3.0 How to Develop an Integrated Alternative

The purpose of this section is to provide guidance on developing an integrated land-use/transportation/demand-management alternative. The section tells the story of the development of the LUTRAQ alternative and provides additional insights from other projects. The discussion is intended as a place to start the process, not as a definitive work on how to develop an alternative. References to more detailed sources of information are provided throughout the document.

The story of developing a land-use/transportation/demand-management alternative is described as a series of steps. It should be noted that the steps are standard procedures in comprehensive planning. The insight LUTRAQ provides is not in the planning process, per se, but in the range of alternatives considered and evaluated. The steps are:

1. Clarify the scope of the project
2. Decide who will be involved
3. Define a range of alternatives
4. Determine performance measures for comparing alternatives
5. Select analytical tools for analyzing alternatives
6. Simulate alternatives and interpret results
7. Implement the preferred alternative

While there is a natural sequencing to the steps they are also interrelated. Some steps need to be considered simultaneously. For instance, the performance measures used to evaluate alternatives are dependent upon the analytical tools available to measure the indicators. In addition, decisions made at one step may require rethinking of previous decisions. The analysis of alternatives might, for example, produce results that indicate a need to consider new or revised alternatives.

3.1 Clarify the Scope of the Project

Basic Questions

- *What type of project is this?*
  - q Regional visioning
  - q Major investment study
  - q Regional transportation plan
  - q Community plan
  - q Other

- *What are the goals of the project?*
  - q Growth management
  - q Identify alternate land-use development patterns that increase use of alternate travel modes
  - q Enhance sustainability of community
  - q Improved transportation performance
  - q Other
- *What are the planning mandates to integrate land-use, transportation, and air-quality planning for this project?*
- *What personnel, time, money, and other resources are available for this project?*

The LUTRAQ Experience

The LUTRAQ integrated land-use/transportation/demand-management plan was developed as an alternative to a proposed bypass highway (the Western Bypass) in Washington County, a fast growing suburban county on the western side of the Portland, Oregon metropolitan area. The plan was developed as one of the alternatives to be evaluated in a Draft Environmental Impact Statement (DEIS) for the Oregon Department of Transportation's Western Bypass Study. During the course of the study, Congress enacted the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA), changing the planning rules for environmental analyses, and allowing the study to be completed as a Major Investment Study (MIS).

ODOT and its advisory committees developed four transportation alternatives for the DEIS/MIS process: No Build, Transportation System Management, Arterial Expansion/High Occupancy Vehicle Express Service, and the Bypass. These transportation strategies assumed that land uses would follow existing comprehensive plan designations. 1000 Friends of Oregon developed the LUTRAQ alternative to demonstrate that a different vision for land use and transportation was feasible and effective.

LUTRAQ challenged the idea that land uses must be held constant when addressing transportation needs. Instead, it created an alternative suburban land-development pattern that located most household and employment growth on vacant or under-utilized lands near planned transit service. This type of analysis was not mandated when the project began, but the rules changed during the course of the project.

In part because of the controversy about the Western Bypass, the Oregon Land Conservation and Development Commission developed and adopted a Transportation Planning Rule in 1991 to clarify the relationship between transportation and land-use planning. The rule requires that land-use alternatives be considered in the development of regional transportation plans in the Portland metropolitan area. Also adopted in 1991, ISTEA requires consideration of inter-relationships between land use and transportation as part of the long-range planning process. Although neither of these mandates specifically applies to project level analyses, the spirit of the requirements was persuasive in broadening the scope of the Western Bypass Study.

Lessons from Other Projects

ISTEA has elevated the importance of considering the interrelationship between land use and transportation as part of the transportation-planning process. Under ISTEA, Metropolitan Planning Organizations (MPOs) and state departments of transportation (DOTs) must consider the effects of transportation policy on land use and development as well as the consistency of transportation plans with land-use plans. These requirements apply at the metropolitan and state levels when developing regional transportation plans and at the corridor/ subarea level in an MIS. In addition, some regions are considering land-use alternatives as part of their strategies to meet the requirements of the Clear Air Act.

During the course of the LUTRAQ project, Metro, the regional planning agency for the Portland area, began another planning process, called Region 2040, to formulate a regional growth-management plan. Metro initiated the project because of concerns about the management of growth, and the need to update the regional transportation plan, review the metropolitan urban growth boundary, and comply with new state requirements, including the Oregon Transportation Planning Rule. As part of the project, Metro developed and tested several alternative patterns of growth over a 50-year period. The alternatives were developed to test the long term consequences of public policies and growth patterns on transportation, land consumption, housing supply, public facilities costs, and other aspects of regional growth management.

Similarly, the Tallahassee-Leon County MPO in Florida developed and analyzed three land-use scenarios when preparing their Year 2020 Transportation Plan. Florida’s growth management act requires that transportation facilities be provided concurrently with development. Florida communities therefore need to consider how development patterns impact transportation. The MPO tested the land-use scenarios in combination with various transportation improvements to determine how growth could be accommodated with minimum deficiencies in levels of service in the transportation system.

3.2 Decide Who Will Be Involved

Basic Questions

- *Who will provide leadership?*
- *What governmental agencies will be involved and what is their role?*
- *How will advocacy groups and individuals be involved?*

The LUTRAQ Experience

1000 Friends of Oregon, a non-profit advocacy group, developed the LUTRAQ alternative. Although any number of public agencies involved in the debate over the Western Bypass could have fulfilled this role (e.g., Metro, ODOT, Washington County), the job fell to 1000 Friends for two fundamental reasons. First, because 1000 Friends had sued Metro and Washington County to stop the bypass project, there was a sense of obligation on the part of the organization to articulate a positive response to the conditions giving rise to the bypass proposal. Second, none of the relevant public agencies was willing to take on the challenge of developing an alternative that included changes to planned land uses, and several of them indicated that the task was not technically possible. This unwillingness on the part of the agencies was most likely a reflection of the political volatility surrounding the notion of changing land-use plans.[1] Although none of the agencies was willing to take the lead in developing the LUTRAQ alternative, they eventually were all willing to work with 1000 Friends in the effort, many with a high degree of support.

Metro, in particular, provided key support for the project, working closely with project staff to develop enhancements to Metro's land-use and travel-forecasting procedures and to run model simulations of the LUTRAQ and other alternatives. Through LUTRAQ, Metro saw an opportunity to improve its already excellent modeling capabilities and to introduce the ideas about changed land-use plans that would eventually be incorporated in the Region 2040 project.[2]

Another key player was ODOT. As the lead agency for the Western Bypass Study MIS, ODOT kept some distance from the process of developing the LUTRAQ alternative. Once the alternative was formulated, however, the agency formally accepted the alternative as one of five to be studied in the MIS.

1. Eventually, these public agencies did accept the notion of altering land-use plans for the purpose of reducing reliance on the automobile, as evidenced in Metro's Region 2040 project. In 1989-90, however, when the LUTRAQ project was just beginning, the agencies were substantially more cautious about—even hostile to—the concept.

2. Not every agency responsible for travel models will be as supportive as Metro. In some cases, advocacy groups may have to develop alternative methods to demonstrate the relevance or travel benefits of land-use alternatives. In Chicago, for example, the Environmental Law and Policy Center has had to develop its own modeling procedure to evaluate a land-use alternative to a proposed suburban highway.

The remaining public agencies—state land-use and environmental-quality agencies and the local governments of Washington County—participated in the project primarily through local technical and policy advisory committees. These two committees provided technical and political input on the shape and viability of the LUTRAQ alternative as it was being constructed.

A third committee—the National Technical Advisory Committee—was instrumental in steering the project's research. It was this committee that outlined the work program for the project, monitored its implementation, and reviewed work products.

It is frequently asserted that the Oregon planning environment is unique and that the LUTRAQ process cannot be replicated elsewhere. While Oregon's land-use laws are distinctive, and thus cannot be relied upon as a foundation for actions in other states, the process of considering land-use alternatives can and does occur in many jurisdictions. The examples that follow illustrate this point.

Lessons from Other Projects

Under ISTEA, either state DOTs or MPOs can be the lead agencies for MIS/EIS alternatives analyses. ISTEA also requires that DOTs develop statewide transportation plans and MPOs prepare regional transportation plans. Thus, DOTs and MPOs are potential leaders for developing integrated land-use and transportation alternatives for these projects. In addition, counties, cities, or advocacy groups could provide leadership. The choice of leadership and other participants depends upon the scope and purpose of the project and the institutional structure and history of the region.

Regardless of who is the lead agency, any project of this sort requires outreach to the public and coordination with affected jurisdictions to gain understanding and support for the alternative. ISTEA requires that governmental agencies developing transportation plans include the public in these processes and coordinate with other affected jurisdictions and agencies. The following examples show varying patterns of leadership and participation in the development of a land-use/transportation alternative.

The Delaware Department of Transportation (DelDOT) is the lead agency developing an infrastructure investment strategy for Churchman's Crossing, a five to six square-mile suburban activity center in New Castle County at the crossroads of I-95, SR 1, and Amtrak's Northeast Corridor. Churchman's Crossing includes several residential communities and some of Delaware's largest existing and proposed banking, medical, and retail businesses. DelDOT is working with the Wilmington Area Planning Council, New Castle County, the public, and the development community within Churchman's Crossing to clarify a vision for the area, develop a coordinated transportation/land-use plan, and assist in the creation of a transportation improvement district to augment public-sector investment. Results of the study will be incorporated into long-range transportation and comprehensive land-use plans. DelDOT is the lead agency in this effort because it plans for and provides highway, bus, and regional-rail facilities and services in this unincorporated area.

The City of Albuquerque is conducting a Transportation Evaluation Study that includes analysis of land-use patterns. Albuquerque is the dominant city in the region and has the greatest stakes in developing an efficient and effective transportation and land-use system because of its size. The city has long pursued an aggressive policy of annexing land and providing urban services. As a result, it influences the urban form of the whole metropolitan area. It has also developed cooperative relationships with other local and county governments and the MPO in order to discuss and plan for regional growth and development. By leading the transportation/land-use study, Albuquerque has an opportunity to reinforce the existing center and focus on infill and redevelopment issues at the same time as addressing development on the urban fringe.

In Maryland, because development is largely controlled by counties, they are the logical candidates to develop land-use/transportation alternatives. Montgomery County, part of the rapidly growing Washington, DC metropolitan area, has a long history of growth management. Building on its vision for the area, the county has utilized Metrorail stations to focus growth in suburban centers. In general, the county has directed the location of growth based on the level of service of transportation facilities and other infrastructure.

In many cases, MPOs are the logical choice to develop or coordinate regional land-use discussions because they are responsible for preparing regional transportation plans and have established working relationships with local jurisdictions. The Portland and Tallahassee examples presented in the previous section are two out of many examples of MPO development of integrated alternatives.

As with the LUTRAQ project, however, the role of non-governmental organizations is still important in many metropolitan areas. In the Chicago area, the non-profit Environmental Law and Policy Center (ELPC) is leading a study of the proposed extension of Illinois Highway 53 by the state's tollway authority. The extension would be located in the same corridor where Metra, the region's commuter rail agency, has begun to provide service. ELPC is assessing whether the new rail service, combined with a more transit-focused land-use plan, can meet the transportation needs of the area without the tollway extension.[3]

3.3 Define a Range of Alternatives

Basic Questions

- *What are current conditions and trends?*
- *How many and what sort of alternatives will be considered?*
- *How will the alternatives differ from current trends?*
- *Will both land-use and transportation systems be varied?*

The LUTRAQ Experience

1000 Friends developed the LUTRAQ alternative while ODOT and the Western Bypass

3. For additional examples, see Carlson et al. (1995).

Study advisory committees developed the more traditional transportation alternatives. The LUTRAQ alternative was developed in stages, in an iterative process that included modeling the transportation outcomes of several draft versions of the alternative, and then revising the alternative in response to those outcomes. Since the LUTRAQ approach was a radical departure from traditional alternatives, the project team anticipated that they would need to fine-tune the proposal. In brief, the steps followed in developing the alternative were:

1. Inventory existing land uses and identify trends
2. Develop a draft alternative
3. Test the transportation outcomes of the alternative
4. Revise the alternative
5. Test the revised alternative
6. Continue with fine-tuning and testing, as needed

Four different versions of the LUTRAQ alternative were created using this approach, as shown in Table 5.

The LUTRAQ analysis began with an evaluation of existing conditions. The project examined regional, study area, and subarea trends for population, housing, and employment. The project also analyzed existing types and locations of land uses, employment, and vacant land in Washington County. Finally, the analysis looked at environmental factors such as flood plains, wetlands, and slopes that could constrain development.[4]

Then, the project team developed the land-use element of the alternative based on an analysis of:

- Demographic and market trends
- Redevelopable and infill sites
- A different type of suburban development focused on the transit system, called Transit-Oriented Development (TOD)

A fundamental premise of LUTRAQ was to work within current real estate market trends and expectations. Therefore, market research was conducted to determine the market conditions through 2010 for residential, commercial, and industrial uses. This research identified the types of housing and jobs that would be feasible in Washington County. The research showed that because of the county's fast growth there is a market for an even greater share of multi-family housing than exists today because of the types of people living in and expected to move to the county. The county will continue to see growth in retail and industrial employment and a slower rate of growth in office employment.[5]

Metro's Regional Land Information System, a geographic information system, was used to identify land with development potential—either vacant or redevelopable. Over 17,000

4. See LUTRAQ Volume 2: *Existing Conditions* (1000 Friends of Oregon, 1991b) for further details.
5. See LUTRAQ Volume 3A: *Market Conditions* (1000 Friends of Oregon, 1992b) for further information.

acres inside the study area were identified as suitable for mixed-use, transit-oriented development. These included 10,000 acres in large (40 acres or more) undeveloped parcels, 6,800 acres of infill or redevelopment sites of at least 15 acres, and between 1,700 and 2,400 acres of small infill sites. Both the large vacant parcels and the infill/redevelopment sites provide opportunities to build TODs, especially since many of the large undeveloped areas are located along light-rail corridors.

The TOD concept is simple: moderate- and high-density housing, along with complementing public uses, jobs, retail, and services, are concentrated in mixed-use developments located at strategic points along the regional transit system. Each TOD has a centrally located transit stop and core commercial area. Accompanying residential and/or employment uses are within an average 2,000 feet walking distance. The location, design, configuration, and mix of uses in a TOD provides an alternative to current suburban development trends by emphasizing a pedestrian-oriented environment and reinforcing the use of public transportation.

Three types of TODs were developed to fit in various parts of the region (see Figure 7). Mixed-Use Centers are planned for the traditional suburban downtowns (Beaverton, Hillsboro, Tigard, Tualatin, and Sherwood), and the emerging “edge cities” of the county (Washington Square and the Tigard Triangle). Urban TODs are located outside of Mixed-Use Centers and would include medium- to high- density residential uses and a commercial core area. Neighborhood TODs emphasize medium-density residential development and local retail. Under current market trends, these three TOD types can accommodate the majority of new development coming to Washington County (65 percent of expected residential units and 78 percent of future jobs).[6]

The transportation components of the LUTRAQ alternative were initially developed with an exclusive focus on transit. This “pure” version of the alternative (listed as “LUTRAQ/No Pricing” in Table 5), was modeled to assess the effectiveness of utilizing just land-use changes and fixed-route transit. It was anticipated from the start that other transportation elements—in particular some roadway improvements—would need to be added. This first model run, and the one that followed it, provided information that allowed such additions to be limited in scope and targeted in location. As a result of the first analysis, a second version of the alternative (“LUTRAQ/Parking Pricing”) was developed. This version added a demand-management program (developed by ODOT) consisting of a work-trip parking charge and a subsidized transit-pass system. Continuing the iterative process, this second version was also modeled, and the output used to develop a third version of the alternative, which was ultimately used in the MIS process. This third iteration—known simply as the “LUTRAQ alternative”—added pedestrian facilities, demand-responsive transit, and selected roadway improvements. Finally, a fourth version of the alternative was developed that added a $.15/mile peak-hour congestion pricing charge. The course of this iterative process is illustrated in Table 5.

---

6. See LUTRAQ Volume 3: *The LUTRAQ Alternative* (1000 Friends of Oregon, 1992a) for a complete description of the land-use element.

Table 5: The Evolution of the LUTRAQ Alternative

<table>
<tr><th rowspan="2"></th><th rowspan="2">Land Use</th><th colspan="3">Transportation</th><th rowspan="2">Demand Management</th></tr>
<tr><th>Transit</th><th>Roads</th><th>Pedestrian/Bike</th></tr>
<tr><td>Version 1: LUTRAQ/ No Pricing</td><td rowspan="3">Transit-oriented development</td><td rowspan="2">4 LRT lines; express & feeder bus service</td><td rowspan="2">Committed projects only</td><td rowspan="2">Committed projects only</td><td>None</td></tr>
<tr><td>Version 2: LUTRAQ/ Parking Pricing</td><td rowspan="2">Parking pricing; transit-pass subsidy</td></tr>
<tr><td>Version 3: LUTRAQ (MIS version)</td><td rowspan="2">4 LRT lines; express & feeder bus service; PLUS demand-responsive service</td><td rowspan="2">Committed projects; PLUS selected improvements to existing facilities</td><td>Committed projects; PLUS sidewalks, bikeways, crossings in <u>most</u> transit corridors</td></tr>
<tr><td>Version 4: LUTRAQ/ Congestion Pricing</td><td>Transit-oriented development; PLUS slightly higher % of households and jobs in TODs</td><td>Committed projects; PLUS sidewalks, bikeways, crossings in <u>all</u> transit corridors</td><td>Parking pricing; transit-pass subsidy; PLUS congestion pricing</td></tr>
</table>

Lessons from Other Projects

Despite differences in geography, history of development, and public policies, the integrated land-use/transportation/demand-management alternatives that regions have developed are quite similar. Basically, the potential alternatives are:

- Continuing current trends of decentralized development
- Concentration of development within an urban service area or urban growth boundary
- Focusing of growth in transportation corridors or in centers connected by multi-modal transportation
- Locating some of the growth in new or existing satellite communities
- Emphasizing growth in parts of the region with underutilized infrastructure

The following examples illustrate in more detail the types of alternatives that different regions have developed.

Portland's Metro developed five scenarios for its Region 2040 process. The Current Trends scenario continues current development trends and public policies. It requires that the urban area expand by over 50 percent. The Growing Out scenario seeks to meet new federal, state, and regional policies to improve air quality and reduce vehicle miles traveled while continuing with current development methods. The urban growth boundary expands by 25 percent in this scenario and some growth is concentrated in transit corridors. The Growing Up scenario retains the current urban growth boundary and accommodates growth by using land more intensely and concentrating development in centers and along transit corridors. In the Neighboring Cities scenario, one-third of the anticipated growth in population and jobs is shifted to nearby cities outside the metropolitan urban growth boundary. Inside the urban growth boundary, more growth is concentrated in urban centers.

After evaluating these scenarios, Metro applied the lessons learned to develop a final alternative, known as the 2040 Growth Concept, that combines elements from the earlier scenarios. The Growth Concept, which was ultimately adopted by the Metro Council, resembles the Growing Up scenario's development focus on centers and transit corridors. Analysis indicates, however, that the Growth Concept is likely to result in higher transit ridership with lower transit service hours than the Growing Out scenario. Table 6 summarizes some of the characteristics of each scenario and the transportation outcomes of each.

Table 6: Portland, Oregon Region 2040—Comparison of Alternatives

	1990	Current Trends	Concentrated Development Scenarios			
			Growing Out	Growing Up	Neighboring Cities	Growth Concept
Land-Use Characteristics						
Ratio of single-family to multi-family housing in 2040	70/30	70/30	74/26	60/40	69/31	65/35
% of growth inside existing urban growth boundary	—	83%	71%	100%	63%	87%
Transportation Impacts						
Mode Choice						
Auto	92%	92%	91%	88%	89%	88%
Transit	3%	3%	4%	6%	5%	6%
Walk/Bike	5%	5%	5%	6%	6%	6%
Daily VMT per Capita	12.40	13.04	12.48	10.86	11.92	11.76
% change from Current Trends	—	—	-4.3%	-16.7%	-8.6%	-9.8%
Transit Service Hours	4,983	9,600	12,300	13,200	12,600	12,000
Transit Riders	136,800	338,323	372,400	527,800	437,200	570,000
% change from Current Trends	—	—	10.0%	56.0%	29.2%	68.5%
Congested Road Miles	151	506	682	643	404	454

Source: Metro, 1994

Similarly, the Metropolitan Council in the Twin Cities (Minneapolis-St. Paul, Minnesota) is evaluating three alternatives that consider different urban service areas, job locations, and development patterns. A Current Trend scenario continues contiguous outward development at lower densities. Growth occurs in response to market forces as well as local and regional policies and infrastructure investment decisions. Under these conditions, the urbanizing area expands in size and the growth rate of rural areas increases consistent with recent experience. The Concentrated Development scenario curbs the outward expansion of the urbanizing area and encourages infill and redevelopment. This alternative optimizes the use of existing infrastructure and consumes the least amount of land. Leapfrog development to adjacent counties is, however, accelerated. The Growth Centers scenario organizes development and redevelopment into nodes and clusters along selected transportation corridors, which also guide sewer investments. In this scenario, development in urbanizing areas and adjacent counties is located primarily along the selected corridors while development in rural areas is confined to rural centers. The Council is currently determining a preferred alternative and the steps needed to implement it (Metropolitan Council, 1995).

The Tallahassee-Leon County MPO evaluated three scenarios that emphasize growth in different parts of the region as part of their regional transportation planning process. The Comprehensive Plan Scenario distributes growth based on historic growth patterns and vacant-land inventories. The Urban Infill Scenario assumes more redevelopment in the low-density urban core and limits or provides disincentives to growth outside the urban infill area. The Southeast Strategy encourages growth in a part of the county where many facilities are underutilized and assumes that growth is discouraged elsewhere. By combining the land-use scenarios with various transportation network configurations, the MPO was able to test the interactions between transportation and land use. As a result, the agency developed a clearer picture of transportation needs and different ways to meet those needs, ultimately adopting the Southeast Strategy for developing a long-range vision over the previous Comprehensive Plan scenario (Post Buckley, 1995).

3.4 Determine Performance Measures for Comparing Alternatives

Basic Questions

- *What performance measures are desirable given the goals of the project? (See Section 3.1)*
- *What performance measures are feasible given the analytical tools available? (See Section 3.5)*
- *What measurement tools will need to be developed?*

The LUTRAQ Experience

The LUTRAQ alternative was designed to show that a transit-focused pattern of development combined with selected transportation improvements could meet the transportation needs of suburban Washington County. As a consequence, the alternative needed to be evaluated on the same transportation performance measures as the other Western Bypass Study alternatives. As discussed in more detail in the next section, the LUTRAQ effort included enhancements of Metro’s travel-demand model to reflect more accurately the effects of mixed-use, pedestrian-friendly environments on travel patterns.

The Western Bypass Study evaluated LUTRAQ using the full range of environmental, social, economic, and transportation indicators needed for a Draft Environmental Impact Statement or Major Investment Study. The following factors were evaluated:

- Geology and soils
- Floodplain hydrology/hydraulics
- Water quality
- Biological resources
- Air quality

- Noise
- Energy
- Visual quality
- Land use
- Economics
- Hazardous materials
- Cultural resources
- Transportation outcomes and costs

The LUTRAQ project, itself, had a narrower focus, but also included some measures that were not in the Western Bypass Study. LUTRAQ compared alternatives on the following measures:

- Auto ownership
- Mode choice—work and non-work trips
- Vehicle trips per household
- Vehicle hours of delay (traffic congestion)
- Peak vehicle hours of travel (traffic congestion)
- Daily vehicle miles of travel
- Accessibility to population, jobs, and shopping[7]
- Emissions of hydrocarbons (HC), nitrogen oxides (NO_x), and carbon monoxide (CO)
- Emissions of greenhouse gases
- Energy consumption

The first six of these measures are outputs from Metro's enhanced travel-demand forecasting model. The remainder use information from that model as inputs. Metro's GIS program maps accessibility using multi-modal travel time outputs from the travel-demand model. Air-quality and energy-consumption models use information on types of vehicles and amount of travel to determine emissions and energy use.

Missing from the list of LUTRAQ criteria is an explicit assessment of costs. This measurement was left out for several reasons. First, simple measures of facility costs (capital, operations, and maintenance) fail to consider the full range of transportation-related costs. While they include some, but not all, governmental costs, they exclude user costs and ignore (or fail to monetarize) the social costs of travel, including pollution costs. Second, the introduction of these costs without a comparable discussion of benefits (to users and the community) is incomplete and misleading. Since the inception of the LUTRAQ project, important new research on the "full" costs and benefits of transportation has occurred, indicating the possibility of developing a consistent, holistic perspective on project benefits and costs (see

7. As measured, respectively, by the proportion of the study area within 30 minutes travel of 800,000 people or 500,000 jobs, or within 15 minutes travel of 25,000 retail jobs.

Delucchi, 1996 and ECONorthwest, 1995).

Lessons from Other Projects

The choice of performance measures depends both upon the scope of the project and the tools available to measure outcomes. Places developing a regional transportation plan will have a more limited set of performance measures than the places developing a regional vision or land-use plan. Travel-demand models can measure many transportation outcomes of integrated land-use/transportation options, but innovative techniques or qualitative methods may be needed to measure other potential measures (see the next section for further details).

The Tallahassee-Leon County MPO analysis of alternatives focused primarily on level of service (LOS) measures. LOS measures are used to determine whether transportation facilities are adequate to serve development, as required by Florida's growth management program. Other measures of effectiveness included fuel consumption, accident rates, and generalized estimates of air-pollutant emissions.

Portland Metro's analysis for Region 2040 took a much wider view since the goal was to develop a regional growth-management plan. In addition to the locational and transportation variables listed previously in Figure 1, Metro evaluated the alternatives for their impacts on air quality, ability to accommodate economic growth, the provision of affordable housing, costs of public services, and social stability. Metro used a mix of computerized models and qualitative assessments by experts in each field to develop these measures (Metro, 1994).

3.5 Select Analytical Tools for Analyzing Alternatives

Basic Questions

- *What models and other analytical tools are available for analysis of land use, transportation, and air quality?*
- *What are the strengths and weaknesses of these models and analytical tools?*
- *What data are needed? What data are available? What data need to be collected?*
- *How sensitive are the models and analytical tools to the policy issues of interest? Can this sensitivity be increased?*

The LUTRAQ Experience

The LUTRAQ project team worked with Metro staff to enhance the agency's modeling capabilities. Metro already had one of the most advanced travel demand models in the United States. However, as described in LUTRAQ Volume 1, *Modeling Practices* (1000 Friends, 1991a), the model had two major shortcomings that limited its usefulness in evaluating transportation/land-use strategies. These were:

- The lack of a formal feedback mechanism from the transportation system to the land-use forecasting process; and
- An inadequate consideration of the many variables representing detailed urban-design options that can reduce the demand for vehicle travel.

To remedy the first situation, the LUTRAQ project obtained a license for Metro to use the DRAM®/EMPAL® land-use models in conjunction with the Metro travel-demand model.[8] The LUTRAQ team worked with Metro staff to calibrate the model for the Portland metropolitan area. The calibration process proved to be time-consuming, and raised several significant issues. In addition, Metro staff had other demands for their time, particularly from work on the Region 2040 project. As a result, work on this aspect of the project was delayed, and has now ceased.[9] Consequently, it was not possible to evaluate how highway building affects suburban land-use patterns and whether adding highway capacity induces additional travel.[10]

The LUTRAQ alternative was, therefore, evaluated using the traditional approach of modeling the travel patterns associated with a specific land-use plan.

Land-Use Assignment

Households and employment were assigned to zones in the LUTRAQ alternative based on available land that was either vacant or redevelopable (given the relative value of buildings and land) within the 20-year period and free of obvious environmental constraints (slopes, wetlands, protected areas). LUTRAQ consultants worked with Metro staff to translate the

8. DRAM and EMPAL are registered trademarks of S.H.Putman Associates.
9. See Appendix B in LUTRAQ Volume 5: *Analysis of Alternatives* (1000 Friends of Oregon, 1996b) for further discussion.
10. These issues are, however, addressed in a recent study from the University of California, Berkeley (Hansen, 1995).

LUTRAQ land-use plan into assignments of households and jobs to use in travel-demand forecasting. Jobs were assigned to transportation analysis zones (TAZs) in several categories (retail, industrial, etc.). Households were assigned according to household size, income, and age. These assignments were based on independent market and demographic research conducted for LUTRAQ regarding the housing needs and preferences of future residents of Washington County.[11] All assignments were made consistent with Metro's own forecasts for future jobs and households for the study area as a whole, to insure the comparability of results. Lastly, TAZs that contained proposed new transit-oriented developments were subdivided, with the TOD portion treated as a separate zone within a zone. This allowed for calculation of the effect of pedestrian-friendly design on mode choice.

Travel-Demand Modeling

The LUTRAQ project utilized Metro's travel-demand model and staff. The project included enhancements of Metro's model to better reflect the effect of land-use and urban-design characteristics that can slow future vehicular growth. This corrected the second limitation of Metro's model, listed above, and increased the model's sensitivity to the policies of interest in the LUTRAQ process. Measures of residential and employment density and the quality of pedestrian environment were incorporated into the auto ownership, pre-mode choice (auto/bus vs. walk/bike), and mode choice models.[12] The forms of several variables were also changed to improve their effectiveness in estimating travel demand. The method of computing intrazonal travel times was changed to improve the ability of the destination choice model to handle short trips.

The variable measuring the quality of the pedestrian environment, called the "pedestrian environment factor" or PEF, is a composite measure of the "pedestrian friendliness" of each of the analysis zones in the model system. It was developed to reflect the factors at the neighborhood and street level that influence individuals' willingness and ability to choose the walk mode for various trip purposes. As developed by the Metro staff in consultation with the LUTRAQ project team, the PEF consists of an assessment of each of 400 TAZs on the following measures:

---

11. See LUTRAQ Volume 3A: *Market Research* (1000 Friends of Oregon, 1992b) for further details on demand for housing and non-residential space in the study area.
12. Trip generation was assumed to be constant.

- Ease of street crossing (width of intersections, traffic volumes, presence of signals)
- Sidewalk continuity
- Local street characteristics (grid versus cul-de-sac)
- Topography

Four Metro staff members individually evaluated each zone, assigning a score of 1 to 3 for each measure. The results were compared and a consensus score developed. The PEF scores proved to be significant in explaining levels of auto ownership and the decision to use vehicular (bus/car) or non-vehicular (walk/bike) modes. As a consequence, a PEF component was added to the model's auto ownership and pre-mode choice modules.[13]

Air-Quality Modeling

The project used MOBILE5a, a computer program developed by the U.S. Environmental Protection Agency (EPA), to estimate carbon monoxide (CO), nitrogen oxides (NO_x), and hydrocarbon (HC) emission rates. The analysis was based on emissions from vehicles traveling on roadways within the study area and the percent of hot soaks and cold starts, as predicted by Metro's travel-demand model.[14]

Greenhouse-Gas and Energy-Consumption Modeling

Other analyses estimated the amounts of greenhouse gases emitted and energy consumed by vehicles in the study area. Greenhouse gases help regulate the earth's temperature, and some affect the ozone layer which protects the earth from ultra-violet radiation. Emissions of three greenhouse gases—carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O)—were estimated using procedures developed by the Environmental Protection Agency and data from Metro's travel-demand model. The travel-demand model outputs were also used to determine energy consumption.[15]

Lessons from Other Projects

Regions use a variety of methods for analyzing alternatives. MPOs have transportation-demand models and air-quality models that can quantify the effects of various alternatives on travel patterns, traffic conditions, and emissions. Travel-demand models require a land-use forecast to determine origins and destinations. Land-use modeling, however, is more complex and less advanced than transportation modeling, and many qualitative and simple quantitative methods are used. This section describes some of the current modeling options and their limitations. The types of analytical tools used depend upon the scope of the project, the types of tools available or developable, and the performance measures chosen to evaluate the alternatives. Typically a chain of tools is used beginning with land-use analysis, then travel-demand modeling, and finally air-quality modeling.

---

13. See LUTRAQ Volume 4: *Model Modifications* (1000 Friends of Oregon, 1996a) for further details on enhancing travel demand models, and LUTRAQ Volume 4A: *The Pedestrian Environment* (1000 Friends of Oregon, 1993) for details on the PEF.
14. See the *Western Bypass Study Sunset Highway - Pacific Highway Air Quality Technical Report* (ODOT, 1994) for details on how Metro modeled air quality.
15. See Appendix A to LUTRAQ Volume 5: *Analysis of Alternatives* (1000 Friends of Oregon, 1996b) for further details on greenhouse-gas and energy-consumption modeling.

As an example, the Southwestern Pennsylvania Regional Planning Commission (SPRPC) evaluated several land-use alternatives when developing their ISTEA-required long-range transportation plan. After evaluating the forecasting tools available, the agency staff decided to use a chain of tools, including one developed in-house to measure the interrelated effects of transportation and land use. First, they used the Regional Economic Models, Inc. (REMI) model for the Pittsburgh region to develop county level population and employment forecasts. This model is an integrated economic/demographic forecasting model. Second, the REMI outputs were used in a sketch-planning model developed in-house to determine the location of households and firms at the zones needed for travel-demand modeling. The sketch-planning model was changed for each alternative to reflect the unique characteristics of each scenario. Third, they used their travel-demand model (a MINUTP model) to estimate the transportation impacts of each alternative. Finally, they used MOBILE5a to estimate air-quality impacts (SPRPC, 1994). The following sections provide further explanations of each of these types of models.

Ideally, land-use and transportation modeling should be integrated so that the effects of each process on the other can be taken into consideration. The state of the practice, however, misses this ideal by a significant degree. In the development of regional and state transportation plans, the actual practice is more of a “single pass” system, where static land-use forecasts determine transportation needs with little or no feedback from the transportation model to the land-use assumptions. To the degree that the potential impacts of transportation on land use are evaluated at all, the analysis occurs mainly at the more specific corridor level analysis of an MIS/EIS or for a downtown, activity center, airport, or other specific area.

Overview of Transportation-Demand Modeling

Several transportation-demand modeling software packages can be purchased and have been modified and enhanced by MPOs, DOTs, and others. These models are based on the four-step process of trip generation, trip distribution, modal splits, and trip assignment.

Most of these models were developed to help determine the size and location of large capital facilities such as highways and transit lines. As such, they focus on vehicular trips and provide scant analysis of trips made on foot or by bicycle. Today these models are being called upon to predict the outcomes of changes in transportation facilities and programs within a single corridor, the effects of congestion pricing, the outcomes of demand management, the effects of urban design on transportation, and a host of other issues for which they were not specifically designed. Many models need updating or reformulating to answer these new questions.[16] A current research project sponsored by a number of federal agencies (the Travel Model Improvement Program) is attempting to respond to these needs.

Overview of Land-Use Modeling Techniques

As outlined above, transportation planners use land-use forecasts as inputs into transportation-demand models. The forecasts may be for a base case (extending existing conditions)

16. For further discussion of transportation models see LUTRAQ Volume 1: *Modeling Practices* (1000 Friends of Oregon, 1991a), Harvey and Deakin (1993), Transportation Research Board (1995), and Beimborn and Kennedy (1996).

or involve alternative scenarios. These forecasts sometimes also attempt to predict the land-use impacts of transportation investments and policies in MIS/EIS studies and other planning processes. A wide variety of approaches ranging from expert opinion to the use of formal land-use models are used.

The basic approaches to forecasting the spatial patterns of households and jobs include:

1. **Comprehensive land-use plans and zoning ordinances.** These documents identify a local jurisdiction's land-use policies and provide maps of future land uses. They provide information on the amount of land designated for residential, commercial, industrial, and other uses and the locations of parcels within each designation. They are used with vacant or redevelopable land inventories to determine how much land is available for various types of development.
2. **Qualitative methods.** These methods rely on the knowledge of experts: developers, lenders, business people, planners, environmental activists, and others who make, influence, or study the decisions that affect land-use patterns. Experts may be interviewed, respond to questionnaires, or meet in panels. Qualitative methods can provide a holistic approach that considers all aspects of the urban system. They can also be limited by the knowledge of the experts involved and the capacity of individuals to comprehend complex systems and anticipate future events.
3. **Trend-extrapolation techniques.** These techniques base predictions of the future on quantitative analysis of events of the recent past. Shift-share analysis assigns future jobs to zones based on recent rates of growth for the zone and for the types of businesses in the zone. Regression analysis determines the amount of growth for a subarea based on the simultaneous influence of several relevant factors. A regression equation for residential development might include the amount of vacant residential land, planned density of development, current density, distance to the CBD, and distance to freeways.

4. **Sketch-planning models.** These computerized spreadsheet models assign population and jobs to zones based on attractiveness factors and amount of developable land. They use fewer zones, have simpler equations, and require less data than the land-use forecasting models described next. Their simple structure makes them easy to use but may gloss over many complexities of the real world, especially in larger metropolitan areas.
5. **Land-use forecasting models.** These are computer programs that simulate the development of urban land. The most widely used model in the United States is DRAM/EMPAL developed by Dr. Stephen H. Putman. Like the sketch-planning models, this model uses attractiveness factors to assign households and employment to zones. Other land-use forecasting models that are used in other countries or under development have different theoretical bases. There is considerable interest in the United States in developing better land-use models. Current issues in formal land-use models are discussed in Appendix B to LUTRAQ Volume 5, *Analysis of Alternatives* (1000 Friends of Oregon, 1996b).

Two other techniques used for land-use analysis are:

- **Rules of thumb.** These approaches borrow measures generated from previous empirical studies. Some examples are estimates of the number of trips generated by specific land uses, the number of residents per acre needed to support light-rail transit, and estimates of the minimum and maximum amounts of parking space needed for various types of land uses. Rules of thumb should be used cautiously since the characteristics of the places used to develop the rules may differ from the place being studied, thereby making the rules inaccurate. Rules of thumb are often used when estimating the land-use impact of transportation investments.
- **Regional economic models.** These models simulate an area's economy to predict how changes in transportation costs affect business location and growth. The models are particularly useful for studying interregional changes in the types and numbers of jobs associated with changes in transportation. They provide total numbers of jobs for regions or large subareas, but do not indicate the specific sites where jobs will be located. REMI and IMPLAN are two commercially available regional economic models. Regional economic models are often used as the first step in allocating jobs to large zones within a region. Other tools are then used to determine more precisely the location of these jobs.

The following section describes three approaches to evaluating alternatives that use different land-use tools.

Qualitative analysis. In Maryland, the DOT used an expert panel to evaluate the land-use impacts of various transportation options for the Highway 301 Corridor Study. The aim was to utilize a diverse set of experts in a clear and open process. Six people with expertise in land economics, transportation, land use, and real-estate lending were recruited to serve on the panel.

The panelists were provided with maps, the MPO's base-case forecast, descriptions of the alternatives, and other pertinent information. Each panelist was sent a questionnaire prior to a one-day panel meeting asking them to forecast how the land uses in the corridor would change from the base case under a number of transportation/land-use scenarios.

At the meeting, the panel produced three forecasts: a revised base case, an estimate that the highway option would attract 80,000 additional employees, and an estimate that light rail would attract fewer employees, about 40,000. They forecast no change in household numbers because the new jobs would be filled by people who already live in the area and currently commute to Washington, DC. The Task Force for the corridor project has accepted the panel's estimates as the market-based forecasts for the highway and light-rail options.

A combination of quantitative and qualitative approaches. When developing its long-range transportation plan, the Denver Regional Council of Governments developed a base case and three alternative scenarios. Council staff developed different attractiveness measures for each scenario. The process used data like that employed in land-use models but relied on a committee of experts to determine the relative effects of each variable.

First, council staff created the four transportation/land-use scenarios for the year 2020: Dispersed (base case), Compact, Corridor, and Satellite.

Second, the staff drew on urban development theory, recent literature, and planner judgment to identify 15 measurable factors that influence development. Both land-use and transportation factors were included. Some of the factors were:

- proportion of each zone in residential (or employment) use
- proportion of land planned for residential (or employment) use
- amount of vacant land
- recent growth rates (residential and employment)
- roadway accessibility
- transit-station proximity
- availability of water and sewer service
- per capita income (a proxy for quality of life)
- change in per capita income, 1980-1990
- proportion developed before 1950 (a proxy for pedestrian orientation)

The factors were measured for each traffic analysis zone (TAZ) and converted to a common scale of 1 to 10. The same zonal scores were used in all scenario evaluations.

Third, a committee of staff members assigned weights to the factors for each scenario to reflect the fundamental differences between scenarios. The committee considered the relative importance of each factor in influencing population and employment growth under each scenario. They assigned the factors a total of 100 points for each scenario forecast, considering households and employment separately. For example, road accessibility was considered:

(a) highly important for both households and employment for the Dispersed and

Corridor scenarios (it was assigned weights of 15 and 20 for employment, 17 and 18 for households, respectively);

(b) more important for employment than for households for the Satellite scenario (13 for employment, 6 for households); and

(c) less important in the Compact scenario (6 for employment and 2 for households).

In contrast, transit-station areas were thought to have the greatest impacts on household and employment growth in the Compact and Corridor scenarios, where they were assigned weights of 10 to 16, but unimportant for Dispersed and Satellite scenarios, where they were assigned weights of 0 to 3.

Finally, to calculate the attractiveness of each zone, the weights were multiplied by the zonal factor scores and then summed across factors. The attractiveness values ranged from the low 200s to the high 600s. Employment and household growth were then assigned to zones in the order of their attractiveness until the total expected population or job number for that part of the region was reached.

Agency staff believed this method was a substantial advance over the trend-line forecasts they had used in the past. It produced distinct results for the scenarios based on policy preferences and actual conditions. The staff found that weights were easiest to assign in the Dispersed scenario because it represented the historic trend, and in the Compact scenario because it provided the sharpest contrast to current trends, both in land-use patterns and in transportation investments. All of the transportation investments in the Dispersed scenario were for roads, while considerable investments in transit were made in the Compact scenario. It was difficult to decide which factors would influence Corridor and Satellite development because the staff lacked experience with these patterns of development.

Sketch planning methods. As discussed earlier in this section, the Southwestern Pennsylvania Regional Planning Commission developed a sketch-planning model to help evaluate several alternative development patterns. The model was called MERLAM (Mature Economic Land Use Allocation Model), and it took into consideration that some industries were declining and parts of the region were losing population. The model used four or five indicators of attractiveness for allocating growth or modifying trend projections for each land-use type (residential, manufacturing, and non-manufacturing). Attractiveness measures included travel characteristics such as the number of jobs within 30 minutes of a residential area or the travel time to key locations such as the airport. These travel measures were produced by the transportation model, providing some integration of the land-use and transportation planning processes. Alternatives were modeled by changing population or employment control totals for regional subareas or by changing attractiveness measures.

The Commission chose to develop a sketch-planning model because agency staff did not think commercially available models would accurately reflect their region or be readily modified to develop forecasts for each of the scenarios. With the sketch-planning model they could explain to decision-makers exactly what variables were changed and how these changes reflected alternate policy choices. Finally, they needed a model they could calibrate and run within the deadlines for their regional transportation plan.[17]

Overview of Air-Quality Modeling

Two main emissions models are used in the United States: the EPA MOBILE model and the California Air Resources Board EMFAC model. In both cases, total emission levels are determined by multiplying the emission rates from the models by the number and types of trips calculated by travel-forecasting models. Atmospheric dispersion models then translate the results into atmospheric concentrations of pollutants.

Evaluations of Current Models

The TRB Special Report 245, *Expanding Metropolitan Highways: Implications for Air Quality and Energy Use* identifies the following general limitations of land-use, transportation, and air-quality models (p. 75):

- *Appropriateness of the models*: Models are being used to solve problems for which they were not originally designed....
- *Validity of the models*: There are large uncertainties in the models themselves, which are manifested in wide variances around some model estimates. These reflect the limited state of the knowledge of the underlying phenomena the models are attempting to capture....
- *Links between the models*. There is a mismatch of detail between the outputs generated and the inputs required by several of the models in the modeling chain....

Likewise, the Travel Model Improvement Program Land Use Modeling Conference made the following recommendations (US DOT, 1995, 1-4):

- More feedback is needed between land-use, transportation, and environmental models.
- Models should be more sensitive to policy variables and be understandable to decision-makers.
- Models should incorporate the land development market decision-making process and be linked to consumers choices.
- Land-use models should account for urban development as an incremental process.
- Current models seem suitable for predicting urban sprawl but not to assessing controlled growth.

17. Tools for land-use analysis are described in greater detail in National Cooperative Highway Research Project (1996). The report updates the work done in LUTRAQ Volume 1: *Modeling Practices* for land-use models and includes a work program to improve land-use tools. Also see US DOT (1995) for further discussion of land-use modeling needs.

3.6 Simulate Alternatives and Interpret Results

Basic Questions

- *How do results compare?*
- *What factors contributed to differences in results?*

The LUTRAQ Experience

Five alternatives were simulated as part of the LUTRAQ project:

- a **"no-build"** or base-case alternative that assumes continuation of current land-use plans and practices, and no new transportation infrastructure beyond projects that are already committed;
- a **highways only** alternative that also assumes continuation of existing land-use plans and trends, but adds a major new freeway (the Western Bypass) and approximately 50 other roadway expansion projects to the study area;
- a **highways with parking pricing** alternative that adds a parking-pricing/transit-subsidy package, and fixed and demand-responsive transit services to the highways only alternative;
- the **LUTRAQ** alternative, which changes existing land-use plans to focus future development around planned and proposed new transit services in a mixed-use, pedestrian-friendly environment, and includes the parking-pricing/transit-subsidy package mentioned above; and
- the **LUTRAQ alternative with congestion pricing**, which contains everything in the LUTRAQ alternative plus peak-hour pricing.

As Table 7 shows, building highways does not effectively address suburban transportation needs. The effects in 2010 of the Highways Only alternative include:

- Highest rates of single-occupancy vehicle use and lowest rates of transit use for work trips of any build alternative
- Most congestion of any build alternative.
- Most peak vehicle hours of travel of any build alternative
- Most vehicle miles of travel per day of all alternatives
- Increases in nitrogen oxide emissions and negligible reductions in hydrocarbons and carbon monoxide emissions
- Increases in greenhouse gas emissions and energy consumption

Table 7: Summary Results of LUTRAQ Simulations

	No Build	Highways Only	Highways/ Parking Pricing	LUTRAQ	LUTRAQ/ Congestion Pricing
Average Autos/ Household	1.9	1.9	1.9	1.8	1.8

Table 7: Summary Results of LUTRAQ Simulations

	No Build	Highways Only	Highways/ Parking Pricing	LUTRAQ	LUTRAQ/ Congestion Pricing
Work Trip Mode Choice:					
Walk/Bike	2.8%	2.5%	2.5%	3.5%	4%
Transit	7.5%	8.8%	15.3%	18.2%	21.1%
Carpool	14%	13.6%	20.4%	20.1%	19.6%
Drive Alone	75.8%	75.1%	61.7%	58.2%	55.3%
Daily Vehicle Trips/ Household	7.53	7.5	7.29	7.17	7.07
Vehicle Hours of Delay (pm peak) (compared to No Build)	—	-43%	-58.7%	-53.2%	-65.9%
Vehicle Hours of Travel (pm peak) (compared to No Build)	—	-5.6%	-13.7%	-15.7%	-23.5%
Daily Vehicle Miles Traveled (compared to No Build)	—	1.6%	-0.4%	-6.4%	-13.2%
Air Pollutant Emissions (compared to No Build):					
HC	—	-0.2%	-3.6%	-6.2%	-11.5%
NO_x	—	6.7%	3.6%	-2.6%	-8.4%
CO	—	-0.6%	-4%	-6.7%	-12%
Greenhouse Gas Emissions (CH_4, N_20, CO_2) (compared to No Build)	—	1.6%	-0.4%	-6.4%	-13.2%
Energy Consumption (compared to No Build)	—	1.6%	-0.4%	-6.4%	-13.2%

Source: LUTRAQ Vol. 5: Analysis of Alternatives (1000 Friends of Oregon, 1996b)

Some of the negative effects of highway building can be moderated by adding transit improvements and demand-management programs, as is shown in the Highways/Parking Pricing scenario. These measures, which were included in the "Bypass" alternative for ODOT's Western Bypass Study, double the amount of transit use and boost carpooling 1.5 times the level achieved under the Highways Only option. This shift in work trip mode of travel reduces peak period vehicle hours of delay significantly. These efforts to manage highway use, however, have quite modest impacts on the number of vehicle trips per day, vehicle miles of travel, air pollution, and energy use.

In contrast, the LUTRAQ alternative reduces vehicle travel, congestion, pollution, and energy use. The effects of the LUTRAQ alternative on the study area in 2010 include:

- Reductions in auto ownership rates by 4 percent compared to either highway alternative
- Fewer work trips by single-occupancy vehicle than the highway alternatives
- More than twice as many work trips by transit as the No Build or Highways Only alternatives
- Fewer vehicle trips per household each day
- Less peak period traffic delay than the No Build or Highways Only alternatives
- A 6.4 percent reduction in vehicle miles of travel compared to the No Build alternative
- Reductions in nitrogen oxide, hydrocarbons, and carbon monoxide emissions of 2.6 to 6.7 percent
- Reductions in greenhouse gas emissions and energy consumption of about 6.4 percent

The model indicates that adding congestion pricing to this package would shift more work trips to walk/bike and transit modes. The resulting reduction in peak period traffic would further decrease congestion, vehicle miles of travel, emissions, and energy use. These results, however, are more speculative than the others because the assumptions about how people will react to congestion pricing have not been tested in the real world yet.

Table 8 separates out data for the transit-oriented development areas of the LUTRAQ alternative. As the table illustrates, these areas made a substantial difference in the overall project results. Part of the benefit of TODs is to concentrate smaller households that are likely to own fewer cars near transit stations. In addition, the pedestrian orientation and mix of uses encourages walking or biking for work, school, or shopping trips and use of transit, especially for work trips. In all, the effects of applying the principles of good planning (by locating transit-oriented households near transit) are as important as the effect of applying principles of good design (mixed uses and pedestrian orientation) (1000 Friends of Oregon, 1995, App. D).[18]

Table 8: Comparison of Standard Suburban and Transit-Oriented Development

	Standard Suburban Development	Transit-Oriented Development
Auto Ownership:		
Percentage of Homes Owning 0-1 Autos	29.4%	44.1%
Average No. of Autos/Household	1.91	1.63
Work Trip Mode Choice:		
Walk/Bike	2.8%	5%
Transit	7.5%	28.2%
Carpool	14%	17.2%
Drive Alone	75.8%	49.6%
Vehicle Trips/Household	7.53	5.79

N.B.: Data for "Standard Suburban Development" taken from the No Build alternative.
Source: LUTRAQ Vol. 5: Analysis of Alternatives (1000 Friends of Oregon, 1996b)

Lessons from Other Projects

Overall, as discussed in Section 2, simulations of alternative transportation and land-use patterns show that focusing growth where it can be served by transit does influence travel patterns. The regional effects are not large because most of the future built environment in the regions studied already exists and only an increment can be rearranged in a more transit-friendly manner.

Portland Metro's Region 2040 study demonstrated that more concentrated development increased transit use but could also produce more congestion and other problems unless carefully combined with other policies. Metro developed a recommended alternative using a combination of policies from the tested scenarios to achieve transit ridership equal to the best scenario but with fewer hours of service and less congestion on highways (see Table 6). This policy was adopted as the Region 2040 Growth Concept (Metro, 1994).

Likewise, Montgomery County, Maryland projected the impacts of different rates of growth, job and housing mixtures, and spatial patterns of development on congestion. County planners concluded that in the long run, the pattern of development (dispersed or clustered), had more influence on congestion than the rate of growth or the job and housing mixtures. Dispersed origins and destinations, regardless of other assumptions, produced more congestion than clustered origins and destinations. They also concluded that they could not eliminate congestion induced by growth using only highway construction. They also needed alternative modes, pricing, and other transportation strategies to reduce automobile use as well as land-use patterns that support transit use (Maryland Nat'l Capitol Park and Planning Comm'n, 1989).

18. For detailed comparisons of the alternatives, see LUTRAQ Volume 5: *Analysis of Alternatives* (1000 Friends of Oregon, 1996b).

3.7 Implement the Preferred Alternative

Basic Questions

- *What actions are needed to implement the alternative?*
- *What jurisdictions must be involved? How will inter-jurisdictional issues be addressed and resolved?*
- *If the alternative is developed by a non-profit organization, how does it become part of public policy?*

The LUTRAQ Experience

The LUTRAQ alternative is being implemented in the Portland region through several approaches, all involving forums different from the one in which it was initially introduced. The preferred alternative that emerged from the Western Bypass Study is a hybrid that emphasizes limited road improvements and endorses the land-use concepts in the LUTRAQ alternative—it does not include the Western Bypass.[19] The LUTRAQ alternative was included primarily because it is largely being implemented through Region 2040. Like the LUTRAQ alternative, the Region 2040 Growth Concept concentrates growth in pedestrian-oriented centers of various sizes and types, and connects these centers with high-capacity transit service. In fact, 91 percent of the LUTRAQ study area has Region 2040 land-use designations similar to those in the LUTRAQ alternative. Region 2040 goes further than LUTRAQ, however, by applying transit-oriented development principles throughout the tri-county Portland metropolitan area, not just in Washington County.

The Metro Council adopted the Region 2040 Growth Concept in December 1994 and is now developing a Regional Framework Plan and an update of the Regional Transportation Plan to implement the Growth Concept. Once these plans are adopted by the Metro Council, cities and counties will be required to change their comprehensive plans and implementing ordinances to be consistent with the two regional plans.

An intermediate plan, known as the Urban Growth Management Functional Plan, contains many of the land-use changes required by the Growth Concept, and was adopted in November 1996. This Functional Plan forms the basis of the Portland region's air-quality maintenance plan under the federal Clean Air Act, with a number of the plan's provisions listed as "transportation control measures" (TCMs). As TCMs, these provisions become enforceable under federal law, and provide the basis for determining conformity between transportation and air-quality plans.

19. This alternative was not modeled in a manner that would allow direct comparisons to other alternatives studied.

This implementation process is possible, in part, because the region has an elected regional government with the power to do regional planning. The region also has a history of working cooperatively with local governments and transportation agencies to develop consensus on transportation issues, and more recently on land use issues (Oliver, 1994).

LUTRAQ implementation is further helped by the Oregon Transportation Planning Rule, which requires that local governments revamp their land-use plans to allow transit-oriented development along all transit lines and to require pedestrian-friendly site designs for all new commercial buildings. Tri-Met, the region's transit agency, is also coordinating a $1 million station-area planning process for the Westside Light Rail Line, the primary transit facility in the LUTRAQ alternative.

Lessons from Other Projects

Two key concepts for implementing integrated land-use/transportation alternatives are (1) limiting the extent of the urban area and (2) focusing growth in transit-oriented locations.

Limits to urban areas

One of the policies supporting the LUTRAQ alternative in the Portland metropolitan area is the metropolitan urban growth boundary. Oregon's statewide planning system, adopted in 1973, required that every city adopt urban growth boundaries to identify and separate urbanizable land from rural land. Metro adopted a single metropolitan urban growth boundary covering 24 cities and portions of three counties in 1979 and has made only minor changes since then. The urban growth boundary has clearly identified where urban growth can occur, and has protected agricultural land from development. But as the region's population has grown, so has the need to consider expanding the boundary. The Region 2040 process was undertaken in part because of this need to review the urban growth boundary.

The Metropolitan Council in the Twin Cities also limits the size of its urbanized area. The Council adopted a metropolitan urban service area (MUSA) in 1975 to direct where urban services will be provided. The goals are to more effectively use existing infrastructure and to more efficiently build new infrastructure. Plans for water and sewer extensions within the MUSA are coordinated by the Council. Land outside the MUSA is reserved for rural and agricultural uses. One problem that the Twin Cities has experienced is leap-frog development to the counties adjacent to the seven-county metropolitan area. The Council has no authority to regulate development outside its boundaries, and neither the state nor the counties themselves have been willing to do so.

A number of other communities including Boulder and Fort Collins in Colorado, San Diego, San Jose, and Orlando have also adopted urban growth or municipal service boundaries. Washington State's growth management act of 1990 also requires that affected cities adopt urban growth boundaries.
Another approach to limiting urban development is adequate public facilities ordinances. Perhaps the most successful of these has been Montgomery County, Maryland which adopted an Adequate Public Facilities Ordinance in 1973 to ensure that public facilities would be available to support development as it occurs. In 1986, the County Council began adopting an Annual Growth Policy that specifies annual jobs and housing ceilings for 25 policy areas based on existing and planned service levels. In most areas the limiting factors

are roads and schools. In policy areas where the existing and approved subdivisions exceed the capacity standard, a building moratorium is declared until deficiencies are corrected.

During the annual policy area review, the county sets threshold standards for both freeway and multi-modal capacity, the latter being an average of service by all modes. The FY 96 ceilings allow residential development to occur in 17 out of 25 policy areas and employment development in 20 out of 25 policy areas.

Station-Area Planning and Development

The following lessons are drawn from the *Guidebook for Practitioners* published by the Transit Cooperative Research Project in Summer 1996 (Parsons Brinckerhoff, 1996e). The guidebook draws mainly on case studies of six regions (three in the United States, two in Canada, and one in Brazil) with exemplary transit service, both rail and bus.

The lessons from the regions that have successfully integrated transit and land-use planning make very clear that a continuing, cooperative process must be in place over a long time period to implement a transit-oriented vision. Many of the principles of transit-oriented development have been employed in downtowns and cities for years. The key to success is applying these principles to subregional centers that are linked by high-quality transit service and to outlying areas.

The key principles of transit-oriented development are:

- Encourage employment and residential density close to the stations.
- Within the higher-density station areas, plan for a mix of land uses.
- Use urban design features to facilitate pedestrian and transit travel.

Station-area development is dependent upon using a range of strategies to focus growth near stations. Major tools include:

Zoning. Station-area development can only occur where zoning allows higher density, mixed-used development, and transit-friendly designs. Incentives can help ensure that planned development occurs. In the Portland metropolitan area, station-area zoning prohibits certain auto-oriented uses (such as fast food restaurants with drive-up windows) within one-half mile of stations, sets minimum densities, limits parking supplies, and requires that buildings be oriented to the light-rail stations. In Montgomery County, Maryland and Arlington, Virginia density bonuses are provided for transit-oriented development and street level retail uses are required in all commercial buildings near Metrorail stations. New York City uses the transfer of development rights to allow higher densities around transit stations.

As important as it is to up-zone around transit, in some cases areas located away from transit need to be down-zoned. This helps to focus the market and ensure that potentially transit supportive development occurs in proximity to transit service. Ottawa, for example, does not allow regional shopping centers with more that 375,000 square feet of gross leasable space to locate away from the busway. This type of zoning pushes development toward station areas.

Strategic timing of station area development. The timing of development and service delivery can be an important factor in achieving higher densities without undue community opposition. Vancouver, BC located Phase I SkyTrain stations in underdeveloped industrial areas with the goals of creating "new towns in town." This helped avoid the "not in my backyard" problem since no neighbors lived nearby. A government agency then coordinated land development planning in the station areas, transforming them from neglected areas to regional subcenters. In Ottawa, outlying segments of the busway were installed before the more expensive downtown segments. This enhanced the ability to channel growth in the rapidly growing outer areas and established momentum for the system. In Washington, DC, regional agencies came to early agreement on the need to match rail-system planning with strategic planning for regional development. In a strong market environment, the presence of transit stations helped attract development.

Locate major activity centers near transit. Major activity centers support ridership. In Ottawa, the regional plan requires that large employment centers (5,000 or more jobs) be located within a five-minute walk of the transitway and smaller employment centers (2,000 or more jobs) near all day transit service. All regional shopping centers with more than 375,000 square feet of space must also be located within a five-minute walk of transit stations. In Vancouver, BC, local comprehensive plans concentrate office, retail, and high-density residential development in regional centers. In Curitiba, Brazil, the city planning authority has rejected all applications for large shopping centers outside transit corridors.

Parking management. As downtown areas have long known, parking management supports higher-density development and increases transit ridership. Portland and Boston have limited the supply of parking in their downtowns since the 1970s to encourage transit use and improve air quality. Bellevue, Washington has eliminated or lowered minimum parking requirements and imposed maximum parking ratios geared to the level of transit service. Vancouver, BC requires that most parking in subregional centers be in structures or underground. This encourages higher densities and a more pedestrian-friendly environment while discouraging excess parking. In Ottawa, park-and-ride lots are provided only at outer terminal stations to encourage feeder bus use and maximize development potential elsewhere on the system.

Auto-free zones. Transit streets and pedestrian ways help free up street space for pedestrians and transit vehicles. The strongest effects on transit ridership occur when these zones are directly integrated with surface routes, as in Denver or Minneapolis, or with underground transit, as in Boston.

Financial arrangements. Transit agencies have worked in partnership with redevelopment authorities and economic development agencies to foster station area development with a variety of innovative practices. In Portland, business districts have formed Local Improvement Districts to partially fund enhancements to the pedestrian environment along light rail. Property owners pay a 20-year benefit-based assessment to help finance bonds. Federal matching funds help gain merchant support. Houston's Uptown district formed a Transportation Improvement District in 1987 to help finance transportation improvements. District benefit assessments have been used for traffic signals, pedestrian crossings, and landscaping. In Vancouver, BC the transit agency has used easements as an alternative to right-of-way acquisition, an alternative facilitated by the aerial transitway design.

Station-area planning and design guidelines. Land-use and transit agencies have joined forces to develop specific guidelines to help developers satisfy station-area requirements. Portland has used transit-station planning to develop specific plans for each station along its light-rail system. The program involves all the affected jurisdictions and transportation agencies and property owners. Ottawa has transit-supportive design guidelines that show how development can be more transit-friendly throughout the region. For example, collector roads must be designed to allow efficient transit circulation within subdivisions, and denser land uses, retail centers, and senior citizen residences must be located closest to transit lines, with single-family homes and recreational parks farthest away.

Transit-supportive housing policies. Land owned by the transit agency can be used as an incentive to foster the location of subsidized housing in station areas, which in turn boosts ridership. In Portland, the transit agency has sold surplus property to developers of apartment buildings along the light-rail line. In the San Francisco Bay area, the Contra Costa County development agency has assembled land and assisted in the development of housing near the Pleasant Hill BART station. In Santa Clara County, the transit agency has leased land to developers for multi-family complexes at the Almaden Lake Village light-rail station.

Public agency buildings and leases in station areas. Public agencies can effectively serve as anchors for station-area development projects, either as building developers or as tenants of privately developed space. In Vancouver, BC, many federal and provincial agencies have located in the sub-regional centers along transit lines. In Portland, government offices and the regional convention center have been built at transit stations.

Collectively, these tools provide a means of implementing an integrated transportation/land-use plan within a region. Many require a regional perspective and cooperative efforts among jurisdictions responsible for land-use planning and transportation. Implementation also requires a long-term commitment.

If a region has a different vision for the way it wants to grow and the leadership to articulate and implement that vision, changes can occur. Each year thousands of individual investment and transportation decisions are made. A concerted effort to shape these decisions can yield a better future.