FINAL REPORT

SENSITIVITY ANALYSIS OF THE NEW FHWA SKETCH PLANNING ANALYSIS SPREAD SHEET MODEL

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EXECUTIVE SUMMARY

The North Jersey Transportation Planning Authority (NJTPA) has begun an effort to test the new FHWA Benefit Cost Analysis Software entitled "Sketch Planning Analysis Spreadsheet Model" (SPASM). SPASM attempts to quantify the transportation planning process for sketch plans, including design criteria, demand needs, and environmental factors. This analysis is conducted through the use of a spreadsheet computer analysis which produces quantified impacts, including "benefit-cost" ratios. The model bases its analysis on four modes of travel: automobile, truck, bus, and rail. It provides the following four sets of outputs:

- The base case in the peak period.
- The base case in the off-peak period.
- The improvement case in the peak period.
- The improvement case in the off-peak period.

The outputs consist of several values, such as quantified impacts and annualized costs and benefits. The key output, however, is the benefit/cost ratio. If the benefit/cost ratio is greater than one, the project is profitable, and hopefully therefore feasible.

The research examined the SPASM model in detail from the aspect of the sensitivity of its variables to local conditions (i.e. the area or region of its use, understanding, and value to the end user). Major improvements are suggested for this model, leading to modifications for the next generation of sketch planning transportation models.
The sensitivity analysis showed that while SPASM is a simple mathematical model which produces many-national based indices for its variables, it would be better to allow the user to input regional or state values and be more specific about the nature of the project.

What is proposed as an improvement to SPASM is a menu-based program that will perform all of the calculations of SPASM without involving too many numerical inputs for the user. Such a menu-based program could be written in a computer language such as C or even HTML (hypertext markup language) for Internet access. The user would have access to the numerical values themselves, in case there is a need to change them. However, the lay user would not have any need to become involved in the tedium of inputs, but still be able to come up with, as an output, not many meaningless numbers, but a few key figures, and graphical representations fit for presentation and support of the alternative of their choice.
INTRODUCTION

In planning for the design and build phases of a project, knowing the impact of that project is key to making a conclusion about its feasibility. It is helpful, as with any problem, to have a way to make a prediction about the result. With engineering problems, it is best to use a mathematical model to approximate and quantify these results. The mathematical model put forth by the North Jersey Transportation Planning Authority (NJTPA) is one which may be used to perform an important analysis involved in the feasibility assessment of transportation-related projects: benefit-cost analysis. It is a computer-based model, with its foundation based on an analytical spreadsheet. The model's name is Sketch Planning Analysis Spreadsheet Model, or SPASM.

OPERATION OF THE MODEL

SPASM attempts to quantify aspects of the design criteria, demand needs, and environmental factors involved in a transportation project. An analysis of these quantities done through the spreadsheet analysis produces quantified impacts. The quantified impacts stated in dollar amounts goes through further analysis to give a final product, the "benefit per cost ratio." The potential user could then perform this procedure for a number of alternatives to the project, comparing the benefit/cost ratios of each. The higher the benefit/cost ratio, the better (that is, more feasible) the project is. A decision could thus be made on whether to go through with a project, to select another option, or perhaps not build at all.
The model divides its analysis into two cases, the base case, which is a no-build option, and the improvement case, which is a final-project option. The user defines the finalproject option by making various inputs, which we will address later.

INPUTS TO THE MODEL

To define the cases, inputs must be made by the user. Some of these remain constant for both the base and improvement cases, and some of them vary. The first set of inputs fall into a category called facilities inputs. These inputs define the "geometric characteristics of the facility." In other words, they allow the user to put in the actual nature of what the project will be, in terms of length, capacity in passenger vehicles per hour, and freeflow speed in miles per hour. Furthermore, these values can be defined for different "facility types": freeways, arterials, high-occupancy routes, and rail lines.

After the facilities inputs, the user is prompted to provide inputs under the heading of agency costs. These are basically the costs to the owner or builder, and are only input for the improvement case. The inputs include the discount rate, or prevailing interest rate pertaining to the project, the capital cost of the project, the years of midpoint of construction and opening, and the construction time (listed as useful life) in years. The interest multiplier and annualized cost are calculated immediately upon the input of these values, but they are only useful at that point for the further calculations done by the model. Also, the miscellaneous operation and management costs per year may be inputted.
The next set of inputs comes into the category of demand inputs. Here, the demand for both the base and improvement cases may be inputted as the user sees fit. The variables are also further broken down at this point into peak and off-peak values, so that the demand may be best modeled for actual conditions. They include person trips per day, average vehicle occupancy, out-of-pocket costs, wait and transfer times for mass transit, percentages of use among the four modes for access, and the access distances for each mode.

IMPACT RATES

Following this, the user then inputs a set of variables called impact rates. These are basically the rates for the emission of pollutants into the atmosphere, which have associated with them various costs. Also included in this set are energy consumption rates. These values vary over time and by region, so they are left to be inputted by the user based on the prevailing literature of his or her region. The main emission that the model is concerned with are hydrocarbons (HC), carbon monoxide (CO), and nitrous oxides (NO). The values for this set have been related, by SPASM, to the freeflow speed, this perhaps being the most important factor in both emissions and energy consumption. For instance, for all three emissions types, the optimum speed is 55 miles per hour.

Any value higher or lower results in a greater rate of emission. The rates are inputted in grams per mile, grams per cold start, or in the case of energy consumption, in energy units per mile. Upon completing the inputs for this category, the model immediately calculates values for the
emissions rates for each vehicle mile traveled (VMT) and the grams of emission per vehicle trip resulting from cold starts. These values are not important at that point, but will be used by SPASM for further calculations.

UNIT COSTS

The final set of inputs to be made by the user are under the heading of unit costs. This is probably the most important category, as it allows the user to assign dollar values to the variables inputted in the previous sets. The values to be used again vary greatly with region and area. For example, the value of travel time would be based on such factors as cost of living, average income, cost of fuel, etc. Therefore, it is best to consult literature providing the most localized values possible for these values. The variables for this category include weekdays per year to be considered, cost of emissions per ton, average speed for access for the various modes, the mass transit delay on arterial roads, traffic assignment factors (given default values by the model to avoid confusion), the value of traveling time per person-hour, energy costs, and other miscellaneous costs and factors which may apply.

After all of the inputs have been completed by the user, SPASM performs its calculations. It produces a rather large and cumbersome chart of values which are not significant to the user, but allow the model to arrive at the values that are. These are the outputs, which are divided into daily impacts by mode and annual benefits and costs.
The daily impacts by mode present the changes in person trips, energy savings, and dollar values for user benefits, emissions savings, external costs, and mass transit operation costs. The annual benefits and costs basically itemize the dollar values for each expenditure and saving produced by the implementation of the project. With these values, the model finally produces the panacea of the analysis, the benefit/cost ratio. If this ratio is greater than one, the project is theoretically profitable, and therefore feasible. Comparing the benefit/cost ratio for each alternative should then result in an option which could be considered most feasible.

EVALUATION OF THE MODEL

SPASM is, as can be seen, confusing at best, and nearly impossible to understand at worst. Despite its lack of user-friendliness, it does provide a neat value, the benefit/cost ratio, from which comparisons for alternatives can be made. However, there are some fundamental flaws to the model. They are not difficult to correct, but ignorance of them may render the benefit/cost ratio to be a virtually meaningless value.

The user interface itself is perhaps the biggest problem with the model. The input process is long, there are too many variables, and they are, at times, ambiguously labeled. Each set of inputs has its own problems with its values, but there is an overall lack of organization and consistency to the inputs.

As far as the Facilities inputs are concerned, it is the one set where the inputs are somewhat simplistic. It may be hard for the user to render the scope of the project into just the four
categories of freeways, arterials, high-occupancy routes, and rail lines. In many cases, these are not the only tasks of the owner for the project. Truly, SPASM is a simple mathematical model, but for decision-making on a large-scale, money- and quantity-wise, it may be better to allow the user to be more specific about the nature of the project.

AGENCY COSTS

The agency cost set of variables is perhaps the best of the categories of inputs in SPASM. The biggest question is the discount rate; why have a default value of 7 percent? The interest rate is highly susceptible to variations over time, region, and nature of the project. The user could be allowed to input a more exact rate (there are large amounts of money involved with these projects), or have a value suggested to them based on other variables inputted. Also, perhaps using dates for the midpoint and opening dates is not as important or necessary as just allowing the user to input the construction time. Otherwise, this set seems to be well in order.

The demand inputs category is also not that bad, but it is somewhat tedious. There is a lot of looking up of values to be done and empirical measurements must be entered repeatedly. Also, values such as out-of-pocket cost and wait and transfer time may be somewhat ambiguous to the user. Again, suggested values may be provided based on other inputs. This is a pretty straightforward set of inputs, much like the agency cost category.

The most tedious and unnecessary set of inputs is the impact rates category. The numbers do not normally vary greatly, but it is required for every alternative to input them all again, and
within every alternative, to input them repeatedly. This is definitely an area where suggested values would do much good to the user. The user should not be required to dig through transportation texts or a multitude of periodicals in search of these values.

UNIT COSTS

The unit costs category is also somewhat tedious, as it also involves the repeated input of values. Also, there are some ambiguous and uncommon terms which may confuse the user. The exponent for traffic assignment and the iteration control factor are not clearly defined, nor is travel time elasticity. There is a redundancy to seeking inputs in energy units per mile in the impact rates set and then asking that they be defined in this set. It is unnecessary to request the number of grams per ton as input; this is a constant value. Again, the inputs for this set all require some degree of research into transportation literature for their values.

Finally, for the outputs, there are a lot of numbers spit out at the user that are not organized within the program, and would be hard to organize for presentation. The only number of true value for evaluation purposes is the benefit/cost ratio, and as we have suggested, the methods by which this value is reached may render it inaccurate, or even meaningless.

It has been suggested to us that we try to be more explicit as to what the variables mean to the user, what function they have in the analysis, and how they affect transportation modeling in general. However, we feel that in preparing a presentation to lay people (i.e. not of the transportation field), it is more imperative to create an interface which is more user-friendly,
where, in fact, the user will not be required to be bogged down by all the redundant values and detailed research involved with transportation modeling.

**PROPOSED IMPROVEMENTS TO THE MODEL**

The primary question is: how can we eliminate the need to input so many numbers? The values do vary greatly by time and region, but there is a solution: customizing. Instead of demanding of the user the repeated input of trivial numbers from obscure sources, let the user make simple choices from a menu. Let the user select the type of project to be implemented, and what modes of travel are to be included, which would determine the value of certain constants to be used in the calculations. The user also could select in what area of the country the project would be located, and the year it would be performed. Associated with each of these choices would be default values that the program would use to perform the calculations, eliminating the need for the user to input them himself. After each choice, however, the user would be given the option of altering any of the values for any particular extenuating circumstances associated with the project. The user would still input the capital and operating costs, and the project duration, but the discount rate would be set based on the menu inputs. Person-trips per day and access mode distances would be inputted by the user, but the rest of the demand inputs would again be based on the menu inputs. Impact rates would also be set, but menu options could be provided to allow the user to select, for instance, which pollutants should be considered or ignored. The unit costs would be entirely set by the menu options from the user.
What would result from these menu inputs, and by clicking a button that says "calculate," would be a benefit/cost ratio specific to the options selected by the user. Annualized costs and benefits could be displayed in numeric tabular form, or they could be saved to the program so that they could be displayed, along with the results from other alternatives and considerations prepared by the user, in graphical form. These would be organized in a manner specified by the user; for example, they could be ranked by benefit/cost ratio, by annualized cost or benefits, or manually, such as by importance to the user or owner.

CUSTOMIZATION OF THE MODEL

The key to the functionality of a program like this, as mentioned before, is customization. The best format for this program, we feel, would be an Internet webpage written in a combination of HTUL and other web languages such as Java.

The pages would have to be localized, i.e. there would have to be one for each particular sized region, as small as a county. With a web page for each county of, for instance, New Jersey, a user could select what township the project would be located in, or for a larger scale such as would span several townships, the whole county. The program would then have associated with it the median values for such variables as value of travel time, derived from median values of cost of living, income, and fuel costs for the area selected. All the unit costs, impact rates, and most of the demand inputs are all basically functions of region and time. Thus, the website containing the program would have to be maintained and updated regularly, perhaps on a monthly basis, which is not a complicated task.
TOWARDS A MORE USER-FRIENDLY MODEL

A program like the one we suggest could even be detailed enough, because of its localized basis, to evaluate socioeconomic impacts in the area. The calculations are not complicated, being based mostly on the prevailing values of economic multipliers in the region; these can also be updated regularly or as the need arises. Our point, however, is this: SPASM is a sufficient, even good, program, but it does not address all the issues involved in transportation modeling, nor does it address the ones it does in a user-friendly manner.

We live in the age of computers and the information superhighway; there is no need to allow a user to be buried under papers and numbers. A simple, Internet-based program allows the user to have an up-to-date, easy-to-understand, and efficient analysis of the alternatives for transportation projects before him. There are a lot of considerations for transportation planners and engineers to heed, and a program like this makes them easy to evaluate. We should take advantage of the technology available to us to provide such a tool to the transportation industry.
APPENDIX

SENSITIVITY ANALYSIS OF THE NEW FHWA SIKETCH PLANNING MODEL

SELECTED TOPICS

- Value of Time

- Multiplier Effect of Transportation

-Improvements
Value of Time

The model cites Miller's studies of value of travel time which recommends, using 60% of the wage rate ($/hr) as the value of time for automobile drivers and 45% of the wage rate for the automobile passenger as well as the in-vehicle time for the bus and rail traveler. The model recommends an hourly wage (average nationally) of $10.02 in 1990 dollars, updated for the current year of the model run. Transit waiting time is valued at 75% of the wage rate, while walking time is valued as 1.5 times the (in) vehicle time.
For use of the model in New Jersey the NJIT reviewers recommend that the value of time be structured by geographic area, type of user (auto, rail, or bus) and that a distinct wage rated ($/hr) be attached to each subgroup. For example of the wide variation by mode with respect to income, data from New Jersey transit is illustrated. For all commuter rail services except the Atlantic City Line, the household income demographics have the following distribution.

Annual Gross Household Income (Commuter Rail)

| (A) | Less than $15,000  | 2%  |
| (B) | $15,000 to $24,999 | 3%  |
| (C) | $25,000 to $34,999 | 7%  |
| (D) | $35,000 to $49,999 | 13% |
| (E) | $50,000 to 74,999  | 27% |
| (F) | $75,000 to $99,999 | 21% |
| (G) | $ 1 000,000 or more| 27% |

100%

Estimating an average income for each of the seven income groups above as follows:
The average income of this group is $76,000, or for a 35 hour week and 52 weeks a year, this equates to $41.76 per hour.

On the other hand, the demographics for Newark cross town bus users are as follows:

Annual Gross Household Income (Newark Cross Town Bus)

- (A) Less than $15,000: 45%
- (B) $15,000 to $24,999: 37%
- (C) $25,000 to $34,999: 11%
- (D) $35,000 to $49,999: 7%
- (E) $50,000 or more: 0%

The average income for this group is $19,600 which equates to $10.77 per hour.

Any benefit-cost model for New Jersey must be sensitive to the vast differences in the user income status by mode and by geographic area. For the example cited contrasting commuter rail passengers and Newark bus riders, the earnings of the rail users was almost 4 times that of the Newark cross town bus commuters.

The Multiplier Effect of Transportation Improvements

In addition to the basic benefits of an transportation improvement (improvement in travel time, reduction of congestion and pollution and better accessibility), there is a multiplier effect as a result of new construction and the added need for services, housing, and retail and wholesale trade. As indicated by economic input-output analyses, there is a interindustry relationship of dollars of input into a region to dollars of output in other industries. Thus, it is
not surprising that the positive experience of cities across the country improving their transportation networks have resulted in major increases in new private investments in hotels, restaurants, housing, and commercial space. Examples are readily available in San Francisco, Washington, DC, Atlanta, Buffalo, San Diego, and Portland. Any model or comparison of alternatives of benefits and costs should include this multiplier effect. An alternative with a great influx of construction monies would produce a much greater multiplier effect as contrasted with one that has no new construction.

The Bureau of Economic Analysis under the U.S. Dept. of Commerce produces a user handbook of the Regional Input-Output Modeling by state. This is available by special request for the current year for the state under study for a $400 fee. Viewing a recent published summary by state (1992), the pertinent Multipliers for a one million dollar investment in new (New Jersey) construction produces an output of activity of employment of 2.76 jobs in the construction industry, 2.04 jobs in wholesale trade, 1.56 jobs in retail trade, 2.34 jobs in finance, 3.11 jobs in insurance, 5.83 jobs in real estate, 1.83 jobs in hotels, and 1.89 jobs in business services. To illustrate, a new transportation project, with construction costs of 200 million dollars would produce multiplier effects equating to 470 million dollars in total output, and 7,620 new jobs.

Progress Report: Interest Rates
We are nearing completion into research pertaining to the effect of interest rates on the Sketch Planning Analysis Spreadsheet Model. We have been researching, more specifically, the effects of construction time and interest rates on the annualized cost of projects, the current interest rates from the Federal Reserve Bank and banks specializing in construction loans, and the state of the construction and transportation industries and their effect on interest rates, based on recent government developments and the outlook of firms specializing in infrastructure construction.

As to the effects of construction time and interest rates on the annualized costs of projects, we have constructed a graph so that the effects can be seen clearly. Increasing interest rates on a project of twenty-year duration seems to increase the annualized cost of the project at a slightly higher rate than on a project of ten-year duration. This varying of the annualized cost is key to performing a proper cost-benefit analysis. We have attached the aforementioned chart and graph with this report.

To understand what a realistic interest rate to use for the model would be, we researched factors affecting interest rates for construction projects. One of the main 'indicators', and the one we started with, is the federal funds rate set by the Federal Reserve Bank. Of course, the rate itself will be somewhat lower than that provided by a private lender, but at the very least the trends in the change of this rate give a basis as to how interest rates to be used in the model will vary.

We next researched the interest rates provided by banks specializing in construction loans. These banks mainly provide loans for private construction, i.e. houses, office buildings,
etc. However, they provide a very good indicator as to what rates may be used in the model. According to our research, most of these banks lend at an average interest rate of about 7%. This is the number used in the current version of SPASM.

One other indicator we have for interest rates is the state of the construction and transportation industries. We figured that the best way to recognize this state was to look at government activity with respect to transportation funding. Recent activity has seen endorsements for transportation by Congress and an improved funding program in the fall. This may foretell a decrease in interest rates due to increase confidence in transportation funding.

We think that the research we have performed in the area of interest rates has helped us to understand how to apply interest rates to the Sketch Planning Analysis Spreadsheet Model, a big step to improving the way this model performs cost-benefit analysis.
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