casts through the relatively easy evaluation of many alternative scenarios. The system has been applied not only to the Tokyo Bay Bridge project but also to impact studies of other projects, such as the construction or improvement of commuter rail lines in several metropolitan areas in Japan. The model is currently being improved as a result of the experience gained from these studies.

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Use of TOPAZ for Transportation-Land Use Planning in a Suburban County

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Techniques used to create and assess a variety of year 2000 joint land use and highway network patterns for Prince William County, Virginia, are described. The assessment has been done mainly in terms of travel and related impacts. The related impacts include the overall cost of travel, congestion levels, fuel consumption, and air pollution emissions. Volume/capacity ratios on each highway link in the county were also estimated. A sketch-planning procedure called Technique for the Optimum Placement of Activities in Zones (TOPAZ) was used to allocate expected future land use activities to 11 districts in the county so as to minimize overall travel cost. Travel impacts were then analyzed in more depth through separate and more detailed models included in a model called Transportation Integrated Modeling Systems (TRIMS) used by the Metropolitan Washington Council of Governments. The results of these efforts led to several preliminary conclusions concerning not only the techniques themselves but also their place in the comprehensive planning process: (a) residents of the county will be faced with an increase in overall travel costs and congestion no matter which reasonable alternatives are implemented; (b) the most ambitious highway improvement program will reduce costs by about 9 percent, and the proper organization of land use will reduce this by an additional 6 percent; (c) future changes in external factors, such as population and fuel price levels, can have impacts on travel as substantial as those created through new highway construction and proper land use organization in the county; and (d) although TOPAZ supported the Prince William County comprehensive planning effort, it had relatively little direct impact on county decision makers, probably because it was not used at a time when citizens and local elected and appointed officials began to examine the draft comprehensive plan.

Prince William County is located in northeastern Virginia, approximately 25 miles southwest of Washington, D.C. (see Figure 1). It lies in the Piedmont plateau and has the unique features of the Potomac River shoreline on its eastern border and the Bull Run mountains on its northwestern border. The county has an area of 345 square miles (227,000 acres) and a 1980 population of 144,700.

Prince William County has a county executive form of government with a seven-member Board of County Supervisors that appoints the county executive and various boards, committees, and commissions. The Planning Office, which serves as staff to the Planning Commission and the Board of County Supervisors, is charged with the preparation of the comprehensive plan for the county.

In 1980 Prince William County began a rigorous countywide comprehensive planning effort. This was intended to update thoroughly all portions of the 1974 comprehensive plan, including land use, community facilities, water and sewers, and transportation. The update was conducted over a period of 2 years. The transportation element of the plan included extensive use of computer-based analytic tools. The horizon for this element was taken as the year 2000.

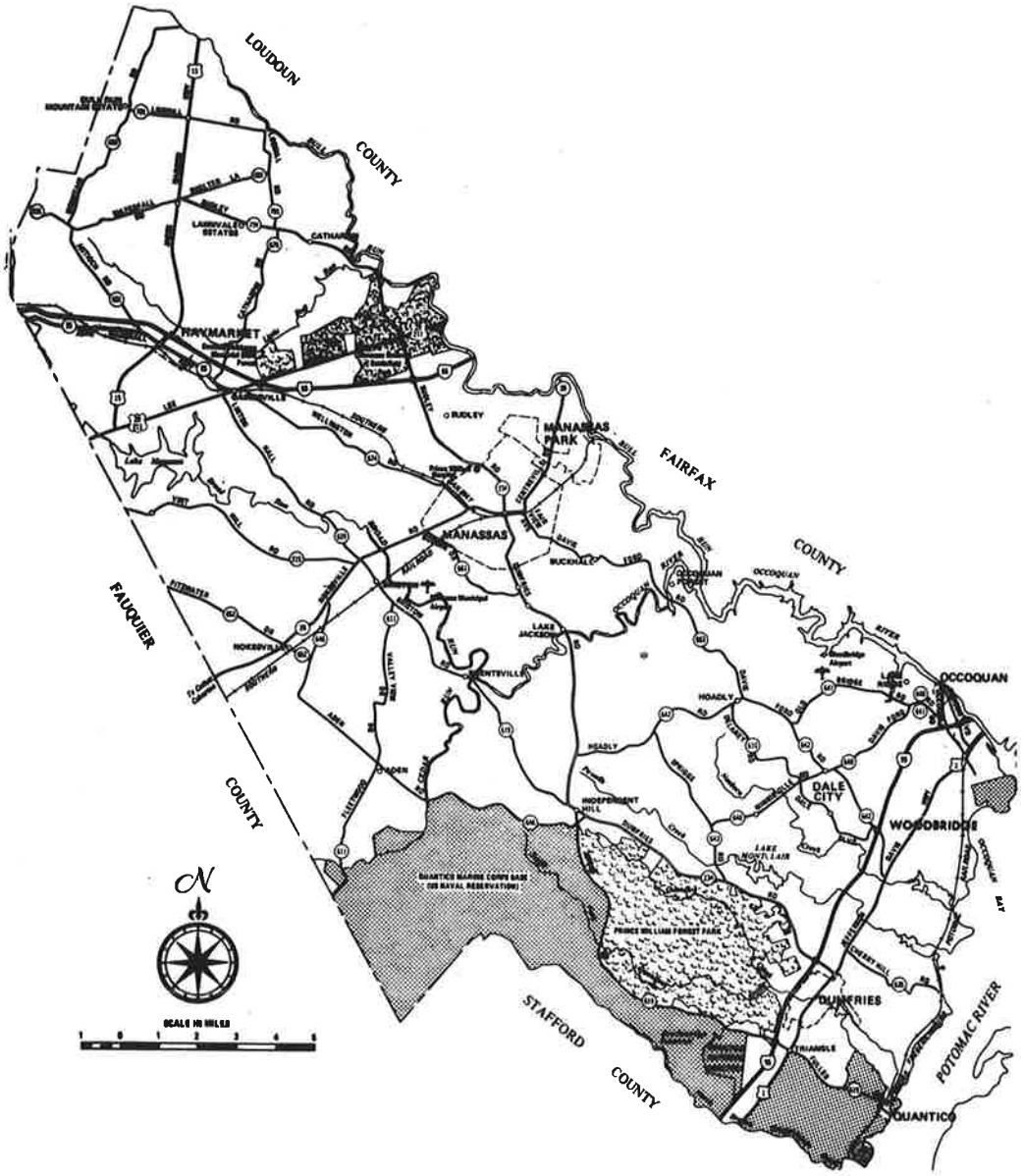
The Metropolitan Washington Council of Governments (MWCOG) provided substantial support in the evaluation and development of a recommended highway network for Prince William County. Through the application of the model, Transportation Integrated Modeling Systems (TRIMS), MWCOG prepared detailed traffic forecasts for the year 2000 as well as information on system performance.

However, because the updated comprehensive plan attempts to achieve a strong link between land development and the timely provision of adequate community facilities, county staff believed that there was a need to supplement MWCOG estimates of future travel demand by examining the impact of various land use scenarios on the county transportation system. The sketch-planning procedure, Technique for the Optimum Placement of Activities in Zones (TOPAZ), was the tool selected to help coordinate transportation and land use planning to an extent not previously practiced in the county.

Although TOPAZ has been used in more than 70 applications around the world, this effort offered several unique opportunities:

1. To test the usefulness of the procedure in a still relatively unpopulated, exurban area;
2. To adapt part of its structure to already existing travel models so that the two could be applied consistently and sequentially; and
3. To determine the general usefulness of TOPAZ in the broader comprehensive planning and decision-making process.

Figure 1. Prince William County, Virginia.



The use of TOPAZ for the third purpose cited has proved particularly interesting. It has been more than a year since the application and the Prince William Board of County Supervisors recently approved the comprehensive plan.

PROCEDURE

TOPAZ first costs out any proposed land use alternative by estimating the resultant travel cost. It then generates a new pattern of land use for the horizon year (2000). The travel cost for this pattern is less than that of the initially proposed solution.

Various constraints are used within TOPAZ. The amount of activities allocated to a district is restricted from exceeding the amount of land in that district that is vacant and available for development. Another (optional) restriction is that certain types and/or amounts of activities can be included or excluded from a district. New residential acreage in an area, for example, may be limited to be no more (or less) than 10 percent of the total growth in residential land use in the county.

TOPAZ provides several indicators of travel and related impacts for each land use scenario tested. These are

1. Number of automobile trips with origin or destination or both in the county;
2. Number of truck trips with origin or destination or both in the county;
3. Vehicle miles of travel;
4. Vehicle hours of travel;
5. Vehicle fuel consumption;
6. Hydrocarbon (HC) emissions;
7. Carbon monoxide (CO) emissions; and
8. Nitrogen oxides (NO_x) emissions.

In addition, TOPAZ outputs hourly volume/capacity (V/C) ratios on each major highway link in the county.

The final output of TOPAZ is a congestion index (CI). This is intended to show the extent to which

links in the highway network have V/C ratios greater than 2.00 (because TOPAZ gives only rough indicators of V/C ratio, a value of 2.00 has been used instead of 1.00 so that the links were assuredly overloaded). In words, the CI is the average, over all links in the county, of the excess of the V/C ratio over 2.00 on those links with V/C ratios greater than 2. If all links have a V/C ratio less than 2.00, CI is zero--i.e., there is no congestion. If all links in the county are highly congested, the CI could be very large (about 1.50 to 2.00 is a reasonable maximum).

Figure 2. External stations and districts in Prince William County.

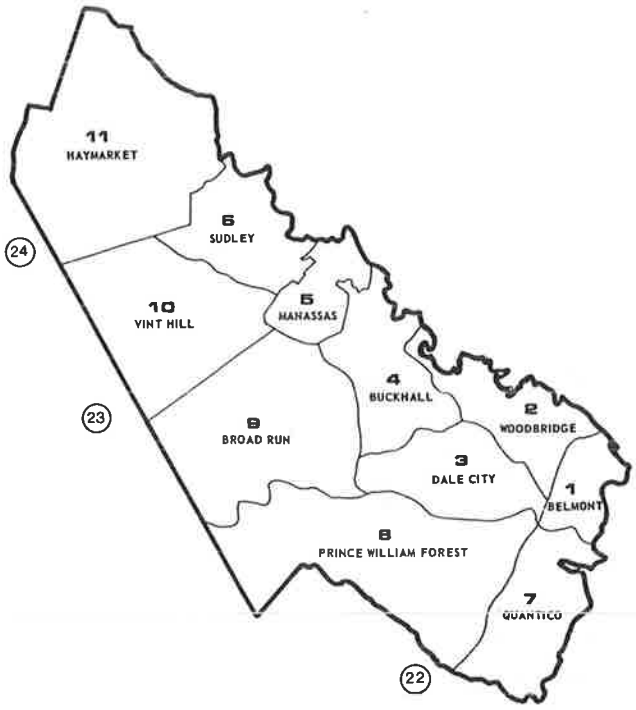
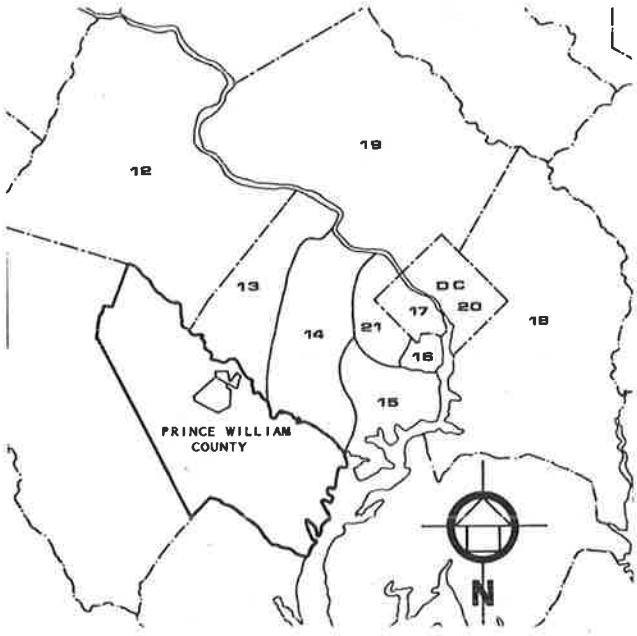


Figure 3. Zones in Washington metropolitan area outside Prince William County.



Prince William County was divided into 11 districts (see Figure 2), and the rest of the Washington area was divided into 10 (see Figure 3). There were three external zones.

Travel in TOPAZ was categorized into five purposes in accordance with TRIMS: home-to-work, home-to-shop, home-to-other, non-home-based, and truck.

Trip generation was then estimated on the basis of location of the district (distance from Washington, D.C.), income of households in the district, amount of land use activity in the district, and trip purpose. Generally speaking, the farther the district from Washington, D.C., the greater the income of the residents, and the more the amount of activity, the larger is the number of trips generated.

Trip distribution was forecast by using a gravity model and depended on the comparative amount of activity in the attracting districts and comparative travel time to the attracting districts.

Trip assignment was done on an all-or-nothing, or uncapacitated, basis (TRIMS does take congestion into account and was used subsequently by MWCOG for this purpose). The trips forecast were automobile trips for the average weekday during the year. All truck trips were expressed in automobile vehicle equivalents, and the initial value used was 3. Car occupancy was initially assumed to be 1.5, and the peak-hour factor was assumed to be 0.10 or 10 percent.

V/C ratios were then computed for each of the 154 links in the county network. This was the network that existed in 1980; in the base run of TOPAZ, it was assumed to be unchanged, except for widenings, to the horizon year (2000). Further runs were made with a larger network in which, for example, the Manassas Bypass was included. In most cases there were 87 links in the network in the rest of the Washington area outside the county.

Two types of travel cost were considered: time and fuel. For time, each hour was valued initially at $10/automobile hour (driver and passengers) and $15/truck hour (driver and passengers). Fuel consumption was specified as a function of speed. For the year 2000 it was assumed initially that automobiles, at their most efficient speed (about 30 mph), would average 50.0 miles/gal and trucks 33.3 miles/gal. Fuel cost then was presumed to be $1.50 for every gallon consumed (all costs are in constant 1980 dollars).

LAND USE ACTIVITIES AND CONSTRAINTS

For compatibility with TRIMS, seven classes of land use activity were established:

1. Households,
2. Group quarters (with occupants),
3. Office employment,
4. Retail employment,
5. Industrial employment,
6. Other employment, and
7. Developable vacant land.

In the base run of TOPAZ, forecasts of the first six activities for the years 1980 and 2000 were taken from the COG Round II Cooperative Land Use Forecast. The 1980 figures have been maintained as the basis for all future runs. (The 1980 Census figures were not available. Even if they were, however, census tracts in Prince William County are larger than traffic zones and thus could not be used without some restructuring.) In other scenarios, different horizon-year numbers were input to TOPAZ and costed out.

The figures for developable vacant land for each

Table 1. Major travel impacts of scenarios generated in the study.

Scenario	Land Use	Network	Special Conditions	Daily Travel Cost ($000s)	Congestion Index
1	COG Round II	1980		894	0.96
2	1980	1980		518	0.40
3[a]	COG Round II	MINBLD		848	0.84
4	COG Round II	MAXBLD		775	0.68
5	COG Round II	MAXMRF		794	0.74
6	COG Round II	1980[b]		875	0.96
7	TOPAZ-COG II	1980[b]		796	1.04
8	TOPAZ-COG II	1980		847	1.09
9	TOPAZ-COG II	MINBLD		804	0.92
10	COG Round II	MINBLD	Fuel = $7.50	1135	0.86
11	TOPAZ-COG II	MINBLD	Fuel = $7.50	1019	0.91
12	Population up 25%	MINBLD	Population up 25%	925	0.96
13	TOPAZ, population up 25%	MINBLD	Population up 25%	914	1.13
14	TOPAZ, worst case	MINBLD		963	0.83
15	Constrained	MINBLD		852	0.85
16	TOPAZ, constrained	MINBLD		814	0.91
17	TOPAZ-COG II	MAXBLD		722	0.71
18	TOPAZ-COG II	MAXMRF		788	0.79
19	COG Round II	MINBLD	2.80/household	884	0.91
20	TOPAZ-COG II	MINBLD	2.80/household	848	1.01
21	COG Round II	MINBLD	Fuel = $0/gal	775	0.84
22	TOPAZ-COG II	MINBLD	Fuel = $0/gal	736	0.90
23	EZ	MINBLD	Fuel = $0/gal	799	0.83
24	TOPAZ-EZ	MINBLD	Fuel = $0/gal	723	0.89
25	COG Round II	MINPMB		836	0.80
26	TOPAZ-COG II	MINPMB		843	0.88
27	COG Round II	MINBLD	Fuel = $4/gal	976	0.84
28	TOPAZ-COG II	MINBLD	Fuel = $4/gal	876	0.89
29	COG Round II	MAXBLD	Fuel = $4/gal	884	0.68
30	TOPAZ-COG II	MAXBLD	Fuel = $4/gal	768	0.72
31	EZ	MINBLD	Fuel = $4/gal	997	0.83
32	TOPAZ-EZ	MINBLD	Fuel = $4/gal	906	0.88
33	EZ	MAXBLD	Fuel = $4/gal	909	0.68
34	TOPAZ-EZ	MAXBLD	Fuel = $4/gal	820	0.69
35	COG II	MINBLD	Population down 15%, fuel = $4/gal	912	0.78
36	TOPAZ-COG II	MINBLD	Population down 15%, fuel = $4/gal	889	0.81
37	COG II	MAXBLD	Population down 15%, fuel = $4/gal	834	0.63
38	TOPAZ-COG II	MAXBLD	Population down 15%, fuel = $4/gal	779	0.65
39	Concentrated	MINBLD	Population down 15%, fuel = $4/gal	901	0.77
40	TOPAZ, concentrated	MINBLD	Population down 15%, fuel = $4/gal	904	0.83
41	Concentrated	MAXBLD	Population down 15%, fuel = $4/gal	823	0.62
42	TOPAZ, concentrated	MAXBLD	Population down 15%, fuel = $4/gal	790	0.67
43	TOPAZ-COG II	MINBLD	Min CI	983	0.83

Note: EZ = land use allocation in which percentage of activity allocated to a district must equal at least that given in last column of Table 2.

[a]Base case.

[b]Liberia Avenue speed set at 45 instead of 25 mph.

district in 1980 were based on available land in census tracts and on area measurements taken from maps of the county. Initially, the definition of developable vacant land was a broad one, including as it did almost any land that did not have some obvious density of structures. This broad definition allowed for future constriction (e.g., for environmentally sensitive areas) and subsequent computations of any added burdens on travel costs and related factors resulting from such restrictions.

Developable vacant land in each district in the horizon years was computed as the difference between that in 1980 and acreage for the other six activities assigned to that zone in the horizon year. The determination of the acreage for the first six activities listed previously required adjustments with assumed density figures. In the base run of TOPAZ, for instance, it was assumed that there would be, countywide, an average of 5.22 households/acre (3.32 people/household), 9.90 people in group/acre, 35 office employees/acre, 30 retail employees/acre, 20 industrial employees/acre, and 20 other employees/acre.

If TOPAZ is used only in the costing-out mode, it is not necessary to maintain these values as constants. They can vary from district to district. A variant of TOPAZ, called TOCOST, was used when only costing out was desired.

Several different population levels were tried with TOPAZ. This helped to show the sensitivity to various factors that, for the year 2000, are bound to be somewhat uncertain in value. But different population levels mean more or fewer acreage requirements for the various land use activities. The computation of the new overall requirements in TOPAZ is carried out by assuming the following:

1. For residences, the proportion of the population that desires each residential type and the number of people per household in that type and
2. For nonresidences, the number of additional employees by each extra person in PWC.

For example, if there are 1,000 new people, 90 percent of whom desire single-family housing at 3.00 people/household, and if the number of new retail employees per added person is 0.06, the calculations would be

$$\text{Single-family households} = 0.90\,(1{,}000)/3.00 = 300 \quad (1)$$

and

$$\text{Retail employees} = 0.06\,(1{,}000) = 60 \quad (2)$$

SCENARIOS

More than 40 scenarios were generated in the study (see Table 1). Scenario 3 served as the base case.

Table 2. Lower land use activity limits used in certain scenarios.

District No.	District	Activity Type	Percentage of Overall Activity Constraints	EZ (%)
11	Haymarket	Household	-	10
7	Quantico	Office	25	25
1	Belmont	Office	25	25
2	Woodbridge	Retail	10	16 2/3
3	Dale City	Retail	10	10
5	Manassas	Retail	10	10
6	Sudley	Retail	10	16 2/3
1	Belmont	Industrial	10	10
10	Vint Hill	Industrial	50	50
1	Belmont	Other	5	10
5	Manassas	Other	5	15

Note: Constrained cases = scenarios 15 and 16; EZ cases = scenarios 23, 24, 31, 32, 33, and 34.

One of five highway networks was used in each scenario. The 1980 network was used mainly for checks against existing volumes. The minimum build (MINBLD) network involved five major widening or reconstruction improvements. No new links were added. The maximum build (MAXBLD) network required all those changes in the MINBLD plus six additional widening or reconstruction projects and three major new arterials. These were Ridgefield Road, the VA-28 Bypass, and the Manassas (Western) Bypass. The fourth alternative was MAXBLD minus Ridgefield Road (MAXMRF) and the fifth was MINBLD plus the Manassas Bypass (MINPMB).

Several scenarios require further explanation:

1. In scenarios 10 and 11, the price of fuel was raised from $1.50 to $7.50/gal (constant 1980 dollars).
2. In scenarios 12 and 13, the horizon-year population of the county was raised 25 percent and distributed in about the same proportion as in the COG Round II forecasts.
3. In scenario 14, TOPAZ was run "backwards" to help identify the worst arrangements of land uses in relation to travel costs.
4. In scenarios 15 and 16, the number of acres of certain employment activities in certain districts was preallocated, constrained to a lower limit (see Table 2). TOPAZ was allowed to allocate more acres than the limit of the activity to the district if this was desirable.
5. In scenarios 19 and 20, the number of people per household was reduced from 3.23 to 2.80 to simulate potentially lower household sizes in the year 2000.
6. In scenarios 21 and 22, fuel cost was set at $0/gal (i.e., not considered a travel cost item).
7. In scenario 23, the EZ land use allocation was introduced. The percentage of the activity allocated to a district had to equal at least that given in the last column of Table 2.
8. In scenarios 27 to 34, fuel cost was set at $4/gal for a variety of land uses, constraints, and networks.
9. In scenarios 35 to 38, population was decreased 15 percent from the base case and fuel cost set at $4/gal for the MINBLD and MAXBLD networks for the COG Round II land use forecast.
10. In scenarios 39 to 41, land use development was concentrated more in districts containing Ridgefield Road. Network (MINBLD and MAXBLD) differences were assessed for conditions in which population was down 15 percent and fuel cost $4/gal.

The first five scenarios were run by using TOCOST. Thus, it was possible to have varying household densities (households per acre) in each district. These were as follows:

District	Density (households per acre)
1	7.10
2	5.70
3	4.70
4	5.10
5	4.95
6	6.00
7	5.90
8	3.20
9	2.50
10	2.70
11	2.90

These densities were assumed to be the overall average for all development in each district in the horizon year.

In addition, in each scenario the population and density of group quarters were held constant. Thus, there was always 92 percent (448 acres) of new group quarters in the Quantico Marine Base and 8 percent (39 acres) in Manassas.

RESULTS

The results of the 43 scenarios are summarized in Table 1.

Overall Travel and Congestion

In Table 1, it can be seen that the base case (scenario 3) results in about $848,000 in daily travel costs and has a CI of 0.84. In comparison, the worst scenario occurs when fuel is priced at $7.50/gal (as opposed to $1.50). The daily travel cost under that condition is $1,135,000/day, although the CI increases only sightly to 0.86.

The least travel cost occurs with scenario 17 (the MAXBLD network with the TOPAZ-generated land use pattern). The travel cost is $722,000, or about 15 percent lower than that for the base case, and the CI is reduced by a similar percentage.

The worst that can happen if base-case conditions (other than land use distribution) are maintained is for travel cost to increase to $983,000 (scenario 43) or 16 percent.

Other results of interest are the following:

1. If no improvements are made to the 1980 network, travel increases by approximately 7 percent but the CI increases 14 percent.
2. If Ridgefield Road, a proposed major arterial, is eliminated from the MAXBLD network, travel increases 3 percent and the IC 8 percent.
3. If the population increase in the county (and the city of Manassas) is 25 percent more than expected, costs and congestion naturally increase, but it appears much more difficult for TOPAZ to find a land use pattern to reduce travel costs (compare scenarios 12 and 13).
4. If population decreases 15 percent, costs go down about 6.4 percent (scenarios 27 and 35).
5. If land use is partly preallocated, as indicated in scenarios 15 and 16, travel increases but only about 1.5 percent versus the base case.
6. If the number of people per household is reduced to 2.80, the TOPAZ-generated land use pattern has about the same travel costs as the base case but much higher congestion.
7. Fuel is only about 9 percent of overall travel costs (scenario 21 versus scenario 3). The rest is travel time.
8. The EZ-constrained land use pattern (scenarios 23 and 24 and 31 through 34) gives slightly

higher (about 2 percent) travel costs than the base. The congestion levels are essentially equal. The same holds for the land uses generated by TOPAZ under the EZ constraints.

9. Raising fuel to $4/gal (versus $1.50) adds about 15 percent to the overall cost (scenario 27 versus scenario 3). This is the same as under the worst land use pattern.

10. Concentrating development around the proposed Ridgefield Road location leads to a slight decrease (about 1 percent) in both overall travel costs and CI. It is interesting that the TOPAZ-generated land use pattern starting with the concentrated solution and the MAXBLD network is somewhat worse than that starting with the COG Round II pattern (and MAXBLD). (More accurate results come from the MWCOG TRIMS runs.)

11. It is difficult to find a land use pattern that results in a significantly lower CI than the base case with MINBLD and COG II (see scenario 43). A reduction in the CI results in a large increase in overall travel costs.

Perhaps the most significant result is that travel cost will increase from approximately $518,000 to $722,000 and the CI from 0.40 to 0.71 from 1980 to 2000 (see scenarios 2 and 17) under the best conditions. Thus, most county residents will probably perceive much higher levels than at present despite any substantial land use and transportation improvements.

Land Use

A review of the land use allocations in the various TOPAZ-generated scenarios indicates that most allocations were to those districts that were already developed and were located close to Interstate highways. This was particularly true for residential allocations. Moreover, the less populated and accessible districts were found in the worst cases (that is, those that were to be avoided).

Office employment seemed best located in districts close to (but not within) current population centers and least desirable in the most remote districts. Retail employment appeared in a variety of districts. This is reasonable because it is usually needed close to residences, which are spread around.

It is interesting that industrial employment showed up in some districts that did not seem good candidates based on concurrent industrial development studies.

Usefulness of Results in Planning and Design-Making Process

Although the TOPAZ-generated results described previously are useful, they tell only part of the story. The remainder has to do with how the technique and the results were (or were not) used in the overall planning and political decision-making process.

From a technical viewpoint, the county planning staff generally found TOPAZ adaptable for testing a wide range of policy variables. However, the first several TOPAZ runs resulted in all of certain land use activities (for example, office uses) being allocated to one zone. This produced an optimal allocation of future land activity but one that was clearly not likely to occur.

It was determined that, if TOPAZ was to produce more realistic results, the staff would have to impose constraints and floors so that the respective future land use activities would be more reasonably distributed. Accordingly, county staff, using their knowledge of local conditions, did the preallocation indicated in scenarios 15 and 16, which ensured that TOPAZ would allocate a minimum of certain uses to various zones. This was somewhat disconcerting to the staff, who felt that by partly preallocating land activity they were making decisions that TOPAZ should be making.

The usefulness of TOPAZ, however, was demonstrated even with preallocations. The planning staff could develop a proposed land use pattern, and TOPAZ would illustrate the transportation impacts with the CI and travel cost measures.

After the initial stage, in which the staff had to become familiar with TOPAZ formats and procedures, it was possible to develop scenarios, adjust the land uses, road networks, or other policy variables, and have a response within a relatively short period of time. This was a particularly attractive feature of TOPAZ because inquiries from citizens and local appointed and elected officials often required quick responses. However, the planning process is such that public hearings are not held until after a draft plan is published. Thus, the inquiries from local elected and appointed officials naturally come well after much of the planning analysis effort. Given that TOPAZ is capable of providing timely responses, it appears to have great potential for use toward the end of the planning process. Moreover, by using TOPAZ at a later stage, it would be possible to focus on fewer but more relevant scenarios. In retrospect, the 40 scenarios run in the Prince William County application appear excessive.

As noted previously, county staff found TOPAZ to be most useful when land activity was preallocated. This helped to clarify the role of TOPAZ and enabled the staff to overcome their skepticism about preallocating and concentrate on evaluating the impacts of scenarios.

For example, the planning staff was interested in evaluating the impact of deleting a proposed facility, Ridgefield Road, from the MAXBLD network. Ridgefield Road, if constructed, would add much-needed capacity to the heavily traveled I-95 commuter corridor. However, land use, environmental, funding, and political factors are working against its construction. The staff was looking for an estimate of the value of Ridgefield Road. Running TOPAZ with identical land activity for two networks, one of which deleted Ridgefield Road, indicated that daily travel costs would increase by about $66,000 and the CI would increase from 0.71 to 0.79. The staff thus retained Ridgefield Road in the draft comprehensive plan and requested that detailed traffic forecasts (a select link analysis) be developed by using TRIMS.

The TOPAZ model lends itself to public discussions and work sessions because it provides easily understood indicators of the impact of a scenario on a network. The daily travel costs indicator and the CI are general terms that help to simplify modeling results without oversimplifying.

In light of regional studies done after the TOPAZ application, it appears that many conclusions have been confirmed by more detailed and expensive analyses. For example, the assertion that even if most highway network improvements are accomplished county residents will still be faced with substantial increases in travel costs and congestion has been borne out by recent studies.

TOPAZ results also worked to confirm the judgment of the county staff that the pattern and intensity of proposed land uses can have a clear impact on the transportation system. In particular, in using TOPAZ it was concluded that a combination of proper land use organization with numerous network improvements would decrease both travel costs and congestion by about 15 percent. Thus, the effort to

achieve improved transportation-land use organization through long-range comprehensive planning can have tangible payoffs. The compatibility of TOPAZ with TRIMS enabled the staff to select four interesting land use scenarios and then have MWCOG apply TRIMS to the land activity data. MWCOG produced three trip tables for each scenario for the year 2000: total person work trips, automobile drive work trips, and all-purpose automobile driver trips.

Although TOPAZ and TRIMS were compatible with regard to land activity inputs, it was difficult to structure activities so that the two models could be used sequentially. Early in the process, it was hoped that TOPAZ would produce land use arrangements that could then be tested by using TRIMS. Although four scenarios were eventually run on TRIMS, the two models never interacted as the county staff had originally hoped. Costs, scheduling, and coordination problems prevented closer interaction.

Graphic representation of TOPAZ output was a weakness throughout the study. Despite several attempts to illustrate results with pie charts, the most effective way of communicating, the TOPAZ graphics did not greatly contribute to the study.

CONCLUSIONS

Several conclusions can be drawn from the studies presented here. The forcefulness of some of these conclusions depends on further analysis of the MWCOG travel prediction process. Nonetheless, some findings are clear enough to be useful:

1. Even if the best land use pattern is put together with the most extensive highway network changes, residents of Prince William County will definitely be faced with solid increases in overall travel costs and congestion. If these are perceived as such by county residents, as they undoubtedly will be, most residents will become unhappier about travel conditions. This will occur even if the most that can be done is done.
2. Construction of the MAXBLD network, including three major new arterials, will help to reduce overall travel costs and congestion by about 9 percent compared with the base case.
3. Proper organization of future growth in Prince William County, which generally involves growth around current populated areas, can lead to reductions in overall travel costs of about 5 percent. Congestion levels will increase even more, however. This seeming paradox results because reducing travel through land use organization can only come about by putting people in proximity to each other, which leads to more congestion.
4. A combination of proper land use organization and the MAXBLD network will bring decreases in both travel costs and congestion of about 15 percent. Thus, joint transportation-land use plans are needed to obtain maximum results.
5. It appears to be difficult to reduce the CI through organization of future growth. Overall travel costs appear to increase substantially when an effort is made to decrease the CI.
6. Many travel-related factors, such as fuel consumption and air pollution emissions, are reduced through proximity. This is particularly true in the case of NO_x emissions, which usually increase as travel speeds increase (and thus increase with improvements in the highway network--a conclusion based on results not presented in this paper).
7. A wide variety of land use patterns have travel and congestion implications close to the optimal ones generated by TOPAZ. The choice between these patterns thus can depend on the many other factors important to land use planning. Still, there is also a broad variety of schemes detrimental to travel and reduced congestion, which should be avoided.
8. Changes in external forces can lead to substantial alternations in overall travel costs and the CI. A population increase 25 percent above that expected, for example, would eliminate any gains from constructing the MAXBLD network. An increase in fuel prices to $4/gal would eliminate any gains from the best combination of land use and highway network changes. These results indicate that monitoring is needed to determine whether changes in such external forces are evolving so that plans can be altered accordingly.

With regard to the broader usefulness of TOPAZ, it should be noted that the revised comprehensive plan for Prince William County was adopted in early August 1982. The TOPAZ application marked the first time that county staff used a sketch-planning computer-based tool to examine the transportation-land use relationship. The TOPAZ exercises clearly contributed to the comprehensive planning effort at the staff level. However, these exercises have little significant impact on county decision makers, probably because the exercises were not used at the time when citizens and local elected and appointed officials began to examine the draft comprehensive plan. That examination, along with public hearings and agency reviews, appears to be the point at which many questions and "what if's" are raised and would be a useful time to apply TOPAZ.

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