JOBMOD2.1: A Comprehensive Model for Estimating Employment Generation from Federal-Aid Highway Projects

Technical Documentation

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Introduction

What is JOBMOD2?

JOBMOD2 is a model that makes quantitative estimates of the total employment income and jobs supported by federally funded highway improvement projects. This includes not only the direct employment of construction workers, but also all those workers who are required to produce inputs to the construction project. It also goes a step further by estimating the number of jobs that are supported by the growth in consumer expenditure that arises due to all the employment income from those jobs supported by the project. Thus, it provides a very broad definition of the total employment impact of expenditures on highway improvements.

The term “highway improvement” can cover a broad range of things, including construction of new highways; reconstruction of old highways; construction, reconstruction or major repair of bridges; improvement of signal systems and traffic flow systems for the purpose of congestion reduction or safety enhancement; and highway alterations for environmental purposes such as the installation of sound barriers. Furthermore, a substantial proportion of highway funds may be spent not on construction *per se*, but on engineering design services. Since these different types of activities will produce different employment impacts, JOBMOD2 makes it possible for the user to specify the highway improvement type.

JOBMOD2 is a user-friendly software program that can be run on all Windows operating systems. While it is coded using Visual Basic, it is delivered as an executable file which calls a number of data files that are stored on the user’s computer. The user is prompted to enter model run options into easy-to-understand Windows screens. The model outputs are written into similar screens but can also be saved into Excel spreadsheets.

JOBMOD2 is a second-generation model based on the original JOBMOD, which was produced at the Boston University Center for Transportation Studies and has been in use by FHWA and other agencies ever since. JOBMOD2 incorporates updated data inputs, but also delivers some new functionality including the ability for the user to separate right-of-way expenditures (which have no direct employment impacts) from construction expenditures and to adjust for changes in the prices of major construction inputs. The updated data sources are described in the section *Data Sources and Methods* and a summary of the differences between JOBMOD and JOBMOD2 and their implications is provided in the section *Comparing JOBMOD and JOBMOD2*.

How Does JOBMOD2 Work? Input-Output Analysis

Highway construction is a relatively labor intensive activity that directly employs a variety of people including laborers, equipment operators, vehicle drivers, engineers, managers and supervisors. Thus, assuming that there is slack labor supply, each construction project creates a number of new jobs directly. It also creates a number of jobs indirectly through its incremental demand for inputs such as steel, concrete, aggregates, lighting equipment etc. Labor is required to produce all of these inputs and to produce inputs to the production of these inputs.

As an example, consider the construction of a bridge. The direct labor requirements of the bridge include all the people working for the prime contractor and all subcontractors, whether on site or off, whose primary work tasks are connected to that particular bridge. The indirect labor requirement includes all the people employed to produce steel, concrete, guard rail, lighting etc. that go into the bridge contract. It also includes workers in a number of other activities further up the production chain. For example, the number of people employed to produce the iron ore and coal used in the production of the steel for the bridge is included in the indirect labor requirements.

But the employment impacts don't end there. The income that is earned by both the direct and indirect workers will be spent, in part, on consumer goods and services. Since it is the construction project that ultimately makes this expenditure possible, the jobs involved in the provision of these consumer goods and services should also be included among its employment impacts. These jobs are called induced employment.

Estimating employment impacts of highway expenditures requires a comprehensive accounting of all direct and indirect employment requirements and the expenditure patterns of the workers involved. Making such assessments on an *ad hoc* basis for each highway project would be prohibitively complicated. Fortunately, *input-output (I-O)* analysis makes it possible to calculate direct and indirect output and employment impacts of highway expenditures based on a set of economic accounts provided by the U.S. Department of Commerce. (A technical description of I-O analysis is provided in the subsequent section.)

While these accounts provide an excellent base of information for comprehensive employment impact assessment, they are somewhat limited as relates to highway construction activity. All such activities are aggregated into two industries: one for new construction and one for repair and maintenance. It is therefore not possible to take account of differences in input structure – and thereby differences in employment generation – among different types of highway construction activities. For example, a new bridge project will require more steel per million dollars of construction expenditure than a new road project, which in turn will require more bituminous inputs than the bridge project. The existing accounts, however, include both projects in the same industry and fail to account for these differences. This could lead to errors in estimates of direct and indirect employment.

JOBMOD2 expands upon the existing input-output accounts so as to make possible better employment impact projections for highway infrastructure

projects. This is accomplished by supplementing the data in the accounts with information from two databases on the input structure of individual federal-aid highway projects that were obtained from the Federal Highway Authority. This makes it possible to disaggregate the two highway construction industries in the existing accounts into 14 more detailed industries and to estimate employment impacts for each of these industries separately.

Interpreting I-O Results

A note of caution is in order with respect to the way the outputs of JOBMOD2, or any I-O based model, should be described and interpreted. I-O analysis assumes that there is slack capacity in the markets for labor and for goods and services. This may not always be the case in reality. Thus, for example, the result of JOBMOD2 may be that the employment impact of 40,000 jobs. If there is sufficient slack capacity in labor supply (i.e. unemployment) these will be 40,000 incremental jobs. If there is no such slack, however, the total employment will not rise by 40,000. Rather, some proportion of those jobs will be filled by workers who leave other jobs. Presumably, these workers will be better off because they would not leave high wage jobs to take low wage jobs, but they will not be going from unemployed to employed. It is important that users of JOBMOD2's outputs do not give the impression that all jobs are incremental jobs. Therefore, it is more appropriate to refer to "jobs supported" rather than "jobs generated." (This issue is addressed in more detail below.)

Input-Output Analysis

Input-Output (I/O) analysis is an analytical framework for assessing the economic impact of exogenous stimuli such as public sector expenditure on infrastructure. It starts by dividing the economy into a mutually exclusive and exhaustive set of *n* industries. The output of each industry *i* is defined by the following accounting relation:

$$x_i = \sum_{j=1}^{n} z_{ij} + y_i \qquad (1)$$

where z_{ij} is the sales of industry *i* to industry *j* and y_i is the sales of *i* to final demand. The former category represents intermediate demand, whereby the output of one industry becomes an input to another, while the latter includes sales to final consumers and the public sector, investment in capital goods, and net exports. Expenditure on a publicly funded highway project would be represented in this framework as sales by the construction industry to final demand.

The critical technical assumption in I/O analysis is that the input structure of demand can be defined by fixed technical relations

$$z_{ij} = a_{ij} x_j \qquad (2)$$

where the technical coefficient a_{ij} is the amount in dollars of the output of industry *i* required to produce one dollar's output by industry *j*. Since these coefficients are fixed, incorporating complications such as input substitution and scale economies or endogenization of prices are precluded. Using (2), (1) is rewritten

$$x_i = \sum_{j=1}^{n} a_{ij} x_j + y_i \qquad (3)$$

and the production accounts of the entire economy can be defined by the following set of interrelated linear equations:

$$
\begin{aligned}
x_1 &= \sum_{j=1}^{n} a_{1j} x_j + y_1 \\
x_2 &= \sum_{j=1}^{n} a_{2j} x_j + y_2 \\
&. \\
&. \\
&. \\
x_n &= \sum_{j=1}^{n} a_{nj} x_j + y_n
\end{aligned}
\tag{4}
$$

This can be rewritten in matrix form as

$$\mathbf{x} = \mathbf{A}\mathbf{x} + \mathbf{y} \tag{5}$$

where **x** is an *(nx1)* vector of output levels, **y** in an *(nx1)* vector of final demand levels and **A** is an *(nxn)* matrix of the technical coefficients a_{ij}.

I/O analysis assumes that final demand for each industry is exogenous and the objective is to predict the vector of outputs **x** generated by a given vector of final demand **y**. By rearranging the terms of (5) it is possible to define output as a function of final demand only:

$$\mathbf{x} = (\mathbf{I} - \mathbf{A})^{-1}\mathbf{y} \tag{6}$$

The *(nxn)* matrix $(\mathbf{I} - \mathbf{A})^{-1}$ is called the matrix of direct and indirect multipliers[1]. The typical element of this matrix defines the total input required *both directly and indirectly* from some industry. For example, a highway construction project may require steel as a direct input as structural elements or for reinforcement of concrete. It may also require steel indirectly as an input to the construction of

[1] It is also called the Leontief matrix after the inventor of I/O analysis.

lighting, signals, or guard rails. The coefficient in this matrix includes all of these requirements.

Total labor requirement can also be calculated by defining a set of coefficients $l_1, l_2, \ldots, l_n$ such that l_i is the labor requirement (in hours or person years) per dollar of output in sector *i*. The sum of employment in all *n* industries can now be defined:

$$L = \mathbf{l}'\mathbf{x} = \mathbf{l}'(\mathbf{I} - \mathbf{A})^{-1}\mathbf{y} \tag{7a}$$

Similar coefficients can be used to project total employment income.

$$E = \mathbf{e}'\mathbf{x} = \mathbf{e}'(\mathbf{I} - \mathbf{A})^{-1}\mathbf{y} \tag{7b}$$

where **e** is a vector of payments to labor per dollar of output.

Since all the relations in the I/O model are linear, it can be applied to estimating the incremental output and employment effects of a particular final demand stimulus such as the expenditure of public funds on a highway infrastructure project. This is achieved by constructing a special final demand vector

$$\mathbf{y} = \begin{bmatrix} 0 \\ \vdots \\ y_j \\ \vdots \\ 0 \end{bmatrix} \tag{9}$$

where *j* is the appropriate construction industry. Putting this vector in place of **y** in (6) and (7) will produce the estimated output and employment respectively supported directly and indirectly by the project.

The model as it is described thus far incorporates only the direct and indirect employment generation effects. A third category of employment generation – known as the *induced employment* – occurs when the income earned by direct and indirect employees is spent in the economy, inducing greater demand for

consumer goods and services and thereby generating additional new jobs. Calculation of induced effect requires an augmentation of the matrix of technological coefficients to include a *household industry*. This industry, which we will designate as industry *h,* supplies labor services (its output) to all other industries in the economy and purchases consumer goods and services (its inputs) from all other industries. Thus, a_{hj} is the sales of labor services from the household industry to industry *j* per dollar of industry *j*'s output, while a_{ih} is household purchase of industry *i*'s output per dollar of total labor services produced. Augmenting the *A* matrix with a row and a column of coefficients described in this way and performing the transformations in equation (6) produces a matrix of direct, indirect, and induced multipliers. Substituting this matrix into equation 7a produces a vector of employment that includes all three effects. The magnitude of the induced effect can be estimated by calculating a vector of employment using both the original (direct and indirect) and expanded (direct, indirect, and induced) matrices and observing the difference.

Consistent with a decision that was made when the original JOBMOD was created, the output of JOBMOD2 deviates slightly from the conventional I-O nomenclature. Employment estimates are assigned to three categories which differ slightly from the standard input-output definitions of direct, indirect, and induced. The three categories are somewhat more intuitive because they convey an idea of the immediacy of the connection between the construction projects in question and the jobs supported. They are defined as follows:

Construction oriented employment includes all those jobs that are created either by the hiring of the construction firms that execute the projects or by the firms who provide direct inputs (paving materials, steel, guard rail, lighting etc.) to the project. This definition is therefore somewhat broader than the conventional definition of direct employment.

Supporting industry employment includes employment in firms that provide inputs to the firms that provide direct inputs. For example, a job in a firm that produces guardrail is part of first construction oriented employment; while a job in a firm that provides the sheet steel to make the guardrail is part of supporting industry employment. The definition of supporting industry employment is therefore somewhat narrower than the standard definition of indirect employment.

Induced employment includes all the jobs supported by the incremental consumer expenditures due to the wages paid for jobs in the first two categories. It is equivalent to the standard definition of induced employment.

Data and Methods for JOBMOD2

1997 Benchmark Accounts

The core of the JOBMOD2 database is a set of I-O accounts for the United States economy. The most recent set of I-O accounts that are available at a level of industrial detail that is appropriate for our purposes is the 1997 Benchmark Input-Output Accounts of the United States provided by the Bureau of Economic Analysis of the U.S. Department of Commerce[2]. This dataset was used to replace the 1992 Transportation Satellite Accounts (TSA), which were used to create JOBMOD. At the time JOBMOD was created, the TSA were selected for use over the 1992 Benchmark Accounts (on which the TSA were based) because they provided a better representation of transportation expenditures by separating out "in-house" transportation expenditures as a separate industry. It was not possible to use an updated version of the TSA for JOBMOD2 because none was ever produced. Furthermore, one major advance of the of the 1997 Benchmark Accounts over previous Benchmark Accounts is that substantial revision was done to separate secondary activities (such as in-house

[2] A technical overview of the 1997 Benchmark Accounts is found in Anne M. Lawson, Kurt S. Bersani, Mahnaz Fahim-Nader and Jiemin Guo (2002) "Benchmark Input-Output Accounts of the United States," *Survey of Current Business*, December 2002, 19-63.

transportation) and assign them to more appropriate industries. Therefore, the shortcoming that the TSA was designed to overcome for 1992 have largely been resolved in the 1997 Benchmark Accounts.[3]

The "detailed" level of aggregation, which traces flows among 491 industries[4], was used for JOBMOD2. This high level of industrial detail was necessary for two reasons. First, creation of the 14 supplementary industries described below requires enough detail so that expenditures on construction inputs can be accurately distributed to industries. The second reason for the high level of detail is so that jobs and income supported can be broken out to various industries. While the output of JOBMOD2 allows the user to see distributions of jobs to either 12 or 48 industrial groups, it would be possible in theory to calculate employment impacts for all 491 industries.

Expanded I-O Accounts

For the purpose of JOBMOD2 we have expanded the 491 by 491 $\mathbf{A}$ matrix to a 505 by 505 matrix $\tilde{\mathbf{A}}$ in order to include 14 detailed highway improvement industries, identified in Table 1. Since these industries sell only to final demand, the rows for these industries in the $\tilde{\mathbf{A}}$ matrix include only zeroes. However, the coefficients in the corresponding columns, which indicate the amount of various inputs used for each type of construction, had to be estimated using data from a

[3] In part the problems of misassignment in the 1992 Benchmark Accounts were corrected in the process of switching over the 1997 accounts from the old SIC industrial definitions to the new NAICS definitions, which are based more on similarities in production processes than similarities in products. This transformation, however, required a substantial effort in the production of JOBMOD2 because substantial revision of the old JOBMOD code was required to make the switch to NAICS definitions.

[4] Strictly speaking, the accounts make a distinction between industries and commodities. Each industry has a primary commodity, but it may also produce some amount of one or more secondary commodities. In order to take full account of possibility of secondary production, a "rectangular" commodity by industry input-output format could be used. However, this would require the creation of much larger data sets and increased the computational burden of the model. The improved accuracy from doing this would have been quite small, since 95% of all commodities are produced in the industry for which they are the primary product (See Lawson et al, 2002, page 27.) We therefore have assumed that each commodity is produced is a single industry and designed the model in an industry by industry format. Note that this does not imply any possibility of undercounting, but only the possibility that a very small amount of output or employment might be assigned to the wrong industry.

database assembled from observations of Forms 47 submitted on federal-aid highway contracts. The creation of these vectors of coefficients was accomplished in the creation of JOBMOD in 2001. For JOBMOD2, these vectors were revised only to take account of rising construction labor costs. Details are provided in the Appendix 1: *Creation of Highway Improvement Industry Accounts*.

When JOBMOD2 is run, the user defines a total value of expenditure and its distribution across the 14 industries in Table 1 and one additional industry: Engineering Services. For this final industry it was not necessary to create a new industry, as Engineering Services already exists as one of the 491 industries in the 1997 Benchmark Accounts. When the model is run, the aggregate expenditure is broken down into 15 components, which are in turn entered into the final demand vector $\tilde{\mathbf{y}}$ (Which has also been expanded to 505 by 1) in the appropriate rows. Direct and indirect output for 505 industries is then calculated as $\tilde{\mathbf{x}} = (\mathbf{I} - \tilde{\mathbf{A}})\tilde{\mathbf{y}}$. The direct, indirect and induced value of output is calculated in an analogous way.

Table1: Highway Improvement Industries

	Improvement Type
1	New Route (New Construction)
2	Relocation
3	Major Widening
4	Minor Widening
5	Restoration/Rehabilitation
6	Resurfacing
7	New Bridge
8	Bridge Replacement
9	Bridge Rehabilitation
10	Minor Bridge Rehabilitation, Bridge Deck Overlay
11	Safety/Traffic/TSM
12	Environment Related
13	Reconstruction with Added Capacity (adding lanes especially for HOV lanes)
14	Reconstruction with No Added Capacity

Employment Calculation

The vector $\mathbf{e}$ of employment income per dollar of output produced is obtained directly from the 1997 Benchmark Accounts for all industries except the 14 improvement type industries, for which an estimate of employment income per dollar of output is estimated from the Form 47 database (see Appendix 1.) Thus employment income for each industry can be calculated by multiplying output for that industry by its value of e_i. (Note that this income value includes both wage/salary income and employment benefits such as health care, pension and vacation pay.) We calculate the value of the jobs coefficient l_i, defined as person year per dollar of output, as follows

$$l_i = e_i / w_i \tag{10}$$

where w_i is the total annual employment cost for industry *i*. Since this value is not included in the I-O accounts, it had to be obtained from publications of the Bureau of Labor Statistics. Average weekly earnings for 2005 were obtained at //ftp.bls.gov/pub/suppl/empsit.ceseeb16.txt. Since these values contain only wages and salary, they were scaled according to the average proportions of all benefits except vacation pay and overtime[5], which were obtained in the News Release: Employer Cost for Employee Compensation found at //www.bls.gov/ncs/ect/home.htm. The resulting value is weekly employee compensation cost, which in turn is multiplied by 52 weeks to get the cost of a person year. (These figures were available for 16 employment categories into which all industries were assigned.) For construction labor only, the value was multiplied by 40 weeks to represent the seasonal character of construction work[6].

[5] Vacation pay benefits were excluded because the weekly value was multiplied by 52 rather than the number of weeks net of vacation. Overtime supplement was excluded to normalize to "straight-time" person years.

[6] The assumption of 40 weeks is consistent with JOBMOD and was made based on instructions on "industry norm" by FHWA staff.

Consumer Expenditure and Induced Effects

As described above, the induced effects are incorporated by expanding the $\mathbf{A}$ matrix with a row and a column for a "household industry." Define the household industry as industry *h*. The new row comprises values of a_{hi}, purchases from *h* per dollar of output from *i*. Clearly, this row is simply the transpose of the vector $\boldsymbol{e}$ defined above. But what about the values a_{ih}, which represent the inputs from all other industries to the household industry. Here we must think of the household industry as purchasing inputs of consumer goods and services in order to produce labor services. To find the value of the a_{ih} we use the vector of consumer expenditures by industries that is provided as part of the final demand data in the 1997 Benchmark Accounts. Dividing each industry *i's* consumer purchases by total consumer purchases gives us the values of a_{ih}. However, in order to avoid over estimating induced effects we must make two adjustments:

1. For most industries, a proportion of purchases will be of imported goods. Since imports represent a "leakage" in the economic system, they have no multiplier effect and should therefore be eliminated from the calculation. The 1997 Benchmark Accounts include import data that allow us to scale down the a_{ih} values appropriately[7].
2. Not all of the earnings of the household sector are spent on consumer goods and services. Some proportion is paid in taxes and some is saved. (Since the net consumer savings rate is currently close to zero, the former is the more important factor.) Again, the a_{ih} values must be

[7] The purpose of JOBMOD2 is to estimate the number of jobs and the amount of employment income supported by highway improvement expenditures in the US economy. Jobs and income outside the US, therefore, should not be included in its output. Some adjustments for imports, therefore, are necessary. Because of legislative restrictions that require the use of domestic inputs in public works projects, we have assumed that inputs to the highway construction projects funded are all from domestic sources. However, there are other expenditures to be considered that may include substantial import proportions. In particular, a large proportion of US consumer goods are currently imported. This has the effect of substantially reducing the induced effects from what they would be if all consumer expenditures were domestically produced.

scaled down to account for savings and taxes, this time using averages provide by the Bureau of Economic Analysis. (News release: Personal Income and Outlays, March 1, 2006, it can be found at //www.bea.gov/bea/newsreel/pinewsrelease.htm.)

Completely eliminating tax payments implies that the public sector has no ability to support employment. To address this, we assume that incremental tax payments result in increases in the activity levels and employment of various categories of government agencies. To do this, we create a vector containing the proportion of expenditures by three classes of government activity (Federal non-defense, State and Local Education and State and Local Other[8]) for each of the 505 industries. New values of a_{ih} are calculated as weighted sums of household and government expenditures, where the weights are the shares of consumer expenditure and taxes respectively in household income.

Estimating Impacts of Price Changes

A new capacity of JOBMOD2 is the ability to estimate the impact of an increase in the price of one or more major inputs on the number of jobs supported a given level of highway improvement expenditure. The logic of this new procedure is as follows. If an increase occurs in the price of an input it will inflate the cost of highway improvement on a per-unit basis. Suppose, for example, that $1 billion could normally achieve 100 miles of reconstruction. Now suppose that the price of bituminous materials doubles. Assume further that bituminous material accounts for 50% of the total cost. This means that the total cost of production increases by 50%. In this case, an investment of $1 billion will produce only 66.6 miles of reconstruction and the employment supported will be only what would previously be supported by $666,666 dollars. If there had previously been 30,000 jobs there would now be only 20,000 jobs.

[8] Defense expenditure was left out because we assume that it is not as much driven by growth in tax revenue as are other categories of government expenditure.

This type of adjustment can be easily implemented in the model. For any input *i* and improvement type *j*, a_{ij} represent the proportion of the input's cost in total cost. The user is asked to enter an index q_i which is greater than one if the price increases and less than one if the price decreases. An overall price index for improvement type *j* which takes account of the change in the price of input *i* is calculated as

$$q_j = 1 + a_{ij} q_i - a_{ij} \tag{11}$$

The new employment value is calculated by dividing the employment value before the price change by q_j.

Price changes in labor are bit more complex because an increase in labor price also affect the translation of labor income into person years. After generating a new employment income as described above, the number of jobs is recalculated based on an inflated cost per person year.

Comparing JOBMOD and JOBMOD2

Previous users of JOBMOD will notice two types of differences when they use JOBMOD2: Difference in the value of employment estimates and differences in model's functionalities. Focusing first on the former, it is instructive to look at a comparison of parallel runs, using the same initial investment of $1.25 billion and distribution of expenditures across improvement types. The results of the runs are shown in Table 2:

Table 2: Comparison of JOBMOD and JOBMOD2 Employment Estimations			
	JOBMOD	JOBMOD2	%Δ
Construction Oriented Employment Income	$570,271,068.71	$545,860,696.00	-4%
Construction Oriented Person-Years	19,584.70	13,591.77	-31%
Construction Oriented Employment Income	$215,367,900.52	$245,349,177.98	14%
Supporting Industry Person-Years	6,939.31	6,058.76	-13%
Induced Employment Income	$527,521,737.02	$697,728,946.22	32%
Induced Person-Years	21,052.38	19,796.69	-6%
Total Employment Income	$1,313,160,706.26	$1,488,938,820.00	13%
Total Person-Years	47,576.39	39,477.23	-17%

Two things are immediately evident. The first is that the estimated employment income is higher for JOBMOD2 and the second is that the employment person years are lower for JOBMOD2. There is also a subtle deviation from these general trends: while other categories of employment income are higher for JOBMOD2, construction oriented employment income is lower.

Turning first to person-years, the lower values for JOBMOD2 are to be expected because they are based on more recent labor compensation data. Since each person-year is more expensive than it was when JOBMOD was first created in 2001, a given investment can be expected to produce fewer jobs.

On closer consideration, the higher values of employment income in JOBMOD2 are not difficult to understand. The difference actually comes down to the relative values of the coefficients a_{hi} in the 1992 TSA versus the 1997 Benchmark

Accounts. For any point in time, we can define the payments to labor per unit of output as follows:

$$a_{hi} = p_h z_{hi} / p_i z_i$$

where the z are physical quantities of inputs and output (for example hours and tons for labor and steel respectively) and the *p* are prices per unit. A change in the ratio of the z's represents a change in technology. However, even if technology stays the same, a_{hi} would go up if the price of labor were to go up more rapidly than the price of commodity *i*. Since per capita earnings tend to go up in real terms, it is not surprising that the price of labor tends to go up more rapidly than the price of everything else. Thus, in the absence of technological change, one would expect a_{hi} to be higher in each successive set of I-O accounts.

Of course if the technology didn't change, the values of a_{hi} would rise fast enough to keep the number of jobs supported constant over time. Our results indicate that this was not the case. (Also note that the I-O coefficients are for 1997, while the labor cost estimates used to calculate jobs are from 2005. The update of the Benchmark Accounts to 2002 is not yet available.)

The fact that the construction oriented employment income declines between JOBMOD and JOBMOD2 probably reflects the refinements that were made to the 1997 Benchmark Accounts. Specifically, efforts were made to separate out various types of "in-house" production of secondary commodities and assign it to more appropriate industry. The process of reassigning "in-house" production has the inherent effect of shifting some employment to the supporting industries category.

As a further note, both the income and employment values for the induced reflect the incorporation of endogenous government expenditures arising from the proportion of labor income that goes to taxes, as defined above. This effect was not included in JOBMOD.

Users will also notice a number of functional changes, including the following:

- *Right- of- Way.* It was the original intention that project investment values entered into JOBMOD should exclude any expenditures on right-of-way. Such expenditures do not trigger any economic activity directly and therefore should not be included in the calculation of employment generation. The page in JOBMOD2 to which the user enters to value of expenditure now includes a box to indicate what percentage of the expenditure was for right-of-way. This percentage is deducted to create thee new variable "net construction cost," which is entered into the final demand vector in the model calculations.
- *Engineering Expenditures.* Recent analysis of federal-aid highway expenditures indicates that a significant proportion of these funds are being spent for engineering services. This was not a category of improvement type expenditure in JOBMOD. It has been added to the menu of improvement types in JOBMOD2. It was not necessary to create a new improvement type industry because engineering services is already defined as an industry in the 1997 Benchmark Accounts.
- *Price level changes.* The addition of the capacity to estimate the short-term impact of price level changes was initially spurred by FHWA staff's (Arthur Jacoby) interest in incorporating the impact of run-ups in the prices of internationally traded commodities such as steel and petroleum on employment generation. User's are asked to enter a price index (1 means no change, 2 means doubling of price) for each of the most important material inputs to road construction as well as for labor. (Appendix 2 demonstrates how this function may be used to assess the sensitivity of JOBMOD2 to price fluctuations.)

Notes on the Applications of JOBMOD2 and Interpretation of its Results

There have been cases where JOBMOD was applied in contexts for which it was not designed and its results interpreted in ways that are not consistent with its underlying assumptions. More care must be taken to avoid inappropriate applications of JOBMOD2 and misinterpretations of its results. (The discussion that follows is included in full in the *User's Manual* for JOBMOD2.)

Like all economic models, JOBMOD2 makes some simplifying assumptions that may, in some circumstances, deviate from reality. Specifically, like all I-O models, JOBMOD2 assumes that there is slack capacity in the markets for labor and for goods and services. If this is true, then any employment supported as the result of an expenditure on highway improvement will be *incremental*. This means that aggregate employment is expected to increases by the quantity estimated by the model. In some times and places, production capacity may be limited and the labor market may be tight. In such cases, while the investment may still support the quantity of employment indicated by the model, some or all of those quantities may be diverted from other economic activities – so they are *non-incremental.*

For example, JOBMOD2 may estimate that the employment impact of a particular highway investment is 40,000 jobs. If there is sufficient slack capacity in labor supply (i.e. unemployment) these will be 40,000 incremental jobs. If there is no such slack, however, the total employment will not rise by 40,000. Rather, some proportion of those jobs will be filled by workers who leave other jobs. Presumably, these workers will be better off because they would not leave high wage jobs to take low wage jobs, but they will not be going from unemployment to employment.

Whether or not an employment impact is incremental may depend on the time and place of the highway investment. During recessions, when there is relatively little private construction activity, a larger proportion of estimated employment will be incremental. Highway projects in regions where there is high unemployment will be more fully incremental than projects in regions with labor shortages. It is important that users of JOBMOD2's outputs do not give the impression that all jobs are incremental jobs.

In order to avoid communication of the results of JOBMOD2 in a potentially misleading way, users should observe the following rules:

- Any report or media release that uses numbers produced by JOBMOD2 should attempt to explain the assumptions inherent in the modeling procedure.
- In a context where the objective is to determine the increase in aggregate employment resulting from highway expenditures, JOBMOD2 estimates should be represented as upper limits that will be achieved only if there is sufficient slack capacity.
- Language such as "creation of new jobs" and "employment growth" should be reserved for environments where the estimated employment impacts are truly incremental. In general, "jobs supported" is a better expression than "jobs generated," which may imply incremental job creation.

Use of JOBMOD2 for state-level impact assessment

JOBMOD2 has been designed for *national* impact assessment. Its main purpose is to estimate the number of jobs supported nationally by a specified program of highway improvement investment. *It is not designed to make state-level employment estimates and should not be used for such a purpose*.

The danger of using JOBMOD2 for state estimates can be summarized as follows. Even if a construction investment occurs entirely within the borders of a

single state, it is likely to generate employment in other states. This is because construction inputs – especially manufactured goods such as steel elements, lights, signals, signs, guard rails, culverts, etc. – are frequently shipped between states. Also, the induced employment effects may accrue to many different states depending on the distribution of the production of consumer goods and services. Detailed information on the interstate sourcing of inputs and consumer goods would be needed in order to determine how much of the national employment indicated by JOBMOD2 accrues within a particular state. JOBMOD2 does not contain such information and therefore cannot generate state level employment estimates.

Use of JOBMOD2 to assess the impact of individual projects

JOBMOD2 was designed to estimate the national employment impacts of a *program* of expenditure on highway improvement rather than the impacts of an individual project. Its multiplier values are national averages that do not take account of difference in the specifications of projects within broad categories, regional differences in production technology due to prevailing labor market conditions (such as regional variations in the labor intensity of construction activities) or differences in input requirements due to variations in conditions such as climate, soils and terrain. Thus, JOBMOD2 is not an adequate substitute for a detailed project-specific economic impact analysis.

Future Directions

Given the caveats expressed above, there are a number of ways in which the structure of JOBMOD2 could be extended in the future in order to make it applicable to a broader range of policy questions and to a larger number of potential users.

Regional Model

Perhaps the most obvious extension would be to build some spatial detail into the model. As noted above, it currently does not provide a basis for state or regional employment estimates. In order to do this it would be necessary to include some information about interregional movements of goods and services. There are two possible levels or regionalization:

1. One or more independent regional version of JOBMOD2 could be created. This would require that for the region in question, input-output coefficients for each industry be scaled down according to the proportion of deliveries from that industry that originate outside the regional borders. In essence, this treats shipments from outside the region as imports.
2. An integrated multiregional model of JOBMOD2 could be created. Here the US would be broken into an exhaustive set of regions and information on all interregional flows would be used to create a multiregional input-output structure. In this type of model it would be possible to estimate the number of jobs supported in one region by highway improvement expenditures in a second region.

The first type of model has been designed and implemented in the state of California. This model, called CT-IO, is closely analogous to JOBMOD except that it generates California-only employment estimates.[9] It is based on a survey of trucking that estimated the annual value of goods shipped into California at the four-digit level. (All services were assumed to be sourced internally.) By subtracting these values from estimates of total California consumption it is possible to scale down total employment to California employment.

The weakness of this approach is that it does not provide any information about where the “non-California” employment occurs. The integrated multiregional model described above would provide a regional distribution of employment impacts associated with highway improvement expenditures in any region. So,

[9] CT-IO was developed in 2003 jointly by the Boston University Center for Transportation Studies and System Metrics Group Inc for Caltrans Division of Transportation Planning, Office of Transportation Economics.

for example, policy makers from the Great Lakes States could see how much of the employment associated with highway projects in the Southwest would accrue to the metals-based industries in their states.

An integrated multiregional version of JOBMOD2 would require a full set of interregional commodity flow estimates. The only source for such data is the Commodity Flow Survey, which provides such information only at the two-digit level. It would therefore be necessary to assume that interregional flows for all four-digit industries are proportional to those of their two-digit aggregate industries.

Labor Market Effects

It has been noted above that employment and income estimates from JOBMOD2 may not be incremental because the labor required may be diverted from other activities. It is also possible that two things that are currently treated as exogenous – the labor input coefficient and the wage – may change as the result of a major investment.

Define l as the dollars of direct labor income generated per dollar of expenditure on a particular type of highway improvement. Naturally this depends on both the physical labor requirement in hours h and the wage w: $l=hw$. In a tight labor market, a rapid increase in labor demand due to the inception of a major project might affect l in three ways:

1. The wage rises, but there is no input substitution. In this case the total labor income l increases while the hours worked remain constant.
2. The wage rises but there is a corresponding decrease in h due to input substitution. These two effects may cancel each other in terms of labor income (l remains constant) but hours worked h goes down.
3. There is a strong input substitution effect whereby the proportional decline in h is greater than the increase in w so l declines.

In order for 3 to occur the labor demand elasticity must be greater than 1, therefore it is an improbably case. If 2 occurs, the current assumptions in JOBMOD2 should produce accurate estimates of income but inflated estimates of person-years. If 1 occurs two things happen. First, construction oriented labor income increases (but the number of jobs stays the same). Second, labor hours and income in the other two categories decreases because a larger proportion of the expenditure value goes to construction labor. At present it is possible for the user to simulate this effect by specifying a construction wage increase in the model run – but that presupposes that the user can estimate the wage impact.

In order to make this effect endogenous, it would be necessary to estimate elasticities of labor supply and build them into the model. One complication in doing this, however, is the fact that labor markets are not national but regional. Thus an expenditure of $10 billion in one region will have a different impact on wages than the same expenditure distributed across the entire country. In order to extend JOBMOD2 to incorporate labor market effects, therefore, it would first be necessary to implement the regional model described above.

Employment Time Trajectory

JOBMOD2's principal output is the number of person-years of employment supported by a program of expenditure. This is rather ambiguous information because, for example, 1000 person years could represent 100 people employed in one year or 100 people employed for 10 years. This makes it impossible to make projections into the future or to answer questions such as "how many people are employed today because of expenditures committed over the past 5 years."

This weakness might be addressed by creating an employment time profile for each category of highway improvement. This profile would specify the proportion of total employment that actually occurs in each year over a seven to ten year horizon. At present, there is no readily available data set on which such profiles

could be based. If we were only concerned with direct construction labor, it might be possible to work with regional FHWA offices to generate expenditure profiles for a sample of projects in each improvement type. Since employment is defined more broadly in JOBMOD2, however, it would be necessary to have a profile of expenditure for all major categories of inputs, upon which we could base estimates of employment profiles on an industry-by-industry basis.

Future Data Issues

The issue of greatest concern for the future of the JOBMOD series of models is the availability of data upon which the technical coefficients of the highway improvement type industries are based (see Appendix 1.) The model currently contains data collected via Form 47 during the 1990s. These data were not ideal for a number of reasons. Most importantly, the vast majority of form submissions lacked the information necessary to assign them to highway improvement types. For this reason, the coefficients currently used in JOBMOD are based on a sample of about 15% of the universe of forms submitted. Also, despite quality controls the high variance in data ratios across observations casts some doubt on the reliability of the numbers.

For the future it appears that not even the Form 47 data will be available to update the technical coefficients in the model. Thus some alternative source of project specific technological data will be needed. One possible strategy may be to base coefficients on a small sample of more detailed project case studies. Project contract reports that are used in the process of project monitoring may also prove to be an alternative source of data on highway improvement technology.

Appendix 1. Creation of Highway Improvement Industry Accounts.

The process of generating I-O coefficients for the 14 was largely completed under the first contract between FHWA and the Boston University Center for Transportation Studies (BU/CTS) under which JOBMOD was completed in 2001. What follows is a narrative description of the process of generating the coefficients, along with explanation of updates that were necessary for JOBMOD2.

The data required for the analyses were drawn from three principal sources. The first is a database of submissions of FHWA Form 47, which includes purchases of labor, material, and supplies. The second is FHWA's Fiscal Management Information System (FMIS) which includes financial information and classifies projects according to improvement types. The third is the national input-output accounts provided by the Department of Commerce. In addition, data on commodity prices are drawn from a set of supplemental sources.

FHWA Form 47

FHWA Form 47 *Statement of Materials and Labor Used by Contractors on Highway Construction Involving Federal Funds* must be filed by all projects for which the construction cost of roadway and bridge is one million dollars or more. (The only exceptions are projects that are primarily for highway beautification or installations of protective devices at railroad grade crossings.) The purpose of this requirement is to provide data that can be used by the USDOT to estimate the economic impact of an increase or reduction in Federal-aid Highway expenditures. The data are also required by the Bureau of Labor Statistics, US Department of Labor, as part of its mandate to track labor trends in all economic sectors.[10]

[10] Federal Highway Adminstration,1991, *Federal Aid Policy Guide*, Chapter 6.

The form is divided into two sections: A and B. Part A is to be completed by either the FHWA divisional office or the state highway agency responsible for the project. It includes general information on the location (county, urban/rural), size (miles of bridge and roadway) and cost of the project. It also includes a unique federal project number. Part B includes detailed information on purchases of labor and material under the contract. The contractor – defined as the company or firm that is awarded the contract and completes 50% or more of the work by dollar value – fills out this part of the form. The contractor may either submit one form for the entire project or separate forms for its own work and for that of each subcontractor. In the latter case, the separate forms are combined into a single form by FHWA.

For quality control, the FHWA Division Administrator must establish review procedures to check the clerical accuracy and engineering reasonableness of the information provided by the contractor. The forms are submitted to the FHWA Office of Engineering where they are checked once again and coded. Common errors that are detected by the division offices and the Office of Engineering include failure to complete all items, unrealistic data entries, use of incorrect units, and combined material and labor costs that exceed total costs.

What follows is a summary of the information on the form.

1. *Project Description*: The state and county in which the project is located is provided, whether it is urban or rural, and the start and completion dates. The length in miles for roadways and both miles and number for bridges is also included, as is the total project cost. The form has an entry for “construction type codes” in a section to be completed by FHWA or state highway personnel.
2. *Labor Inputs:* Only two pieces of information are provided: total labor hours and gross earnings. There is therefore no way to break down labor input by

skills level or functional category. The instructions stipulate that this should include labor for operation and maintenance of equipment.

3. *Material and Supplies:* A single value is given for the total cost of materials and supplies. This does not include rental, leasing, or depreciation cost of equipment, but it does include the cost of fuel and lubricants used for the equipment. Materials and supplies are broken down into the categories shown in Table A1.1.

In addition, the numbers of linear feet for several sizes of culvert items are included in the following categories: corrugated steel culvert, concrete pipe, clay pipe, corrugated aluminum culvert, and plastic pipe. In no case are both dollar and physical unit values provided, so it is not possible to infer a price for any category of material or supply from the data. However if price data were obtained from supplementary sources it is possible to estimate a proportional breakdown of the total costs of materials and supplies to the different categories.

Table A1.1: Categories of Material and Supplies Identified in Form FHWA-47.

Category	Reporting Units
Petroleum products	gallons
Cement	barrels of pounds
Aggregates purchased	tons or cubic yards
Bituminous materials	gallons
Lumber	thousands of board feet
Reinforcing steel	pounds
Structural steel	pounds
Ready-mix concrete	cubic yards
Premixed bituminous paving material	tons
Aggregates produced	tons or cubic yards
Miscellaneous steel	pounds
Noise barriers	linear feet
Guardrail	linear feet
Bridge rail	linear feet
Final contract amount for signs	dollars
Final contract amount for lighting	dollars
Final contract amount for traffic signs	dollars

The sum of the costs for labor and materials and supplies should be substantially less than the total project cost. This is because the latter includes the costs of equipment, overhead and profit – items that are not reported on Form 47.

Given the level of detail, the FHWA Form 47 data records provide an excellent basis for estimating the economic impact of highway projects. They have two important weaknesses, however. The first is that projects below one million dollars are excluded. This is a problem not only because the sum of all projects below this level account for a significant share of federal-aid highway funds, but also because input-output ratios calculated on the basis of the Form 47 data may be biased by the absence of small projects. The second major weakness of these data is the fact that the information on the forms does not provide an adequate basis for calculation of separate input-output ratios for different types of highway improvement projects. For example, it is not possible to distinguish between roadway resurfacing projects, reconstruction projects, and new construction. (Part A includes a space for "construction type codes," but this information is absent in all but about 2.5% of submitted forms.) It is because of this second problem that matching of Form 47 records with records from the FMIS (see below) is necessary.

For the purpose of this project, BU/CTS acquired a database of all available FHWA Form 47 records from FHWA.[11] This database comprised a total of 10,604 records, each referring to a separate contract. The records were organized into annual files for 1990 through 1997, depending upon the date at which the record in its current form was entered into the database. However, many of the records were from projects with completion dates much earlier than 1990, with some as early as 1977. In total, 23% (2436) of the records have completion dates earlier than 1990, and 77% (8168) have completion dates of 1990 or later. The average time interval between the project start date and

[11] "All available records" refers to all those that have been coded into a consistent format for organization into a relational database.

completion date is 18 months, but varies from as little as one month to over 11 years.

The distribution of the records across states is shown in Table A1.2. Naturally, large states like Texas and Florida have large numbers of records. However the number of records is clearly not proportional to population. For example, Iowa has more records than either California or New York. Since the number of records should be equivalent to the number of contracts over one million dollars, it provides some rough measure of federal-aid highway activity. It is only a rough measure, however, since contracts vary widely in terms of both size (miles) and dollar cost.

Review of the FHWA Form 47 database indicated some likely problems with data accuracy. For example, in a relatively small number of cases the sum of reported labor and materials cost exceeds the total cost. Records with such obvious problems were screened and eliminated from the data set. Also, a number of data items are missing in many cases. Most notably, the county is reported only in those records in the most recent (1996 and 1997) data files, which account for only about 18% of the total records. Start and end dates, however, are reported for all records.

The most troubling problem with the FHWA Form 47 data is the fact that project numbers lack a consistent format. Some contain only numbers, but most contain numbers and letters in some combination. Some contain spaces, dashes, parentheses, and/or brackets. This presented a significant problem since, in order to assign records to highway improvement types, it was necessary to match records across the FHWA Form 47 and FMIS databases. The federal project numbers reported in the latter contain only one letter with the rest numbers. Also, the fact that county information is missing from most of the FHWA Form 47 database made it impossible to verify matched records by location.

Table A1.2: FHWA Form 47 Records: Distribution by State					
	number of records	percent of total		number of records	percent of total
Texas	1199	11.31%	Maryland	158	1.49%
Illinois	810	7.64%	Oregon	147	1.39%
Pennsylvania	541	5.10%	New Mexico	146	1.38%
Florida	421	3.97%	MS	140	1.32%
Georgia	387	3.65%	North Dakota	135	1.27%
Missouri	363	3.42%	Montana	131	1.24%
Missippi	327	3.08%	Kansas	129	1.22%
Iowa	320	3.02%	West Virginia	125	1.18%
Minnesota	318	3.00%	Arkansas	122	1.15%
Wisconsin	286	2.70%	Idaho	121	1.14%
Indiana	273	2.57%	Utah	116	1.09%
Oklahoma	251	2.37%	Virginia	113	1.07%
Colorado	249	2.35%	Massachusetts	106	1.00%
Alabama	238	2.24%	Maine	96	0.91%
Ohio	235	2.22%	Alaska	90	0.85%
California	207	1.95%	Rhose Island	75	0.71%
Washington	204	1.92%	South Carolina	69	0.65%
Connecticut	190	1.79%	Wyoming	65	0.61%
Tennessee	187	1.76%	Nevada	60	0.57%
North Carolina	185	1.74%	Kentucky	56	0.53%
South Dakota	183	1.73%	New Hampshire	51	0.48%
New York	176	1.66%	DC	47	0.44%
Arizona	164	1.55%	Delaware	39	0.37%
Louisiana	164	1.55%	Vermont	35	0.33%
Nebraska	164	1.55%	Hawaii	22	0.21%
New Jersey	162	1.53%	Puerto Rico	4	0.04%
			Not Identified	1	0.01%

FMIS

FHWA's Fiscal Management Information System (FMIS) keeps track of financial information for each highway project for which federal aid is provided. It records details of the aid including the program under which it is authorized, the date it is approved, and the amount of federal funds. It identifies the state, county, and rural/urban status of the project as well as several codes identifying the nature of

the highway improvement. For ongoing projects it keeps track of federal transfers to date and the steps along a project life-cycle. For completed projects it includes the total cost and the federal share, as well as the date of completion. It does not, however, include costs breakdown into expenditure categories.

The critical piece of information that is found in FMIS but *not* in Form 47 is a construction type code for each project. To get an accurate indication of improvement type, therefore, it is generally necessary to match the federal project number included on each form with the FMIS records to obtain an improvement type code for each project.

For the purpose of this project, BU/CTS was able to gain access to the FMIS database through the divisional office of FHWA located in Cambridge MA. Appropriate FMIS reports were downloaded to disks in that office on a state-by-state basis. They were processed and assembled into a relational database.

Matching Records from FHWA Form 47 and FMIS

FMIS project numbers are almost all numeric, although a small proportion begin with letters. Form 47 project numbers may be numeric, alpha-numeric, or alpha-numeric with any combination of symbols, including dashes, parentheses, brackets, periods, commas, and the abbreviation “ETC.” — in any order. Consequently, matching records by project numbers was problematic because project number formats are inconsistent. Also, there are many duplicates.

After consultation with FHWA staff, our approach to matching records was to reduce all project numbers in the Form 47 database to their numeric components and match those against the project numbers reported in the FMIS database. This produced a number of matched records, which were then further checked for consistency. For example, it was verified that both sources gave the same urban/rural designation for the record in question, and that the completion dates and total project costs coincided roughly. This extra layer of quality control

helped to eliminate both incorrect matches and correct matches that contain incorrect data.

The entire process yielded 1266 matched records. While this number is small relative to the total size of the Form 47 database, it constitutes a sufficiently large sample for statistical purposes. Comparisons of mean values from the matched sample with those from the entire data set indicate that, despite the high rate of observation attrition, the sample appears to be highly representative of the full data set.

Price data for labor, materials, and supplies were needed in order to create new input-output coefficients (see below) it is necessary to calculate the ratio of the dollar cost for each type of input to the total cost of the project. Since most non-labor input data in the Form 47 database is reported in physical units, unit prices are needed to calculate the cost of each input. Table A1.3 indicates the principle sources for price data for various categories of inputs.

Table A1.3: Sources for Unit Price Data	
Petroleum products ($/gal.)	Energy Information Administration and American Petroleum Institute
Cement ($/lb)	FHWA construction cost database Statistical Abstract of United States Department of Interior, Bureau of Mines
Aggregates purchased ($/ton)	Statistical Abstract of the United States DOI Bureau of Mines
Aggregates produced ($/ton)	(assumed zero material input)
Bituminous material ($/lb.)	Statistical Abstract of the United States
Premixed bituminous paving material ($ / ton)	FHWA construction cost database, Statistical Abstract of United States Engineering News-Record
Lumber ($/ 1000 board ft.)	Cahners Business Information (Purchasing Magazine), Western wood products association
Reinforcing steel ($/lb.)	Cahners Business Information (Purchasing Magazine), FHWA construction cost database trade publications
Structural steel ($/lb.)	Cahners Business Information (Purchasing Magazine), FHWA construction cost database trade publications
Ready mix concrete ($/ cu. yd.)	FHWA construction cost database Engineering News Record

In some cases more than one source is available. In these cases care is taken to explain any inconsistency between sources. Also data from trade publications such as magazines, newsletters, and corporate product price lists, often represent a single observation rather than a sample mean. We base our estimate on more than one source wherever possible.

For many of the input categories listed in Table A1.3, price data are available in only one or a few years. It is possible to generate complete time series from as few as one observation by applying deflators. The Bureau of Labor Statistics

Producer Price Index (PPI) series is defined at a level of detail sufficient to match all the input categories.

The coefficients estimated from the data were incorporated into the 14 new highway improvement industries included in JOBMOD. In order to incorporate these industries into JOBMOD2, a couple of revisions were needed. The first arose from the switch from the SIC industrial definitions of the 1992 TSA to the NAICS definitions of the 1997 Benchmark Accounts. It was necessary to recreate each industry's vector of coefficients, reassigning expenditures on various inputs to the new industry definitions.

The second revision involved payment to labor coefficients calculated from the Form 47 database. Comparing these coefficients to those of other construction industries in the Benchmark Accounts, it was clear that they were too low. This reflects the general upward trend in the share of labor compensation in total expenditures explained above. In order to correct this, the a_{hi} values for all industries were scaled up so that their mean was equivalent to the corresponding value for the single road construction industry included in the Benchmark Accounts. Other coefficients in the column for each of the 14 industries were also rescaled to ensure that expenditure coefficients added up to the same total as they had before the adjustment of the a_{hi} values.

Appendix 2: Sensitivity Analysis for Input Prices

A feature of JOBMOD2 that was not included in JOBMOD gives the user the option of adjusting the employment estimation model for changes in the prices of the most important material inputs: steel products, ready-made concrete, petroleum products, asphalt products, lumber and cement. The rationale for introduction of this facility is the recent volatility on the price of internationally traded commodities (most notably steel and petroleum) due in part to growth in demand from China and other rapidly developing economies.

The way these price changes affect the estimation of income and employment can be described as follows. If the price of some major input such as petroleum products increases, we can envision two types of changes in the production of highway improvement. The first is an increase in the cost of executing a given highway project and the second is some form of input substitution by which other inputs are substituted to make the production technology less petroleum-intensive. Since the input-output model is not capable of projecting endogenous changes in the production technology, only the first effect is captured by JOBMOD2. In essence, an increase in the cost of highway projects means that that a given value of investment (say $1 billion) buys less construction activity, therefore less employment income and person-years are supported. (Another way to think about this is that if a higher proportion of the $1 billion must go to petroleum, a smaller proportion goes to labor.)

This new feature was used to produce the results in Table A2.1, which illustrate the sensitivity of JOBMOD2 income and person-year estimates to changes in the price of six material inputs. They are based on a total construction expenditure of $1.25 billion ($1 billion federal expenditure with a 20% state match). A base case run (equivalent to the results presented in Table 2) is compared with three hypothetical runs in which the price of each input is assumed to decrease by 50%, increase by 50% and increase by 100%.

Table A1: Sensitivity of Income and Employment Estimates to Input Price Changes				
Input	% price change			
	-50%	0% (base)	+50%	+100%
Steel				
Income ($M)	$1,492	$1,489	$1,485	$1,481
Person Years	39,552	39,447	39,343	39,239
Ready Made Concrete				
Income ($M)	$1,513	$1,489	$1,466	$1,443
Person Years	40,083	39,447	38,838	38,254
Petroleum Products				
Income ($M)	$1,541	$1,489	$1,441	$1,396
Person Years	40,823	39,447	38,177	37,000
Asphalt Products				
Income ($M)	$1,521	$1,489	$1,458	$1,430
Person Years	40,304	39,447	38,647	37,897
Lumber				
Income ($M)	$1,490	$1,489	$1,486	$1,492
Person Years	39,490	39,447	39,361	39,532
Cement				
Income ($M)	$1,492	$1,489	$1,486	$1,483
Person Years	39,532	39,447	39,362	39,278

The results indicate that the main model outputs of employment income and person-years are not highly sensitive to changes in materials prices. This reflects the fact that the overall expenditure on direct and indirect inputs is dominated by labor and service provisions rather than material inputs. However, the impacts are not inconsequential. For example, a doubling of petroleum prices results in a reduction of almost 2500 person years (roughly 6%).

JOBMOD2 also allows the user to adjust for changes in the wage level of construction labor. As expected, the impacts of these changes are more dramatic because labor accounts for a much larger share of construction cost than do material inputs. As in the case of materials, an increase in the price of construction labor leads to an increase in the price of construction activity. Since a given investment level buys less activity, the total employment declines. The picture is somewhat more complicated in the case of labor, however, because construction labor income and construction person-years will move in opposite

directions as wages increase. (*Note: The model permits adjustments only in highway construction wages. All other wages are assumed constant.)*Table A2.2 shows the effect of decreasing wages by 50%, increasing them by 50% and increasing them by 100%.

Table A2.2: Sensitivity of Income and Employment Estimates to Construction Wage				
	% price change			
	-50%	0% (base)	+50%	+100%
Construction Oriented				
Employment Income ($M)	$427	$546	$628	$689
Person Years	16,490	13,592	11,589	10,120
Supporting Industries				
Employment Income ($M)	$280	$245	$221	$204
Person Years	6,907	6,058	5,469	5,035
Induced				
Employment Income ($M)	$831	$697	$605	$538
Person Years	23,581	19,797	17,179	15,258
Total				
Employment Income ($M)	$1,538	$1,489	$1,455	$1,430
Person Years	46,979	39,447	34,237	30,414

The results are much more dramatic than those in Table A2.1. Doubling construction wages decreases total person-years by over 20%. Employment income, however, is relatively stable because the extra wages earned by construction employment offsets most of the wages lost due the reduction in all other categories of employment. Looking specifically at the changes in construction oriented employment, here person years and income move in opposite directions as a larger amount of income is distributed across a smaller number of workers.