,998	1,492,026	2,423,395	3,194,167
1956	1,649,037	1,907,966	975,791	1,341,230	2,624,828	3,249,196
1957	2,019,842	2,192,832	1,645,929	2,091,921	3,665,771	4,284,753
1958	1,812,341	2,089,965	1,402,379	1,929,138	3,214,720	4,019,103
1959	2,217,275	2,346,790	1,963,010	2,539,595	4,180,285	4,886,385
Total	14,145,356	15,676,925	9,739,517	12,986,326	23,884,873	28,663,251
1960	1,887,604	2,313,316	2,419,361	2,796,238	4,296,965	5,109,554
1961	3,247,933	4,105,745	1,365,419	2,155,932	4,613,352	6,261,677
1962	2,771,255	3,116,958	2,111,944	3,121,027	4,883,199	6,237,985
1963	2,803,745	3,894,069	2,717,342	4,111,512	5,521,087	8,005,581
1964	3,196,000	4,820,000	1,209,318	1,765,689	4,405,318	6,585,689
1965	4,031,000	6,360,000	3,049,964	5,298,482	7,080,964	11,658,482
1966	2,175,000	2,925,000	2,651,310	4,228,880	4,826,310	7,153,880
1967	2,649,000	3,493,000	1,339,923	2,686,104	3,988,923	6,179,104
1968	1,886,000	2,592,000	1,502,532	3,504,894	3,388,532	6,096,894
1969	1,852,000	2,580,000	1,514,844	2,748,152	3,366,844	5,328,152
Total	26,489,537	36,200,088	19,881,957	32,416,910	46,371,494	68,616,998
1970	1,819,000	2,830,000	1,449,917	2,424,218	3,268,917	5,254,218
1971	2,446,000	3,643,000	1,950,479	3,792,824	4,396,479	7,435,824
1972	2,850,000	4,018,000	1,147,868	2,247,130	3,997,868	6,265,130
1973	3,568,000	5,554,000	2,674,278	4,551,601	6,242,278	10,105,601
1974	1,971,580	3,645,644	6,172,050	9,996,598	8,143,630	13,642,242
1975	2,985,927	5,835,430	6,203,266	9,386,295	9,189,193	15,221,725
1976	2,846,050	5,653,902	3,482,477	6,744,627	6,328,527	12,398,529
Total	18,486,557	31,179,976	23,080,335	39,143,293	41,566,892	70,323,269

DATA SOURCE: U.S. Bureau of Mines, unpublished data, provided by DOGAMI.

Table 34. Annual production and value, 1940-1976, for sand and gravel, and crushed stone (including road metal cinders): Clatsop, Lincoln, and Tillamook Counties

Year	Sand and Gravel Production (tons)	Sand and Gravel Value ($)	Crushed Stone Production (tons)	Crushed Stone Value ($)	Total Production (tons)	Total Value ($)
1940	63,924	32,445	151,726	118,141	215,650	150,586
1941	73,897	54,432	173,353	134,261	247,250	188,693
1942	91,753	62,284	285,723	300,137	377,476	362,421
1943	633,961	546,028	304,657	248,827	938,618	794,855
1944	151,885	121,787	176,243	229,000	328,128	350,787
1945	58,615	63,047	144,281	132,954	202,896	196,001
1946	149,772	174,123	48,375	65,400	198,147	239,523
1947	130,295	90,412	64,604	78,610	194,899	169,022
1948	147,072	47,997	150,904	274,180	297,976	322,177
1949	22,295	21,136	250,429	298,035	272,724	319,171
Total	1,523,469	1,213,691	1,750,295	1,879,545	3,273,764	3,093,236
1950	5,056	4,868	208,114	252,120	213,170	256,988
1951	127,396	152,485	204,418	261,114	331,814	413,599
1952	26,818	35,638	211,231	296,244	238,049	331,882
1953	102,600	77,500	191,030	218,365	293,630	295,865
1954	177,772	228,901	331,878	471,317	509,650	700,218
1955	114,086	138,941	642,646	786,452	756,732	925,393
1956	377,885	389,513	545,432	674,340	923,317	1,063,853
1957	328,615	349,358	714,019	965,985	1,042,634	1,315,343
1958	175,933	196,356	760,306	913,724	936,239	1,110,080
1959	140,709	129,016	479,116	625,277	619,825	754,293
Total	1,576,870	1,702,576	4,288,190	5,464,938	5,865,060	7,167,514
1960	111,824	117 177	912,861	1,705,193	1,024,685	1,822,370
1961	189,328	184,977	509,910	739,050	699,238	924,027
1962	337,840	409,873	1,118,549	1,606,582	1,456,389	2,016,455
1963	485,250	604,434	637,567	820,396	1,122,817	1,424,830
1964	203,000	252,000	840,944	1,174,601	1,043,944	1,426,601
1965	276,000	388,000	1,001,553	1,375,710	1,277,553	1,763,710
1966	194,000	193,000	1,315,364	3,024,109	1,509,364	3,217,109
1967	124,000	92,000	369,761	673,589	493,761	765,589
1968	207,000	127,000	583,667	956,042	790,667	1,083,042
1969	260,000	402,000	894,894	1,565,706	1,154,894	1,967,706
Total	2,388,242	2,770,461	8,185,070	13,640,978	10,573,312	16,411,439
1970	130,000	224,000	893,016	1,391,125	1,023,016	1,615,125
1971	267,000	391,000	692,532	1,248,607	959,532	1,639,607
1972	1,054,000	1,261,000	858,467	1,330,843	1,912,467	2,591,843
1973	1,119,000	1,596,000	745,230	1,319,812	1,864,230	2,915,812
1974	1,119,615	1,549,009	1,003,268	2,063,849	2,122,883	3,612,858
1975	408,606	952,374	1,145,913	2,745,288	1,554,519	3,697,662
1976	411,316	848,528	1,125,416	2,666,778	1,536,732	3,515,306
Total	4,509,537	6,821,911	6,463,842	12,766,302	10,973,379	19,588,213

DATA SOURCE: U.S. Bureau of Mines, unpublished data, provided by DOGAMI.

Table 35. Annual production and value, 1940-1976, for sand and gravel, and crushed stone (including road metal cinders): Gilliam, Morrow, and Umatilla Counties

	Sand and Gravel		Crushed Stone		Total	
Year	Production (tons)	Value ($)	Production (tons)	Value ($)	Production (tons)	Value ($)
1940	140,239	63,300	76,601	59,040	216,840	122,340
1941	87,822	32,514	54,000	40,000	141,822	72,514
1942	84,737	38,412	69,804	48,247	154,541	86,659
1943	17,107	6,336	88,480	96,406	105,587	102,742
1944	59,940	44,400	224,166	275,173	284,106	319,573
1945	50,736	20,786	239,041	322,140	289,777	342,926
1946	47,502	28,614	167,248	201,670	214,750	230,284
1947	201,207	181,243	75,000	100,000	276,207	281,243
1948	228,981	233,919	-	-	228,981	233,919
1949	113,598	109,179	47,877	42,747	161,475	151,926
Total	1,031,869	758,703	1,042,217	1,185,423	2,074,086	1,944,126
1950	143,430	147,406	82,551	106,810	225,981	254,216
1951	294,061	278,365	543,791	452,643	837,852	731,008
1952	315,703	313,999	217,291	225,365	532,994	539,364
1953	205,515	209,425	309,015	286,160	514,530	495,585
1954	305,617	422,389	248,459	209,299	554,076	631,688
1955	329,164	335,930	442,792	485,615	771,956	821,545
1956	707,045	741,091	225,026	301,236	932,071	1,042,327
1957	289,438	319,745	536,490	616,758	825,928	936,503
1958	298,857	338,963	1,210,387	1,220,654	1,509,244	1,559,617
1959	345,150	338,494	854,300	982,927	1,199,450	1,321,421
Total	3,233,980	3,445,807	4,670,102	4,887,467	7,904,082	8,333,274
1960	1,313,665	692,908	1,372,370	1,638,852	2,686,035	2,331,760
1961	552,681	680,000	609,260	862,755	1,161,941	1,542,755
1962	1,811,433	950,175	971,488	1,154,283	2,782,921	2,104,458
1963	692,345	767,148	1,429,728	1,788,048	2,122,073	2,555,196
1964	2,507,000	3,623,000	1,824,191	2,879,278	4,331,191	6,502,278
1965	583,000	789,000	1,346,437	2,016,408	1,929,437	2,805,408
1966	18,179,000	11,774,000	16,001,375	23,459,677	34,180,375	35,233,677
1967	1,603,000	3,514,000	1,194,308	2,096,662	2,797,308	5,610,662
1968	148,000	241,000	420,315	556,374	568,315	797,374
1969	189,000	330,000	262,624	391,454	451,624	721,454
Total	27,579,124	23,361,231	25,432,096	36,843,791	53,011,220	60,205,022
1970	394,000	1,623,000	302,976	496,900	696,976	2,119,900
1971	310,000	303,000	698,429	2,208,600	1,008,429	2,511,600
1972	231,000	382,000	307,181	576,596	538,181	958,596
1973	320,000	602,000	435,886	666,837	755,886	1,268,837
1974	391,975	741,034	1,129,470	2,036,084	1,521,445	2,777,118
1975	319,903	623,967	866,514	1,928,780	1,206,417	2,552,747
1976	271,280	566,790	393,777	877,590	665,057	1,444,380
Total	2,238,158	4,841,791	4,154,233	8,791,387	6,392,391	13,633,178

DATA SOURCE: U.S. Bureau of Mines, unpublished data, provided by DOGAMI.

Table 36: Annual production and value, 1940-1976, for sand and gravel and crushed stone (including road metal cinders): Benton and Linn Counties

	Sand and Gravel		Crushed Stone		Total	
Year	Production (tons)	Value ($)	Production (tons)	Value ($)	Production (tons)	Value ($)
1940	186,979	82,996	4,731	4,381	191,710	87,377
1941	235,115	146,141	-	-	235,115	146,141
1942	464,098	312,784	89,700	72,810	553,798	394,594
1943	368,621	289,439	91,100	102,147	459,721	391,586
1944	319,370	231,095	98,949	92,505	418,319	323,600
1945	333,513	218,869	103,322	96,514	436,835	315,383
1946	678,591	473,964	85,757	177,989	764,348	651,953
1947	375,687	261,125	142,685	213,707	518,372	474,832
1948	505,946	485,119	42,690	30,493	548,636	515,612
1949	527,408	411,532	108,375	107,624	635,783	519,156
Total	3,995,328	2,922,064	767,309	898,170	4,762,637	3,820,234
1950	322,817	276,351	83,372	91,754	406,189	368,105
1951	139,064	141,854	51,500	51,500	190,564	193,354
1952	138,299	143,050	105,805	179,653	244,104	322,703
1953	498,900	325,290	67,500	75,000	566,400	400,290
1954	623,059	588,014	127,182	136,936	750,241	724,950
1955	876,009	750,143	91,210	83,361	967,219	833,504
1956	671,879	588,179	311,826	391,545	983,705	979,724
1957	888,298	768,882	226,717	244,715	1,115,015	1,013,597
1958	509,705	508,735	217,093	175,667	726,798	684,402
1959	2,006,105	2,323,517	889,662	698,380	2,895,767	3,021,897
Total	6,674,135	6,414,015	2,171,867	2,128,511	8,846,002	8,542,526
1960	617,402	574,126	354,412	254,025	971,814	828,151
1961	488,246	488,887	657,429	579,083	1,145,675	1,067,970
1962	846,340	728,644	1,063,101	642,278	1,909,441	1,370,922
1963	1,076,204	1,148,889	891,592	722,160	1,967,796	1,871,049
1964	1,109,000	1,231,000	559,612	484,698	1,668,612	1,715,698
1965	2,583,000	3,465,000	971,046	1,099,099	3,554,046	4,564,099
1966	1,772,000	1,873,000	2,027,254	2,456,066	3,799,254	4,329,066
1967	594,000	546,000	136,491	192,578	730,491	738,578
1968	840,000	987,000	392,776	524,022	1,232,776	1,511,022
1969	1,049,000	1,341,000	313,868	367,974	1,362,868	1,708,974
Total	10,975,192	12,383,546	7,367,581	7,321,983	18,342,773	19,705,529
1970	1,170,000	1,944,000	243,531	311,968	1,413,531	2,255,968
1971	953,000	1,167,000	119,804	88,209	1,072,804	1,255,209
1972	1,382,000	1,781,000	269,986	454,482	1,651,986	2,235,482
1973	1,211,000	1,883,000	183,069	225,272	1,394,069	2,108,272
1974	853,447	1,424,451	1,781,484	3,168,319	2,634,931	4,592,770
1975	843,366	1,579,681	914,712	1,943,341	1,758,078	3,523,022
1976	1,116,436	1,912,754	529,074	897,799	1,645,510	2,810,553
Total	7,529,249	11,691,886	4,041,660	7,041,660	11,570,090	18,781,276

DATA SOURCE: U.S. Bureau of Mines, unpublished data, provided bo DOGAMI.

Table 37: Annual production and value, 1940-1976, for sand and gravel, and crushed stone (including road metal cinders): Marion, Polk, and Yamhill Counties

	Sand and Gravel		Crushed Stone		Total	
Year	Production (tons)	Value ($)	Production (tons)	Value ($)	Production (tons)	Value ($)
1940	298,415	139,023	244,705	160,880	543,120	299,903
1941	185,204	96,754	107,513	78,320	292,717	175,074
1942	851,436	419,859	144,809	127,839	996,245	547,698
1943	346,160	270,851	52,691	67,032	398,857	337,883
1944	449,845	336,607	217,979	247,918	667,824	584,525
1945	585,619	369,152	178,376	202,198	763,995	571,350
1946	617,472	446,791	123,085	127,714	740,557	574,505
1947	651,104	519,729	350,029	401,940	1,001,133	921,669
1948	697,005	478,258	308,363	367,031	1,005,368	845,289
1949	666,025	547,657	745,760	810,567	1,411,785	1,358,224
Total	5,348,285	3,624,681	2,473,310	2,591,439	7,821,595	6,216,120
1950	426,882	401,255	317,844	353,970	744,726	755,225
1951	322,089	344,244	122,895	145,721	444,984	489,965
1952	2,268,938	1,659,436	71,025	87,473	2,339,963	1,746,909
1953	303,900	328,730	93,655	94,461	397,555	423,191
1954	961,102	906,565	245,950	372,203	1,207,052	1,278,768
1955	749,160	640,185	219,644	344,870	968,804	985,055
1956	1,243,911	1,045,314	350,499	491,764	1,594,410	1,537,078
1957	1,502,456	1,557,875	346,580	602,395	1,849,036	2,160,270
1958	1,551,821	1,303,251	329,124	627,600	1,880,945	1,930,851
1959	706,068	749,996	266,995	279,747	973,063	1,029,743
Total	10,036,327	8,936,851	2,364,211	3,400,204	12,400,538	12,337,055
1960	1,029,798	1,065,020	256,067	282,843	1,285,865	1,347,863
1961	582,039	581,940	230,087	255,301	812,126	837,241
1962	974,599	947,066	365,271	456,673	1,339,870	1,403,739
1963	884,540	995,078	627,616	869,643	1,512,156	1,864,721
1964	1,214,000	1,508,000	292,287	316,522	1,506,287	1,824,522
1965	1,436,000	1,986,000	473,362	559,685	1,909,362	2,545,685
1966	1,297,000	1,477,000	450,949	501,077	1,747,949	1,978,077
1967	1,377,000	1,493,000	485,828	869,378	1,862,828	2,362,378
1968	1,213,000	1,083,000	195,533	219,164	1,408,533	1,302,164
1969	1,318,000	1,383,000	158,875	222,189	1,476,875	1,605,189
Total	11,325,976	12,519,104	3,535,875	4,552,475	14,861,851	17,071,579
1970	1,267,000	1,397,000	310,848	432,097	1,577,848	1,829,097
1971	1,634,000	1,700,000	216,088	287,132	1,850,088	1,987,132
1972	2,185,000	3,119,000	219,980	293,728	2,404,980	3,412,728
1973	3,007,000	4,806,000	635,620	978,866	3,642,620	5,784,866
1974	2,201,919	2,546,931	1,127,986	1,951,977	3,329,905	4,498,908
1975	1,785,060	2,122,591	871,579	1,501,745	2,656,639	3,624,336
1976	1,198,771	2,363,446	1,013,879	1,809,108	2,212,650	4,172,554
Total	13,278,750	18,054,968	4,395,980	7,254,653	17,674,730	25,309,621

DATA SOURCE: U.S. Bureau of Mines, unpublished data, provided by DOGAMI.

Table 38. Annual production and value, 1940-1976, for sand and gravel, and crushed stone (including road metal cinders): Baker, Union, and Wallowa Counties

	Sand and Gravel		Crushed Stone		Total	
Year	Production (tons)	Value ($)	Production (tons)	Value ($)	Production (tons)	Value ($)
1940	2,500	1,500	89,292	41,816	91,792	43,316
1941	157,638	20,111	54,962	13,740	212,600	33,851
1942	81,259	21,099	25,880	20,704	107,139	41,803
1943	62,882	40,019	57,200	37,000	120,082	77,019
1944	27,535	8,263	13,969	12,921	41,504	21,184
1945	42,387	16,088	24,120	20,085	66,507	36,173
1946	38,001	26,089	113,252	220,113	151,253	246,202
1947	16,394	10,663	93,882	57,200	110,276	67,863
1948	4,673	5,612	96,833	56,621	101,506	62,233
1949	61,934	19,277	89,964	83,515	151,898	102,792
Total	495,203	168,721	659,354	563,715	1,154,557	732,436
1950	108,975	71,610	106,165	114,841	215,140	186,451
1951	101,062	62,052	296,023	366,600	397,085	428,652
1952	81,888	33,858	187,272	223,393	269,160	257,251
1953	133,090	97,200	494,930	615,435	628,020	712,635
1954	285,835	235,064	593,774	1,135,498	879,609	1,370,562
1955	331,917	325,593	725,864	1,133,720	1,057,781	1,459,313
1956	157,725	156,790	845,882	1,371,846	1,003,607	1,528,636
1957	449,108	503,452	804,454	841,633	1,253,562	1,345,855
1958	169,870	195,653	1,455,115	1,495,864	1,624,985	1,691,517
1959	136,409	109,307	1,471,016	2,083,947	1,607,425	2,193,254
Total	1,955,879	1,790,579	6,980,495	9,382,777	8,936,374	11,173,356
1960	240,529	182,635	1,877,789	2,525,643	2,118,318	2,708,278
1961	191,360	174,973	1,716,983	2,392,225	1,908,343	2,567,198
1962	391,276	368,700	1,067,990	1,520,375	1,459,266	1,889,075
1963	184,253	168,077	1,117,931	1,590,547	1,302,184	1,758,624
1964	277,000	276,000	993,130	1,271,891	1,270,130	1,547,891
1965	551,000	887,000	1,356,128	2,078,387	1,907,128	2,965,387
1966	252,000	341,000	1,403,804	1,567,477	1,655,804	1,908,477
1967	707,000	1,137,000	962,719	1,359,494	1,669,719	2,496,494
1968	674,000	517,000	1,104,463	2,164,667	1,778,463	2,681,667
1969	521,000	528,000	934,028	1,374,397	1,455,028	1,902,397
Total	3,989,418	4,580,385	12,534,965	17,845,103	16,524,383	22,425,488
1970	1,092,000	2,328,000	942,603	1,734,216	2,034,603	4,062,216
1971	970,000	1,708,000	2,163,908	4,896,668	3,133,908	6,604,668
1972	942,000	1,355,000	1,434,515	2,730,016	2,376,515	4,085,016
1973	254,000	507,000	549,858	874,032	803,858	1,381,032
1974	317,874	546,596	693,765	1,477,170	1,011,639	2,023,766
1975	283,846	563,346	706,162	1,472,369	990,008	2,035,715
1976	448,855	1,038,930	716,336	1,715,295	1,165,191	2,754,225
Total	4,308,575	8,046,872	7,207,147	14,899,766	11,515,722	22,946,638

DATA SOURCE: U.S. Bureau of Mines, unpublished data, provided by DOGAMI.

Table 39. Annual production and value, 1940-1976, for sand and gravel, and crushed stone (including road metal cinders): Grant and Wheeler Counties

	Sand and Gravel		Crushed Stone		Total	
Year	Production (tons)	Value ($)	Production (tons)	Value ($)	Production (tons)	Value ($)
1940	-	-	132,026	99,859	132,026	99,859
1941	-	-	-	-	-	-
1942	-	-	22,100	13,600	22,100	13,600
1943	-	-	-	-	-	-
1944	-	-	-	-	-	-
1945	-	-	-	-	-	-
1946	-	-	-	-	-	-
1947	-	-	67,726	66,281	67,726	66,281
1948	-	-	-	-	-	-
1949	-	-	-	-	-	-
Total	-	-	221,852	179,740	221,852	179,740
1950	-	-	-	-	-	-
1951	-	-	10,790	16,600	10,790	16,600
1952	-	-	-	-	-	-
1953	-	-	8,420	12,955	8,420	12,955
1954	10,274	14,313	18,400	39,450	28,674	53,763
1955	45,643	69,407	-	-	45,643	69,407
1956	82,925	119,125	-	-	82,925	119,125
1957	20,250	45,000	114,040	107,974	134,290	152,974
1958	35,381	46,044	352,928	375,287	388,309	421,331
1959	43,310	43,826	152,425	226,537	195,735	270,363
Total	237,783	337,715	657,003	778,803	894,786	1,116,518
1960	745	596	107,794	130,408	108,539	131,004
1961	66,446	40,066	113,976	157,450	180,422	197,516
1962	102,062	114,985	64,090	127,241	166,152	242,226
1963	90,768	141,580	265,724	371,806	356,492	513,386
1964	81,000	117,000	238,614	265,319	319,614	382,319
1965	97,000	186,000	69,615	54,010	166,615	240,010
1966	123,000	157,000	387,173	451,545	510,173	608,545
1967	441,000	608,000	207,984	278,911	648,984	886,911
1968	226,000	295,000	129,036	131,081	355,036	426,081
1969	384,000	479,000	396,604	620,990	780,604	1,099,990
Total	1,612,021	2,139,227	1,980,610	2,588,761	3,592,631	4,727,988
1970	217,000	239,000	248,136	404,200	465,136	643,200
1971	186,000	232,000	410,153	839,354	596,153	1,071,354
1972	190,000	257,000	167,000	272,500	357,000	529,500
1973	79,000	132,000	245,897	504,304	324,897	636,304
1974	163,084	426,033	135,384	251,334	298,468	677,367
1975	53,573	124,450	64,163	148,329	117,736	272,779
1976	153,270	304,264	88,200	125,000	241,470	429,264
Total	1,041,927	1,714,747	1,358,933	2,545,021	2,400,860	4,259,768

DATA SOURCE: U.S. Bureau of Mines, unpublished data, provided by DOGAMI.

Table 40. Annual production and value, 1940-1976, for sand and gravel, and crushed stone (including road metal cinders): Hood River, Sherman, and Wasco Counties

	Sand and Gravel		Crushed Stone		Total	
Year	Production (tons)	Value ($)	Production (tons)	Value ($)	Production (tons)	Value ($)
1940	10,198	11,656	98,873	71,035	109,071	82,691
1941	30,388	32,052	62,280	30,356	92,668	62,408
1942	81,905	37,371	21,264	21,070	103,169	58,441
1943	70,154	33,967	30,225	23,000	100,379	56,967
1944	49,034	24,703	20,855	25,300	69,889	50,003
1945	70,534	63,096	20,315	26,375	90,849	89,471
1946	53,426	38,040	104,719	89,580	158,145	127,620
1947	38,438	32,206	28,889	30,953	67,327	63,159
1948	11,131	6,822	12,800	13,700	23,931	20,522
1949	29,684	25,781	72,737	51,432	102,421	77,213
Total	444,892	305,694	472,957	382,801	917,849	688,495
1950	84,511	51,828	65,055	83,749	149,566	135,577
1951	31,521	38,096	93,095	76,630	124,616	114,726
1952	142,855	68,345	73,486	57,934	216,341	126,279
1953	178,200	84,465	121,260	153,960	299,460	238,425
1954	643,734	385,717	239,539	244,852	883,273	630,569
1955	1,672,722	978,897	616,344	650,410	2,289,066	1,629,307
1956	102,479	129,385	409,623	416,419	512,102	545,804
1957	20,371	20,206	2,419,634	1,491,019	2,440,005	1,511,225
1958	74,329	45,648	659,437	686,118	733,766	731,766
1959	164,538	139,848	1,007,276	1,216,763	1,171,814	1,356,611
Total	3,115,260	1,942,435	5,704,749	5,077,854	8,820,009	7,020,289
1960	470,085	196,256	771,014	967,314	1,241,099	1,163,570
1961	222,973	261,894	836,305	963,990	1,059,278	1,225,884
1962	182,377	199,934	756,565	1,026,883	938,942	1,226,817
1963	1,284,675	766,556	2,637,100	3,264,702	3,921,775	4,031,258
1964	1,184,000	1,821,000	1,873,618	2,077,697	3,057,618	3,898,697
1965	3,059,000	5,148,000	819,791	1,494,177	3,878,791	6,642,177
1966	1,613,000	2,782,000	310,990	480,824	1,923,990	3,262,824
1967	203,000	340,000	305,628	405,478	508,628	745,478
1968	130,000	201,000	178,532	275,586	308,532	476,586
1969	75,000	95,000	427,181	822,608	502,181	917,608
Total	8,424,110	11,811,640	8,916,724	11,779,259	17,340,834	23,590,899
1970	236,000	850,000	429,192	796,656	665,192	1,646,656
1971	167,000	288,000	754,984	1,521,194	921,984	1,809,194
1972	68,000	114,000	793,235	1,528,262	861,235	1,642,262
1973	117,000	128,000	271,033	412,411	388,033	540,411
1974	101,230	129,396	288,297	477,086	389,527	606,482
1975	54,203	39,675	742,957	1,518,139	797,160	1,557,814
1976	65,090	172,269	276,377	482,271	341,467	654,540
Total	808,523	1,721,340	3,556,075	6,736,019	4,364,598	8,457,359

DATA SOURCE: U.S. Bureau of Mines, unpublished data, provided by DOGAMI.

Table 41. Annual production and value, 1940-1976, for sand and gravel, and crushed stone (including road metal cinders): Crook, Deschutes, and Jefferson Counties

	Sand and Gravel		Crushed Stone		Total	
Year	Production (tons)	Value ($)	Production (tons)	Value ($)	Production (tons)	Value ($)
1940	52,686	31,738	2,000	2,500	54,686	34,238
1941	30,387	17,616	-	-	30,387	17,616
1942	33,376	16,803	1,890	1,890	35,266	18,693
1943	75,835	84,625	4,000	3,400	79,835	88,025
1944	12,600	20,750	31,200	70,000	43,800	90,750
1945	47,517	39,327	47,250	32,050	94,767	71,377
1946	56,120	56,070	120,600	202,000	176,720	258,070
1947	78,927	85,092	94,268	114,092	173,195	199,184
1948	25,000	11,250	26,000	40,000	51,000	51,250
1949	33,750	50,000	162,683	229,672	196,433	279,672
Total	446,198	413,271	489,891	695,604	936,089	1,108,875
1950	31,725	47,000	59,725	87,000	91,450	134,000
1951	37,445	48,318	42,674	55,380	80,119	103,698
1952	40,950	67,125	73,631	102,545	114,581	169,670
1953	29,700	50,875	4,240	26,985	33,940	77,860
1954	81,215	105,593	47,717	106,636	128,932	212,229
1955	130,110	183,565	236,767	344,537	366,877	528,102
1956	132,789	239,427	208,197	289,525	340,986	528,952
1957	289,046	359,154	575,224	443,931	864,270	803,085
1958	250,116	172,974	334,373	338,190	584,489	511,164
1959	269,104	283,279	152,490	231,645	421,594	514,924
Total	1,292,200	1,557,310	1,735,038	2,026,374	3,027,238	3,583,684
1960	254,214	350,650	619,803	797,951	874,017	1,148,601
1961	237,720	151,296	612,716	751,921	850,436	903,217
1962	272,488	261,909	140,492	218,000	412,980	479,909
1963	395,793	563,653	853,366	898,168	1,249,159	1,461,821
1964	270,000	330,000	1,022,126	1,298,820	1,292,126	1,628,820
1965	322,000	320,000	493,410	789,631	815,410	1,109,631
1966	414,000	485,000	350,077	566,478	764,077	1,051,478
1967	417,000	555,000	317,086	385,051	734,086	940,051
1968	336,000	332,000	373,220	409,499	709,220	741,499
1969	261,000	307,000	274,062	339,979	535,062	646,979
Total	3,180,215	3,656,508	5,056,358	6,455,498	8,236,573	10,112,006
1970	177,000	265,000	168,253	169,000	345,253	434,000
1971	118,000	193,000	235,136	514,513	353,136	707,513
1972	439,000	559,000	153,085	386,580	592,085	945,580
1973	279,000	225,000	298,817	534,273	577,817	759,273
1974	241,325	564,913	272,102	596,643	513,427	1,161,556
1975	207,906	548,126	260,690	483,693	468,596	1,031,819
1976	338,834	990,079	300,241	606,738	639,075	1,596,817
Total	1,801,065	3,345,118	1,688,324	3,291,440	3,489,389	6,636,558

DATA SOURCE: U.S. Bureau of Mines, unpublished data, provided by DOGAMI.

Table 42. Annual production and value, 1940-1976, for sand and gravel, and crushed stone (including road metal cinders): Harney and Malheur Counties

Year	Sand and Gravel Production (tons)	Sand and Gravel Value ($)	Crushed Stone Production (tons)	Crushed Stone Value ($)	Total Production (tons)	Total Value ($)
1940	1,533	1,368	-	-	1,533	1,368
1941	21,000	750	-	-	21,000	750
1942	511,143	439,739	31,250	37,500	542,393	477,239
1943	194	28	-	-	194	28
1944	73,791	24,597	94,500	119,000	168,291	143,597
1945	-	-	-	-	-	-
1946	-	-	13,635	25,000	13,635	25,000
1947	-	-	-	-	-	-
1948	4,725	875	-	-	4,725	875
1949	39,375	8,500	-	-	39,375	8,500
Total	651,761	475,857	139,385	181,500	791,146	657,357
1950	87,750	13,000	-	-	87,750	13,000
1951	-	-	37,635	57,900	37,635	57,900
1952	-	-	-	-	-	-
1953	-	-	-	-	-	-
1954	13,134	10,251	1,613	3,630	14,747	13,881
1955	140,368	153,675	812,571	934,449	952,939	1,088,124
1956	530,964	510,707	112,325	124,457	643,289	635,164
1957	595,290	556,094	1,196	1,270	596,486	557,364
1958	470,237	357,441	330,388	267,449	800,625	624,890
1959	727,125	776,612	141,016	230,890	868,141	1,007,502
Total	2,564,868	2,377,780	1,436,744	1,620,045	4,001,612	3,997,825
1960	93,107	92,624	292,993	364,397	386,100	457,021
1961	179,207	173,585	187,192	315,314	366,399	488,899
1962	150,968	192,374	302,820	486,381	453,788	678,755
1963	282,100	326,267	125,336	202,706	407,436	528,973
1964	283,000	458,000	137,008	187,737	420,008	645,737
1965	603,000	1,005,000	34,636	89,014	637,636	1,094,014
1966	275,000	265,000	220,624	543,430	495,624	808,430
1967	253,000	340,000	59,245	144,017	312,245	484,017
1968	236,000	262,000	66,188	106,015	302,188	368,015
1969	497,000	767,000	77,050	166,800	574,050	933,800
Total	2,852,382	3,881,850	1,503,092	2,605,811	4,355,474	6,487,661
1970	409,000	674,000	150,213	218,626	559,213	892,626
1971	208,000	354,000	358,068	809,223	566,068	1,163,223
1972	287,000	385,000	757,105	1,022,902	1,044,105	1,407,902
1973	286,000	454,000	138,796	462,384	424,796	916,384
1974	194,092	355,071	130,950	293,592	325,042	648,663
1975	272,463	481,655	397,095	883,895	669,558	1,365,550
1976	180,372	419,642	171,412	362,577	351,784	782,219
Total	1,836,927	3,123,368	2,103,639	4,053,199	3,940,566	7,176,567

DATA SOURCE: U.S. Bureau of Mines, unpublished data, provided by DOGAMI.

Table 43. Annual production and value, 1940-1976, for sand and gravel, and crushed stone (including road metal cinders): Klamath and Lake Counties

	Sand and Gravel		Crushed Stone		Total	
Year	Production (tons)	Value ($)	Production (tons)	Value ($)	Production (tons)	Value ($)
1940	74,410	13,550	171,002	161,322	245,412	174,872
1941	3,900	3,000	19,143	28,860	23,043	31,860
1942	239,687	215,422	13,750	19,250	253,437	234,672
1943	-	-	39,000	45,000	39,000	45,000
1944	78,645	113,100	225,500	367,500	304,145	480,600
1945	105,064	114,483	42,204	69,917	147,268	184,400
1946	69,035	24,250	90,744	163,692	159,779	187,942
1947	77,991	83,313	279,480	342,625	357,471	425,938
1948	160,562	174,938	-	-	160,562	174,938
1949	174,209	125,341	116,908	130,092	291,117	255,433
Total	983,503	867,397	997,731	1,328,258	1,981,234	2,195,655
1950	121,123	82,508	63,614	98,956	184,737	181,464
1951	43,845	40,972	315,976	370,082	359,821	411,054
1952	101,935	58,781	157,077	149,361	259,012	208,142
1953	152,540	137,950	44,000	61,000	196,540	198,950
1954	257,147	235,737	24,000	42,000	281,147	277,737
1955	167,192	144,298	415,180	412,552	582,372	556,850
1956	225,086	202,357	388,978	416,990	614,064	619,347
1957	368,081	200,529	241,202	321,124	609,283	521,653
1958	243,601	231,621	417,495	468,414	661,096	700,035
1959	57,841	82,935	118,842	190,785	176,683	273,720
Total	1,738,391	1,417,688	2,186,364	2,531,264	3,924,755	3,948,952
1960	84,785	95,921	432,156	427,814	516,941	523,735
1961	41,655	29,247	842,919	1,187,782	884,574	1,217,029
1962	96,714	94,221	557,244	763,396	653,958	857,617
1963	203,814	251,954	791,257	1,165,073	995,071	1,417,027
1964	284,000	486,000	665,013	958,478	949,013	1,444,478
1965	600,000	1,186,000	613,192	880,713	1,213,192	2,066,713
1966	860,000	1,279,000	1,053,182	1,852,066	1,913,182	3,131,066
1967	502,000	670,000	1,056,856	1,683,387	1,558,856	2,353,387
1968	643,000	773,000	922,204	949,401	1,565,204	1,722,401
1969	536,000	657,000	1,314,939	1,973,241	1,850,939	2,630,241
Total	3,851,968	5,522,343	8,248,962	11,841,351	12,100,930	17,363,694
1970	551,000	728,000	1,687,783	2,445,409	2,238,783	3,173,409
1971	459,000	625,000	1,443,891	2,255,324	1,902,891	2,880,324
1972	289,000	534,000	1,122,913	2,034,084	1,411,913	2,568,084
1973	384,000	548,000	1,307,160	2,332,961	1,691,160	2,880,961
1974	357,553	729,527	961,531	1,447,208	1,319,084	2,176,735
1975	327,303	927,421	1,136,940	1,731,302	1,464,243	2,658,723
1976	302,425	974,642	1,001,656	1,577,272	1,304,081	2,551,914
Total	2,670,281	5,066,590	8,661,874	13,823,560	11,332,155	18,890,150

DATA SOURCE: U.S. Bureau of Mines, unpublished data, provided by DOGAMI.

Table 44. Annual production and value, 1940-1976, for sand and gravel and crushed stone (including road metal cinders): Lane County

	Sand and Gravel		Crushed Stone		Total	
Year	Production (tons)	Value ($)	Production (tons)	Value ($)	Production (tons)	Value ($)
1940	243,398	136,693	30,287	29,123	273,685	165,816
1941	210,880	142,120	70,702	64,600	281,582	206,720
1942	225,880	138,506	97,393	140,604	323,273	279,110
1943	487,451	373,389	86,737	152,173	574,188	525,562
1944	505,974	361,449	166,394	179,955	672,368	541,404
1945	846,309	500,896	66,003	78,860	912,312	579,756
1946	956,702	677,157	104,617	138,887	1,061,319	816,044
1947	878,186	791,239	186,910	215,475	1,065,096	1,006,714
1948	757,360	759,801	172,777	225,710	930,137	985,511
1949	793,464	826,516	176,260	232,594	969,724	1,059,110
Total	5,905,604	4,707,766	1,158,080	1,457,981	7,063,684	6,165,747
1950	772,454	760,417	250,576	341,217	1,023,030	1,101,634
1951	740,130	815,539	898,290	965,292	1,638,420	1,780,831
1952	891,303	1,009,913	308,683	419,731	1,199,986	1,429,644
1953	1,552,463	2,036,710	880,825	920,903	2,433,288	2,957,613
1954	2,209,360	2,118,967	123,047	183,460	2,332,407	2,302,427
1955	2,009,002	2,012,990	488,538	588,115	2,497,540	2,601,105
1956	1,225,179	1,246,486	641,451	771,725	1,866,630	2,018,211
1957	1,645,618	1,387,858	1,199,286	1,466,643	2,844,904	2,854,501
1958	1,163,724	1,041,257	3,936,323	2,619,837	5,100,047	3,661,094
1959	6,641,176	3,360,631	2,335,405	2,066,698	8,976,581	5,427,329
Total	18,850,409	15,790,768	11,062,424	10,343,621	29,912,833	26,134,389
1960	6,276,397	5,114,306	3,112,475	2,729,675	9,388,872	7,843,981
1961	2,000,935	2,240,935	5,340,893	5,548,531	7,341,828	7,789,466
1962	3,273,935	3,281,451	7,088,175	6,764,887	10,362,110	10,046,338
1963	2,687,088	2,853,019	4,269,776	4,456,536	6,956,864	7,309,555
1964	2,672,000	3,403,000	2,998,602	2,292,581	5,670,602	5,695,581
1965	3,214,000	4,034,000	6,679,793	5,661,158	9,893,793	9,695,158
1966	4,719,000	5,855,000	1,886,153	2,405,955	6,605,153	8,260,955
1967	6,015,000	5,346,000	1,533,162	2,277,885	7,548,162	7,623,885
1968	5,713,000	5,564,000	893,096	1,176,806	6,606,096	6,740,806
1969	2,720,000	2,784,000	737,344	1,168,694	3,457,344	3,952,694
Total	39,291,355	40,475,711	34,539,469	34,482,708	73,830,824	74,958,419
1970	2,165,000	1,856,000	779,067	1,189,749	2,944,067	3,045,749
1971	2,583,000	3,690,000	1,196,402	1,595,902	3,779,402	5,285,902
1972	1,778,000	2,113,000	1,195,738	1,531,824	2,973,738	3,644,824
1973	2,959,000	3,124,000	1,594,675	2,838,081	4,553,675	5,962,081
1974	3,083,602	4,277,770	1,668,045	3,431,226	4,751,647	7,708,996
1975	2,350,452	3,452,793	1,213,663	3,267,613	3,564,115	6,720,406
1976	2,799,723	4,126,347	1,470,395	3,636,063	4,270,118	7,762,410
Total	17,718,777	22,639,910	9,117,985	17,490,458	26,836,762	40,130,368

DATA SOURCE: U.S. Bureau of Mines, unpublished data, provided by DOGAMI.

Table 45. Annual production and value, 1940-1976, for sand and gravel, and crushed stone (including road metal cinders): Various Counties

	Sand and Gravel		Crushed Stone		Total	
Year	Production (tons)	Value ($)	Production (tons)	Value ($)	Production (tons)	Value ($)
1940	843,688	280,372	1,499,219	1,236,679	2,342,907	1,517,051
1941	1,379,263	685,004	1,779,214	1,503,071	3,158,477	2,188,075
1942	1,390,779	856,832	1,266,944	1,261,018	2,657,723	2,117,850
1943	1,807,174	1,750,138	332,164	496,212	2,139,338	2,246,350
1944	1,036,562	1,011,474	88,981	96,717	1,125,543	1,108,191
1945	793,440	878,847	352,067	279,512	1,145,507	1,158,359
1946	672,664	607,522	163,208	173,488	835,872	781,010
1947	1,339,434	1,071,429	1,158,511	2,199,419	2,497,945	3,270,848
1948	2,612,482	4,974,490	2,110,299	3,813,911	4,722,781	8,788,401
1949	1,308,448	1,956,631	1,669,281	3,206,858	2,977,729	5,163,489
Total	13,183,934	14,072,739	10,419,888	14,266,885	23,603,822	28,339,624
1950	2,517,565	2,363,461	2,017,752	3,303,810	4,535,317	5,667,271
1951	4,359,719	2,755,783	5,290,354	7,081,403	9,650,073	9,837,276
1952	234,559	324,329	2,975,667	4,778,358	3,210,226	5,102,687
1953	1,254,505	948,300	1,920,570	2,925,230	3,175,075	3,873,530
1954	2,593,164	3,557,450	2,345,663	3,595,010	4,938,827	7,152,460
1955	294,435	410,100	267,456	317,270	561,891	727,370
1956	119,340	84,100	439,250	588,535	558,590	672,635
1957	44,522	15,061	1,460,665	2,164,705	1,505,187	2,179,766
1958	136,745	141,120	1,722,351	2,358,142	1,859,096	2,499,262
1959	171,910	204,582	2,692,366	3,531,709	2,864,276	3,736,291
Total	11,726,464	10,804,376	21,132,094	30,644,172	32,858,558	41,448,548
1960	739,921	602,338	2,866,718	3,376,197	3,606,639	3,978,535
1961	949,207	711,619	2,741,664	3,204,060	3,690,871	3,915,679
1962	697,538	462,555	1,451,650	1,609,370	2,149,188	2,071,925
1963	830,397	908,227	1,927,024	2,154,988	2,757,421	3,063,215
1964	765,000	620,000	2,204,380	2,687,107	2,969,380	3,307,107
1965	155,000	177,000	3,004,960	4,235,664	3,159,960	4,412,664
1966	--	--	3,502,755	3,890,883	3,502,755	3,890,883
1967	18,000	11,000	3,471,695	4,470,342	3,489,695	4,481,342
1968	--	--	3,713,350	4,910,976	3,713,350	4,910,976
1969	219,000	268,000	2,485,758	3,672,753	2,704,758	3,940,753
Total	4,374,063	3,760,739	27,369,954	34,212,340	31,744,017	37,973,079
1970	1,196,000	1,152,000	4,197,121	6,057,768	5,393,121	7,209,768
1961	2,202,000	3,020,000	1,775,811	3,092,919	3,977,811	6,112,919
1972	2,960,000	4,841,000	141,845	245,874	3,101,845	5,086,874
1973	955,000	1,017,000	--	--	955,000	1,017,000
1974	--	--	4,816,910	9,633,820	4,816,910	9,633,820
1975	--	--	4,953,537	10,565,068	4,953,537	10,565,068
1976	--	--	7,156,750	15,744,846	7,156,750	15,744,846
Total	7,313,000	10,030,000	23,041,974	45,340,295	30,354,974	55,370,295

DATA SOURCE: U.S. Bureau of Mines, unpublished data, provided by DOGAMI.

Table 46. Estimated annual production and value, 1960-1966, of sand and gravel, and of crushed stone used in John Day Dam, Foster Dam, and Green Peter Dam and in related projects.

	Sand and Gravel		Crushed Stone		Total	
Year	Production (tons)	Value ($)	Production (tons)	Value ($)	Production (tons)	Value ($)
1960	1,128,878	1,523,578	458,188	1,531,579	1,587,066	3,055,157
1960	--	--	350,825	1,666,764	350,825	1,666,764
1962	1,537,565	1,207,631	177,094	1,256,999	1,714,659	2,464,630
1963	329,190	911,450	945,995	2,000,951	1,275,185	2,912,401
1964	1,049,008	2,509,751	1,902,354	3,479,651	2,951,362	5,988,402
1965	211,000	1,164,020	2,000,115	3,022,229	2,211,115	4,186,249
1966	15,650,000	9,996,221	16,479,678	23,986,752	32,129,678	33,982,973

DATA SOURCE: U.S. Bureau of Mines, unpublished data, provided by DOGAMI.

ANALYSIS AND FORECASTS OF THE DEMAND FOR ROCK MATERIALS IN OREGON

ADDENDUM

Each of the projections of demand in 2030 (Table 13) was computed by compounding annually a base level of production from a given year to 2030 using the annual growth rate shown in the table. For the projections stemming from the historic growth rates, the base level of production was the antilogarithm of the intercept shown for the appropriate growth model in Table 14 or 15. The annual growth rate was the model's coefficient of time, and the base year was the first year of the model (1950 or 1964). Using the rounded figures in Tables 14 and 15 may yield projections which differ slightly from those in Table 13.

For the projections stemming from the simulations, the annual growth rate was the rate indicated by the simulated production levels for 1963 and 1990. The base level of production was the mean value of production during 1963-1976 (the period for which the data for the simulations are available). The base year was 1969 (i.e., the middle year of the period).

For the reasons expressed on pages 46 and 48, all the projections to such a distant year must be considered as extremely tenuous.

ERRATA

The projected annual demand in 2030 in the Portland area based on the 1964-1976 growth rates should read 233.8 million tons per year for sand and gravel and 70.8 million tons per year for crushed stone.

State Department of Geology and Mineral Industries Special Paper 5, Analysis and Forecasts of the Demand for Rock Materials in Oregon, 1979, Table 13.