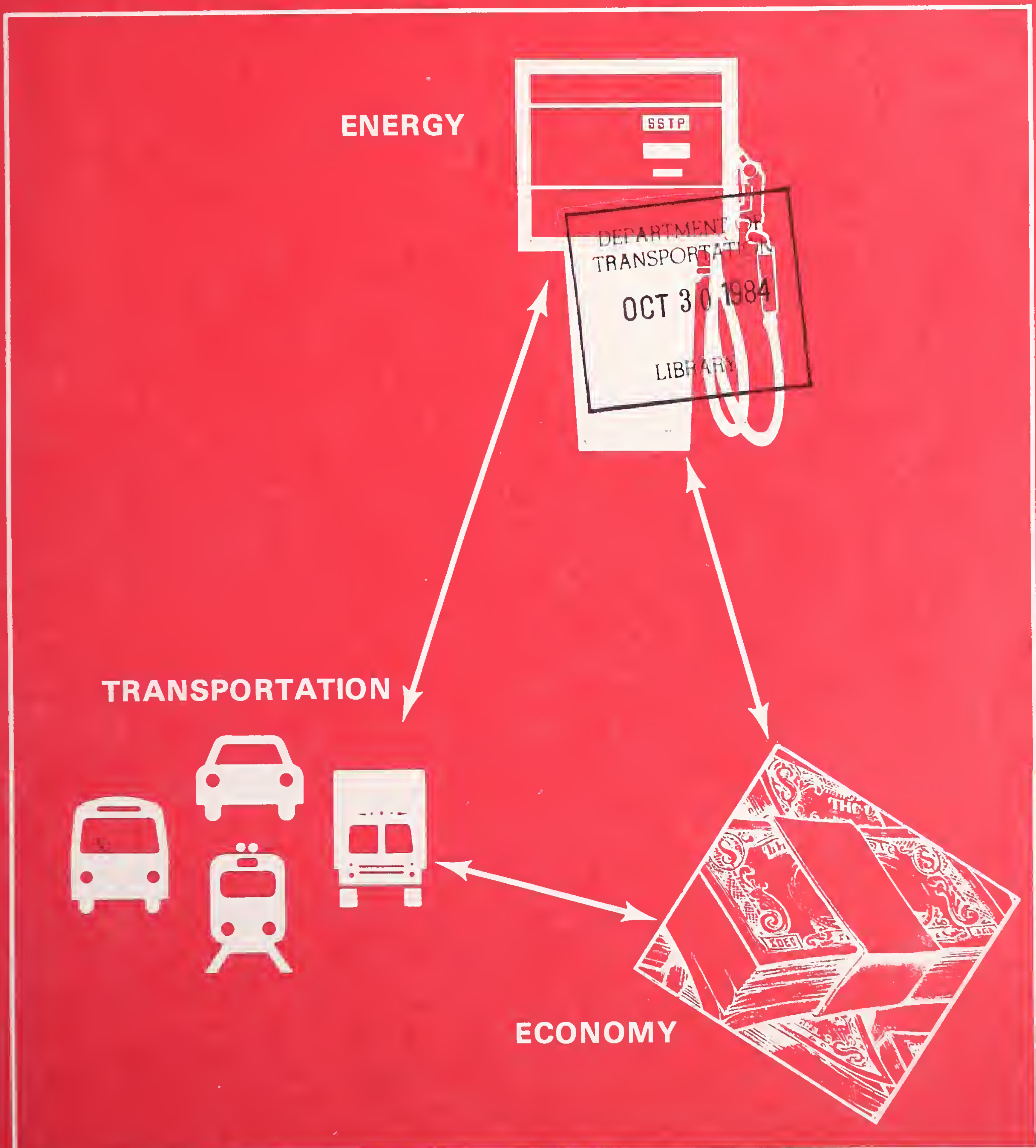
U.S. Department of Transportation

Incorporating Energy Analysis in the Transportation Improvement Program Process

July 1984



Incorporating Energy Analysis in the Transportation Improvement Program Process

July 1984

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16. Abstract

The New York State Department of Transportation, in cooperation with the Genesee Transportation Council (GTC), the MPO in Rochester, N.Y., evaluated the energy impact of proposed transportation projects, described these findings to local officials, and examined the impact of this information on project selection.

The results of the energy analysis of 92 projects proposed for the 1983-84 Transportation Improvement Program showed that their implementation will result in an annual user saving of 5.9 million gallons by 1990; the annualized construction energy required for these projects is 2.1 million gallons and the annual net saving is 3.8 million gallons (1.3% of 1980 gasoline consumption). The assessment of the long term changes in transportation energy use showed that improvements in vehicle efficiency will result in an annual saving of 85.7 million gallons by 1990 (29.2% of 1980 gasoline consumption) increase in consumption resulting from increases in traffic due to expect growth in the number of households.

Review of the process to create GTC's 1983-1988 TIP showed that while no decisions were changed solely because of the energy impact information provided, this information enhanced the projects' acceptance. Once presented on a regular basis in the TIP process, the energy impact data may be more useful. Two additional places in the project development process where energy impact information could be useful are systems planning and design.

The issue of the transferability of the findings was investigated and it was found that the results, methodologies and ideas could be employed by other places, constrained by those factors which make other cities unique or different from Rochester.

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FOREWORD

Many urban areas today share a desire to consider the energy implications of their transportation improvements. This is true for a number of reasons: to keep costs of transportation improvements down, to increase user cost savings from project expenditures, to help evaluate the merit of a particular project or program of projects, or to simply conserve fuel. In response to similar needs the New York State Department of Transportation (NYSDOT) and the Genessee Transportation Council (GTC), the metropolitan planning organization for the Rochester, New York area, jointly undertook a study to assess the energy implications of a proposed Transportation Improvement Program. The results of this study and its local impact are documented in this report.

Ninety-two projects proposed for the 1983-84 Transportation Improvement Program (TIP) were examined. The analysis found that bridge projects and transportation system management (TSM) projects offered the greatest potential in saving energy. Bridge projects saved energy by removing traffic detours due to bridge closures. TSM projects saved energy by reducing travel delay and by improving traffic flow. An examination of the TIP's long term energy implications found that by 1990 as much as 4 million gallons of fuel could be saved per year, were all projects implemented and the energy used to construct the projects discounted. This amounts to about a 1.3 percent saving in areawide fuel consumption, reflecting current savings of $5 million. This information, while not effecting a change in the decision-making process, did enhance the acceptance of certain projects. Accordingly, we believe this report will greatly assist other States and metropolitan planning organizations which wish to examine similar issues.

Related reports are available on Transportation Energy Contingency Planning, Transportation Energy Management, Scenario Planning, Estimating Transportation Energy Consumption of Residential Land Use Types, Transportation and Energy Planning in Mid-Sized Areas and Local Energy Impacts of Transportation Fuel Consumption. Additional copies of this report are avaialble from the National Technical Information Service, Springfield, Virginia 22161. Please reference report DOT-I-84-28 on your request.

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I. ABSTRACT

The New York State Department of Transportation, in cooperation with the Genesee Transportation Council (GTC), the MPO in Rochester, N.Y., studied ways to incorporate energy conservation in urban transportation planning and project decision-making. The study evaluated the energy impact of proposed transportation projects, described these findings to local officials, and examined the impact of this information on project selection. The study was supported by the Federal Highway Administration, Urban Mass Transportation Administration, and Department of Energy.

The results of the energy analysis of 92 projects proposed for the 1983-84 Transportation Improvement Program showed that their implementation will result in an annual user saving of 5.9 million gallons by 1990; the annualized construction energy required for these projects is 2.1 million gallons and the annual net saving is 3.8 million gallons (1.3% of 1980 gasoline consumption). Bridge repair projects, because of the removal or avoidance of traffic detours due to load limits or bridge closure and improvements to traffic flow, and TSM projects, because of reductions in delay through improvements in traffic flow, offer the greatest potential for energy conservation. Pavement projects result in increases in energy use because of speed increases resulting from the improvements to the road surface. The assessment of the long term changes in transportation energy use showed that improvements in vehicle efficiency will result in an annual saving of 85.7 million gallons by 1990 (29.2% of 1980 gasoline consumption), more than offsetting the 60.4 million gallons (20.6% of 1980 gasoline consumption) increase in consumption resulting from increases in traffic due to expect growth in the number of households.

Review of the process to create GTC's 1983-1988 TIP showed that while no decisions were changed solely because of the energy impact information provided, this information enhanced the projects' acceptance. The participants in the process did not have problems with the materials prepared or the means by which they were presented. However, this project over-emphasized the energy information in relation to other impacts. Once presented on a regular basis in the TIP process, the energy impact data may be more useful.

Two additional places in the project development process where energy impact information could be useful are systems planning where it could be one factor used in identifying and evaluating possible problem locations, and design where energy impacts of competing alternatives, materials, and equipment could be a useful criteria in the decision-making process.

The issue of the transferability of our findings was investigated and it was found that the results, methodologies and ideas could be employed by other places. Of course, this should be constrained by obvious factors which make other cities unique or different from Rochester.

II. EXECUTIVE SUMMARY

The New York State Department of Transportation (NYSDOT), in cooperation with the Genesee Transportation Council (GTC), the MPO in Rochester, N.Y., studied ways to incorporate energy conservation in urban transportation planning and project decision making. The study: (1) evaluated the energy impact of proposed transportation projects for the Rochester area; (2) described these findings to local officials; and (3) examined the impact of this information on project selection. This study was supported by the Federal Highway Administration, Urban Mass Transportation Administration, and Department of Energy.

Method

The energy impacts of projects proposed for inclusion in the 1983-1988 Transportation Improvement Program (TIP) were calculated. This was also done for projects not required to be on the TIP, but listed for informational purposes. To put these short term findings into perspective, an assessment was also undertaken of the possible longer term changes in transportation energy consumption in the Rochester area. The calculated energy impacts of all of these projects were then provided to each of the various implementing agencies and, for those projects required to be in an approved TIP, to decision makers on all levels in GTC's TIP approval process.

Energy Analysis

Energy impacts were calculated for 92 projects. The results of the energy analysis showed that implementation of these projects will result, by 1990, in an annual user saving of 5.9 million gallons per year (2% of 1980 gasoline consumption in the region). The energy expended to construct these projects was 2.1 million gallons, with an annual net saving of 3.8 million gallons (1.3% of 1980 gasoline consumption).

Of the various project types evaluated, it was found that bridge, TSM and safety projects offer the greatest potential for energy conservation. The saving associated with bridge projects results from the removal or avoidance of traffic detours due to load limits or bridge closure and improvements in traffic flow. The saving from TSM and safety projects results from reductions in delay due to improvements in traffic flow. Pavement projects frequently result in increases in energy consumption because of speed increases resulting from improvements to the road surface.

The results of the long term assessment are:

- Improvements in fuel efficiency will save 85.7 million gallons by 1990 (29.2% of 1980 gasoline consumption).

- Increases in traffic growth result in an annual fuel consumption increase of 60.4 million gallons by 1990 (20.6% of 1980 gasoline consumption).

- Highway improvements contained in the 1990 GTC Transportation Plan result in an annual saving of 3.2 million gallons by 1990 (1.1% of 1980 gasoline consumption).

- The net effect of these changes by 1990 is a saving of 28.9 million gallons (9.7% of 1980 gasoline consumption). These savings do not consider the increases in energy use resulting from construction rather only the effect of improvements to the existing network.

From the above it is clear that improvements to vehicle efficiency will result in the largest energy saving of any changes in the area. These savings more than offset the increases in fuel consumption that result from growth in travel. The effect of proposed transportation projects is a small decrease in gasoline use.

Institutional Findings

Review of the process to create GTC's 1983-1988 TIP and use of the energy impact information showed that <u>no decisions were changed solely because of the energy impact information provided</u>. This was because there are many financial and institutional considerations surrounding project selection.

Projects selected for inclusion in the TIP are generally designed to be the best solution to the most severe problems in the region. The number of projects developed and proposed are also designed to make maximum use of outside resources. Thus, few decisions to reject a project are made at the TIP stage. However, the additional information on the energy impacts of each of these projects enhanced their acceptance.

In evaluting the effectiveness of the demonstration project, the following observations can be made:

- The participants in the GTC TIP process did not have any problems with the materials prepared or the means by which they were presented.

- Use of these materials highlighted the fact that the energy impacts of the proposed transportation projects were small and the importance placed on them in this project overemphasized them in relation to other impacts.

- Once energy impact information is incorporated on a regular basis into the TIP process and presented along with other project data, it may be more useful.

- Two additional places in the project development process where energy impact information could be useful are in systems planning and the design phase. In systems planning this information could be one factor used in identifying and evaluating possible problem locations. In design the energy impacts of competing alternatives, materials, equipment, etc. could be a useful criteria in the decision-making process.

Transferability of Findings

The purpose of specifying the transferability of the findings of this study to other situations is to assist others in determining the extent to which the results may be useful in reducing energy consumption in other communities. The recommendations concerning the transferability of the findings are as follows:

- The methods used in the analysis are very general and can be used in other situations. However, we do recommend that the specific calculations be redone.

- The project mix in the Rochester area clearly influences the results with respect to the net energy saving and the specific project mix in other areas would influence their findings. Concerning the results regarding specific project types, we believe the findings related to pavement projects would be replicated in other areas. We do recommend more caution in the use of our findings concerning bridge projects, since detour distances, which are site specific, greatly influence the energy calculations.

- Concerning the results of the long range analysis, we believe that other areas will find that as in Rochester, changes in fuel efficiency from vehicle turnover will result in a significant drop in energy use, with an additional very small decline resulting from long term transportation improvements. Between one third and one half of this decline may be offset by growth in the region.

- The procedures used to develop institutional relationships and to work with local governments to incorporate energy findings in the project development process are generally transferrable, keeping in mind of course the factors that are unique to the GTC process. The finding that the most appropriate use of energy data is in systems planning and project design will be true in other places.

III. INTRODUCTION

A. Background

In 1982, the transportation sector used approximately 61% of the nation's petroleum, with over 96% of the energy used in the transportation sector being petroleum based. Clearly, therefore, reductions in transportation energy use will help reduce the nation's petroleum use and its dependency on foreign oil. Lasting reductions in transportation energy use have been accomplished primarily through increased purchasing of more fuel efficient vehicles. In 1982, gasoline use in the United States has fallen 2.3% while travel has risen 22.5%, since 1973.

At the state and local level, limited progress has been made to incorporate energy concerns into the urban transportation planning and project decision-making process. To investigate ways to increase energy concerns at this level, the New York State Department of Transportation (NYSDOT) and the Genesee Transportation Council (GTC), the Metropolitan Planning Organization of Rochester, New York, jointly assessed the energy implications of the proposed 1983-1988 Rochester Transportation Improvement Program (TIP) [the TIP is a federally-mandated compilation of all transportation projects and expenditures planned for a region] and to make this energy assessment available to local decision makers. This study was supported by the Federal Highway Administration, Urban Mass Transportation Administration, and Department of Energy. The purpose of this study was to:

1. Determine the energy savings and energy costs (of construction) for all projects proposed for inclusion in the 1983-1988 TIP.

2. Use these results at various points in the local area's process for setting project priorities.

3. Assess the effectiveness of the procedures, both technical and administrative.

To accomplish these goals, the study also: 1) developed analysis tools for those projects for which current methods are weak or not available; 2) monitored key energy use and travel indices for the Rochester area; and 3) sketched future energy use in the area, accounting for the long range plan, changes in car efficiency, employment, and population.

This report documents the results of this study. The main body highlights and summarizes the the technical findings, the current TIP development process, amendments to include energy considerations, and the success of the demonstration in incorporating energy consideration in the TIP process. The appendices provide detailed documentation of energy analysis methods, project evaluations, long range assessment, monitoring, and current institutional processes and proposed changes.

B. Transportation Planning in Rochester, N.Y.

The Rochester New York metropolitan area is situated on Lake Ontario in western New York (Figure III.1). The area, containing 1,085,000 people and 381,400 households, is basically circular shaped and focused on a strong downtown. The area is situated about 60 miles from Buffalo and 70 miles from Syracuse. The employment base is broad, high-tech oriented. Eastman Kodak and Xerox are the two largest employers, employing over 60,000 of the area's total work force of 360,000.

Transportation planning in Rochester has followed a traditional pattern. The current long range plan for transportation facilities, The 1990 Plan, was adopted in 1969 after six years of development by the Rochester Metropolitan Transportation Study (RMTS), the predecessor of the Genesee Transportation Council. Like other studies conducted at that same time, RMTS used land use and travel forecasting models to develop a plan of recommended highway and transit improvements which would provide for the projected population growth and land use. In the 1970's planning has become sub-area focused, more diverse and short-range oriented. The present transportation planning process focuses on periodic development of the TIP. Project development typically follows this process. Figure III.2 outlines this process. It is

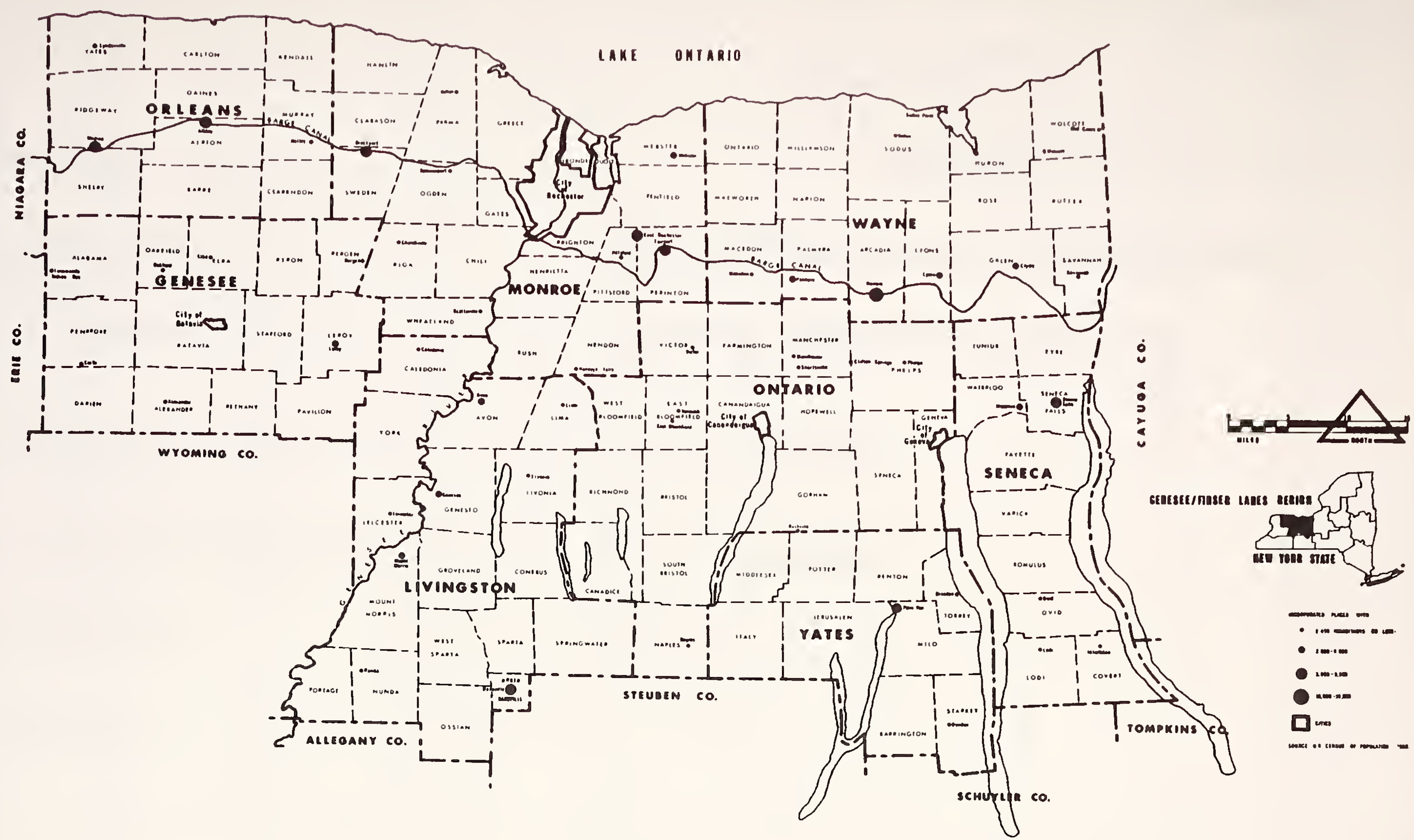


FIGURE III.I

GENESEE/FINGER LAKES REGION

PREP. BY: | DATE: | DRWN. BY: | FILE NO.-

GENESEE/FINGER LAKES REGIONAL PLANNING BOARD
65 BROAD STREET, ROCHESTER, NEW YORK.

Figure III.2

Step in the TIP Development Process

1. Identification of Transportation Problems

2. Ranking or Problem Sites

3. Development of Alternatives

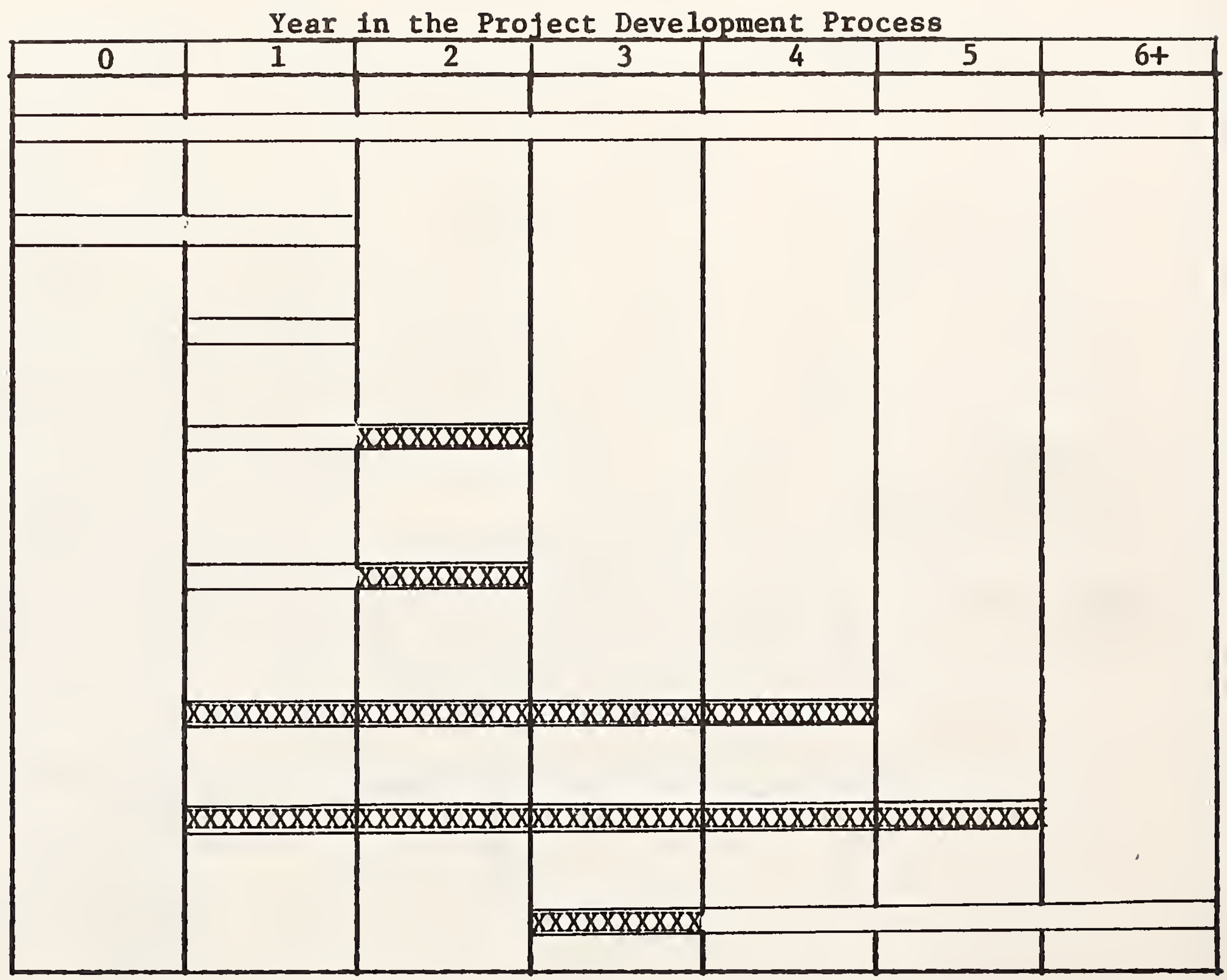
4. Selection of Preferred Solution for Each Alternative

5. Ranking of Proposed Projects in Terms of Priority

6. Applying Funding Constraints

7. Production of Final Document

8. Project Implementation



Pre/Post TIP Step in the Process

Step involving process selection of capital program XXXXXXXXXX described in detail in a separate technical support document to this report entitled "Overview of Transportation Planning in Rochester, New York".

Planning is conducted by a number of individual agencies, including the State DOT, GTC staff, the City of Rochester, Monroe County, the Rochester-Genesee Regional Transportation Authority, the Genesee/Finger Lakes Regional Planning Council, town planning boards, etc. Each of these agencies has a particular role in the overall process, basically related to specific transportation facilities. A project may be initiated as a result of planning studies or system monitoring conducted by any of these agencies.

Smaller scale projects generally follow a three-year process involving planning (alternatives analysis and consideration of all appropriate issues), design, and implementation. These are usually done by a single implementing agency, the one responsible for the system involved. Many of the short-range projects are the result of TOPICS or TSM planning studies. In general, the reduction in available funding has led to an increase in the number of short range (1-5 year) solutions to transportation system problems. Funding has been concentrated more on rehabilitation and preservation of the existing system than on major expansion of capacities.

Larger scale projects, called Major Actions or Category 1 projects, involve more actors during the entire process. In evaluating such projects, each agency follows the same general basic steps:

(1) Identification of transportation problems - establishing system goals, defining problem types, and monitoring the transportation system for problem locations.

(2) Ranking of problem sites - all the problem sites identified are ranked for priority, regardless of the problem type.

(3) Development of alternatives - for each problem, a number of alternative solutions, including the null, are identified.

(4) Selection of the preferred alternative for each problem site - primarily based on economic efficiency or related factors.

(5) Ranking of proposed projects in terms of priority - All of the selected projects are priority ranked.

(6) Applying funding constraints - selecting those projects which best achieve area goals with the available budget.

(7) Production of a final capital program - organizing projects by funding category, along with more detailed narrative descriptions.

(8) Project implementation - actual construction or acquisition of the capital project.

Each agency's process focuses on projects relevant to its own responsibilities.

NYSDOT

NYSDOT is responsible for the development, operation, and maintenance of the state highway system. NYSDOT categorizes its transportation system problems into six "program areas." These are:

(1) Rehabilitation and Preservation (R & P) - directed at maintaining existing facilities, including bridge deck repaving.

(2) Bridges - structural improvement or replacement

(3) Safety - directed primarily at accident reduction

(4) Transportation Systems Management (TSM) - projects to reduce congestion, air pollution, energy consumption, etc. through coordinated improvements to the existing system.

(5) New Capacity and Major Reconstruction - construction of a new major transportation facility. These projects are almost always classified as Category 1 (major action) projects by NYSDOT, requiring a more complex development process than other projects.

(6) Other - signing, landscaping, building demolition (prior to construction), etc. These are actually part of larger projects, but are classified separately because they are usually awarded as separate contracts.

Within each of these program areas, a separate problem identification process is used. Once these problem locations are identified on the system, they are priority ranked relative to all the other problems identified in the region. This is an informal and partially subjective process, taking place at various times in project development. Following project initiation, NYSDOT classifies each project as Category I, II or III, depending on the degree of its expected social, economic, and environmental impacts. A project is then developed through a series of project analysis reports, whose complexity and comprehensiveness depend on the project category. Once projects are developed for funding they are ranked in terms of priority. Within each funding category, a priority ranked list of eligible projects is generated based on the severity of the problem and the effectiveness of the solution. Once this list of ranked projects is produced for each funding source, the top projects are chosen until the yearly allocation of funds is exhausted.

Finally, the project is implemented by "letting" a contract and monitoring and supervising its construction by NYSDOT engineers.

R-GRTA

The Rochester-Genesee Regional Transportation Authority (RGRTA) operates publically owned transit systems in the Rochester metropolitan area. In general, R-GRTA's capital projects are developed as grant applications, according to the procedures of the Urban Mass Transportation Administration (UMTA) and the NYSDOT Transit Division. Problem identification consists of applying standard vehicle age and service criteria to the existing facilities; this usually involves applying a retirement age to buses in order to maintain a sufficient fleet. For transit capital projects the highest priority problems are:

(1) Deterioration of fixed route buses in scheduled service.

(2) Deterioration of Lift Line (for the elderly and handicapped) and rural transit services due to worn out equipment.

(3) Lack of needed support equipment.

Once problems are identified and ranked, alternative solutions are identified and one is selected. There are three basic alternatives: purchase of new vehicles, continued maintenance of the existing equipment, or provision of the service by another agency (Lift Line or rural systems only). Analysis of the alternatives is based on economic efficiency. In bus replacement, R-GRTA applies standards which reflect the transit industry's determination of the break even point for replacement versus continued maintenance. Once the decision to purchase is made, however, a number of considerations affect what vehicle to purchase. While cost, availability, labor intensiveness, E.E.O. considerations, etc. are usually the major factors in awarding bids, energy efficiency of the alternatives can also be a consideration.

Once a priority list of capital projects is produced, R-GRTA, interacting with NYSDOT and GTC, develops a final project list which matches the estimates of available funds for the year and contains all the related documentation. R-GRTA also produces a five-year program showing the amount and source of both operating and capital funds for each system that R-GRTA operates.

Following approval of the final UMTA Grant application and the setting aside of funds in the state and local budgets, each project is put out to bid and awarded. The final step, project closeout, consists of acceptance by the project manager and final payment to the contractor.

Monroe County

Within Monroe County's transportation system, problems are identified in three ways: through comprehensive planning; by periodic structural rating of pavements; and by special attention to consideration of special needs, such as those of bicycles and pedestrians. Analysis of alternatives is similar to that for Category II and III projects carried out by NYSDOT, that is, examination of the problem, a generalized environmental impact assessment, and the selection of the preferred solution, based on economic analysis, public review, and other inputs to the decision making process. Projects are ranked, and funding restraints applied, as part of the Capital Improvement Program (CIP) process. This process involves submittal, by a number of county departments of proposed projects, all competing for the same capital funds. Projects are also submitted by the City of Rochester for those projects which are partially funded by the county. Those city projects originate in turn, from an entirely separate city CIP process, which must take into account the lead time necessary to feed them into the county's program. The County Planning Board reviews the projects and prepares the CIP with staff assistance from the County Planning Department and Budget Office. Projects are usually programmed in the CIP during their planning phase. The second year involves project design, and construction occurs in the third year. The County Legislature must then authorize the letting of these projects for construction.

City of Rochester

Transportation projects are of three types: projects implemented jointly with Monroe County, projects funded solely with city funds, and line items for general repair and maintenance of residential streets, street lights, bridges, and sidewalks. As with Monroe County, the city's CIP contains all capital projects, including transportation. The only major difference, in fact, between the CIP processes for Monroe County and the City of Rochester is that development of the CIP is overseen by a special CIP committee as opposed to the county's permanent Planning Board. Again, as with the Monroe County CIP, the city CIP goes through a series of draft versions before approval by the City Council.

Genesee County

The basic reference for transportation issue is the Genesee County Highway Plan. This plan presents the general policies for problem identification through a set of highway objectives. One of the major methods of achieving these objectives identified in the Highway Plan is the functional classification of highways, similar to that described for Monroe County and the City of Rochester. Each functional classification has special characteristics which dictate the quality and quantity of service that should be provided. In applying these factors to the existing system, transportation problems are identified. The classification of each roadway as either an arterial, collector, or local road, allows the county to determine a "primary system of roads" which is a specific network of county roads. This system will be achieved by constructing new links and transferring existing links to the towns. The plan lists the specific links to be added to and deleted from the primary system. A second source of county funded projects is the roadway maintenance policy, especially in reference to roads not on the primary system.

County highway projects are chosen by the Genesee County Highway Department, based on the recommendations of the plan and the condition inventory of the existing system. They are then submitted for inclusion in the Genesee County CIP. At the same time, other county departments submit their capital project requests. The County Planning Board then produces the draft CIP for submission to the County Legislature. Project implementation generally involves each project in the CIP going individually before the County Legislature. Once a project design is accepted by the County Legislature, it is let for construction or implemented by the Highway Department.

Energy Planning

Energy planning in the Rochester area has taken the form of a series of responses to perceived "crises" in energy availability. At present, emergency energy planning focuses on Rochester Transit System's ability to respond to an energy emergency through schedule supervision and radio-directed deployment of vehicles. Development of a comprehensive energy plan is expected by mid-1983 with the preparation of the Energy Element of the Monroe County Comprehensive Plan. For transportation related energy conservation this element will include:

(1) An energy data base for Monroe County, including energy consumption by major modes of travel;

(2) Conservation policies for transportation, including evaluations of different techniques and policies for their implementation;

(3) Energy contingency plans and policies, including specific actions to be taken under different conditions of fuel shortage; and

(4) Incorporation of energy impact information into the transportation project development process.

Overall, then the planning process in Rochester is modally partitioned, project oriented, and well structured institutionally. In this regard it parallels the process in many other metropolitan areas.

IV. DEMONSTRATION PROCEDURE

This Chapter summarizes the methods used to (1) estimate energy savings of transportation projects; and (2) use energy information in project selection.

A. Description of Projects

This section will characterize the projects proposed for implementation on the 1983-88 GTC TIP, highlighting the 92 projects that have been examined by type, jurisdictional responsibility, funding source and location within the GTC study area.

Projects by Project Type

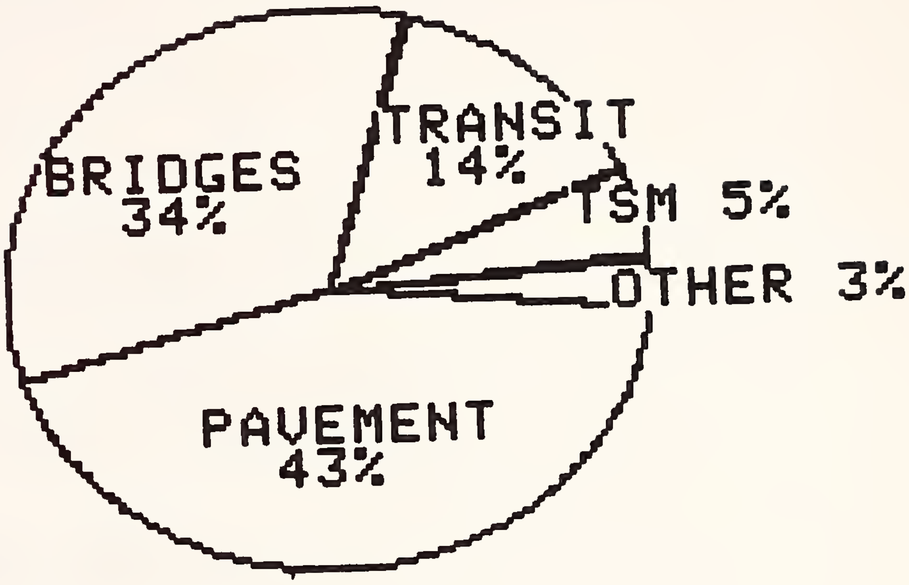
There are basically 7 major types of projects:

(B) Bridge
(P) Pavement
(S) Safety/TSM
(N) New Construction
Transit Vehicle Acquisition
(T) - Standard Transit Vehicle
(M) - Mini Bus Transit Vehicle
(W) Transit Mall
(D) Drainage
(E) 1 project that represents 3 of the above types (P,N,B)

The bulk of the 92 projects examined fall into only 4 actual categories. These categories are:

Figure IV.1 - Project Types

- Structures/Bridges
- Roadways/Pavement
- Safety/TSM actions
- Transit/Vehicle Acquisition



Most project types deal with improvements or repair to deficiencies in the existing highway system. Most of the transit projects represent normal scheduled replacement of like-kind vehicles, based upon existing NYSDOT/UMTA performance standards and specifications for those vehicles.

Of the 92 projects from the 1983-88 GTC TIP 83 projects fall into just 3 categories: 31 bridge projects, 40 pavement projects and 12 transit bus acquisition projects (that will acquire 52 buses). The remaining project types each contain 5 or fewer projects.

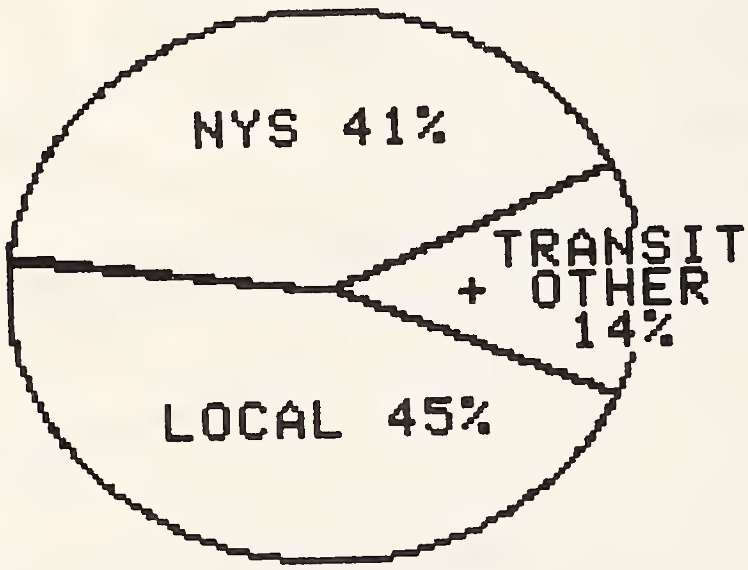
Projects by Jurisdictional Responsibility

There are basically three jurisdictional categories by which we may group the various projects:

- New York State Projects (Those on the NYS Public Transportation Action Plan)
- Non-NYS or LOCAL Projects
- Transit and other projects

The 92 projects proposed for implementation as identified on the 1983-88 GTC TIP are divided between these three categories as shown below:

Figure IV.2 - Jurisdiction



However, examination of the 92 projects by project type shows that jurisdictional responsibility influences the types of projects that have been undertaken.

Figure IV.3 - Project Type: NYS Jurisdiction

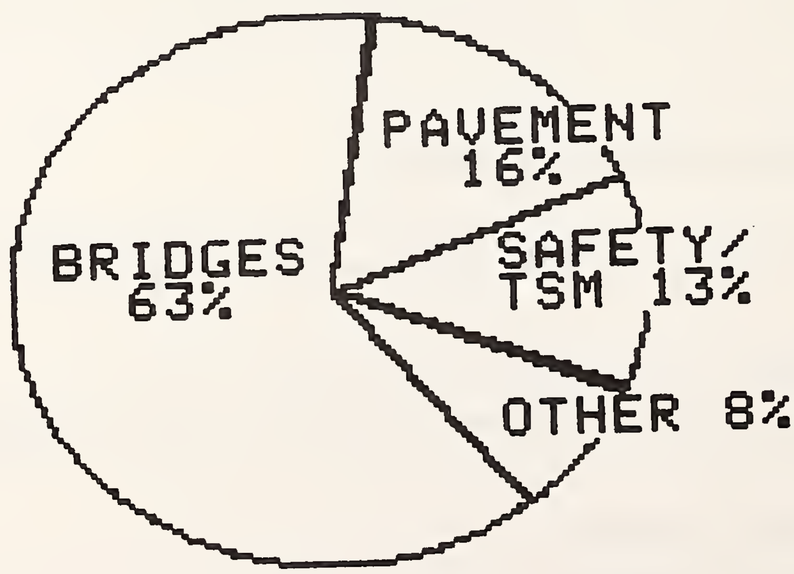


Figure IV.4 - Project Types: Local Jurisdiction

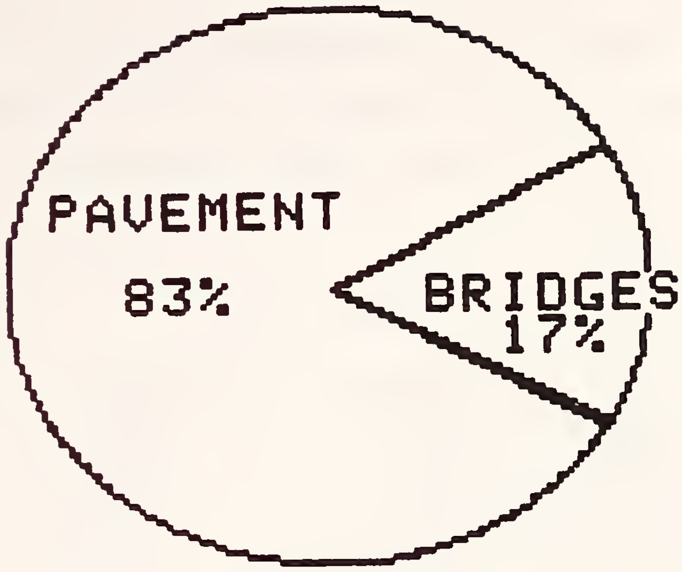
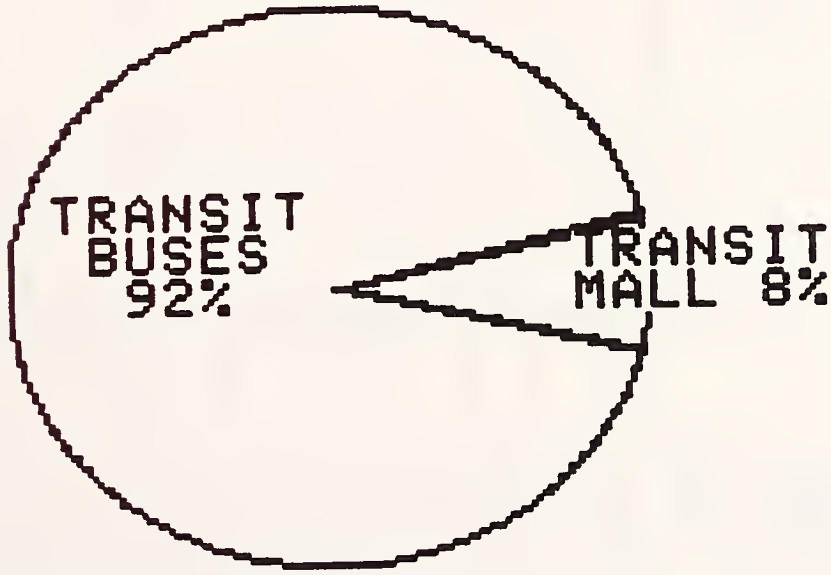


Figure IV.5 - Project Types: Transit Authority Jurisdiction

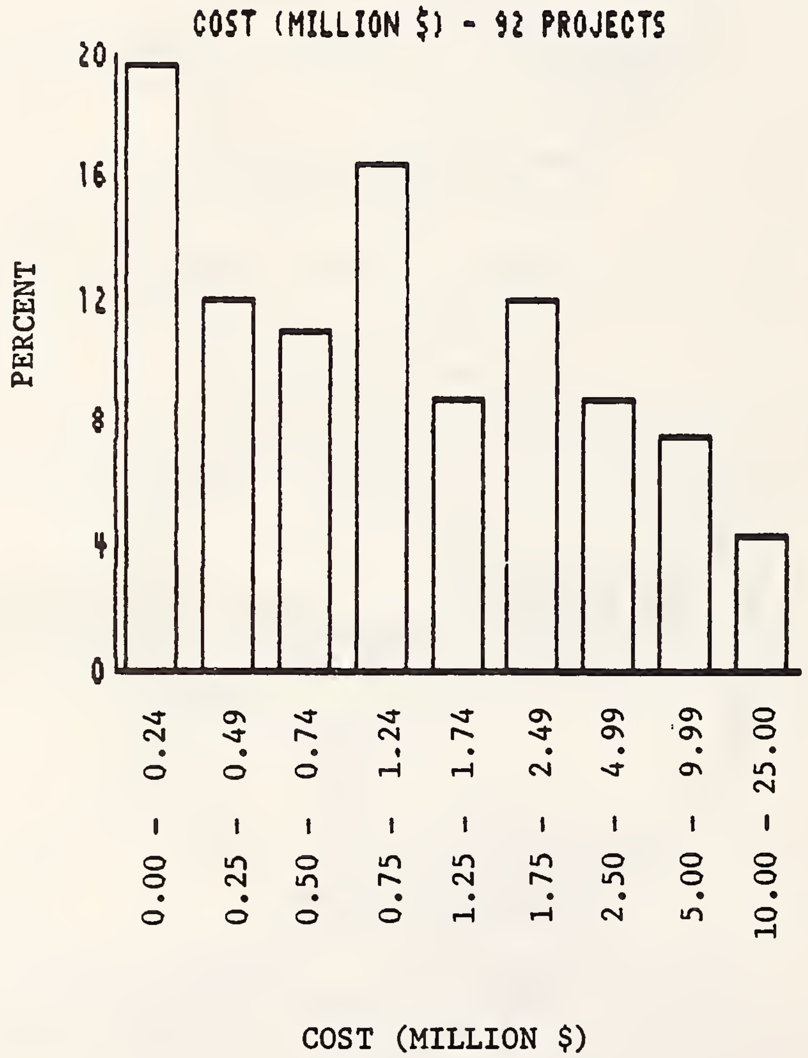


Projects under the jurisdiction of NYS include all projects funded with Federal dollars, as well as those using 100% NYS funds. Unlike local projects which are focused primarily on pavement rehabilitations, 24 of 38 projects for which NYS has jurisdiction are for bridge rehabilitation. The remaining projects are split between the correction of pavement and/or safety related defects.

Projects By Cost

The projects range in cost from \$0.028 million to \$24.568 million. The majority of the projects (80%) will cost less than \$2.5 million, with only 4 projects costing more than \$10 million. The distribution of the projects by cost is shown on Figure IV.6.

FIGURE IV.6



Projects by Funding Category

There are ten distinct funding categories. However, several projects may be funded by more than one category of funds. All projects funded with Federal funds have a local matching share. The local matching share may be 100% New York State funds or distributed among the various government jurisdiction.

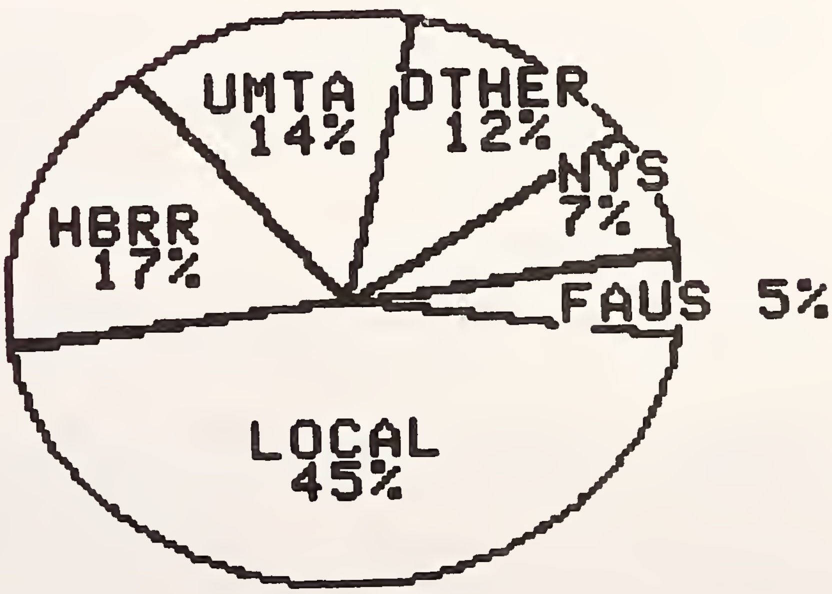
The primary funding categories are:

1.	NYS	100% New York State
2.	HBRR	Highway Bridge Reconstruction
3.	FAPR	Federal Aid Primary-Rural
4.	FAPU	Federal Aid Primary-Urban
5.	FAUS	Federal Aid Urban System
6.	UI	Urban Interstate
7.	UMTA	Urban Mass Transit
8.	IR	Interstate 4R Funds
9.	HBRR & FAUS	
10.	LOCAL	100% Local Funding
11.	HES	Hazard Elimination Safety

Most of the projects analyzed fall into 5 of the above categories. These funding categories are:

Figure IV.7 - Projects By Funding Category

- Local
- HBRR
- UMTA
- NYS
- FAUS



Of the 92 projects from the 1983-88 GTC TIP for which we have performed an energy analysis, 70 projects are funded by just 3 categories of funds; 41 projects by local funding; 16 projects with funds from the HBRR program and 13 projects with funds from UMTA (12 projects for the acquisition of 52 buses and 1 Transit Mall). The remaining funding categories each contain 6 or fewer projects. This small number of projects is insufficient to make estimates with a high degree of confidence.

Observations

We may make the following observations with respect to the various project characteristics:

- The projects are split with respect to government jurisdiction as follows: New York State 38, Local 41, Transit Authority 13.

- Local projects are primarily paving projects.

- New York State projects are primarily bridge projects.

- Projects under local jurisdiction are primarily those projects on the local highway system and are funded with 100% local funds.

- Projects under New York State jurisdiction are primarily those projects on the designated State Highway System or one of the Federal Aid system, and as such are eligible for funding from one of several Federal funding sources.

- All but one of the transit authorities projects are bus purchases.

Figures F.2 through F.7 are maps of the various counties of the GTC area containing projects on the TIP. Tables F.1 through F.4 contain project descriptions corresponding to the coded symbols on Figures F.1 as shown in Figure F.2 through F.7. (See Appendix F.)

B. Energy Analysis Methods

This section briefly describes the analysis methods used to determine energy savings. More detail is provided in Appendix A.

Basically, all projects contain the following components for which an energy evaluation may be necessary.

1. VEHICLE or USER

   - TRAFFIC - The energy associated with factors related to the vehicle (i.e., changes in flow operation, speed, detours, capacity improvements to the roadway, etc.) that change the way in which the vehicle is driven on or in proximity to the project location.

   - PAVEMENT - The energy associated with vehicle operation resulting from improvements to the pavement wearing surface and/or the speed changes resulting from such surface changes.

2. CONSTRUCTION

   - HIGHWAY - The energy associated with those construction activities related to the construction or rehabilitation of the roadway.

   - STRUCTURE - The energy associated with those construction activities related to the rehabilitation of structural components (bridges, culverts, etc.)

The following sections will deal more specifically with methods for each of these components and project type evaluations.

Vehicle or User Energy

In general, vehicle energy consumption is evaluated by the following relationship.

$$\text{ENERGY} = \text{AADT} \times \text{PROJ LENGTH} \times \text{DPY} \times \sum_i \text{Vehicle Type } i \times \text{GPM } i$$

Where

AADT = Annual Average Daily Traffic

VEHICLE TYPE i = Share of Auto, Light Trucks, Heavy Trucks (i= 1,2,3,)

GPM i = Gallons per mile for each vehicle type

Adjusted for

1. Model year efficiency improvements (Auto)
2. Vehicle Type
3. Speed & Flow Condition (free flow or stop-n-go)
4. Grade

PROJ LENGTH = Length of the project in miles

DPY = Days per year (330 or 365)

Changes in energy consumption can easily be obtained by evaluating this relationship for differences in the existing condition and the proposed alternative(s). For certain project types, as described in Appendix A, this evaluation has been simplified through the use of worksheets, table lookup procedures, and/or computer programs.

Construction Energy

Roadway, structural and other construction related components are converted into energy estimates of gallons of equivalent gasoline by:

a. Adjusting the component cost estimate to 1980 dollars using the GNP inplicit price deflator.

b. Multiplying the 1980 cost estimate by the appropriate BTU/dollar construction action conversion factor as shown in Appendix A, Tables A.1 through A.4 (Ref. 1, 2, 3, 5, 19).

c. Dividing the BTU's obtained in (b) by 125,000 to convert the energy into equivalent gallons of gasoline.

d. Dividing the component energy consumption by the corresponding service life to obtain annual energy estimates.

<u>Pavement Projects</u>

For pavement projects, vehicle energy computations are similar to those noted above for changes in operational flow. Improvements to a pavement's structural condition may affect automotive fuel consumption in two ways:

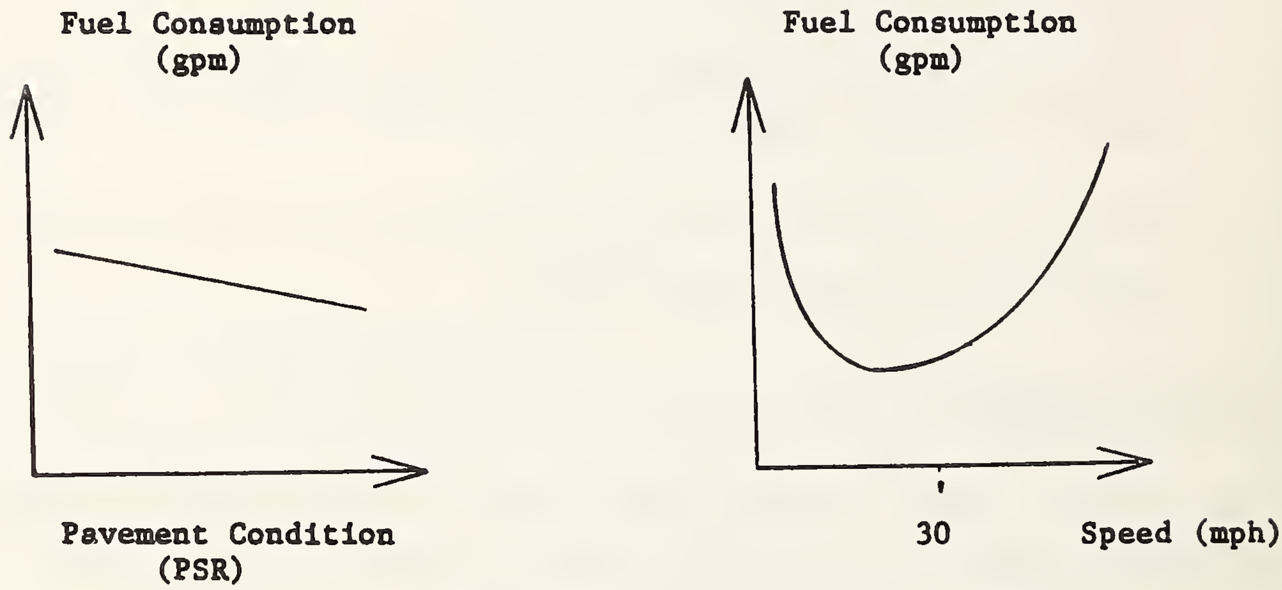
(1) directly, through improved smoothness which reduces rolling friction and variance in operation, and

(2) indirectly, through a change in vehicle speed.

Existing literature is not definitive on the magnitude of the impact of road conditions on fuel consumption. Values reported range from a 30% increase for a very rough potholed road compared to smooth pavement (Claffey, Ref. 15), to no change (Zaniewski, Ref. 16). We believe that the latter finding is due to problems with the design of the experiment, and accept at this time a value of a 1.5% increase for a road rated at a Pavement Service Rating (PSR) = 4.5 over a road rated at PSR = 1.5.

Both changes are small; the smoothness change is consistent over the whole range of pavement condition, i.e., as condition improves fuel consumption drops; the speed change has a saddle point between 25 and 35 mph (depending on vehicle mix), with consumption increasing with improving pavement condition for speeds higher than the saddle point and decreasing with improving condition for speeds below the saddle point. These peculiarities are due to the shape of the fuel consumption versus speed curve shown below:

Figures IV.8 Condition & Speed Effects on Fuel Consumption



Construction components of pavement projects are evaluated as described earlier by selecting the appropriate BTU/$ factor for each of the pavement actions undertaken.

<u>Bridge Projects</u>

For bridge projects, vehicle energy computations are similar to those already noted above. However, because the possibility exists that the bridge might have to be closed if unattended in its present condition, a more specific analysis is used to assess the vehicle energy impact of total or modified bridge closings in the following manner:

1. AADT is separated into the three major vehicle component (cars, light trucks and heavy trucks).

2. The energy impact of a total or partial vehicle detour due to bridge closing or posting is calculated for each vehicle type as the product of the AADT X GPM x Miles x Days/yr. with respect to travel speed, flow condition and model year efficiency improvements.

3. Geometric limitations on the bridge or its approaches often cause speed changes from the travel speed to the speed necessary to cross the bridge, or if there is a detour then the route itself may have a different speed. These effects are evaluated by determining the speed change and the corresponding change in fuel consumption times the AADT for the vehicle types affected.

Construction components of bridge projects are also evaluated for the pavement and bridge portion as described earlier by selecting the appropriate BTU/$ factor for each of the actions undertaken.

TSM Safety & Other Projects

The construction and user energy impacts are computed using various methods depending upon the actions undertaken. Since most of the TSM type projects analyzed dealt with traffic flow conditions and reduction of delay, the vehicle energy computations noted above are applicable. Worksheets and other computation aids are described in Appendix A.

Transit Vehicles

Transit vehicle acquisition projects result from the scheduled replacement cycle for these vehicles. Since the 12 vehicle acquisition projects represent 52 vehicles, the analysis was taken on a per vehicle basis. The potential savings, if any, result from improvements in vehicular efficiency. The energy consumption of both the replacement vehicles and the existing vehicles presently in service may each be computed using the following relationship:

Energy = # vehicles x annual mileage / MPG

Differences in vehicle efficiency (MPG) and annual mileage may work together or against each other to provide fuel savings or increases for a given vehicle replacement.

C. Administrative Procedures

This study arose from a desire to increase the opportunities for transportation energy conservation offered through project planning in urban areas' planning processes. Because project planning means "TIP Planning" in most areas, the study evaluates the means for increasing energy awareness in the TIP process. While the Rochester MPO structure is not the only institutional arrangement within which to address such matters, it is, in general, better equipped, technically and administratively, to undertake the task. Nevertheless, since energy considerations are not an explicit part of the TIP process, this process needs to be modified to use the energy data.

This section addresses those points in each agency's process where energy planning, not currently done, could be incorporated most efficiently. These recommendations were used as a starting point to the activities conducted as part of this project. The 8 basic steps in the project evaluation process and those points at which energy considerations should be included is shown in Figure IV.9.

Preparation and distribution of project energy impact information was done jointly by GTC and the NYSDOT Transportation Statistics and Analysis Section (TSAS). GTC identified sources for the data needed for the analyses and established contacts to obtain it; the information was then sent to NYSDOT (TSAS) for analysis. The results of the analyses were returned to GTC and then distributed to the project implementors. The following describes the process by which GTC staff prepared the information and presented it to the project implementors.

GTC Committees

The projects required to be listed in the TIP include the "Urban Systems" highway projects [Federal-Aid Urban Systems (FAUS), Federal Aid Primary (Urban), and Federal-Aid Interstate (Urban)]; and transit projects (UMTA funded operating and capital projects for systems operated within the Rochester urban area). The necessary information for these highway or transit projects was obtained from NYSDOT and R-GRTA, respectively.

FIGURE IV.9: STEPS IN THE TIP PROCESS

Step		Institutional Inputs	Energy Inputs	Outputs
1.		Transportation system goals and policies	System-wide measures of energy efficiency	Identification of problems in the transportation system
2.	(a)	Interaction between agencies, public, etc. through an informal decision-making process.	--	Ranking of problem sites in priority order
	(b)	Application of problem identification criteria		
3.	(a)	Alternative solutions to individual problems	--	Development of alternatives for individual projects
	(b)	Application of alternatives analysis procedures		
4.	(a)	Agency staff recommendations	Development of energy impact information and selection of the most energy efficient alternative	Selection of the preferred solution for each alternative
	(b)	Political and other issues concerning individual projects		
5.	(a)	Transportation projects submitted for the capital program	Use of energy analysis methods to select the most energy efficient program of projects	Ranking of proposed projects in terms of priority
	(b)	Non-transportation projects submitted for the capital program		
6.	(a)	Comparison of available funds vs. cost of proposed projects	--	Application of funding constraints to the program of projects
	(b)	Application of decision		
7.	(a)	Public review of the proposed capital program	--	Production of the final Capital Improvement Program document
	(b)	Inclusion of projects listed for information purposes		
	(c)	Description of the project selection process		
8.	(a)	Highway projects - location and design criteria	Selection of the most energy efficient methods and materials in project design or vehicle purchase	Implementation of individual projects
	(b)	Transit projects - solicitation and acceptance of project bids.		
	(c)	Public and agency review of alternatives.		

Project review for the TIP is conducted by three committees: the Technical Subcommittee of the Planning Committee, the Planning Committee itself, and the Council.

The material presented to the Technical Subcommittee for the highway projects included: project description, proposed scheduling of funds, reasons for the project, project benefits, project disbenefits, and conformance with GTC goals. The energy impact information included with the above information consisted of a description of methods and assumptions used for the analysis and the results of the analysis itself. (Examples are shown in Appendix E.)

The energy analysis broke down the energy effects of a project into costs of construction and user costs (or benefit), both expressed in terms of equivalent gallons of gasoline. In both cases, sufficient detail was presented to allow users to determine how the data was generated. As a summary statistic, the payback period (the time, in years, it would take user benefits to equal construction costs) was also presented. (See Appendix E, Exhibit E.1.) For transit vehicle replacement, information consisted of the indirect (manufacture) and direct (operation) costs associated with both the existing and replacement vehicles, again expressed as equivalent gallons of gasoline. The net indirect and direct costs, arrived at by subtracting the cost of existing vehicles from the cost of replacement vehicles, was also presented. These two were combined to produce a total net energy cost.

Information presented to the Planning Committee basically consisted of summaries of the above information. For highway projects, the construction and user effects and the payback period of each project were presented on a single table. For transit vehicles, the net energy effects of each vehicle purchase were also presented. In addition, two summary tables, showing the energy effects of the entire TIP were also presented to the Planning Committee. The first classified the projects by type and presented the average annual construction, user, and total cost (in equivalent gallons of gasoline) for each type of project. The second presented the projected energy consumption for the Rochester area under various conditions of base and future traffic and network. This information is summarized in Tables V.1-3 and Figure V.1.

Similar information was included in the public presentation of the TIP and presented to the Genesee Transportation Council. Both meetings also included a description of the TIP process and a listing of the recommended projects required to be in the TIP.

New York State Department of Transportation (Rochester Regional Office)

In NYSDOT a number of methods exist for assessing user energy costs generated by a specific roadway segment, or alternatively, for each of the segments of a network. The application of this analysis to a network or subarea would produce a set of roadway segments where user energy consumption is judged to be a problem according to some criteria.

The development of alternatives presents a further opportunity to incorporate project energy impact information. For Category I projects, the PR-II report, which presents project location alternatives, contains special subjects such as air quality and soils. The PR-IV does the same for design alternatives. When appropriate, either or both of these reports, could contain a separate study of the energy impact of the alternatives, including both user and construction energy costs associated with each.

For Category II projects a design report is prepared, detailing the effects of each alternative. While the user energy costs are identified, the energy costs and benefits of each alternative are usually not identified separate from the monetary costs and benefits. The identification of energy related construction and user costs, with the methods used for this demonstration project, would provide project decision-makers with the total energy effects of each alternative.

The third point in the NYSDOT process where energy data can be an effective input is priority ranking. This is the step at which the project energy analyses were done for this research project. The type of energy data collection done at this step also depends on the project type; however, if energy analyses were done for each alternative, the analysis for the selected alternative should be readily available.

The projects for which energy impact information was submitted included some state highway projects not required to be in the TIP, but listed there for information purposes only. The format of the energy information was similar to that presented to the Technical Subcommittee, except that it included only energy impact information. The information was presented in a consistent form for the two basic types of projects listed in the TIP (bridge and highway). (See Appendix E, Exhibits E.2 and E.3.)

The information, including a description of the methods used to generate it and a summary table, was sent to the NYSDOT regional director. The cover letter stated the purpose of the project and the reason the information was sent, (i.e., to identify its possible usefulness in the project selection process).

<u>Rochester-Genesee Regional Transportation Authority</u>

At present R-GRTA simply applies industry standards to its fleet (determining that any bus over 12 years old should be replaced). The only alternatives available to R-GRTA for the problem of deterioration of RTS buses are replacement versus the null (maintenance) alternative. The energy impact analysis for such a project would simply consist of computing the energy savings of the replacement alternative over the null alternative. This is done by the applying energy information to standard benefit/cost analysis methods.

The point at which energy planning can be incorporated into R-GRTA's project programming process is during the project ranking process. As with NYSDOT, the information gathered during alternatives analysis can be used for each alternative chosen for the project.

Review of proposed R-GRTA transit capital projects by NYSDOT Transit Division basically consists of determining whether project costs are reasonable and whether there is adequate documentation. Review by GTC consists of committee review to insure the cost-effectiveness of the proposed projects. This is currently done on the basis of project justification material included in the UMTA capital grant request and on the completed Goals Achievement Checklists.

This checklist is a questionnaire used to determine the project's conformance to the adopted goals and policies of the Genesee Transportation Council. The energy impact of each proposed project could be added to this information and used by R-GRTA, NYSDOT, and GTC in their examination of proposed projects.

The final point at which project energy impact could be incorporated in the TIP process is in the bidding process. The review of bid proposals can include an assessment of the energy impact of each bid alternative.

The data presented to R-GRTA basically consisted of an application of the same data supplied to the Technical Subcommittee, expanded to include all the transit vehicles in R-GRTA's 5-year program, as listed in the TIP. This includes the direct and indirect energy costs (or benefits) of existing and replacement vehicles for all the vehicle purchase projects, and the net cost of each project, expressed as equivalent gallons of gasoline. (See Appendix E, Exhibit E.4.)

An additional energy analysis was presented to R-GRTA for the construction of a downtown transit mall, a project which is being developed under their auspices. The information for this project was in the same form as the highway projects including project description, scheduling and justification material, the methods and assumptions used for the energy analysis.

Locally Funded Projects (Monroe Co., City of Rochester, Genesee Co.)

The transportation development process used by the localities is similar to that used by NYSDOT, with the exception that all local capital projects compete for the same funds. The recommendations presented for NYSDOT generally apply to the programming of locally funded projects.

In addition Monroe County is currently preparing an Energy Element of its comprehensive plan. This would provide the opportunity to use excessive energy consumption as one basis for problem identification and project initiation. The identification of energy consumption problems in transportation would involve a TSM-like energy study similar to that discussed for NYSDOT. After completion, the resulting list of problem sites would go through the remaining steps of project development, following the procedure outlined previously or used for the project energy analysis done for this study.

The TIP projects funded by the City of Rochester and Monroe County were, with few exceptions, highway pavement rehabilitation and preservation projects. These types of roadway improvements were readily analyzed with the computer programs available at NYSDOT for projection of their construction and user energy costs (or benefits). This uniformity of method enabled the presentation of standardized information to Monroe County and the City of Rochester. (See Appendix E, Exhibit E.5.) In each case, the project energy impact information, along with an explanation of methods and a letter presenting issues for discussion, were sent to the City and County agencies normally responsible for submitting transportation projects for the Capital Improvement Program.

V. FINDINGS

A. Energy Analysis

1. Project Evaluations

This section discusses the project energy analysis results (described more fully in Appendix B), the annual fuel consumption associated with each project, and those measures that may be useful in comparing or contrasting the projects within a project group or between groups.

The 1983-88 GTC TIP contained 92 projects for which an energy assessment was undertaken. Table V.1 shows the overall findings for all projects analyzed. Tables V.2 and V.3 contain summary results of the energy assessments on the basis of the project types and funding categories described in Section IV. The energy assessments described in these tables are based on the measured energy difference or change between the proposed project alternative and the expected null or existing situation. Three points should be noted with respect to evaluation of the results: 1) Project type descriptions (Table V.1) represent aggregated categories; 2) Although there are ten distinct funding categories (Table V.3), several projects may be funded by more than one category of funds; and 3) Negative numbers in Tables V.1 through V.3 represent reductions in energy usage, i.e., energy savings resulting from the projects. Postive numbers represent increases in energy use, or losses resulting from the projects.

General findings are:

- Overall, as shown in Table V.1, the projects proposed for implementation during the next five year period have the potential for conserving 3.8 million gallons of gasoline annually, this is about 1.3% of the 293.2 million gallons of gasoline consumed on the region's transportation network in 1980.

TABLE V.1

PROJECT ENERGY ANALYSIS FINDINGS

Total Number of Projects: 92

	Change In Average Annual Gallons *
User Energy	-5,903,708
Construction Energy	2,137,228
Net Energy	-3,766,480
1980 Regional Transportation Network Fuel Consumption	293,227,440
Net Energy Improvement	1.3%
Project Dollars ($=1981)	198,872,000
Overall Payback Period	5.9 yrs.

*Negative numbers refer to energy savings

Table V.2 - Project Based Energy Analysis Findings[9]

Project Type	Service Life	#	Total Annual Energy (000) Veh. or User	Total Annual Energy (000) Construction	Total Annual Energy (000) Net	Total Project Construction Energy (000)	Av. Cost Mil $ - 81	Av. Traffic AADT	Δ[1] Av. An. Gallons (000) Veh. or User	Δ[1] Av. An. Gallons (000) Construction	Δ[1] Av. An. Gallons (000) Net	Net Cal[2] Proj. $	Net Cal[2] 1000 Veh	Energy[2,3] B/C	Payback[4] Period (yrs.
Bridge	30	31	-7,272.0	528.3	-6,743.7	13,233	2.478	13,680	-234.6	17.1	-217.5	-0.08	-48.2	-13.8	1.8
Pavement[5]	10	38	46.5 Speed Surface 109.6 -63.1	928.9	975.4	9,805	1.452	8,472	1.2 Speed Surface 2.9 -1.7	24.4	25.7	0.02	9.2	0.05	—
Safety/TSM	15	5	-236.6	167.6	- 69.1	2,323	3.809	13,056	-47.3	33.5	-13.8	-0.004	-3.2	-1.4	9.8
New Const.	30	1	1,667.5	347.3	2,014.8	7,303	17.557	19,160	1,667.5	347.3	2,014.8	0.11	318.7	4.8	--
Drainage	20	1	-1.3	.1	- 1.2	2	.080	13,700	-1.3	.1	-1.2	-0.01	-0.3	-9.7	2.0
Other[6]	14.7	1	-51.4	87.5	36.1	1,674	11.511	54,100	-51.4	87.5	36.1	-0.003	2.0	-0.6	-32.6
Transit Veh.[7] Mini Buses	4	33 (10)	1.1	23.4	28.5	94	.034	--	.033	.710	.743	.022	-	.046	--
Stand. Buses[7]	12	19 (2)	20.4	13.0	33.4	156	.163	--	1.076	.683	1.759	.011	-	1.576	--
Transit Mall	30	1	-27.8	5.5	-22.3	165	11.167	--	-27.8	5.5	-22.3	.002	-	-5.1	5.9
All Project Types[8]		92	-5,903.7	2,137.2	-3,766.5	34,754									

1: Δ - Difference Between Proposed and Null Alternatives
2: Ratios are Based Upon the Differences Noted Under Av. An. Gallons
3: Vehicle Gallons ÷ Construction Gallons
4: Total Project Construction Energy ÷ Annual Vehicle Energy
5: 40 Projects were analyzed, however, 2 have been deleted as they are atypical and distort the vehicle energy values for this category.
6: This project is atypical as portions of it could be categorized as Br. Pav. or New Const.
7: # Buses are shown; # projects are in ( ).
8: Total includes all 92 projects analyzed.
9: Negative numbers refer to energy savings.

Table V.3 - Funding Source Based Energy Analysis Findings[9]

Funding[10]	#	Total Annual Energy (000) Veh. or User	Total Annual Energy (000) Construction	Total Annual Energy (000) Net	Total Project Construction Energy (000)	Av. Cost Mil $ = 81	Av. Traffic AADT	Δ[1] Av. An. Gallons (000) Veh. or User	Δ[1] Av. An. Gallons (000) Construction	Δ[1] Av. An. Gallons (000) Net	Net Gal[2] Proj. $	Net Gal[2] 1000 Veh.	Energy[2,7] B/C	Payback[8] Period (yrs.
100% NTS[3]	6	-7.1	93.3	86.2	1,213	1.267	5,646	-1.2	15.6	14.4	0.01	7.7	-0.08	170.5[3]
HBRR	16	-3,905.5	196.8	-3,708.7	5,257	2.030	6,710	-244.1	12.3	-231.8	-0.11	-104.7	-19.8	1.3
FAPP	2	48.4	49.3	.9	531	2.301	13,850	-24.2	24.6	0.4	0.0002	0.10	-1.0	11.0
FAPU	1	1,667.5	347.3	2,014.8	7,303	17.557	19,160	1,667.5	347.3	2,014.8	0.11	0.32	4.8	--
FAUS	5	-1,430.5	182.1	-1,248.4	2,435	3.786	47,920	-286.1	36.4	-249.7	-0.07	-40.4	-7.9	1.7
UI	3	-494.3	266.1	-228.2	6,675	12.787	79,867	-164.8	88.7	-76.1	-0.006	-2.9	-1.9	13.5
UMTA[5]	13	-6.3	41.9	35.6	165[4] (414)	1.184	--	-0.5	3.2	2.7	0.002	--	-0.15	5.9[4]
IR	1	--	70.2	70.2	1,104	6.867	--	—	70.2	70.2	0.01	--	--	--
HBRR + FAUS	3	-347.1	17.5	-329.5	468	0.916	14,420	-115.7	5.8	-109.8	0.12	-23.1	-19.8	1.4
100% Local[6]	41	-1,325.3	867.2	-458.1	9,249	1.296	8,410	-32.3	21.2	-11.2	-0.009	-4.0	-1.5	7.0
HES	1	-6.9	5.6	-1.3	105	1.200	14,000	-6.9	5.6	-1.3	-0.001	-0.3	-1.2	15.2
All Funding Categories	92	-5,903.7	2,137.2	-3,766.5										

1: Δ = Difference between Proposed and Null Alternatives.
2: Ratios are based upon the differences noted under Av. An. Gallons.
3: The project types contained in this category are dissimilar and severely distort these values.
4: Payback period shown is for Transit Mall only.
5: The 13 projects include 52 buses and 1 transit mall.
6: Same as footnote 3, here 7 br. projects are providing the savings to offset the 34 pavement projects.
7: Vehicle Gallons ÷ Construction Gallons.
8: Total Project Construction Energy ÷ Annual Vehicle Energy.
9: Negative numbers refer to energy savings.
10: See Section IV for Definitions of Funding categories.

- Bridge projects offer the greatest potential for energy conservation. This is due primarily to the removal or avoidance of traffic detours and/or reroutings due to load limits or bridge closure, and secondarily to improvements in flow over the structure.

- For pavement projects, energy savings due to improvements in surface are frequently offset by increases in fuel consumption due to increases in operating speed (because of the fuel consumption versus speed relationship). Capacity improvements due to widening or shoulder improvements may also contribute to speed increases. The energy savings from surface replacement is almost always insufficient to offset the capital energy investment required to replace the pavement surface.

- Safety/TSM projects, although represented by only 5 projects, offers the second greatest potential for energy conservation. This type of project derives its energy savings and reductions in vehicle delay through improvements in traffic flow.

- Transit vehicle purchases generally increase energy use. This happens because while it is desirable to obtain more fuel efficient replacement buses, other requirements and criterion may preclude this.

- On the average those projects saving energy will also provide a return or payback of the total construction energy in terms of vehicle savings in less than 7 years.

- Funding category is not indicative of energy conservation. Funding categories comprised of a significant number of bridge projects and to a lesser extent safety/TSM projects offer greater conservation potential.

2. Comparison Measures

For contrasting the various project and funding categories, a variety of measures and ratios are provided in both summary Tables V.2 and V.3.

Change in Gallons/Project Dollar ($=1981)

This may be viewed as the monetary measure of energy effectiveness, i.e., the change in net energy conserved or consumed per project capital expenditure dollar. These values, as shown in Table V.2, range from .11 to -.08. As expected, positive values are associated with projects that consume energy and negative values are associated with projects that conserve energy. Since none of the negative numbers are greater than the 1981 average price per gallon of gasoline ($1.37), none of the project categories save as much gasoline as is invested in the project.

Net Change in Gallons/1000 Vehicles

This figure is the annual change in net energy conserved or consumed per vehicle using the facility. As shown in Table V.2, except for the new construction project most values are small and represent rather insignificant savings or losses per 1000 vehicles.

Annual Change in Vehicle Gallons/Annual Change in Construction Gallons

This figure represents the change in annual vehicle energy per change in annual construction energy (the energy benefit/cost ratio). As seen in Table V.2, the range for those project types with positive values (energy users) is small, .046 to 4.8. For those project types which save energy the range is much larger, -1.4 to -13.8. The project types with the largest ratio are bridge and drainage projects.

Payback Period

This figure represents the period of time required for vehicle energy savings to offset total construction energy costs. Values are calculated only when there are vehicle energy savings. As seen on Table V.2, for most project types the payback period is less than 10 years.

3. Monitoring of Trends

As part of the demonstration project a system was established to monitor a variety of measures to track trends in travel, economic conditions, car ownership, gasoline price and use, and other measures in the Rochester area. The data is reported, assessed, and distributed quarterly as a supplement to the GTC "DATA GUIDE". The "DATA GUIDE" is a comprehensive directory, published annually, of transportation data sources and other data available for the Rochester area. Each quarterly supplement included at least two years of data for each item (when possible), and line graphs for a visual perspective of the data.

By continuously monitoring and reporting this data, GTC is able to maintain a picture of travel, energy consumption and economic activity in the region whereby, both short and long term effects of various transportation actions can be examined. The specific data items collected are contained in Appendix D, "Monitoring".

Most of the data items were obtained from NYSDOT. The remaining items were obtained from transportation providers, federal or state economic and statistical reports, or local sources.

The monitoring effort to date (February, 1983) has indicated the following recent trends in the Rochester area:

- Between March and August of 1982 a significant decline (33%) in transit ridership occurred following the increase in fares by 15% for the average rider. However, 70% of the decline represents riders from the discontinued free fare zone in downtown Rochester. As of May 1983 approximately 1/3 of the loss had been regained.

- A decline (30% since December 1980) in traffic entering the New York State Thruway in the Rochester area following the opening of the Genesee Expressway which connects Rochester with points south of the New York State Thruway.

- A decline in air (70%) and rail (30%) freight tonage, while at the same time a significant increase in the number of registered trucks (20%) in the Rochester area occurred in 1982. This could lead to increased pavement maintenance requirements due to higher levels of truck usage.

- The economic base in the Rochester area appears to be more stable than that of the State, as unemployment (7.5% in December, 1982) is less than the State.

- Vehicle efficiency and energy prices and consumption in the Rochester area appear to follow statewide trends of moderating prices and consumption. (Between December 1981 and 1982 the price of full service, leaded gasoline declined 6%.)

Since it is early in the monitoring process, it is too soon to determine any long term trends in the observed data. Ultimately this activity will provide transportation planners with a view on how key measures of transportation system performance are moving over time. Using this information as a base it will be possible for the GTC staff to develop or assess the interrelationship of these measures with other key background parameters. It is then possible to see whether or how changes in transportation and energy policy are reflected in the measurement of transportation system performance.

4. Long Range Assessment

Energy consumed by travel on the Rochester area highway system will change over time due to short and long range improvements to the highway system, increases in vehicle efficiency, and changes in socio-demographic characteristics in and around the study area.

The long range assessment analyzed the effects of the 1990 GTC Transportation Plan, improvements in vehicle efficiency, vehicle turnover, and changes in socio-economic characters on vehicular energy consumption in the Rochester area. This assessment was accomplished by utilizing the New York State traffic simulation model. (For a description of this model and a list of improvement included in the 1990 plan, see Appendix C, "Long Range Assessment".)

Three traffic simulations (assignments) were undertaken:

1. Base network and base year travel with the 1980, 1990, and 2000 year estimates for vehicle fleet efficiency.

2. Base network and future year travel with the 1990 and 2000 year estimates for vehicle fleet efficiency.

3. Future year network and future year travel projections with the 1990 and 2000 year estimates for vehicle fleet efficiency.

The three assessments noted above then enable us to examine separately and collectively, fuel consumption on the highway system in the Rochester area for changes due to the highway network improvement; changes due to the expected growth in traffic due to growth in the region; and lastly changes due to improvements in vehicle fleet efficiency. The results of these three assessments are shown in Table V.4 and Figure V.1.

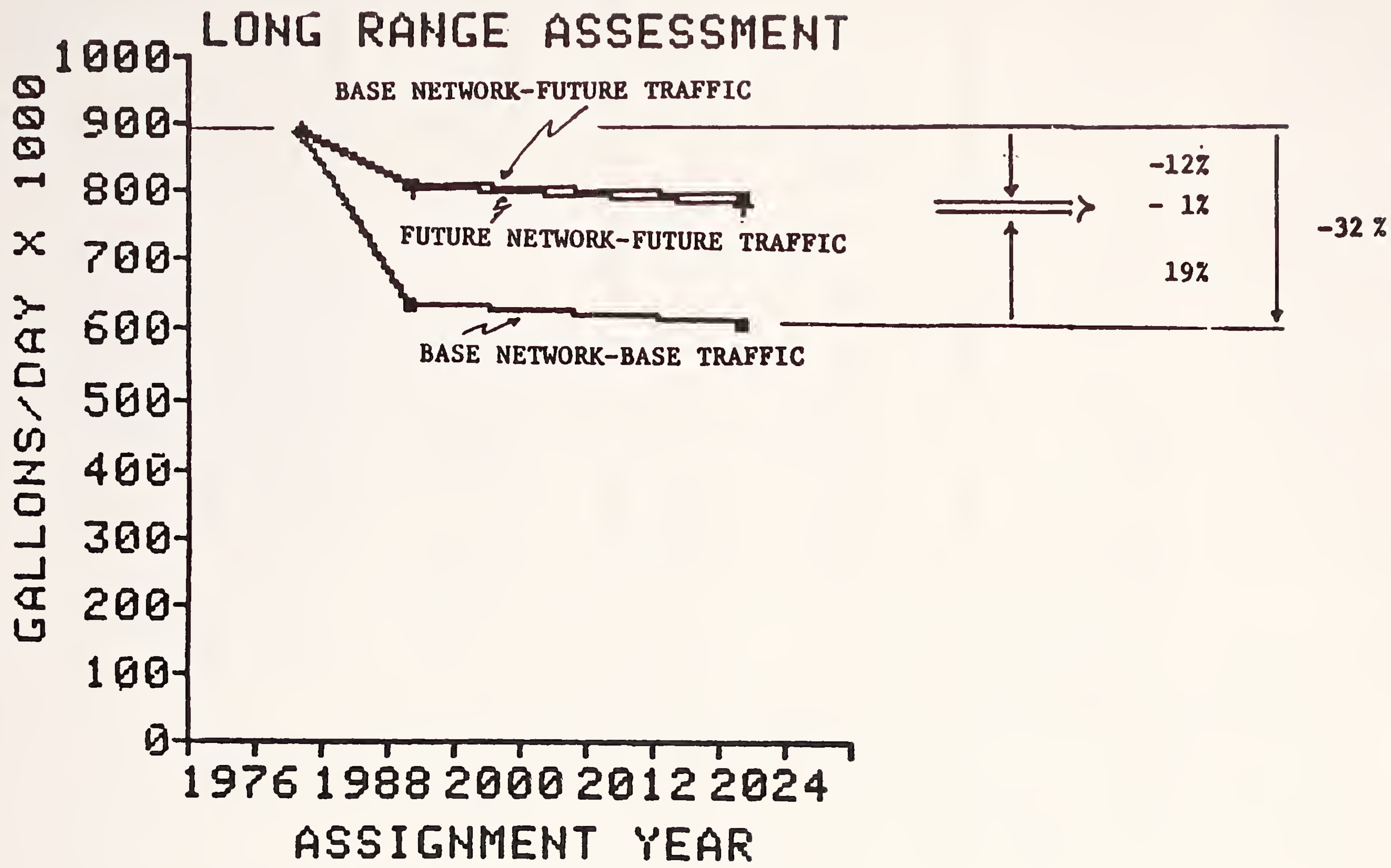
Table V.4[1]

Network Traffic Assignments
Estimated Gallons/Year (Millions)

Year	Assignment (1) Base Network/ Base Traffic	Change From Previous Period	Assignment (2) Base Network/ Future Traffic	Change From Previous Period	Assignment (3) Future Network/ Future Traffic	Change From Previous Period
1980	293.2	--	293.2	--	293.2	--
1990	207.5	85.7 (-29.2%)	267.9	25.3 (-8.6%)	264.7	28.5 (-9.7%)
2000	199.9	7.6 (-3.7%)	258.3	9.6 (-3.6%)	255.2	9.5 (-3.6%)
Total Change from 1980		93.3 (-31.8%)		34.9 (-11.9%)		38.0 (-13.0%)

[1]Negative values imply savings

Figure V.1



LONG RANGE ASSESSMENT
1000
900
800
700
600
500
400
300
200
100
0
GALLONS/DAY X 1000
1976 1988 2000 2012 2024
ASSIGNMENT YEAR
BASE NETWORK-FUTURE TRAFFIC
FUTURE NETWORK-FUTURE TRAFFIC
BASE NETWORK-BASE TRAFFIC
-12%
- 1%
19%
-32 %

The conclusions that can be drawn from the long range energy assessment are:

- The expected improvements in vehicle fuel efficiency between 1980 and 2000 can reduce annual highway system fuel consumption 85.7 million gallons by 1990 (29.2% of 1980 fuel consumption) and an additional 7.6 million gallons (2.6% of 1980 usage) by 2000. Fuel consumption between 1980 and 2000 is reduced 93.3 million gallons (31.8%).

- The effects of traffic growth in the region results in a fuel consumption increase of 60.4 million gallons (20.6% of 1980 consumption) between 1980 and 1990.

- The net effect of these two changes results in the saving of 25.3 million gallons by 1990 (8.6% of 1980 fuel consumption) and an additional savings of 9.6 million gallons (3.3% of 1980 fuel consumption). The total saving by 2000 is 34.9 million gallons (11.9% of 1980 fuel consumption).

- The highway improvements to the transportation system contained in the 1990 GTC Transportation Plan will result in a savings of approximately 3.2 million gallons by 1990 (1.1% of 1980 fuel consumption).

From the above assessment it is clear that vehicle efficiency improvements will result in the largest energy savings, with the savings resulting from transportation improvements being much smaller. These savings more than offset the increases in fuel consumption resulting from a growth in travel, with a resultant net fuel reduction by 1990 of approximately 28.9 million gallons (9.7% of 1980 fuel consumption). It should be noted, however, that these savings do not include the effect of the construction energy costs to put these improvements in place.

5. Comparison Between Long-Term and Short-Term Impacts

The short term project assessment discussed earlier reflects the energy analysis of the individual TIP projects, and includes both user and construction energy. The long range assessment, discussed above, addresses <u>only</u> the user benefit obtained by the network improvements.

The completion of the projects contained in the 1983-88 TIP and the 1990 GTC Transportation Plan will result in the likely reduction of <u>vehicle</u> or user energy requirements in the Rochester area by approximately 9.1 million gallons (3.1% of 1980 fuel usage) per year by 1990. (That is, 3.2 million gallons from 1990 Plan improvements and an additional 5.9 million gallons from TIP projects not already included in the network analysis of the 1990 Plan)

This assessment of vehicle or user energy must be reduced by the capital energy costs for construction which will offset some of the expected savings. For those projects listed on the 1983-88 TIP for which an energy assessment was undertaken, the resultant annual construction energy expenditure is approximately 2.1 million gallons. However, since there are several projects from the 1990 plan that are included in our long range simulation assessment, but are not within the TIP period, and for which construction energy assessments are unavailable, it is not unreasonable to expect this value to be somewhat greater. Therefore, it will be assumed that the actual <u>construction</u> energy requirements are probably closer to 2.4 million gallons per year.

Taking both the expected vehicle (user) energy savings and the estimate for the construction energy requirements into consideration, an overall <u>net</u> savings of approximately 6.7 million gallons per year (2.3% of 1980 consumption) can be expected by 1990. When the effects of improved vehicle efficiency and increases in travel are accounted for, the total savings is 32.0 million gallons (10.9% of 1980 consumption). The energy savings attributed to vehicle turnover, still overshadows any savings resulting from planned transportation improvements.

6. Observations

Based upon our long range energy assessment of improvements to the Rochester area highway system and our detailed energy assessment of the various projects included on the 1983-88 TIP for implementation during that period we may make the following observations:

- In general, the projects proposed for inclusion in the 1983-88 TIP will assist (moderately) in making progress toward the goals of energy reduction.

- Improvements in vehicle operating efficiency brought about by vehicle replacement actions on the part of the public will much more significantly alter energy consumption than capital investment to and improvement or maintenance of the infrastructure.

- Savings due to vehicle efficiency improvements are likely to be 12 times greater than the net savings that can be expected by the combined network and specific project improvements expected to be in place by 1990.

- The prevailing trend of improved vehicle efficiency and reduced consumption of energy for transportation for Rochester is consistent with that for the rest of the State. However, the level of expected economic activity and subsequent resumption in normal growth in VMT could alter this trend.

B. Observations on Institutional Elements

Agency views on the usefulness and appropriateness of the project energy analysis was determined through a series of meetings or transmittals. Each agency was first asked whether they collected similar energy impact information for their project development process, whether the provided information was used, and, if so, how. They were also asked about instances in which the information was not useful, due to such issues as the inappropriateness of the timing or form of the information. Each agency also described the effect that it had, both on the selection of individual projects and on the capital programming process as a whole. Each agency then considered specific points in the process where the information could be presented to be most effective. As a basis for discussion, the recommendations presented in Section IV.C were also suggested. Finally, each agency was asked if they anticipated using the type of project energy information presented, while being advised that both GTC and NYSDOT would be able to assist in making the methods available to them.

1. GTC Committees

Projects which are judged by their implementors to be eligible for funding under the federal highway funding categories required to be listed in the TIP are usually submitted for programming following the preparation of a Project Initiation Report. The GTC technical subcommittee usually makes its decisions as to which projects to program partially on the basis of the information contained in the Project Initiation Report, or in the latest available project reports, which may contain information on the project's energy impact. This year, the energy impact information received for each highway project by the technical subcommittee was used with the project report and the decision criteria described previously. Most of the projects, in fact, had been previously programmed in the TIP, and thus had the impetus of past commitments.

The subcommittee was presented an overview of the TIP/Energy Analysis project and discussed the usefulness of the energy impact information. It was noted by the subcommittee that the ability of the energy information, by itself, to influence a decision would be difficult to determine, and unlikely to be significant in light of the fact that energy consumption is already built into many aspects of the traditional project evaluation process. The Planning Committee's response to the project energy impact information basically reflected the position taken by the technical subcommittee.

2. New York State Department of Transportation (Regional Office)

The position taken by the NYSDOT Regional Planning Engineer was that the separate presentation of energy costs for smaller scale projects, such as safety, R&P and bridges, was generally not useful, since the decision to implement these projects is based on the current or projected deterioration of a facility, not on the energy costs and benefits per se. Therefore, providing separate energy information especially after the alternatives analysis process, would have little effect on the decision to implement the project. For larger scale projects, energy impact information may be quite useful, particularly in the analysis of location or design alternatives, and in such cases it is developed by NYSDOT. Further, many project benefits are often not quantifiable. Thus it would be unfair to over-emphasize specific types of benefits, such as energy benefits, as compared to other types of benefits. Use of energy information for selection of TSM TOPICS projects is good in theory, but these projects often expand after they are initiated to include such items as movement or replacement of utilities. Thus, costs could increase to a point where they far exceed the original energy benefits, and the result would be another example of a situation in which energy benefits, when stated explicitly, can provide a biased view of a project whose benefits include a number of quantifiable and non-quantifiable components.

Concerning the pre- and post-TIP process, the Regional Planning Engineer's position was that for Category I type projects, energy information at the systems level is already available, and further information may not be useful prior to the location planning and design phases. In general, however, energy analysis is useful in system planning, and in the selection of methods and materials in the design and construction phases. However, having the project energy impact analysis tools available at the NYSDOT regional office on a permanent basis was important.

3. Rochester-Genesee Regional Transportation Authority

The basic reaction to the information was that it would be more appropriate if the vehicle purchase impact data were used either to develop a five-year purchase program or to examine the incremental energy effects of different types of vehicles with different options such as air conditioning, engine and fuel types, etc. In other words, vehicle energy impact information would be useful at either the pre-TIP or post-TIP stages in the process. While R-GRTA is currently engaged in a massive vehicle purchase program and thus will not need to make any additional large capital purchases for several years, it is currently developing the data base (to be available in about 2 years) which would greatly facilitate the kind of energy planning described above for the purchases anticipated for the last 1980's. R-GRTA would have preferred to see the null alternative in the energy impact analyses to be the removal of the existing vehicles from service after a certain age, as opposed to their continued use and maintenance, thus forcing present riders to find alternate means of transportation and calculating the energy consequences therefrom. This would be consistent with the method used in analyzing the energy impact of bridge projects i.e., having the eventual closing of the bridge as the null alternative.

Another issue discussed was whether the indirect (manufacture) energy costs of two otherwise similar vehicles considered for purchase would have any bearing on the decision of which to purchase. R-GRTA had no such policy since, due to the pressure to buy American buses, the manufacturers are too similar to use indirect energy cost as a criteria for purchase. More important to the decision are such issues as Minority Business Enterprise (M.B.E.) considerations, and the labor costs (of drivers and mechanics) which would accrue from purchase of a particular vehicle. In addition, R-GRTA is not by policy committed to any type of fuel per se, but places preference on those fuels judged to be most available.

On the transit mall project, energy considerations would be highly important in the selection of a design, both in the choice of material and in the emphasis on the completion of the project in as short a time as possible. This position supports the finding of other project implementors, that energy impact information is very useful in the design of a project and in the selection of construction materials.

4. Monroe County

The project energy impact information presented to the Monroe County Department of Engineering consisted of an individual summary for each project listed in the TIP, showing the direct and indirect energy effects of both the null and proposed alternatives and of the net energy effects. In general, the agency was satisfied with the form of the information, but noted that it was received too late to be of use in the preparation of the current CIP. The Monroe County Engineering Department would be interested in receiving the information on a regular basis, since it would provide additional information for the projects submitted to the County Planning Board for programming in the CIP. An outcome of the meeting, therefore, was the desire that GTC staff work with the Monroe County Engineering Department staff in the future to produce energy analyses of the projects submitted for the CIP. In addition, GTC staff will be able to provide access to the computer facilities to conduct the analyses.

The issue of the use of energy efficient materials in project design was also presented. The Monroe County Engineering Department is aware of these methods and is beginning to make use of them. It was also suggested that as part of the development of the Energy Element of Monroe County's Comprehensive Plan, the County might conduct a comprehensive energy planning study. The reaction was that such a study may be useful, although it was pointed out that locations where energy consumption was high might be highly correlated with locations experiencing high congestion.

5. City of Rochester

Since the City of Rochester programs mainly repaving and reconstruction projects for local roads, the energy information for these projects was viewed by City Engineering staff as relatively useless since they had no bearing on the programming of projects in the CIP. In addition, the City saw no real need for use of such methods in the future.

On the subject of the use of the energy impact information in the system planning phase of project development, the City basically reiterated the position stated by NYSDOT that there was no general need for information not already developed as part of system planning. They did agree, however, that the use of energy efficient materials and methods in design and construction is important.

6. Summary

The major results of the meetings held to discuss the energy impact information generated for projects listed in the TIP and sent to project implementors is summarized in the following points:

a. In general, energy information is more useful for larger scale highway projects, which involve a number of location and design alternatives. In most cases, energy information is currently developed when appropriate.

b. For medium or small scale rehabilitation and preservation, safety and bridge projects, project energy information was generally judged to not normally have any bearing on the decision as to whether to fund a project.

c. For TOPICS or TSM type projects, the use of energy impact information as a basis for decision-making is good in theory, but the reality is that in many cases these projects expand to include such additional components as utility movement or replacement, so that costs could easily expand to exceed the original energy benefits of the project.

d. While energy information in some cases is useful at the TIP stage, it would be more useful in the evaluation of possible future actions at the system level, and in the selection of methods and materials in project design.

e. Decision making for transit projects, as to whether to purchase new vehicles, is based generally on the application of industry age and fleet size standards, with vehicle purchase energy impact information being irrelevant. In addition, the decision as to which vehicle to purchase is limited to a choice between two American manufacturers and is based on such issues as M.B.E. considerations, effect on labor, etc. and is not affected by either the indirect or direct energy costs associated with a particular vehicle. The only area in which energy considerations are useful is in decision making concerning vehicle options.

f. For the pavement and rehabilitation projects programmed in local capital improvements programs, the most badly deteriorated roads are selected for programming, with the energy impact of a particular project not being relevant to decision making.

g. The availability and use of the project energy impact analysis tools used for this project by project implementors was judged to be desirable, but the possible misuses of such information must be recognized and prevented.

h. The desire to compare one type of project with another presents problems in the selection of a universally acceptable and applicable null alternative.

VI. EVALUATION OF DEMONSTRATION PROJECT

A. Evaluation of the Process

A major finding presented in the previous section was that for medium and small scale roadway projects the energy impact data was generally not relevant to the decision to implement them. Three factors generally account for this assessment. The first, of course, is the relationship between project energy benefits and user benefits in general, and between energy costs of construction and construction costs in dollars. User costs generally increase with increased congestion, and with increased operating costs, both of which are postively correlated with energy use. For construction, the methods and materials used have dollar costs which correlate positively with energy costs. Therefore, the energy component of the benefit/cost ratio is generally redundant, i.e., a restatement of the overall benefit/cost ratio. This redundancy could change through a significant increase in the price of energy, such that it becomes a major decision factor in selection of projects for the TIP. At present, however, with stable oil prices, ample supplies, and the continued increase in vehicle fuel economy, this seems unlikely.

The second factor is that limited financial resources are currently provided for transportation projects. This causes project implementors to submit for funding only those projects which provide the most effective solutions to the worst problems. In such cases, energy concerns are not likely to tip the balance. An increase in funding would have the effect, however, of allowing the submission of projects with lower cost-effectiveness. In this case, the separate energy impacts of these projects would provide additional criteria to the decision-makers as to which projects to implement. The same, of course, could be said of any decision criteria not normally generated.

The final factor is the lack of availability of techniques for the analysis of project design methods and materials. Although project energy impact information would be more useful in the design stage than in the project selection stage, energy analysis for use at this stage are just beginning to be developed. Two examples are provided below.

The first deals with the assessment of the use of recycled asphalt pavement in roadway construction or rehabilitation. At present, asphalt milled when rehabilitating pavements can be used for mixing with new asphalt to provide a cheaper alternative to completely new asphalt in roadway construction or reconstruction. Since 1982, NYSDOT has allowed contractors the option of substituting a mix of 60% new and 40% old asphalt for new asphalt. This practice has been used by Rochester and Monroe County for several years. There appears, however, to be little information available as to the energy impact of recycled pavement. Transportation Research Report #780 notes that "reported figures for energy conservation (from FHWA Demonstration Projects) expressed as equivalent gallons of diesel fuel saved for each lane mile of recycled pavement, varied from a low of 390 gallons to a high of 7730 gallons." The same reference also notes that "because the many combinations of equipment and procedures, and the rehabilitative techniques that are available do not provide the same level of performance or length of service before additional measures must be taken, estimates of energy or cost savings for various classes of recycling based on theoretical considerations are so dependent on the assumptions made that they are of questionable value."

A second example is the development of the Management Information System (MIS) by R-GRTA. This system will provide a significant data base on the various costs and benefits associated with the operation of the systems owned by R-GRTA. Such costs include vehicle operation and labor costs, as well as energy costs. Benefits include the monetary or energy savings accrued from using specific vehicles on specific routes. At present the MIS is being developed and will be completed in a few years. These two examples illustrate that the need exists for a great deal of additional research into the energy impact of various methods and materials at the project design and implementation stages of the process, and for the acceptance of these findings by project implementors before regular use is made of this information. The usefulness and acceptability of this information should be the subject of further research.

B. Effectiveness of Materials Prepared

Two general conclusions have been reached concerning the effectiveness of the materials prepared. The first deals with the "newness" of the project energy impact information presented. Because many of the users of this information were unaccustomed to its possible use in decision making, it was generally ignored. Although no specific evidence exists to support this opinion, it is felt that if the project energy impact was supplied on a regular basis or there was a sufficient period of time to allow decision makers to become familiar with all its aspects, then the information would have been put to greater use. An analogous situation existed with the use of the goals achievement rating lists, a rating system used to identify the conformance of a project to the adopted GTC goals and policies. While there was some resistance to the gathering and use of this information during its initial use, it has reached a point where it is expected by many members of the GTC committees responsible for selection of projects for the TIP. Were the energy impact information of the type generated by this project made available when appropriate, at a cost of approximately $10,000-15,000 per year, it might be expected as a regular part of the process.

The second conclusion, is that many projects contain non-transportation components, which were not included in the calculation of either the energy-related construction costs or user energy benefits. For example, it was pointed out that many TOPICS projects expand after initial programming in the TIP to include utility improvements. A possible change, therefore, which might have made the energy impact analyses of these projects more useful would have been to include the energy costs and benefits of the non-transportation related components of the project.

C. Effectiveness of the Delivery Mechanism

A third viewpoint in the evaluation of this report deals with how the energy impact information, once prepared, was delivered to the project implementors. Two issues have been identified which affected the results of the project, as presented in Section V. The first issue was raised as a result of the meeting described in Section V, with the Monroe County Engineering

Department. One result of that meeting was a commitment from both GTC and Monroe County Engineering staffs to work together in the future to produce energy analyses of projects proposed for the TIP in a timely manner. The result of the meeting led to the conclusion that better coordination with the individual processes of the implementing agencies in the preparation of their capital programs might have made the energy impact information more useful. Since the current project involved the analysis of the projects as they were submitted and programmed in the TIP, the situation was such that some of the projects listed in the TIP for informational purposes had already been programmed in other capital programs. The analysis of these projects, therefore, provided little information that was presently useful. An area for future investigation might be the usefulness of working within the context of transportation capital programs other than the TIP, to assess the usefulness of the data within different insitutional settings.

A final issue deals with the subject previously raised, that the project information might have been more useful if presented at different stages in the project development process. Two possible points in the process which were identifed in this report are the policy planning stage, and the project design and implementation stage. A possible research project would therefore involve the development of new methods or the application of existing methods to energy impact analysis at these two, or possibly other stages in the process.

D. Observations

In general, it appears that the participants in the GTC TIP process did not have any problems with the materials prepared or the means by which they were presented, per se. However, use of the materials just served to highlight the fact that the energy impacts of proposed transportation projects were small and the importance placed on these impacts in this study overemphasized them in relation to other impacts. Once this type of energy impact information is incorporated on a regular basis into the TIP process and is presented along with other impact data, it may be more useful.

The study did indicate that energy impact information would be useful and well received in two other places in the project development process. The first is early on in the systems planning phase. The second is in the design phase where information could be presented on the energy impacts of the various design alternatives.

CHAPTER VII. TRANSFERABILITY OF FINDINGS TO OTHER CITIES

The purpose of this chapter is to specify how the findings of this study can be transferred to other cities, communities, or project analysis situations. The goal of this assessment is to help other transportation analysts, local officials, and the federal government in determining the extent to which energy savings associated with transportation improvement programs may reduce energy consumption in their communities.

By transferability we mean the extent to which specific and general findings from this study can be used by others. We define three general levels of transferability as follows:

1. Direct transferability - results can be incorporated directly in the activities of other cities, with no modifications.

2. Transferability with new inputs or selected modifications - methodologies may be transferable but calculations would have to be redone using the specifics of other sites.

3. Not transferable - findings are so unique to the Rochester Metropolitan situation or to the State of New York that transferability beyond the immediate context is not appropriate.

With respect to each level of transferability, the methodological, technical, and institutional findings of the demonstration are now reviewed.

A. Methodology

As described in the Appendices and in the main text, methods used for the analysis of energy savings were based upon review of the literature, and in several cases the development of new but straightforward methods for handling particular problems. The generality of these methods is quite large, and the researchers find no reason not to recommend that transportation analysts in other communities consider the methodologies themselves to be directly transferable. Not directly transferable, of course, are the specifics of calculations for particular projects in other communities. Calculations of the energy savings of pavement rehabilitations, bridges, TSM and safety actions would need to be redone with numbers specific to the particular sites. However, recognizing that need, we still are inclined to suggest that the overall conclusion of such work is likely to be similar to ours: that is, in general, pavement-related projects are likely to be shown to use more energy than saved, and bridge-related projects to save more energy than used.

B. Findings Concerning Energy Savings

The project mix in the Rochester TIP clearly substantially influences the bottom-line with respect to energy savings. In fact, the positive results of the demonstration (that 3.8 million gallons would be saved by the projects in the Rochester TIP) stems largely from the preponderance of the bridge-related projects in the proposal. These projects generally have energy savings which are large enough in total to offset the energy losses attributable to one major construction project and to the pavement rehabilitation projects. In metropolitan areas which do not have a preponderance of bridge projects in their TIP's, therefore, conclusions about the energy savings of a TIP would have to be moderated substantially. We obviously, therefore, recommend that the specific mix of projects for other metropolitan areas be applied in partitioned fashion, so that the energy savings associated with each group of projects can be separately calculated.

However, we are more confident about the specific results for project types. The projects in our pavement group are on balance (we believe) generally representative of the kinds of projects likely to be under-taken in many metropolitan areas. We, therefore, find no prior reason to believe that the general findings concerning the energy savings of pavement projects would not be replicated in other places. Rather than transfer these results directly, however, we recommend that the calculations be redone for pavement projects in other places, or (short of that) that calculations be completed for representative projects and then generalized to a broader set.

As Appendix B shows, a particularly critical assumption in the analysis of pavements concerns the relationship between pavement condition and fuel savings. Our review of the literature was inconclusive and we assumed a 1.5 percent slope. However, a sensitivity analysis shows that the slope would have to be as great as 15 percent in order for energy savings as a result of condition improvement to be large enough to offset the energy loss due to changes in speed. Some of the literature is beyond 15 percent (Claffey shows 30 percent), but others recommend numbers below this 15 percent. On balance we are inclined to recommend a smaller number, but we think that individual cities ought to understand the sensitivity of that recommendation to the specific results.

An additional important finding is our conclusion that the savings due to improvements in pavement smoothness are more than offset by the increases in energy consumption due to increased speed. This is particularly true for rural sections. The standard conventional wisdom that repairing potholes may save energy does not appear to be borne out by our analysis. We are not suggesting, however, that potholes not be repaired but rather that their benefits be more carefully quantified in terms of vehicle repair savings and savings in travel time, which are likely to be the larger payoffs.

The same is true for the bridge group. While we anticipate that specific findings concerning project rehabilitation for bridges are likely to be similar for other places, we suggest that the calculations be redone. The primary reason for this is that the energy savings associated with bridge rehabilitation come largely from the savings in detour distance. The distance vehicles would have to go to detour depends, of course, upon local topography and the extensiveness of the existing transportation system: both factors, of course, are not generalizable from the Rochester area. The topography of the Rochester area is largely flat, but the region is cut by a number of quite deep ravines necessitating a considerable number of bridges. The network is reasonably dense and is typical of northeastern cities. We are unable to determine the degree to which such factors are generalizable to other regions of the country, and therefore, we caution generalization of the results.

However, it may be safe to assume that metropolitan areas which are less constrained geographically and have more extensive networks would likely show less energy savings for the bridges as a group, and those situated in hillier environments or with a sparser network would show greater energy savings per bridge project on the average. With this in mind we show in Appendix A, Exhibit A.7 the average detour distances for each of the bridge rehabilitation projects studied in the Rochester situation.

Our conclusions are less tentative with respect to TSM projects. We believe that projects of similar magnitude and size in most metropolitan areas, with respect to traffic, length, and duration would yield similar results in energy savings.

C. Monitoring and Long-Range Analysis

Our conclusion concerning the transferability of monitoring results is straightforward. Our monitoring effort consists largely of a compilation of existing statistics from agencies who are responsible for such information. Obviously, institutional arrangements in each place vary, and the compilation of such statistics in other places would depend on the availability of that information. We see no reason to think that methodology necessary to put together monitoring of data cannot be transfered to other places.

Our conclusions with respect to the findings on long-range energy consumption are to some extent generalizable, but we hestitate to do so in blanket fashion. Vehicle fleet turnover is rapidly occurring in most metropolitan areas of the country, and it is likely that similar calculations for those metropolitan areas will show that they also are likely to yield between 25-35 percent reduction in energy consumption between 1980 and the year 2000, based solely on turnover alone. Obviously those regions in which vehicle turnover is proceeding more slowly, or which have a high proportion of light trucks as opposed to cars (light trucks are not subject to the same improvements in fleet efficiency as are cars) will be proceeding at a slower pace. NYSDOT is presently working with the Urban Mass Transportation Administration to develop guidelines for fleet turnover assumptions, and simple procedures to estimate average energy efficiency in metropolitan regions based on market share of vehicles of different types. Interested readers are urged to contact the authors of this report.

Obviously the findings concerning the magnitude of population growth are site-specific, but the methodology that would be applied to the problem is straightforward. Most metropolitan areas have an existing assignment process in place and computerized networks which can be used to assess energy consumption under assumptions of growth/no growth scenarios. These calculations are straight forward and the methodology is available and has already been transferred.

We believe that our general findings concerning the relative effects of vehicle turnover, growth in regional travel, and the effects of improved energy efficiency from the TIP or the long-range plan are likely to be true in most metropolitan areas. That is, <u>while we expect that in most areas vehicle efficiency will account for a significant drop in energy use, between one-third and one-half of this drop will be offset by growth in VMT and an additional very small drop will be attributable to network improvements</u>. Most metropolitan regions have only a few large-scale projects currently on-going or likely to be constructed in the next 20 years which would effect travel over the highway network. Most of the infrastructure of metropolitan regions is already in place and is not likely to be revised substantially in this time frame. Since it is a very rare facility indeed which serves more than one percent of the traffic in a metropolitan region, it is not likely that any combination of new or existing facilities in TIP's or long-range plans would serve enough traffic to generate more than one or 1.5 percent energy savings for the total region.

D. Institutional Findings

The procedures we have used to develop institutional relationships and to work with local governments to incorporate energy findings are generally transferable. All metropolitan areas have a 3-C planning process, all have a metropolitan planning organization, composed of elected officials and supported by technical agencies. Most metropolitan areas have a transit system, a county and city planning or engineering department responsible for road repair, and of course, all have a state highway agency. Obviously the specifics of the responsibilities of these various entities will vary in each place, and clearly those responsibilities are not transferable from Rochester. However, the general process of selecting and evaluating projects is universal, and most agencies are likely to go through a similar kind of review. We, therefore, feel confident that the general conclusions concerning the applicability of findings on institutional processes will hold in other places. Specifically we believe that <u>findings concerning the most appropriate use of energy data (in systems planning and in project design, rather than in project development and selection) will hold in other places</u>. We believe also that our conclusions concerning the relevance of energy numbers to a broader decision structure are likely to be true in other places.

On balance, we believe strongly that the methodologies used in this report are generalizable, and are prepared to work with other groups to provide them in usable format. We recommend recalculation of existing energy estimates where possible. We place greater faith on the results concerning pavement rehabilitation, recognizing that the critical assumption about fuel use and pavement condition must be made. We suggest more caution in the use of our findings concerning bridges. We are confident about recommending the procedures we used in institutional arrangements and we believe that the findings will be similar. In general, therefore, we see no reason not to recommend transferability of these results to other places and the use of methodologies and ideas in other places, constrained by obvious factors which make other cities unique or different from Rochester.

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APPENDIX A: ENERGY ANALYSIS METHODS

Methods to evaluate the energy impacts of transportation projects are focused on general transportation actions and the interaction between those actions, rather than on specific procedures for evaluating projects.

Much has been written in regard to quick response methods for evaluating the energy impacts of Transportation System Management (TSM) actions. Many of the TSM energy impact assessments are aimed at estimating the potential area wide or system impact of a group of different actions. However, less attention has been directed at assessing the energy implications at the project level. The difficulty is that a transportation project often represents a group of actions that function together to provide a solution. Proposed solutions for similar types of projects may vary in terms of actions selected to meet comparable but different sets of circumstances.

In general, we have found that the major references in the literature are in themselves synthesis documents containing methods for applying energy cost or unit factors, or methods for evaluating the energy associated with individual transportation actions. From the standpoint of evaluating the energy associated with a certain type of project, it is necessary to describe the project in terms of its action-related components or the change in those components in order to apply the various energy evaluation methods.

Basically, all projects contain the following components for which an energy evaluation may be necessary.

1. VEHICLE or USER RELATED ENERGY IMPACTS

- ° TRAFFIC - The energy associated with factors related to the vehicle (i.e., changes in flow operation, speed, detours, capacity improvements to the roadway, etc.) that change the way in which the vehicle is driven on or in proximity to the project location.

° PAVEMENT - The energy associated with vehicle operation resulting from improvements to the pavement wearing surface and/or the speed changes resulting from such surface changes.

2. CONSTRUCTION

° HIGHWAY - The energy associated with those construction activities related to the rehabilitation of the roadway.

° STRUCTURE - The energy associated with those construction activities related to the rehabilitation of structural components (bridges, culverts, etc.)

The following sections will deal more specifically with methods for each of these components and project type evaluations.

Vehicle or User Energy

Changes in travel patterns and vehicle energy may vary from project to project or action to action. However, the method for assessing changes in vehicle energy varies only slightly. In general, vehicle energy consumption is evaluated by the following dimensional relationship.

$$\text{ENERGY} = \text{AADT} \times \text{PROJ LENGTH} \times \text{DPY} \times \sum_{i} \text{Vehicle Type } i \times \text{GPM } i$$

Where

AADT = Annual Average Daily Traffic

VEHICLE TYPE i = Share of Auto, Light Trucks, Heavy Trucks (i = 1,2,3)

GPM i = Gallons per mile for each vehicle type

Adjusted for

1. Model year efficiency improvements (Auto)
2. Vehicle Type
3. Speed & Flow Condition (free flow or stop-n-go)
4. Grade

PROJ LENGTH = Length of the project in miles

DPY = Days per year (330 or 365)

Changes in vehicle energy can easily be obtained by evaluating this relationship for differences in the existing condition and the proposed alternative(s). For certain project types, as described later, this evaluation has been simplified through the use of worksheets, table lookup procedures, and/or computer programs.

Construction Energy

Roadway, structural and other construction related components are converted into energy estimates of gallons of equivalent gasoline by:

a. Adjusting the component cost estimate to 1980 dollars using the GNP inplicit price deflator.
b. Multiplying the 1980 cost estimate by the appropriate BTU/dollar construction action conversion factor as shown in Tables A.1 through A.4(from References #1, 2, 3, 5, 19).
c. Dividing the BTU's obtained in (b) by 125,000 to convert the energy into equivalent gallons of gasoline.
d. Dividing the component energy consumption by the corresponding service life to obtain annual energy estimates.

Both the construction and vehicle energy computations can be done manually, or for some evaluations with the aid of a computerized version of the project energy analysis procedures described in detail in the appendices to the text of "Energy and Transportation Systems" (Ref 1, 22), the "Caltrans Manual". This computer program is available in Fortran as Energy 3 (from CALTRANS) or OPGAS/CAL (available at NYSDOT). Basic machine code was also provided by CALTRANS and converted by NYSDOT to run on an APPLE II+. This program is called PROLEV. These programs perform an energy analysis of structural, roadway and other construction components, as well as, an assessment of the energy impact of the vehicles using the facility. A sample program output for PROLEV is shown as Exhibit A.1. Additional program documentation is available from Reference No. 28.

TABLE A.1

Energy/Dollar For Roadway Construction (1980 $)

	BTU/$
Freeway Construction	
New Construction - Rural	3.77×10^4
- Urban	3.02×10^4
Widen - Rural	2.35×10^4
- Urban	1.34×10^4
Arterial Roadway Construction	
New Construction - Rural	3.59×10^4
- Urban	2.88×10^4
Widen - Rural	2.53×10^4
- Urban	1.26×10^4
Structure Construction	
Reinforced Conceret Box Girder Bridges	2.42×10^4
Concrete Deck Steel Grider Bridges	2.62×10^4
Landscaping	0.67×10^4
Signals, Illumination, Misc.	6.34×10^3
Roadway (Highway) New Construction	2.97×10^4

Source: Reference 1, 19

TABLE A.2

Energy For Roadway Construction (1980 $)

NYS Category	BTU/$ x 10^4
New Construction	3.31
Reconstruction	2.58
Restoriation & Preservation	1.90
All Categories	2.64

Source: Reference 19, 22

TABLE A.3

REPRESENTATIVE ENERGY REQUIREMENTS FOR MAINTENANCE AND REHABILITATION ACTIVITIES (1980$)

Maintenance Activity	Energy Requirements BTU/$ x 10^3	Percent of total Pavement Area Treated
Fog Seal - Partial Width	7.7	50 percent
Fog Seal - Full Width	10.7	100 percent
Chip Seal - Partial Width	13.2	15 percent
Chip Seal - Full Width	12.6	100 percent
Surface Patch - Hand Method	13.2	2.5 percent 1 in. thick
Surfact Patch - Machine Method	24.8	10 percent 1 in. thick
Digout & Repair - Hand Method	9.4	2 percent 4 in. thick
Digout & Repair - Machine Method	29.7	5 percent 6 in. thick
Crack Pouring	6.6	250 Lin. Ft Per Station
Asphalt Concrete Overlay	19.4	100 percent 2 in. thick

Source: Reference 2, 19

TABLE A.4

Energy Requirements for Various Highway Maintenance Activities in Arkansas (1980 $)[1]

Rank		BTU/$ x 10^3
1.	Premix Leveling	20.8516
2.	Mowing	11.9163
3.	Restoring Gravel Surface	43.3081
4.	Premix Patching	8.9848
5.	Spot Surface Replacement (bituminous)	20.6370
6.	Blading Nonpaved Surface	18.9618
7.	Seal Cost	29.1327
8.	Restoring Gravel Shoulder	48.6170
9.	Fog Coat	55.4974
10.	Cleaning and Repairing Minor Drains	8.6025
11.	Mudjack and Underseal	74.9265
12.	Gravel Surface Patching	15.1479
13.	Blading Nonpaved Shoulders	15.8785
14.	Machine Ditches	17.4890
15.	Surface Treatment Patching	14.9809
16.	Joint Repair and Crack Filling	10.8445
17.	Spot Surface Replacement (concrete)	21.0424
18.	Litter Pickup	68.8503
19.	Paint Striping and Edge Marking	0.0805
20.	Painting Pavement	0.5317

Source: Reference 3, 19

1. Adjusted to 1980 dollars using FHWA cost trends for Highway Maintenance and Operation.

```
NEW YORK STATE DEPARTMENT OF TRANSPORTATION
VERSION OF ENERGY 3 CALLED OFGAS/CAL

RUN DATE IS DECEMBER 1982
```

Exhibit A.1

PROLEV Sample Output

```
TEST EXAMPLE


INPUT DATA :

 1 STUDY PERIOD ................................ : 1982-1984
 2 TYPE OF TRAFFIC FLOW ........................ : FREE FLOW
 3 SPEED OF TRAFFIC (MPH) ...................... : 55
 4 LENGTH OF ROADWAY (MILES) ................... : 1.2
 5 NUMBER OF VARIED GRADES ..................... : 1
 6 ONE-WAY CAR TRAFFIC (VEH./DAY) .............. : 10800
 7 ONE-WAY 2-AXLE TRUCK TRAFFIC (VEH./DAY) ..... : 960
 8 ONE-WAY SEMI TRUCK TRAFFIC (VEH./DAY) ....... : 240
 IDENTICAL TRAFFIC IN OPPOSITE DIRECTION
 9 TPYE OF PROJECT ............................. : WIDEN URBAN
10 COST OF ROADWAY ($) ......................... : 540000
11 COST OF STRUCTURES ($) ...................... : 180000
12 COST OF LANDSCAPING ($) ..................... : 10000
13 COST IF MISC., SIGNALS, LIGHTING ($) ........ : 5000
14 TOTAL COST OF PROJECT ($) ................... : 735000
15 TOTAL LANE MILES (INCL. EXISTING) ........... : 4.8
16 PAVEMENT TYPE ............................... : AC


 OUTPUT DATA  :    $ YR =  82 GNP FACTOR= .564574209

 ENERGY CONSUMED DURING THE ENTIRE STUDY PERIOD(TWO-WAY TRAFFIC)

 ENERGY VALUES ARE IN TRILLIONS OF BTU'S (TBTU)
            1 TBTU = 1 E + 12 BTU

 1 DIRECT ENERGY CONSUMED BY CARS (TBTU) ....... : .1622
 2 INDIRECT ENERGY CONSUMED BY CARS (TBTU) ..... : .105

 3 DIRECT ENERGY CONSUMED BY ALL TRUCKS (TBTU) . : .05082
 4 INDIRECT ENERGY CONSUMED BY ALL TRUCKS (TBTU) : .03109

 5 ENERGY CONSUMED BY CONSTRUCTION
 5.1    ROADWAY ENERGY           (TBTU) ........... : 7.50000001E-04
 5.2    STRUCTURE ENERGY         (TBTU) ........... : 3.912E-04
 5.3    LANDSCAPE ENERGY         (TBTU)............ : 1.7445E-05
 5.4    SIGN,LIGHT,MISC. ENERGY  (TBTU) ........... : 8.214E-06
TOTAL PROJECT CONSTRUCTION ENERGY
   (PRORATED OVER PROJECT LIFE) (TBTU) ........... : 1.167E-03

 6 ENERGY CONSUMED BY MAINTENANCE (TBTU) ....... : 1.93E-03

 7 TOTAL ENERGY CONSUMED DURING
   ENTIRE STUDY PERIOD (TBTU) .................. : .3522

 8 THIS IS EQUIVALENT TO  55.5  BARRELS OF CRUDE PER DAY


              ** END OF PROGRAM **
```

Energy Evaluation by Project Type

Pavement Projects

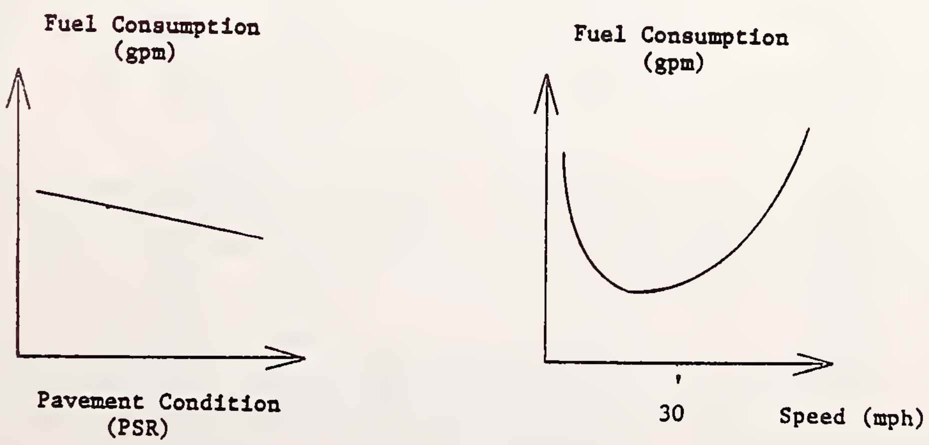
For pavement projects vehicle energy computations are similar to those noted above for changes in operational flow. However, improvements to a pavements structural condition may affect automotive fuel consumption in two additional ways:

(1) directly, through improved smoothness which reduces variations in vehicle operation (i.e. slow downs, etc.) due to pavement decay, and
(2) indirectly, through a change in vehicle speed.

Both changes are small; the direct change is consistent over the whole range of pavement condition, i.e., as condition improves fuel consumption drops; the indirect change has a saddle point between 25 and 35 mph (depending on vehicle mix) with consumption increasing with improving pavement condition for speeds higher than the saddle point and decreasing with improving condition for speeds below the saddle point.

This peculiarity is due to the shape of the fuel consumption versus speed curve shown below:

FIGURE A.1 Condition and Speed Effects on Fuel Consumption



For speeds at the low range an increase in speed actually results in a decrease in fuel consumption, while for speeds in the upper range, further increases result in an increase in fuel consumption. Within limits, improved road conditions result in higher travel speed. Hence, the peculiarity that at low running speeds an improvement in road condition results in a decrease in fuel consumption due to speed changes, while at higher speeds fuel consumption will increase. Clearly, at higher speeds the direct impact (resulting in savings) and the indirect impact (resulting in increased fuel consumption) work against each other, while at lower speeds they reinforce each other.

Existing literature is not uniform on the magnitude of the impact of road conditions on fuel consumption. Values reported range from a 30% increase for a very rough potholed road compared to smooth pavement (Claffey, Ref. 15), to no change (Zaniewski, Ref. 16). We believe that the latter finding is due to problems with the design of the experiment, and accept at this time a value of a 1.5% increase for a road rated at a Pavement Serviceability Rating (PSR) of 4.5 over a road rated at a PSR of 1.5. Table A.5 contains the results of a sensitivity analysis undertaken to see the effect of alternate values for change in fuel consumption with respect to pavement condition (Ref. 24).

To evaluate pavement projects for the effects of pavement surface and speed changes, the specific surface and speed change equations identified by Zaniewski (Ref. 16) were developed into an algorithm for use on the Apple II+ micro computer (Ref. 25). The computer program is called PROLEV.HICOND. This program utilizes the same data base as that for the OPGAS/CAL and PROLEV programs. A sample program output is shown as Exhibit A.2. Additional program documentation is available from Reference No. 28.

Construction components of pavement projects are evaluated as described above by selecting the appropriate BTU/$ factor for each of the pavement actions undertaken.

Table A.5

Average Pavement Project Fuel Consumption Under Different Assumptions for the Pavement Condition Fuel Consumption Relationships

Energy Consumption (1000's gallons)[2]

Δ[1]	# PROJECTS	PAVEMENT SPEED	+	PAVEMENT SURFACE	=	TOTAL PAVEMENT EFFECT	+	CONSTRUCTION ENERGY	=	NET PROJECT ENERGY
1.0%	20	3.6		- 1.0		2.7		17.6		20.3
1.5%	20	3.6		- 1.4		2.2		17.6		19.8
5.0%	20	3.6		- 4.8		- 1.1		17.6		16.5
15.0	20	3.6		-14.3		-10.7		17.6		6.9

[1]Change in fuel consumption in GPM for improvements in pavement condition to PSR = 4.5 (0-5 scale)

[2]Equivalent Gallons of Gasoline.

Exibit A.2

PROLEV.HICOND Sample Output

```
HIGHWAY CONDITION AND PERFORMANCE MODEL

ENERGY CONSUMPTION DUE TO CHANGES IN PAVEMENT CONDITION AND VEHICLE PERFORMANCE


DATE  : SEPTEMBER 1982


TITLE : TEST EXAMPLE

CALCULATION RESULTS
CURRENT SPEED = 30
AFTER   SPEED = 30.3692611
OLD PSR = 2.5
NEW PSR = 4.5
SEGMENT LENGTH = 1
AADT = 1000
CHANGE IN GPM FOR SMOOTH SURFACE = 1.5%
% LT TRUCKS =  8
% HD TRUCKS =  2
DAYS PER YEAR =  330
AADT YR OR PROJECT YR =  1982

DELTA FUEL CONSUMPTION
 NEGATIVE VALUE = DECREASE
 POSITIVE VALUE = INCREASE

DELTA CONSUMPTION = -186.771647  GALLONS PER YEAR


PERCENT CHANGE OVER BASE  = -.919249704


DELTA DUE TO SPEED = 16.5724765  GALLONS PER YEAR


DELTA DUE TO SURFACE = -203.344085  GALLONS PER YEAR
```

Bridge Projects

For bridge projects vehicle energy computations are similar to those already noted above. However, because the possibility exists that the bridge might have to be closed if unattended in its present condition, a more specific analysis is structured to assess the vehicle energy impact of total or modified bridge closings in the following manner:

1. AADT is separated into the three major vehicle component (cars, light trucks and heavy trucks). If vehicle mix was not known or indicated in the project data then a percentage mix of 90/8/2 was assumed respectively for the vehicle types. This mix was based on results of NYSDOT traffic counts.

2. The energy impact of a total or partial vehicle detour due to bridge closing or posting is calculated for each vehicle type as the product of the AADT X GPM x Miles x Days/yr. with respect to travel speed, flow condition and model year efficiency improvements.

3. Geometric limitations on the bridge or its approaches often cause speed changes from the travel speed to the speed necessary to traverse the bridge, or if there is a detour then the route itself may have a different speed. These effects are evaluated by determining the speed change increment and the corresponding change in fuel consumption times the AADT for the vehicle types affected.

The above analysis is a fairly straight forward manual technique that will vary from project to project depending upon the various actions necessary to be undertaken. To assist in evaluating bridge vehicle energy, a worksheet table lookup approach was prepared based upon the steps described above. A selection chart and sample worksheet are included as Exhibits A.3 and A.4. Additional documentation for this approach is available in Ref #27.

Construction components of bridge projects are also evaluated for the pavement and bridge portion as described above by selecting the appropriate BTU/$ factor for each of the actions undertaken.

Exhibit A.3

Typical Bridge Problem Situation

Case	Description*	Candidate Work Sheet(s) for Selection	Notes
1	Total or Partial Vehicle Detour No speed changes	A or C	Use net mileage for distance (Net = Detour - Before)
2	Total or Partial Vehicle Detour With speed changes	B, A or C	Use net mileage
3	Speed Change on Bridge Approach speeds the same	B	
4	Different Approach Speeds	A or C	
5	Different Approach Speeds With speed change	B, A or C	
6	Posting or Weight Limits	A or A,B,C	See Case 1, 2 and adjust accordingly for affected vehicles

* May apply for the institution or removal of the problem situation. In either case some type of delta analysis is required between the before (or null) situation and the "after" situation.

Exhibit A.4

Bridge Traffic Energy Worksheets

WORKSHEET A:

Free flow [ ]
Stop-n-go [ ]

	AADT						Flow/ Speed GPM Table 2		TABLE 3 GPM ADJ		Dist. (Mi.)		Gals.
	[ ]	x	% Cars [ ]	=	Cars [ ]	x	[ ]	x	[ ]	x	[ ]	= (1)	[ ]
Before Speed 1 [ ]		x	% LT TRK [ ]	=	LT TRK [ ]	x	[ ]			x	[ ]	= (2)	[ ]
		x	% HD TRK [ ]	=	HD TRK [ ]	x	[ ]			x	[ ]	= (3)	[ ]

WORKSHEET B:

Include for Speed Change

		Speed Δ			TABLE 4 Speed Δ		
	Cars	[ ]	Cars [ ]	x	[ ]	= (4)	[ ]
Speed 1 [ ]	LT TRK	[ ]	LT TRK [ ]	x	[ ]	= (5)	[ ]
Speed 2 [ ]	HD TRK	[ ]	HD TRK [ ]	x	[ ]	= (6)	[ ]

WORKSHEET C:

			TABLE 2		TABLE 3		Dist.		
	Cars [ ]	x	[ ]	x	[ ]	x	[ ]	= (7)	[ ]
After Speed 2 [ ]	LT TRK [ ]	x	[ ]			x	[ ]	= (8)	[ ]
	HD TRK [ ]	x	[ ]			x	[ ]	= (9)	[ ]

				Days/Yr.		Total Gal.
(1)+(4)+(7)	=	[ ]	x	330	=	[ ]
(2)+(5)+(8)	=	[ ]	x	330	=	[ ]
(3)+(6)+(9)	=	[ ]	x	330	=	[ ]
						[ ]

TSM Safety & Other Projects

The construction and user energy impacts of TSM, safety and other related projects are computed using various methods depending upon the actions undertaken. Since most of the TSM type projects analyzed dealt with traffic flow conditions and reduction of delay, the vehicle energy computations noted above were applicable. Worksheets (from Ref. 18) for intersection and traffic flow conditions are included at Exhibits A.5 and A.6, which simplify the vehicle energy computations previously discussed. Although TSM/Safety projects are generally focused upon actions to improve operational flow, they may also require construction improvements to pavements or structures. In these cases, the procedures previously described are applicable. However, in the case of certain types of actions, specific construction energy assessments may be required. Table A.6 (Ref. 19) provides the necessary construction action energy assessment procedures for TOPICS type projects. As noted earlier, TSM type actions have received considerable attention in terms of their energy impacts than other project types, and numerous evaluation methods and synthesis reports abound (Ref. 14, 18, 19, 20, 21).

Transit Vehicles

Transit vehicle acquisition projects result from the scheduled replacement cycle for these vehicles. The potential savings if any result from improvements in vehicular efficiency. The energy consumption of both the replacement vehicles and the existing vehicles presently in service may each be computed using the following relationship:

$$\text{Energy} = \#\text{ vehicles} \times \text{annual mileage} / \text{MPG}$$

Differences in vehicle efficiency (MPG) and annual mileage may work together or against each other to provide fuel savings or increases for a given vehicle replacement.

TSM
ENERGY ANALYSIS
WORKSHEET

Exhibit A.5

TRAFFIC OPERATIONS: INTERSECTION ANALYSIS

A. BASE DATA

	APPROACH VOLUME		% STOPPING		TOTAL STOPPING		AVG. DELAY (SEC)				TOTAL DELAY (HR)
A		X		=		X		÷	3600	=	
T		X		=		X		÷	3600	=	

	APPROACH SPEED (MPH)		
A		T	

B. FUEL CONSUMPTION

	TOTAL DELAY		FCR		FUEL ECONOMY ADJ (TABLE 1.2)		FUEL CONSUMPTION (GAL)
A		X	.58	X		=	
T		X	.61			=	

	TOTAL STOPPING		FCR (TABLE 1.4)				
A		X		X		=	
T		X				=	

SUBTOTAL [ ] DAILY FUEL CONSUMPTION

A = AUTO
T = TRUCK
FCR = FUEL CONSUMPTION RATE (GALLONS PER VEHICLE HOUR)

X [250] WORKDAYS PER YEAR

TOTAL [ ] ANNUAL FUEL CONSUMPTION

98

TSM
ENERGY ANALYSIS
WORKSHEET

Exhibit A.6

TRAFFIC OPERATIONS: UNINTERRUPTED FLOW

A. BASE DATA

	DEMAND VOL.		SEGMENT LENGTH (MI)		DAILY VMT	SPEED (MPH)
AUTO		X		=		
TRUCK		X		=		

B. FUEL CONSUMPTION

	VMT		FCR (GPM) (TABLE 1.1)		FUEL ECONOMY ADJ (TABLE 1.2)		FUEL CONSUMPTION (GAL)
AUTO		X		X		=	
TRUCK		X		X		=	

SUBTOTAL		DAILY FUEL CONSUMPTION
X	250	WORKDAYS PER YEAR
TOTAL		ANNUAL FUEL CONSUMPTION

Table A.6

Direct and Indirect Energy Costs
for Topics Projects

Table 1.1	A Direct Energy Costs			B Indirect Energy Costs						A & B Total Energy Cost
Project Type	Propulsion Energy	Service Life In Years	Annual Energy Cost in Equivalent Gallons of Gasoline	Construction, Operation and Maintenance Energy	Service Life In Years	Annual Energy Cost in Equivalent Gallons of Gasoline	Manufacturing and Installation Energy	Service Life in Years	Annual Energy Cost in Equivalent Gallons of Gasoline	Total Annual Energy Cost in Equivalent Gallons of Gasoline
Topics[1]	None		None	[2] a) Construction-Widen Urban Arterial	15	6.75 gal/$1000	a) Equipment Manufacture and Installation (lights)	15	5.10 gal/$1000	6.75 gal/ $1000 (for arterial widen) + 390 gal/inter. (for traffic signal operation and maintenance + 5.10 gal/$1000 (for lights)
				b) Operational Cost-Power Consumption (traffic signal operation)	1	388 gal/intersect				
				c) Signal Maintenance - (bulb replacement, equipment cleaning & adjustment)	1	2 gal/intersect.				

1. The projects that were analyzed were those principally involving signalization improvements.

2. In general, the construction and installation components of the TOPICS projects that were examined average 70/30 percent respectively of the total implementation cost.

Other Actions

So far we have discussed methods for evaluating the energy in the various components and actions associated with typical projects. Another area for which attention should be focused is in the area of pavement material substitution such as in sulphur extended and recycled asphalt. Frequently, energy savings can be achieved by the use of recycled materials or modified construction techniques. Our review of the literature to evaluate these options, (Ref. 29) in conjunction with the projects included on the 1983-88 GTC TIP, indicate that where and when available, alternative materials are being tried.

Sulphur extended asphalt pavements presently are not used in New York State and are currently being tested by FHWA as part of a demonstration program. Preliminary results indicate that it is very likely that the performance of the sulphur extended asphalt will be comparable to that of regular asphalt. There is insufficient information and experience at the present time to quantify any potential energy savings to be obtained by its use.

Recycled asphalt pavement is presently permitted for use under certain circumstances in New York projects, while it is generally utilized by both the city of Rochester and the County of Monroe on their projects as a paving material option. However, the haul distance between job site and the location of recycled material vs. new material appears to be the crucial element for both the economics and energy involved in the recycling of pavement.

In general, there appears to be a concensus in the literature that the use of recycled materials offer both cost and energy savings; the magnitude of those savings are project specific. The decision to use such materials, however, usually occurs in the project design stage which is further along in the project implementation process than the planning/TIP stage at which we are conducting our energy assessments. Therefore, while we may conclude that recycled pavement may offer both potential cost and energy savings, it is not possible for us to identify its use in the projects that we are analyzing, nor estimate the cost or energy impact on the paving component of those projects.

NET BRIDGE DETOUR MILEAGE

PIN #		DESCRIPTION	NET DETOUR MILEAGE
4088.0002	MON	CAN OF WORMS	--
	MON	SCIO-UNIV. FLYOVR	--
4750.80	GEN	WALNUT ST.	--
4084.0701	ONT	RT. 21	0.75
3037.23	WYN	RT. 31	0.2
4084.07	ONT	RT. 21	1.0
			0.4
			0.6
4044.02	ORL	RT. 387	10.56
6042.0801	YTE	SR 364 PT.1	2.0
4025.03	MON	RT. 260	5.0
4750.81	ONT	SALTONSTALL ST.	2.0
4118.05	GEN	RT. 237	2.3
4750.76	MON	DRIVING PARK AVE.	2.5
6042.0701	YTE	SR 364 PT. 3	1.9
4750.78	MON	LONG POND RD. III	3.8
	MON	ELMWOOD AVE.	2.7
	MON	THORNELL RD.	1.9
	MON	PARMA CENTER RD.	1.9
	MON	N. GREECE RD.	1.0
	MON	DEAN RD.	2.3
	MON	W. RUSH RD.	2.7
	MON	FLINT MILL RD.	2.7
4750.85	COR	LAKE AVE.	0.74
4047.08	MON	E. MAIN ST. 96 & 253	0.53
4750.84	LIV	CHEESE FACTORY	6.5
4750.86	COR	E. MAIN ST.	0.5
			0.74
4353.00	MON	RT. 259	--
4008.10	MON	RT. 15 HONEOYE	1.75
4008.11	MON	RT. 15 OVER TWAY	1.85
4012.11	GEN	RT. 63 CONRAIL	1.14
4750.70	MON	CR 71	4.2
4002.78	MON	I 490 GEN RIVER	1.0
			1.8
4040.33	MON	I-590 WINTON 1490	3.52

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APPENDIX B: PROJECT EVALUATIONS

The project energy analysis results to be described below are based upon the measured energy difference or change between some proposed alternative (i.e. the proposed project) and the expected null or existing situation. In the case of the proposed alternative, the specified construction actions and roadway improvements are evaluated along with the expected vehicle or user energy improvements. For the null or existing case, no work is expected or planned to be undertaken. However, for certain types of projects, the "ultimate" null alternative can be evaluated. For instance, failure to rehabilitate a seriously deteriorated structure will result in eventual closure of the structure to traffic. Failure to rehabilitate a pavement will result in continued deterioration to the point where it must be rehabilitated or reconstructed. In some instances the null alternative reflects increased congestion. In those cases where such an evaluation was possible, an energy assessment of the null alternative was undertaken.

Project Type Energy Analysis

Bridge Projects

Bridge projects indicate considerable savings potential. This savings occurs in the vehicle or user energy component. We have to draw the distinction here between conservation and energy not consumed. Sometimes it may be difficult for a vehicle to negotiate a bridge or its approach resulting in a change of vehicle operation and the consumption of excess fuel. Resolving this problem will result in that excess fuel consumption being conserved. In a situation where a bridge is in serious structural deterioration, a closing or posting may be imminent if the bridge is not rehabilitated. Fixing the bridge prevents route detours and their corresponding additional fuel consumption. The repair or fix prior to a bridge closing or posting then results in a substantial amount of vehicle/user energy that did not, as a result, have to be consumed.

From the B/C ratio contained in Table V.2 it can be seen that Bridge or Structural treatments offer the user potential savings in the form of operational conservation, while at the same time, obviating the consequential energy consumption due to inaction. A complete listing of bridge projects is contained in Table B.1.

Pavement Projects

Pavement projects, because they address conditions of roadway deterioration, offer the opportunity for conservation and/or additional consumption depending upon the project circumstances (most particularly the project speed). Because of the shape of the fuel consumption v.s. speed curve, continued pavement deterioration could possibly result in an energy savings. A complete listing of pavement projects is contained in Table B.2.

Safety/TSM Projects

Examination of Table V.2 indicates that Safety/TSM type projects offer significant energy conservation opportunities in terms of vehicle/user energy savings that are available to offset the implementation or construction energy cost of the action, yielding a net savings for this project type. A complete listing of pavement projects is contained in Table B.3.

Transit Bus Acquisition Projects

Transit Bus acquisition projects result from the industry's standard for replacement of these vehicles. The potential savings in this project type category results from improvements in vehicular efficiency. While it is always desirable to obtain a more fuel efficient vehicle during replacement this may not always be possible. Other criterion or established equipment requirements may limit or reduce the expected fuel efficiency of newer buses. A complete listing of transit projects is contained in Table B.4.

Other Projects

Due to the small number of projects in this category it is difficult to generalize from the results. The project shown as other in Table V.2 is included in Table B.1. The new construction project and draingage project of Table V.2 are included in Table B.2. The transit mall project shown in Table V.2 is included in Table B.4.

Project Funding Category Energy Analysis

In general, with respect to funding and matching shares, the State pays 100% of the required Federal match for a project on the State Highway System. In this situation, the provision of the local match has little or no effect on decisions concerning whether or not a project is selected.

With respect to the local (town, city, or county) projects, local "debt services" (i.e., bonding) is the method normally used to finance most of their capital/non-maintenance highway projects. In general, local jurisdictions do not seek Federal aid funding for this type of project and the availability of federal and state funds would have little or no impact upon the selection of these projects.

Examination of the Energy/Benefit Cost ratio of Table V.3 shows that for almost every Funding category, the projects contained therein offer potential energy savings (as the energy B/C ratio is negative). In most of the funding categories the ratio is quite significant. The funding categories of HBRR; and HBRR funds have the greatest return in terms of energy benefit for construction energy expended. These two funding categories contain only bridge projects, and as such, the results are consistent with those of Table V.2 for the project type analysis. FAUS funds contains three safety and two bridge projects and the value of the benefit cost ratio here is also consistent with the results in Table V.2. The next most significant funding category is local funds. The 41 projects within this category are both paving and bridge projects. Examination of the Funding listing for the individual projects indicates the potential savings from the few bridge projects to be quite significant. Again the findings for this Funding category as shown in Table V.3 are also consistent with the results shown in Table V.2.

Those funding categories offering the best return on the energy construction investment contain or reflect the potential savings available from bridge and safety/TSM projects. The more bridge projects or safety/TSM projects supported by a particular funding category the greater the energy return. Similarly, the more diverse the projects contained in a funding category the more likely energy saving projects may trade off against or be overshadowed by energy consuming projects. Such is the case with projects funded with 100% New York State funds.

Comparison Measures

A variety of measures and ratios are provided in both summary Tables V.2 and V.3 for contrasting the various project and funding categories. Both summary tables allow for the comparison of the average value for each project type or funding category for the following measures:

° Average Project Cost in 1981 Dollars
° Average AADT
° Average Annual Change in Energy (1000's of Equivalent Gallons of Gasoline)
    - Vehicle (User) Energy (1000's of Equivalent Gallons of Gasoline)
    - Construction Energy (1000's of Equivalent Gallons of Gasoline)
    - Net Total Energy (1000's of Equivalent Gallons of Gasoline)

° Change in Gallons/Project in 1981 Dollars
° Net Change in Gallons/Vehicle (1000's)
° Annual Change in Vehicle Gallons/Annual Change in Construction Gallons.
° Payback Period (Total Const. Gal./Annual Change in Vehicle Gal.)

Negative values for all measures indicate energy saved or conserved; positive values energy expended. All values reflect the difference between the proposed project alternative and the existing conditions. The last four measures are explained below:

1) Change in Gallons/Project Dollars ($ = 1981)

This measure may be viewed as the monetary measure of energy effectiveness, i.e., the change in total net energy conserved or consumed per project capital expenditure dollar.

If the 1981 average price per gallon of gasoline is assumed to be $1.37, then -1.37 as the value of Gallon/Project $ would be the energy project cost break even point, where a dollar invested saves the dollar equivalent of 1 gallon of gasoline. Those values less than -1.37 (i.e. -2.0 etc.) have a greater dollar payback per project dollar invested. Those values greater than -1.37, but less than 0 offer very small energy dollar savings; while values greater than 0 consume energy per dollar invested.

2) Net Change in Gallons/1000 Vehicles

This measure reflects the total annual change in net energy conserved or consumed per vehicle using a facility. As a means for assessing the magnitude of this measure, the following example is constructed by comparing project savings to the expected vehicle operating cost increase of the new 5¢ per gallon tax. If we assume an average auto utilization rate of 10,188 miles per year, a vehicular efficiency of 15.7 miles per gallon, and a gasoline price in 1981 of approximately $1.37 per gallon, we then have annual fuel consumption per vehicle of 649 gallons at a cost of $889. A 5% change in the annual gasoline cost, results in an annual change of $44 or 32 gallons per vehicle. This is slightly greater than the $32 per year additional cost of a 5¢ per gallon gasoline tax. Since there are no values in absolute terms for gallons/1000 vehicles in Table B.1 or B.2 greater than 3,200, we may view the net energy saved per vehicle by all project categories as insignificant.

3) Annual Change in Vehicle Gallons/Annual Change in Construction Gallons

The Energy Benefit/Cost Ratio is represented as the change in annual vehicle (user) energy per change in annual construction energy. A ratio value of "-1" indicates a vehicle or user gallon saved per 1 gallon expended in project construction. Positive values indicate vehicle or user expenditures of energy. In both the project type and funding summary tables we see that bridge projects or in the case of Funding sources, HBRR and FAUS funding categories have the lowest negative values for this ratio. The local funding category is also negative as it contains many bridge projects. What constitutes the decision making point on this measure as to how much energy must be saved (if any) before a project is deemed cost effective, is a policy decision.

4) Payback Period

This measure represents the period of time required for the vehicle (user) energy savings to offset the construction energy cost investment. Values are computed only when there are vehicle energy savings. Values less than 1.0 represent time intervals of less than 1 year. As we can see from examining Tables V.2 and V.3 for almost all projects with negative energy B/C ratios the average payback period is less than 15 years, with the largest project and funding categories averaging less than 7 years. The exception is the category of projects funded with 100% NYS funds. The payback period, as we have defined it, is the measure of the change in annual user energy savings available to offset the total construction energy; as such, it is not possible to compute such a value if there are no vehicle or user savings.

However, the values shown in several categories of Table V.3, "Funding Source Based on Energy Analysis Findings," may be misleading as project funding categories noted as NYS, FAPR, and LOCAL also contain pavement projects for which a payback period is not computed unless a vehicle or user savings acrues.

Table B.1

ANNUAL FUEL CONSUMPTION - BRIDGE PROJECTS

PIN #	CTY	DESCRIPTION	VEHICLE ENERGY	CONSTRUCTION ENERGY	NET ENERGY	AADT	PROJECT $ 1981 (1000)	BENEFIT / COST	PAYBACK PERIOD
4088.0002	MON	CAN OF WORMS	-442860	166919	-275941	121500	24568	-2.65	10.505
	MON	SCIO-UN.FLYVR	-57088	12339	-44749	29040	1200	-4.63	4.547
4750.80	GEN	WALNUT ST.	-90090	10604	-79486	32385	1685	-8.50	3.013
4084.0701	ONT	RT 21 CULVERT	-134144	836	-133308	8625	130	-160.46	0.178
3037.23	WYN	RT 31	-9958	13034	3076	2271	2225	-0.76	35.522
4084.07	ONT	RT 21	-122834	6101	-116733	2250	934	-20.13	1.409
4044.02	ORL	RT 387	-120340	9388	-110952	717	1215	-12.82	2.025
6042.0801	YTE	SR 364 PT.1	-33183	7775	-25408	1100	653	-4.27	4.842
4025.03	MON	RT 260	-251543	20186	-231357	2500	1830	-12.46	2.019
4750.81	ONT	SALTONSTALL ST	-76531	2516	-74015	1750	440	-30.42	0.947
4118.05	GEN	RT 237	-47556	2546	-45010	1026	377	-18.68	1.567
4750.76	MON	ORIVING PK.AV	-822143	49459	-772684	13200	9786	-16.62	1.781
6042.0701	YTE	SR 364 PT.3	-36590	6838	-29752	1218	716	-5.35	4.148
4750.78	MON	LONG PONO III	-1143671	77977	-1065694	13267	6751	-14.67	0.929
	MON	ELMWOOO AVE	-969578	12296	-957282	25000	2000	-78.85	0.380
	MON	THORNELL RO	-83903	2942	-80961	3300	551	-28.52	1.052
	MON	PARMA CTR.RO	-45310	1864	-43446	1600	342	-24.31	1.234
	MON	N.GREECE RO	-22111	1573	-20538	1800	313	-14.06	2.134
	MON	OEAN RO	-178308	1165	-177143	4500	228	-153.05	0.196
	MON	W.RUSH RD	-29397	1573	-27824	900	304	-18.69	1.605
	MON	FLINT HILL RO	-8937	990	-7947	300	228	-9.03	3.325
4750.85	COR	LAKE AVE	-445895	4532	-441363	18678	630	-98.39	0.207
4047.08	MON	E MAIN 96&253	-145553	12073	-133480	13700	1760	-12.06	2.397
4750.84	LIV	CHEESE FACTORY	-13994	2213	-11781	149	384	-6.32	4.114
4750.86	COR	E MAIN ST	-703932	38002	-665930	20000	8553	-18.52	1.403
4353.00	MON	RT 259	-38311	22766	-15545	8250	2821	-1.68	13.398
4008.10	MON	RT 15 HONEOYE	-203487	1773	-201714	7500	317	-114.77	0.237
4008.11	MON	RT 15 OVR TWAY	-546379	12695	-533684	13000	2231	-43.04	0.674
4012.11	GEN	RT 63 CNRAIL	-138097	8707	-129390	6950	739	-15.86	1.261
4750.70	MON	CR 71	-310300	5032	-305268	3596	630	-61.67	0.487
4002.78	MON	I 490 GEN RIVR	0	11600	11600	64000	2283		0
4040.33	MON	I 590 WNTN 490	-51391	87540	36149	54100	11511		32.575

Table B.2

ANNUAL FUEL CONSUMPTION - PAVEMENT PROJECTS

PIN #	CTY	DESCRIPTION	VEHICLE ENERGY	CONSTRUCTION ENERGY	NET ENERGY	AADT	PROJECT $ 1981 (1000)	BENEFIT / COST	PAYBACK PERIOD
4750.88	MON	SH166 PNFIELD	- 1286	132	- 1154	13700	80		2.047
4037.1501	MON	RT 31 RELOC.	1667508	347257	2014765	19160	17557		0
4035.03	ONT	RT 332	- 61699	5952	- 55747	24000	1709		1.014
6042.07	YTE	SR 364 PT.2&3	5132	25900	31032	1218	1675		0
6042.08	YTE	SR 364 PT.1&2	11561	29650	41211	1100	1600		0
	MON	WHITNEY RO.	- 478	42299	41821	10000	2215		0
	MON	SOUTH AVE	- 1384	11898	10514	17000	600		0
	MON	S.CLINTON AVE	2022	25737	27759	9000	2900		0
	MON	CULVER RO	- 4512	41057	36545	14000	2000		0
	MON	DEWEY AVE	- 909	12134	11225	10500	650		0
	ONT	CR 32	701	16975	17676	250	1000		0
	ONT	CR 23	802	22058	22860	250	1300		0
	ONT	CR 14	600	13546	14146	300	800		0
	ONT	CR 40	551	13535	14086	300	800		0
	COR	MARSDEN RO	- 1	1312	1311	100	062		0
	COR	LIME ST	- 31	1689	1658	2500	081		0
	COR	EOMONTON RD	- 1	598	597	100	028		0
	COR	HIGHLANO AVE	- 416	1021	605	7200	107		0
4111.12	COR	RT 20&98&63	13323	43318	56641	3700	2893		0
3030.03	WYN	RT 350	10730	5681	16411	3000	399		0
4076.24	MON	LOSP ISLANO	5060	9212	14272	6607	1025		0
	MON	CULVER/NRT-HFF	- 5108	31889	26781	16000	1611		0
	MON	ELMGROVE RD	9369	16104	25473	18000	829		0
	MON	SALT RO	264	13911	14175	2500	1487		0
	MON	MWCL RO-APRCHS	61	4090	4151	900	150		0
	MON	S CLNTON WF-BR	360	6792	7152	6000	701		0
	MON	ST PAUL TH-PTD	918	42201	43119	7000	1980		0
	MON	OEWEY LTTA-EDG	1747	17760	19507	8000	813		0
	MON	TITUS AVE	2271	19438	21709	10000	1010		0
	MON	ELMWOOD 12CRN	2460	15837	18297	15000	766		0
	MON	CULVER HF-SEAB	1698	3451	5149	8000	1511		0
	MON	WINTON RD	1823	16486	18309	17000	829		0
	MON	FETZNER RD	2318	15276	17594	18000	750		0
	MON	S CLNTON CL-WF	1893	25898	27791	8500	2711		0
	MON	ST PAUL TTS-TH	2897	56674	59571	16000	2688		0
	MON	WESTFALL RD	1167	8042	9209	10000	385		0
	MON	STONE RD	1814	11460	13274	13000	556		0
	MON	WHITNEY/BAIRO	442	15712	16154	10000	2070		0
	MON	LYELL/ MT REAO	- 2456	68494	66038	15000	3411		0
	MON	OEWEY ORV-EMER	- 780	21411	20631	10000	1103		0
	MON	CULVER ATL-WAR	- 4603	126610	122007	15000	6197		0
	MON	PRTLNO N-SYLVR	- 3232	103426	100194	12000	5068		0

Table B.3

ANNUAL FUEL CONSUMPTION - SAFETY PROJECTS

PIN #	CTY	DESCRIPTION	VEHICLE ENERGY	CONSTRUCTION ENERGY	NET ENERGY	AADT	PROJECT $ 1981 (1000)	BENEFIT / COST	PAYBACK PERIOD
4062.07	MON	RT 15A	- 45483	64939	19456	18150	6085		15.179
4037.17	MON	RT 31 PITT.	- 170662	1968	- 168694	20333	2288		0.150
4043.01	MON	RT 386	- 13566	24851	11285	12797	2604		32.262
4037.18	MON	RT 31&19 SAFTY	- 6906	5638	- 1268	14000	1200		15.220
4086.0001	MON	I 490 & I 390	0	70158	70158	0	6867		0

Table B.4

ANNUAL FUEL CONSUMPTION - TRANSIT BUS ACQUISITION

PIN #	CTY	DESCRIPTION	VEHICLE ENERGY	CONSTRUCTION ENERGY	NET ENERGY	AADT	PROJECT $ 1981 (1000)	BENEFIT / COST	PAYBACK PERIOD
	MON	ULIFTLINE LL	0	7098	7098	0	335		0
	MON	ULIFTLINE LL	0	4259	4259	0	206		0
	GEN	BBS	- 1113	710	- 403	0	33		2.551
	GEN	BBS	458	710	1168	0	92		0
	MON	RLIFTLINE LL	0	1420	1420	0	67		0
	WYN	WATS	0	2129	2129	0	109		0
	WYN	WATS	0	2129	2129	0	101		0
	LIV	LATS	1308	2129	3437	0	106		0
	LIV	LATS	436	710	1146	0	33		0
	GEN	BBS	0	2129	2129	0	35		0
	MON	TCOACHRPL RTS	18295	11605	29900	0	2750		0
	MON	TCOACHRPL RTS	2152	1365	3517	0	352		0
4820.15	MON	TRANS.MALL	- 27809	5504	- 22305	0	11167		5.939

APPENDIX C: LONG RANGE ASSESSMENT

Energy Consumed by Highway Travel

Energy consumed by travel on the Rochester area highway system is expected to change over time due to improvements in vehicle efficiency in the highway network and growth in employment and households in and around the study area. The New York State traffic simulation model was employed to help determine the effect of these changes. The effects of both highway improvements and VMT growth are analyzed (separately and together) to determine the impacts of each.

New York State Traffic Simulation Model

The New York State traffic simulation model is actually a series of procedures to predict travel in the Rochester area. The model uses a three-step traffic simulation process similar to that used in urban areas throughout the country. Major inputs to the model are highway network characteristics (length, posted speed, intersection control, width, etc.) and development characteristics (number of households, employment, automobiles available, etc.). Traffic is predicted by first determining the number of trips that would begin or end in a given zone. This step, called trip generation, is extrapolated from the development characteristics of the zone. Where these trips begin and end, the trip distribution step, is then determined from the ease of travel between two areas (i.e., travel time) and the number of opportunities available to satisfy the trip purpose in each area. Opportunities are based on the number of trip ends in an area which satisfy the purpose. Finally, the travel between each pair of areas is assigned to the highway route that takes the least time. Travel delays due to congestion are taken into account in this last step.

Approximate Boundaries of Area Simulated

All highway travel regardless of origin is theoretically simulated by the model on highways in the Rochester area. Data on energy consumed by travel is for vehicles traveling on highways in Monroe County and the 15 towns immediately adjacent to Monroe County which are part of 5 other counties.

Social/Economic Data Base

In the Monroe County area the number of households, automobiles, the number of persons employed in retail trade, service industries and the total employment along with the number of shopping plaza parking spaces are used to determine the number of trips that will be generated on a daily basis. These variables were estimated for the over 300 zones in the area for the year 1977, using the best data available.

It is expected that the predicted population and employment levels will not be reached for at least 20 years, but could possibly occur within 40 years. Regionwide, these forecasts predict an 18% increase in population, a 26% increase in households, an 11% increase in employment, and a 29% increase in the number of autos owned by county residents from 1977 levels.

Note, that while the population of Monroe County declined by 1.4% between 1970 and 1980 the number of households grew by 15.7% The national trend of smaller family sizes is basically responsible for this increase. Similarly, the City's population declined in this period by 18.1%, but experienced only a 2.3% decline in the number of city households. Another national trend, the increased median age of the population is related to the 3.5% increase in the number of licensed drivers in Monroe County and also the 7% increase in the number of autos in use from 1975 to 1979. Thus, while the area population may only grow slightly or might even decline over the next 40 years, growth in travel should continue to increase.

Future Highway Network

In the Rochester area, a significant number of highway improvements are either commited or under construction which, when completed, will affect travel in and around the study area. The improvements are as follows and are shown on the attached maps, Figure C.1 and C.2.

1. Outer Loop, Scottsville Road to Winton Road (I-590/390)
2. Genesee Expressway, Outer Loop to southern New York State (I-390)
3. Doresey Road Extention
4. Outer Loop Expressway Ridge Road (US 104) to Lake Ontario State Parkway (NY 390)
5. NY 31 West Expressway Elmgrove Road to Union Road
6. Maplewood Drive Extension
7. Conversion of Andrews Street from one-way to two-way
8. Extension of Chestnut Street
9. Fetzner Road Extension
10. Long Pond Road widening
11. Replacement and improvements to the Driving Park Bridge
12. Improvements to the "Can of Worms"
13. Widening of NY 590 from the "Can of Worms" to Keeler Street Expressway (US 104)

Assessment

The New York State traffic simulation model has an optional procedure as part of its user cost allocation model to calculate on a link-by-link basis the fuel consumption of the vehicles assigned to the highway network. The fuel consumption procedure uses vehicle consumption data by mode of operation drawn from Claffey (15), as noted in Caltraus (1) and PRR 174 (22) in conjunction with descriptive link statistics from the network link summary files of the traffic simulation model. Fuel consumption is evaluated on a link by link basis for the highway network based upon a travel trapezoid representing the various modes of vehicle operation (i.e. acceleration, cruise and deceleration) in conjunction with link characteristics for volume, capacity, number of stops, etc.

Improvements in vehicle efficiency and their impact on the various modes of vehicle operation are handled with an adjustment factor series that is applied to the fuel consumtpion rates for the various modes of operation as noted in CALTRANS (1).

Vehicle fleet efficiency as a specific fuel efficiency rate is not an explicit input, nor is it explicitly computed for the network as a whole, as the procedure output is the number of gallons consumed by ring, sector or zone of the network.

However, the adjustment factor series noted in CALTRANS (1) does make several assumptions about future fuel efficiency. The most important are 1) federal fuel efficiency standards will be met; and 2) the required 1985 27.5 mpg average will remain unchanged between 1985 and 2000. Essentially, what this implies is approximately a 1974-75 auto fleet efficiency of 13-14 mpg with a 1990-2000 efficiency of 23-25 mpg.

Given that traffic simulation models are designed to assign vehicle trips and that these trips are factored for vehicle type after assignment, the expected future auto efficiency noted above would probably be a fair estimate of the combined efficiency of the auto and truck fleet on the road at the that time.

Using this procedure, several traffic assignments were performed under varying assumptions for traffic, vehicle efficiency and the use of the base or future year network.

These assignments may be described as follows:

1. Base network and base year travel with the 1980, 1990, and 2000 year estimates for vehicle fleet efficiency.

2. Base network and future year travel with the 1990 and 2000 year estimates for vehicle fleet efficiency.

3. Future year network and future year travel projections with the 1990 and 2000 year estimates for vehicle fleet efficiency.

By varying the average fleet efficiency between the base year and a horizon year it is possible for us to isolate the effect of expected vehicle efficiency improvements. Since the future traffic projections represent traffic not likely to occur for 20 years but possibly occuring within 40 years, this type of vehicle efficiency assessment is required.

The three assignments noted above then enable us to examine separately and collectively, fuel consumption on the highway system in the Rochester area for changes due to the highway network improvement; change due to the expected growth in traffic due to growth in the region; and lastly change due to improvements in vehicle fleet efficiency.

These changes are best described by an examination of Figure C.3 and Table C.1. This graph shows the daily expected fuel consumption of vehicle travel in the Rochester area, as determined by the traffic assignment fuel consumption estimation.

There are several important observations to be made from this graph:

1. The expected improvements in fuel efficiency alone between 1980-1990 and 1990-2000 have the potential for reducing 1980 daily fuel consumption by 29.2% and 3.7% respectively. The bulk of the fuel savings will occur by 1990.

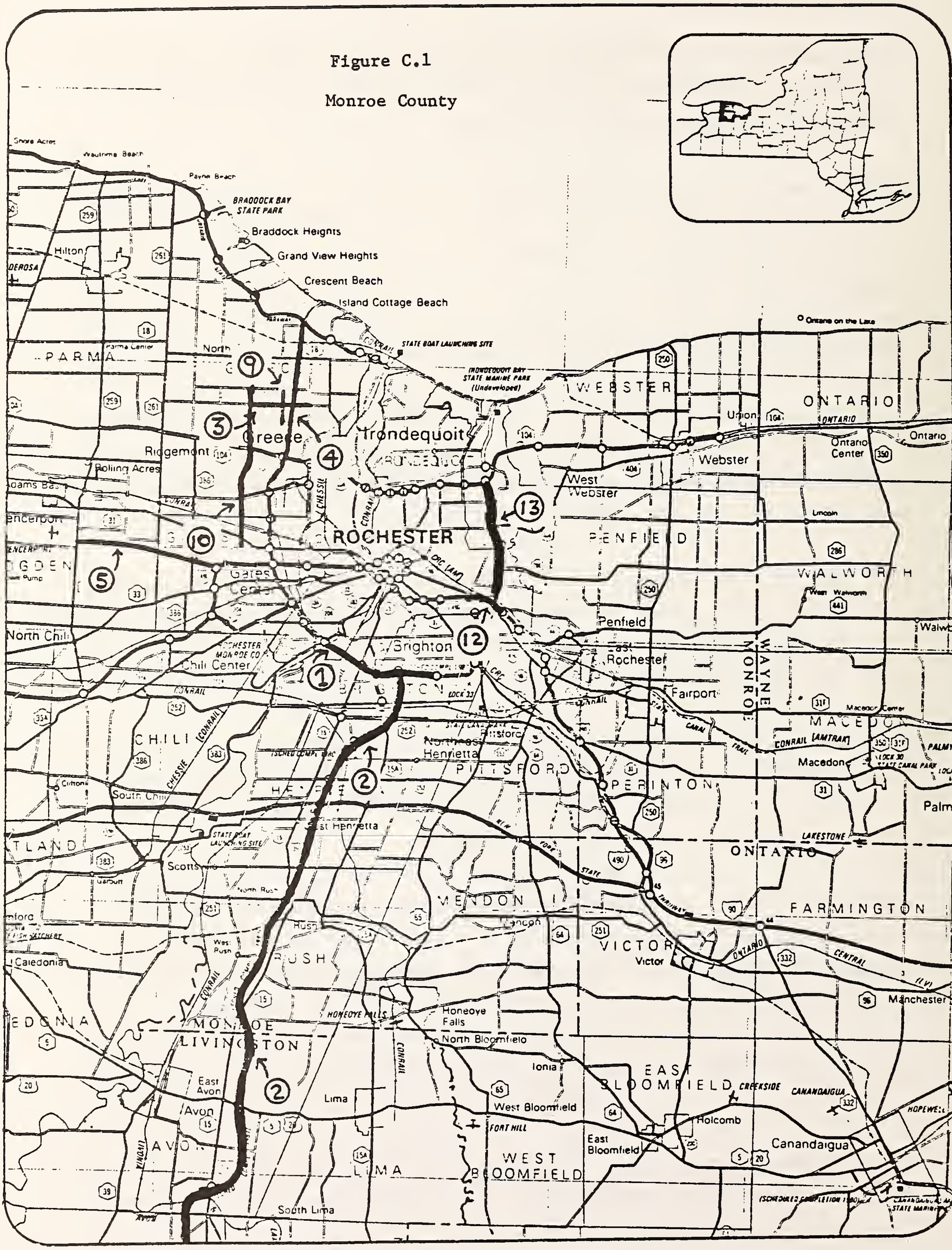
2. The expected change in fuel consumption due to the differences between the present highway system and the programmed and/or committed system for the future (20-40 years hence) represents a fuel consumption savings of 1.1% of 1980 fuel usage.

3. The effect of traffic growth on fuel consumption on the highway system is reflected as the difference between the future and base assignments (#1, & #2) described above. Traffic growth by 1990, represent 20.6% of the base network 1980 fuel consumption.

Fleet efficiency improvements alone can offset expected increases in fuel consumption due to projected growth in travel. Capital improvements to the highway system in future years will have a much smaller impact on reducing fuel consumption in the Rochester area.

Figure C.1

Monroe County



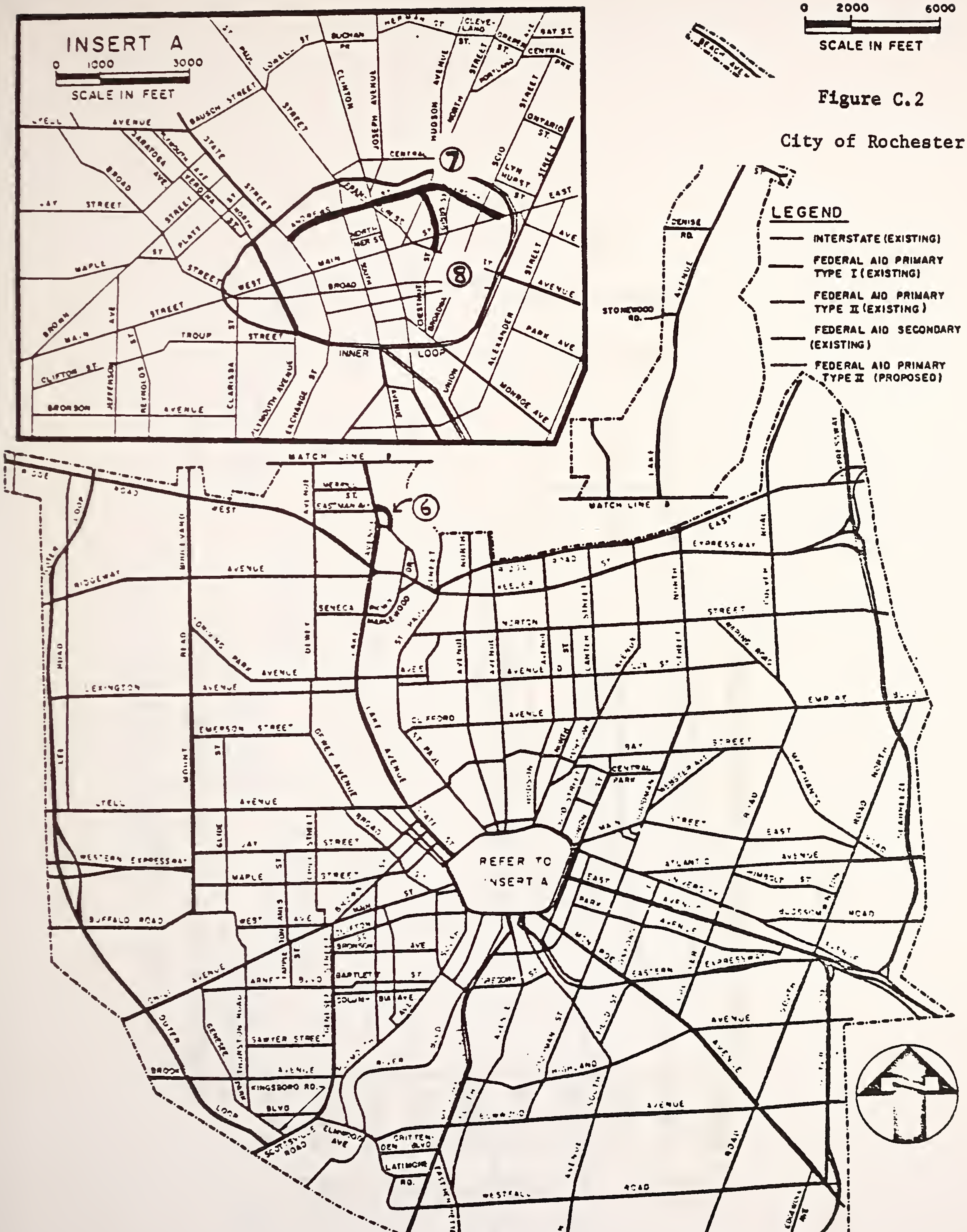


Figure C.2

City of Rochester

Figure C.3

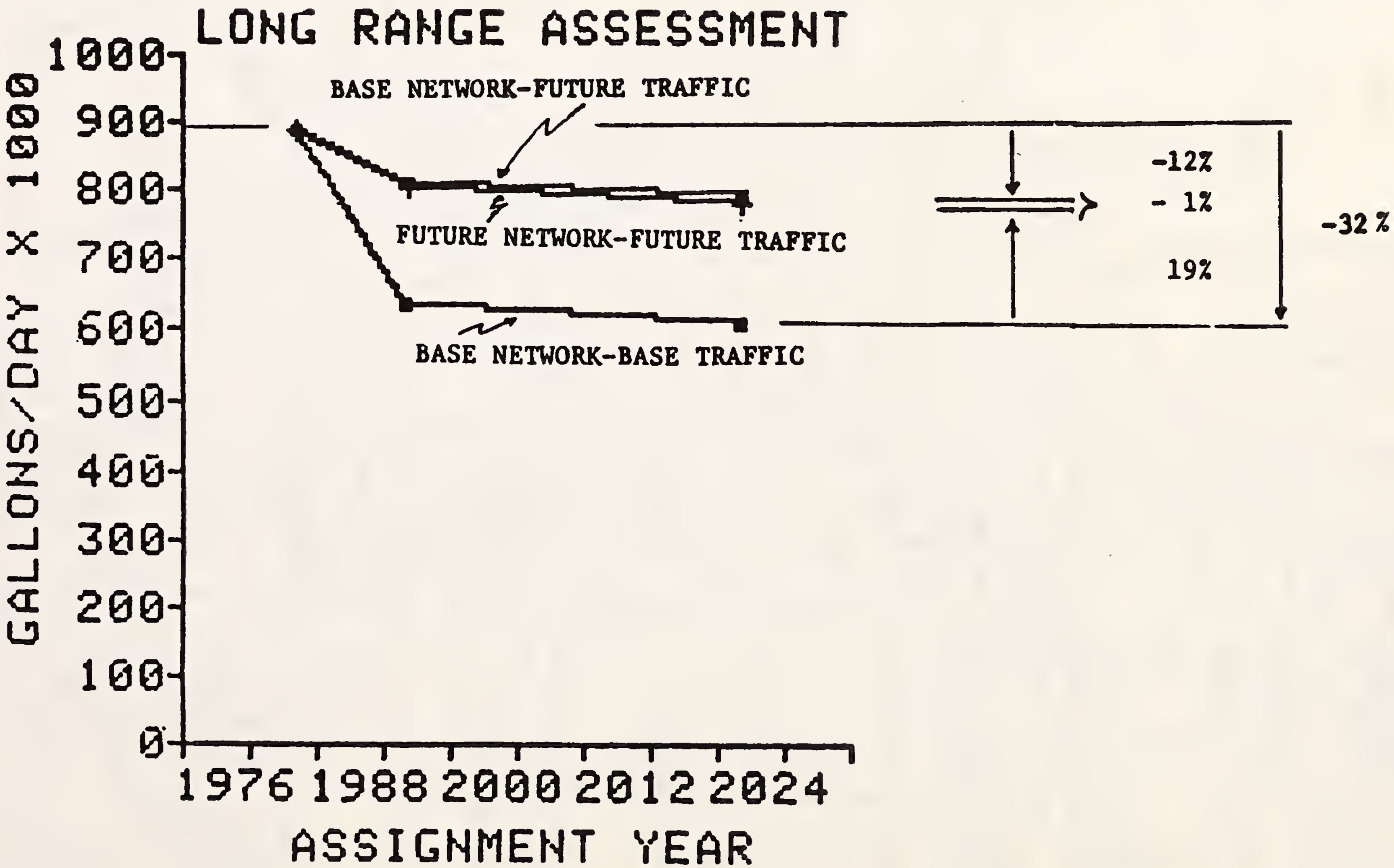

LONG RANGE ASSESSMENT
GALLONS/DAY X 1000
1000
900
800
700
600
500
400
300
200
100
0
1976
1988
2000
2012
2024
ASSIGNMENT YEAR
BASE NETWORK-FUTURE TRAFFIC
FUTURE NETWORK-FUTURE TRAFFIC
BASE NETWORK-BASE TRAFFIC
-12%
- 1%
19%
-32 %

Table C.1[1]

Network Traffic Assignments
Estimated Gallons/Year (Millions)

Year	Assignment (1) Base Network/ Base Traffic	Assignment (1) Change From Previous Period	Assignment (2) Base Network/ Future Traffic	Assignment (2) Change From Previous Period	Assignment (3) Future Network/ Future Traffic	Assignment (3) Change From Previous Period
1980	293.2	--	293.2	--	293.2	--
1990	207.5	85.7 (-29.2%)	267.9	25.3 (-8.6%)	264.7	28.5 (-9.7%)
2000	199.9	7.6 (-3.7%)	258.3	9.6 (-3.6%)	255.2	9.5 (-3.6%)
Total Change from 1980		93.3 (-31.8%)		34.9 (-11.9%)		38.0 (-13.0%)

[1] Negative values imply savings

APPENDIX D: MONITORING

This section focuses on the development and design of the monitoring system in the Genesee Transportation Council (GTC) planning area. The Genesee Transportation Council prepares an annual document called the "Data Guide" which is assembled from many sources of readily available data related to transportation in the Genesee/Finger Lakes Region. The intent of the "Data Guide" is not to provide comphrehensive information, but rather to serve as a quick reference to make the user aware of material and data sources available.

Data collection for monitoring and surveillance type activities fall into three broad areas of information gathering.

1. Continuous data that is essential to the daily or regular operation of an agency or organization. Some examples are transit ridership and fare collection data, or continuous traffic counts.

2. Information gathered for a special project or purpose, to evaluate and address new problems or issues of immediate concern or of limited duration.

3. Data gathered to track or monitor the performance of the overall local, regional or state transportation system, economy or demographic background.

In a comprehensive program for surveillance and monitoring, data from all of the above areas may be included. However, those data activities associated with the last item are generally those most appropriate for monitoring system performance. The objective of this effort in the GTC area is to establish a continuing monitoring function to identify the trends in transportation and energy use and consumption.

A key step in this or any data collection/monitoring activity would be the examination of any existing data guides, monitoring reports, historical data bases or data collection reference materials. To this end the GTC "Data Guide" and existing monitoring activities at NYSDOT as described below were utilized in the design of the monitoring activity for GTC.

NYSDOT currently has an existing data collection and monitoring activity that is summarized on a monthly basis in the form of a document entitled "Transportation Statistics Report". This represents a small subset of a much larger data base report that contains historical and current data collected on a monthly basis as a means for monitoring transportation system performance and energy consumption throughout the state. All data items noted in this report are collected and presented on a statewide basis, although lower levels of jurisdiction may be available. The documents provide the user with a historical profile of each measure and with a more expanded view of recent movement in the measure.

Additionally, NYSDOT under a funding grant from the Urban Mass Transportation Administration (UMTA) developed the "Data Source and Reference Directory of Transportation and Energy Data". The purpose of this document is to both identify key reference sources and measures or parameters of transportation and energy activity; to develop procedures where necessary for the compilation of key energy and travel parameters at the metropolitan level; and prepare several case study examples of such applications.

Utilizing these two references, staff experience at NYSDOT and the existing work efforts associated with the GTC "Data Guide" it was then possible to develop the attached list of 19 potential measures that formed the basis for the development of the GTC monitoring activity. Of the measures contained on this list: item 1-14 reflect measures that may be viewed as being indicative of changes occuring in the GTC planning area that may have an impact upon travel on energy; items 16-19 on the other hand are measures useful for representing the background picture which broadly specaking influences the very nature of travel and are frequently used as parameters of trip generation and attraction models.

Based upon discussions between NYSDOT and GTC staff it was agreed that as a minimum items 1, 3, 4, 6, 7, 11 would be collected as part of the monitoring effort as these measures more closely attempt to measure travel related changes. Other measures would be selected based upon their usefulness, ease of collection and discretion of the GTC staff. It was also agreed that these data would be incorporated into a quarterly supplement to the existing GTC "data guide". The reason for doing so was that the "data guide" obviously reaches a wider audience than those expected to be involved with this grant. As a result the monitoring activity would gain greater visibility within the GTC planning area and be of greater use.

A monitoring activity such as that now undertaken by GTC will ultimately provide transportation planners with a view on how key measures of transportation system performance are moving over time. Using this information as a base it will be possible for the GTC staff to develop or assess the interrelationship of these measures with other background parameters. It is then possible to see how changes in transportation and energy policy are reflected in the measurements of transportation system performance.

Monitoring Measures

1. Gasoline and diesel fuel consumption
2. Aviation fuel consumption
3. Prices of gasoline and diesel fuel
4. Motor vehicle registrations
5. Licensed drivers
6. Fuel efficiency
7. Transit passenger travel
8. Intercity bus travel
9. Air passenger and freight activity
10. Rail passenger and freight data
11. Highway Usage
12. Business activity index
13. Department store sales
14. Hotel and motel occupancy
15. Consumer price index
16. Personal income
17. Employment and percent unemployed
18. Population
19. Households

APPENDIX E: EXHIBITS

Exhibit E.1

Energy Analysis for a Bridge Project

GENESEE TRANSPORTATION COUNCIL
NEW YORK STATE DEPARTMENT OF TRANSPORTATION
TRANSPORTATION PROJECT ENERGY IMPACT ASSESSMENT

A. PROJECT: PIN 4084.07 Three Bridges and One Culvert over Sucker Brook, City of Canandaigua

B. PROJECT DESCRIPTION: Rehabilitation of the Parrish Street Bridge and replacement of the Chapin Street and North Pearl Street bridges and the Bristol Street culvert. All structures will provide for two travel lanes. Design studies should provide for consideration of a pavement width compatible with the existing highway approaches. Sidewalks will be provided as necessary.

C. PROPOSED SCHEDULING OF FUNDS: (Dollars in thousands)

1983/84	1984/85	1985/86	1986/87	1987/88
985				

D. REASONS FOR THE PROJECT: All four structures are in need of repairs and their continued service, if no action is taken, is questionable.

E. PROJECT BENEFITS: Detailed monetary benefits have not been calculated for this project. However, the major benefit will be to maintain the investment in the existing highway system. Other benefits could arise from reduced maintenance costs and improved safety to both motorists and pedestrians.

F. PROJECT DISBENEFITS: None have been identified at this time.

G. CONFORMANCE WITH GTC GOALS: Not available.

H. ENERGY ANALYSIS METHOD AND ASSUMPTIONS: Construction costs were adjusted using GNP to 1980 dollars. Energy costs of construction were obtained from Table 2.1 of "Project Level Energy Costs for Transportation Actions" and were applied directly to the adjusted dollar estimates. An increase of 30% is noted in "Energy and Transportation Systems" by Caltrans for placement of material prior to bridge construction. Based on this, a demolition cost of 15% is assumed. No indication was made in the project of the need to close existing structures or divert traffic during construction. However, if the project is not implemented, the bridges will have to be closed, resulting in the following permanent diversions of traffic:

Bridge	Diversion Length	Type of Facility	Vehicle Mix	Speed
N. Pearl St.	1 mile	collector	no heavy trucks	30 mph
Chapin St.	.4 mile	local	no trucks	30 mph
Bristol St.	.6 mile	arterial st.	80/20 trucks	30 mph
Parrish St.	.75 mile	collector	no heavy trucks	30 mph

I. ENERGY IMPACT ANALYSIS

1. Construction costs

a. North Pearl Street Bridge

1. Bridge Costs
2.52×10^4 BTU/dollar x $.229 \times 10^6$ dollars x. 091 (GNP adjustment) x 1.15 (demolition costs) ÷ 125,000 BTU/gallons = 48,313 equivalent gallons of gasoline

2. Highway costs
2.53×10^4 BTU/dollar x $.036 \times 10^6$ dollars x .91 ÷ 125,000 BTU/gallon - 6631 equivalent gallons of gasoline

3. Total = 54,944 equivalent gallons of gasoline

b. Bristol Street Culvert

1. Bridge costs:
2.52×10^4 BTU/dollar x $.276 \times 10^6$ dollars x .91 (GNP adjustment) x 1.15 (demolition costs) ÷ 125,000 = 58,229 equivalent gallons of gasoline

2. Highway costs
2.53×10^4 BTU/dollar x $.036 \times 10^6$ dollars x .91 ÷ 125,000 BTU/gallon - 6631 equivalent gallons of gasoline

3. Total = 58,229 + 6,631 = 64,860 equivalent gallons of gasoline.

c. Chapin Street Bridge

1. Bridge costs
2.52×10^4 BTU/dollar x $.221 \times 10^6$ dollars x. 91 x 1.15 ÷ 125,000 = 46,625 equivalent gallons of gasoline

2. Highway costs
2.53×10^4 BTU/dollar x $.036 \times 10^6$ dollars x .91 ÷ 125,000 = 6,631 equivalent gallons of gasoline

3. Total = 46,625 + 6,631 = 53,256 equivalent gallons of gasoline.

d. Parish Street Bridge Costs

1. Bridge costs
2.52×10^4 BTU/dollar x $.118 \times 10^6$ dollars x .91 ÷ 125,000 = 21,648 equivalent gallons of gasoline

2. Highway costs:
2.53×10^4 BTU/dollar x $.012 \times 10^6$ dollars x .91 ÷ 125,000 = 2,210 equivalent gallons of gasoline

3. Total - 21,648 + 2,210 = 23,858 equivalent gallons of gasoline

e. Total construction costs = 54,944 + 64,860 + 53,256 + 23,858 + 196,918 equivalent gallons of gasoline

2. User costs - If the existing bridges are closed, vehicles would have to be diverted, resulting in the following user costs:

a. North Pearl Street Bridge

1. passenger cars
3500 AADT x 1 mile x .059 gpm x 330 = 68,145 equivalent gallons of gasoline.

2. light trucks
280 AADT x 1 mile x .107 gpm x 330 = 9,887 equivalent gallons of gasoline

3. Total - 68,145 + 9,887 - 78,032 equivalent gallons of gasoline

b. Chapin Street Bridge

passenger cars
1120 AADT x .4 miles x .059 gpm x 330 = 8,723 equivalent gallons of gasoline

c. Bristol Street Culvert

1. passenger cars:
2475 AADT x .6 miles x. 059 gpm x 330 = 28,913 equivalent gallons of gasoline

2. light trucks:
220 AADT x .6 mile x .107 gpm x 330 = 4,661 equivalent gallons of gasoline

3. heavy trucks:
   55 AADT x .6 miles x .230 gpm x 330 = 2,505 equivalent gallons of gasoline

4. Total = 28,913 + 4,4=661 + 2,505 = 36,079 equivalent gallons of gasoline.

d. Parrish Street Bridge

1. passenger cars:
   7935 AADT x .75 mile x .059 gpm x 330 = 115,870 equivalent gallons of gasoline

2. light trucks:
   690 AADT x .75 mile x .107 gpm x 330 - 18,273 equivalent gallons of gasoline

3. Total = 115,870 + 18,273 - 134,144

e. Total user costs - 78,032 + 8,723 + 36,079 + 134,144 = 256,978 equivalent gallons of gasoline

3. Payback period = 196,918/256,978 = .766 years

Exhibit E.2

Energy Analysis for a Bridge Project

GENESEE TRANSPORTATION COUNCIL
NEW YORK STATE DEPARTMENT OF TRANSPORTATION
TRANSPORTATION PROJECT ENERGY IMPACT ASSESSMENT

PIN: 4008.11

PROJECT: Rt. 15, West Henrietta Road, bridge over Thruway (BIN 1011530)

FUNDING: HBRR and NYSDOT

PROJECT DESCRIPTION: This project is located on SR 15 in the Town of Henrietta, Monroe County. The purpose of the project is to replace the structurally deficient bridge. The bridge was originally built in 1953, and repaired several times by the NYS Thruway Bridge maintenance forces, however, it is in such poor condition that further maintenance actions would be useless.

ENERGY ANALYSIS METHOD:

A. Roadway and structural construction project cost estimates are converted into energy estimates in gallons of equivalent gasoline by the following:
   (1) Adjusting dollar estimates to 1980 dollars using the GNP implicit price deflator.
   (2) Multiplying by the appropriate BTU/$ energy conversion factor.
   (3) Dividing the BTU's so obtained in (2) by 125,000 BTU/Gal. to convert the energy into gasoline equivalents.

B. The possibility exists that the bridge might ultimately be closed if left unattended in its present condition. A traffic analysis was undertaken to assess the traffic energy impact of the bridge closing in the following manner:
   (1) AADT is separated into the 3 major vehicle components (cars, light trucks-- 2 axle-6 tire, and heavy trucks). If vehicle mix was not known or indicated in the project data then a percentage mix of 90 / 8 / 2 was assumed respectively for the vehicle types.
   (2) The energy impact of the detour is calculated for each vehicle type as the product of the AADT x GPM x Miles x Days/yr.
   (3) Geometric limitations on the bridge or its approaches often cause speed changes from the travel speed to traverse the bridge or if there is a detour then the route itself may have a different speed. These effects are evaluated by determining the speed change increment and the corresponding change in fuel consumption (gals.) times the AADT for the vehicle types affected.

ANALYSIS SUMMARY
BRIDGE PROJECTS

I. ENERGY EFFECTS OF CONSTRUCTION
(in equivalent gallons of gasoline)

Alternative	Project Component	Total Gallons	Service Life/Yrs.	Gallons/ Year	
A. Proposed	Roadway	25,704	20	1,285	
	Structures	342,285	30	11,410	
	Total	367,989		12,695	(1)
B. Null	Roadway				
	Structures				
	Total	--		--	(2)

Net Energy Loss (Savings) from Repair = 12,695 (3)

II. USER ENERGY EFFECTS
(in equivalent gallons of gasoline)

Alternative	Type of Energy Effect	Energy Loss (Savings)	
A. Proposed	Removal of Detour		
	Elimination of Speed Change		
	Total	—	(4)
B. Null	Institution of Detour	546,379	
	Institution of Speed Change	--	
	Total	546,379	(5)

Net User Energy Loss (Savings) (4-5) = (546,379) (6)

III. NET ENERGY LOSS (SAVINGS) (3 + 6) = (533,684) (7)

IV. ENERGY BENEFIT/COST (6/3) = 43.0 (8)

Exhibit E.3

Energy Analysis for a Pavement Project

GENESEE TRANSPORTATION COUNCIL
NEW YORK STATE DEPARTMENT OF TRANSPORTATION
TRANSPORTATION PROJECT ENERGY IMPACT ASSESSMENT

PIN:	3030.03
PROJECT:	Rt. 350, Macedon to Rt. 104
FUNDING:	NYSDOT
PROJECT DESCRIPTION:	The project involves resurfacing Rt. 350 from Walworth-Macedon Town Line Road to Rt. 104 in the Town of Macedon, Wayne County. The pavement was last resurfaced 11 years ago and is presently dried and cracking. The proposed resurfacing will correct the problem before expensive work is required.

ENERGY ANALYSIS METHOD:

A. Roadway and structural construction project cost estimates are converted into energy estimates in gallons of equivalent gasoline by the following:
   (1) Adjusting dollar estimates to 1980 dollars using the GNP implicit price deflator.
   (2) Multiplying by the appropriate BTU/$ energy conversion factor.
   (3) Dividing the BTU's so obtained in (2) by 125,000 BTU/Gal. to convert the energy into gasoline equivalents.

B. The effects of improved pavement condition are evaluated by using a computer algorithm to assess the change in energy due to the pavement surface condition and the change in energy due to speed changes associated with such improvements.

ANALYSIS SUMMARY
ROADWAY PROJECTS

I. ENERGY EFFECTS OF CONSTRUCTION
(in equivalent gallons of gasoline)

Alternative	Project Component	Total Gallons	Service Life/Yrs.	Gallons/ Year	
A. Proposed	Roadway, signs, misc.	56,810	10	5,681	
	Structures	0		0	
	Total	56,810		5,681	(1)
B. Null	Roadway				
	Structures				
	Total	0		0	(2)

Net Energy Loss (Savings) from Repair = 5,681 (3)

II. ANNUAL USER ENERGY EFFECTS[1]
(in equivalent gallons of gasoline)

Alternative	Type of Energy Effect	Energy Loss (Savings)	
A. Proposed	Improved speed	6,705	
	Improved surface	(1,983)	
	Total	4,722	(4)
	Service Life Adjustment[2] =	3,305	(5)
B. Null	Reduced Speed	(13,581)	
	Deteriorated Surface	2,974	
	Total	(10,607)	(6)
	Service Life Adjustment	(7,425)	(7)

Net User Energy Loss (Savings) (5 - 7) = 10,730 (8)

III. NET ENERGY LOSS (SAVINGS) (3 + 8) = 16,411 (9)

IV. ENERGY BENEFIT/COST (8/3) = n/a (10)

NOTES

[1] The fuel efficency vs. speed curve is trough shaped. As a result, fuel consumption is higher both above and below the approximate speed range of 25-35 mph, varying for different vehicle types. As such, incremental speed increases due to pavement resurfacing may increase fuel consumption, but savings result in travel time reduction.

[2] Pavement projects are considered to have a maximum service life of ten years. The effect of deterioration of the pavement during its ten year life, however, is equivalent to the impact of a new surface for seven years. The service life adjustment is thus 0.7 times the total user energy effect.

Exhibit E.4

Energy Analysis for a Transit Project

GENESEE TRANSPORTATION COUNCIL
TRANSIT CAPITAL PROJECT ENERGY IMPACT ASSESSMENT
(In Equivalent Gallons of Gasoline)

System	Year Programmed	Number of Vehicles	Indirect Costs per year		Direct Costs per year		Net Cost (savings) per Year		
			Existing	Replacement	Existing	Replacement	Indirect	Direct	Total
RTS	1984/85	17	0	11,605	173,810	192,105	11,605	18,295	29,900
RTS	1987/77	2	0	1,365	20,448	22,600	1,365	2,152	3,517
Lift-Line (Urban)	1985/86	10	0	7,097	33,584	33,584	7,097	0	7,097
	1986/87	6	0	4,258	20,151	20,151	4,258	0	4,258
Lift-Line (Rural)	1985/86	2	0	1,419	6,717	6,717	1,419	0	1,419
BBS	1985/86	1	0	710	3,175	2,062	710	(1,113)	(403)
		1	0	710	1,604	2,062	710	458	1,168
	1986/87	3	0	2,129	6,185	6,185	2,129	0	2,129
WATS	1984/85	3	0	2,129	11,861	11,861	2,129	0	2,129
	1985/86	3	0	2,129	11,861	11,861	2,129	0	2,129
LATS	1983/84	3	0	2,129	4,378	5,685	2,129	1,307	3,436
	1985/86	1	0	710	1,459	1,895	710	436	1,146
Totals		52	0	36,390	295,233	316,768	36,390	21,535	57,925

Exhibit E.5

Energy Analysis for a County Pavement Project

GENESEE TRANSPORTATION COUNCIL
ENERGY IMPACT ANALYSIS
MONROE COUNTY FUNDED PROJECTS

Project: Whitney Road (Five Mile Line Road to Baird Road)

A. Construction Costs:

1. Proposed improvements: 42,299 gallons/year
2. Null alternative: 0
3. Net construction energy costs: 42,299 gallons/year

B. User Costs:

1. Proposed Alternative:

   a. Energy effects of improved speed = 1611 gallons/year (loss)

   b. Energy effects of improved surface = 980 gallons/year (savings)

   c. Total = 631 gallons/year (loss)

   d. Service Lift Adjustment = 442 gallons/year (loss)

2. Null Alternative:

   a. Energy effects of reduced speed = 157 gallons/year (savings)

   b. Energy effects of deteriorated surface = 1471 gallons/year (loss)

   c. Total = 1314 gallons/year (loss)

   d. Service Life Adjustment = 920 gallons/year

3. Net User Energy Costs (savings) = 478 gallons/year (savings)

C. Total Energy Costs (savings) = 41,821 gallons/year (loss)

Exhibit E.6

Goal Achievement Rating Lists

GOAL:

1. CAPACITY/CONDITION

Project______________________________

ACHIEVEMENT CRITERIA (objectives):

Achievement Ratings

+2 The project *meets* or contributes to the objective *totally* or significantly.

+1 The project *meets* or contributes to the objective *partially* or slightly to moderately.

0 The project *does not meet* or contribute to the objective at all.

-1 The project *counteracts* the objective.

a. Provide an adequate, but not exceptional level of service.

measures: Level of service

now_____
after_____
norm or standard_____

b. Maintain existing transportation facilities in an adequate and reliable condition.

measures: Sufficiency index

now_____
after_____
norm or standard_____

c. Improve quality and reliability of non-auto or High Occupancy Vehicle (HOV) transportation services.

measures: decrease in breakdowns _____
decrease in delay _____
improved on-time performance _____

d. Use TSM or other non-capital intensive improvements over new construction.

or

e. In the case of a new construction project, this was initiated only after an analysis of do-nothing, TSM, or maintenance was shown to be infeasible.

measures: b/c of project _____
b/c of best TSM alternative_____

Briefly state reasons for infeasibility:

Implementing Agency	Central Staff

GOAL:

2. MODAL BALANCE

Project ________________________

ACHIEVEMENT CRITERIA (objectives):

Achievement Ratings

+2 The project *meets* or contributes to the objective *totally* or significantly.

+1 The project *meets* or contributes to the objective *partially* or slightly to moderately.

0 The project *does not meet* or contribute to the objective at all.

-1 The project *counteracts* the objective.

Criteria	Implementing Agency	Central Staff
a. Bring a greater modal mix of transportation services or a viable High Occupancy Vehicle (HOV) alternative to the people served by this project. measures: # of people having a greater modal mix or a new HOV alternative		
b. Improve quantity of already existing non-auto or HOV transportation services. measures: increase in # of buses per day increase in miles of bikeways, trails, etc.		
c. Provide or improve access via walking and bicycles.		

GOAL:

3. INTERMODAL COORDINATION

Project ______________________

ACHIEVEMENT CRITERIA (objectives):

Achievement Ratings

+2 The project *meets* or contributes to the objective *totally* or significantly.

+1 The project *meets* or contributes to the objective *partially* or slightly to moderately.

0 The project *does not meet* or contribute to the objective at all.

-1 The project *counteracts* the objective.

	Implementing Agency	Central Staff
Goal 3: Intermodal Coordination		
a. Provide or improve intermodal transfer opportunities for passengers. measures: Intersecting points exist? ______ Opportunities used? ______ Transfer time - old ____ new ____ Cost of transfer - old ____ new ____		
b. Provide or improve intermodal transfer for freight.		
c. Share common rights-of-way between modes where appropriate.		
GOAL: 4. SAFETY ACHIEVEMENT CRITERIA (objectives):		
a. Reduce statistical accident hazard. measures: see the table below		
b. Different modes are physically separated or protected.		

	Existing accidents (rate x volume =)	New accidents (rate x volume =)
fatalities	x =	x =
injuries	x =	x =
$ property damage	x =	x =

GOAL:

5. COST EFFECTIVENESS

Project______________________________

ACHIEVEMENT CRITERIA (objectives):

Achievement Ratings

+2 The project *meets* or contributes to the objective *totally* or significantly.

+1 The project *meets* or contributes to the objective *partially* or slightly to moderately.

0 The project *does not meet* or contribute to the objective at all.

-1 The project *counteracts* the objective.

	Imple-ment-ing Agency	Central Staff
a. Solve the problem being addressed by this project. State problem being solved.______________________________ ______________________________ ______________________________ ______________________________		
b. Maximize return on investment (i.e. at least a minimally acceptable B/C). B/C *______________		
c. Quantify in as comprehensive a fashion as possible the cost and benefits and to whom they accrue. - show what is accounted for and the B/C derivations (including the number of people affected). e.g., time savings, operating costs, accident reduction, maintenance, construction/implementation; ______________ ______________________________ ______________________________ ______________________________ ______________________________ Are the following adequately addressed (or irrelevant)? ✓ (yes) ✗ (no) or IRR (irrelevant) energy_____ environment_____ land use_____ economy_____ community cohesion/ appearance_____ distribution of costs & benefits _____		

*See attachment: Guide to Calculating Benefit-Cost Ratio

GOAL:

6. EQUITY

Project__________________________

ACHIEVEMENT CRITERIA (objectives):

Achievement Ratings

+2 The project *meets* or contributes to the objective *totally* or significantly.

+1 The project *meets* or contributes to the objective *partially* or slightly to moderately.

0 The project *does not meet* or contribute to the objective at all.

-1 The project *counteracts* the objective.

Criteria	Implementing Agency	Central Staff
a. Project serves people in region as equitably as possible. measure(s): characteristics of population being served in relation to area norms__________		
b. Costs fall as equally as possible on population deriving benefits from the project. measure(s): characteristics of population being served (same as above)__________ characteristics of population paying for project__________ characteristics of population bearing environmental or social costs__________		
c. Project provides or improves mobility to the economically disadvantaged, the elderly or handicapped. explain:__________		

GOAL:

7. ENERGY CONSERVATION

Project ______________________

ACHIEVEMENT CRITERIA (objectives):

Achievement Ratings

+2 The project *meets* or contributes to the objective *totally* or significantly.

+1 The project *meets* or contributes to the objective *partially* or slightly to moderately.

0 The project *does not meet* or contribute to the objective at all.

-1 The project *counteracts* the objective.

Imple-ment-ing Agency	Central Staff

a. Promote energy efficient projects.

measure(s):

annual energy savings (gal. of gas) _____

annual change in VMT _____

Return on energy invested (for Capital Projects only):

(i) amount of energy saved over the operating life of the facility (BTU) - [Typical Year] ______________________

(ii) amount of energy invested in facility over its lifetime (BTU) - [Average Annual] ______________________

Ratio i ÷ ii ________________ = energy saved per unit of energy invested over lifetime of the project.

The "return on energy invested" measure is calculated by annualizing the implementation energy of each project element over their service lives (initial construction, annual maintenance, etc.) The annualized* energy investment is then divided into the projected annual operating energy savings when project is fully operational [if such annual savings will vary, pick a typical operating year (and identify which year it is)].
[See sample sheet attached].

NOTE: Any information you would need on energy consumption by modes, model years, etc. should generally be available in recent handbooks or planning guides. Call Ed Muszynski of the Central Staff if you can't find what you need to do the calculations.

*use arithmetic average

GOAL:

8. LAND USE AND REDEVELOPMENT

Project ____________________

ACHIEVEMENT CRITERIA (objectives):

Achievement Ratings

+2 The project *meets* or contributes to the objective *totally* or significantly.

+1 The project *meets* or contributes to the objective *partially* or slightly to moderately.

0 The project *does not meet* or contribute to the objective at all

-1 The project *counteracts* the objective.

	Imple-ment-ing Agency	Central Staff
a. Develop projects consistent with local and regional land use plans. b. Protect and enhance the role of Rochester's CBD and other city, town and village centers. c. Foster more compact long-term development patterns. d. Promote a quality pedestrian environment. e. Provide jointdevelopment opportunities.		
GOAL: 9. ENVIRONMENT AND NATURAL RESOURCES ACHIEVEMENT CRITERIA (objectives): a. The project enhances the environment. (one overall rating) Note effects on: air pollution ____________________ noise and vibration ____________________ wetlands ____________________ endangered species ____________________ viable agriculture ____________________ infra-structure systems, facilities and services ____________________		

GOAL:

10. COMMUNITY VALUES

Project ______________________

ACHIEVEMENT CRITERIA (objectives):

Achievement Ratings

+2 The project *meets* or contributes to the objective *totally* or significantly.

+1 The project *meets* or contributes to the objective *partially* or slightly to moderately.

0 The project *does not meet* or contribute to the objective at all.

-1 The project *counteracts* the objective.

Criteria	Implementing Agency	Central Staff
a. Do not split or disrupt communities or neighborhoods through transportation projects. measure(s): # of facilities removed (specify types) (e.g. houses, trees, historic, or acheological facilities, churches, schools, parkland, etc.) ______________________ ______________________ # of people relocated ______		
b. Make projects visually compatible with the natural and man-made environments.		
c. Apply sound design principles to traffic circulation elements without encouraging through traffic or excessive speeds in residential areas.		

GOAL:

11. ECONOMIC DEVELOPMENT

Project ______________________________

ACHIEVEMENT CRITERIA (objectives):

Achievement Ratings

+2 The project *meets* or contributes to the objective *totally* or significantly.

+1 The project *meets* or contributes to the objective *partially* or slightly to moderately.

0 The project *does not meet* or contribute to the objective at all.

-1 The project *counteracts* the objective.

Criteria	Implementing Agency	Central Staff
a. Facilitate the transport of industrial goods and supplies.		
b. Facilitate the access of employees and customers.		
c. The project involves the direct expenditure of private funds (either as a direct result of the project or as a direct cause for the project being necessary.) measure(s): private $ ____ public $ ____ ratio $ ____		
d. Maintain existing business and industry. measure(s): # of businesses relocated (with same city, town, etc) ____ # of employees ________ # of businesses relocated (elsewhere): within 30 miles _____ # of employees _____ greater than 30 mi. _____ # of employees _____ # of businesses to close _____ # of jobs eliminated _____		
e. Maintain and enhance inter-regional connections.		

GOAL:

12. INTERGOVERNMENTAL COORDINATION

Achievement Ratings

+2 The project *meets* or contributes to the objective *totally* or significantly.

+1 The project *meets* or contributes to the objective *partially* or slightly to moderately.

0 The project *does not meet* or contribute to the objective at all.

-1 The project *counteracts* the objective.

Project ______________________

ACHIEVEMENT CRITERIA (objectives):

	Imple-ment-ing Agency	Central Staff
a. The project was coordinated with affected governmental and non-governmental bodies. List them:		

GOAL:

13. COMMUNITY PARTICIPATION

ACHIEVEMENT CRITERIA (objectives):

	Imple-ment-ing Agency	Central Staff
a. Provide opportunities for citizen involvement before project alternatives are fixed and before policy or programming decisions are made. b. Involve all groups affected by the project, including often under-represented groups such as minorities, the poor, the elderly, etc. c. Be responsive to citizens by addressing their concerns and comments..		

APPENDIX F: Project Locations & Description

FIGURE F.1: <u>Symbol Code for Figure F.2 - F.7</u>

P - Pavement Project ▬

B - Bridge Project ●

S - Safety Project ▲

Table F.1
Project Descriptions for Figures F.2, 3, 4

GENESEE, MONROE AND ORLEANS COUNTIES
FEDERAL AND STATE FUNDED HIGHWAY PROJECTS

A. FAUS Projects

S-1	PIN 4062-07	Rt. 15A - Lehigh Station Rd. to Castle
S-2	PIN 4037.17	Rt. 31 - Montore Ave., Town of Pittsford
B-1		Socio-University Inner Loop Flyover
P-1	PIN 4750.78	Long Pond III - Lyell to Ridgeway
S-3	PIN 4043.01	Chili-Coldwater Rd. - Rt. 33A to West Side Drive

B. F.A. Primary System (Urban) Projects

P-2	PIN 4037.15 (01)	Rt. 31 Relocation - Elmgrove Rd. to Manitou Rd.

C. F.A. Interstate System (Urban) Projects

S-4	PIN 4086.00	Rts. 490, 390I and 390 Rochester-Western Expressway, Rochester Outer Loop, Contract #2
B-2	PIN 4088.00(02)	I-490 Eastern Expressway - Winton Rd. to Landing Rd., "Can of Worms"
B-3		Rt. I-490 Bridge Decks, Brown St. to Clinton Ave.; Genesee River Bridge - Additional Stage Deck Construction, R&P
P-3		Rt. I-490 - Clinton Avenue to Winton Rd.
P-4		Rt. I-590 - Winton Road to Highland Avenue

D. Non-Urbanized Area (Rural) Interstate System Projects

S-4	PIN 4086.00	Rts. 490-I, 390I, and 390 Rochester Western Expressway and Rochester Outer Loop, Contract #2

E. Federal Aid Primary and Secondary (Rural) Projects; Federal Aid Urban System (Rural Projects)

P-5	PIN 4111.12	Rt. 20 Alexander - Cananwaugus - Rt. 98 to Rt. 63

F. Highway Bridge Replacement and Rehabilitation Program

B-4	PIN 4026.02	- Rt. 261 Manitou Rd. over West Creek
B-5	PIN 4750.76	- Driving Park Bridge over Genesee River
B-6	PIN 4750.86	- East Main St. Bridge over Conrail, City of Rochester
B-7	PIN 4008.10	- Rt. 15 over Honeoye Creek
B-8	PIN 4008.11	- Rt. 15 West Henrietta Rd. Bridge over Thruway
B-9	PIN 4044.02	- Rt. 387 Fancher Bridge over Barge Canal
B-10	PIN 4012.11	- Rt. 63 Pavilion-Batavia, Part 2 over Conrail (E. Bethany)
B-14	PIN 4118.05	- Rt. 237 over Black Creek; CR 19A over Spring Creek
B-12	PIN 4750.70	- Cr. 71 Erie Station Rd. Bridge over Lehigh Valley RR
B-13	PIN 4750.80	- Walnut St. over Tonawanda Creek, City of Batavia
B-14	PIN 4750.85	- Lake Ave. Bridge over Chessie System

S-5 PIN 4037.18 Rt. 31 and Rt. 19, Brockport

G. Non-Federally Aid Projects

P-7 PIN 4076.24 - Lake Ontario State Parkway (Island Cottage Rd. to Rochester W. City Line)
P-6 PIN 4750.88 - S.H. 166 Penfield Rd. under Conrail Mainline - Drainage Improvement
P-8 PIN 4353.00 - Rt. 259 Chili-Monroe PCRR Buckabee Corners - North Chili

MONROE COUNTY FUNDED PROJECTS

P-13	Whitney Rd. - Baird Rd. Intersection and Railroad underpass
P-14	Stone Rd. - Ridge Rd. to Mt. Read Blvd.
B-15	Thornel Rd. Bridge
B-15	Monroe-Wayne County Line Rd. - Bridge Approaches
P-16	Portland Ave. - North St. to Clifford Ave.
P-17	Portland Ave. - Clifford Ave. to Sylvester St.
P-18	Elmgrove Rd. - Buffalo Rd. to Spencerport Rd.
P-19	Salt Rd. - Rt. 104 to a point 4,500 feet north
P-20	South Clinton Ave. - City Line to Westfall Rd.
B-16	Elmwood Ave. Bridge
B-17	Parma Center Rd. Bridge
P-21	St. Paul Blvd. - Titus Ave. to Thomas Ave.
P-22	S. Clinton Ave. - Westfall Rd. to Brighton-Henrietta Town Line Rd.
P-23	South Ave. - Gregory St. to Rockingham St.
B-18	North Greece Rd. Bridge
P-24	St. Paul Blvd. - Thomas Ave. to Pattonwood Drive
P-25	Lyell Ave. - Mt. Read Blvd. to Moore St.
P-26	Whitney Rd. - Five Mile Line Rd. to Baird
P-27	Dewey Ave. - Latta Rd. to Edgemere Dr.
B-19	Dean Rd. Bridge
B-20	Rush - W. Rush Rd. Bridge
P-28	Culver Rd. - Atlantic Ave. to Waring Rd.
P-29	Titus Ave. - Kings Highway to Sea Breeze Expressway
P-30	Elmwood Ave. - 12 Corners to Clover St.
B-21	Flint Rd. Bridge
P-31	Culver Rd. - Hoffman Rd. to Sea Breeze Expressway
P-32	Winton Rd. - North City Line to Empire Blvd.
P-33	Dewey Ave. - Driving Park Ave. to Bloss St.
P-34	Buffalo Rd. - West Ave. to Mt. Read Blvd.
P-35	Fetzner Rd. - Ridge Rd. to Maiden Lane
P-36	Westfall Rd. - Winton Rd. to Monroe Avenue

CITY OF ROCHESTER FUNDED PROJECTS

P-9	Edmonton Rd. - Coleridge Rd. to Monticello
P-10	Highland Avenue - Monroe Ave. to City Line
P-11	Lime Street - Orchard St. to Whitney
P-12	Marsden Road (Coleridge to Winton)

Table F.2
Project Description for Figure F.5

WAYNE COUNTY
FEDERAL AND STATE FUNDED HIGHWAY PROJECTS

A. Highway Bridge Replacement Rehabilitation Program

B-22	PIN 3037.23	Rt. 31 Clyde - Savannah Bridge over Conrail

B. Non-Federally Aided Projects

P-36	PIN 3030.03	Rt. 350 Macedon to Rt. 104

WAYNE COUNTY
LOCAL FUNDED HIGHWAY PROJECTS

P-37	Sodus Center Rd., C.R. 241 - Barclay to N. Geneva Rd.
P-38	Maple Street Rd., C.R. 242 - Zurich Rd. to Champlin Rd.
P-39	Minsteed Rd., C.R. 228 - Decker Rd. to Lee Rd.
P-40	Ridge Rd., C.R. 143 - West of Village of Wolcott
P-41	Wolcott - Spring Lake Rd., C.R. 262 - Yates Rd. to Saeli Rd.
B-23	Christian Holler Rd. Bridge

Table F.3
Project Descriptions for Figure F.6

ONTARIO AND YATES COUNTIES
FEDERAL AND STATE FUNDED HIGHWAY PROJECTS

A. Federal Aid Primary System (Rural) Projects

P-43 PIN 4035.03	Rt. 332 Canandaigua North Main St. (Buffalo St. to North City Line)
B-24 PIN 6042.07(01)	Rt. 364 Penn Yan-Potter Pt. 3: Bridge over Nettles Valley Creek

B. Highway Bridge Replacement and Rehabilitation Program

B-25 PIN 6042.08(01)	Rt. 364 Penn Yan-Potter: Bridge over Sugar Creek
B-26 PIN 4084.07	Rt. 21-2 Bridge and 1 culvert over Sucker Brook, City of Canandaigua
B-27 PIN 4750.81	Saltonstall Street Bridge over Feeder Canal, City of Canandaigua

ONTARIO COUNTY
LOCAL FUNDED HIGHWAY PROJECTS

P-44	W. Bloomfield-Pittsford Rd. in W. Bloomfield to C.R. 35
P-45	C.R. 32 in Canandaigua
P-46	C.R. 32 in Canandaigua and Bristol
P-47	C.R. 32 in Bristol
P-48	C.R. 23 in Phelps
P-49	C.R. 14 in W. Bloomfield
P-50	C.R. 40, E. Bloomfield

Table F.4
Project Description for Figure F.7

LIVINGSTON COUNTY
FEDERAL AND STATE FUNDED HIGHWAY PROJECTS

A. Highway Bridge Replacement and Rehabilitation Program

B-28	PIN 4750.84	Cheese Factory Rd. over Kesequa Creek; Hunts Hollow over Conrail, vicinity of Dalton

Figure F.2: Genesee, Monroe, and Orleans Counties

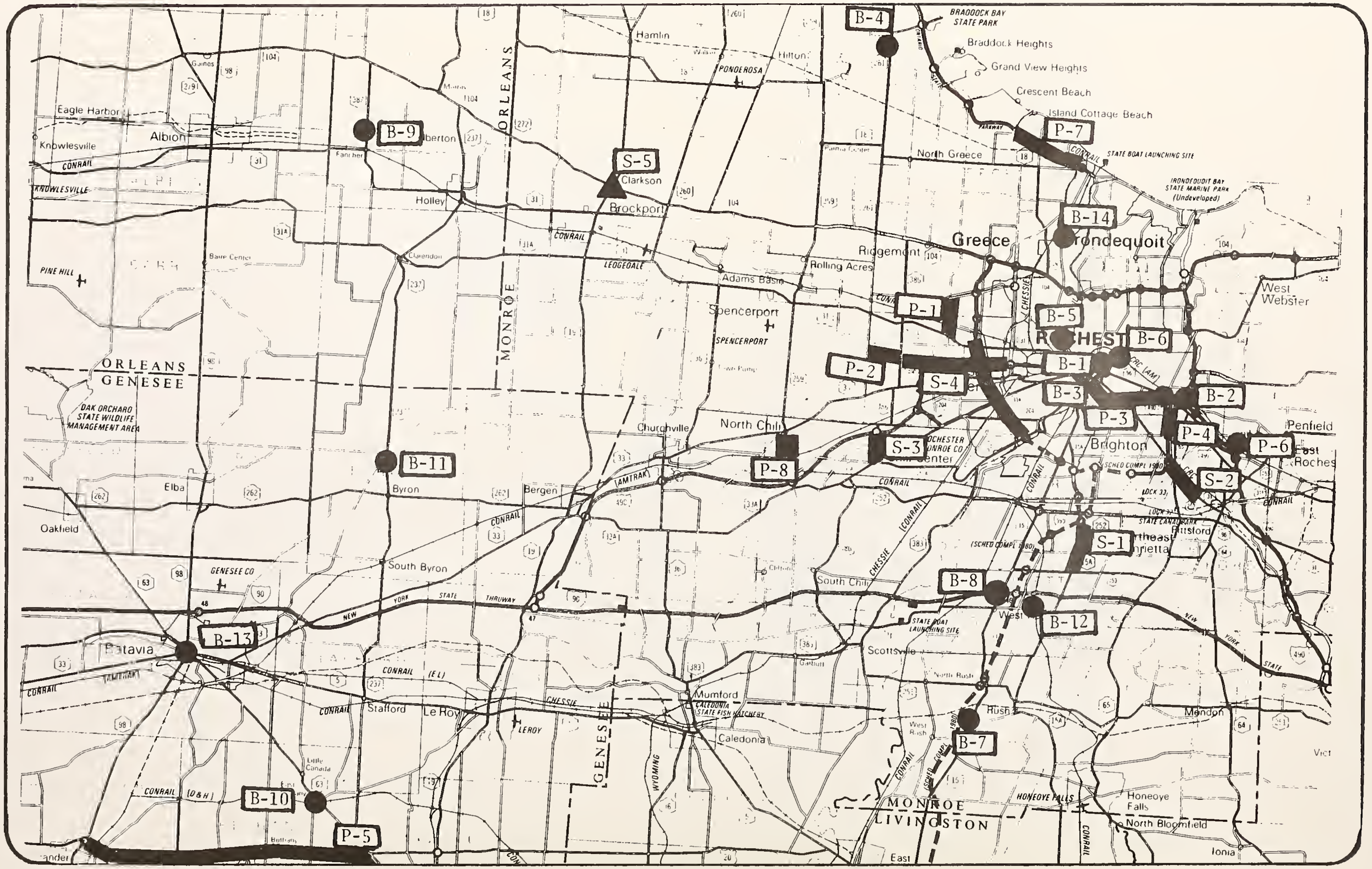


Figure F.3: Monroe County

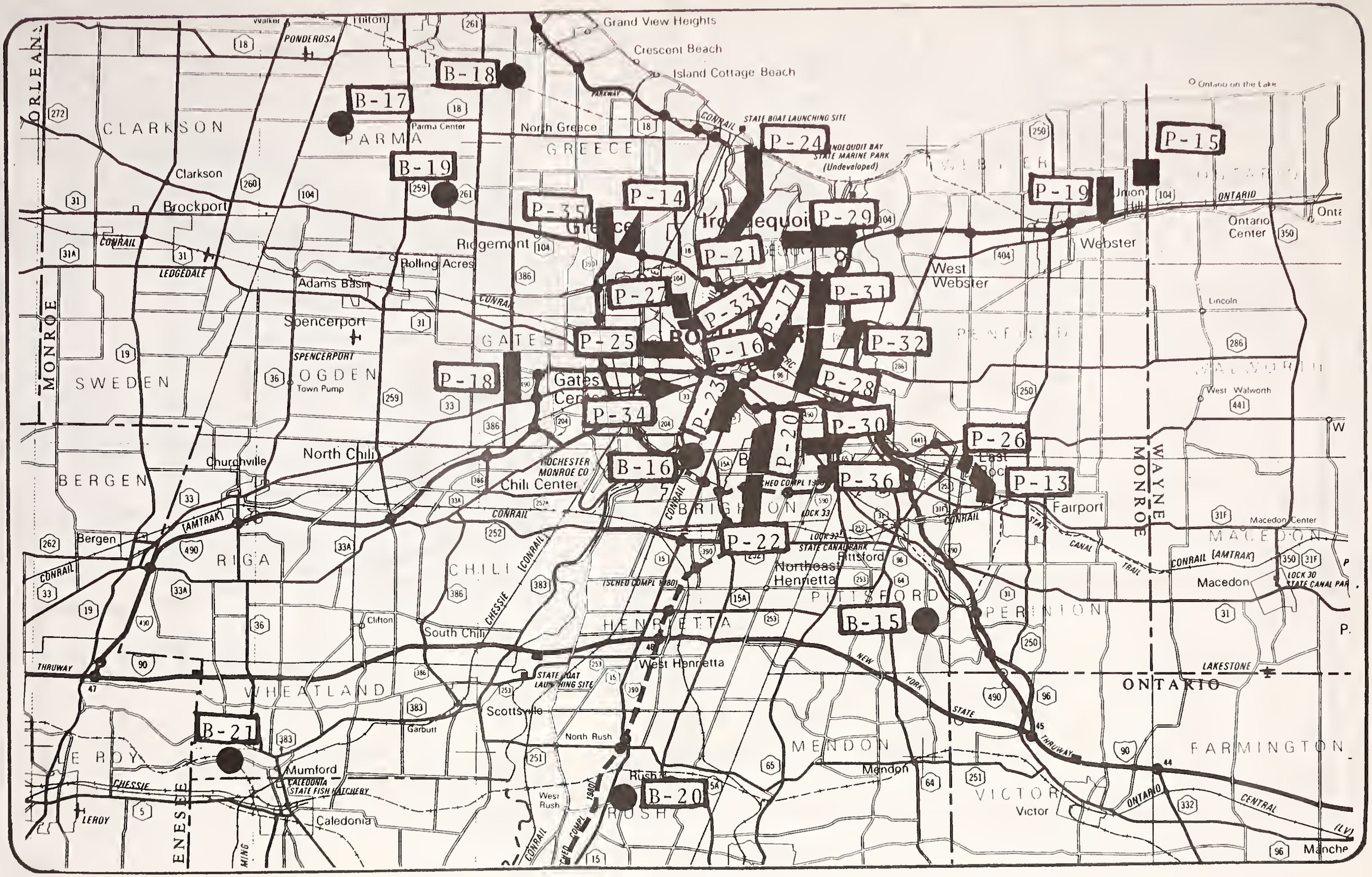


Figure F.4: Monroe County

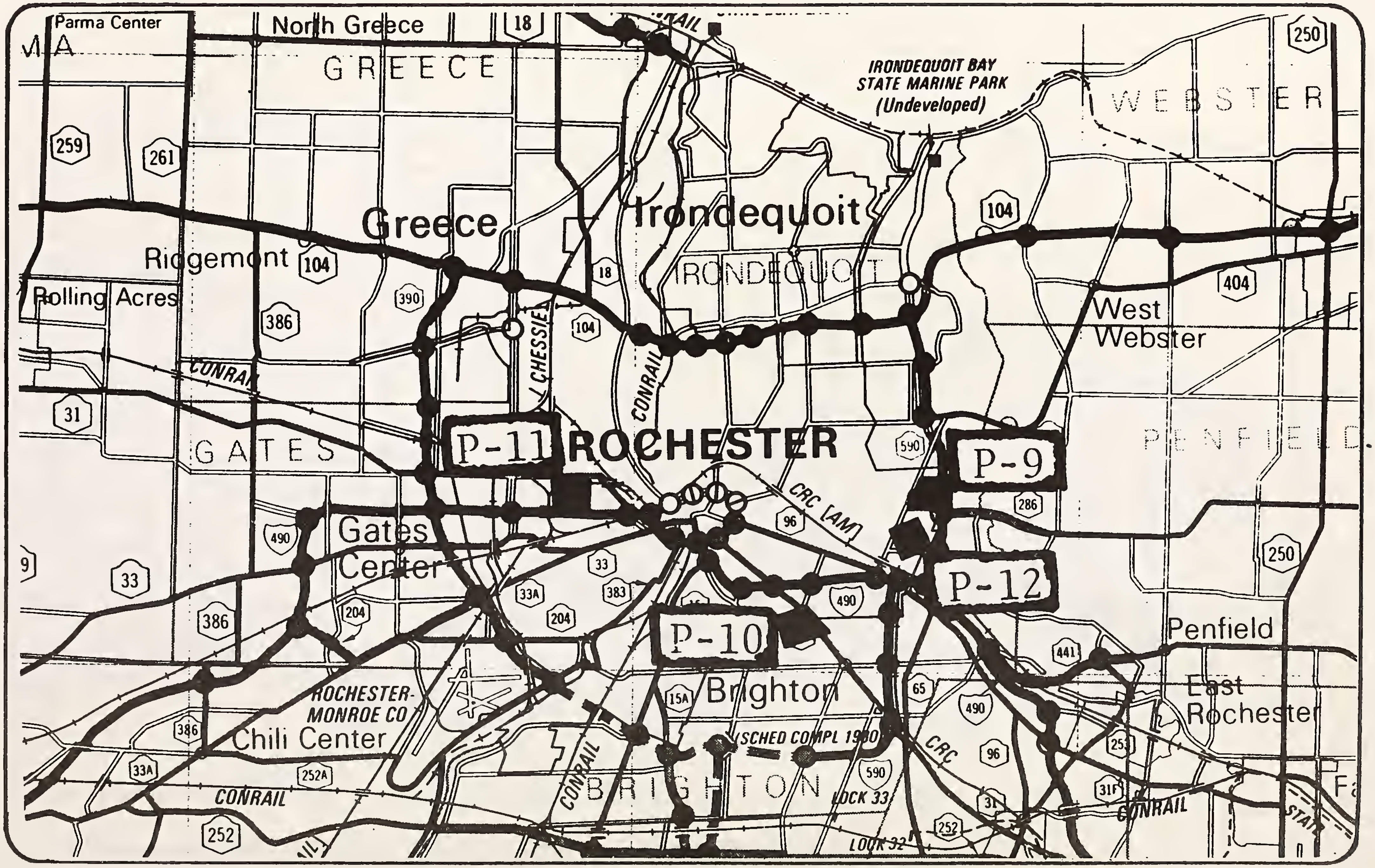


Figure F.5: Ontario and Yates Counties

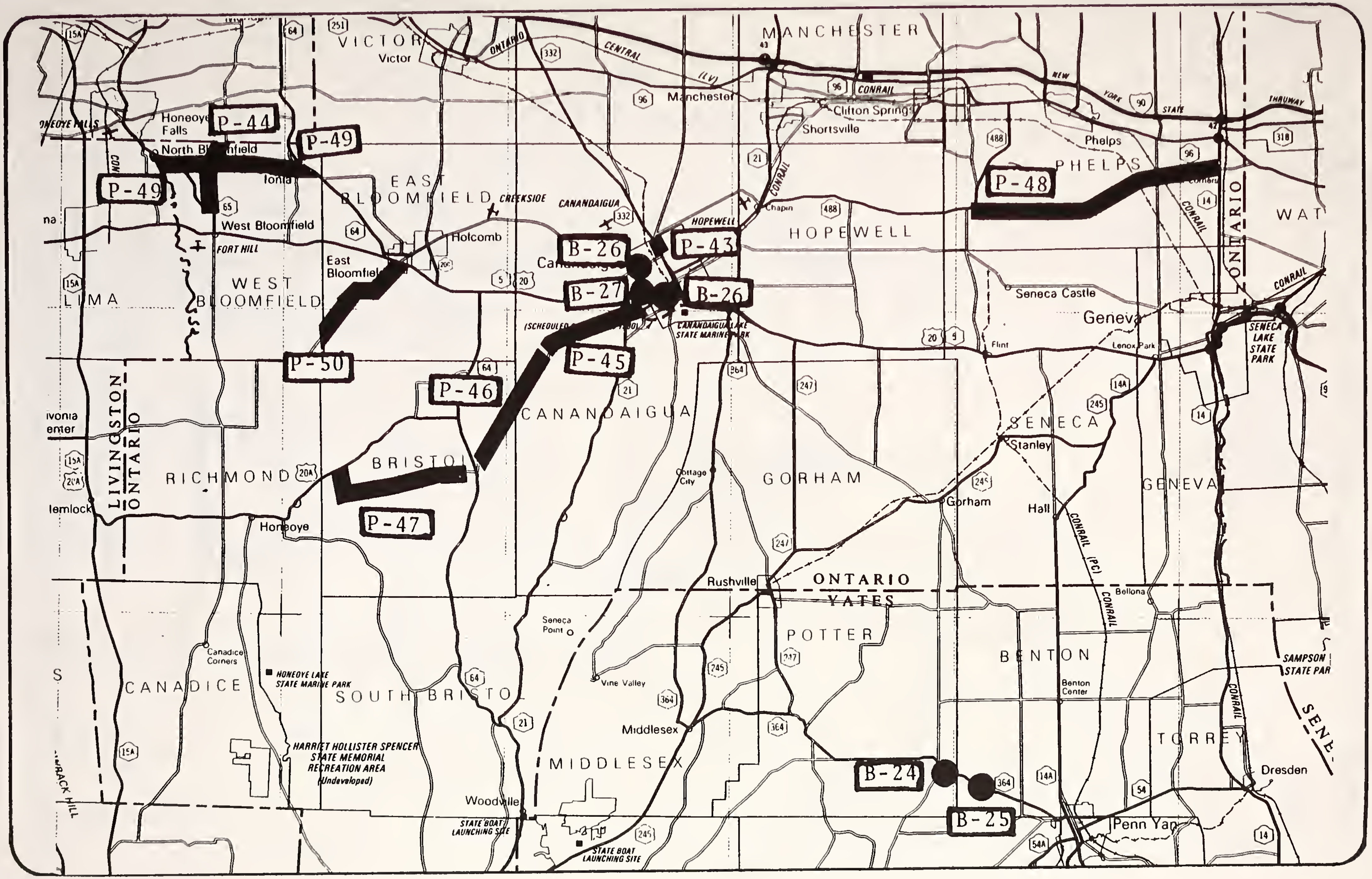


Figure F.6: Wayne County

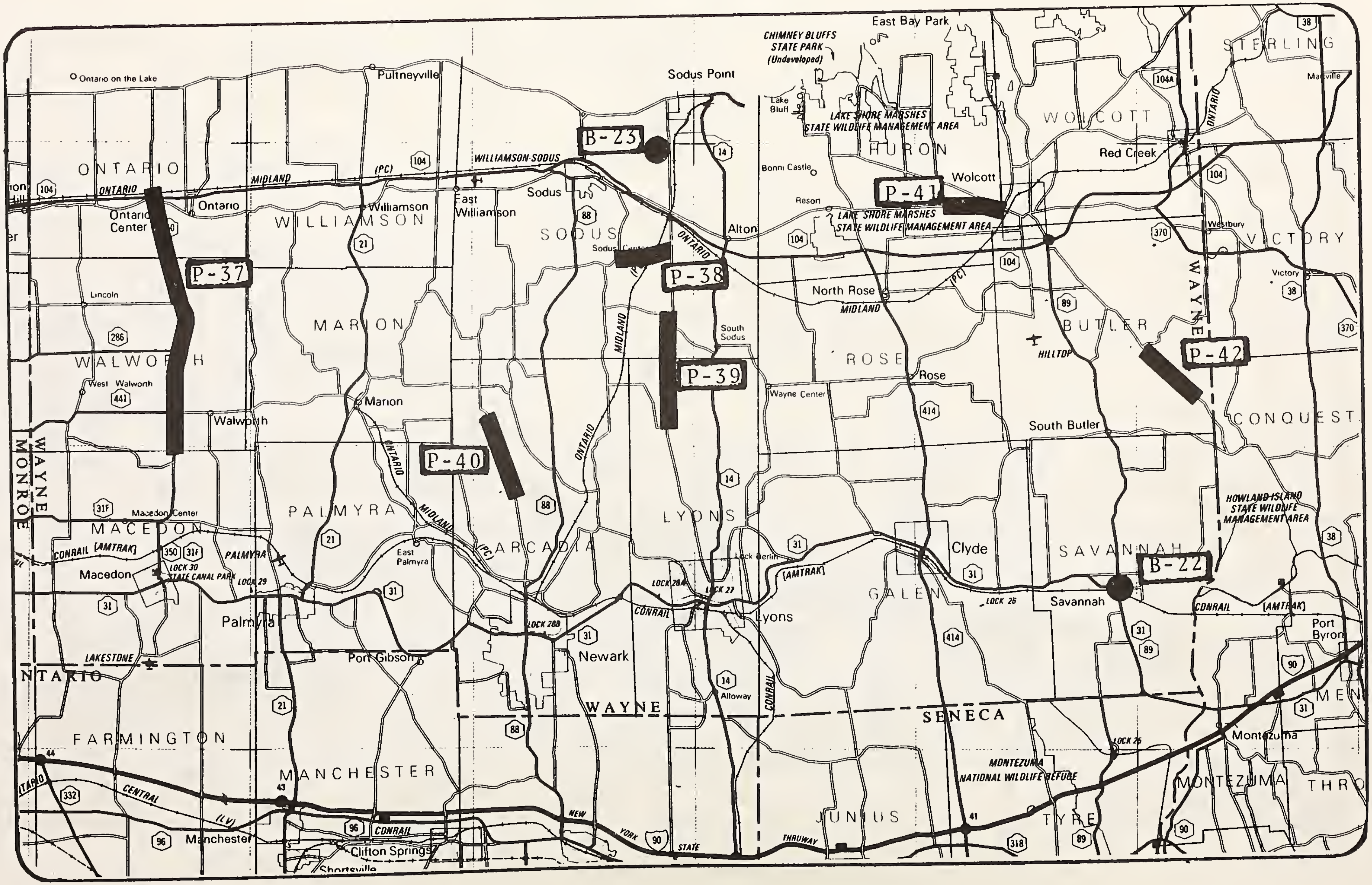
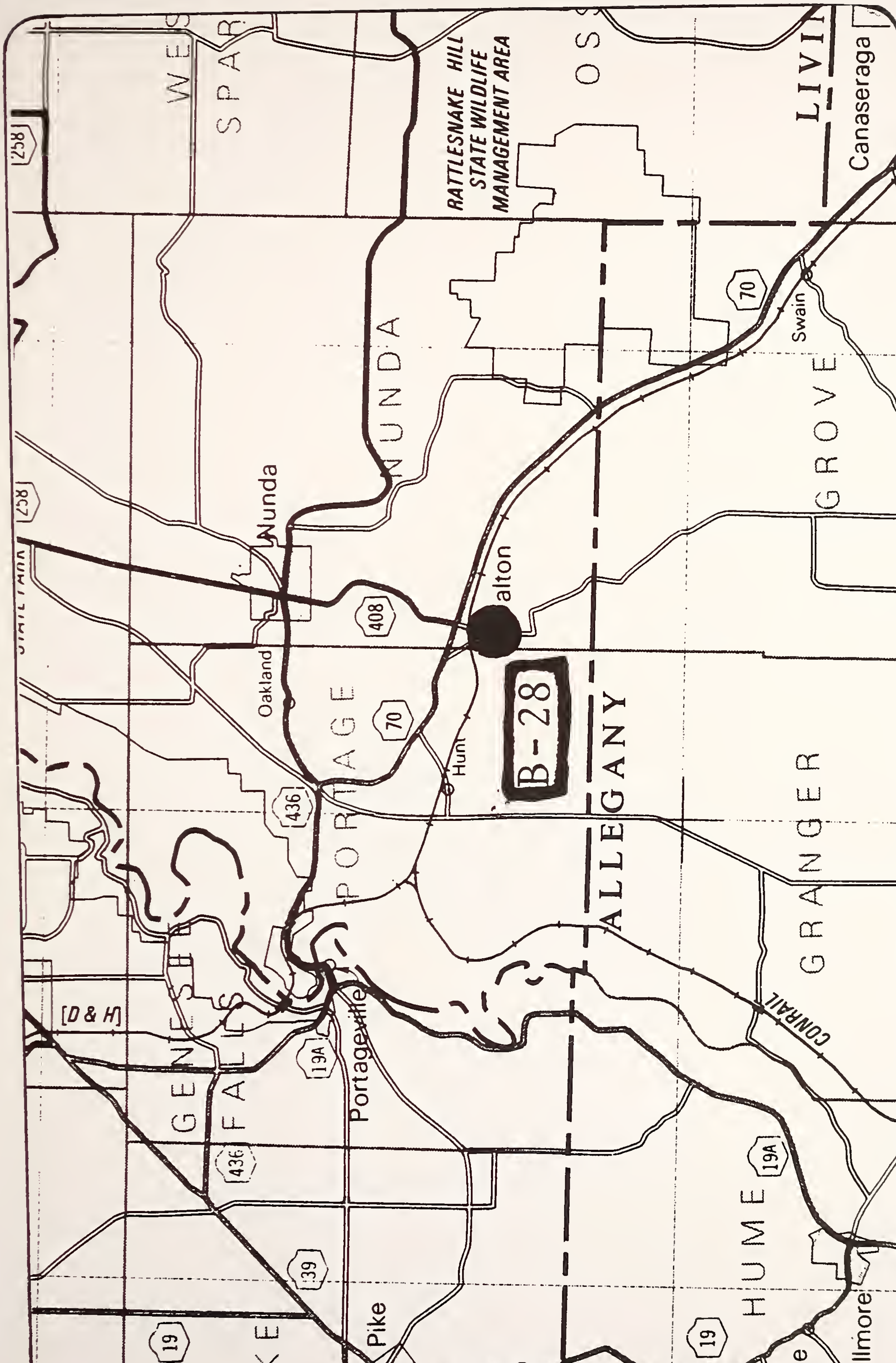


Figure F.7: Livingston County



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