TRANSPORTATION ENERGY CONSERVATION:
TOOLS TO MEET THE NATIONAL OBJECTIVE

Summary of Meeting Held at
Argonne National Laboratory
February 12, 1976

Sarah J. LaBelle
Editor

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TRANSPORTATION ENERGY CONSERVATION:
TOOLS TO MEET THE NATIONAL OBJECTIVE

Results of a One Day Meeting
edited by
Sarah J. Labelle

Energy and Environmental Systems Division

March 1976
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TRANSPORTATION ENERGY CONSERVATION TOOLS TO MEET THE NATIONAL OBJECTIVE

Results of a One Day Meeting
by
Sarah J. LaBelle
Energy and Environmental Systems Division
March 1976

1. PURPOSE OF THE MEETING

A meeting to discuss ways to achieve energy conservation in urban transportation systems was held at Argonne National Laboratory on February 12, 1976. The Energy and Environmental Systems Division sponsored the meeting of Chicago area transportation planners and researchers with ERDA Conservation representatives from Washington, D.C. The energy and transportation professionals convened to explore the current situation in urban transportation energy use in terms of the strategies available to reduce energy consumption in the future. The focus was on the practical aspects of strategy implementation and on the role of government - federal, state, regional and local - in research, evaluation, and implementation of these strategies. The needs of local planners, as well as their data and professional resources, were presented for discussion. Of special concern to the participants is the adaptability of existing planning models and methods to the design and implementation of energy conservation strategies. Given the pressing need to incorporate the use of energy resources as a planning variable, the ability to use existing methods hastens us towards the day when energy resource use will directly affect planning decisions. The interdependence of transportation systems and land use patterns was recognized, as well as the complexity of attempting to deal with both simultaneously.

2. CURRENT ACTIVITIES (Morning Speakers)

- Summary of presentations -

2.1 Energy and Environmental Systems (EES) Division Staff

Presentations by the EES staff members and other Argonne National Laboratory staff highlighted the use of existing techniques in solving energy
conservation problems. Concepts to structure the analysis of energy consumption in urban transportation were set forth. Descriptions of ongoing programs that bear on the topic of transportation energy consumption were submitted to the group.

*URBAN TRANSPORTATION PLANNING - Sarah J. Labelle*

We are focusing on transportation energy conservation - that is, trying to provide the same or better level of service in the transportation system yet consuming less energy to do it. Towards this goal, then, we need a conceptual model of the urban transportation system that highlights the controlling factors for energy consumption. A very simple model meeting that requirement is found in Figure 1. Public policy both directly and indirectly influences the amount of energy consumed in urban areas. This concept is expanded in Figure 2, which specifies more completely the nature of the interaction between the public and private sectors. Examination of the conceptual model depicted in Figure 2 leads to the definition of four focuses for conservation research: (1) the planning process, (2) modeling and data base development, (3) policy impacts and (4) technology commercialization and utilization.

Many specific programs can be outlined under each topic. In examining the transportation planning process, a guidebook through the maze of existing planning requirements, illustrating the impact of planning decisions on energy consumption would be useful both to transportation planners and energy planners. In outlining any program, the need for pertinent data becomes immediately apparent. Fuel consumption data, for example, are available on a highly aggregate basis compared to the needs of regional and local planners. Slight changes in the reporting method for motor fuel tax collection could ameliorate this situation. Following the model of air pollution regulation studies, the economic impact of proposed energy policies can be evaluated in a cost-effectiveness or cost-benefit framework. Lastly, in the area of technology utilization there is a great need to ease the entry into the market place of right-of-way and vehicular improvements which increase energy efficiency. Examples include regenerative braking in rail transit and drive train improvements in internal combustion automobiles.

The speakers coming up next will illustrate approaches which can be taken in analyzing energy conservation issues. The use of simulation as a
Figure 1. SIMPLIFIED VIEW OF THE URBAN DEVELOPMENT PROCESS
Fig. 2. Urban Development Process
modeling technique, the importance of land use and site design in total urban energy consumption, vehicle technology and commercialization will be addressed.

*AIRPORTS AND AIRCRAFT - A SIMULATION EXPERIMENT - Richard R. Cirillo*

Simulation modeling is one of the techniques very frequently used in environmental analysis. I would like to give you a very specific example of how we use this tool to look at a specific component of the urban system, an airport.

The ELS Division has been studying airports from an air quality perspective under the sponsorship of the U.S. Environmental Protection Agency, the U.S. Federal Aviation Administration and the Air Force. In the fall of 1973, the EPA and FAA undertook a test program at the Atlanta Airport to determine the impacts of going to a particular kind of ground operation and control strategy. Specifically, the strategy requires that all inbound aircraft shut one engine off while taxiing into the terminal area, and selected aircraft shut down one engine while taxiing out and restart at the end of the runway.

To analyze this particular situation, we constructed a fairly detailed simulation model of the airport. The driving functions were passenger demand and cargo demand (how much cargo was being shipped out of the airport). This generates a certain requirement for employees, and a fair amount of visitors at the airport. All of these combine to generate an access traffic flow pattern for the airport ground traffic. The passenger and cargo demand also drove the aircraft activity index. Aircraft activity has certain demands associated with it: ground service vehicles, fuel storage and handling, and engine test facilities. There were also requirements for hangers and terminals, which determine the space heating requirements. The simulation that we built was fairly detailed. We outlined very specifically the path that an aircraft would take from terminal to runway, profiling the speed as it was going out to determine where the aircraft had to slow down, where it had to wait in a queue. Similarly for the ground access traffic, we identified the access traffic in terms of vehicle type, vehicle mix, vehicle speeds. The fuel storage and handling systems and ground service vehicle activities were geared to the aircraft activity themselves.

All of the circles on Figure 3 represent sources of air pollutant emissions; by extension they also represent energy consumption sources. The model, in addition to predicting emissions and energy consumption, allowed us
Figure 3. A MODEL OF AIRPORT ACTIVITY
to make the transition from those parameters to air pollutant dispersion. One use of the simulation package was to evaluate several different strategies. The engine shutdown strategy was in fact tried at the Atlanta Airport. At the same time we were able to conduct tests on the effectiveness of capacity control, i.e. increasing the passenger load factor on all flights in and out of the narrow body aircraft and phasing in all wide body aircraft, speeding up the natural progression of fleet mix change. There is the possibility of towing aircraft instead of having aircraft taxi in and out under their own power, and also one technological fix, the fix of engine emission standards promulgated by the U.S. EPA. All of these strategies were evaluated for their impact on air quality. An energy analysis is merely one more step in the analysis.

*SITE DESIGN AND ENERGY CONSUMPTION - Danilo J. Santini*

In the context of a National Science Foundation (NSF) project, we have been studying the new town concept in urban contexts with reference to environmental considerations. We are interested in studying the same concept with respect to energy considerations, and relating it to a proposed project in the Chicago area called the South Loop New Town. It is located just south of the Loop (central business district). Rather extensive development would continue up to the year 2000. The approach that we have taken is to model and collect data on the environmental problems, assess our results and recommend some public actions. Primarily, we generate policy statements. The statements go out to planners and individuals who might be interested in our results, and hopefully, that results in private actions as a response.

The new town concept is somewhat of an old concept. An example is the town of Farsta, Sweden, built in 1958. By contrast to Farsta, an independent town, our work looks at a new-town-in-town, a community within the city. A small scale version of this can be found in the South Commons development in the Chicago area. The total population is much smaller than the proposed South Loop New Town, but the densities are similar.

To familiarize you with some of the characteristics of a new town, here are some of the findings of the NSF project. We find that environmentally, the new town close to the core employment area is a desirable concept with respect to air quality. It improves air quality because it reduces automotive emissions by reducing total vehicle miles traveled. If you build a new town downtown instead of building a development somewhere in the suburbs,
this means that the people who live downtown, if they do drive, are going to drive shorter distances, and in many cases they are going to substitute public transit for auto use. So whenever public action can encourage the construction of communities closer to place of employment and have people live there instead of a more distant location, the energy and environmental picture is improved.

It is also interesting to look at overall air quality. Though people often think that the downtown areas are environmentally worse, an air pollution index which we developed indicated that the center city frequently was better than the suburbs in terms of the five pollutants analyzed by U.S. EPA. In fifty to eighty percent of the cases, the center city was better than the suburbs, based on five Chicago area monitoring stations, including a very high carbon monoxide count at one of the center city monitors. Looking at building configuration only from the point of view of exposure to polluted air, which is of course extreme since there are other considerations, a high rise building is more desirable than several low rises because more of the residents are removed from higher ground level pollutants.

Given the desirability of the new town concept, at a given density, how is the goal of energy conservation realized? There are many aspects to this problem; only a few will be addressed in detail here. However, we present here a comprehensive list of dimensions (Table 1), open to suggestions, that is intended to cover the options open to a designer. A brief description of each dimension follows.

**TABLE 1. Variable Elements**

1. Building Configuration
2. Vertical Transportation Costs
3. Vertical Differences in Meteorology
4. Surface Design Features
5. Building Materials
6. Building Orientation
7. Heating-Cooling System Efficiencies
8. Administrative or Operating Characteristics
Building configuration: This describes whether a building is square, rectangular, or round in cross section; whether it has two floors or twenty floors.

Vertical transportation costs: The higher you have to lift people, the more energy you have to use in lifting the dead weight of an elevator, so at some point as you go up in a high rise, you would expect the cost of lifting people up and down to become substantial.

Vertical differences in meteorology: An example here in Chicago is the John Hancock Tower, where the people who live in the top of the tower are actually exposed to different weather conditions than the people who live on ground level.

Surface design features: These include balconies, sunscreens, etc.

Building orientation: If you look at the Chicago skyline, very few high rise buildings respond to the fact that the sun comes from the south. Typically, the north side of the building has exactly the same design as the south side of the building.

Heating-cooling efficiency: This dimension delineates the use of solar energy, gas or electricity; whether there is a central unit that heats and cools ten buildings or whether there are ten separate units that heat and cool each building.

Administrative operating characteristics: For example, assigned parking places reduce search time when people come home. Other characteristics include whether individuals are charged for heating and cooling costs on a separate basis or whether that's included in the rent.

The first two items will be examined in further detail herein.

My hypothesis is that the least efficient dwelling units are units that are found at the top of the extreme high rise. For example we see here in Chicago the John Hancock building, which has residential floors from 45 to 92; in other words, the people who live in the residential area in this building must be hauled 45 floors before they even get to their residence, aside from the fact that all the structural material was lifted up to that level to build the thing in the first place. Then at the other extreme, there is the single family dwelling unit with four or in some cases, even more exposed sides, an exposed roof, and in some cases quite a bit of glass. On a per
square foot basis this building does not do well in terms of energy consumption in heating and cooling.

Somewhere in the middle of this density curve (Fig. 4) is the most efficient configuration. It is not clear where it is, nor is the shape of the curve documented. It is only a hypothesis, one element of a study that might be conducted. For a community like the South Loop New Town, it would be useful to know whether the townhouses, multi-story walkups, or 11-30 floor high rises are more energy consumptive on a per-standardized dwelling unit basis. Is this curve actually flat in the midrange densities or are there some substantial differences between these different types of buildings?

One potentially useful tool is the elevator efficiency index, which involves the square footage served by the elevator. It is inversely related to the expected number of floors that you have to haul passengers in the dead weight of the elevator. The more square feet of residential area that is serviced by a given elevator, the more people are going to use that elevator. Like an airplane, the load factor would then be higher and the operation more energy efficient. Another measure of interest is the amount of outside wall per standard unit. Except in the case of a solar heating system, it is desirable to minimize the outside wall per standard unit. In a high rise, for example, a corner unit has two exposed walls as compared to one in the central unit. Thus, a design minimizing corner units relative to total units would tend to be more energy efficient.

The Marina Towers in Chicago is an example of a very high highrise building which is round in cross-section. The elevator efficiency index value of this building is much lower than for the twenty floor highrises. In this building, one has to go twenty floors before one gets to the residential floors, similar to the John Hancock Building. It is efficient on the outside wall per standard unit basis. The interesting question for this building is whether or not the implied wall area per unit efficiencies of the round floor plan outweigh the inefficiencies of the elevator system.

At the broader scale the latter trade-off type of question is what this brief and incomplete discussion of site design and energy consumption is all about. We have listed eight factors which may be important in determining the relative energy efficiency of a given site plan. We have more thoroughly discussed only the first two of these eight issues. Even this dis-
Figure 4. ENERGY CONSUMPTION PER DWELLING UNIT AS A FUNCTION OF BUILDING TYPE (HYPOTHETICAL)
Discussion has been rather cursory. However, we have demonstrated our ability to quickly develop methods of analysis of the individual components. None of the comments we received attack the basic nature of this introduction to the problem. Comments were generally critical of the absence of further analysis and inadequate comparison of the components. In other words, the method of research was not criticized but the absence of further research was. In a discussion of a proposal to do research, this is as it should be.

*THE REGIONAL STUDIES PROGRAM - L. John Hoover*

Regional Studies is an Energy Research and Development Administration program being carried out by the national laboratories of ERDA. The goal of this program is to develop a set of alternative energy supply and demand options for various regions of the country and to assess the associated health, environmental, socioeconomic and resource consequences.

In addition to this regional orientation, the program also has a technology focus. As an element of this study, a National Coal Assessment is being conducted which will assess the impacts of increased coal utilization in the United States including the relative impacts and consequences of alternative technology options as a function of the level and geographic distribution of use. This assessment will generate outputs that can be used by ERDA, other Federal agencies, Congress and the states. ERDA can use the outputs of the program in order to determine environmental control and energy technology R&D priorities, evaluate alternative environmental policies and regulations for implementation of coal technologies, and evaluate coal development and utilization policies. Congress, other Federal agencies and the states can use the outputs of the program in carrying out their policy responsibilities in regard to energy and environmental activities.

The complete coal fuel cycle is being addressed in this program from extraction through product distribution with the time frame of analysis being the present until the year 2020. The focus of the program will be on commercial application and implementation of coal technologies with specific emphasis on the potential bottlenecks or constraints to increased coal use. The impact analysis to be carried out covers the full range of associated health, environmental, resource and socioeconomic consequences. The geographic scale of analyses includes both local, regional and national effects.
Assessments will be carried out at four levels of analyses. These represent a hierarchical structure in which the lower level of assessments contribute to higher level studies. The four levels of assessments are technology, geographic, coal utilization and interfuel. Technology assessments evaluate the relative impacts of alternative modes of coal production, transport and use on a region sensitive basis. Geographic assessments evaluate alternative patterns of implementation of increased coal use such as clustering or dispersion of energy conversion facilities and various rates of coal development. The coal utilization assessment integrates and synthesizes the previous assessments into a regional and national perspective on increased coal use. Finally, the interfuel comparison places coal in perspective by comparing coal vs. other energy options.

In order to conduct these various assessment levels, technical studies will be carried out in the following areas: scenario development, technology characterization, siting analysis, health and environmental impacts, socio-economic impacts and resource utilization. The various assessments will be generated by integrating these particular technical studies within a common framework.

*COMMERICALIZATION - Kevin Croke*

The focus of this presentation is the process of commercialization of new technology as it is associated with the electric power industry. The work is being done in the context of a U.S. Energy Research and Development Administration (ERDA) program, within the Community Systems Division of the Office of Conservation. To begin, here is the definition of commercialization worked out for the program, in five steps:

1. Characterize cost and performance,
2. Characterize market structure,
3. Define market impediments,
4. Forecast market penetration,
5. Design marketing program.

The first step in such a study is to characterize the cost and performance of both the present technology and the conservation measure being examined. A comparison can be made either with a number of competing technologies, or some baseline technology that is presently dominant in the mar-
ket. The second aspect of the program is to look at the market structure into which the technology is going to be introduced. A third aspect of the commercialization problem is to determine what are those impediments which could stop introduction of the conservation technology or slow down its rate of market penetration. It can take a number of forms; one of the most significant is the regulatory restraints, for example, environmental. We will be getting involved with groups like the Securities and Exchange Commission. Commercial banking practices can be an impediment that is not always economically based. There are a number of impediments to entry that we should investigate. We also would look at, because this is a federal government program, alternative policies. Perhaps certain government policies will have to be created to overcome these impediments.

The next to the last phase is to make a market penetration calculation or forecast for the technology of interest. The final stage is a marketing program, which consists of educational programs, financial incentives, government policies, proposed regulatory changes. We are aiming for that final step, but obviously we are in a far earlier stage of the process. Actually, this kind of a study is in some way an integration of some of the studies we have done here but have never put together under one umbrella.

The first commercialization study that the EES Division did for U.S. ERDA had to do with off-peak storage technology. The general problem here is that the utilities are operating increasingly at poorer and poorer utilization rates over time because their loads are becoming more uneven. A diagram of required capacity versus the percentage of time that the capacity is required, would illustrate this problem. Peak capacity requirements have been growing at a much faster rate than average loads. The utility, of course, has to plan for peak demands. It has to plan for the maximum load as specified by its regulatory charter. Thus, utilities have had to rely on off-peak units more and more, which now use oil. Previously they used natural gas. The reliance is less on base load units that use coal and nuclear power. A base load plant could have a utilization factor of 60%, with low unit cost of operation. There are intermediate units, older coal fired plants that have 30% utilization factor and a higher unit cost. The peaking plants have less than 10% utilization at a very high unit cost. The heavier reliance on peaking units to meet demand is raising utility cost.
It is not just the cost that's involved here. It is the fact that these plants are using petroleum based products. So in looking at off-peak storage systems, what is needed is some way of running base load systems constantly, be able to store the power over the off-peak hours (nighttime), then be able to use that stored power during peak periods. Then we can reduce the use of peaking units.

One of the big problems that must be addressed in commercialization studies, is that our nation is behind in generating off-peak rate structures. With an off-peak rate structure a home owner or community, if willing to buy a storage system, could get power for 20% of peak rates. The Wisconsin Rate Commission has recently come up with some calculations like this; indeed the off-peak rates are about 20% of the peak rates. That is a fairly sizable incentive to commercializing home storage systems. The Europeans have been much more sensitive to load management than we have been, so there is some experience for us to learn from.

In support of this work, I would like to state my view: based on the experience of commercialization studies and somewhat more extensive experience in the National Science Foundation work and other assessment work we've done, in the short run, off-peak strategies are going to produce more conservation in the next five to ten years than the development and application of new technologies. Off-peak storage allows a utility to keep its basic mix of technologies. The storage device is added on and does not require extensive conversions. In the long run, utilities will probably change direction. But in the next ten years, it is really a technological, regulatory and financial fix.

*ELECTRIC VEHICLES AND HIGH TEMPERATURE BATTERIES*

A. A. Chilenskas, Chemical Engineering Division

My presentation focuses on the development of a high temperature and a high energy battery system which can be used both as energy storage for utilities and as a power source for electric vehicles. I would agree with the previous speakers that the emphasis for electric vehicles is not so much on energy conservation or the improvement of air quality, as much as it is substitution for petroleum by the use of coal or nuclear energy in the form of electricity. With advanced batteries such as the ANL lithium/iron sulfide system, sufficient range is provided to the electric vehicles (automobiles, vans, buses) that charging during the day is not required. Off-peak energy
can thus be used to charge these vehicles at night permitting higher use of existing electrical generating equipment and potentially cheaper electricity cost.

The work described here is being carried out at Argonne National Laboratory, in the Chemical Engineering Division.

The battery developed at Argonne has a lithium-aluminum (negative) electrode and an iron sulfide (positive) electrode in a molten salt electrolyte. This is a high temperature, high energy system. The operating temperatures is about 450°C at atmospheric pressure. One design goal - energy of 150 watt hours per kilogram - has been achieved in sealed laboratory cells. This is considerably more energy per kilogram than a conventional lead-acid battery. Of course, there is still significant laboratory and engineering development to be completed before this battery system becomes a commercial reality.

Cells are currently being fabricated for testing for Argonne by commercial battery firms. The performance goals for these cells are shown in Table 2.

The performance of a sub-compact sized electric vehicle that would be equipped with these cells is shown in Table 3. As noted, a car equipped with a battery meeting 1978 goals would serve quite well as a "second-car" while the car equipped with the battery expected to be available in 1981 would have performance equal to today's gasoline powered sub-compact.

Our current design effort is to build and test a full-scale 30 kW-hr battery in a vehicle early in 1978. It is expected that a full-scale demonstration battery meeting program goals will be ready in 1981 and a commercialization goal of a mass-produced battery available about 1985.
TABLE 2. Performance Goals for industrially-Fabricated Cells

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<tr>
<td>Specific Energy, W-Hr/Kg</td>
<td>75</td>
<td>100</td>
<td>100</td>
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<tr>
<td>Peak Power(^a), W/Kg</td>
<td>75</td>
<td>100</td>
<td>200</td>
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<tr>
<td>Energy Efficiency, %</td>
<td>70</td>
<td>73</td>
<td>75</td>
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<tr>
<td>Lifetime(^b)</td>
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<tr>
<td>Deep Discharges</td>
<td>200</td>
<td>400</td>
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<tr>
<td>Automobile Cycles</td>
<td>600</td>
<td>1,290</td>
<td>2,400</td>
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<tr>
<td>Equivalent Miles</td>
<td>20,000</td>
<td>40,000</td>
<td>80,000</td>
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<tr>
<td>Years of Use</td>
<td>2</td>
<td>4</td>
<td>8</td>
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\(^a\)15 second pulse. Cell discharged to 50% capacity at C/4 rate.

\(^b\)Lifetime based upon a deep discharge equivalence to 100 miles. Automobile cycles based upon 5 cycles/week at 20 miles/cycle and one cycle/week at 100 miles/cycle (10,000 miles/year).
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<td>Test Weight (136 Kg Load), Kg</td>
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<td>1,272</td>
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<td>Cell Weight, Kg</td>
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<td>Battery Weight, Kg</td>
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<td>Battery Output at Terminals</td>
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<td>Energy, Kwh at C/r Rate</td>
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<td>Peak Power, Kw (15 Second Pulse)</td>
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<td>Acceleration</td>
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<td>0-64 Km/Hr, Seconds</td>
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<td>0-89 Km/Hr, Seconds</td>
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<td>&lt;15</td>
<td></td>
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<td>Top Speed, Km/Hr</td>
<td>&gt;97</td>
<td>&gt;97</td>
<td>&gt;129</td>
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<td>Driving Range, Km</td>
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<td>Residential (SAE J27)</td>
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<td>At Constant Speed, Km/Hr</td>
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<td>40</td>
<td>600</td>
<td>600</td>
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<tr>
<td>89</td>
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2.2 Research Centers

The informal presentations by representatives of various energy research programs being carried out, or proposed, in the Chicago area describe the directions of transportation energy conservation research, emphasize the fruitful use of existing techniques and the problems caused by the largely inadequate data base.

*A SIMULATION MODEL OF TRANSPORTATION, LAND USE AND ENERGY INTERACTIONS IN AN URBAN AREA*

Robert L. Peskin, Joseph L. Schofer
Department of Civil Engineering
Northwestern University

The problem we are exploring is the relationship between the transportation system, land use and transportation energy consumption. The work is funded by the U.S. Department of Transportation (University Research). One constraint on the work is that only existing modeling techniques will be used; no technique development is allowed. It is felt that existing methods have much to offer in this analysis. Previous study by Jerry L. Edwards at Northwestern University forms the point of departure for this effort. Edwards' work was a computer simulation study of the energy consumption and accessibility characteristics of approximately 40 different hypothetical urban forms, defined in terms of shape, density, transportation network, and land use arrangement. With the significant improvements we have made to Edwards' method, the model will prove to be an efficient one for studying and explaining energy-land use relationships in the context of more realistic cities. It is proposed in this research that Edwards' computer model be advanced in realism, made more efficient and responsive to promising policy options, and -- to a limited extent -- be validated. It will then be used to test some of the policies that have been proposed in the face of the energy crisis, as well as to extend the previous studies to include additional and more complex urban forms.

This effort makes a significant contribution to the development of both national and regional policies related to the development of urban land use as it affects energy consumption and the use of other natural resources. The products of this research are intended to serve as strong guidelines for the assessment and implementation of land use controls, for the allocation of
resources for urban development, and for the development of regional and local land use plans. The revised computer model is to be a useful research tool for transportation and land use planners. It will be possible to conduct many additional urban transportation and land use planning experiments with the model once this research is completed. Ultimately, the modeling philosophy may be adapted to the form of a more general policy evaluation model as opposed to a pure research-oriented model.

The fundamental purpose of this research is to identify those policies which will reduce urban transportation energy consumption. Yet, to be politically viable, such policies must minimize the degradation of the quality of life that may result. This could be measured in terms of the impedance to travel in the land use/transportation system. Toward that end, this research will examine various alternative urban land use/transportation/energy conservation policies, first in terms of their energy consumption impacts and then in terms of their accessibility/mobility characteristics. Research to date is quite limited in this regard. Edwards' work is definitely the most sophisticated although it was limited primarily to an analysis of the physical arrangement of land use, population, employment, and the transportation network. That approach was prompted, in part, by Wilfred Owen's suggestion (in Accessible City, 1972) that proximity may be the best substitute for mobility. By designing cities where the environment allows proximity to supplant mobility, it would seem possible to respond simultaneously to the two goals of providing greater accessibility and minimizing energy consumption. It should be possible to extend Edwards' approach and results to be applicable to existing urban areas, in particular to developing conurbations and redevelopment areas, as well as to establish general guidelines for adaptation of the transportation planning process to changing urban goals.

It will be the intent of this research to show that physical alterations to the transportation system are not necessarily the sole (or best) approach to reducing transportation energy consumption. Rather, a variety of pricing and land use approaches will be examined to determine what impacts they will have. In general, the simulation model used in this research will be more sensitive to non-transportation network policy decisions and will provide a much more quantitative analysis than Edwards' research.
A conceptual model of the simulation is presented in Figure 5. The dashed lines indicate the extensions of our work beyond Edwards' study. Indeed, energy consumption and other pricing effects are allowed to influence land use. Also, mode split (auto/transit) is influenced by the energy costs and the land use pattern.

Preliminary development and testing of the model on empirical data are now completed. A refined model, with a fictitious city's data base, is nearly ready to begin sensitivity analysis and, finally, the simulation experiments. The Energy and Environmental Systems Division here at Argonne is involved with these latter two phases of the study.

*A NONLINEAR PROGRAMMING MODEL FOR MINIMIZING ENERGY CONSUMPTION IN URBAN LAND USE AND TRANSPORTATION SYSTEMS*

by

Deepak Bhatti
Systems Engineering Department
University of Illinois at Chicago Circle

The model described here is an extension of the existing multiple objective function, land use policy model developed and made operational by detailed studies conducted jointly by the University of Illinois at Chicago Circle and the DuPage County Regional Planning Commission. More detailed description of the model and its application can be found in two publications, OMEGA, The International Journal of Management Science, July-August, 1975 and Environment and Planning A., March-April, 1976. The model as presently used allocates acreages of 10 land use types into 147 regions of two square miles or less that are mostly undeveloped. Multiple objectives and constraints on desired growth patterns are considered simultaneously in arriving at the optimal acreages. Objectives that are currently considered are: (i) minimization of conflict between different land uses, (ii) minimization of travel distance of new trips to the existing transportation network, (iii) generation of a fiscally sound plan which minimizes the overall tax cost index, and (iv) minimization of adverse environmental impact, and (v) minimization of capital costs for community development. Constraints are established on land use types and regions to specify the range of feasible solutions. For example, constraints are put on acreage for each land use type on a county -
Figure 5. CONCEPTUAL MODEL OF SIMULATION
wide basis by considering the projected population, employment, forecasted mix of residential dwelling units, and the desired people per acre of local commercial land, schools, or open space.

Linkage between land use and transportation planning exists in two ways already. Firstly, the transportation objective function in the land use model minimizes the travel time of trips generated by the new residents in the County by locating high trip generator kinds of land uses in regions of high accessibility. Secondly, there have been several interactions between the land use study and the multi-modal transportation study of the County. The preliminary land use allocations were used to develop a preliminary transportation plan was used in developing the final land use plan. Now, the final land use allocations are being used in completing the final transportation study.

Energy Objective

The optimization model has been extended to include an energy minimizing objective function. This objective function is based on a hybrid land use-transportation-energy consumption model. Traditional transportation models take land use allocations as known parameters. However, this model lets both the land use allocations as well as travel behavior be variable concurrently. The energy consumed in traveling between various origin regions of the County to all destination regions both inside and outside the County is obtained by summing over all modes of transportation, origin and destination regions, and origin and destination land use types of the product of 1) trip rate between each pair of land use types 2) existing and proposed acreage for the origin land use type in the origin region, 3) probability of termination in the destination region, 4) probability of mode choice, 5) travel distance between each pair of regions by mode and chosen route, and 6) energy consumed between the origin and destination region by mode of travel.

On the other hand, the energy consumed in building and operating structures is obtained simply by summing over all land use types and regions the product of the energy consumed in building and operating structures and the acres devoted to different land use types.

The energy consumed in building structures can be prorated over the life of the structure to yield a daily cost. This building cost is added to the operating cost to yield the energy consumed by stationary users per acre.
per day. When multiplied by the existing and new acres we obtain the total energy consumed by stationary users.

![Figure 6. Opportunity Model Configuration](image)

When the existing and new acres in the origin region for the origin land type are multiplied by the trip rate between the origin and destination land uses, we obtain the total trips originating from land type $i_1$ in region $j_1$ destined for land type $i_2$ in any one of the regions in our study area. The probability that a trip terminates in destination region $j$ is given by the opportunity model formulation. Since the distance between regions is, in general, different for each region pair there is only one region which is within the envelope $V_1$ and outside the envelope $V$ of Figure 6. Thus we can examine each destination region in turn. A probability mode choice model is used to determine the probability of choosing mode $k$ between a particular pair of regions and land use types. This model considers various factors in the mode choice decision including distance, cost, time, acres of destination land type, safety, comfort, accessibility, and auto ownership. The distance is calculated by finding the shortest path between the regions and by considering the existing transportation network. The traffic assignment part of the model may be refined in subsequent work by taking the capacity of the transportation links into account. By multiplying the total trips by the energy consumed per trip, we obtain the total energy consumption in moving people and goods between various regions in our study area.

The function is currently being tested on one township containing 25 regions; soon we hope to expand to the entire county. The success of this concept could contribute significantly to the incorporation of energy considerations in transportation and land use planning, as well as to our understanding of the interaction between the transportation system and land use patterns. This work is being supported by a scholarship to John R. Andrews from the Granite City Steel Foundation, and also by the University of Illinois at Chicago Circle.
Several of us at the College of Urban Sciences are working on a $390,000 grant from the Urban Mass Transportation Administration. The grant has four distinct sections. We are working on one, but we will describe the entire program briefly. The sections are demand analysis, evaluation techniques, modal evaluation and marketing. The preliminary analysis performed in connection with the demand section has uncovered some interesting results. Among transit modes (rapid transit, bus), people seem to prefer buses. Even when rapid transit trains have a slight travel time advantage, buses are preferred for the journey to work. These observations are based on census data. Additionally, some work is being done on the competition between commuter rail and rapid transit, looking at the fare elasticity for commuter rail (given fixed transit fares). This study is an example of the kind of work that can be done with a readily available data set. Other preliminary work is leading us toward the concept of the express bus. It appears that one reason buses are relatively attractive to people is the higher probability of getting a seat. This leads to the idea that the express bus, rather than electrified rail, may better serve dense corridors for the journey to work.

Some work is being done on the development and refinement of evaluation techniques for application in the program. Another section of the program, in fact, has its goal the formulation of matrix whose contents includes descriptors of all the mass transit modes. The fourth section of the program concerns transit marketing, an area needing considerable effort.

The College is also involved with a program called the Chicago Area Geographic Information Study (CAGIS). CAGIS has been in existence for about five years now; it receives funding from various sources, including the Chicago Association of Commerce and Industry. One long term goal is to gather data for this area and organize it on two consistent geographic basis, using the DIME file (Dual Independent Map Encoding). Data from the energy utilities, the census and various transportation data (vehicle registration, drivers license, etc.) have already been set up in this way. In doing this work, another goal has arisen; CAGIS has developed software to utilize these data-quick mapping programs and other user-oriented programs.
One of our concerns has been the mismatch between existing statistical procedures and the transportation planner's needs. This results in cumbersome procedures relative to the planner's specific problems, and often in incorrectly interpreted statistics. We would like to devise procedures aimed more precisely at the planner's data and the problems encountered.

A proposal that we have been developing in the area of transportation, not yet funded, might be of interest today. Current mass transit modes serve high population density areas with well defined travel corridors. Our suburban areas, however, do not fit these characteristics, although there is fairly high trip generation from the suburbs. Suburban trip patterns are more diffuse. In fact, we expect that an origin-destination matrix can be broken down into sub-matrices of similar trip patterns, each of which is suitable united to a para-transit mode. Para-transit modes serve less dense population, more diffuse trip patterns. Our study then has four parts: 1) to assemble information on current experience with para-transit modes; 2) partition the origin-destination matrix into sub-matrices that are susceptible to service by a single mode, including para-transit and automobile modes; 3) integrate para-transit systems into the existing network (scheduling); 4) implement such a system. The concept here, for transportation energy conservation, is to bunch trips where possible, increasing vehicle load factors while balancing against initial capital cost.
2.3 Research Users

The informal presentations by those present who might be loosely grouped under the heading of users of research, point out the difficulties of implementing energy conservation strategies.

Planners and operating agencies are concerned with many variables; energy is only one, and a recent addition at that. One also notices that these "user groups" are not just users of the research of others. These agencies are most often the original source of the data necessary for conservation planning and also do some of their own research.

*THE REGIONAL TRANSPORTATION AUTHORITY OF NORTHEASTERN ILLINOIS*

Martin J. Bernard III

I am in charge of transit programming and finance for the six county area. From a regional perspective the six county area is in essence the northeastern Illinois region. Our boundaries are the same as those of the Chicago Area Transportation Study and the Northeastern Illinois Planning Commission. RTA was created by referendum in the six counties about two years ago.

In the last several months, the planning and research activities have been stepped up. Soon the results will be visible, in the form of an RTA logo on all the new buses in the region and a unified fare structure. We are also working on plans to expand the regional mass transit system. We are a new agency to the region, so the results cannot come as fast as we might hope. Actually, though, the RTA is even more of a novelty: the U.S. Department of Transportation looks at us as an experiment. We are an experiment because in an era of large scale transit operating deficits, RTA has the potential to levy enough taxes to sustain itself (although none have been assessed yet).

We are a very small staff to do planning for the entire six county area, but we are progressing. Our outlook on transit is that it has never been used to its full potential as a vehicle for conserving energy. In fact, it has probably never been used to its full potential to enjoy many of its benefits, energy conservation being one. Transit is an area where the technology exists and in most cases is in use, so there is no significant technology
gap. Sarah LaBelle and I presented a paper last December in which we outlined the ways in which energy might be conserved in and through further use of urban mass transit systems. We discussed system changes, operating changes, many of which are non-capital intensive changes. Some of these changes earn only small savings, but the sum of the strategies suggested represents a significant savings. These results are based in part on data collected for the Chicago system, which is not available at a national level. In Chicago, we are taking steps in that direction. In the spring, contra-flow bus lanes will significantly improve the level of bus service in the Loop by raising the average speed. The greater utilization of the buses leads to reduced pollutant emissions per passenger-mile and less energy per passenger-mile than under the current service. Additional ridership will further lessen these impacts.

We are also examining transit and car pooling lanes on expressways. The southwest area of the city is the only one without rapid transit; it is under study.

My interest in transportation—all forms—and energy stems from my doctoral dissertation. It dealt with the future environmental and energy constraints to the transportation system. An optimization model was developed and made accessible via a computer terminal. The model was done at a national level, but is readily adaptable to regional or even sub-regional analyses. It is really a transportation supply model given limited resources. An example of a limited resource is Central Business District (CBD) land. The CBD has just about peaked in the amount of land that can be devoted to transportation uses. With this as a constraint, various forms of mass transit become more viable than automobile transit in the CBD. Transit can occupy any where from zero land, for a subway, to two and a half car lengths for a bus. The buses do not require as much CBD storage space as autos for the same passenger volume; in fact, transit vehicle storage is typically done on much less valuable land on the fringe.

In sum, I would say that there is strong potential, particularly in the Chicago area, for transportation energy conservation through the implementation of mass transit based strategies.
The American Society of Planning Officials (ASPO) is a trade association whose membership includes city planners, non-professional persons involved in planning such as elected officials, planning commissioners and citizens. There are two kinds of membership: institutional, of whom there are 1,300 members; and the 15,000 individual members. ASPO has two major functions in serving its clientele. One is to perform research in-house that serves planning. The other is to serve as a pipeline or clearing house for planning information, making a wide variety of planning research and reports of current activities easily available to the membership.

ASPO is concerned with energy conservation in several ways. We are involved in several studies currently, on the ways in which energy conservation now affects planning decisions and on how we might more effectively channel information to planners on the effect of the decisions on energy consumption. Regarding the former, we have done limited survey work among our agencies to determine how energy is now incorporated in the decision-making process. In summary, we observed that most communities who responded are now studying how energy might be incorporated into their decision making process, but few have begun new programs. We are involved with the Energy and Environmental Systems Division on two studies. In the Regional Studies Program, which John Hoover described earlier, we are working on the evaluation of the impacts of coal development on people in the Williston Basin. This work focuses on socio-economic problems encountered on account of the rapid but temporary influx of workers for the energy facility. More directly in the realm of energy conservation we are working with Al Kennedy of EES on the commercialization of new technologies for space and water heating. Our role is to examine the public administration problems, the planning problems and some of the legal barriers. In addition, we recently published an energy bibliography. This is a first effort to bring together materials whose original focus was not energy conservation but are relevant to the issue.

We have also responded to a request for proposal from the U.S. Department of Housing and Urban Development (HUD) to disseminate research on solar energy.
ASPO is committed to aiding its members on responding to this new national priority—energy conservation. Toward that end we have been working with the EES Division at Argonne on proposals, not yet funded, to produce reports that relate planning decisions to their energy impacts. We are interested in the impact of transportation and zoning and construction-related decisions, made or influenced by planners, on energy consumption.

*CHICAGO AREA TRANSPORTATION STUDY*

SuHail al Chalibi, David Schulz, Nancy Huebner, Thyra Zerhusen

The Chicago Area Transportation Study (CATS) has been in existence since 1956. We are responsible for transportation planning in the six county region in Illinois, and also work with the two counties in Indiana. Our interest in being here today is primarily that we have to face the reality of implementing energy conservation strategies. We must deal with the local government units. Our first activities in the area of energy conservation occurred in 1973 and 1974 when the state government was concerned with the possibilities of fuel allocations. In trying to respond to this request, we found no data to answer it adequately. Then we began efforts to strengthen our data base on the amount of transportation energy consumption and the impacts of changes in fuel availability. We have continued these efforts to the present. Several of our staff, present today, are working to develop a gasoline demand model and on a larger scale, a fuel consumption model for all modes.

One major activity now is the Year 2000 Transportation Plan. We have begun the process of determining that plan, using our 1970 update of the home interview survey. In looking at data from the original survey in 1956 and the recent update, we learned that the time of travel, rather than the distance, is extremely important in people's choices for trips. It still is not clear how price of travel affects trip choices.

We perceived a need to be able to make quick decisions about the future as affected by energy availability. With the assistance of Joe Schofer of Northwestern University, led by David Schulz of our staff, we have taken a new approach to planning for the Year 2000 Plan. We hope to design transportation alternatives that stand up well under a reasonable range of possible futures, conditioned on energy availability.
The Year 2000 Plan will contain four elements: 1) a facilities plan with staged development; 2) a policy plan; 3) the 1985 transportation system management plan; 4) a meta-plan, or a meta-plan - a plan for planning. Energy considerations enter into this plan in three ways. First is the direct consideration of energy consumption as an evaluation criterion for final plan selection. We are aiming for an energy consumption model that has as its input the output of our battery of travel models. The output of this energy model would feed directly into the evaluation criteria for each alternative plan. The second point is the effect of energy on trip generation. Here we are going into the travel models themselves, specifically trip generation, to incorporate the effects of fuel supply and price on trip production. The third interface of the plan with energy is that the alternative futures postulated for the environment of the plan are distinguished from one another according to energy availability.

These alternative futures we have been referring to are part of our new approach to the Year 2000 Transportation Plan. With a single forecast of future conditions, about the only thing that is certain is that it is wrong. Given the large number of parameters of interest it is impossible to pinpoint everyone. Thus we have decided to look instead at a small number of scenarios. These scenarios each indicate one possible future; taken together they outline a range of possible futures. Given this set of alternative futures, we can evaluate all aspects of the Year 2000 Plan against the range of possibilities. If, for example, a proposed alternative transportation system plan does well only under conditions of high energy availability, we can modify, or even discard, that plan for one that works under a variety of levels of energy supply or stage decisions so that no capital is committed until the uncertainty is cleared up.

One of the reasons for our coming today is that we are concerned with just how energy will enter into the federal evaluation criteria for transportation planning. For example, air quality is now a rigid standard that must be met, cannot be traded off in the region for any other benefit. Most agencies now faced with this constraint were brought into the process late. If energy use is set up the same as air quality in the federal requirements, and today's discussion does not eliminate that possibility, we would like to take part in the formulation of these policies. We would like to contribute to the determination of policies that will be realistic and meaningful energy policies for urban transportation planning.
3. **PROPOSALS FOR FUTURE ACTION** (Afternoon Session)

The participants were sent a list of specific questions intended to structure the afternoon discussion. It seemed, however, that more abstract and general issues had to be addressed first by the group. Thus the nature of the discussion, summarized below, was that of a general presentation of the issues facing the individuals present. The full range of controversies in the area of energy conservation was covered, and appropriate roles for the federal government to play in this area were proposed. In discussing the role of models in energy planning, it was proposed that simple models are used for planner's analysis of energy problems because we have nothing better. It was also argued that a simple model is the most useful for presentation to the decision-maker, since most sophisticated mathematics is of no use to them.

This view is countered by the experience in the DuPage County Planning Commission. There a complex linear programming model is being used in the formulation of the comprehensive land use plan, with much citizen involvement. The planning commission members have been pleased with the use of the model and the resulting plan. The model is used in an iterative fashion, with comments on the intermediate results being incorporated into the next iteration. Further comments on the use of models in planning indicated a need to tailor existing statistical procedures to the needs of planners. The inexact fit now existing, it was argued, leads to incorrect use of statistics on occasion.

Discussion then turned to the role of the federal government in energy conservation. The consensus was that the federal government can play a crucial role as a central information source, a well coordinated clearing house of technological and management information on energy conservation. It was hoped that the federal government would realize this. It was also pointed out that the ERDA is exhibiting a technology bias in their selection of energy conservation strategies. Although technological strategies are initially attractive, they often turn out to be cost-ineffective. There is a potentially large energy savings to be achieved through management, operations and regulation strategies. The faster ERDA learns to work with existing systems, particularly the transportation system, the faster it will see results bringing the nation closer to its goals.
Other aspects of the discussion were concerned with the effectiveness of modeling efforts - is it all a waste of time? Although there was contention on this point, some felt that planner's efforts do influence land use and trip behavior, although not as directly as we might hope. The day-to-day decisions that are made because of building codes, zoning laws, Department of Transportation grant requirements, are hard to chart through gross metropolitan area statistics - our measures of change. But the effects are there and impossible to undo in the short run. This situation impresses upon us the need to think through potential effects of these policy decisions on energy consumption since we will see our mistakes standing for a long time.

The topic of energy conservation in transportation is complex, difficult to set out in brief terms. Our discussion reflects this complexity; every point led to five or ten relevant and complex issues, until one must step back again to see what is happening. That is the recommended approach with a few caveats: beware of promises from technology, unless the marketability has been examined; beware of models that grow too large, but do not make decisions without data to back them.
4. CONCLUSIONS

The participants concluded as a result of the day's discussion, that:

- energy conservation can be achieved in transportation systems through the implementation of system operation and technological strategies.

- the federal government should play a vital role in achieving energy conservation by strengthening its position as a central information source, a clearing house for state and local governments, industry and private citizens.

- the potential for energy savings in transportation system operation and management, demand shifts and reductions must not be overlooked.

- modeling can be a useful tool in both research program management and forecasting the effects of implementing a particular strategy for energy conservation.

- the evaluation and selection process for technology research and development must include commercialization studies along with the technological indicators of program success.

- federal agencies need to coordinate their own activities in this area - that is, the Department of Transportation, the ERDA, the Federal Energy Administration and the Environmental Protection Agency, among others, must work together so that research programs will be efficient and not redundant and strategies will not work at cross purposes.
5. **AGENDA**

Transportation Energy Conservation - Tools to Meet the National Objective

at Argonne National Laboratory
9700 South Cass Avenue
Argonne, Illinois 60439

9:00 a.m. Welcome - E. J. Croke, Director, EES Division
Brief remarks by ERDA conservation representatives

9:30 a.m. Planning and Assessment Programs
Energy and Environmental Systems Division (EESD)
Urban Systems and Transportation Planning
Research, Regional Studies, Community Design,
Commercialization Programs - EESD staff

10:15 a.m. Participating Universities - Capabilities and Activities
Northwestern University - Civil Engineering Department
Transportation Center
University of Illinois, Chicago Circle
- Systems Engineering
University of Iowa
University of Minnesota

11:15 a.m. User Group Activities
Chicago Area Transportation Study (CATS), Northeastern
Illinois Regional Transportation Authority (RTA), DuPage
County Regional Planning Commission, state DOTs (Michigan,
Ohio), American Society of Planning Officials (ASPO)

12:15 -
1:15 Lunch
1:30 p.m. - 3:00

Discussion:

1. What role can existing planning models and methods play in:
   
a. identifying promising strategies for transportation energy consumption?
   b. assessing cost effectiveness of such strategies?
   c. increasing the confidence of decision makers in those strategies?

   What can planning models tell us about hardware vs. non-hardware options?

2. What sectors of the transportation system (urban, inter-city, passenger, freight, modal distribution) are the most likely targets for reductions in energy consumption, especially oil consumption?

3. What is the potential for non-hardware strategies for energy conservation? How might these strategies be classified?

4. What steps can state, regional and local governments take to execute selected energy conservation strategies, with respect to their control and/or guidance of the transportation and land use systems?

5. What data requirements should be met to develop the strongest energy conservation planning capability?

6. What are the potentials for implementation of the proposed strategies - that is, are they marketable?

3:15

Summary and Conclusions
ACKNOWLEDGMENTS

Thanks are due to my supervisor Allen S. Kennedy, for his guidance throughout the preparation for the meeting. I also thank Joseph L. Schofer of Northwestern for his helpful suggestions on the structure of the meeting. Diane Duff is responsible for the well-done job of typing and layout. Of course, all errors rest with me.