Comparing Land Use Forecasting Methods

Expert Panel Versus Spatial Interaction Model

Reid Ewing and Keith Bartholomew

Major highway construction projects are promoted for their economic development and congestion relief benefits. They may also have unintended consequences, increasing vehicle miles traveled and urban sprawl. Central to both intended and unintended consequences is the phenomenon of induced development, in which future land development patterns adapt to new accessibility patterns that accompany major highway investments (Bhatta & Drennan, 2003; Boarnet & Haughwout, 2000; Cervero, 2002; Ewing, 2008; Noland & Lem, 2002).

The federal environmental review process, mandated principally by the National Environmental Policy Act of 1969 (NEPA), requires detailed analysis of such impacts.1 NEPA itself, however, does not specify the manner in which these impacts should be assessed or how the outcome of the assessments should be employed in decision-making processes. Nor are administrative agencies’ guidance documents much help in selecting the best method of analysis, as they present a wide range of methodological options, but do not recommend preferred methods or even say which methods are sufficient to satisfy legal requirements.

Problem: Legal requirements and good planning practice dictate that land development induced by major highway investments be forecasted. Two forecasting methods, the first qualitative and based on expert judgment and the second quantitative and based on formal spatial interaction models, are often presented as equivalent.

Purpose: We aim to extract lessons about the strengths and weaknesses of the two methods from a case study of a controversial highway, the Intercounty Connector (ICC), in the suburbs north of Washington, DC.

Methods: We compare forecasts of induced development obtained using both methods and judge their reasonableness against the empirical literature.

Results and conclusions: The two methods gave dramatically different results. The subjective judgment of experts predicted small impacts, on average, compared to a simple spatial interaction model. Also, subjectively forecasted impacts were limited to lands near the new facility, while modeled impacts rippled out across a much larger area. The subjective method seemed to give too little weight to accessibility effects and too much to zoning constraints, while a simple spatial interaction model seemed to do the opposite.

Takeaway for practice: Where time, budget, or data limitations preclude the development of state-of-the-art integrated land use and transportation models, we conclude based on this case study that the best approach is to combine simple models and expert judgment. Expert panels can be used to check model inputs against local knowledge and to adjust outputs in light of factors otherwise unaccounted for. Conversely, model outputs can be used to check expert opinion for inconsistency with known land use–transportation relationships.

Keywords: highway-induced development, land use forecasting, land use model, expert panel, Delphi method

Research support: None.

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Thus we seek to inform the choice of methodology when time, budget, or data limitations preclude the use of state-of-the-art integrated land use and transportation models. This article presents the results of analyses of the Intercounty Connector (ICC) highway project in the Washington, DC, suburbs employing two leading methods: a Delphi-style expert panel and a simple spatial interaction model. The ICC provides a unique opportunity to compare and contrast the two methods and assess the strengths and weaknesses of each.

Results of the two approaches differ sharply, with the forecasts using the model predicting much larger and more geographically extensive impacts than those relying on expert opinion alone. Given the limitations of the model, it likely overstates the effects of accessibility, while understating the role of constraints on development, particularly those originating in state and county growth management policies. Limitations in the expert panel process likely had the opposite effect. We thus conclude that, short of developing a combined approach that draws on the strengths of the two approaches and mitigates some of their weaknesses.

The Intercounty Connector

The ICC has long been planned and debated in metropolitan Washington, DC. It is an 18-mile, six-lane highway that will connect two major radial corridors: I-95/US 1 between Washington and Baltimore, and I-270 between Washington and Frederick, MD. There is no continuous east-west travel corridor across the northern metropolitan area apart from the Capital Beltway at the southern end of Montgomery County and I-70 some 30 miles to the north. Because opponents fear that the ICC may represent the first step in the construction of an outer beltway around Washington, DC, the decision to build the ICC carries added significance.

Two alignments were considered for the ICC, differing only in the eastern half of the facility (see Figure 1). One, referred to as the southern alignment, crosses sensitive stream valleys and wetlands; the other, northern, alignment jogs to the north away from wetland areas but closer to Montgomery County’s rural preserve, adding several miles to the facility’s length. The southern alignment was ultimately selected on the grounds that its impacts could be adequately mitigated with design and environmental measures.

While the primary purpose of the facility would be to connect east and west, thus presumably alleviating intense traffic congestion on the Capital Beltway, the new facility would have 10 interchanges along its length, providing significant new access to previously undeveloped areas in the interior of Montgomery County. This new accessibility raises the possibility of significant induced development in areas that ICC opponents would like to preserve (Trejos, 2005).

Despite a pair of lawsuits and various attempts to derail the project in the Maryland Legislature, construction began on the ICC in November 2007. It is scheduled for completion in late 2011, with the first section of the highway to open in 2010. At least two large real estate developments appear tied to the ICC. Longmead Crossing was laid out along the alignment, and the new town of Konterra is planned south of the corporate limits of Laurel, around the new interchange of the ICC and I-95.

The expert land use panel (ELUP) process described in this article was the basis for indirect and cumulative impact assessments in the Final Environmental Impact Statement (FEIS) for the project. Working with ELUP growth allocations, the FEIS pegged the amount of land consumed by ICC-induced development at 4,945 acres. For reasons explained below, the actual impact may be significantly greater.

Legal Requirements

NEPA requires federal agencies to assess impacts and evaluate alternatives for all projects that significantly affect human and natural environments (42 U.S.C. § 4332). NEPA’s implementing regulations split the definition of effects into direct effects and indirect effects. Direct effects are those that “occur at the same time and place” as the proposed action (40 C.F.R. § 1508.8(1)). Indirect effects, on the other hand, “are later in time or farther removed in distance,” while still being reasonably foreseeable (40 C.F.R. § 1508.8(b)). Indirect effects include “growth inducing effects and other effects related to induced changes in the pattern of land use, population density or growth rate, and related effects on air and water and other natural systems” (40 C.F.R. § 1508.8(b)).

The impacts of major highway projects on land use patterns, or induced development, fall within this latter definition. On a number of occasions, federal courts have held that environmental documents that fail to address induced development impacts violate NEPA (Coalition for Canyon Preservation v. Bowers, 1980; Davis v. Coleman, 1975; Davis v. Mineta, 2002; Mullin v. Skinner, 1990; Rankin v. Coleman, 1975; Senville v. Peters, 2004; but see Florida Wildlife Federation v. Goldschmidt, 1981; Gloucester
Moreover, a growing body of jurisprudence suggests that the differences in land use patterns occurring under no-build and build alternatives must be accounted for when modeling travel demand (Citizens for a Better Environment v. Deukmejian, 1990; Conservation Law Foundation v. Federal Highway Administration, 2007; Sewell v. Peters, 2004; Sierra Club v. Department of Transportation, 1997). In other words, it is not enough for transportation planners to assess the possible induced development impacts of proposed transportation projects; they must also use the resulting land use forecasts as inputs to the region’s travel demand model. Only then can NEPA’s requirement to take a “hard look” at the possible environmental impacts of the proposed project be said to be satisfied (Sierra Club v. Department of Transportation, 1997).
Forecasting Options

These and other court rulings have prompted the publication of more than 30 guidance documents since 1998 on the subject of highway-induced development (ICF Consulting, 2005a, Appendix C; ICF Consulting, 2005b; Louis Berger Group, 2002; Stanley, 2006). These publications, produced by federal and state transportation and environmental agencies and transportation research organizations, were recently reviewed and synthesized in a project sponsored by the American Association of State Highway and Transportation Officials (AASHTO). The review notes that despite the large number of guidance documents, the assessment of highway-induced development remains “a largely ad-hoc field lacking focused guidance and research-based understanding of land use responses to transportation improvements” (Avin, Cervero, Moore, & Dorney, 2007, p. 6).

The AASHTO review classifies current methods into two broad categories: qualitative approaches, including those utilizing expert panels, and quantitative approaches such as formal land use models. As will be seen, the two approaches (expert panels and land use models) may result in very different forecasts. It is hoped that comparative analysis of these techniques might begin the process of replacing the “largely ad-hoc field” (Avin et al., 2007, p. 6) with some sense of best practice.

Delphi Panels

The Delphi method was developed in the 1950s by the RAND Corporation and used initially to predict which U.S. industrial sites were being targeted by the Soviet Union’s nuclear arsenal (Linstone & Turoff, 1975). Since the method’s declassification in the 1960s, it has been used in diverse fields when forecasts do not lend themselves to precise analytical techniques but can benefit from “subjective judgments on a collective basis” (Ziglio, 1996, p. 3). In the Delphi method, carefully selected experts each make independent forecasts in two or more rounds. After each round, a facilitator provides an anonymous summary of the experts’ forecasts from the previous round as well as the reasons they provided for their judgments. Participants are then encouraged to revise their earlier forecasts in light of others’ opinions. It is believed that during this process the group responses will converge on a consensus forecast that is more accurate than individual forecasts by the experts working alone (Dalkey, 1969; Delbecq, Van de Ven, & Gustafson, 1975; Powell, 2003).

The Delphi method was first applied to land use forecasting in the early 1970s (Badger, Higgins, & Ketron, 1976; Ervin, 1974). It was quickly adapted to allocate future growth to traffic analysis zones for purposes of travel forecasting; the process was touted as saving time and money in small metropolitan areas that lacked the resources to develop formal land use models (Baipai, 1990; Conder & Lawton, 2002; Faris, Beever, & Brown, 2000; Gamble & Pearson, 1993; Porter, Melendy, & Deakin, 1995).

The first reported use of the Delphi method to assess probable land use impacts of major transportation projects (i.e., induced development) was in San Jose, CA, where an expert panel estimated growth allocations, commute patterns, and transportation mode shares for three different transportation system alternatives (Cavalli-Sforza & Ortolano, 1984). During the 1990s, several high-profile transportation projects were subjected to Delphi-type forecasts of induced development, including State Highway 26 in Wisconsin (ICF Consulting, 2005b) and interstate highways I-5 in Washington (Seskin, Still, & Boroski, 2002) and I-93 in New Hampshire (Parsons Brinckerhoff Quade & Douglas, 2002).

The State of Maryland has come to rely on Delphi panels (ELUPs) for the assessment of highway-induced development impacts. In fact, the document that guides indirect impact analysis in Maryland prescribes the use of ELUPs for complex and controversial projects and actively discourages the use of intensely quantitative methods such as interactive modeling (Maryland State Highway Administration, 2000). Maryland has employed ELUPs to assess indirect impacts of improvements to I-270, State Highway 32, U.S. Highway 301, and most recently, the ICC (Parsons Brinckerhoff Quade & Douglas, 1998).

Curiously, the popularity of the Delphi method for land use forecasting has not translated into a robust literature on its validity. In fact, only two reported studies evaluate its accuracy in forecasting induced development. In the first study, panelists were asked to estimate, post hoc, the induced development impacts of transportation improvements made 20 years earlier in two cities unknown to the panelists (Mulligan & Horowitz, 1986). The researchers report that the forecasts “were reasonably accurate and a good measure of agreement was present” (p. 14), although no data or other evidence were offered to substantiate these conclusions.

The second study compared the results of travel demand forecasts in the Portland, OR, metropolitan area based on two allocations of future growth, one using a Delphi method and the other using a land use model (Conder & Lawton, 2002). The authors report substantial differences in the land use and transportation outcomes predicted with the two methods. For one of the region’s four counties, the two results were more than 15,500 households and 60,000 jobs apart only 20 years out. Since these are forecasts of future conditions, neither approach could be checked...
Land Use Models

Land use models have been used to allocate future growth for half a century (Iacono, Levinson, & El-Geneidy, 2008; Moeckel, Costinett, & Weidner, 2008). Pioneering work by Hansen (1959) and others in the late 1950s employed basic gravity models to relate the attractiveness and accessibility of particular districts within a metropolitan area to future development. As with Delphi processes, land use modeling was substantially advanced by researchers at the RAND Corporation, principally Ira Lowry (1964). Lowry-type models allocate future residential development and service employment to zones based on the location of basic employment and the zones’ relative attractiveness (frequently measured by the amount of developable land) and accessibility (measured as a function of travel impedance; Horowitz, 2004). The leading modern Lowry-type model, DRAM/EMPAL, is widely used in U.S. metropolitan areas (Hunt, Kriger, & Miller, 2005; Kanaroglou & Scott, 2002; U.S. Environmental Protection Agency, 2000; Wegener, 2004). Although recent state-of-the-art land use models have theoretical and practical advantages over more traditional spatial interaction models (e.g., Waddell, Wang, & Charlton, 2008), they also are dramatically more complex and data intensive. As a consequence, there is growing interest in simple, basic models that can be deployed easily in decision-making contexts (Gregor, 2007; Moeckel, Costinett, & Weidner, 2008).

The Baltimore-Washington region currently does not have a land use model. For a region so large, this fact is remarkable. The Metropolitan Washington Council of Governments (MWCOG), which is the metropolitan planning organization (MPO) for the DC area, long ago attempted to use the EMPIRIC land use model with disappointing results. The experience soured the MWCOG on formal models, and the agency has no current plan to develop an integrated land use and transportation model. Previous attempts to develop an integrated model for the Baltimore area also proved unsuccessful.

MWCOG acknowledges that land use and transportation influence each other. The MWCOG Metropolitan Development Policy Committee attempts to make its cooperative land use forecasts consistent with modeled travel projections for the future transportation network. Still, the current MWCOG cooperative forecasting process is, at best, a reflection of development trends and current local planning and zoning. As in most metropolitan areas, it is a heavily political process in which jurisdictions vie for economic development and transportation dollars.3

The ICC ELUP Process

The ICC ELUP Delphi panel consisted of 15 members who met five times between December 2003 and June 2004. It included the lead author of this article, other academics, planners, appraisers, a businessman, a developer, an attorney, a banker, and a citizen activist. Two meetings were for the exchange of background information and three were for the presentation and discussion of three rounds of Delphi panel forecasts.

Given the scale of the ICC project, the study area (the area of expected induced development impact) was defined to include all of Montgomery County, Howard County, and the District of Columbia, and adjacent parts of Prince George’s, Frederick, Anne Arundel, and Baltimore counties. The study area was partitioned into zones to which forecast growth would be allocated. After some discussion among panelists, a system of 34 zones was created (see Figure 1). The zones in the immediate vicinity of the highway were smaller than others to allow impacts to be assigned in these areas with more geographic precision.

At the initial ELUP meetings, planning directors from each of the affected jurisdictions presented highlights of their long-range transportation and comprehensive land use plans to the panelists. MWCOG provided data for the allocation process: population, households, and employment in 1990 and 2000 from the U.S. Census, and population, housing and employment for the 2030 horizon year from regional cooperative forecasts.

The horizon-year forecasts were initially thought to define the no-build population and employment baseline, but it turned out that before the panel could begin its job of allocating jobs and households for the build alternatives, it would be necessary to agree on a new 2030 no-build baseline. While MWCOG had never included the ICC in any of its transportation planning analyses, Montgomery County had assumed the presence of the ICC when making its land use forecasts, and MWCOG subsequently used these forecasts in the regional planning process. Hence, the ELUP facilitator permitted the panel to reconsider the no-build numbers and suggest revisions.

This process took a counterintuitive turn. Rather than scaling back what might have been overstated no-build growth forecasts for zones immediately adjacent to the highway, the majority of panelists increased the jobs and housing assumed under the no-build baseline. The higher baseline reduced remaining development capacity, causing
the ELUP forecasts of ICC impacts to be more constrained than if the baseline had remained unchanged.

Our Simple Models

During the ELUP process, perhaps the most difficult idea to convey was the importance of regional accessibility, specifically how a major regional transportation facility like the ICC could affect travel times and hence development potential over a wide area. While panelists could see the advantage to sites immediately adjacent to the facility, it proved harder to envision how the new facility would affect accessibility in the larger region. It was the absence of explicit accounting for accessibility that caused three panelists (including the lead author) to conclude that the ELUP process would be incomplete, and potentially highly inaccurate, unless informed by a formal land use model. Because there was no working land use model available for the region, these three panelists combined resources to develop simple land use allocation models (one for households and one for jobs) and apply them to final build forecasts for the ICC.

Model Form

The first step in developing the models was to estimate the relationships between regional accessibility and existing household and job distributions. The simplest way to do this is by estimating a long-run elasticity (predicted percentage change in one variable, like the number of households, when another variable, like accessibility to jobs in the region, increases by 1%) to forecast how development would shift if the ICC were built.

The models were equilibrium models because they predicted equilibrium distributions of households and jobs in a target year rather than rates of change in household and job distributions over time. They were also spatial interaction models because they assumed that forces attracting households and jobs to other jobs are useful for predicting the location of future development in the study area.

As we were constrained by time and data availability, we developed models for the ICC that were simplified versions of DRAM/EMPAL. Like DRAM/EMPAL they:

- assumed that spatial interactions influenced future equilibrium locations for households and employment;
- used relatively large zones compared to the usual traffic analysis zones (TAZs);
- assumed accessibility relationships to be nonlinear (power functions); and
- included measures of land availability and regional accessibility as independent variables.

The main differences between our models and DRAM/EMPAL were that:

- land availability was the only measure of the attractiveness of ICC zones for future development; and
- future households and employment were both located based on their accessibility to jobs, which was the only regional accessibility measure available from MWCOG.

Compared to current state-of-the-art models, which integrate land use and travel forecasts as well as account for a wide range of influences on development patterns (Hunt, Kriger, & Miller, 2005), the models we developed for the ICC were very simple. Still, they were based on empirically observed relationships in the study area.

Input Data

MWCOG supplied the basic data used in this modeling exercise. The base year for forecasting purposes was 2000 and the target year was 2030. Total area was known for all zones, while developable land (the area suitably zoned for development) was known only for Montgomery County zones. Since total area performed almost as well as an explanatory variable as did developable land for Montgomery County zones and was available for the entire study area, we used it to measure land availability in the models.

Rather than providing standard gravity measures of accessibility, MWCOG provided opportunity measures of cumulative trip attractions: the number of jobs reachable during the morning peak within 25, 45, and 60 minutes. We calculated a measure for each ICC zone by averaging the opportunity accessibility values for all of the MWCOG TAZs within that zone.

The MWCOG accessibility values did not include jobs outside the MWCOG region, most notably jobs in the City of Baltimore and in Baltimore and Harford Counties. This particularly understated the employment accessibility of ICC zones at the northern end of the I-95 corridor, specifically in Ellicott City, Columbia, Fulton, and Severn. We were able to correct this major shortcoming by acquiring comparable data on accessibility to Baltimore jobs from the Baltimore Metropolitan Council, the MPO for Baltimore, which we added to MWCOG accessibility values to obtain total jobs reachable within various travel times from ICC zones.
Scatterplots and regression analyses showed that total jobs within 25 minutes explained the most variance in numbers of households and jobs for both highway and transit modes, even though standard practice in the MWCOG region has been to evaluate transportation system performance using 45-minute accessibility measures. The decline in work trips’ share of all trips may have increased the explanatory power of the 25-minute accessibility measure, since work trips are substantially longer than most other types. That is to say, Washington area residents may have become acclimated to long commutes to work but prefer to keep travel times for other trip purposes shorter.

Model Estimation

We estimated the land use models using multiple regression analysis. Since scatterplots showed that relationships were nonlinear, we put all variables in logarithmic form. Running a log-log regression produces a power function in the original variables. The regression coefficients can be interpreted as arc elasticities of the dependent variable with respect to the independent variables.

The regression models explained 57% of the variation in the logarithm of households across ICC zones and 73% of the variation in the logarithm of jobs across ICC zones. The $r$ statistics of all coefficients were significant at conventional levels. Log-log regressions for Montgomery County zones alone, using either measure of land availability, produced even higher $R^2$s.

Table 1 shows elasticities for households and jobs with respect to accessibility and attraction for all of the ICC zones, for Montgomery County zones alone, and the final values we chose to use in the model, which lie between these two. (Since the primary impact of the ICC will be on Montgomery County, it seemed appropriate to give Montgomery County extra weight in parameter selection.) As an example, the elasticities we calculated using data for all of the ICC zones indicate that a 1% increase in a zone’s level of highway accessibility would result in a 0.61% increase in households and a 1.09% increase in jobs. The elasticities in Table 1 are higher for highway accessibility than for transit accessibility, reflecting the relative importance of the two modes. Elasticities are also higher for jobs than for households, indicating that employment locations are more sensitive to variations in accessibility.

Pivot Point Forecasts

These elasticity estimates allowed us to forecast numbers of households and jobs in each zone in 2030 if the ICC were built, based on the change to accessibility from the already forecast no-build future.\(^4\) Pivot point models are widely used in this kind of sketch planning activity (e.g., Herzog, Hall, & Carlson, 2002; Horowitz & Farmer, 1999; Marshall & Grady, 2006). We computed the numbers of households and jobs in each zone for build alternatives as follows:

$$H_{2030\ build} = H_{2030\ no\ build} \times \left( \frac{R_{2030\ build}}{R_{2030\ no\ build}} \right)^{E_{hh}} \times \left( \frac{T_{2030\ build}}{T_{2030\ no\ build}} \right)^{E_{ht}}$$

$$J_{2030\ build} = J_{2030\ no\ build} \times \left( \frac{R_{2030\ build}}{R_{2030\ no\ build}} \right)^{E_{jh}} \times \left( \frac{T_{2030\ build}}{T_{2030\ no\ build}} \right)^{E_{jt}}$$

Where:
- $H$ = households
- $R$ = highway accessibility
- $T$ = transit accessibility
- $J$ = jobs
- $E_{hh}$ = elasticity of households with respect to highway accessibility
- $E_{ht}$ = elasticity of households with respect to transit accessibility
- $E_{jh}$ = elasticity of jobs with respect to highway accessibility
- $E_{jt}$ = elasticity of jobs with respect to transit accessibility

As noted earlier, we had information on the amount of developable land only for Montgomery County. Our forecasts of households and jobs for some Montgomery County zones exceeded what could be absorbed under current zoning, sometimes by substantial margins, while in other zones forecasts fell short of capacity. Thus, if forecasts fell below zoned capacity (known only in Montgomery County) or capacity was unknown (in the rest of the study area) we used the forecasted values, even though some neighboring counties have strong zoning constraints and long histories of denying up zonings. Absent estimates of development capacity outside Montgomery County, this approximation was the best we could do. We reasoned that the ICC would have the largest effect on Montgomery County, and thus was most likely to reach or exceed the constraints in zones where we knew development capacities. We capped growth at zoned capacity in Montgomery County in all but a few zones likely to experience particularly intense development pressures, where we used our best judgment to increase capacity.\(^5\)

The models could be inaccurate for various reasons. We modeled zone growth only with accessibility measures, which provide an incomplete picture of development potential. Equilibrium models assume that the real estate...
Market fully adjusts to changes in accessibility, and thus they overstate change when adjustments are incomplete, as they often are. On the other hand, the use of 25-minute job accessibility measures probably understates change, since the ICC would also increase the accessibility of more distant jobs. The lack of zoning capacity data outside of Montgomery County is another potential source of forecasting error. It would have been preferable to treat the other counties as we treated Montgomery County, capping their growth allocations. Another possible source of forecasting error stems from MWCOG’s conventional four-step travel forecasting process, which likely understates future travel times and hence overstates accessibilities. As much as 30% of the ICC’s new capacity may be consumed by induced travel (additional trips made in response to the new capacity) and the triple convergence of travel mode, route, and time changes (Bartholomew, 2007; Downs, 2004). Over the 20-year period between the completion of the ICC and the end of the planning horizon (2011–2030) these effects can be expected to erode the accessibility benefits of the ICC, dampening its induced development impacts, particularly toward the end of the forecast horizon.

The Expert Panel Forecasting Rounds

Round 1 Build Forecast Results
The underlying assumption was, as is common, that the total number of jobs and households in the study area in 2030 would be the same whether or not the ICC was built. The ELUP panelists were to reallocate their (amended) no-build baseline forecast of where jobs and households would locate to reflect the ICC build alternatives. Panelists were advised to consider existing zoning and development capacities, but could assume some loosening of zoning constraints over time; they simply had to share their assumptions in accompanying write ups. None of the panelists had accessibility data or model results as they prepared their Round 1 forecasts.

Several things are noteworthy about the Round 1 forecasts:
- Panelists’ adjustments to households and jobs for most of the jurisdictions were less than the panel’s previous changes to MWCOG’s baseline forecasts.
- Panelists were of widely differing opinions as to which areas would receive or lose development due to the ICC. If added together, these differences would cancel one another, and yield only small net changes.
- Many panelists presumed that the effects of the ICC on development patterns would only be felt close to the highway, which meant that changes for jurisdictions other than Montgomery County were quite small.

Round 2 Build Forecast Results
In the second round, panelists were instructed to consider all of the Round 1 forecasts and rationales, and revise accordingly. In a true Delphi process, this interaction would be expected to result in gradual convergence of forecasts among panel members.

The MWCOG staff supplied the panelists with accessibility data for both the build and no-build alternatives, but not until after the scheduled deadline for Round 2 submissions. The three panelists relying on land use models had the accessibility data in time to use them in the models, which then informed their Round 2 forecasts. Two panelists did not complete forecasts. As for the other panelists, given the similarity of their Round 1 and Round 2 forecasts, it seems doubtful that they seriously considered the accessibility data made available between rounds.

There was some convergence between Rounds 1 and 2. Factorial analyses showed that the total variance of build

<table>
<thead>
<tr>
<th>Independent variables (1% change)</th>
<th>Elasticities for entire ICC study area</th>
<th>Elasticities for Montgomery County only</th>
<th>Final simple model elasticities</th>
</tr>
</thead>
<tbody>
<tr>
<td>ICC zone area (acres)</td>
<td>0.62% 0.66%</td>
<td>0.62% 0.83%</td>
<td>0.50% 1.20%</td>
</tr>
<tr>
<td>Jobs within 25 minutes by highway</td>
<td>0.61% 1.09%</td>
<td>0.40% 1.37%</td>
<td>0.25% 0.30%</td>
</tr>
<tr>
<td>Jobs within 25 minutes by transit</td>
<td>0.18% 0.24%</td>
<td>0.32% 0.33%</td>
<td></td>
</tr>
</tbody>
</table>
forecasts relative to the no-build forecast declined, and there was an equivalent decline in variance across panelists between rounds for both households and jobs. However, when panelists’ forecasts are combined into a composite (see Table 2) the net differences between build and no-build were small compared to the range of values for each county.

**Round 3 Build Forecast Results**

After the presentation of Round 2 forecasts, panelists were given one more opportunity to revise their forecasts. While they had important new information in the form of modeled forecasts for the build alternative, this came very late in the process, panelists were tired, and minds were made up. No one on the panel revised their forecasts, and the process effectively ended with Round 2.

**Comparison of Modeled Results and Expert Opinion**

The six county graphs in Figure 2 show differences between build and no-build Round 2 household and employment forecasts for each of the submitting panel members of the ELUP, allowing us to compare forecasts based solely on expert opinion with those based on expert opinion supplemented by the results of a simple spatial interaction model. Where differences are shown to be zero, panelists anticipated no difference between build and no-build alternatives. The three panelists who relied on model results were panelists 3, 8, and 15.

**Montgomery County**

In Montgomery County, where the ICC would logically have its greatest impact, the forecasts based on the simple models of growth in both jobs and households were about three times greater than those based on expert opinion only. Whereas the panelists who relied on judgment forecasted an average gain of 11,075 households and 14,697 jobs, the modeling group forecasted increases of 30,424 households and 46,916 jobs.

Differences were not uniform across the county. The models predicted larger job increases at locations near the ends of the ICC facility, such as Rockville, Gaithersburg, Germantown, and Montgomery Village, and in places with an existing commercial character that would be given new direct access via the ICC, such as Wheaton, White Oak, Aspen Hill, and Burtonsville. With regard to households, the models predicted increases in the interior of the county where accessibility has been limited in the past, at Deer

<table>
<thead>
<tr>
<th>County</th>
<th>2030 no-build(^a) forecast</th>
<th>Difference between 2030 no-build(^a) and composite build(^a) forecasts</th>
<th>Minimum difference</th>
<th>Maximum difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Montgomery County</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Households</td>
<td>432,710</td>
<td>16,252</td>
<td>3,000</td>
<td>33,500</td>
</tr>
<tr>
<td></td>
<td>Jobs</td>
<td>709,237</td>
<td>21,617</td>
<td>48,000</td>
</tr>
<tr>
<td>Frederick County</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Households</td>
<td>83,686</td>
<td>1,457</td>
<td>−9,400</td>
<td>15,198</td>
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<tr>
<td></td>
<td>Jobs</td>
<td>150,691</td>
<td>1,084</td>
<td>15,513</td>
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<tr>
<td>Howard County</td>
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<td>Jobs</td>
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<td>Anne Arundel County</td>
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<td>Households</td>
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<td>Households</td>
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<td>Jobs</td>
<td>829,021</td>
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Notes:
a. This is the ELUP panel’s amended no-build forecast.
b. This is the mean of all panelists’ Round 2 build forecasts, plus median of all panelists’ Round 2 build forecasts, divided by two.
Figure 2. Differences between panelists' forecasts of households and employment for each study-area county and the 2030 no-build forecasts for that county.

Note:
Arrows indicate panelists 3, 8, and 15, who relied on model results. Panelists 10 and 13 did not submit forecasts.
Park, Cloverly, Burtonsville, and Potomac. In these places, household growth potential would overwhelm existing zoned capacity. These are the places where the modeling group relaxed zoning caps to accommodate at least some of the projected growth.

The differences in forecasts illustrate the main philosophical divide within the panel. Some believed that Montgomery County’s growth controls would protect undeveloped areas from accessibility-driven growth pressures, while others thought that the design of the ICC to include 10 internal interchanges would inexorably open nearby areas to development. Indeed, immediately following federal approval of the project, The Washington Post carried a story about development interests’ euphoria over the future of the corridor (Mosk, 2006).

**Frederick County**

While differences between forecasts informed by models and those based exclusively on judgment were significant for Montgomery County, differences for surrounding counties were even more pronounced. Most panelists did not perceive much impact on development beyond the corridor itself, even though the travel time changes brought about by the ICC would extend throughout the study area.

Still heavily rural, Frederick County has grown rapidly over the past 15 years as job growth in the I-270 corridor and scarcity of affordable housing in Montgomery County have made living in Frederick County an economically attractive alternative. As Figure 2 shows, most panelists felt that construction of the ICC in Montgomery County would have no effect on this trend. The averaged difference in households based solely on expert opinion was only 33, compared to the model’s forecast of 15,198 additional households. As for employment, panelists relying on expert opinion forecasted a loss of 1,500 jobs, while the modeling group forecasted a gain of 15,513 jobs.

**Howard County**

In fast growing Howard County, the models forecasted increases of 2,584 households and 9,366 jobs. The panelists relying solely on expert opinion forecasted average growth of only 385 households and 1,493 jobs. The differences are likely due to the same phenomenon as in Montgomery County, where modeled forecasts reflect huge improvements in accessibility while judgmental forecasts were constrained by existing zoning.

**Prince George’s County**

Prince George’s County officials are concerned that the ICC will siphon off future economic development in favor of Montgomery County. Somewhat in response to this concern, panelists relying on expert opinion forecasted modest growth of households and jobs as a result of building the ICC, specifically increases of 3,800 households and 4,864 jobs. Using accessibility information, the modeling group forecasted considerably larger increases: 14,603 households and 46,722 jobs.

According to the models, much of the new growth would be located in the more suburban portions of Prince George’s County, not in the older inner core, and particularly in places that would be well served by the ICC eastern extension into Prince George’s County: Beltsville, Muirkirk, Laurel, and Laurel Pines. The mega-development of Konterra, noted above, is planned for the eastern end of the ICC in Prince George’s County. Though it will mix land uses, Konterra will be substantially auto-oriented due to its separation from the (existing and planned) Metrorail system.

**Anne Arundel County**

For Anne Arundel County, the modeled forecasts were entirely different from those based solely on expert judgment. The panelists using models forecasted 1,429 fewer households and 5,305 fewer jobs under the build alternative compared to the no-build alternative, while other panelists forecasted 1,375 more households and 1,795 more jobs if the ICC were built. The modelers’ results initially seemed counterintuitive, since one purpose of the ICC is to support continued growth around BWI Airport, which should benefit Anne Arundel County. However, this part of the region stands to lose in a relative and absolute sense as congestion increases on approaches to the ICC where highway capacity is limited and no highway improvements are programmed.

**District of Columbia**

For Washington DC, the panelists using models forecasted losses of 367 households and 5,305 jobs. The other panelists forecasted average losses of only 108 households and 1,795 jobs.

**Reasonableness of Results**

The forecasts informed by models were dramatically different from those based on expert opinion alone. Which method is right? Our observation that the subjective forecasts tended to be closer to the status quo, and that higher and lower forecasts often cancelled each other out, may indicate a conservative bias in the forecasts based strictly on expert opinion (Sackman, 1975). The provision of accessibility data too late to affect most panelists’ Round 2 forecasts, and the lack of response to accessibility data and
modeled results in Round 3, suggest that the process itself may have failed, providing critical information only after all minds were made up. The models had their own weaknesses; for example, they may have overstated estimates of ICC effects by failing to consider zoning constraints and attraction factors. When accessibility is the only thing considered, it is bound to appear important.

Ultimately, what counts is how well forecasts predict actual growth of households and jobs. Yet, beyond the obvious problem that we will not know conditions in 2030 for a long time, is the additional issue that even in 2030 we will lack a counterfactual. If the ICC is completed, there will not be a no-build alternative in 2030 to compare it to. Likewise, if it is not built, there will not be a counterfactual build alternative.

The best we can do is to look at the reasonableness of forecasts in light of the empirical literature on highway-induced development. We used recent work updating earlier literature reviews (Ewing, 2008) and applied the results to the ICC. The conclusions were:

- Major highway investments have only small net effects on economic growth and development within a region. Instead, they mostly move development around to take advantage of improved accessibility. Induced development is very close to a zero-sum game. The ICC will produce winners and losers.
- Highway investment patterns tend to favor suburbs over central cities and thereby contribute to decentralization and low-density development. This will be true of the ICC.
- Major highway investments may actually hurt regional productivity if they induce inefficient (low-density) development patterns. This may be true of the ICC.
- Corridors receiving major highway investments experience land appreciation, and are therefore likely to be developed at higher densities than lands outside the corridor. This will be true of the ICC.
- Highways may be necessary, but they are not sufficient, to induce development. MWCOG has acknowledged that the extraordinary level of induced development in the I-270 corridor following its widening would not have occurred without zoning changes to accommodate it. To the extent that current planning and zoning caps hold, particularly in Montgomery County, impacts within the corridor will be moderated.
- Counties receiving major highway investments attract more population and employment growth than they would otherwise. This will be true of Montgomery County and to a lesser extent of some of the adjacent counties.
- Nearby counties may experience more or less growth than they would otherwise, depending on the strength of spillover effects. The big losers in this case are likely to be at a distance, including Washington DC and Baltimore.
- Nonresidential development is more strongly attracted to major highways than is residential development, particularly in the immediate vicinity of highway facilities. There will be tremendous pressure to allow commercial and office development along the ICC.
- The induced development impacts are wider and deeper for interstate-quality highways than for lesser highways and streets. The ICC is of interstate quality, which means its impacts are likely to be wide and deep.
- It takes many years after construction for development to adjust to a new land use and transportation equilibrium. The development impacts of the ICC will be felt for 10 years or more.
- The induced development impacts of major highways extend out at least one mile, and probably much farther. While the most intense impacts of the ICC will be within that one-mile buffer, a project of this scale will produce development impacts at greater distances. Whether the impacts will be felt out to the boundaries of the study area, as the models suggest, is debatable. The geographic extent of induced development impacts is not settled by the guidance documents, referenced above, and is one of the least addressed issues in the research literature.

Conclusion

Although the use of Delphi methods for land use forecasting has now become widespread, one of the leading guidance documents (Seskin, Still, & Boroski, 2002) cautions against sole reliance on Delphi when:

- the proposed projects have been well publicized and everyone has formed an opinion;
- the affected area includes numerous proposed transportation projects;
- the transportation alternatives are so similar to each other that panelists cannot make significant distinctions among them;
- the affected area is so large that no panelist knows the entire area well.
The ICC panel process was undermined by the presence of three of these four factors: The ICC has been contentious for decades, so panelists had strong predispositions going into the process; the build alternatives (the two alignments) were sufficiently similar that panelists had difficulty distinguishing between them; and the affected area was arguably larger, even, than the study area defined in the project scoping.

In this case study, expert opinion alone and expert opinion informed by a simple land use model produced dramatically different results. They are clearly not simple substitutes for one another, as sometimes assumed. The two may bound the likely impacts of the ICC, with one (the simple model) giving too much weight to accessibility effects and too little weight to zoning constraints, and the other (expert opinion) doing just the opposite. As important as accessibility may be, it is not a sufficient condition for development to occur.

Short of developing a state-of-the-art integrated land use and transportation model, with the expense, multi-year time commitment, and data intensiveness that entails, we think that the combination of the two approaches, each somewhat enhanced, may produce the most credible results. Enhancement of the simple model would, at the very least, account for zoning constraints on developable land. Enhancement of the expert panel process would, at the very least, feed accessibility data to the panelists early in the process. Perhaps then the forecasts by the two methods would begin to converge, allowing analysts to settle on consensus values. In addition, a good process would temper model inputs and outputs based on the expert panel’s real-world business sense and knowledge of local conditions and trends. This did not occur in the case of the highly polarized ICC expert panel process.

Even in circumstances where they use the same baseline conditions, different land use models are known to produce different results (Hunt et al., 2001). Thus, even the most sophisticated, integrated land use and transportation models may benefit from expert input. The experience and expertise of panelists may shed light on what would otherwise just be a black box crunching out numbers. In the ideal, integrated model outputs would be just one input into a deliberative process based on local knowledge and diverse expertise.

Further research should aim to define the constructive roles expert panels can play in forecasting exercises, and might explore how panel members arrive at their individual forecasts. Which factors did they find determinative? Which were inconsequential? While some Delphi processes collect this type of information on response forms (e.g., Parsons Brinckerhoff Quade & Douglas, 2002), systematic interviews could improve the contributions expert panels make to future highway-induced impact analyses.

Acknowledgments
The authors wish to acknowledge help with the modeled forecasts from two other members of the Expert Land Use Panel, J. Richard Kuzmyak and Harry Sanders. We also thank the consultant on the project, Parsons Brinckerhoff Quade & Douglas, for preparing the original graphs upon which our figures are based.

Notes
2. The panel assessing induced development impacts for the I-93 project was unable to reach consensus positions on either the build or the no-build alternatives. Hence, to represent the panel’s results, a blended average was calculated that divided the sum of the mean and the median of the panelists’ responses by two. The New Hampshire Department of Transportation (NHDOT) elected to not use the panel’s land use allocations in travel demand modeling for the project environmental impact statement (EIS), a decision that was later determined to violate NEPA (Conservation Law Foundation v. Federal Highway Administration, 2007). NHDOT is now preparing a supplemental EIS, but has decided to replace the Delphi results with projections derived from a land use allocation model (New Hampshire Department of Transportation, 2008).
3. A second-generation model, TRANUS, was not implemented by the Baltimore Metropolitan Council (BMC) after the software developer failed to meet contractual obligations. A trio of academics involved with the Baltimore Ecosystem Study abandoned their planned implementation of a third-generation model, UrbanSim, when the data requirements proved too great. BMC hired another contractor to develop another third-generation model, PECAS, at about the time of the ICC study. It is still not calibrated and validated, and would not have covered much of the relevant study area for the ICC in any case.
4. We began with the expert panel’s collective no-build forecasts. Starting with the original no-build forecast from MWCOG would have affected the difference between build and no-build alternatives very little.
5. We did this to avoid allocating too much growth to places like Germantown, Gaithersburg, Montgomery Village, Aspen Hill, and Wheaton, while allowing for a slight increase in allocations to places like Laytonsville, Burtonsville, Cloverly, and Deer Park where current capacities are quite low and where the added accessibility provided by the ICC will create tremendous growth pressures. All Montgomery County zones assumed to absorb more development than current zoning would allow fall within Priority Funding Areas under Maryland’s Smart Growth Priority Funding Areas Act of 1997 and either currently have urban levels of water and sewer service or are planned to have them by 2014 (Maryland State Highway Administration, 2006).

References


Coalition for Canyon Preservation v. Bowers, 632 F. 2d 774 (9th Cir. 1980).


Davis v. Coleman, 521 F. 2d 661 (9th Cir. 1975).

Davis v. Mineta, 302 F. 3d 1104 (10th Cir. 2002).


