Measuring Economic Stimulation from Capital Investment in Transportation

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This paper reports on an interactive computer model developed to calculate the economic impacts of capital investment in transportation facilities. The Transport Impact Model (TRIM) works within the framework of input-output analysis and is based on the 43-commodity input-output table for the province of Ontario in Canada. For a given capital project, described in terms of several categories of input costs, TRIM computes values for labor income, gross domestic product, employment, gross sales, tax revenue, imports from other provinces and abroad, and primary energy consumed. Some of the preceding categories are further disaggregated. For each impact indicator, TRIM shows the initial effect and the indirect and induced effects of a capital expenditure. While the version of TRIM described herein applies to the Ontario economy, it can be adapted for use in any economic unit for which input-output data exist.

In addition to providing new services and maintaining service quality, capital expenditures by transportation agencies have secondary effects on the economy: they affect income, employment, and production inside and outside the jurisdiction involved; they generate tax revenues of various sorts; and they use energy resources. Such secondary effects are of interest to those who decide how much to spend on transportation capital projects and how to allocate the funds across projects. For any particular project it is useful to know what the impacts are and how they change in response to adjustments in the content or scale of the project. Comparisons of economic impacts across projects in different parts of the transport sector are also useful in deciding which projects to fund. The purpose of this research effort has been to construct an analytical tool that will provide transportation decision makers with a comprehensive set of indicators of the economic impacts of spending programs.

The result of the project is the Transport Impact Model (TRIM), a self-contained microcomputer program based on a prototype model developed by Econometric Research Ltd. of Burlington, Ontario. With TRIM, analysts can calculate impact indicators for a variety of capital projects in minutes. In the present version, designed for use in the Ontario provincial transportation system, one can view the impacts on the Ontario economy of 35 predefined typical projects, either individually or in combinations; one can adjust the assumptions made about the content or scale of these typical projects; and one can run one's own specially defined projects through the program.

The next section of this paper briefly describes the logic of TRIM and sets out the variables that are calculated as indicators of the effects of capital expenditures. A full description of TRIM is provided by Allen et al. (*1*). Other sections explain how the data that define a simulated project were constructed and entered into the model and describe some illustrative simulations with the present version of TRIM. The concluding remarks indicate how the model will be further developed.

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ECONOMIC IMPACTS

Input-output analysis provides a framework within which industrial linkages, as well as the feedbacks between consumers and the producing sector of the economy, can be simulated. Miller and Blair have written a useful textbook on the subject (*2*). The economy is modeled as a set of linear equations, the parameters of which are estimated by a central statistical agency and organized into an input-output table. The input-output table is an extension of the familiar national product accounting system to the level of individual industries and commodity groups. TRIM operates within this framework.

A variety of economic impacts may be of interest to decision makers. TRIM calculates the set shown in Table 1. For each of these variables, an economic impact is defined as the sum total of changes in all sectors of the relevant economy associated with a given capital project or program expenditure. In the output of TRIM, these changes are broken down into initial, indirect, and induced effects. Consider each of these effects in turn.

The initial effect measures the change in the impact variables closely associated with the original expenditure

TABLE 1 ONTARIO IMPACT INDICATORS CALCULATED BY TRIM

- Labor Income
- Gross Domestic Product (at market prices)
- Employment
- Gross Sales
- Tax Revenue (by level of government & type of tax):
    - Personal Income Tax
    - Indirect Business Tax
    - Customs Duties
    - Corporate Profits Tax
    - Property & Business Tax
    - Total Tax Revenue (Federal & Provincial)
- Imports from other provinces
- Imports from abroad
- Primary Energy Consumed:
    - Coal
    - Crude Oil
    - Natural Gas
    - Electricity
    - Other
    - Total Primary Energy

itself. For instance, in the case of gross sales, the initial effect of a transport project is the value of expenditures on equipment and materials required to construct the facility; otherwise put, it is the project expenditure itself less the payments to labor working directly on the project and the profit generated directly by the project. In the case of gross domestic product (GDP) (at market prices), the initial effect is equal to the value of materials, equipment, and labor used in the project itself plus profit and indirect taxes paid. Alternatively, the initial GDP effect is equal to the original expenditure, i.e., the sum of the input values entered into TRIM in the first place. The initial employment impact variable measures the number of person-years of work used directly in project construction.

Second, the output of one industry cannot be expanded without drawing on the output of other industries. The changes associated with these latter products are called the indirect impacts of the project. Indirect impacts are those associated with the production of intermediate goods and services that enter into the initial inputs. Note that there are many rounds of indirect effects. For example, one initial input into highway construction is mineral aggregate. To deliver the amount required, the quarry operator uses equipment that consumes fuel. The delivery of the extra fuel is part of the indirect effect; it is part of a first round of intermediate goods expenditures following the initial expenditure. But to deliver the extra fuel, a petroleum wholesaler also has to use extra fuel. This is a second round indirect effect. The extra demand for fuel by the gravel supplier and the petroleum supplier together creates an extra need for fuel at the refinery, creating a third round, and so on. This process continues until the extra increments of production in subsequent rounds become negligible.

Finally, as income expands due to the initial and indirect effects, households increase their purchases of goods and services, thereby giving rise to still further changes in production and corresponding changes in all of the other impact variables. These effects, which work through changes in household consumption, are referred to as induced effects.

It is important to interpret the numbers calculated by an impact model such as TRIM accurately and with some caution. TRIM provides consistent useful estimates of the specific variables identified within it. These estimates should not, however, be mechanistically interpreted as the net benefits of the project expenditure involved, although they are related to such benefits. For a variety of reasons (e.g., a lack of idle productive resources or the presence of pollution and other types of spillover effects), the net effect of a given capital expenditure can be evaluated comprehensively only in its own context. (A standard textbook on cost-benefit analysis will provide a discussion of this problem.)

INPUT DATA

The use of TRIM to estimate the impacts of a given spending project involves two steps. First, an account of the goods and services to be used in the project is prepared. These are the dollar values of labor, equipment, and materials (excluding the cost of land) that go into constructing the facility involved. Up to 20 categories of project inputs are involved. Then this "recipe" is used as input data for TRIM, which calculates the values of the impact variables shown in Table 1 for the project under consideration.

While the user of TRIM can prepare input cost data for any transportation project, it was regarded as useful to provide a series of typical capital projects within the program database. These sample data sets are referred to as standard unit projects (SUPs). To construct them, members of the research team obtained information from engineers and estimators involved in actual design and construction of transportation facilities. For a given SUP, a list of the tasks required to build or service the transport facility was prepared. For instance, in the case of a municipal arterial road, this list included excavation of the existing road base; grading and shaping the subbase; filling with granular "A"; granular backfilling for soft spot excavation; adjusting manholes, catchbasins, and valve chambers; constructing curb drains; relocating utilities; and so on until the full recipe for the unit-section of road was well defined.

With the help of engineers and estimators, the cost for performing each of these tasks was obtained and then broken down into the categories of inputs defined by the Ontario input-output table. Examples of these categories are wage payments, equipment, fuel, nonmetallic mineral products (e.g., gravel), primary metal products, electrical products, and so on. The result was a cost data matrix for each standard unit project, with the tasks defining rows and the input categories defining the columns. A sample is shown in Table 2, which reproduces the data matrix for standard unit project 6, a 100-m length of two-lane municipal roadway.

This process was followed for 25 of the 35 SUPs shown in Table 3. (The data for SUPs 18–27 were adapted from an earlier project on highway impacts carried out by the Ontario Ministry of Transportation and Communications.) When the TRIM program is run on a microcomputer, the user chooses at the outset whether to calculate impact indicators for one of these SUPs or whether to construct a unique simulated project. If an existing SUP is chosen, the user has the option of viewing and adjusting the table of input costs, in which case a list of cost categories like the one shown across the top of Table 2 will appear on the screen. The column total for each cost category is the number entered into the TRIM input cost list.

TRIM OUTPUT

This section illustrates the use of TRIM for the analysis of projects and programs. As already noted, such analysis focuses on the economic impacts of a capital expenditure

TABLE 2 INPUT DATA, STANDARD UNIT PROJECT 6, TWO-LANE LOCAL MUNICIPAL ROAD

		ADMINISTRATION		LABOUR			EQUIPMENT		
	TOTAL	OVERHEAD	PROFIT	WAGES	BENEFITS	FUEL	REPAIRS	INSURANCE	DEPREC.
Tasks									
EARTH EXCAVATION	6020	482	120	2252	337	368	283	57	2122
GRANULAR 'A' (450 MM)	9450	756	189	987	147	123	95	19	709
HOT MIX HL-8 (80 MM)	7650	612	153	865	129	99	77	15	574
HOT MIX HL-3 (40 MM)	4080	326	82	461	69	53	41	8	306
CONCRETE CURB AND GUTTER	5250	420	105	1233	184	82	63	13	473
HOT MIX HL-3 FINE IN DRIVEWAYS	990	79	20	241	36	21	16	3	119
CACL2	460	37	9	40	6	3	2	0	17
ADJUST EXISTING MANHOLES	1335	107	27	441	66	0	0	0	0
WATER FOR COMPACTION	250	20	5	98	15	15	11	2	84
RELOCATION OF UTILITIES, MISC.	3549	710	177	772	115	115	89	18	665
ENGINEERING DESIGN	3123	874	219	1766	264	0	0	0	0
ENGINEERING CONSTRUCTION MANAGEMENT	2732	765	191	1545	231	0	0	0	0
COLUMN TOTAL	44889	5188	1297	10702	1599	879	676	135	5069

	NON-MET. MINERALS	NON-MET. MINERAL PRODUCTS	PETROLEUM & COAL PRODUCTS	TAX	PRIMARY METAL PRODUCTS	CHEMICALS CHEMICAL PRODUCTS	ELECTRICAL & COMM PRODUCTS	PLASTIC FABRICAT PRODUCTS	TRANS
EARTH EXCAVATION	0	0	0	0	0	0	0	0	0
GRANULAR 'A' (450 MM)	4284	0	0	0	0	0	0	0	2142
HOT MIX HL-8 (80 MM)	1595	0	2392	342	0	0	0	0	797
HOT MIX HL-3 (40 MM)	765	0	1371	215	0	0	0	0	382
CONCRETE CURB AND GUTTER	0	2008	0	167	0	0	0	0	502
HOT MIX HL-3 FINE IN DRIVEWAYS	106	0	297	0	0	0	0	0	53
CACL2	0	0	0	0	0	345	0	0	0
ADJUST EXISTING MANHOLES	0	93	0	0	601	0	0	0	0
WATER FOR COMPACTION	0	0	0	0	0	0	0	0	0
RELOCATION OF UTILITIES, MISC.	0	133	0	11	71	0	532	106	33
ENGINEERING DESIGN	0	0	0	0	0	0	0	0	0
ENGINEERING CONSTRUCTION MANAGEMENT	0	0	0	0	0	0	0	0	0
COLUMN TOTAL	6749	2235	4060	736	672	345	532	106	3910

NOTE: Values are hundreds of meters.

TABLE 3 STANDARD UNIT PROJECTS IN TRIM

Program Type	SUP No.	Nature of Project
Municipal Roads	1	6-lane Collector/Arterial road
	2	5-lane Collector/Arterial road
	3	4-lane Collector/Arterial road
	4	2-lane Collector/Arterial road
	5	2-lane Rural Road
	6.	2-lane Local Road
Airports	7	Major runway upgrade, 3500 ft
	8	Major runway upgrade, 5000 ft
	9	Major runway upgrade, 2000 ft
	10	Navigation aid upgrade, 3500 ft
	11	Navigation aid upgrade, 5000 ft
	12	Navigation aid upgrade, 2000 ft
	13	Minor runway upgrade, 3500 ft
	14	Minor runway upgrade, 5000 ft
	15	Minor runway upgrade, 2000 ft
	16	Airport access road, 200 m
	17	Airport access road, 500 m
Provincial Highways	18	New construction, unpaved, 2 lanes
	19	New construction, paved, 4 lanes
	20	Reconstruction, paved, 2 lanes
	21	Recon., paved (with rock), 2 lanes
	22	Resurfacing, 2 lanes
	23	Resurf. recycled hot mix 2 lanes
	24	Post-tensioned concrete structure
	25	Bridge deck, latex/concrete overlay
	26	Br. deck repairs, latex patch/asphalt
	27	Major widening (no structures)
Provincial Transit	28	Suburban parking lot
	29	Ride-Share parking lot
Municipal Bridges:		
	30	3-span Rehabilitation
	31	Single span, land
	32	Single span, water
	33	Medium span, land
	34	Medium span, water
Municipal Transit	35	Municipal transportation centre

on the total economy. It takes account of interindustry demands and feedbacks and of the effects on consumer spending. The version of TRIM described here is based on the Ontario input-output table for 1979 (the most recent provincial table available until the 1984 table is ready for use in 1988–89). Standard-unit-project data reflect prices at the beginning of 1987; appropriate adjustments have been made to convert impact values to 1987 prices.

Our illustration is based on SUP 3, a 100-m section of four-lane collector/arterial road. Input data for the project were developed from a reconstruction job in the city of Hamilton during 1985, with adjustments to eliminate atypical aspects of that particular project. The hypothetical project assumes reconstruction of an existing road that has deteriorated to such a level that resurfacing or other such remedial work will not provide a satisfactory riding surface and/or sufficient roadway life. Traffic is maintained on the roadway during all construction activities. Each lane is 3.5 m wide, with standard concrete curb and gutter, a 1.5-m boulevard and a 1.5-m concrete sidewalk on each side of the road. It is assumed that some roadway widening is required to provide standard lane widths. As a result, new catchbasins are required; storm sewers are assumed not to require replacement. The roadbed is excavated, subgrade is prepared, and subbase is provided to a depth of 600 mm with granular "A," covered with 120 mm of HM5 binder asphalt, and a surface course of 40 mm of HM3 surface asphalt. Intersections with local roads are provided for, and an allowance equal to 15 percent of total construction costs is provided to cover the cost of utility relocations necessitated by roadway widening. Finally, it is assumed that only minor grade changes are required.

The TRIM printout for SUP 3 is shown in Table 4. An initial expenditure of $137,647 generates a total increment to Ontario income (GDP) of $192,360 when the indirect and induced effects are included. The ratio of the total effect to the initial effect—the multiplier—for GDP is 1.82. The employment multiplier is significantly higher than the GDP multiplier in this case; 1.1 initial direct jobs expand into 4.7 jobs when the total impact of the project expenditures are tallied. This finding suggests that an expenditure on municipal roads uses inputs from sectors of the economy that tend to be labor intensive, making it an efficient area of expenditure for job creation. (The latter

TABLE 4 TRIM OUTPUT, STANDARD UNIT PROJECT 3, FOUR-LANE COLLECTOR/ARTERIAL ROAD

Provincial Impact

(Canadian Dollars)

	Initial	Indirect & Induced	Total
Gross Domestic Product	137647	54713	192360
Gross Sales	93409	180287	273696
Labour Income	38026	74595	112622
Employment (Person-Years)	1.1	3.6	4.7

Taxes	Federal	Provincial	Local	Total
Personal Tax	13270	6245	0	19515
Indirect Business Tax	4921	7913	0	12834
Tariffs	2894	0	0	2894
Corporate Profit Tax	3982	1961	0	5944
Property & Business Tax	0	0	6850	6850
Total Taxes	25068	16119	6850	48037

Imports	
Imports from Other Provinces	33567
Imports from Outside Canada	32475
Total Imports	66041

Energy	
Physical Units	
Coal	0.0 Kilotonnes
Crude Oil	0.2 Megalitres
Natural Gas	0.0 Gigalitres
Electricity	0.1 Gigawatt-Hours
Energy Units	
Coal	0.8 Terajoules
Crude Oil	6.5 Terajoules
Natural Gas	1.5 Terajoules
Electricity	0.4 Terajoules
Liq. Pet. Gases & Nuc. Steam	0.1 Terajoules
Total Energy	9.2 Terajoules

hypothesis can, of course, be checked by comparing this employment multiplier with those for other SUPs.)

The income and gross output (sales) generated by municipal road construction give rise to tax recoveries, indicating that the net cost to the provincial government of a municipal road project is significantly less than the initial cost. In this case, a total of $16,119 is recovered by the provincial government from sales, income, and corporate taxes. The federal government collects a larger amount, about $25,000, while local governments recover $6,850. Total tax recoveries add up to $48,037, about 35 percent of the original cost of the project.

Economic impacts associated with this project are not restricted to Ontario; other provinces experience an increase in demand for their products to the tune of $33,567. A slightly smaller amount of increased demand, $32,475, flows outside Canada. Total imports associated with this project amount to $66,401. In other words, about 23 percent of the total sales generated by expenditure on 100 m of four-lane municipal road involve goods produced outside Ontario.

Finally, Table 4 shows the amounts of primary energy consumption associated with the initial, indirect, and induced effects of the project. The use of crude oil accounts for the largest portion of energy use, amounting to 71 percent of the total energy units—in addition to the petroleum-based fuels used in construction and in the manufacture and delivery of intermediate goods, asphalt, and related materials used on the road itself. In general, transportation projects depend heavily on oil-based energy, although a comparison across SUPs shows that the "oil intensity" of energy use varies across different types of projects.

The above illustration shows the results of the simulation of a standard unit project with no adjustment to the input data. The TRIM user considering a road project that varies from the above description could adjust the input data accordingly. In addition to running any of the 35

SUPs individually, the program easily handles combinations of projects. With one run, the user might analyze a more complex expenditure program, e.g., expanding an airport, improving an access road, constructing a parking lot, or building a new stretch of highway to the airport. It is also a simple matter to convert the calculations from projects defined in physical units to projects defined in dollar amounts. Thus the model can be used for the simulation of budgetary changes.

The usefulness of the TRIM database is obviously influenced by whether standard unit projects can be rescaled. Although the SUP data are most accurate for the project sizes originally costed, projects can be rescaled to multiples of the standard unit within a set of judgmental constraints. When variations in the scale of projects are being analyzed, the user of TRIM must decide whether to rescale the SUP data mechanistically or to construct a new set of input data. For scale changes of large magnitude relative to the defined SUP, a new data set is advisable.

CONCLUDING COMMENTS

This paper has provided a brief overview of a system of indicators of economic stimulation and energy use associated with capital investment in various transportation modes in the province of Ontario. Based on input-output accounting, TRIM calculates the impacts of a transportation project on labor income, gross domestic product, employment, gross sales, tax revenue, imports from other provinces and abroad, and primary energy consumed. For each impact indicator, TRIM measures the initial effect and the indirect and induced effects of a capital expenditure.

In addition to providing estimates that are directly useful to decision makers, TRIM can be viewed as an aid to analysis and communication that, for various reasons, will enhance the planning process within transportation agencies. For instance, in an agency using such a model, staff involved in different activities will be led to communicate reports and opinions on project planning in a common framework and to focus on a common set of variables that are mutually understood. Furthermore, it is likely to help agency staff to develop consistent techniques of cost analysis. Users of TRIM who become familiar with the standard-unit-project database will learn how to analyze project costs in a way that allows their secondary impacts to be calculated.

While TRIM is a working model as it stands, in its present form it should be viewed as a starting point. There is scope for further development, both in terms of the model itself and in terms of how it can be used in a transportation agency. The Ontario Ministry of Transportation is now deciding the specific ways it would like to extend, customize, and maintain the model.

A number of observations are relevant:

- To remain useful, an economic impact model should be updated regularly. As already noted, there is a considerable lag in the publication of input-output data by Statistics Canada. When the 1984 version of the Ontario input-output table becomes available, it will be desirable to update TRIM to account for structural changes in the Ontario economy between 1979 and 1984.
- The input data and the parameters of the model also depend on the prices of goods and services. As inflation occurs, and as the prices of goods and services important in the construction of transportation facilities change relative to each other and to other goods prices, the existing model will produce outdated calculations. Price data in the model should be updated regularly.
- TRIM can be converted to calculate economic impacts for any other jurisdiction for which input-output data exist.
- An input-output-based computer program involves literally hundreds of decisions regarding the source and use of data and the method of calculation (*1*, Appendix A). In the initial development of such a complex model, it is inevitable that some aspects of its structure will involve arbitrary assumptions and/or assumptions necessarily made for pragmatic reasons. After some experience in using it, the model can be customized to meet an agency's specific needs.
- An interesting possibility for a fundamental extension of the model is the integration of cost analysis into it. In the present version, the cost of each input component of a capital project is prepared ahead of time and entered into TRIM. Instead, one could develop a module to generate a task/input cost matrix. Input data would then be developed more conveniently and standardized further. The impacts of variations in design could be more easily simulated within such a framework.
- While the set of 35 projects represented in the TRIM database provides extensive coverage of various transportation facilities, there is scope for expanding the number and variety of standard unit projects in the database. Cost data, for example, are currently being gathered for a set of rapid transit SUPs based on the Toronto subway system. For those users who wish to depend on the standard unit projects, an expanded database would be desirable.

Note that TRIM calculates only the secondary impacts of capital expenditures. Obviously a transportation agency is also interested in the development of indicators of the primary effects of transportation investment initiatives. (Estimates of the primary impacts of a project would capture the value of the actual transportation services produced as a result of capital spending. Secondary impacts are all other effects.) Various primary indicators are in use, e.g., value of travel time saved, reduction in accidents per time period, etc. If such indicators were to be standardized within an internally consistent framework, applicable across the various transportation modes, it would be useful to integrate them into a model that provides secondary impact indicators. Preliminary work on such a strategy is already under way.

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