UrbanSim:
Development, Application and Integration with the Wasatch Front Regional Travel Model

Technical Report CUSPA-03-01

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Chapter 1

Background and Project Context

The objective of this report is to present the results of a project to evaluate the application of the UrbanSim land use model system and its integration with the Wasatch Front Regional Council (WFRC) travel model system. The intent is to describe reasonably completely the entire process of developing and applying UrbanSim in the Greater Wasatch Front Region, including the development of the database, estimation and calibration of model parameters, integration with the WFRC travel model system, and validation of the model system through sensitivity analysis designed to explore the responsiveness of the model to major transportation system and land use policy changes.

1.1 QGET and Initial UrbanSim Application

The project described in this report has several antecedents. An initial project to apply UrbanSim to the Greater Wasatch Front region was funded by the Governor's Office of Planning and Budget (GOPB) of the State of Utah as part of the Quality Growth Enhancement Tools (QGET) project. The UrbanSim model application was conducted by Urban Analytics from 1996-2000, with most of the database development conducted by staff of the Utah Automated Geographic Resource Center (AGRC) in coordination with GOPB staff. In 2001, The Center for Urban Simulation and Policy Analysis at the University of Washington received a grant from the National Science Foundation Digital Government Program, and a matching grant from the Federal Highway Administration (FHWA). The FHWA grant directly supported the analysis contained in this report and the peer review process it describes. In short, the project was intended to document as a case study the application of UrbanSim within a Metropolitan Planning Organization (MPO), and its integration with the MPO travel model system. WFRC was chosen as the site for this case study, based on the status of the UrbanSim application there and the willingness of the WFRC to collaborate in the project.

1.2 Envision Utah

The Greater Wasatch Area, which incorporates 80 percent of Utah's population and is centered on Salt Lake City, is rapidly growing as an urban metropolis. The problems presented by Utah's rapid growth are compounded by several factors unique to the area. Surrounding mountains and the Great Salt Lake (GSL) have limited developable land and an abundance of critical environmental resources require protection. In 1994, Utah Governor Mike Leavitt convened a summit of government officials, businesses, community leaders, and interested citizens to deal with the issue of urban growth in Utah.

Building upon the agenda identified at the growth summit, a public/private partnership known as Envision Utah was formed in 1997. With Governor Leavitt serving as honorary co-chair, Envision Utah has emphasized an inclusive, open, and participatory approach in its effort to provide tools and resources to help the region accommodate growth sustainably and intelligently.

Through a series of workshops with key stakeholders, public awareness efforts, and research into the values of Utah residents, Envision Utah developed the Quality Growth Strategy (QGS) for Greater Wasatch in 1999. The QGS consists of 32 individual strategies that seek to improve air quality and transportation, preserve critical lands and resources, and provide diverse housing opportunities. Envision Utah also created an urban planning toolbox to assist local communities in planning future development, and continues to offer local and regional planning assistance and workshops.

At the state level, the Quality Growth Commission has sought to enhance and complement local initiatives building on the Envision Utah process. The Commission's members include developers, ranchers, county commissioners, city mayors and councilors, and state department directors. The Commission has focused on preserving Utah's critical lands through open space grants. It has also funded local government planning activities to build core technical capabilities in local planning staff.

1.3 Legacy Parkway

By the year 2020, population and travel demand in the five counties along the eastern shore of the Great Salt Lake (GSL) is predicted to increase by 60 and 69 percent, respectively. In order to deal with this projected demand, Utah state, regional, and local officials developed a series of transportation improvement plans collectively known as the "Shared Solution." The Shared Solution calls for widening Interstate 15, enhancing transportation systems and management, increasing the availability and usage of mass transit, and constructing the Legacy Parkway Project.

The Legacy Parkway is planned as a four-lane, limited-access, divided highway starting near Salt Lake City and extending north approximately 14 miles to US 89. The project will include a pedestrian/equestrian/bike trail and will block traffic noise by using earthen berms rather than sound walls. The 14-mile Legacy Parkway should not to be confused with the 100+-mile Legacy Highway - running from Brigham City to Nephi - proposed by Utah Governor Michael Leavitt in 1996. That project has been the subject of considerable controversy, leading to a series of legal challenges.

1.3.1 FHWA and COE Approvals

In order to begin construction, the Legacy Parkway Project required approval from the Federal Highway Administration (FHWA) because it would merge with the interstate highway system. The project also needed to obtain a 404(b) permit from the U.S. Army Corps of Engineers

(COE) because construction would entail the filling of 114 acres of wetlands. Both the FHWA approval and COE permit were considered major federal actions that required that an Environmental Impact Statement (EIS) be performed. Between 1996 and January 2001 the Utah Department of Transportation (UDOT) prepared a draft and final EIS, awarded the contract for construction of the Legacy Parkway, obtained the COE 404(b) permit, and was granted approval by the FHWA.

1.3.2 Legal Claims

In response to these approvals, on January 17, 2001, the NGO Utahns for Better Transportation (UBT) and Salt Lake City Mayor Rocky Anderson filed a suit in federal district court alleging that the FHWA and COE violated the National Environmental Policy Act (NEPA) and the Clean Water Act (CWA). The Sierra Club filed a second suit against the U.S. Department of Transportation adding a Clean Air Act (CAA) complaint alleging that the Salt Lake area Transportation Implementation Plan (TIP) was in violation of transportation conformity requirements and that Legacy Parkway would result in increased mobile source emissions. The UBT and Sierra Club cases were consolidated by the district court and the CAA conformity claims were separated from the Legacy Parkway permitting and review claims.

Permitting and Review Claims

On August 11, 2001, U.S. District Judge Bruce S. Jenkins dismissed the plaintiff's permitting and review claims, upholding the 404(b) permit decision and FHWA approval process, thereby ruling in UDOT's favor. The plaintiffs filed for injunctive relief with the federal district court and after being denied, filed for injunctive relief with the 10th Circuit Court of Appeals. On November 16, 2001, the 10th Circuit Court of Appeals granted injunctive relief and construction on Legacy Parkway was halted. On September 16, 2002, the court ruled in favor of the plaintiffs, citing inadequacies of the EIS and the permitting process.

Conformity Claims

On June 26, 2002, the Sierra club, U.S. DOT, FHWA, Federal Transit Administration (FTA), COE, and the State of Utah entered into an agreement to settle the conformity claims against the Legacy Parkway. Under the settlement, the FHWA research program would provide funding for application of the University of Washington UrbanSim modeling program in the Salt Lake City Region. If the assessment of UrbanSim is favorable, WFRC would then use UrbanSim to produce socioeconomic and development forecasts and integrate these into WFRC's operational planning activities, such as updating the Long-Range Transportation Plan (LRP), Transportation Improvement Program (TIP), and corridor planning projects. Full text of the settlement is included as Appendix A.

Chapter 2

Project Scope

The current project was launched in 2003 with the formation of a Peer Review Panel and the organization of a Management and Policy Committee and a Scenarios Committee. The Management and Policy Committee represents stakeholders from WFRC management and other related organizations, and was established to address questions relating to the incorporation of UrbanSim into the policy and institutional setting in the region. The Scenarios Committee consists principally of planners from jurisdictions in the region, and was established to provide local input to and review of scenarios tested. The Peer Review Panel, consisting of technical experts in land use and transportation modeling, were charged with the overall coordination of the evaluation, and with making recommendations to the WFRC on the use of UrbanSim in operational planning. Due to the schedule stipulated in the terms of the settlement, the entire review had to be completed by the end of 2003.

2.1 First Peer Review Meeting

The first meeting of the Peer Review Panel (PRP) was held June 26-27, 2003 to organize the work scope and obtain initial feedback from the PRP. The recommendations developed by the PRP at the first meeting are included in this report as Appendix B. The core of the recommendations were to document the model system and its development and calibration, and to conduct a validation of the combined UrbanSim - Travel Model system using a series of tests:

- Use the validation version of Urbansim to produce two forecasts for 2030, the baseline using the current network, and a test forecast in which the long range transportation plan (LRP) is introduced in stages.
- Conduct a series of sensitivity tests by forecasting to 2030, making the following changes individually and in sequence:
  1. Remove a major highway link included in the LRP.
  2. Remove a major transit link included in the LRP.
  3. Significantly increase parking prices in downtown Salt Lake City (e.g., 50% increase in daily rates).

4. Introduce a significant urban growth policy, e.g., an urban growth boundary or substantial cost increase in a rapidly developing part of the region.
5. Test two different values of vacancy rate price sensitivity parameter.

2.2 Framing the Evaluation

The evaluation of UrbanSim as a tool for operational planning in conjunction with the regional travel models involves many considerations, broadly grouped into the validity of the model system and its usability. Some of the questions the evaluation of the UrbanSim model application is intended to consider are outlined below. We return to these questions in the closing section.

2.2.1 Model Validity

- Is the model structure theoretically sound? Based on a review of the written documentation of the model system and of the presentations, are there any theoretical deficiencies in the model design that would undermine the validity of the model and its capacity to address the intended planning functions within the region? Are there areas in which it could be improved?
- Are the quantitative methods used in the model appropriate? Are there any concerns about the validity of the quantitative methods used in the model system (multinomial logit, multiple regression, monte carlo simulation)?
- Are the estimation results valid? Based on review of the documentation of the model specification and estimation results for the Wasatch Front region, are there any significant concerns about the estimation results that would call into question the validity of the model?
- Are the simulation results reasonable? Given the absence of sufficient historical data with which to undertake a historical validation of the model in the Wasatch Front Region, the simulation results must be evaluated against theory and local knowledge. Based on this review, are there any significant concerns about the validity of the simulation results?
- Is the model appropriately sensitive to constraints and policies of interest, especially effects of major transportation improvements? Do the model predictions show patterns of response to changes in key policy variables, such as the transportation system, that are consistent with theory and local knowledge? To which policies should the model be made sensitive in the regional planning context?
- Does it integrate well with the regional travel model system? Is the approach to integration with the travel model specified and implemented in a way that is consistent with theory?

2.2.2 Model Usability

- Does it have an effective user interface? What characteristics would be useful in the user interface to support the range of intended applications for the model?

- Is the computing performance adequate? What level of computing performance would define a usable system for interaction with the travel model system, given an expectation of running the travel model approximately every 10 years of simulated time?

- Are requirements for data and expertise manageable? What level of staff support and expertise is appropriate to devote to the land use model as a part of the broader integrated regional modeling system? Do UrbanSim's requirements fall within those limits?

- Does it produce needed indicators for diagnosis and evaluation? Given the range of possible policies to be evaluated, which indicators would be useful to local stakeholders for effectively evaluating alternative policy scenarios?

- Does it integrate adequately into the institutional and political context? What are the institutional and political concerns regarding the use of UrbanSim in the region? How should the UrbanSim implementation be managed and accessed by various stakeholders in the roles of creating scenarios, runing the model system, and evaluating results? How should local land use policies, major transportation alternatives, major development plans, regional visioning, and other significant inputs be incorporated?

- How useful is it in different use cases, including updating the regional transportation plan, corridor planning, regional visioning, and local community planning? What are the different usage contexts, or situations, envisioned for applying UrbanSim? In each of these use cases, who are the stakeholders and what criteria are important to them in evaluating the use of the model system?

2.3 Comparison to Current Procedures

In order to assess the potential for operational use of UrbanSim by the WFRC, it must be examined in comparison to the existing operational procedures for land use forecasting. The existing WFRC land use procedures are provided in Appendix C. The land use forecasting procedure is based on a trend-based model to allocate households, population and jobs by five sectors to Traffic Analysis Zones. It is implemented in a spreadsheet, and has enhancements to account for capacity constraints and planned developments. The land use forecasting process also relies on considerable review and adjustment based on an expert panel and by the cities in the region.

Chapter 3

Overview of UrbanSim

This section provides a general overview of the design of UrbanSim, and compares it to other urban models. The description draws from an earlier publication (Waddell, 2002).

3.1 The Database

The data integration process for UrbanSim is depicted in Figure 3.1. The input data used to construct the model database, called the data store, include parcel files from tax assessor offices; business establishment files from the state unemployment insurance database or from commercial sources; census data; GIS overlays representing environmental, political, and planning boundaries; and a location grid. A set of software tools, collectively referred to as the data integration tools, reads these input files, diagnoses problems in them such as missing or miscoded data, and applies decision rules to synthesize missing or erroneous data and construct the model data store.

The database represents each household in the metropolitan area as an individual entity, with the primary characteristics relevant to modeling location and travel behavior: household size, number of workers, presence of children, age of head, and household income. The household list is synthesized by integrating census household-level data from the Public Use Microdata Sample with Summary Tape File 3A tabulations by census tract, and assigning synthesized households probabilistically to parcel data, using a variant of the procedure developed for the TRANSIMS model system (Beckman et al., 1996). Employment is represented in the data store as individual records for each job and its employment sector.

The data store represents locations using grid cells of 150 by 150 meters, which contain an area just over 5.5 acres (the cell size can be modified). This location grid allows explicit cross-referencing of other spatial features including planning and political boundaries such as city, county, traffic zones, urban growth boundaries; and environmental features such as wetlands, floodways, stream buffers, steep slopes, or other environmentally sensitive areas.

Parcel data are collapsed into the cells to generate composite representations of the mix and density of real estate at each location, labeled development types. These development types are somewhat analogous to the development typology developed by Calthorpe (1983), in that they represent at a local neighborhood scale the land use mix and density of development. Table 3.1 provides the rules for classifying grid cell development into types, based on the combination of

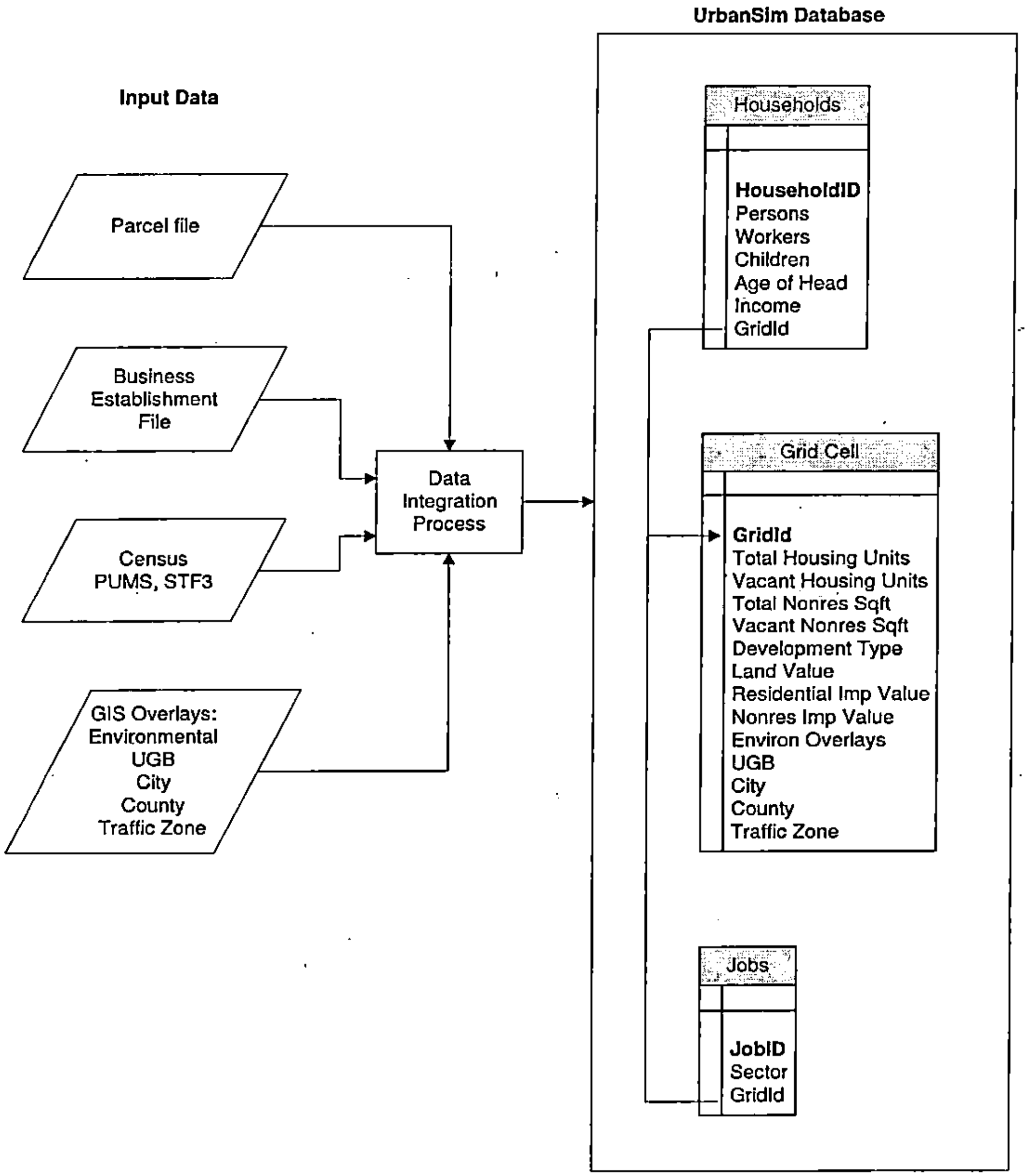

Figure 3.1: UrbanSim Database Integration

housing units, nonresidential square footage, and the principal land use of the development.

Table 3.1: Development Types

DevType	Name	Units	Sqft	Primary Use
1	R1	1	< 1,000	Residential
2	R2	2 - 4	< 1,000	Residential
3	R3	5 - 9	< 1,000	Residential
4	R4	10 - 14	< 2,500	Residential
5	R5	15 - 21	< 2,500	Residential
6	R6	22 - 30	< 2,500	Residential
7	R7	31 - 75	< 5,000	Residential
8	R8	76 - 1,000	< 5,000	Residential
9	M1	1 - 9	1,000 - 4,999	Mixed R/C
10	M2	10 - 30	2,500 - 4,999	Mixed R/C
11	M3	10 - 30	5,000 - 24,999	Mixed R/C
12	M4	10 - 30	25,000 - 49,999	Mixed R/C
13	M5	10 - 30	50,000 - 3,000,000	Mixed R/C
14	M6	31 - 1,000	5,000 - 24,999	Mixed R/C
15	M7	31 - 1,000	25,000 - 49,999	Mixed R/C
16	M8	31 - 1,000	50,000 - 3,000,000	Mixed R/C
17	C1	< 10	1,000 - 24,999	Commercial
18	C2	< 10	25,000 - 49,999	Commercial
19	C3	< 10	50,000 - 3,000,000	Commercial
20	I1	< 10	1,000 - 24,999	Industrial
21	I2	< 10	25,000 - 49,999	Industrial
22	I3	< 10	50,000 - 500,000	Industrial
23	GV	< 10	5,000 - 1,000,000	Government
24	VC	0	0	Vacant Dev
25	UN	0	0	Undevelopable

The database maintains an explicit accounting of real estate and occupants, linking individual households to individual housing units, and individual jobs to job spaces that can be either nonresidential square footage or a residential housing unit to account for home-based employment. When jobs or households are predicted to move, the space they occupy is flagged as becoming vacant, and when they are assigned to a particular housing unit or job space, that space is reclassified as occupied. By explicit assignment of housing units and nonresidential square footage to grid cells of fixed size, densities and mixtures of housing units and nonresidential square footage of industrial, commercial, or governmental types are inventoried. Land values and residential and nonresidential improvement values are also identified for each cell in the database. This integrated data store of households, jobs, land, and real estate is what the model components update over time. Although this data store is derived from data about real households, businesses, and parcels, it is a synthetic database that represents only selected characteristics of people, jobs, real estate, and locations. Similarly, the models and their estimated parameters attempt to reflect the patterns of observed behavior of real agents but are simplifications and abstractions of real behavior, as are all models.

Over the past year, a process to develop the base year database has been developed by the Center for Urban Simulation and Policy Analysis as part of a project to apply UrbanSim for the Puget Sound Regional Council. This process has become considerably more streamlined and robust than the one used initially for the WFRC model application, and may prove useful in updating the base year for future operational use. Details of the new procedures, and all programs to support it, are available from www.urbansim.org/projects/dataprep.

3.2 Software Architecture

The UrbanSim software architecture consists of four principal components:

- *models* that encode the behavior of agents in the simulation, as well as the objects they operate upon, such as land parcels and buildings,
- a *model coordinator* that schedules models to run and notifies them when data of interest has changed,
- an *object store* that holds the shared representations of agents and other entities in the simulated world, and
- a *translation and aggregation layer* that performs a range of data conversions to mediate between the object store and the models.

Models represent different actors or processes in the urban environment. In addition to encapsulating the behavior of the actor or process, each model is also responsible for defining the set of object types it operates on, and the fields of those objects with which it is concerned. A model can specify that it wishes to share fields also declared by other models, thus providing one technique for data-level coupling and integration of models via the object store. A model can also declare new object types that encapsulate domain-specific data not previously declared (e.g., a water quality model might declare a nutrient load value). A model may specify a set of object types and fields it wishes to monitor for updates, creations, or deletions. Each model is also responsible for indicating how frequently it wishes to be executed; there are no external constraints on how frequently or regularly a model needs to run.

The models do not communicate directly with each other; rather, they communicate via shared data held in the object store, mediated by the translation and aggregation layer. This extensible, modular architecture supports system evolution, in particular replacing a model with a revised one, and creating and integrating new models. It allows models to define and share common sets of objects that they all operate upon, via the object store (regardless of the original source of the data), and also allows them to monitor changes to data fields, providing a convenient method for models to synchronize their actions. Lastly, it provides the Translation/Aggregation Layer that automatically performs a range of data conversions that facilitate model integration.

A primary goal of this architecture is to move as much of the software complexity out of the individual models and into the supporting infrastructure as possible. This supporting infrastructure need be written just once, and can have the attention of an expert programmer. The models, on the other hand, are both numerous and frequently changing. Often, specifying them is a complex process, involving considerable domain-specific knowledge and testing; the more one can relieve the model writers of programming burdens the better, so that they can concentrate on issues arising from the domain.

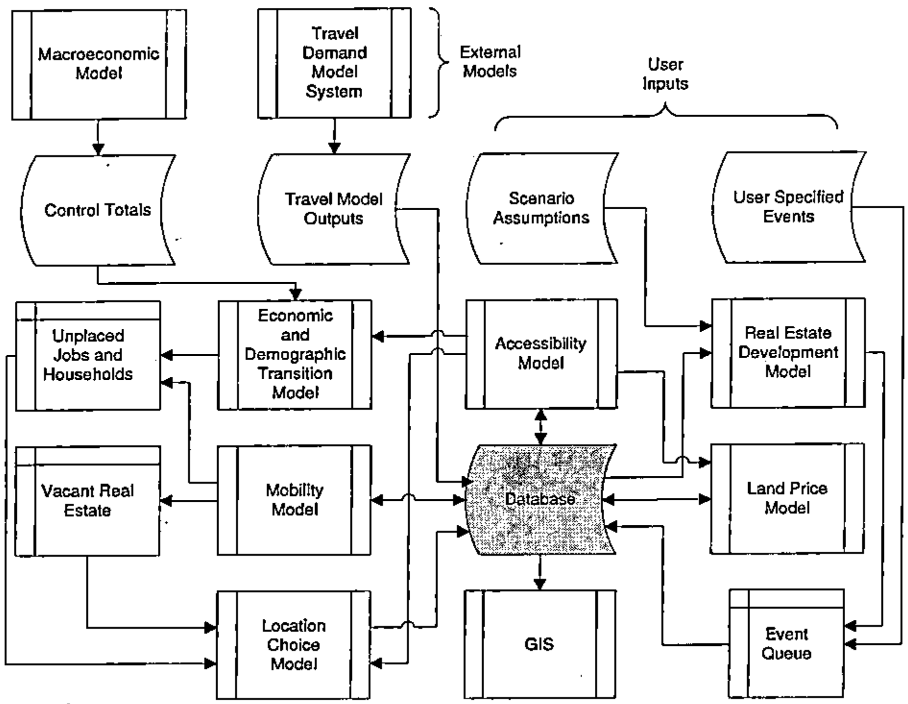

Figure 3.2: UrbanSim Model Structure

3.3 Model Structure

UrbanSim takes several key inputs as exogenous. Two of these are from external model systems: a macroeconomic model to predict future macroeconomic conditions such as population and employment by sector, and a travel demand model system to predict travel conditions such as congested times and composite utilities of travel between each interchange. The latter is loosely coupled to UrbanSim, with land use predictions input to the external travel models, and travel conditions input to subsequent annual iterations of the UrbanSim land use model system.

UrbanSim operates on an annual scheduling of key model components, and data flow is as shown in Figure 3.2. The data store contains the current state of all objects in the system, with archiving as needed by individual model components, or as requested by the model user into ASCII extracts from the model. Each of the key model components are described in the following sections. The mathematical structure of the underlying procedures in the model are virtually identical for the household and employment aspects of the model system, so for brevity the household equations are omitted from the presentation below.

The model system reads exogenous inputs not only from external macroeconomic and travel demand models, but also from user input. These user inputs include assumptions reflecting land use policies that regulate real estate development, and any user-specified events that describe scheduled events representing changes in employment, real estate development or land policy the user intends to apply to the model in a simulation year beyond the initial, or base year.

The main model components, in the order of their execution, are the economic and demographic transition models, the household and employment mobility models, the accessibility model, the household and employment location choice models, the real estate development model, and the land price model. An export model writes simulation results in user-specified forms to output files for further analysis or processing, such as by travel demand models or by GIS.

Locations in the model are based on a grid with a resolution of 150 by 150 meters per grid cell. Cells are cross-referenced to Traffic Analysis Zone for indexing travel model outputs, and to city, county, and other geographic overlays for indexing land use policies that apply to specific jurisdictions or overlays.

3.3.1 Economic Transition Model

Employment is classified by the user into employment sectors based on aggregations of Standard Industrial Classification codes. Typically 10 to 20 sectors are defined based on the local economic structure. Aggregate forecasts of economic activity and sectoral employment are exogenous to UrbanSim, and are used as inputs to the model. These forecasts may be obtained from state economic forecasts or from commercial or in-house sources.

The Economic Transition Model integrates these exogenous forecasts of aggregate employment by sector with the UrbanSim database by computing the sectoral growth or decline from the preceding year, and either removing jobs from the database in sectors that are declining, or queuing jobs to be placed in the employment location choice model for sectors that experience growth. If the user supplies only total employment control totals, rather than totals by sector, the sectoral distribution is assumed consistent with the current sectoral distribution. In cases of employment loss, the probability that a job will be removed is assumed proportional to the spatial distribution of jobs in the sector. The jobs that are removed vacate the space they were occupying, and this space becomes available to the pool of vacant space for other jobs to occupy in the location component of the model. This procedure keeps the accounting of land, structures, and occupants up to date.

New jobs are not immediately assigned a location. Instead, new jobs are added to the database and assigned a null location, to be resolved by the Employment Location Choice Model. The model proceeds as follows.

Calculate the number of jobs to be added or removed (a scalar). Here |'s are used to indicate the number of elements in (cardinality of) the set $J_{s(t-1)}$.

$$\Delta J_{st} = C_{st} - |J_{s(t-1)}|, \tag{3.1}$$

where:

ΔJ_{st}	is the change from year $t-1$ to t in total jobs in sector s,
C_{st}	is the exogenous total employment in sector s in year t,
J_{st}	is the set of all jobs in sector s in year t.

The set of all jobs at time t is defined by one of two cases. Either it is the union of the previous year's jobs and some newly created jobs or the difference between the previous year's jobs and some number of jobs to remove.

$$J_{st} = \begin{cases} J_{s(t-1)} \cup F_{st}, & \text{if } \Delta J_{st} > 0, \\ \emptyset & \text{if } \Delta J_{st} = 0, \\ J_{s(t-1)} - F_{st}, & \text{if } \Delta J_{st} < 0, \end{cases} \tag{3.2}$$

and

$$J_{st} \subset J_A, \tag{3.3}$$

where:

F_{st} is the set of jobs in flux in sector s in year t,
J_A is the universe of jobs.

The jobs in flux are jobs being added or removed from this sector at this time. If we are adding jobs, new jobs are taken from the universe of all jobs and added to the set of jobs present in the model at time t. Otherwise, the flux jobs are a random subset of the current jobs in the model.

$$F_{st} = \begin{cases} \{\, j \notin J_{st}, j \in J_A \mid j \text{ is in sector } s \,\}, & \text{if } \Delta J_{st} > 0, \\ \emptyset & \text{if } \Delta J_{st} = 0, \\ \{\, j \in J_{st} \,\}, & \text{if } \Delta J_{st} < 0, \end{cases} \tag{3.4}$$

given that

$$|F_{st}| = |\Delta J_{st}|. \tag{3.5}$$

The cardinality of flux jobs is equal to the absolute value of the change in number of jobs.

If we are adding new jobs then they are currently without a location. They are added to the set of unplaced jobs and will be taken care of by the Employment Location Choice Model.

$$U_{jt} = \begin{cases} U_{jt} \cup F_{st}, & \Delta J_{st} > 0, \\ U_{jt}, & \text{otherwise}, \end{cases} \tag{3.6}$$

where:

U_{jt} is the set of jobs that do not have a location match at time t.

If we are removing jobs then we need to remove the placed jobs pairs.

$$P_{jlt} = \begin{cases} \{\, (j,l) \in P_{jlt} \mid j \notin F_{st} \,\}, & \Delta J_{st} < 0, \\ P_{jlt}, & \text{otherwise}, \end{cases} \tag{3.7}$$

where:

P_{jlt} is the set of all jobs j and locations l that correspond to placed jobs at time t.

Also, the locations previously occupied by the jobs must be added to the unplaced locations set.

$$U_{lt} = \begin{cases} \{\, l \in L_t^J \mid \forall j \in J_t \; (j,l) \notin P_{jlt} \,\}, & \Delta J_{st} < 0, \\ U_{lt}, & \text{otherwise}, \end{cases} \tag{3.8}$$

where:

U_{lt} is the set of locations that do not have a job match at time t,
L_t^J is the set of all locations at time t where a job could be placed,
J_t is the set of jobs at time t.

3.3.2 Demographic Transition Model

The Demographic Transition Model accounts for changes in the distribution of households by type over time, using an algorithm analogous to that used in the Economic Transition Model. In reality, these changes result from a complex set of social and demographic changes that include aging, household formation, divorce and household dissolution, mortality, birth of children, migration into and from the region, changes in household size, and changes in income, among others. The data (and theory) required to represent all of these components and their interactions adequately are not readily available. Instead, the Demographic Transition Model, like the Economic Transition Model described above, uses external control totals of population and households by type (the latter only if available) to provide a mechanism for the user to approximate the net results of these changes. Analysis by the user of local demographic trends may inform the construction of control totals with distributions of household size, age of head, and income. If only total population is provided in the control totals, the model assumes that the distribution of households by type remains static.

As in the economic transition case, household births are added to a list of movers that will be located by the Household Location Choice Model. Household deaths, on the other hand, are accounted for by this model by removing those households from the housing stock, and by properly accounting for the vacancies created by their departure. The demographic transition model is analogous in form to the employment transition model described above.

3.3.3 Employment Mobility Model

Employment mobility and location choices are made by firms. However, in the current version of UrbanSim, we use individual jobs as the units of analysis. This is equivalent to assuming that businesses are making individual choices about the location of each job, and are not constrained to moving an entire establishment.

The Employment Mobility Model predicts the probability that jobs of each type will move from their current location or stay during a particular year. This is a transitional change that could reflect job turnover by employees, layoffs, business relocations or closures. Similar to the economic transition model when handling job losses in declining sectors, the model assumes that the hazard of moving is proportional to the spatial distribution of jobs in the sector. All placement of jobs is managed through the employment location model.

As in the case of job losses predicted in the economic transition component, the application of this model requires subtracting jobs by sector from the buildings they currently occupy, and the updating of the accounting to make this space available as vacant space. These counts will be added to the unallocated new jobs by sector calculated in the economic transition model. The combination of new and moving jobs serve as a pool to be located in the employment location choice model. Vacancy of nonresidential space will be updated, making space available for allocation in the employment location choice model.

Since it is possible that the relative attractiveness of commercial space in other locations when compared with an establishment's current location may influence its decision to move, an alternative structure for the mobility model could use the marginal choice in a nested logit model with a conditional choice of location. In this way, the model would use information about the relative utility of alternative locations compared to the utility of the current location in predicting whether jobs will move. While this might be more theoretically appealing than the specification given, it is generally not supported by the data available for calibration. Instead, the mobility decision is treated as an independent choice, and the probabilities estimated by annual mobility rates directly observed over a recent period for each sector. The resulting form of the employment mobility model is as follows.

M_{st} is a set of jobs that are chosen to be moved based on $P(j,t)$, a Monte Carlo sampling process using the annual mobility rate for sector s.

$$M_{st} = \{\, j \in J_{st} \mid P(j,t) \,\}, \tag{3.9}$$

where:

M_{st}	is the set of jobs in sector s at time t that are uprooted by the mobility model,
$P(j,t)$	is a Monte Carlo sampling process determining if job j will be moved at time t.

The jobs to be moved are now unplaced and added to the unplaced jobs set:

$$U_{jt} = U_{jt} \cup M_{st}, \tag{3.10}$$

and they are removed from the job location pairs set:

$$P_{jlt} = \{\, (j,l) \in P_{jlt} \mid j \notin M_{st} \,\}. \tag{3.11}$$

The locations once occupied by the jobs to be moved must be added to the unplaced locations set.

$$U_{lt} = \{\, l \in L_t^J \mid \forall j \in J_t \; (j,l) \notin P_{jlt} \,\}. \tag{3.12}$$

3.3.4 Household Mobility Model

The Household Mobility Model is similar in form to the Employment Mobility Model described above. The same algorithm is used, but with rates or coefficients applicable to each household type. For households, mobility probabilities are estimated from the Census Current Population Survey, which provides a national database on which annual mobility rates are computed by type of household. This will reflect differential mobility rates for renters and owners, and households at different life stages.

Application of the Household Mobility Model requires subtracting mover households by type from the housing stock by cell, and adding them to the pool of new households by type estimated in the Demographic Transition Model. In the database, this is accomplished by setting the location field for the moving households to a null value. The combination of new and moving households serves as a population of households to be located by the Household Location Choice Model. Housing vacancy is updated as movers are subtracted, making the housing available for occupation in the household location and housing type choice model.

3.3.5 Real Estate Development Model

Data

The real estate developer model simulates the construction of new real estate, either through the construction of new development or the intensification or conversion of existing development. The data is structured as grid cells, currently specified as 150 meter x 150 meter in resolution (though this is a specification issue and not a restriction in the software). Parcel data is preprocessed to obtain the intersection of parcels and grid cells, and then to construct a composite representation of the real estate development within each cell. Cells are then classified on the basis of their real estate composition, into 'Development Types', as shown in Table 3.1.

The data to estimate the coefficients for the developer model is derived from preprocessing the parcel and grid data to make heavy use of the year built values of the existing development in the assessor records. The data preparation procedure imputes year built values for those records that are missing by examining the surrounding cells of the same type and drawing from the distribution of observed values. Once the data is complete, historical development 'events' are identified for some user-specified period of time, and these events are extracted to a file for further analysis. Events, within this framework, are any changes in the real estate development within a cell that is identified by examining the year built values within the data. This means that the procedure is capable of identifying any new construction that has a year built occurring within the specified time frame. It does not, however, identify events that involve the demolition of buildings at some historical point in time, since there is no current evidence of the existence of demolished buildings within the current assessor records. This procedure could be augmented with data derived from building demolition and permit records, but that has not been accounted for in the current specification.

The result of this procedure, then, is the production of a set of development events that represent all observed transitions between any pairs of development types within each year of the specified historical time frame. Note that the time slice for determining the existence of an event is annual, since this is the limit of the information on the vintage of real estate. Note also that development events are observed in the data that do not indicate a change of development type, but rather an intensification of use within the range specified in the definition of the development types.

Structure

The developer model is structured to predict the probability within a single simulation year of a grid cell experiencing a development event, and if it does experience such an event, identifying the type of event that is most likely. A multinomial logit model is used to estimate these probabilities. Once these probabilities are estimated for a grid cell, commitment of development is simulated using a Monte Carlo sampling process. Implementation of the development takes place by using a development template to obtain the most likely characteristics of the resulting development project within the cell, including the number of housing units, square feet of commercial, industrial and government space, improvement value, and construction schedule. These commitments are then added to the 'development event' queue, to be built (added to the database) as scheduled.

Constraints on development outcomes are included through a combination of user-specified spatial overlays and decision rules about specific types of development allowed in different situations. First, each cell is assigned a series of overlays through spatial preprocessing using GIS overlay techniques. These overlays include the following features in the Eugene-Springfield model application :

- Land use plan designation
- City
- County
- Wetland designation
- Floodplain/floodway
- Stream or riparian buffer
- High slope areas
- Urban Growth Boundary

These overlays can be used to assign user-specified constraints on the type of development that is allowed to occur within each of these overlay designations. The intended constraints are indicated as allowed conversions between each land use plan designation and each development type in a file supplied by the user as part of the construction of a scenario for simulation. Those conversions that are contained in this file are not considered in the model, by eliminating them from the choice set for any cell affected by the constraint. These constraints are therefore interpreted as 'binding' constraints, and not subject to market pressure. Currently, if users wish to examine the impact of these constraints, they would need to 'relax' a particular constraint within one scenario and compare the scenario results to a more restrictive policy.

The independent variables used in the real estate development model can be organized into categories of site characteristics, urban design-scale effects, regional accessibility, and market conditions, as shown below:

- Site characteristics
  Existing development characteristics
  Land use plan
  Environmental constraints
- Urban design-scale
  Proximity to highway and arterials
  Proximity to existing development
  Neighborhood land use mix and property values
  Recent development in neighborhood
- Regional accessibility
  Access to population and employment
  Travel time to CBD, airport
- Market Conditions
  Vacancy rates

The real estate development model proceeds as follows.

$$T = \{ (d_1, d_2) \mid \text{devtype } d_1 \text{ can transition to devtype } d_2 \}, \tag{3.13}$$
$$T_{lt} = \{ d_2 \mid (d_1, d_2) \in T, l \in L_t, d_1 \text{ is the devtype of } l \}, \tag{3.14}$$
$$P_{lt} = \{ (d, p) \mid j \in T_{tl},\ p \text{ is the probability of transitioning to devtype } d \text{ at location } l \}, \tag{3.15}$$

where:

- T is the set of valid development type transitions,
- T_{lt} is the set of all valid development type transitions at location l at time t,
- L_t is the set of all locations at time t,
- P_{lt} is the set of probabilites of transitioning to a particular development type at location l at time t.

The devtype for each location is defined to be the outcome of the chosen transition. One probable transition is one that includes no change.

$$L_{dt} = \{ (l, d) \mid (d, p) \in P_{lt}, l \in L_t,\ d \text{ is chosen given a Monte Carlo sampling of } p \},$$

where:

- L_{dt} is the set of location and development type pairs at time t.

3.3.6 Employment Location Choice Model

In this model, we predict the probability that a job that is either new (from the Economic Transition Model), or has moved within the region (from the Employment Mobility Model), will be located at a particular site. The grid cells used as the basic geographic unit of analysis in the current model implementation contain variable quantities of space to be occupied by jobs. The number of locations available for a job to locate within a grid cell will depend mainly on the total square footage of nonresidential floorspace in the cell, and on the density of the use of space (square feet per employee). Given the possibility that some jobs will be located in residential units, however, housing as well as nonresidential floorspace must be considered in job location. We have defined a maximum rate of home-based employment, determined using local data for a particular metropolitan region, to identify the potential set of spaces available for home-based employment. The set of job locations available for placing a job, then, are the union of the spaces in nonresidential floorspace and a subset of the residential units in the cell. The model is specified as a multinomial logit model, with separate equations estimated for each employment sector.

$$|L_t^J| = s_l / r_{sd} + h_l / r_{hd} \tag{3.16}$$

where:

s_l is a scalar representing the total nonresidential square footage of floorspace in location l,

h_l is a scalar representing the total number of housing units in location l,

r_{sd} is a space utilization rate for nonresidential space for devtype d (sqft per employee),

r_{hd} is a home-based employment rate, defined as the minimum units per job for devtype d

For both the employment location and household location models, we take the stock of available space as fixed in the short run of the intra-year period of the simulation, and assume that locators are price takers. That is, a single locating job or household does not have enough market power to influence the transaction price, and must accept the current market price as given.

The variables included in the employment location choice model are drawn from the literature in urban economics. We expect that accessibility to population, particularly high-income population, increases bids for retail and service businesses. We also expect that two forms of agglomeration economies influence location choices: localization economies and inter-industry linkages.

Localization economies represent positive externalities associated with locations that have other firms in the same industry nearby. The basis for the attraction may be some combination of a shared skilled labor pool, comparison shopping in the case of retail, co-location at a site with highly desirable characteristics, or other factors that cause the costs of production to decline as greater concentration of businesses in the industry occurs. The classic example of localization economies is Silicon Valley. Inter-industry linkages refer to agglomeration economies associated with location at a site that has greater access to businesses in strategically related, but different, industries. Examples include manufacturers locating near concentrations of suppliers in different industries, or distribution companies locating where they can readily service retail outlets.

One complication in measuring localization economies and inter-industry linkages is determining the relevant distance for agglomeration economies to influence location choices. At one level, agglomeration economies are likely to affect business location choices between states, or between metropolitan areas within a state. Within a single metropolitan area, we are concerned more with agglomeration economies at a scale relevant to the formation of employment centers. The influence of proximity to related employment may be measured using two scales: a regional scale effect using zone-to-zone accessibilities from the travel model, or highly localized accessibilities using queries of the area immediately around the given grid cell. Most of the spatial queries used in the model are of the latter type, because the regional accessibility variables tend to be very highly correlated, and because agglomerations are expected to be very localized. Note that the use of radial queries surrounding grid cells also avoids the problems of arbitrary zonal aggregations.

Age of buildings is included in the model to estimate the influence of age depreciation of commercial buildings, with the expectation that businesses prefer newer buildings and discount their bids for older ones. This reflects the deterioration of older buildings, changing architecture, and preferences, as is the case in residential housing. There is the possibility that significant renovation will make the actual year built less relevant, and we would expect that this would dampen the coefficient for age depreciation. We do not at this point attempt to model maintenance and renovation investments and the quality of buildings.

Density, the inverse of lot size, is included in the location choice model. We expect businesses, like households, to reveal different preferences for land based on their production functions and the role of amenities such as green space and parking area. As manufacturing production continues to shift to more horizontal, land-intensive technology, we expect the discounting for density to be relatively high. Retail, with its concentration in shopping strips and malls, still requires substantial surface land for parking, and is likely to discount bids less for density. We expect service firms to discount for density the least, since in the traditional urban economics models of bid-rent, service firms generally outbid other firms for sites with higher accessibility, land cost, and density.

We might expect that certain sectors, particularly retail, show some preference for locations near a major highway, and are willing to bid higher for those locations. Distance to a highway is measured in meters, using grid spatial queries. We also test for the residual influence of the classic monocentric model, measured by travel time to the CBD, after controlling for population access and agglomeration economies. We expect that, for most regions, the CBD accessibility influence will be insignificant or the reverse of that in the traditional monocentric model, after accounting for these other effects.

Calibration of the model is based on a geocoded establishment file (matched to the parcel file to link employment by type to land use by type). A sample of geocoded jobs in each sector is used to estimate the coefficients of the location choice model. As with the Household Location Choice Model, the application of the model produces demand by each employment type for cell locations.

The employment location model processes each job in the mover queue individually, and queries grid cells for alternative locations to consider. These alternatives are sampled in proportion to the capacity of the built space in the cell for accommodating jobs, and the number of alternatives to consider may be determined by the user. Note that jobs may be located in housing units, as is increasingly the case with home-based employment through telecommuting and small independent home-based businesses. A logit model is applied to estimate the probability that the current job will move to each of the alternative job spaces under consideration. Monte carlo simulation is used to generate a decision to locate in a particular alternative, and once this choice is made, the job is assigned to the cell, and the respective quantities of vacant and used space in the cell are updated. If a preferred alternative for a job becomes unavailable during a simulation run, having been chosen and occupied by a previously locating job, the currently locating job is assigned its next best available alternative.

The independent variables used in the employment location choice model can be grouped into the categories of real estate characteristics, regional accessibility, and urban-design scale effects as shown below:

- Real Estate Characteristics
  Prices
  Development type (land use mix, density)
- Regional accessibility
  Access to population
  Travel time to CBD, airport
- Urban design-scale
  Proximity to highway, arterials
- Local agglomeration economies within and between sectors: center formation

The employment location model proceeds as follows.

The job location pairs set is defined to contain all pairs of jobs and locations that correspond to jobs occupying a particular location.

$$P_{jlt} = \{ (j,l) \mid j \in J_t, l \in L_t^J, \text{job } j \text{ is placed at location } l \}, \tag{3.17}$$

$$U_{jt} = \{ j \mid j \in J_t, \forall l \in L_t^J \ (j,l) \notin P_{jlt} \}, \tag{3.18}$$

$$U_{lt} = \{ l \mid l \in L_t^J, \forall j \in J_t \ (j,l) \notin P_{jlt} \}, \tag{3.19}$$

$$D_{st} = \{ (l,p) \mid l \in U_{lt}, \ p \text{ is the probability of a job in sector } s \text{ locating in } l \} \tag{3.20}$$

where:

D_{st} is the set of pairs representing the probability of an employee of sector s locating to a particular location at time t.

Monte Carlo sampling of the location choices for each sector occurs over the distribution given by D_{st}.

$$F_{jlt} = \{ (j,l) \mid j \in U_{jt}, \text{ monte carlo choice of } l \text{ from } D_{st} \text{ given the sector of } j \}, \tag{3.21}$$

where:

F_{jlt} is the set of new job/location pairs created using a monte carlo sampling from D_{st} for each sector.

The cardinality of the new job/location pairs is equal to the cardinality of unplaced jobs or unplaced locations, whichever is smaller.

$$|F_{jlt}| = \min(|U_{jt}|, |U_{lt}|). \tag{3.22}$$

The set of job/location pairs is modified to reflect the new matchings.

$$P_{jlt} = P_{jlt} \cup F_{jlt}. \tag{3.23}$$

3.3.7 Household Location Choice Model

In this model, as in the employment location model, we predict the probability that a household that is either new (from the transition component), or has decided to move within the region (from the mobility component), will choose a particular location defined by a grid cell. As before, the form of the model is specified as multinomial logit, with random sampling of alternatives from the universe of available (vacant) housing units, including those units vacated by movers in the current year.

The model architecture allows location choice models to be estimated for households stratified by income level, the presence or absence of children, and other life cycle characteristics. Alternatively, these effects can be included in a single model estimation through interactions of the household characteristics with the characteristics of the alternative locations. The current implementation is based on the latter but is general enough to accommodate stratified estimation, for example by household income. The variables used in the model are drawn from the literature in urban economics, urban geography, and urban sociology. An initial feature of the model specification is the incorporation of the classical urban economic trade-off between transportation and land cost. This has been generalized to account not only for travel time to the classical monocentric center, the CBD, but also to more generalized access to employment opportunities and to shopping. These accessibilities to work and shopping are measured by weighting the opportunities at each destination zone with a composite utility of travel across all modes to the destination, based on the logsum from the mode choice travel model.

These measures of accessibility should negate the traditional pull of the CBD, and, for some population segments, potentially reverse it. In addition to these accessibility variables, we include in the model a net building density, to measure the input-substitution effect of land and capital. To the extent that land near high accessibility locations is bid up in price, we should expect that builders will substitute capital for land and build at higher densities. Consumers for whom land is a more important amenity will choose larger lot housing with less accessibility, and the converse should hold for households that value accessibility more than land, such as higher income childless households.

The age of housing is considered for two reasons. First, we should expect that housing depreciates with age, since the expected life of a building is finite, and a consistent stream of maintenance investments are required to slow the deterioration of the structure once it is built. Second, due to changing architectural styles, amenities, and tastes, we should expect that the wealthiest households prefer newer housing, all else being equal. The exception to this pattern is likely to be older, architecturally interesting, high quality housing in historically wealthy neighborhoods. The preference for these alternatives are accommodated through a combination of nonlinear or dummy variable treatment for this type of housing and neighborhood.

A related hypothesis from urban economics is that, since housing is considered a normal good, it has a positive income elasticity of demand. This implies that as incomes rise, households will spend a portion of the gains in income to purchase housing that is more expensive, and that provides more amenities (structural and neighborhood) than their prior dwelling. A similar hypothesis is articulated in urban sociology in which upward social mobility is associated with spatial proximity to higher status households. Both of these hypotheses predict that households of any given income level prefer, all else being equal, to locate in neighborhoods that have higher average incomes. (UrbanSim does not attempt to operationalize the concepts of social status or social assimilation, but does consider income in the location choice.)

The age hypothesis and the two income-related hypotheses are consistent with the housing filtering model, which explains the dynamic of new housing construction for wealthy households that sets in motion a chain of vacancies. The vacancy chain causes households to move into higher status neighborhoods than the ones they leave, and housing units to be successively occupied by lower and lower status occupants. At the end of the vacancy chain, in the least desirable housing stock and the least desirable neighborhoods, there can be insufficient demand to sustain the housing stock and vacancies go unsatisfied, leading ultimately to housing abandonment. We include in the model an age depreciation variable, along with a neighborhood income composition set of variables, to collectively test the housing filtering and related hypotheses.

Housing type is included in the model as a set of dummy variables for alternative development types. Development types correspond to the density and land use mix within a cell, with multiple categories of residential development, and mixed use development encompassing both commercial space and residential housing. These are discussed further in Section 3.3.5 describing the real estate development model.

One of the features that households prefer is a compatible land use mix within the neighborhood. It is likely that residential land use, as a proxy for land uses that are compatible with residential use, positively influences housing bids. On the other hand, industrial land use, as a proxy for less desirable land use characteristics, would lower bids.

The model is calibrated using a random sample of alternative locations, which has been shown to provide consistent estimates of the coefficients. In application for forecasting, each locating household is modeled individually, and a sample of alternative cell locations is generated in proportion to the available (vacant) housing. Monte carlo simulation is used to select the specific alternative to be assigned to the household, and vacant and occupied housing units are updated in the cell.

The market allocation mechanism used to assign households and jobs to available space, then, is not done through a general equilibrium solution in which we assume consumers and suppliers optimize across all alternatives based on perfect information, and zero transaction costs, with prices on all buildings at each location adjusting to the general equilibrium solution that perfectly matches consumers and suppliers to clear the market. Rather, the solution is based on an expectation of incomplete information and nontrivial transactions and search costs, so that movers obtain the highest satisfactory location that is available, and prices respond at the end of the year to the balance of demand and supply at each location.

The independent variables can be organized into the three categories of housing characteristics, regional accessibility, and urban-design scale effects as shown below.

- Housing Characteristics
  Prices (interacted with income)
  Development types (density, land use mix) Housing age
- Regional accessibility
  Job accessibility by auto-ownership group
  Travel time to CBD and airport
- Urban design-scale (local accessibility)
  Neighborhood land use mix and density
  Neighborhood Employment

3.3.8 Land Price Model

UrbanSim uses land prices as the indicator of the match between demand and supply of land at different locations and with different development types, and of the relative market valuations for attributes of housing, nonresidential space, and location. This role is important to the rationing of land and buildings to consumers based on preferences and ability to pay, as a reflection of the operation of actual real estate markets. Since prices enter the location choice utility functions for jobs and households, an adjustment in prices will alter location preferences. All else being equal, this will in turn cause higher price alternatives to become more likely to be chosen by occupants who have lower price elasticity of demand. Similarly, any adjustment in land prices alters the preferences of developers to build new construction by type of space, and the density of the construction.

We make the following assumptions:

1. Households, businesses, and developers are all price-takers, and market adjustments are

made by the market in response to aggregate demand and supply relationships. Each responds, therefore, to previous period price information.

2. Location preferences and demand-supply imbalances are capitalized into land values. Building value reflects building replacement costs only, and can include variations in development costs due to terrain, environmental constraints or development policy.

3. There is a long-term structural vacancy rate for each type of property, and the relationship of current vacancy rates to this long-term vacancy rate influences price adjustments.

Land prices are modeled using a hedonic regression of land value on attributes of the land and its environment, including land use mix, density of development, proximity of highways and other infrastructure, land use plan or zoning constraints, and neighborhood effects. The hedonic regression may be estimated from sales transactions if there are sufficient transactions on all property types, and if there is sufficient information on the lot and its location. An alternative is to use tax assessor records on land values, which are part of the database typically assembled to implement the model. Although assessor records may contain biases in their assessment, they do provide virtually complete coverage of the land (with notable exceptions and gaps for exempt or publicly owned property).

The hedonic regression equation encapsulates interactions between market demand and supply, revealing an envelope of implicit valuations for location and structural characteristics. These relative prices have been documented to be relatively consistent over time, with the acknowledgement that the relative values at specific locations change as their underlying characteristics change [2]. Because the hedonic regression includes variables that are to be maintained as part of the simulation system, these can be used to update relative prices over time.

In addition to these relative prices captured by the hedonic regression, the overall price level within the market for each type of real estate moves over time in response to shifts between supply and demand. These fluctuations can be tied to the relationship between the actual market vacancy rate and the long-term structural vacancy rate. As the current vacancy rate falls below the structural rate, price levels rise, and when the current vacancy rate exceeds the structural level, they fall.

These two effects on prices are combined in the land price model. The estimated hedonic regression equation is used to establish relative prices, and the intercept of the equation is adjusted based on the relative position of the current and structural vacancy rate, as follows:

$$P_{ilt} = \alpha + \delta V_{it}^{c} + \beta X_{ilt} \tag{3.24}$$

where:

p_{ilt} is the price of land per acre of development type i, at location l in time t
V_{it}^{c} is the current vacancy rate at time t, weighting local and regional vacancy
X_{ilt} is a vector of locational and site attributes
α and β are estimated parameters
δ is set by the user based on sensitivity testing

Prices are updated annually, after all construction and market activity is completed. These end of year prices are then used as the values of reference for market activities in the subsequent year.

The independent variables influencing land prices can be organized into site characteristics, regional accessibility, urban-design scale effects, and market conditions, as shown below:

- Site characteristics
  Development type
  Land use plan
  Environmental constraints
- Regional accessibility
  Access to population and employment
- Urban design-scale
  Land use mix and density
  Proximity to highway and arterials
- Market Conditions
  Vacancy rates

3.3.9 Accessibility Model

Since this model is not of the monocentric or spatial interaction genre, in which the choice of workplace is exogenous and residential locations are chosen principally on the basis of commute to the city center or to a predetermined workplace, we deal with accessibility in a more general framework. Accessibility is considered a normal good, like other positive attributes of housing, which consumers place a positive economic value on. We therefore expect that consumers value access to workplaces and shopping opportunities, among the many other attributes they consider in their housing preferences. However, not all households respond to accessibility in the same way. Retired persons would be less influenced by accessibility to job opportunities than would working age households, for instance.

We operationalize the concept of accessibility for a given location as the distribution of opportunities weighted by the travel impedance, or alternatively the utility of travel to those destinations. The utility of travel is measured as the composite utility across all modes of travel for each zone pair, obtained as the logsum of the mode choice for each origin-destination pair. The resulting access measure for each location is thus:

$$A_i = \sum_{j=1}^{J} D_j e^{L_{aij}} \tag{3.25}$$

where:

D_j is the quantity of activity in location j
L_{ij} is composite utility, or logsum, for vehicle ownership level a households, from location i to j.

The accessibility model reads the logsum matrix from the travel model and the land use distribution for a given year, and creates accessibility indices for use in the household and business location choice models. The general framework is to summarize the accessibility from each zone to various activities for which accessibility is considered important in household or business location choice.

Since UrbanSim operates annually, but travel model updates are likely to be executed for two to three of the years within the forecasting horizon, travel utilities remain constant from one travel model run until they are replaced by the next travel model result. Although travel utilities remain constant, the activity distribution in these accessibility indices is updated annually, so that the accessibility indices change from one year to the next to reflect the evolving spatial distribution of activities.

3.3.10 User-Specified Events

Given our current understanding, no model will be able to simulate accurately the timing, location and nature of major events such as a major corporate relocation into or out of a metropolitan area, or a major development project such as a regional shopping mall. In addition, major policy events, such as a change in the land use plan or in an Urban Growth Boundary, are outside the range of predictions of our simulation. (At least in its current form, UrbanSim is intended as a tool to aid planning and civic deliberation, not as a tool to model the behavior of voters or governments. We want it to be used to say "if you adopt the following policy, here are the likely consequences," but not to say "UrbanSim predicts that in 5 years the county will adopt the following policy.")

However, planners and decision-makers often have information about precisely these kinds of major events, and there is a need to integrate such information into the use of the model system. It is useful, for example, to explore the potential effects of a planned corporate relocation by introducing user-specified events to reflect the construction of the corporate building, and the relocation into the region (and to the specific site) of a substantial number of jobs, and examine the cumulative or secondary effects of the relocation on further residential and employment location and real estate development choices. Inability to represent such events, in the presence of knowledge about developments that may be 'in the pipeline,' amounts to less than full use of the available information about the future, and could undermine the validity and credibility of the planning process. For these reasons, support for three kinds of events has been incorporated into the system: development events, employment events, and policy events.

Chapter 4

Development and Specification of the Wasatch Front UrbanSim Application

4.1 Database Development

In this section, we review the development and specifications of the database for the Wasatch Front UrbanSim application. Much of the initial processing was conducted by the Automated Geographic Reference Center of the State of Utah, and was coordinated by Stuart Challender. Data was obtained from the Utah State Geographic Information Database; the Utah Workforce Services Division; the Tax Assessment Departments of Davis, Salt Lake, Utah and Weber Counties; the Wasatch Front Regional Council (WFRC); Mountainlands Association of Governments (MAG); the Property Research Group and Experian Information Solutions.

4.1.1 Base Year

The base year for the implementation of the model is 1997, for which employment data and parcel data are approximately consistent. Population data from the home interview survey and from the census were also used, and adjusted to the 1997 base using the parcel distribution of the housing stock in that year.

4.1.2 Geographic Scope and Zonal System

The scope of the study area is the extent of the Traffic Zone system represented in the combined WFRC and MAG travel model. This covers the urbanized areas of Davis, Salt Lake, Utah, and Weber Counties, as well as a substantial rural fringe surrounding the currently urbanized region. The Traffic Zone System used by MAG has been recently updated, and these updates are included in the zonal system to be used in applying UrbanSim.

4.1.3 Classification of Households

The classification of households for use in the model is based on household income, household size, age of head of household, and presence of children. These characteristics are likely to influence residence location choices and travel behavior.

Table 4.1: Development Types

Income	Age of Head	Household Size	Workers	Children
Under $5,000	Under 29	1	0	0
$5,000-9,999	20-49	2	1	1 or more
$10,000-14,999	50-64	3	2	
$15,000-24,999	65 or Over	4	3 or more	
$25,000-34,999		5 or more		
$35,000-49,999				
$50,000-74,999				
$75,000-99,999				
$100,000 or more				

4.1.4 Classification of Employment

For the classification of employment, sectors were aggregated from 2-digit standard industrial classification codes as shown below.

Table 4.2: Employment Sectors

Sector	SIC	Description	Travel Model
1	001-14	Resource Extraction	Omitted
2	15-17	Construction	Omitted
3	20-39	Manufacturing	Industrial
4	40,41,43-49	Transport, Communications and Utilities	Industrial
5	42,50,51	Trucking and Warehousing, Wholesale Trade	Other
6	52-53,56-57,59	General Retail	Retail
7	54,58	Restaurants and Food Stores	Retail
8	55,75	Auto Sales and Services	Retail
9	60-62,67	Finance	Other
10	63-66	Insurance and Real Estate	Other
11	73,81,87	Business and Professional Services	Other
12	80	Health Services	Other
13	70-72,76-79,83-86,88-89	General Services	Other
14	82,91-99	Government and Education	Other

The sector definitions used in the regional travel model to produce the current projections are:

Sector	SIC	Description
1	1000-1499, 1800-9999	Total NAGC
2	2000-4999	Industrial
3	5200-5299	Retail
4	1000-1499, 1800-1999, 5000-5199, 5300-9999	Other

4.1.5 Parcel Data

Although land use data was ultimately processed into grid cells for use in the model, it was based on parcel data. This section describes the collection, processing and limitations of the parcel data. The compilation of parcel data for use in the model involved substantial effort beyond the collection of the assessor files and GIS layers from Davis, Salt Lake, Utah and Weber Counties. Inconsistencies in the coding of key attributes such as land use, incomplete initial coverage, and absence of key attributes such as the square footage of nonresidential buildings and apartment unit counts required substantial augmentation of the original files. Data from Experion Information Services and the Property Research Group were used to fill missing data, in addition to efforts by WFRC and MAG to provide additional review and feedback on missing data.

The resulting parcel database contains 536,355 parcels and represents 2,436 square miles, of which 305 appear to be in parcels that are developed in urban uses. Table 4.3 summarizes the parcel characteristics. Substantial effort was made to augment the attributes and coverage of the original parcel files obtained from the county tax assessor offices. This report does not attempt to provide a detailed recounting of these procedures, which were undertaken by AGRC in coordination with Urban Analytics.

Following the initial collection of the parcel maps and tax assessor databases from the four counties in the study area, several identified limitations in the data prompted significant additional data collection and integration. In particular, the absence of building square footage on nonresidential buildings was significant for the employment accounting in the model, and prompted the integration of this data from the Property Research Group. Experion data was used to fill missing land use classifications, especially in Davis County. General Land Use Plan values were obtained by AGRC from WFRC, MAG, and numerous municipalities. MAG and WFRC also provided assistance with verification and augmentation of the housing unit counts for multi-family parcels.

Based on the results shown here, the parcel data were augmented with information from Metroscan, particularly for nonresidential building square footage. Further gaps in the data were addressed using synthetic techniques during the integration of the database. As shown in Table 4.3, the initial parcel data contained a significant number of parcels that are not classified by land use. There were 26,430 parcels (4.9% of the total) with a land use code of 0, accounting for 116,447 acres. These tended to not have improvements, and accounted for only 3 dwelling units. These needed to be reclassified. Considering the low average land value per acre, it is likely that these were principally nonurban and nonagricultural.

The low number of parcels in warehouse land use (643) suggested that it was not reasonable to maintain it as a separate land use category. It is not clear at this point what degree of miscoding there might be in this land use code, but the far higher number of industrial parcels (4,816) indicates that it is likely that many parcels were misclassified as industrial.

Similarly, the office land use appears under-represented in the data, with only 1,083 (0.2%) of the parcels in this category, and only 285,963 building square feet accounted for. Based on communications with Stuart Challender, the most likely interpretation appeared to be that the office parcels have been generally misclassified into other commercial uses. The most likely coding would be into retail use, but it is possible that some of the office space has been coded into special purpose or exempt classifications. Land uses of office and retail were subsequently merged and labeled commercial. The importance of the office land use may warrant further efforts in the future to clean up the land use classifications for large buildings in order to maintain this as a distinct land use.

It is clear that there was undercounting in the residential square footage, leading to relatively low average square footage per unit for the residential categories. It is also apparent that the nonresidential building square footage is low, based on the implied FAR density measures for the nonresidential land uses. These undercounting problems appear most acute for the warehouse and office classes discussed above, but also for special purpose and exempt classes. These two classes capture government buildings, hospitals, hotels, and university buildings.

Improvement values per square foot appear reasonable for retail and industrial ($34 and $16 respectively), but are unrealistically high for the other nonresidential land uses, again suggesting that building square footages have been under-reported for these categories.

The total housing unit counts appear consistent with 1990 census and 1993 WFRC and MAG estimates. In 1990 there were 417,132 housing units recorded in the census for the combined metropolitan statistical areas (larger than the study area). In 1993, the WFRC and MAG travel model input data reported 472,554 housing units in the study area. In 1997, estimates by Stuart Challender using the parcel data generate a total of 541,828 housing units. These appear to be a plausible pattern over this period of time. The process of preparing for model calibration and data loading into the model required resolution of inconsistencies in the data, such as businesses assigned to parcels with no building square footage, or improvement value and commercial land use codes with no square footage. To accomplish this, a set of procedures was developed to check for inconsistencies and gaps in the data, and to synthesize values for these based on the indications of other attributes and the spatial context of the parcels. As noted earlier, documentation on all of the preprocessing of these data is incomplete. Current procedures and tools for accomplishing this process have been compiled by the UrbanSim development team and are available at www.urbansim.org/project/dataprep.

Table 4.3: Parcel Characteristics

LUCode	Land Use	Parcels	Acres	Impval(000)	Landval(000)	Units	Sqft(000)
0		26,430	116,447	2,334	12,347,873	3	1,224
AG	Agriculture	13,306	134,469	155,366	1,226,326	78	4,172
C1	Retail	14,692	17,411	6,485,999	2,506,057	167	72,922
C2	Industrial	4,816	15,554	2,966,327	818,453	3	52,173
C3	Warehouse	643	1,767	137,735	41,603	6	73
C4	Office	1,083	547	259,798	77,545	37	285
C5	Special Purpose	5,079	32,414	281,016	1,504,457	23	11,771
EX	Exempt	13,637	701,558	19,386	877,942	2	1,383
OS		57	413	30	184	0	54
R1	Single Family	397,852	121,090	41,042,480	14,794,088	397,852	524,027
R2	Residential 2-4 Unit	10,859	2,325	1,341,998	437,922	30,969	18,266
R3	Multi Family	2,098	2,235	2,057,244	465,687	89,329	12,332
R4	Mobile Home	1,262	2,016	53,885	93,777	23,678	391
R5	Group Quarters	49	111	34,832	6,870	490	13
VA	Vacant	44,472	410,799	49,843	2,302,342	46	2,951

4.1.6 Business Establishment Data

Business establishment data for 1997 was obtained from the Department of Workforce Services, and included the name of the business, the address, the 4-digit SIC, and the number of jobs at the establishment in April of 1997. Considerable effort was expended by the staff of the AGRC and GOPB to improve the geocoding of these establishments for use in model development. Problems typical in employment data from state unemployment insurance records, or ES202 data, include the common assignment of all of the employment of a multi-establishment firm such as a grocery store chain, to its headquarter or accounting office location, and the under-representation of jobs in the government, education, and self-employed sectors. The resulting total jobs by sector are shown below.

Table 4.4: Employment by Sector in 1997

Sector	Name	Employment
1	Resource Extraction	7,317
2	Construction	50,359
3	Manufacturing	101,237
4	Transport, Communications and Utilities	38,662
5	Trucking and Warehousing, Wholesale Trade	58,529
6	General Retail	62,157
7	Restaurants and Food Stores	73,688
8	Auto Sales and Services	27,377
9	Finance	27,683
10	Insurance and Real Estate	21,746
11	Business and Professional Services	89,866
12	Health Services	58,708
13	General Services	63,215
14	Government and Education	121,975

Chapter 5

Model Specification and Estimation

This section provides the results of statistical estimation of each of the core models in the Wasatch Front application, using the database described in the preceding section. Model estimation was performed on each equation in the core model components in UrbanSim. A set of tools have been created to generate estimation files that include all the relevant variables, formatted for use in statistical packages with capacity for multinomial logit model estimation, such as Limdep or SAS. The estimation reported here was done using Limdep.

Due to recent changes in the regional travel model, the project team decided to re-estimate all of the models to ensure that the parameters in the models in UrbanSim that are sensitive to accessibility would be consistent with the logsum measures from the new travel model. A script to automate the estimation, given a specification for each model that has previously been tested, was used to re-estimate the models in a single overnight run. Some minor changes were needed to account for a small number of equations that no longer converged.

5.1 Household Location Choice

In this model we predict the probability that a household will choose a housing unit at a location defined by a grid cell of 150 by 150 meters. We assume that if multiple housing units occupy a grid cell, they are identical. The form of the model is specified as multinomial logit. This represents a highly disaggregate choice model, with over 500,000 housing units in the inventory. We include in the choice set the chosen location, given from the assignment of the household survey to a grid cell as shown in Figure 4, and randomly sample 9 non-chosen alternatives from the remaining inventory to set up the model estimation. Since the number of alternative choices is equivalent to the number of available housing units, the size of the choice set is too large to estimate the model using the full universe of alternatives, so we use random sampling of alternatives from the universe of available (vacant) housing units to estimate the model, a procedure that has been shown to produce consistent estimates of model parameters.

The data used in this analysis draw principally from a household travel survey conducted in the region in 1997. Approximately 4,000 households were surveyed throughout the region. The data from the travel survey were supplemented with housing and spatial context variables by geographically assigning the survey coordinates to a grid cell, and associating the housing and spatial characteristics of the grid cell, and regional access variables that are associated with the traffic analysis zone in which the household is located.

The variables used in the model are drawn from the literature in urban economics, urban geography, and urban sociology. An initial feature of the model specification is the incorporation of the classical urban economic trade-off between transportation and land cost. This has been generalized to account not only for travel time to the classical monocentric center, the CBD, but also to more generalized access to employment opportunities and to shopping. These accessibilities to work and shopping are measured by weighting the opportunities at each destination zone with a composite utility of travel across all modes to the destination based on the logsum from the mode choice travel model.

The specific variables used in the Wasatch Front model were revised based on initial testing of the integrated model, which indicated that the model needed to be more sensitive to budget constraints and to the interaction between the characteristics of the locating household and the socioeconomic composition of the neighborhood under consideration.

- Log of the quantity (household income minus one tenth of the gridcell's average price per residential unit) if positive, otherwise this is set to Log of .0000001 to indicate a budget constraint.
- Interaction between income and log of improvement value per residential unit. This is intended as a proxy for the interaction between household income and housing quality.
- Household income interacted with percent of the gridcell that is residential land. This measures the degree to which taste for homogeneous residential land use is correlated with income.
- Log of the distance to nearest highway, measuring disutility of more remote locations.
- Log of accessibility to employment in the cell's TAZ, given that it is a zero-vehicle household. Access to jobs for zero-car households is weighted by the composite utility of travel by transit and non-motorized modes.
- Log of accessibility to employment in the cell's TAZ, given that it is a one-vehicle household. Access to jobs for one-car households is weighted by the composite utility of travel in the one-car mode choice model stratum.
- Log of accessibility to employment in the cell's TAZ, given that it is a two-vehicle household. Access to jobs for one-car households is weighted by the composite utility of travel in the two-plus-car mode choice model stratum.
- Log of the quantity household income times accessibility to employment for one-car households. This variable proxies for the correlation of income with accessibility. It allows for measuring a declining marginal utility of accessibility for wealthier households, compared to other locational attributes.
- Log of the number of residential units in the grid cell. This is a simple and direct measure of housing density at each location.
- Log of quantity of retail within walking distance. This variable serves as a proxy for mixed-use locations in which some shopping can be done without the need for auto travel.
- Percent of households within walking distance that are designated as high-income, given that the decision-making household is high-income. This is an interaction of high income locating households with the degree of concentration of high income households in the neighborhood under consideration.

- Percent of households within walking distance that are designated as low-income, given that the decision-making household is low-income. This is an interaction of low income locating households with the degree of concentration of low income households in the neighborhood under consideration.
- Percent of development type group residential within walking distance. This measures a taste for residential character shared by all households.
- Number of residential units in the cell, given that the decision-making household has children. This measures the interaction between density and households with children, given that families with children may prefer lower density locations.
- Indicator for a young head of household in a high density residential cell. This interaction term tests for the degree to which households with a young head may prefer higher density locations, *ceteris paribus*.

The specification of the household location choice model includes variables representing the interaction of household characteristics and the characteristics of residential locations. Descriptive names for variables are included in the presentation of the results below. Note that the choice of residential location is at the level of a grid cell of 150 meters.

These results capture the effect of housing costs, interacted with income, showing that households prefer less expensive alternatives that are comparable in quality, consistent with economically rational behavior. Higher income households show also a taste for quality, as measured by the interaction of income and improvement value (building value) per housing unit. Households with higher income also show a taste for areas with more residential character, as measured by the percentage of the land within walking distance that is in residential use. We also find self-segregating tendencies in these results, with high income households positively attracted to locations in which there are high percentages of higher income households within the neighborhood, and low income households also showing positive correlation with the percentage poor households in the neighborhood. The latter effect may be due more to constraint than preference.

Housing density is generally a negative influence on location preferences, as reflected in the coefficient on the number of housing units in a cell, but the effect is actually positive for younger households. There is a stronger than average aversion to density for households with children.

Distance from highways proved to be a significantly negative influence on location probabilities, on average. Accessibility to employment for zero-car households, which would be heavily weighted by transit accessibility, was a quite positive effect. For one and two-plus car households, the employment access effect diminished in magnitude and statistical significance. Localized access to retail employment in the neighborhood was a significantly positive influence on average location preferences.

5.2 Employment Location Choice

Theoretical models of employment location date at least to the seminal work of von Thnen (von Thnen, 1826), which described a negatively sloped agricultural land rent gradient in which land prices fall with distance from a central market to offset transportation costs to the market. This early work on bid-rent later stimulated the development of the monocentric model of urban structure (Alonso, 1964; Mills, 1967; Muth, 1969). Early applications of spatial theory of urban firm location can be traced to Christaller's work on central place theory and the hierarchy of cities (Christaller, 1933), and that of Losch, who derived an idealized hexagonal representation of market areas based on spatial competition between firms (Losch, 1944). While these early contributions provided conceptual foundations for understanding the competitive bidding for sites with higher accessibility, which produces declining land rent gradients from high access locations, and the spatial separation of firms competing for market share, the framework would be insufficient to explain the rise of central business districts in the 19th century, and the rapid rise of secondary suburban centers in the latter third of the 20th century.

A third major theoretical contribution is the concept of agglomeration economies, which help to explain the existence of employment clusters on the basis of externalities associated with spatial proximity. These agglomeration economies have been described as arising from information spillovers, local non-traded inputs, and a local skilled labor pool (Marshall, 1920). An important theoretical problem in urban economic models is that neo-classical economic assumptions include constant returns to scale, but the essence of agglomeration economies is the idea of increasing returns to scale for firms that cluster with other firms in their own or related industrial sectors (Krugman, 1991). There are offsetting forces that neutralize the agglomeration advantages of clustering as centers become large, producing opportunities for the creation and growth of suburban centers. Other relevant work on employment location has focused on transportation costs (Chinitz, 1960), the influence of amenities and governmental services and taxes (Bartik, 1991; Waddell and Shukla, 1993).

The model developed in this application draws on these antecedents, bringing together the concepts of bid-rent theory, agglomeration economies, and the effects of transportation and local government policy in a discrete choice model.

Estimation results for the employment location choice logit models for all industry sectors in the Greater Wasatch Front region are presented in Tables D.2 through D.8. Since the coefficients are based on random sampling of alternatives, there are no alternative-specific constants, and no base alternative. The coefficients are therefore interpretable in terms of the direction of the influence of a variable on the utility and the probability of a location choice. In addition, coefficients can be compared across industry sectors, since the same specification is used for all sectors, with the exception of insignificant variables, which were restricted to zero.

Interpreting the coefficients is complex, however, due to the interaction between correlated variables. This is particularly true of the access to population and access to employment variables, and the travel time to the CBD and to the regional airport, since these are fairly close to each other within the broader region. Nevertheless, including these correlated variables improved the goodness of fit of the model.

Beginning with site characteristics, the total commercial square footage within a cell measured a local density effect, with all sectors showing a negative and significant effect, and the strongest aversion being shown by the resource extraction and auto sales and service sectors, while the lowest aversion was shown by manufacturing; transportation, communications and public utilities; finance; and government and education. Housing units within a cell indicate the affinity for sites that include residential uses. Construction showed the only positive effect among the sectors identified as basic; with Transport, Communications, and Utilities, along with Trucking, showing significant negative results; and retail and service sectors 7-13 all had positive and significant coefficients. Total value in the cell refers to the combination of all land value and building (improvement) value in the cell, and is not normalized per square foot of land or building. Most sectors had a positive coefficient on this, with the highest magnitudes for the service sectors 9-13. The development type of the cell was included in the models as a set of binary indicator variables representing mixed use, low-density commercial, mid-density commercial, high-density commercial, industrial, or governmental types. The base of comparison for these are cells of principally residential type, and these variables must be interpreted holding constant the other variables in the model. No clear interpretation of patterns in these development type variables is apparent, though they were generally significant.

Neighborhood characteristics include the housing density within 600 meters, the average land value per acre in the area, and the quality of housing within the area as measured by improvement value per unit. The sectors showing positive coefficients on neighborhood housing density were all the retail and service sectors, in addition to construction, with the highest effects for retail sectors and health services. Higher quality of housing in the neighborhood had positive effects on location probabilities for most sectors, with the exceptions of general retail, finance and health services. Higher land values in the neighborhood reduced the probability of location for almost all sectors, with only insurance and real estate actually showing a positive effect, indicating the relative propensity of this sector to bid successfully for the most prized locations.

Accessibility characteristics include regional multi-modal accessibility of population and employment, as well as travel times to the CBD and airport. The accessibility to population and employment were generally significant and with offsetting signs, with variation across sectors in terms of the relative weights of these two effects. The sectors attracted to sites with relatively high access to population as compared to employment are construction and insurance and real estate. Sectors showing aversion of sites with relatively high accessibility to population as compared to employment are manufacturing; transportation, communications and public utilities; and auto sales and service. Sectors attracted to sites with relatively high access to employment relative to population are trucking, warehousing and wholesale trade; and general retail. Sectors showing aversion to sites with relatively high employment access relative to population are resource extraction, health services and government and education. Travel time to the CBD, controlling for access to the airport and all the preceding accessibility effects, was positive for most sectors, but remained negative for health services, general services, and government and education. By contrast, travel time to the airport, a few miles to the west of the Salt Lake City CBD, was negative for most basic and retail sectors, and positive only for service sectors 11-14.

The agglomeration effects were measured by estimating the effect on location probabilities of the number of jobs in each sector that are within 600 meters, representing a degree of spatial clustering that facilitates face-to-face interaction and walk access within employment centers. Some general patterns are apparent from the summary of these industry interactions, shown in Table 4. All the agglomeration effects for the same industry were positive (indicated by the plus-sign on the diagonal in Table 4), showing a positive externality for clustering of employment within the same industry. Since this is a job-based location choice model specification, and not a firm-based model, this outcome may indicate more about average establishment size than about clustering of different establishments of the same industry. The patterns of agglomeration across industry sectors show complex positive and negative geographic associations between industry sectors. For example, general retail shows a positive effect on location probability in locations with more employment in the immediate vicinity in the construction; transportation, communications and utilities; restaurants and food stores; and general services. Location probability of jobs in the finance sector is positively influenced by agglomerations of insurance and real estate and general services. These results are derived from empirical estimation of the affinities for spatial proximity between jobs in each sector, rather than imposed on the data using an input-output matrix, as is done in spatial input-output models such as MEPLAN or TRANUS (de la Barra, 1989).

5.3 Land Price

The theoretical foundations of the land price model and the real estate development model draw heavily on Random Utility Maximization (RUM) models pioneered by McFadden, on bid-rent theory of land markets, and on hedonic price theory. Our approach in modeling real estate prices assumes that individual consumers and suppliers are too small in scale to manipulate prices directly, making them exogenous to these individual actors. Whereas this assumption could be argued in the event of oligopolistic behavior by large-scale developers or large corporations seeking sites, it is a relatively weak assumption to impose and avoids complications arising from modeling prices as endogenous to the interaction between consumers and sellers, such as having to simulate search and auction processes, imperfect information, and oligopolistic market behavior. A second assumption is that the advantages of location, such as neighborhood amenities and accessibility, are capitalized into land values. This assumption follows from a wide consensus of theoretical and empirical work in urban economics that has consistently found that in competitive land markets, the quasi-unique characteristic of land (they aren't producing any more of it, every location is unique, and housing or commercial buildings are tied to their location) implies that consumers bid for location based on their willingness to pay for locational attributes, and the highest bidder wins the use of the site and sets the market price for it.

Rosen developed the approach of hedonic price analysis, which attempts to disentangle the implicit prices for the components of the bundle of services provided by housing (the same theory applies to nonresidential space). By regressing the sale price of housing on characteristics of the housing structure and location, we obtain estimates of the implicit prices of individual characteristics-holding other characteristics constant-despite us observing only the single price of the bundle for any individual property. These implicit prices do not, strictly speaking, represent either demand functions (willingness to pay) or supply functions (reservation prices), but rather, the composite of all of the willingness to pay and reservation price functions of all consumers and sellers in the market. Given our assumption that prices are exogenous to individual consumers or sellers, this provides a reasonable way to estimate the land price function within a given market.

Following DiPasquale and Wheaton, we interpret market prices of land within a metropolitan market as consisting of two parts. The first component is a mean price level, which fluctuates around long-term trends that are driven by short-term imbalances between supply and demand of real estate, by interest rates and other development costs, and in the longer-term by overall expansion and contraction of the metropolitan economy, population, and changes in income. The second component is the relative price of land across sites within the metropolitan market. These relative prices are based on relative advantage and abundance of sites with characteristics that are valued or avoided by consumers. As these underlying characteristics and the resulting relative advantage change, so to do relative prices, as these advantages are capitalized into land values. This paper focuses principally on the characteristics influencing relative prices, since these will have the greatest influence on intra-metropolitan variation in real estate development and consumer location choices.

The land value for each cell, taken as the aggregation of the land value of the parcel fragments that lie within the cell, and originating from the tax assessor's estimates of the land value of each parcel, is used as the basis for the dependent variable of the land price model. The independent variables used as predictors-essentially the same as for the real estate development model-are the characteristics of the cell, its surrounding environment, and its accessibility. A semi-log specification is used, with the log of land price as the dependent variable, as is common in hedonic price studies since it generally provides a more robust specification.

The model is a linear multiple-regression of the log of land prices for each cell on an array of housing structural, neighborhood, and accessibility characteristics. The full set of grid cells in the study area is used in model estimation, using base year (1997) characteristics and values. As such, this is a cross-sectional estimation of the market hedonic price function, rather than an estimation of a dynamic price function. Dynamics are introduced through the process of annual changes in the characteristics of grid cells due to simulated results from the real estate development, residential location and employment location models, and the external transportation model system, all of which combine to change the characteristics of grid cells on an annual basis. Each year, after all other model components have executed, the land price model simulates end-of-year prices of land, based on the updated cell characteristics. These become the land prices that influence location choice and developer behavior in the subsequent year. The estimated model is shown in Table D.9. The model had an Adjusted R^2 of .7.

5.4 Real Estate Development

Specification

Real estate development is a collection of choices made by individual developers on individual sites, about whether, when, and how to develop or redevelop those sites. We assume their behavior is motivated by profit (they attempt to maximize their profits), within constraints imposed by their resources, the physical environment, and by public land use regulations. The main influences on their choices will then be factors influencing prices of different types of real estate at different locations, the costs of producing those development projects, and the constraints relevant at those sites. There are two general approaches that developers consider in making development choices. The first is known as the use looking for a site, and corresponds to a specialized developer who has a specific project in mind, and attempts to find the most profitable site for the project. The second general approach is known as the site looking for a use, and corresponds more closely to the landowner's problem of sorting out which type of developer to sell the property to in order to generate the highest return. In the real world, both approaches occur. We have structured the current model as a discrete choice model from the perspective of the site looking for a use-the landowner's perspective. This approach lends itself to formulation as a standard multinomial logit model, where an individual landowner considers alternative uses, or developments, for a particular site.

The purpose of the real estate development model is to simulate discrete developer choices about whether to develop particular sites within a given year, what type of construction to undertake, and the quantity of construction. The construction of real estate can be either new development (sometimes referred to as Greenfield development) or the intensification or conversion of existing development (referred to as infill and redevelopment, respectively). The model takes a bottom-up view, i.e. from the vantage point of a developer or a land-owner at a single location (grid cell) making choices about whether to develop, and into what type of real estate. This bottom-up view is tempered by market information that reflects the state of the market as a whole, such as vacancy rates.

The model is designed in terms of discrete alternatives that represent development events, including the base case of no development on a particular site within a given year. In addition, there are development alternatives that represent transitions between the different development types defined in Table 3.1, including the alternative of increasing the density of the current cell without changing its development type (where this is feasible).

The probability of each alternative (the no development, the increasing density of current cell within its development type, and transitions to other development types) being chosen is calculated using a discrete choice model. We draw on discrete choice theory and random utility maximizing models, following the work of McFadden, to design a multinomial logit model. Similar approaches have been developed to model land cover change and land use change, although none of these models interact with disaggregate demand-side models of residential and employment location choice as is done in UrbanSim.

We estimate one choice model (i.e. one set of coefficients) for each development type, since the types are very different and the development alternatives open to each development type vary. To estimate the model coefficients we need data for cells experiencing no development and for cells development events of all types.

The estimation data are derived from the parcel and grid data for a base year of 1997. The year-built values of the existing development in the assessor's records are the foundations of the process. Year-built values are imputed for records for which they are missing by examining the surrounding cells of the same type and drawing from the distribution of observed values. Historical development 'events' are identified in the data for a user-specified period of time. Events, within this framework, are any changes in the real estate development within a cell that is identified by examining the year built values within the data.

The procedure is capable of identifying any new construction that has a year-built occurring within the specified time frame. However, the procedure does not identify events that involve the demolition of buildings at some time in the past, since normally there is no record of demolitions within the current assessor database. This procedure could be augmented with data derived from building demolition and permit records.

The result is a set of cells experiencing development events that represent all observed transitions between any pairs of development types, including increases in density that didn't result in a development type change, within each year of the specified historical time frame. The time slice for determining the existence of an event is annual, since this is the limit of the information on the vintage of real estate.

To form the estimation data we take all the development event cells, i.e. cells with a known development event and look up the values for a set of independent variables from the grid cell database. The independent variables in the real estate development model include characteristics of the grid cell (current development, land use plan, environmental constraints, policy constraints, land and improvement value), characteristics of the site location (proximity to highways, arterials, existing development, and recent development, neighborhood land use mix and property values, local accessibility measures), and regional accessibility (access to population and employment, travel time to central business district and airport). The local accessibility measures correspond to activities that can be reached by walking, over a distance of 600 meters (approximately 1/3 mile) and they are calculated using spatial queries on the network of grid cells.

We now need to take into account the much larger set of cells that didn't experience a development event. We take a random sample of these cells to generate a set of similar size as the development event set. This gives us a choice-based sample of cells. Choice-based sampling only biases the alternative-specific constants but other coefficients remain consistent. We adjust the alternative-specific constants after estimation to account for this bias.

Given this data, we estimate multinomial logit, discrete choice models for real estate development for each development type, with alternatives of no development, increasing density of cell without changing the development type, and observed transitions to other development types. The models are estimated using maximum likelihood, with separate estimation for cells of each development type, representing a total of 24 models. These estimation results are provided in Tables D.10 through D.30.

Application

UrbanSim simulates real estate development using the presented model on a yearly basis. Each year, the model iterates over all grid cells on which development is allowed and creates a list of possible development alternatives for each cell. Development constraints may reduce the number of alternatives from the estimation stage.

Constraints on development outcomes are included through a combination of user-specified spatial overlays and decision rules about specific types of development allowed in different situations. Each cell is assigned a series of overlays through spatial preprocessing using GIS overlay techniques. These overlays can be used to assign user-specified constraints on the type of development that is allowed to occur within each of these overlay designations. The constraints are indicated as allowed conversions between each land use plan designation and each development type. Currently, if users wish to examine the impact of these constraints, they would need to relax a particular constraint and compare the results to the results for more restrictive policy. For example, the plan designation of 'agricultural' may not allow conversion to any developed urban category under restrictive interpretation of the land use plan, or may allow conversion to rural density single-family residential under a less restrictive interpretation. The overlays used in the Greater Wasatch Front Region of Utah model application include the following features: a) water cover, b) flood plane, c) steep slope, d) open space, e) public space, f) roads, g) land use plan designation. Constraints are implemented by eliminating the constrained development alternatives from the choice set for any cell affected by the constraint. These constraints are therefore interpreted as binding constraints, and not subject to market pressure.

The estimated logit model is used to calculate the probabilities of each allowed alternative, i.e. the no development alternative, and one or more development alternatives. Development is then simulated using a Monte Carlo sampling process. Actual implementation of development takes place by using a development template, which gives the most likely characteristics of the resulting development project within the cell. The development template has defined probability distributions for development changes, including the number of housing units, square feet of commercial, industrial and government space, improvement value, and construction schedule. These development events are then added to the 'development event' queue in UrbanSim, to be built as scheduled.

Chapter 6

Model Validation

This chapter presents results of testing the integration of UrbanSim and the regional travel models using several different scenarios. While the models could be interfaced annually, to coincide with the annual steps in UrbanSim, the logistical difficulties presented by the development of annual networks and runnning the travel model every year would be excessive[1]. There is also not a compelling argument to require such frequent interactions, considering that the accessibilities in UrbanSim are updated annually to reflect changes in the spatial distribution of population and employment. The precipitating factors for scheduling travel model runs would seem to be of two types: 1) any significant change to transportation supply, such as new or modified facilities, level of transit service, or altered prices; or 2) cumulative congestion effects that occur due to growth and spatial distribution of jobs and population. In order to provide adequate feedback from congestion effects and to reflect major supply changes, UrbanSim and the travel models are interfaced periodically, with the intervals being no longer than 5 years. The specific interaction years are: 1997 (Base Year), 2000, 2003, 2008, 2012, 2016, 2020, 2025, and 2030.

The logistics of connecting UrbanSim and the regional travel model, which is implemented in TP+ (Citilabs), involved creating a series of scripts to automate the extraction of data from the UrbanSim output database, reformatting of these data to the form required for Trip Generation in TP+, execution of the travel model, extraction of logsums and travel times from the travel model and inserting them into the UrbanSim scenario database, and then running UrbanSim for the time interval until the next scheduled travel model run. This process was completely automated by a script that runs UrbanSim from the base year of 1997 to the end year of 2030, interfacing with the travel model for each of the 8 scheduled years listed above. The run time from start to finish for the combined model system for a single scenario using a standard desktop computer is under 48 hours.

One consideration to be kept in mind when reviewing these results is that the UrbanSim outputs include no adjustments or 'K-factors' as are generally used in other land use or travel models. They are the direct results of input assumptions, data, model specifications, and estimation. The previously adopted 2030 land use forecast against which the UrbanSim LRP scenario results are compared in this section, by contrast, have been substantially revised from the direct results of the current WFRC land use algorithms based on local knowledge and negotiation.

[1]Each run of the travel model requires 2 hours to complete on a standard desktop computer with a 2.6 Ghz CPU

6.1 Long Range Plan

The first integrated scenario combining UrbanSim and the regional travel model is based on the adopted Long Range Plan (LRP). Transportation improvements are phased in within the travel model run that immediately follows the actual year of opening of the facility. A map of the projects included in the Long Range Plan are shown in Figure 6.1.

6.1.1 Common Assumptions

In all the scenarios examined, there were several common assumptions. These include the total population and employment in the region in each year, the model coefficients, land use plan assumptions, and all other aspects of the input data except as noted in the description of each alternative below.

One of the common assumptions that bears noting is the treatment of anticipated development plans by Kennecott Copper, which owns approximately half of the remaining developable land in Salt Lake County, and has extensive and detailed plans for development of their properties over the next several decades. For the purpose at hand, that is, for evaluating the sensitivity of UrbanSim to various alternatives being considered, the decision was made not to impose the Kennecott plans as explicit development events that would impose a specified quantity of real estate development in locations and on time tables identified by the company. Rather, we have used their information to impose changes in land use plan designations that would *allow* development to occur in ways that are consistent with the revised land use plan designation for the specified locations. The timing of these changes coincides with the company's plans for development, but this approach means that the model must still simulate whether or not to predict development in these areas. This would appear to be a more useful evaluation of the model, and avoids the problem of confounding the introduction of user-specified development events with reactions by the model to transportation or land use policy changes.

The locations of the Kennecott plans are shown as an overview in Figure 6.2, and by year in Figure 6.3.

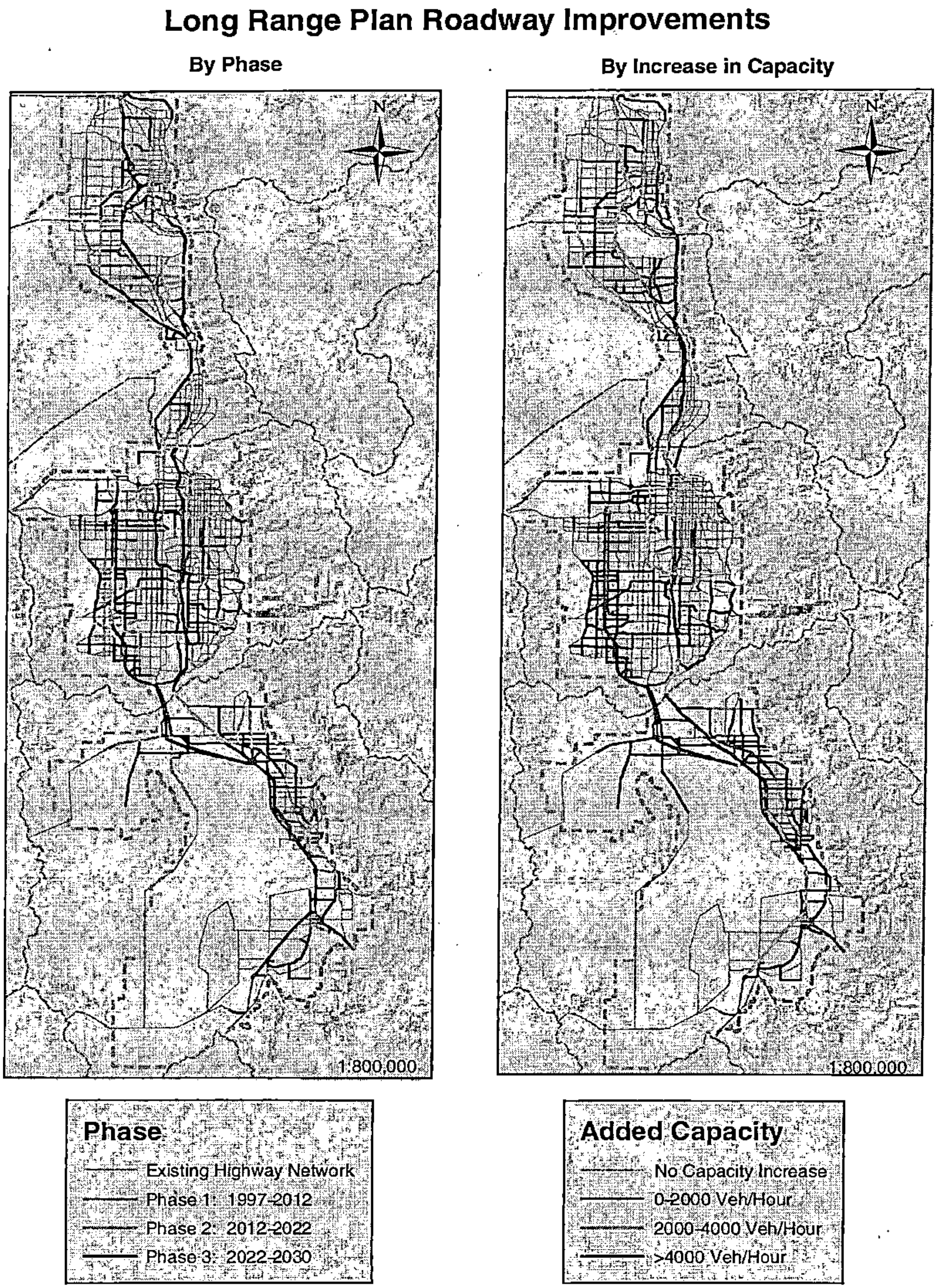

Figure 6.1: Phasing of the Long Range Plan

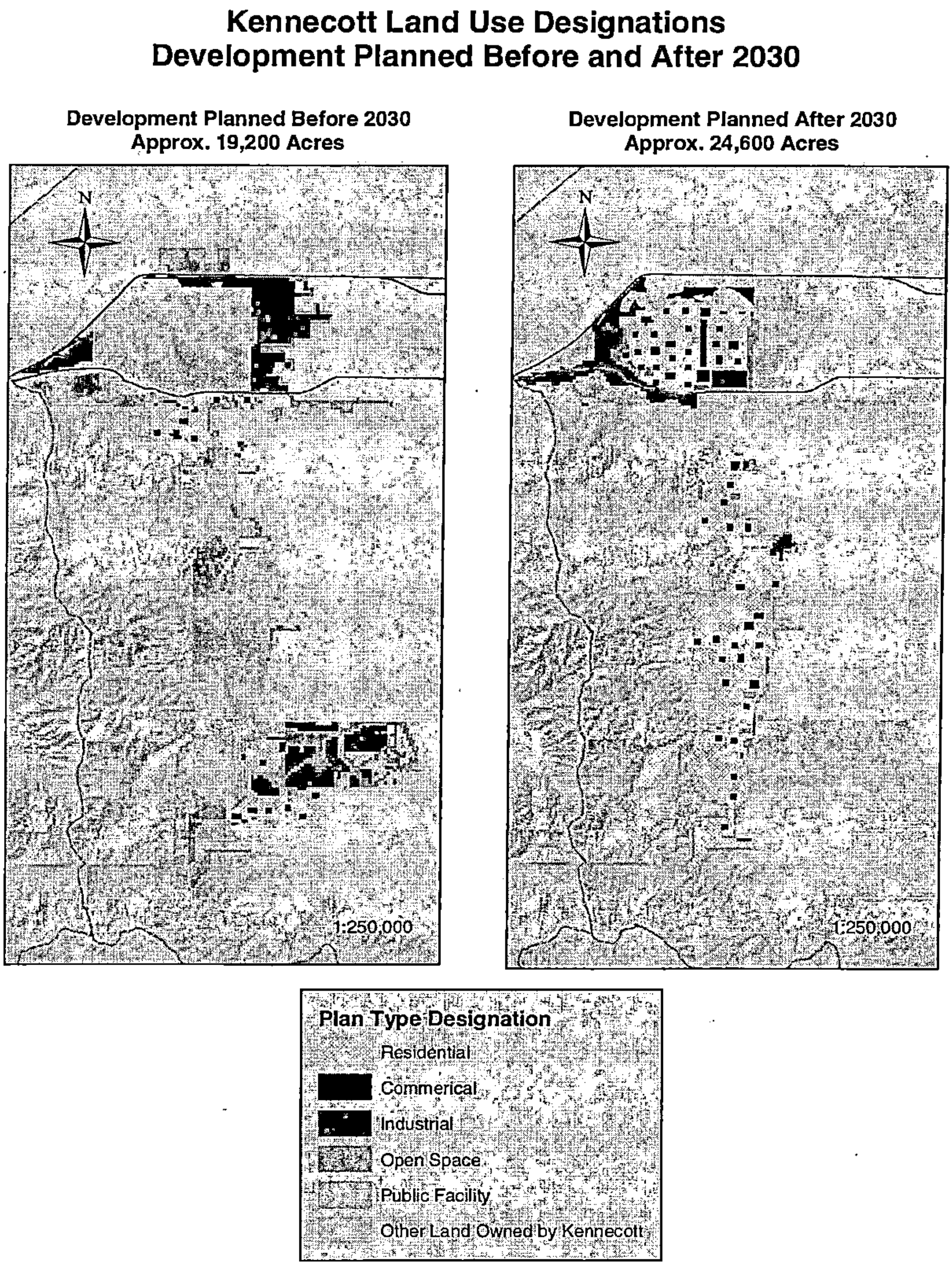

Figure 6.2: Kennecott Development Plans: Overview

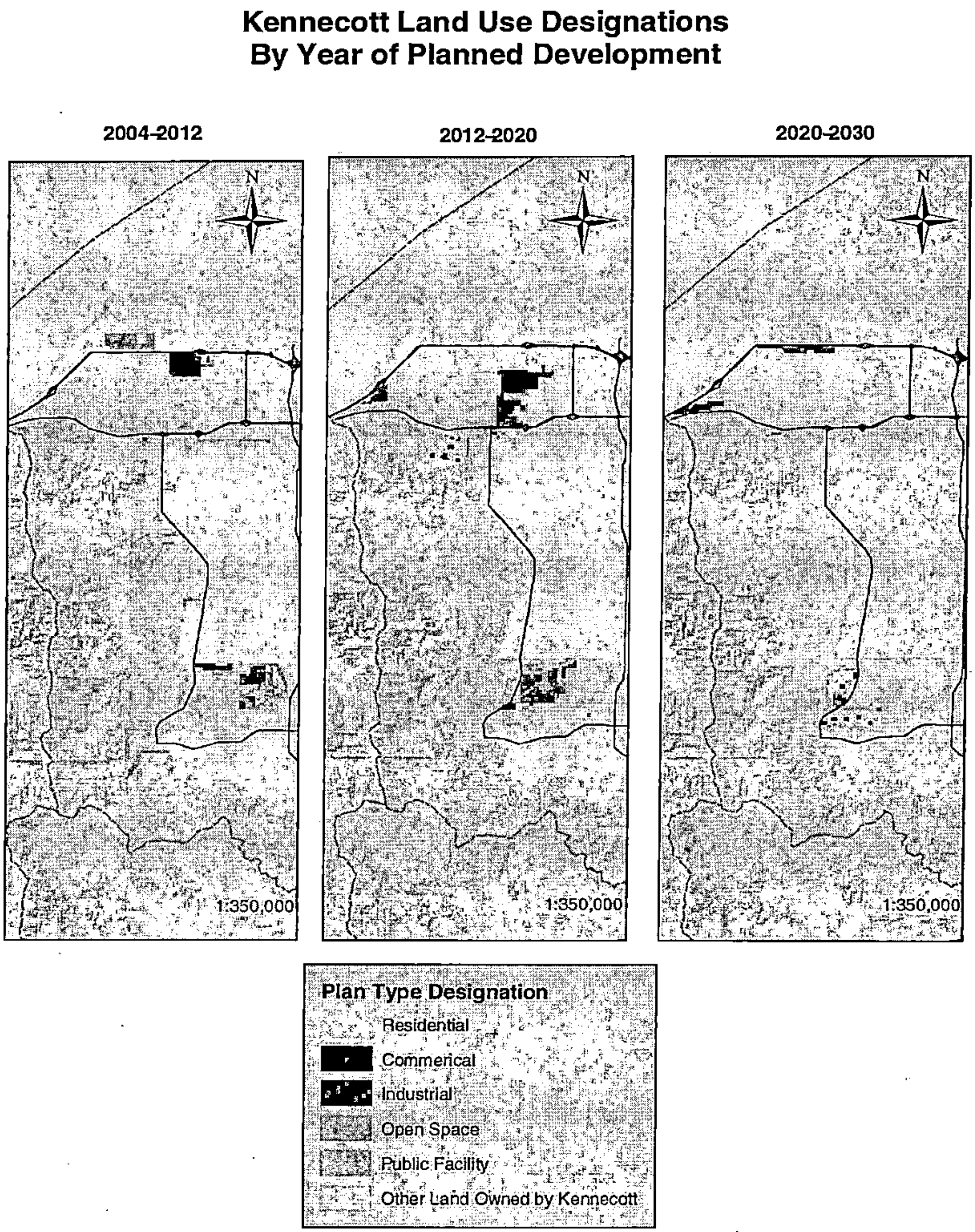

Figure 6.3: Kennecott Development Plans: by Year

In developing the input assumptions for the model, a set of development constraints are coded to reflect the interpretation of the Land Use Plan designations applied to each location. These represent the user's view of what kinds of development would be consistent with the Land Use Plan, and these constraints play a significant role in constraining the behavior in the real estate development model, essentially ruling out any development outcomes that would be inconsistent with these constraints. It can be difficult to summarize the impact of these constraints, since more than one constraint may apply to a specific location. In figure 6.4, the capacity of each grid cell for further housing and nonresidential square footage is depicted, based on the application of the development constraints to determine the maximum allowable development, less the existing development in the cell. Again, these constraints apply to each of the scenarios, except as noted. Specifically, only the Urban Growth Boundary scenario alters these constraints, by reducing development capacity outside the boundary.

In reviewing the results of the alternative scenarios, the impact of these development constraints is clear, and warrant further review and refinement for production use of the model. The residential development constraints need some refinement to better match master plans, and non-residential intensification in the existing built-up areas appears overly constrained. These are input assumptions that are relatively easy to revise.

Results of the Long Range Plan baseline scenario are shown in a series of maps below. The PM Peak Volume to Capacity Ratio, focused in Salt Lake County, is shown in Figure 6.5. Accessibility to Employment is shown in Figure 6.6, land prices in Figure 6.7, population in Figure 6.8, housing units in Figure 6.9, employment in Figure 6.10, and non-residential floorspace in Figure 6.11. The predicted changes in the spatial distribution of housing, households, population, non-residential floorspace, and jobs from 1997 to 2030 in the LRP scenario show a focus of growth in housing, households and population in southwest Salt Lake County, where Kennecott Development owns a substantial amount of vacant land within Salt lake County.

Scenario A: Long Range Plan
Remaining Capacity in 1997 Under Development Constraints

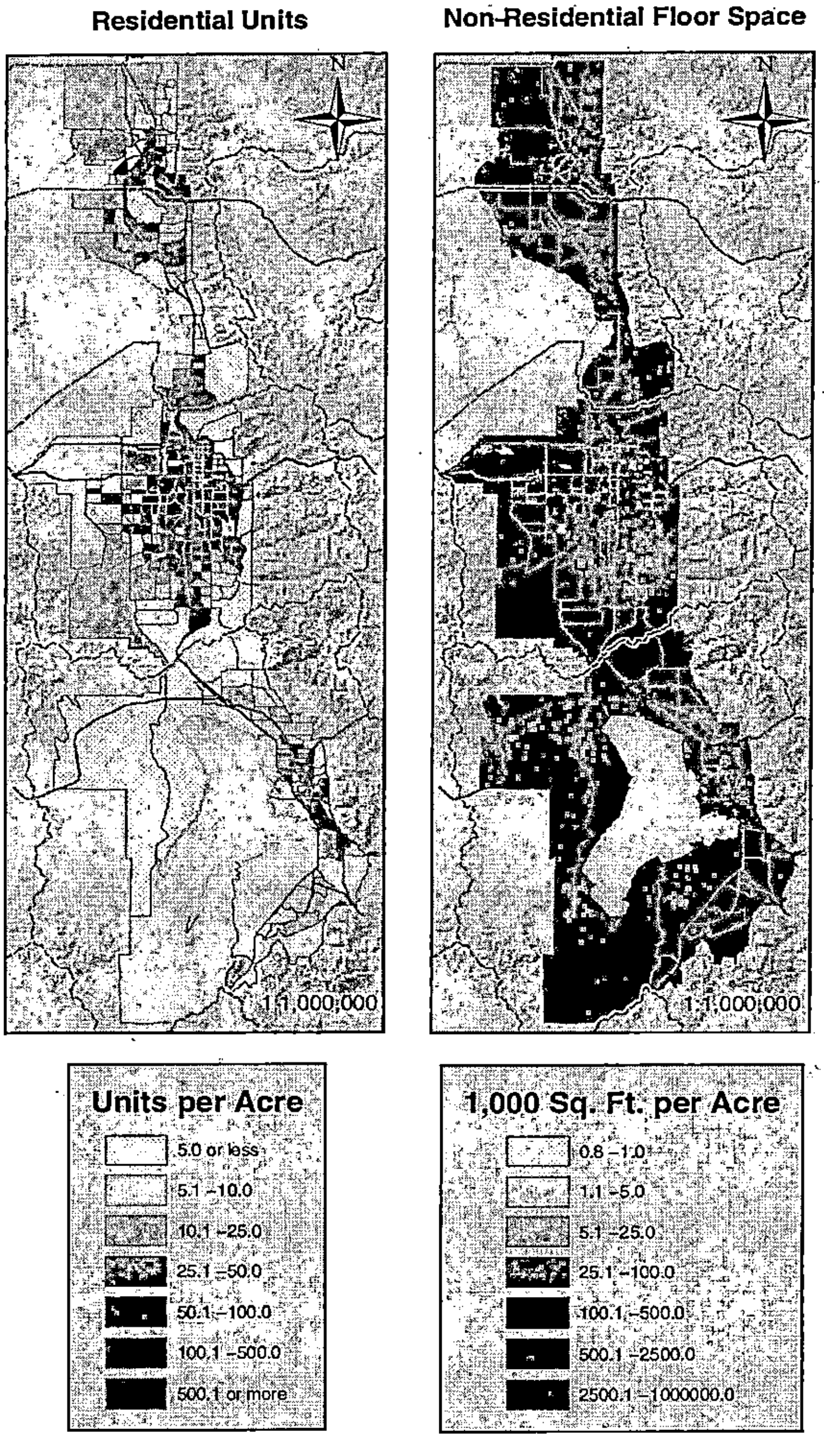

Figure 6.4: Remaining Development Capacity by Grid Cell

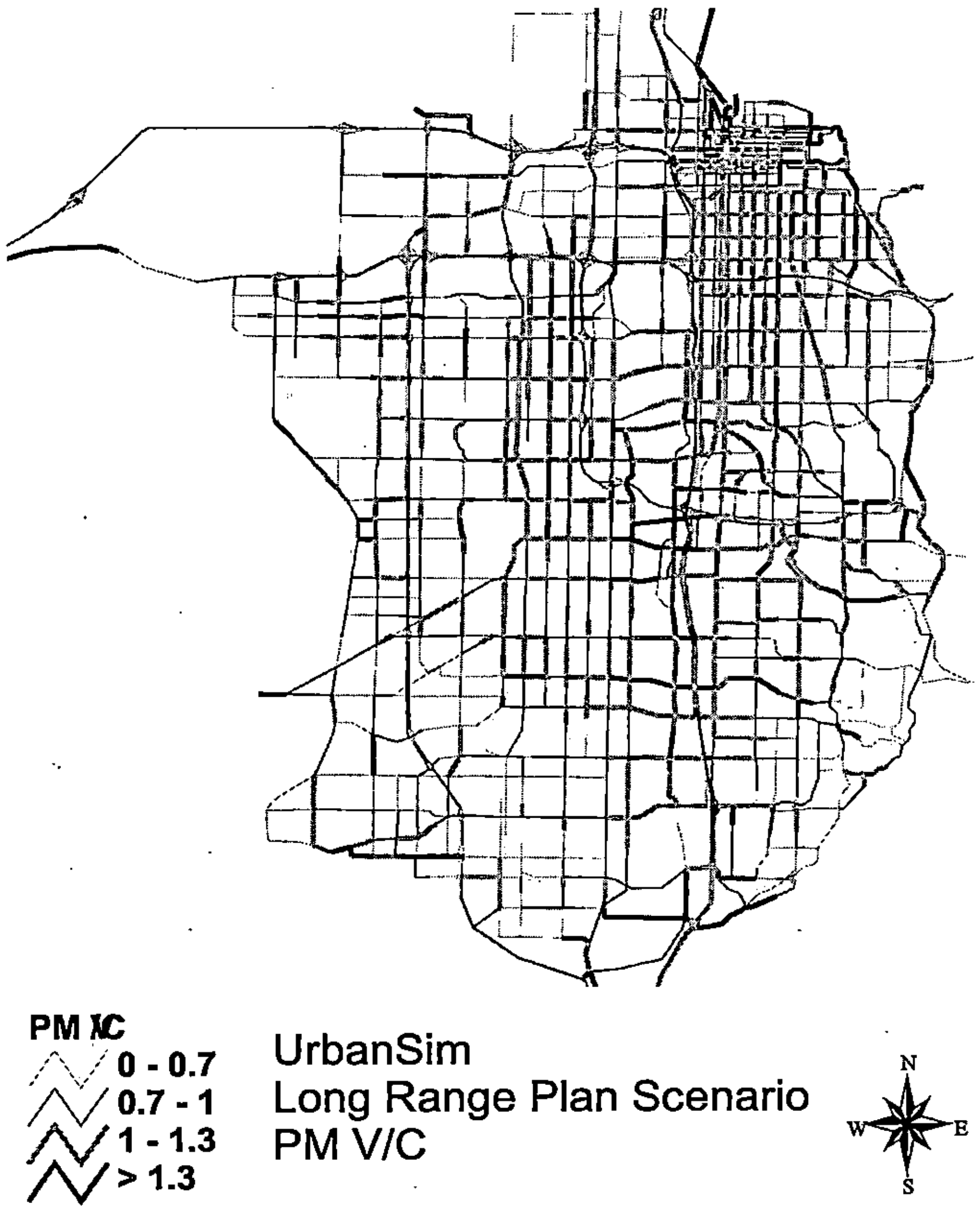

Figure 6.5: LRP PM Peak Volume to Capacity Ratio

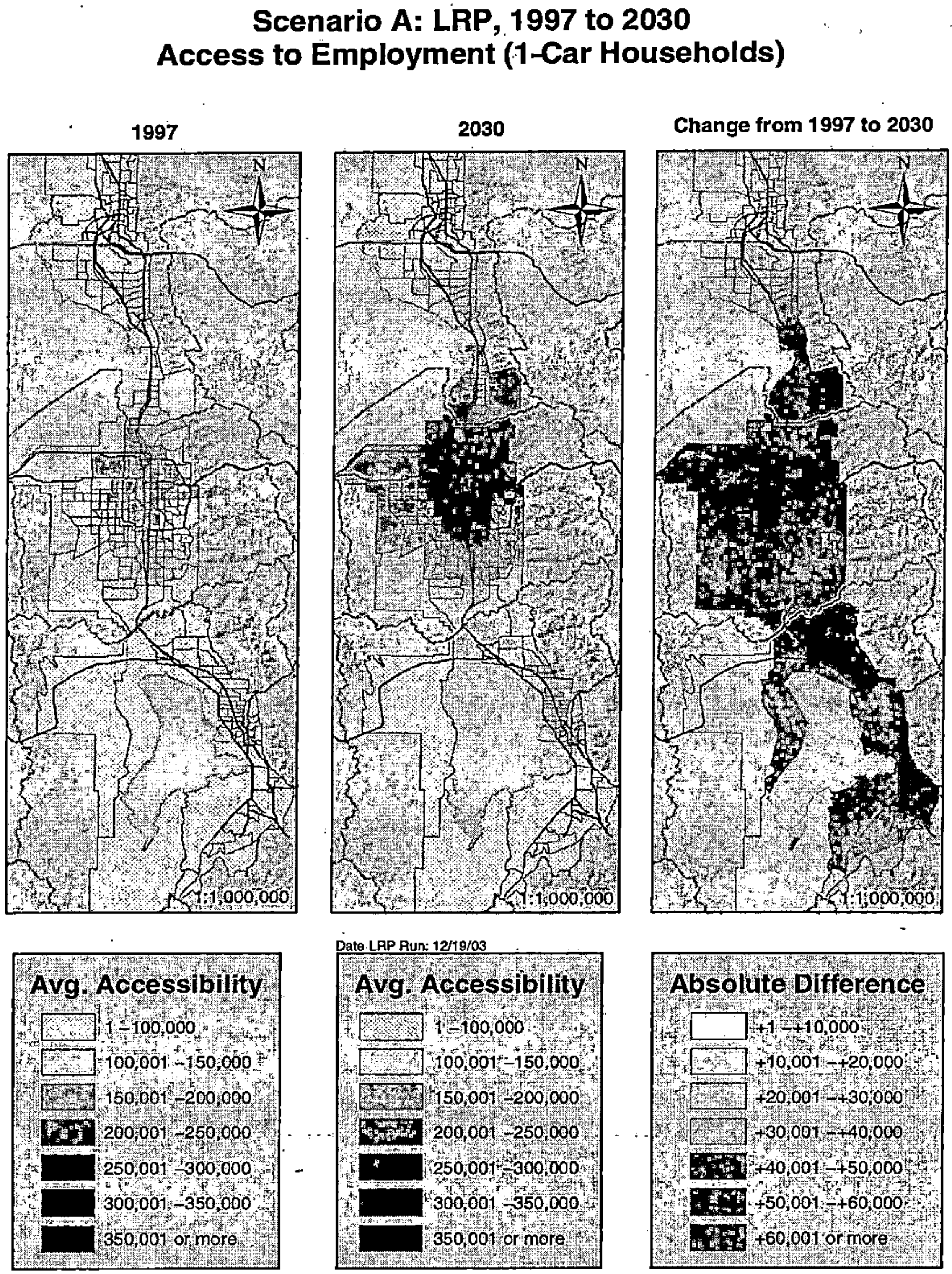

Figure 6.6: LRP Change in Accessibility to Employment from 1997 to 2030

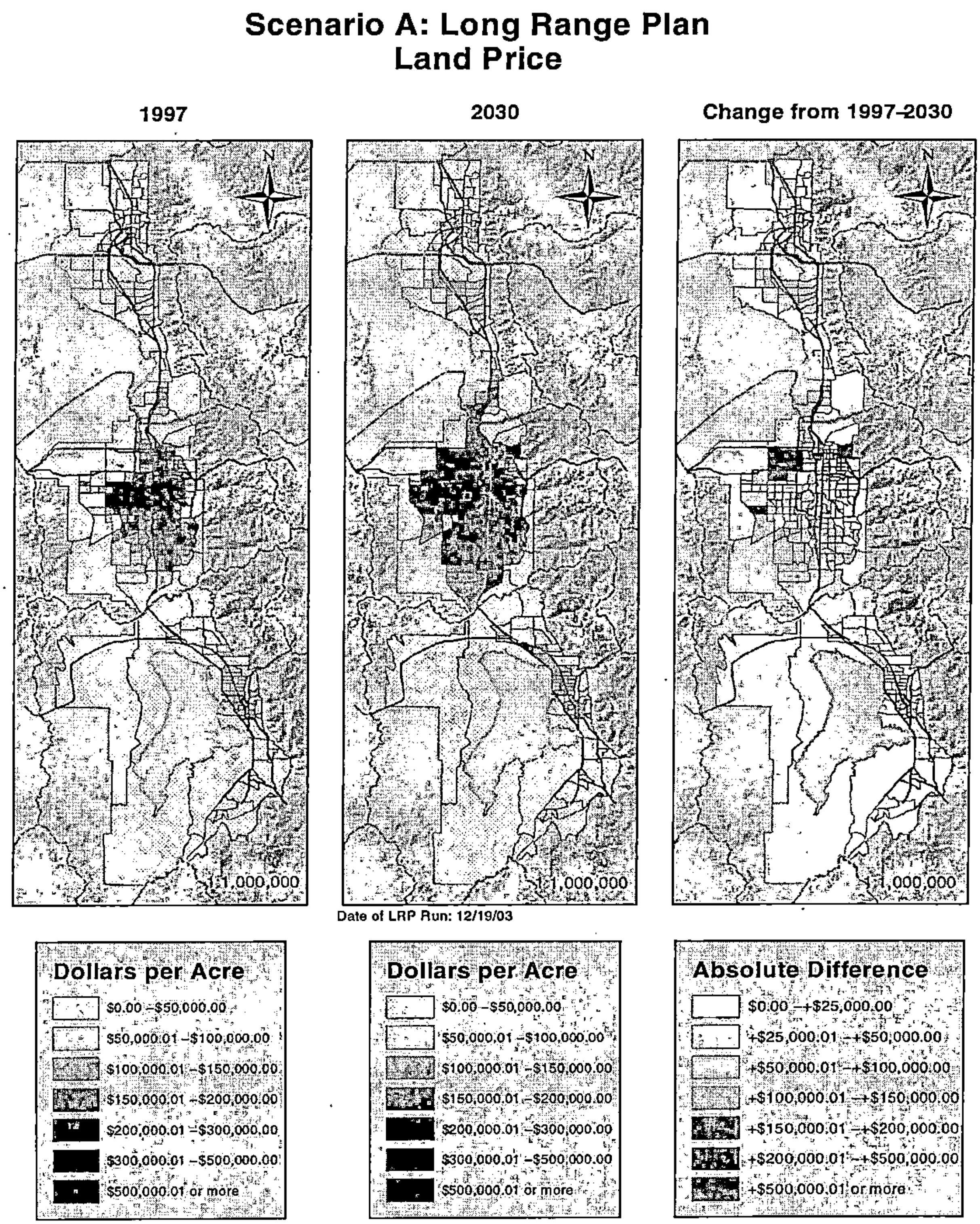

Figure 6.7: LRP Change in Land Price from 1997 to 2030

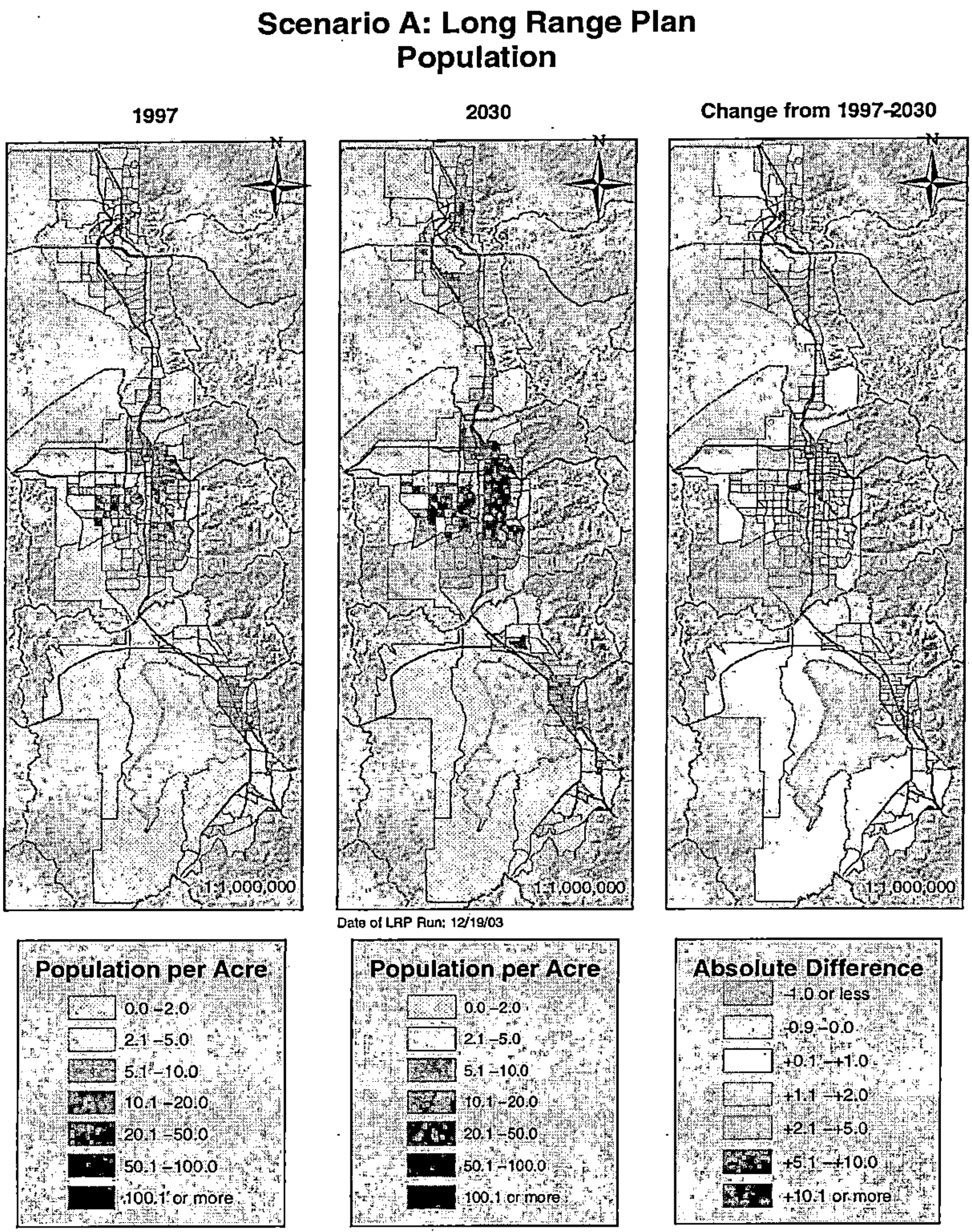

Figure 6.8: LRP Change in Population from 1997 to 2030

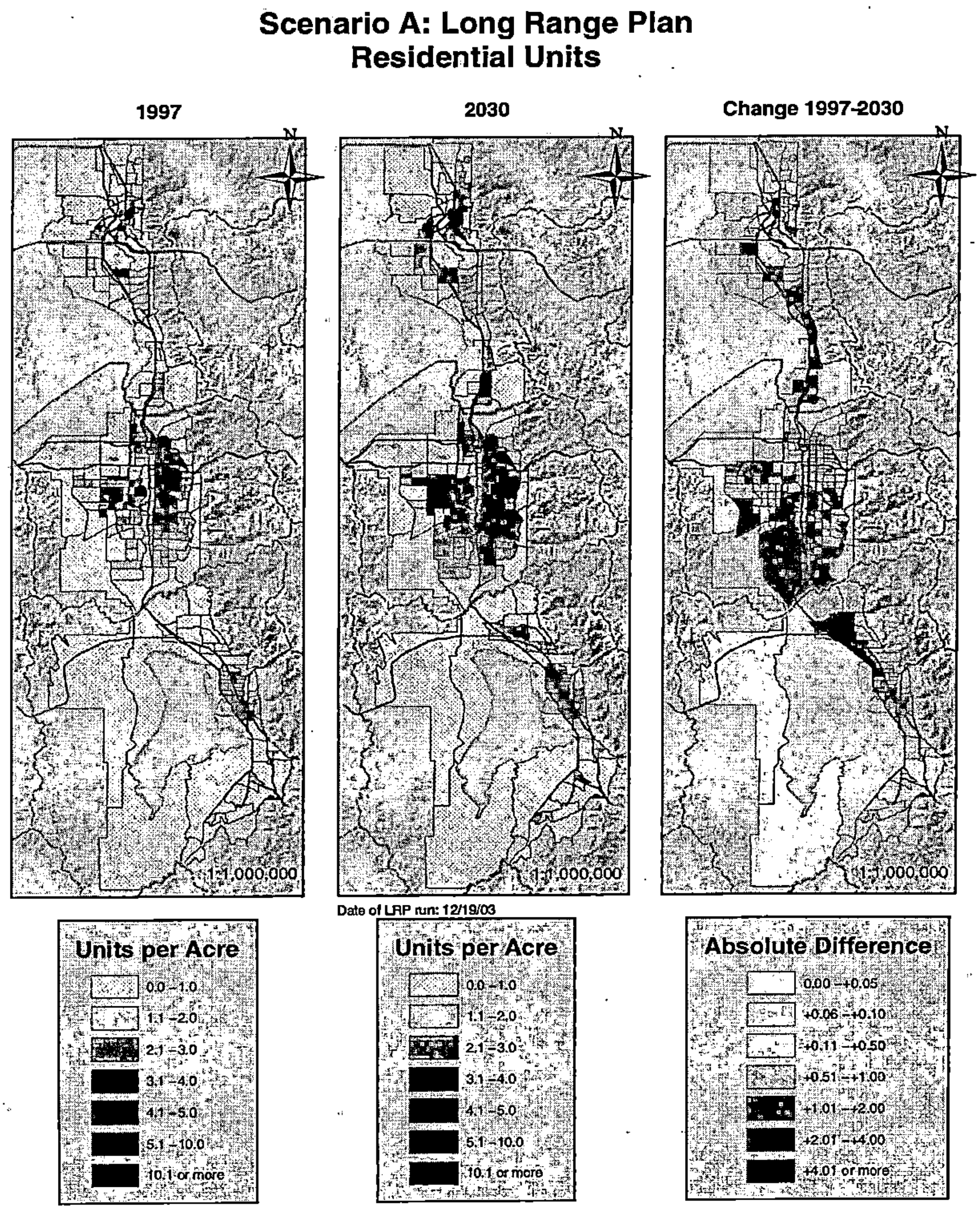

Figure 6.9: LRP Change in Housing Units from 1997 to 2030

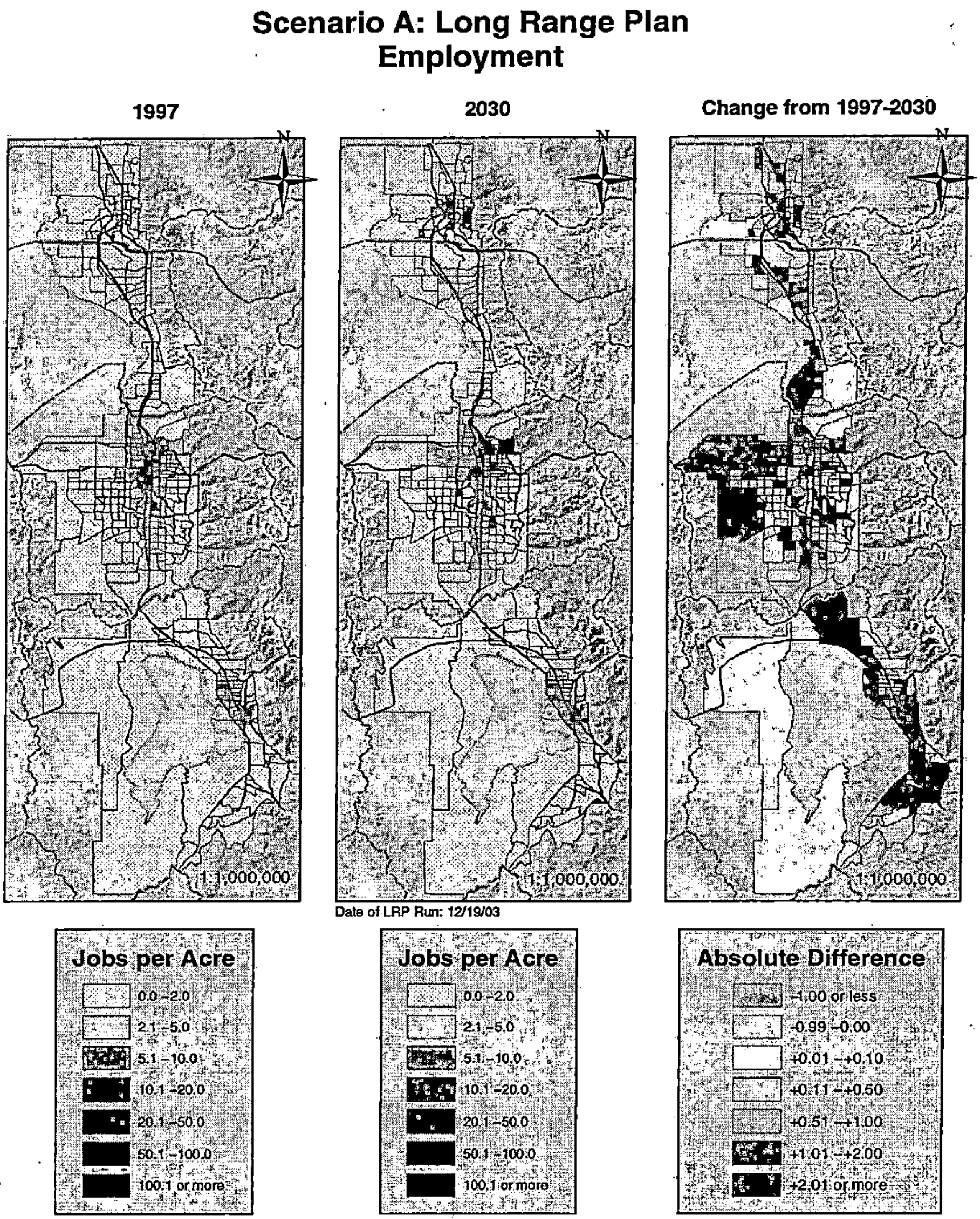

Figure 6.10: LRP Change in Employment from 1997 to 2030

Scenario A: Long Range Plan
Non-Residential Floor Space

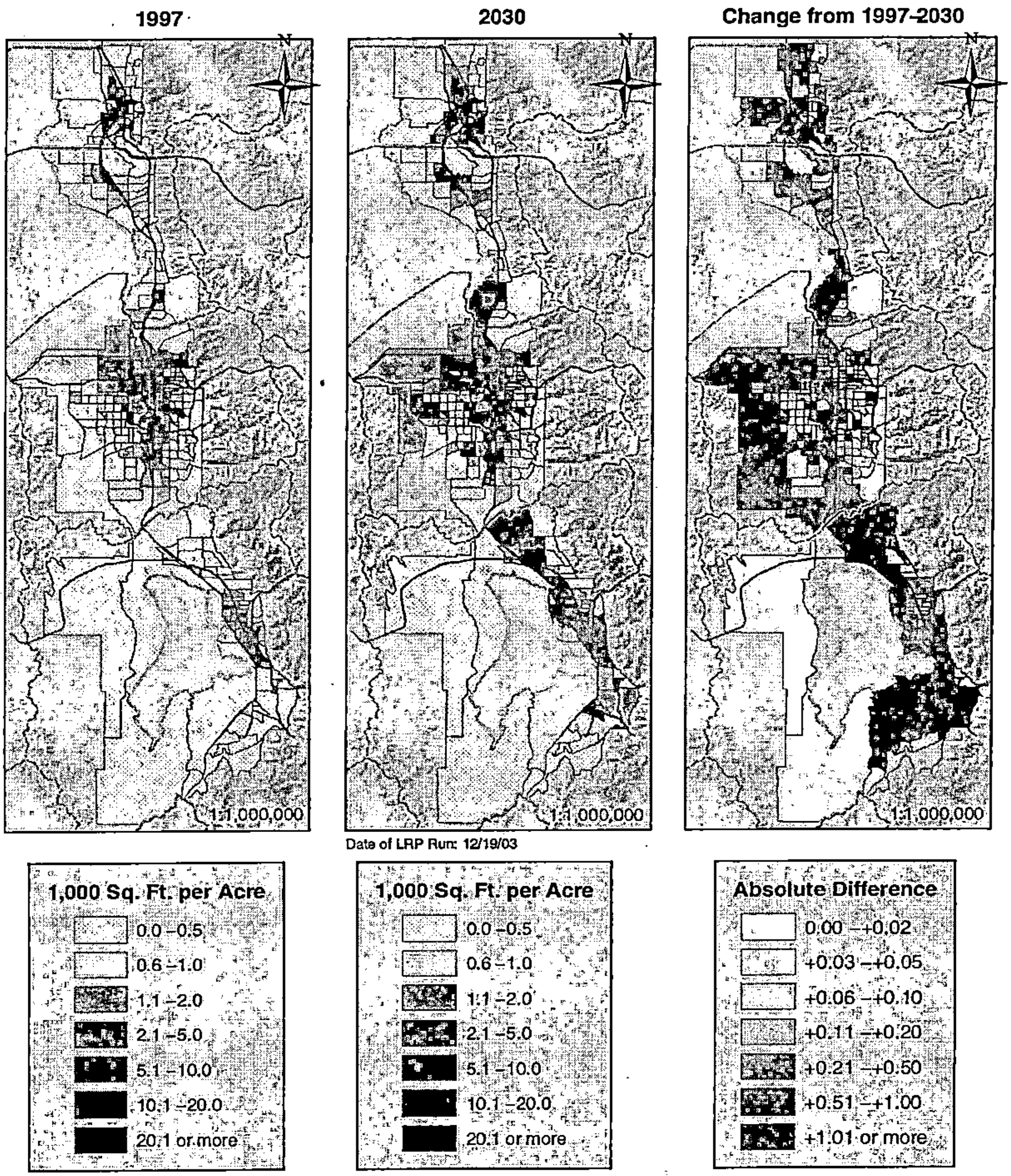

Figure 6.11: LRP Change in Non-residential Square Feet from 1997 to 2030

6.1.2 Comparison to Historical Trends

The aggregate totals for population and employment by sector specified in the control totals as inputs to UrbanSim are compared to historical data from the census for 1980, 1990, and 2000 in Figures 6.12 and 6.13 below. Also shown on these figures are the housing stock and non-residential floorspace, which is predicted by UrbanSim, and is not an input constraint. These two figures show that the trends predicted by control totals and simulated real estate development are consistent with historical trends from 1980 through 2000. Note that the employment growth accelerated from 1990 to 2000, compared to 1980 to 1990, and that the control totals show this rate decelerating slightly from approximately 2015 through 2030.

In addition to these aggregate trends, we compare the average annual growth rates from 1997 to 2030 in key variables in the LRP scenario to the growth rates from 1990 to 2000. These comparisons are presented in map form in figures 6.14 through 6.16 for population, housing and jobs. Note that the historical data for jobs was not available in Utah County, so the map does not show employment change for this area.

These comparisons suggest that growth in housing, and consequently in households and population, was higher in the LRP forecast than historical trends in selected areas such as surrounding and south of the airport – areas that saw declines in housing and population in the 1990s. By contrast, the area of southwest Salt Lake County and Northwest Utah County west of Utah Lake were predicted to grow in housing, households and population at a rate that is lower than the average growth rates in the 1990s. The 2030 population in the LRP scenario is, however, higher than in the currently adopted forecast, discussed below.

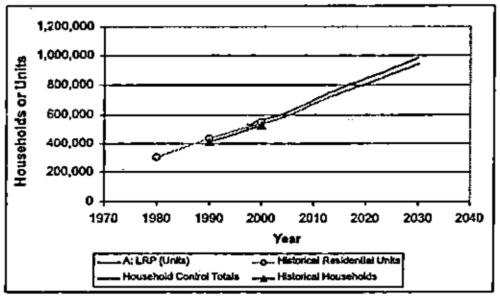

Figure 6.12: Household and Housing Unit Trends

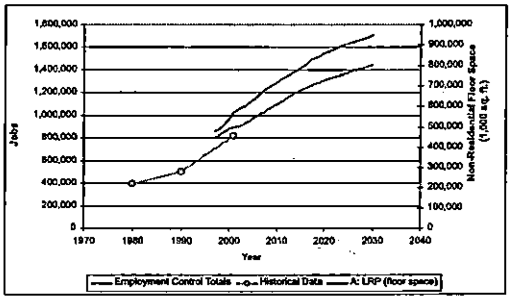

Figure 6.13: Employment and Non-residential Square-footage Trends

Table 6.1: Development Transitions from 1997 (rows) to 2030 (columns)

	R1	R2	R3	R4	R5	R6	R7	R8	M1	M2	M3	M4	M5	M6	M7	M8	C1	C2	C3	I1	I2	I3	G	VD	VU	Total
R1	41%	18%	17%	12%	9%	2%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100
R2	0%	29%	25%	21%	18%	4%	1%	0%	0%	0%	1%	0%	0%	0%	0%	0%	1%	0%	0%	0%	0%	0%	0%	0%	0%	100
R3	0%	0%	28%	30%	32%	7%	2%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100
R4	0%	0%	0%	34%	53%	11%	2%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100
R5	0%	0%	0%	0%	77%	20%	2%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100
R6	0%	0%	0%	0%	0%	87%	13%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100
R7	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100
R8	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100
M1	0%	0%	0%	4%	2%	0%	0%	0%	78%	0%	12%	0%	0%	0%	0%	0%	4%	0%	0%	0%	0%	0%	0%	0%	0%	100
M2	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100
M3	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100
M4	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100
M5	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100
M6	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100
M7	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100
M8	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100
C1	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	40%	0%	0%	0%	0%	0%	59%	0%	0%	1%	0%	0%	0%	0%	0%	100
C2	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	45%	0%	0%	0%	0%	0%	55%	0%	0%	0%	0%	0%	0%	0%	100
C3	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%	100
I1	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	100
I2	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	100
I3	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%	100
G	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	1%	0%	0%	98%	1%	0%	100
VD	4%	4%	5%	3%	3%	1%	0%	0%	0%	0%	2%	0%	0%	0%	0%	0%	1%	0%	0%	5%	2%	1%	0%	68%	0%	100
VU	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	99%	100

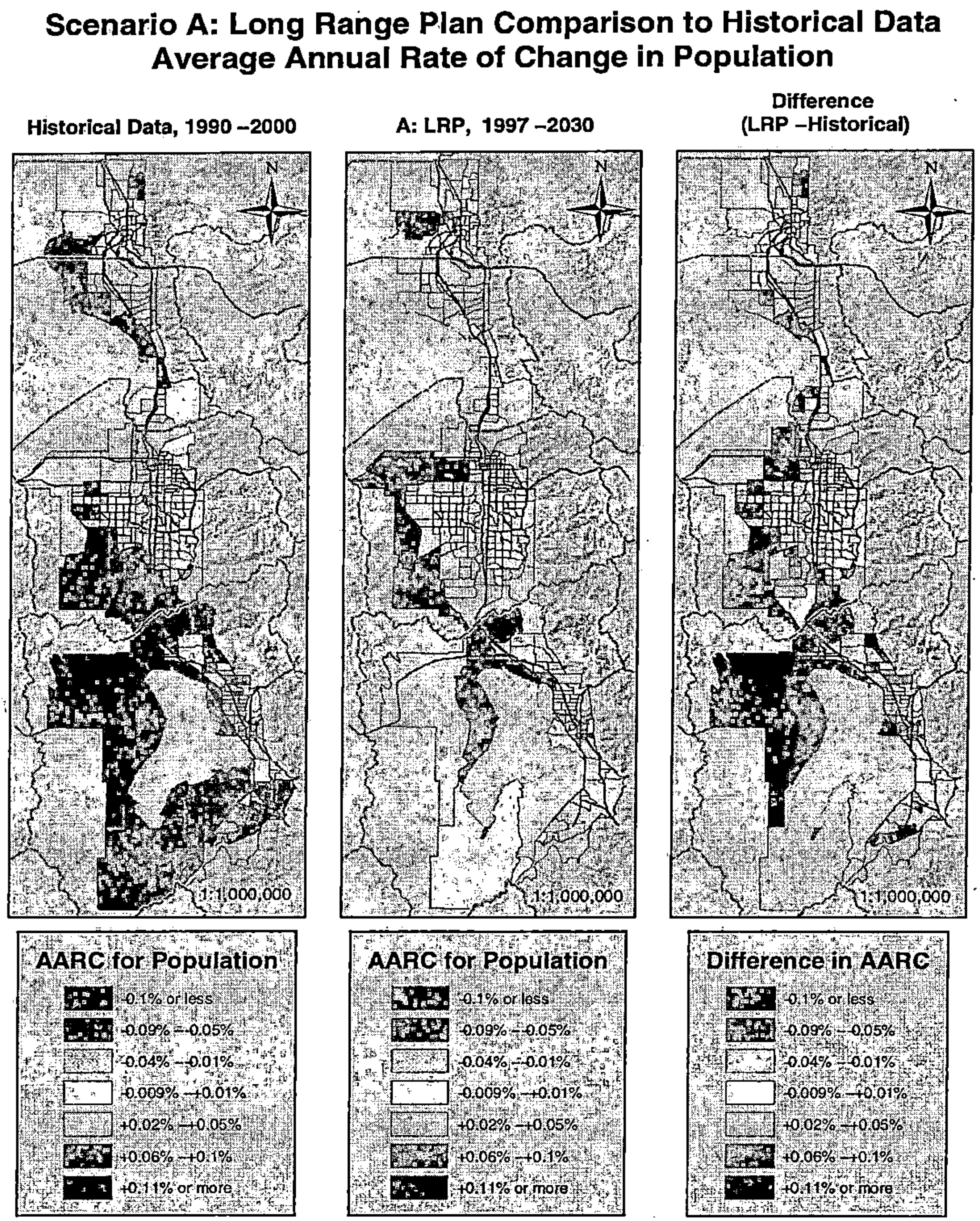

Figure 6.14: Comparison of LRP to Historical Population Growth Rates

Scenario A: Long Range Plan Comparison to Historical Data
Average Annual Rate of Change in Residential Units

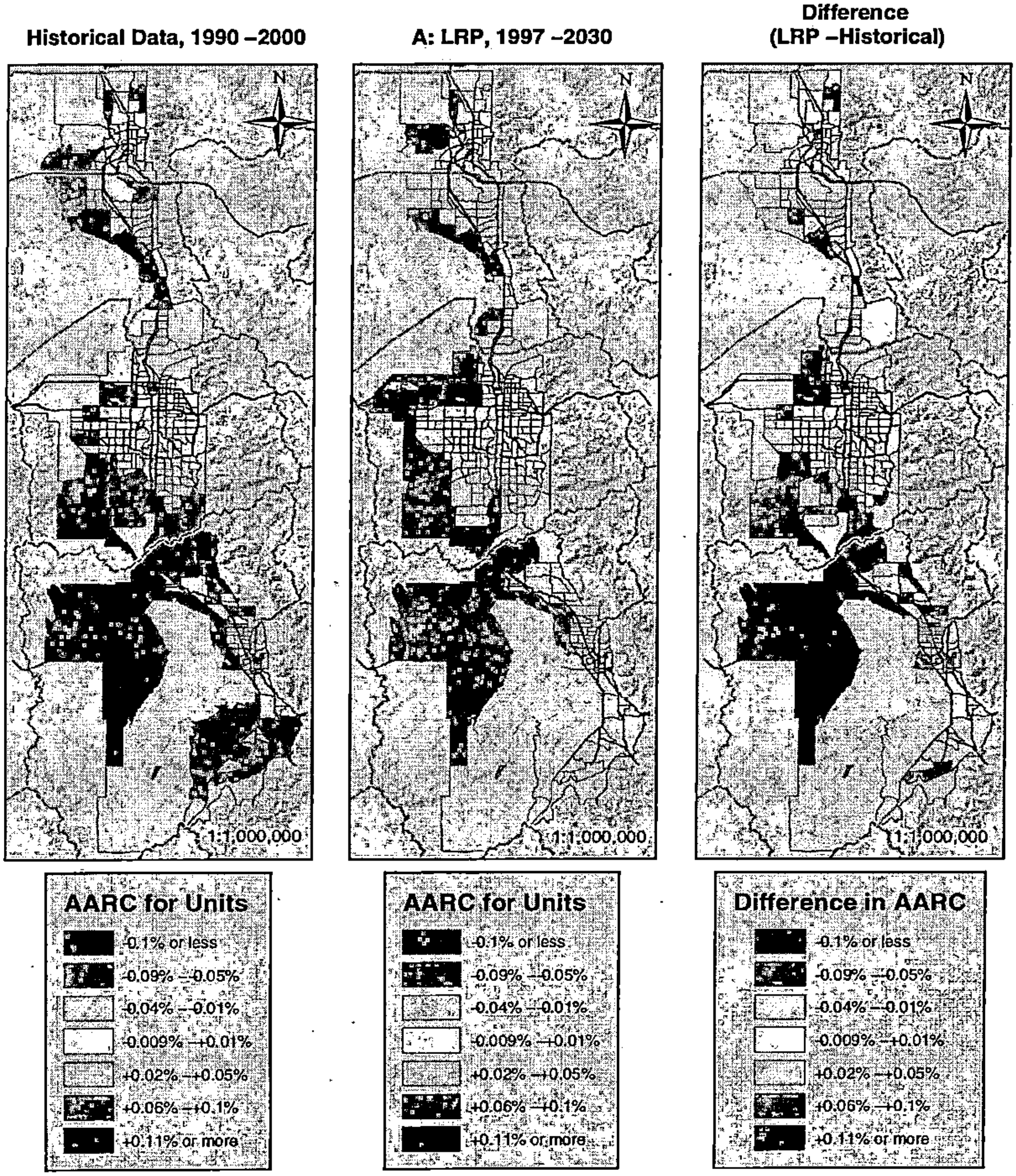

Figure 6.15: Comparison of LRP to Historical Housing Unit Growth Rates

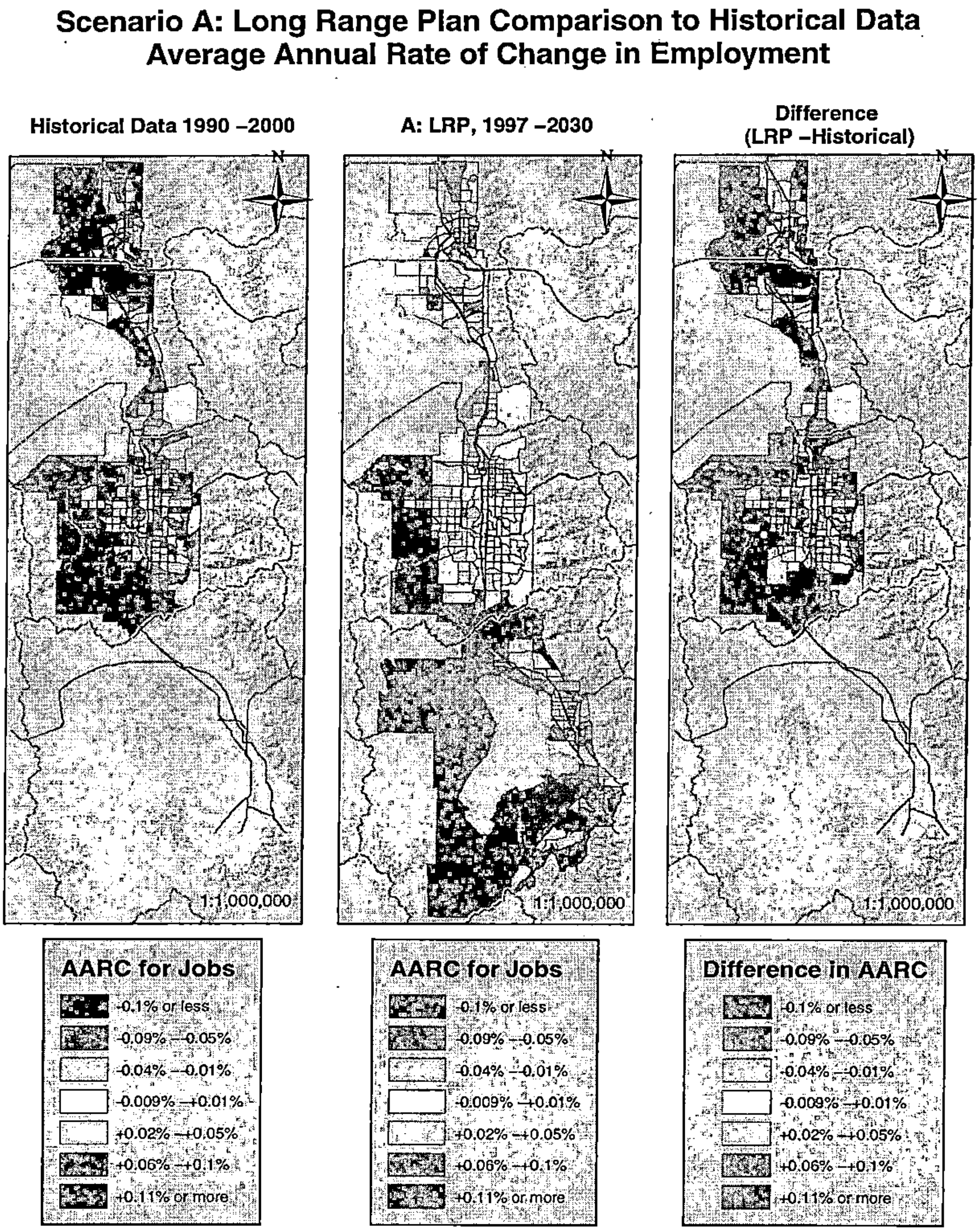

Figure 6.16: Comparison of LRP to Historical Employment Growth Rates

6.1.3 Comparison to 2003 Observed Data

One of the suggestions from the First Peer Review meeting was to examine the results of the model from 1997 through 2003, comparing the results against observed data for this period. WFRC examined the available observed data, and concluded that the employment data available for this validation exercise were problematic, and would confound forecasting errors with errors in the observed data. A summary of the comparisons is provided in this section, though caution is needed in comparing the observed employment data in particular. The 1997 through 2003 model runs included interaction with the travel model in 2000 and 2003. The comparisons are presented in the tables below, by medium districts. UrbanSim base year 1997 and 2003 predicted values for population and employment are inserted in the appropriate sequence with observed data.

The overall pattern in these results that warrants further investigation is that the amount of population growth in Salt Lake County appears high relative to historical trends, and appears considerably below historical trends in Utah County. But the reverse pattern is evident for employment, with too much employment growth in Utah County and too little in Salt Lake, relative to trends. A key explanation for this pattern has emerged from initial investigations. First, there appears to be an initial period of 5-6 years during which there is considerable loss of employment in Salt Lake County, after which the trend stabilizes and reverses. Similar volatility appears to occur for population (though not in the same pattern as for employment) over the first several years of the simulation. These appear to be related to a combination of patterns of vacancies in the input data, and initial convergence of model processes that are initially somewhat inconsistent in the base year. In particular, the land price data used to estimate model components such as residential and employment location, and real estate development, was 'observed' land price, but when the model begins simulating into the future, only simulated land prices are available, and where the observed prices differ significantly from simulated prices, the results are initially unstable until the model fully adjusts to the simulated prices. In a future update of the model, this would be straightforward to correct for, and a standard instrumental variables approach is appropriate to reflect the endogeneity between prices, location choices and development.

The data are summarized by medium districts, as shown in Figure 6.17. Districts 1-8 are in Weber County, 9-10 are in Davis County, 11-23 are in Salt Lake County, and 24-31 are in Utah County.

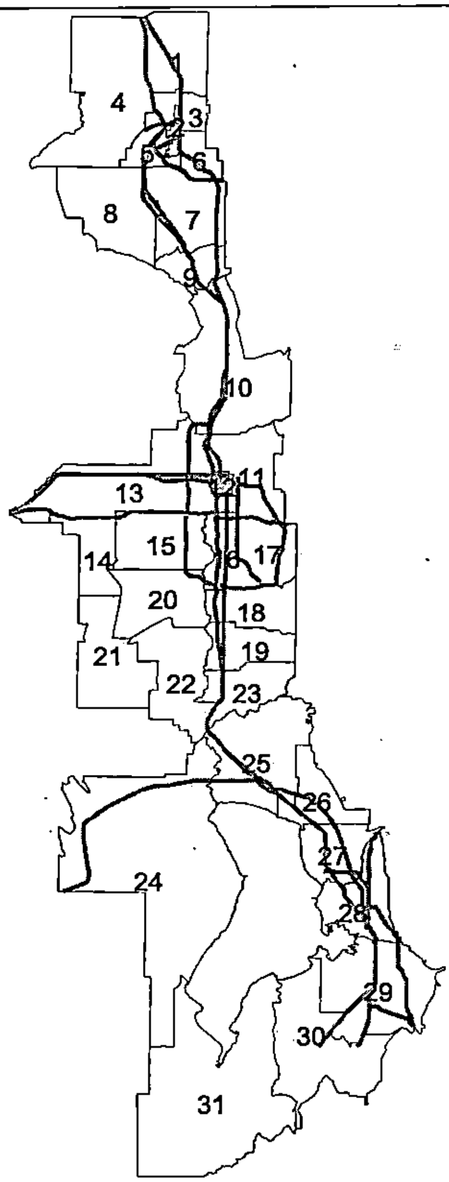

Figure 6.17: Map of Medium Districts

Table 6.2: Predicted and Observed Population Trends

MEDDIST	Observed 1980	Observed 1990	UrbanSim 1997	Observed 2000	UrbanSim 2003
1	35,038	40,380	44,338	50,688	48,714
2	6,412	5,524	3,608	6,511	5,683
3	35,567	33,013	26,879	38,890	34,507
4	8,854	20,296	34,193	32,517	33,203
5	24,392	28,631	29,405	29,760	33,064
6	23,978	27,267	31,833	30,305	38,460
Weber	134,241	155,111	170,256	188,671	193,631
7	34,891	52,105	56,809	67,820	64,336
8	32,026	39,405	42,741	56,606	45,355
9	14,261	18,346	20,068	25,463	21,310
10	63,675	73,423	72,997	89,106	80,349
Davis	144,853	183,279	192,615	238,995	211,350
11	101,729	96,314	91,851	101,575	117,591
12	10,133	9,999	10,135	12,090	15,932
13	36,948	39,432	43,677	53,428	49,020
14	14,127	17,803	21,713	22,793	23,311
15	114,198	130,849	146,039	156,530	161,692
16	62,575	67,848	73,777	76,183	91,025
17	91,286	88,766	93,010	92,446	111,057
18	86,471	96,088	112,279	104,216	126,235
19	38,062	51,937	64,035	65,090	70,163
20	52,135	79,386	113,962	107,133	118,919
21	935	1,259	14,033	6,411	14,964
22	17,899	26,773	57,484	55,819	63,289
23	6,073	8,332	18,383	23,590	23,879
Salt Lake	632,571	714,786	860,378	877,304	987,077
24	NA	311	3,503	3,339	3,380
25	NA	34,015	44,878	56,127	48,101
26	NA	19,536	26,270	36,260	27,098
27	NA	67,686	69,648	84,909	71,755
28	NA	86,793	69,447	105,395	73,339
29	NA	30,720	45,637	48,133	45,546
30	NA	15,309	20,689	23,895	19,124
31	NA	3,920	15,132	7,141	15,275
Utah	NA	258,290	295,204	365,199	303,618
Region	NA	1,311,466	1,518,453	1,670,169	1,695,676

Table 6.3: Predicted and Observed Employment Trends

MEDDIST	Observed 1980	Observed 1990	UrbanSim 1997	Observed 2000	UrbanSim 2003
1	8,968	17,221	14,319	13,341	17,089
2	16,832	13,717	13,304	14,807	13,479
3	14,879	16,610	22,918	16,867	26,174
4	611	1,380	3,867	7,810	9,532
5	5,026	9,665	18,554	17,112	19,456
6	7,512	10,834	9,220	12,010	12,751
Weber	53,828	69,427	82,182	81,947	98,481
7	25,307	31,009	26,221	18,978	26,492
8	7,267	11,238	13,092	21,355	15,818
9	1,595	3,161	3,471	6,032	4,661
10	15,667	20,982	27,221	34,357	44,569
Davis	49,836	66,390	70,005	80,722	91,540
11	72,179	76,756	83,562	73,586	85,537
12	66,098	64,490	75,286	70,183	63,683
13	37,465	52,990	67,846	89,509	97,700
14	5,403	5,835	4,174	4,484	7,964
15	19,705	37,781	51,110	60,714	60,610
16	44,184	57,030	76,282	82,991	85,003
17	18,401	25,163	30,446	27,010	29,581
18	11,319	21,234	32,121	37,143	42,901
19	7,427	11,079	22,593	28,315	28,866
20	5,385	12,059	16,596	23,056	25,317
21	0	31	106	1,517	2,555
22	1,165	2,590	5,800	8,616	8,615
23	1,252	1,908	4,921	6,701	9,594
Salt Lake	289,983	368,946	470,843	513,825	547,926
24	NA	NA	8	169	1,780
25	NA	NA	12,387	14,199	35,887
26	NA	NA	5,229	7,206	10,288
27	NA	NA	33,589	39,497	43,810
28	NA	NA	54,623	62,132	62,663
29	NA	NA	11,977	13,350	23,412
30	NA	NA	3,866	4,358	7,738
31	NA	NA	134	494	779
Utah	NA	NA	121,813	141,405	186,357
Region	NA	NA	744,843	817,899	924,304

6.1.4 Comparison to Adopted Forecast

Land Use

Comparisons to the most recently adopted WFRC forecasts are presented in Figures ?? through 6.25. Note that the control totals used in the scenarios included in this report were significantly different than those in the previous adopted forecasts. The adopted forecast used a total 2030 population of 2,816,793, while the control total used in the UrbanSim testing for 2030 is 2,664,900 – more than 150,000 less than in the adopted forecast. By contrast, the adopted forecast employment total is 1,344,099 while the control total we're using is 1,446,000, or

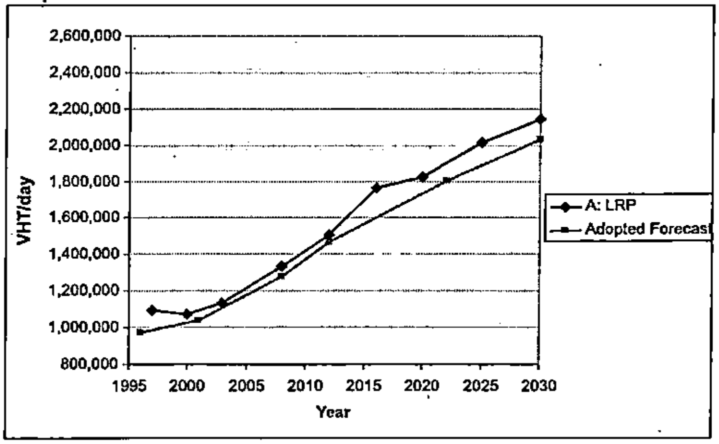

Figure 6.18: Vehicle Hours Travelled vs Adopted Forecast

100,000 higher. Differences in spatial patterns of growth should be interpreted with these differences in control totals kept in mind.

The population growth in the LRP scenario is somewhat lower in Southwest Salt Lake County and in much of Utah County than in the adopted forecast, and is considerably higher in the area that is already developed in central Salt Lake County as well as in the northwest area of Salt Lake County that is principally industrial in character, west of the airport. Employment, in general, appears lower in the LRP scenario in most current employment centers, and considerably higher in more peripheral areas, especially in west Salt Lake County and throughout most parts of Davis, Weber and Utah Counties. These systematic patterns of differences appear to correlate visually to the patterns that appeared in the remaining development capacity maps in Figure 6.4. This would suggest further review of the development constraints that are inputs to the model. The feedback provided by running the model has in this and numerous other instances served a valuable role in identifying issues with the input data that warrant attention or refinement. Certainly, more time to analyze these results will be valuable in improving the model for operational use.

Travel Model

The travel model results from the LRP scenario are compared to travel model results in the adopted forecast in Figures 6.18 through 6.21. These results indicate that the LRP scenario produced slightly more VMT, VHT and total hours of congestion delay than the adopted forecast, and somewhat lower transit mode shares. Considering that the transportation network assumptions were the same, the differences are attributable to the feedback of the travel model to land use. This result is not surprising since the adopted forecast did not involve any feedback from transportation to land use. In general, these results appear reasonable given the differences in population and employment between the LRP run and the adopted forecast.

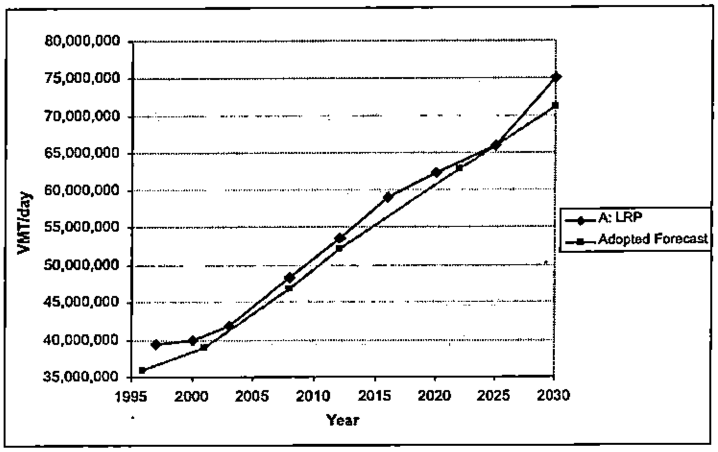

Figure 6.19: Vehicle Miles Travelled vs Adopted Forecast

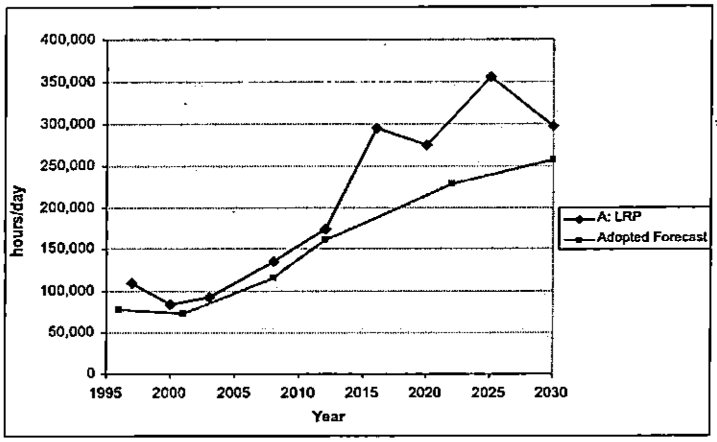

Figure 6.20: Total Hours of Congestion Delay vs Adopted Forecast

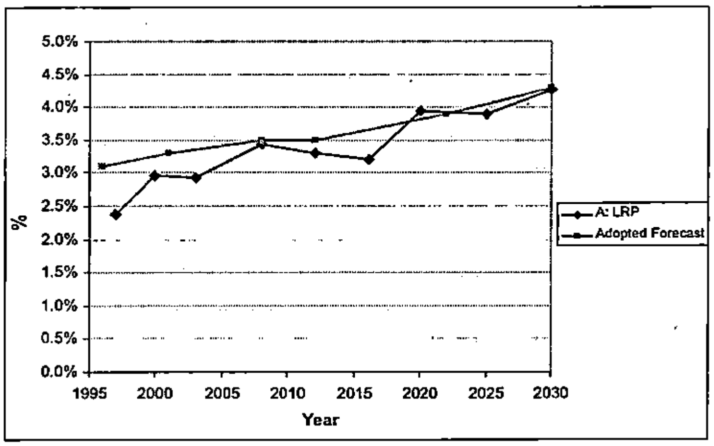

Figure 6.21: Transit Mode Share vs Adopted Forecast

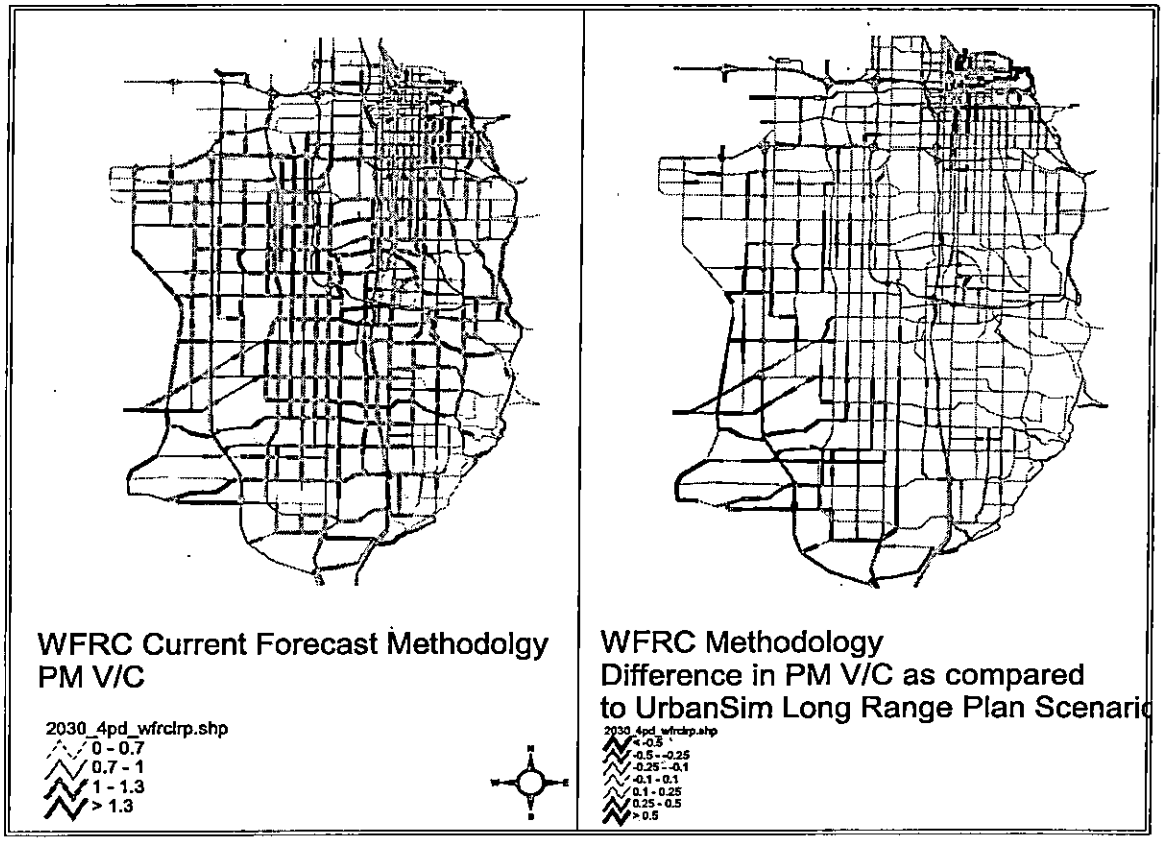

Figure 6.22: Comparison of Adopted Forecast to LRP PM Peak Volume to Capacity Ratio

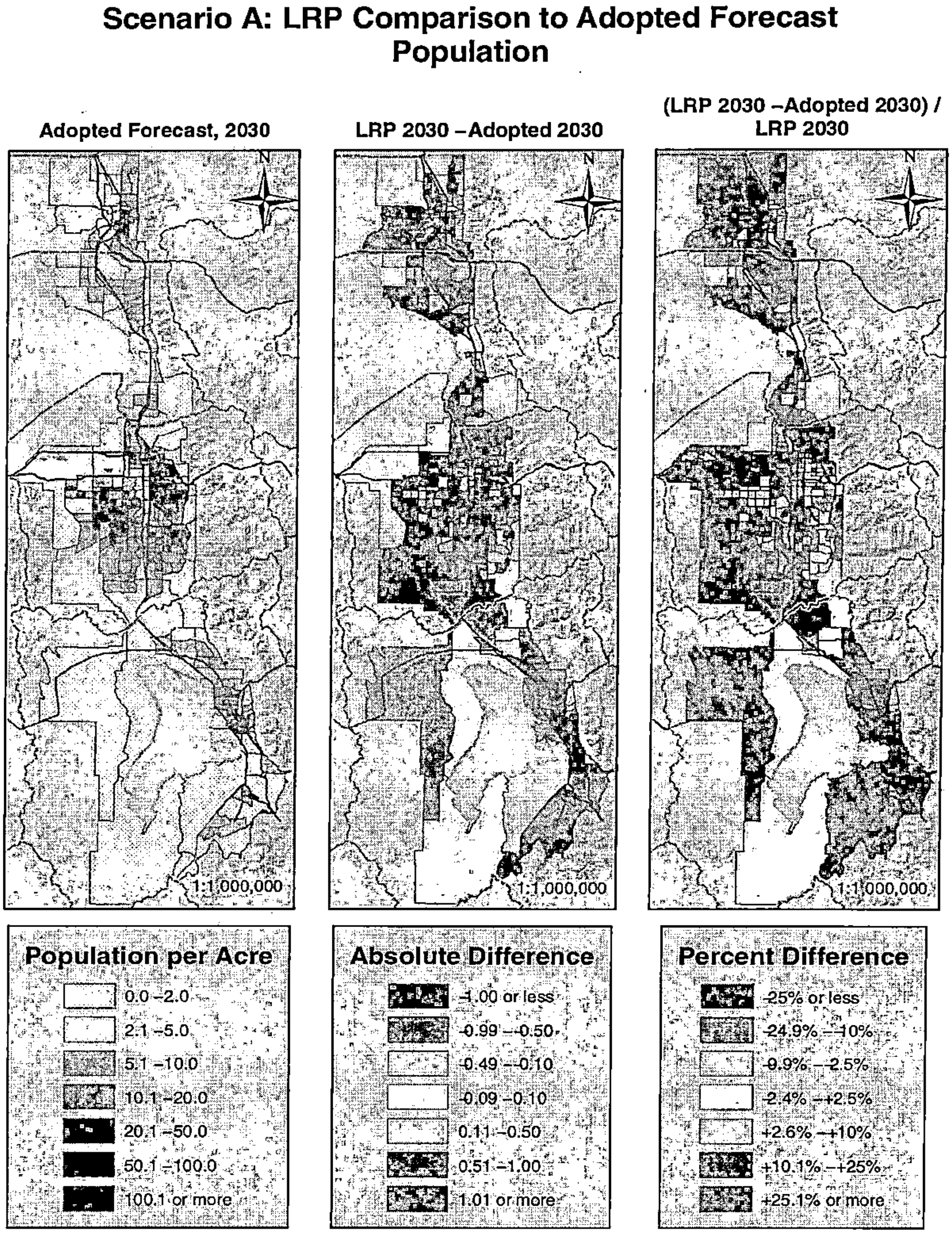

Figure 6.23: Comparison of LRP population in 2030 to Adopted Forecast

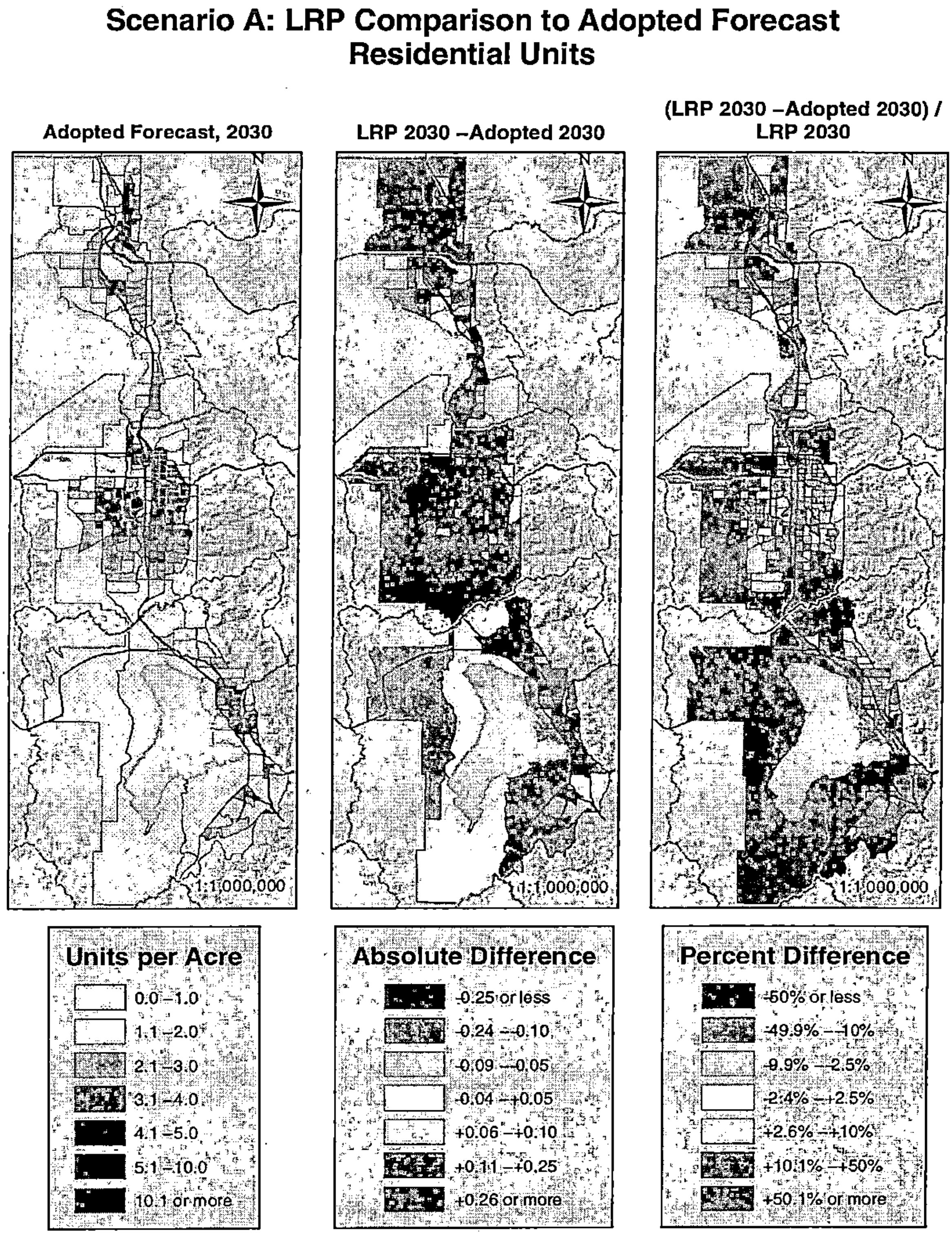

Figure 6.24: Comparison of LRP Housing Units in 2030 to Adopted Forecast

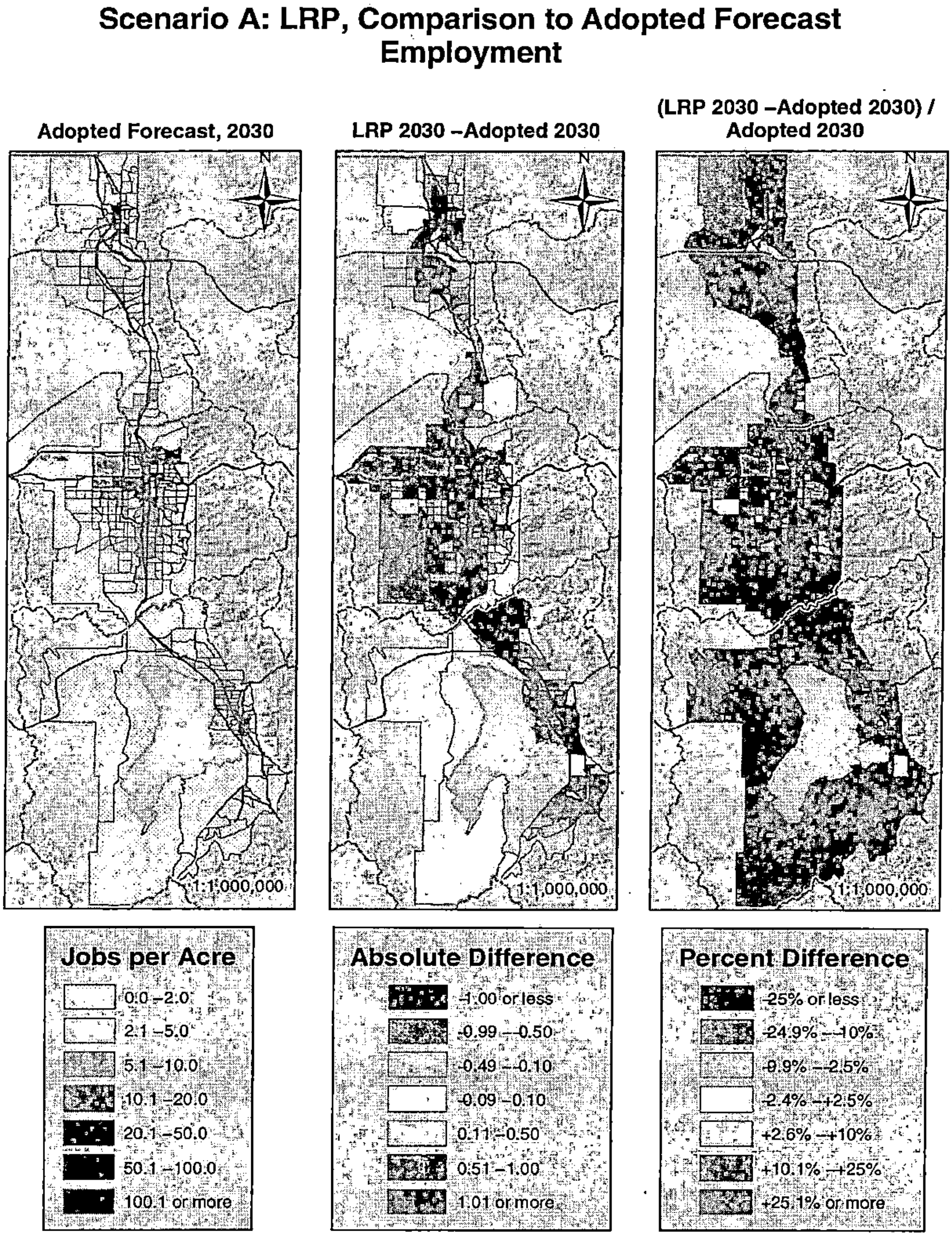

Figure 6.25: Comparison of LRP Jobs in 2030 to Adopted Forecast

6.2 Sensitivity Analyses

Based on discussion at the first Peer Review Meeting in June, 2003, a validation process was devised for this project. The process involves testing UrbanSim in combination with the regional travel model system on a set of scenarios that would allow exploration of the sensitivity of the model system to specified changes in policy. Note that the exercise was not designed to assess these policies, but to assess the model system responsiveness to the policies. Given the objectives of the project, scenarios were selected that would provide valuable information about the sensitivity of the model system that could be used to learn more about its utility for operational planning. For ease of interpretation, the scenarios are controlled experiments, which is to say, only one significant input is changed in each one. The scenarios examined were the following:

- The currently adopted WFRC *Long Range Plan*, phased in over 1997 to 2030.
- A *No-build* scenario that holds the transportation system constant from 1997 to 2030, but includes congestion effects.
- A *Highway Alternative* that removes a major section of Bangerter Highway in southern Utah County.
- A *Transit Alternative* that removes the proposed Mid-Jordan LRT line (planned for the next 10 years, first LRP phase).
- A *Parking Cost Alternative* that doubles the cost of parking in Salt Lake City.
- An *Urban Growth Boundary Alternative* that imposes a boundary limiting urban expansion.
- Two *Vacancy Sensitivity Tests* on alternative values of a vacancy rate coefficient in the land price model. This was requested by the Peer Review Panel to examine the model's sensitivity to vacancy rates.
- A set of runs to examine the effects of *Random Variation* in results, using the same inputs and allowing random seeds to vary between the runs.

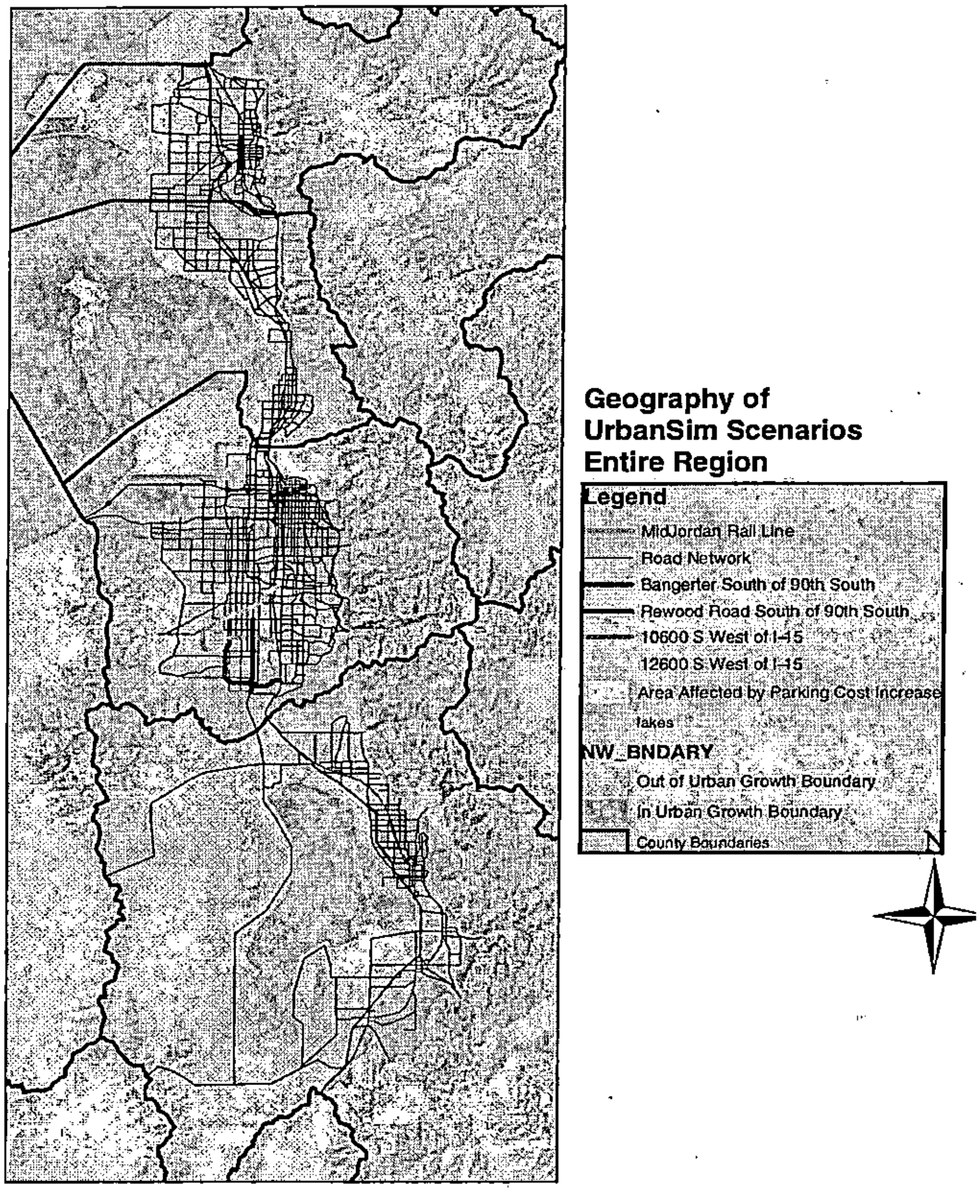

Figure 6.26: Regional Map of Projects Used in Scenarios

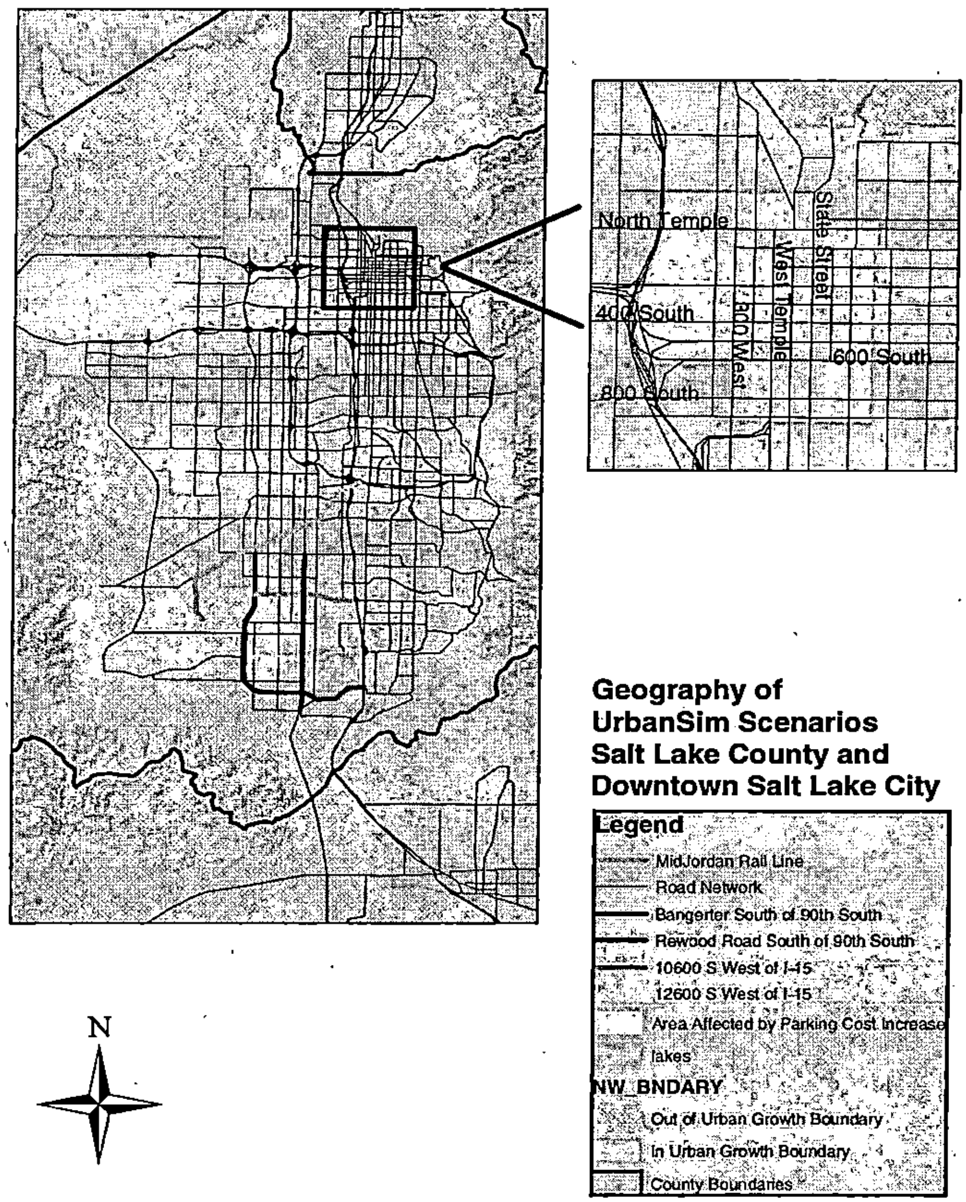

Figure 6.27: Subarea Map of Projects Used in Scenarios

6.3 No-build Alternative

The no-build scenario assumes the 1997 network does not change over the period 1997 through 2030. The scenario does include interaction between UrbanSim and the travel model system for the same years as in the LRP and other scenarios, meaning that congestion effects are captured from the growth and spatial change in population and employment. Considering that the population of the region is predicted to almost double over this time frame, the congestion effects could be expected to be very significant.

In the results, shown in Figures 6.28 through 6.34, there are several evident patterns of differences from the LRP scenario.

- Accessibility is significantly lower in the No-build alternative, especially in the areas affected by the concentration of planned highway and transit improvements in southwestern Salt Lake County.
- Land prices show a marked response to the lower accessibilities, in the areas expected.
- Household and population growth is also diminished in these areas that were disadvantaged by lower accessibility.
- Job growth is less in Utah and southwestern Salt Lake County, also consistent with the drop in accessibility in these areas, and job growth is higher in inner Salt Lake County and in Weber County than in the LRP scenario.
- Vehicle Miles Travelled is significantly lower than all other scenarios tested.
- Vehicle Hours Travelled is significantly higher than all other scenarios tested.
- Total Hours of Delay is significantly higher than all other scenarios tested, and appears to grow at a geometric rate.
- Transit mode share is significantly below the other scenarios tested.

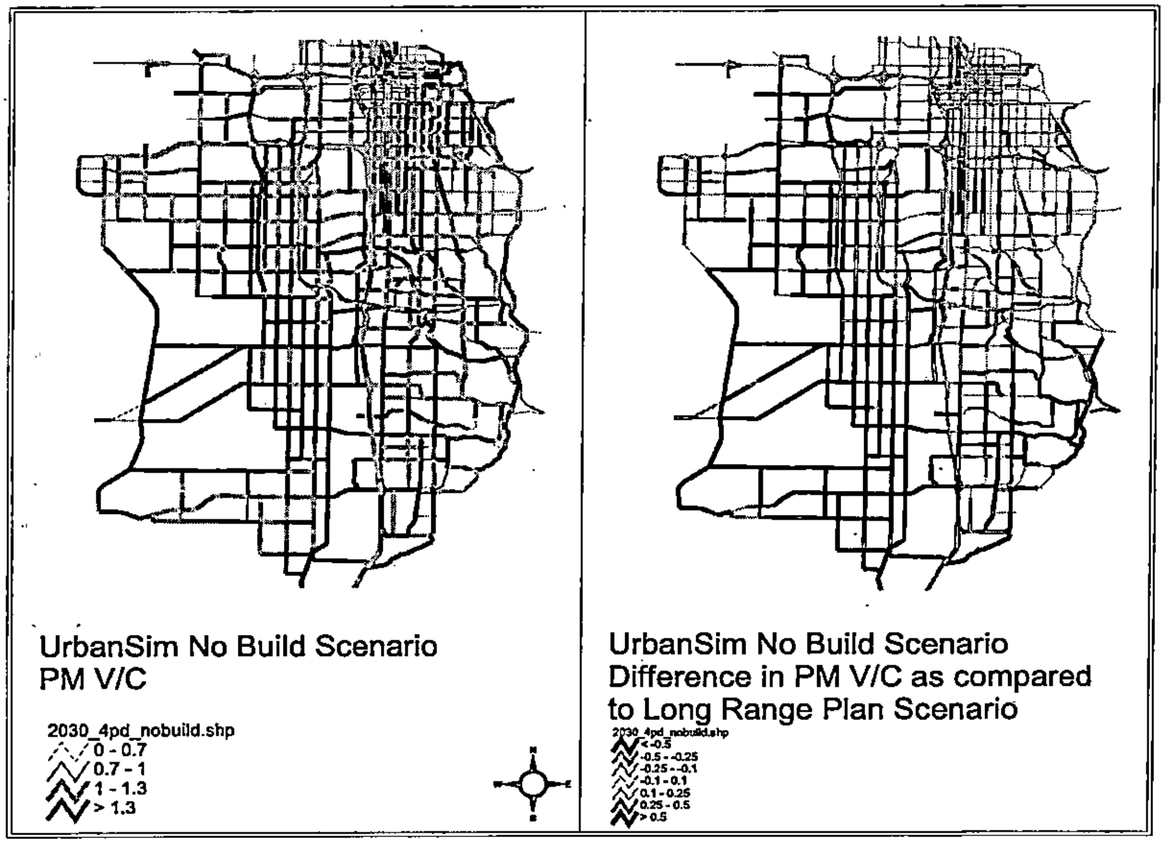

Figure 6.28: Comparison of No-Build Scenario PM Peak Volume to Capacity Ratio to LRP

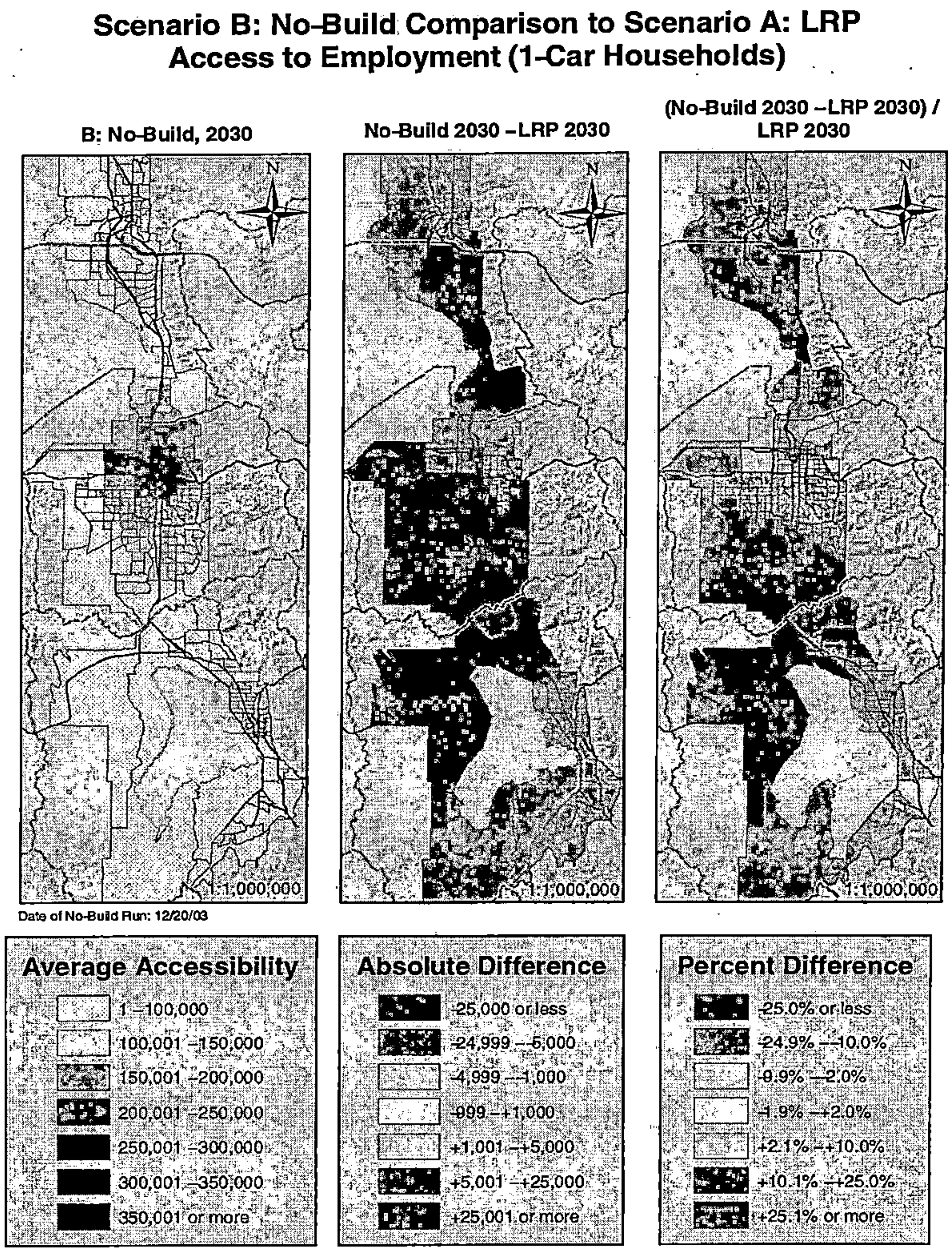

Figure 6.29: Comparison of No-Build Scenario Accessibility to Employment in 2030 to LRP

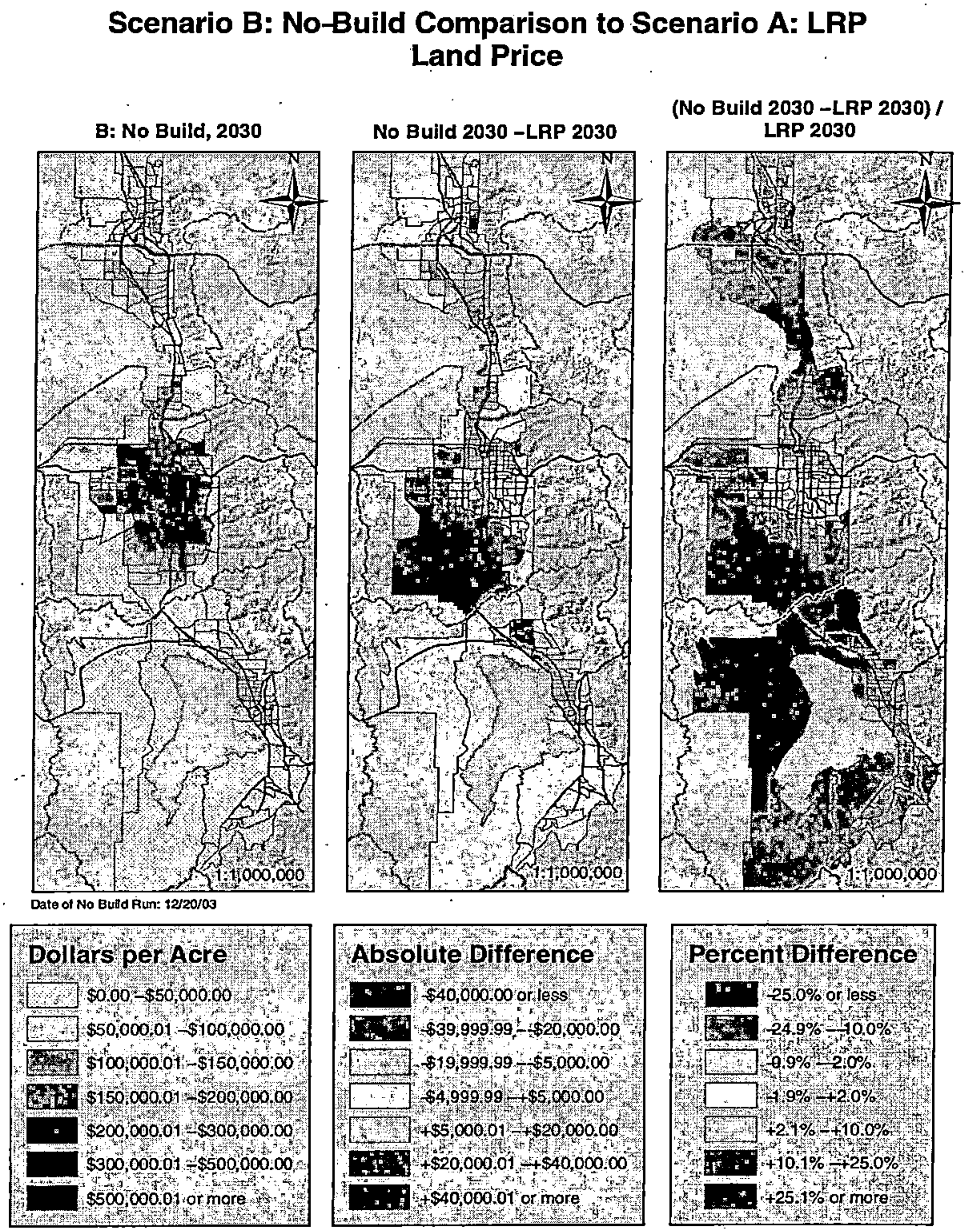

Figure 6.30: Comparison of No-Build Scenario Land Price in 2030 to LRP

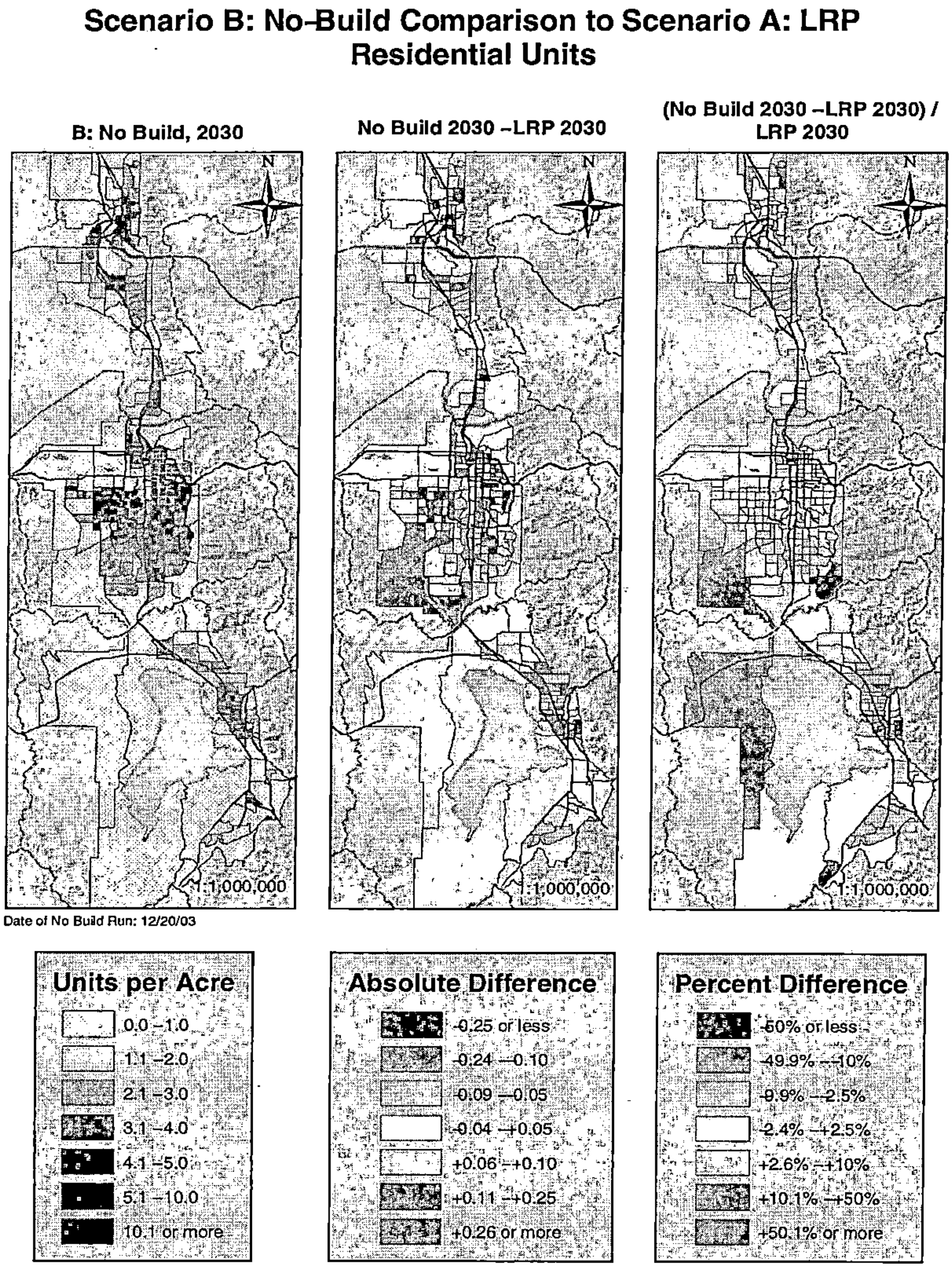

Figure 6.31: Comparison of No-Build Scenario Housing Units in 2030 to LRP

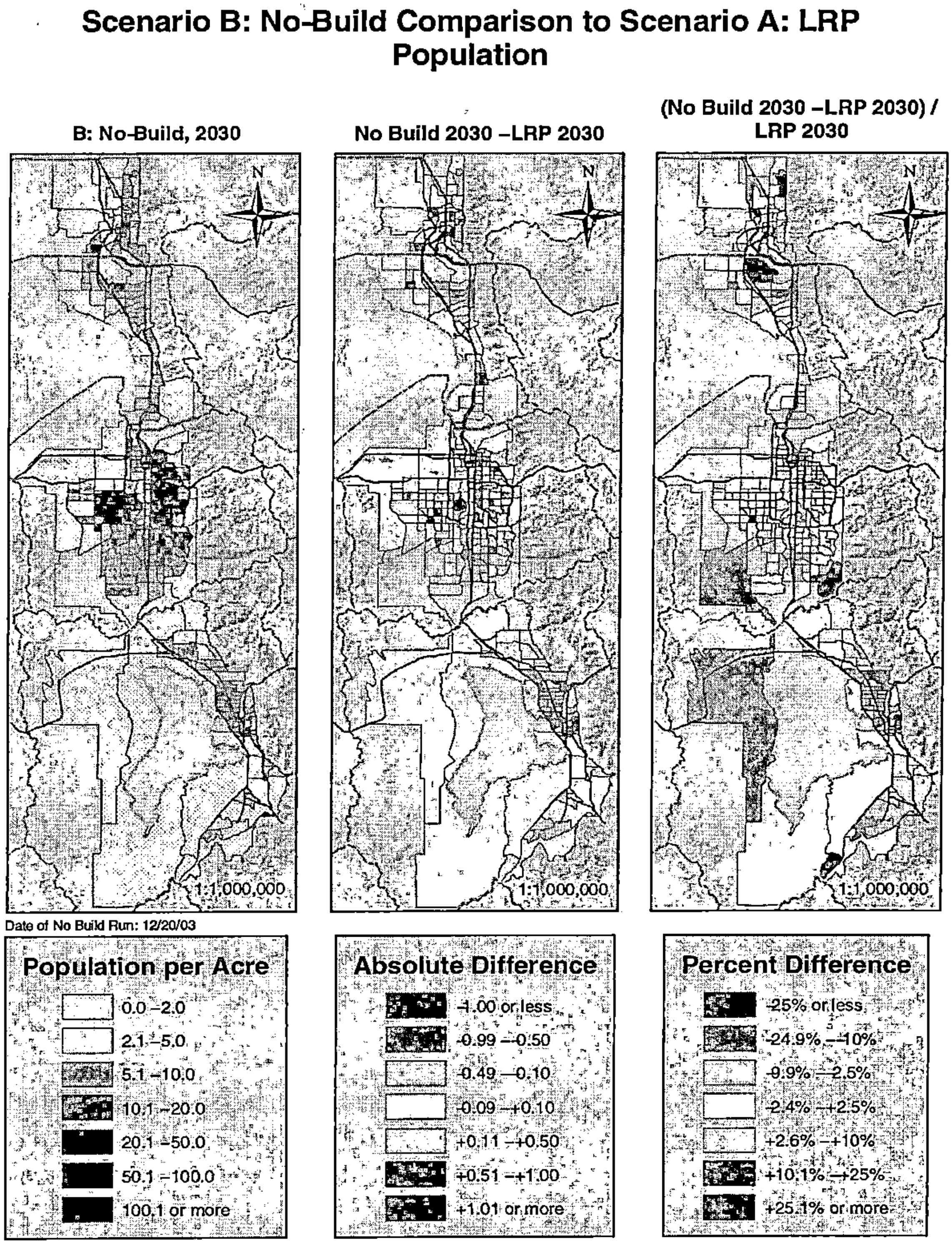

Figure 6.32: Comparison of No-Build Scenario Population in 2030 to LRP

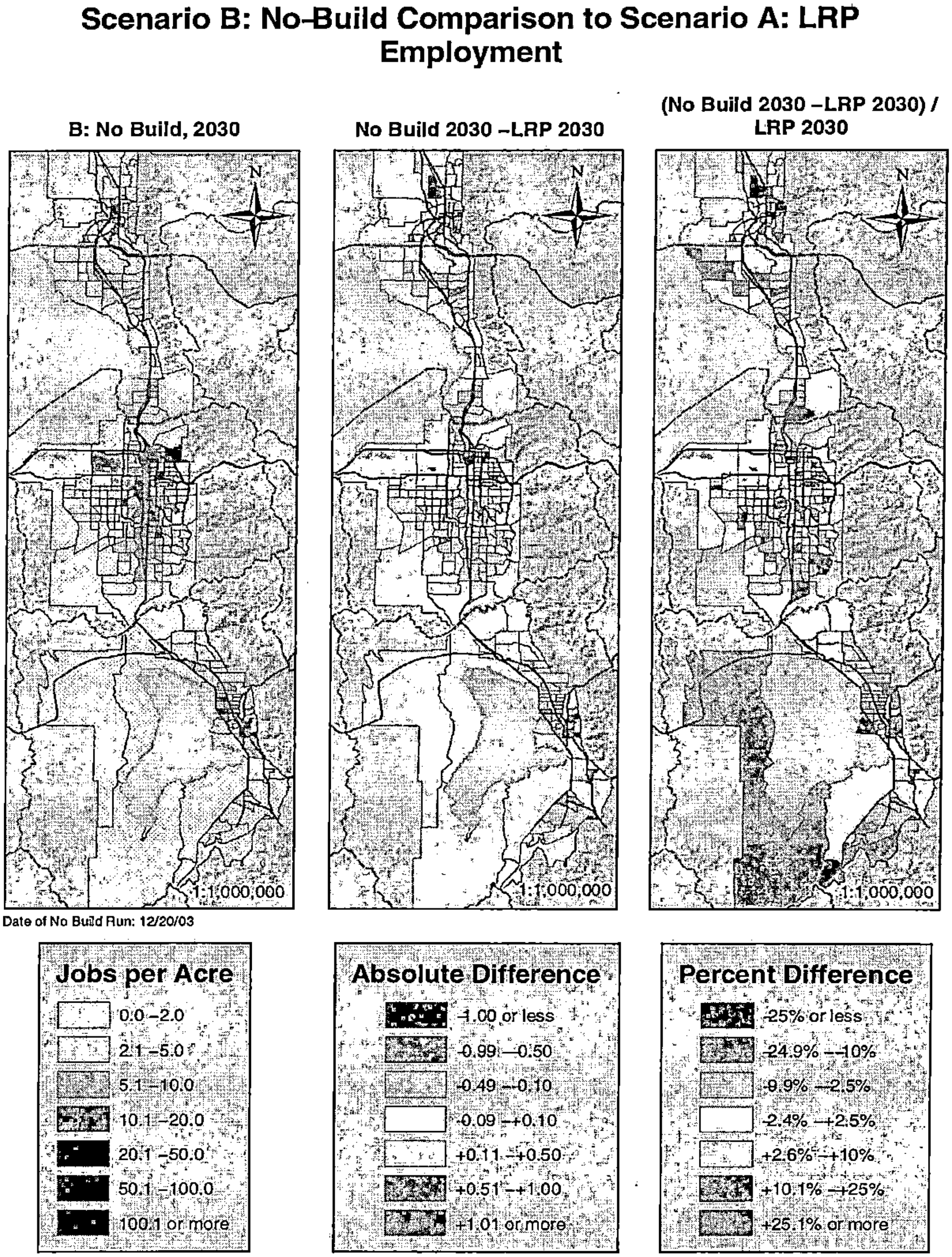

Figure 6.33: Comparison of No-Build Scenario Jobs in 2030 to LRP

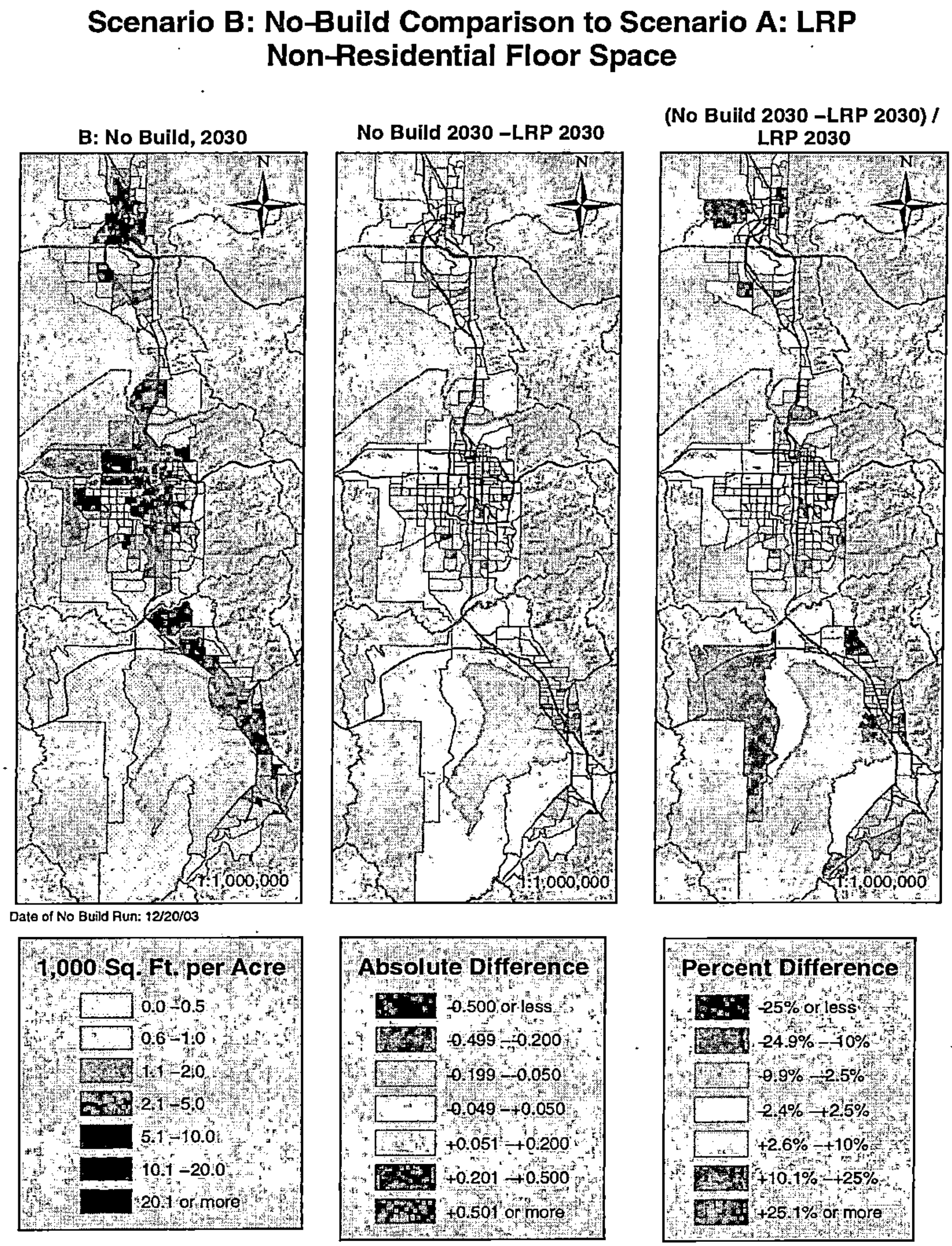

Figure 6.34: Comparison of No-Build Scenario Non-residential SQFT in 2030 to LRP

6.4 Highway Alternative

This scenario removes Bangerter Highway south of 9000 South, a section that was not built until 1998. There are several East/West arterials south of 9000 South that serve to move traffic to Bangerter and I-15. A constant highway network is retained in that portion of the valley for the first 20 years of simulation, which required removing a couple of other planned improvements, or improvements made since 1997. A "study area" was defined as follows:

- 9000 S. is the northern bounday
- Bangerter is the western boundary
- I-15 is the eastern boundary
- The SL/Utah Co. border is the southern boundary

The 1996 network is held constant through 2030 inside this study area (and on Bangerter), with the exception of one arterial, and allowing improvements to I-15 and 9000 S.

The results of removing these highway projects are presented in Figures 6.35 through 6.46, and again with a zoomed-in view of the area immediately surrounding the projects in question in Figures 6.37 through 6.47.

These results generally agree with intuition about the expected results from removing significant new highway capacity in a rapidly developing section of Salt Lake County:

- Accessibility is adversely affected in the immediate vicinity of the highway projects that are removed, but also to a lesser extent in southern Utah County.
- Land prices appear to respond in expected ways, dropping in those areas where access was diminished.
- Population growth was significantly lower, especially in the less developed areas to the south and west of the immediate vicinity of these projects, where there is more open land for development and for which the access provided by the omitted projects would be significant.
- Empoyment growth was also dampened in the area affected by the drop in access due to removing these projects, though the effect was less pronounced than for housing and population.

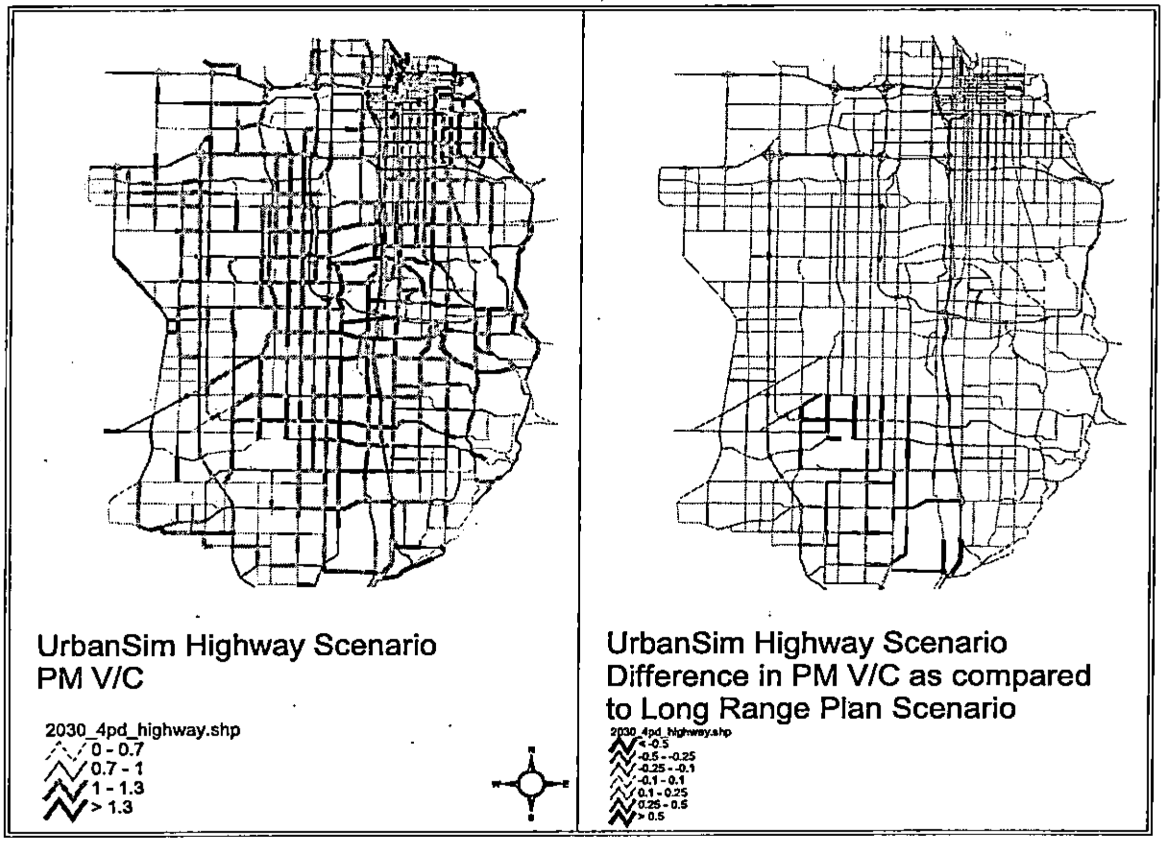

Figure 6.35: Comparison of Highway Scenario PM Peak Volume to Capacity Ratio to LRP

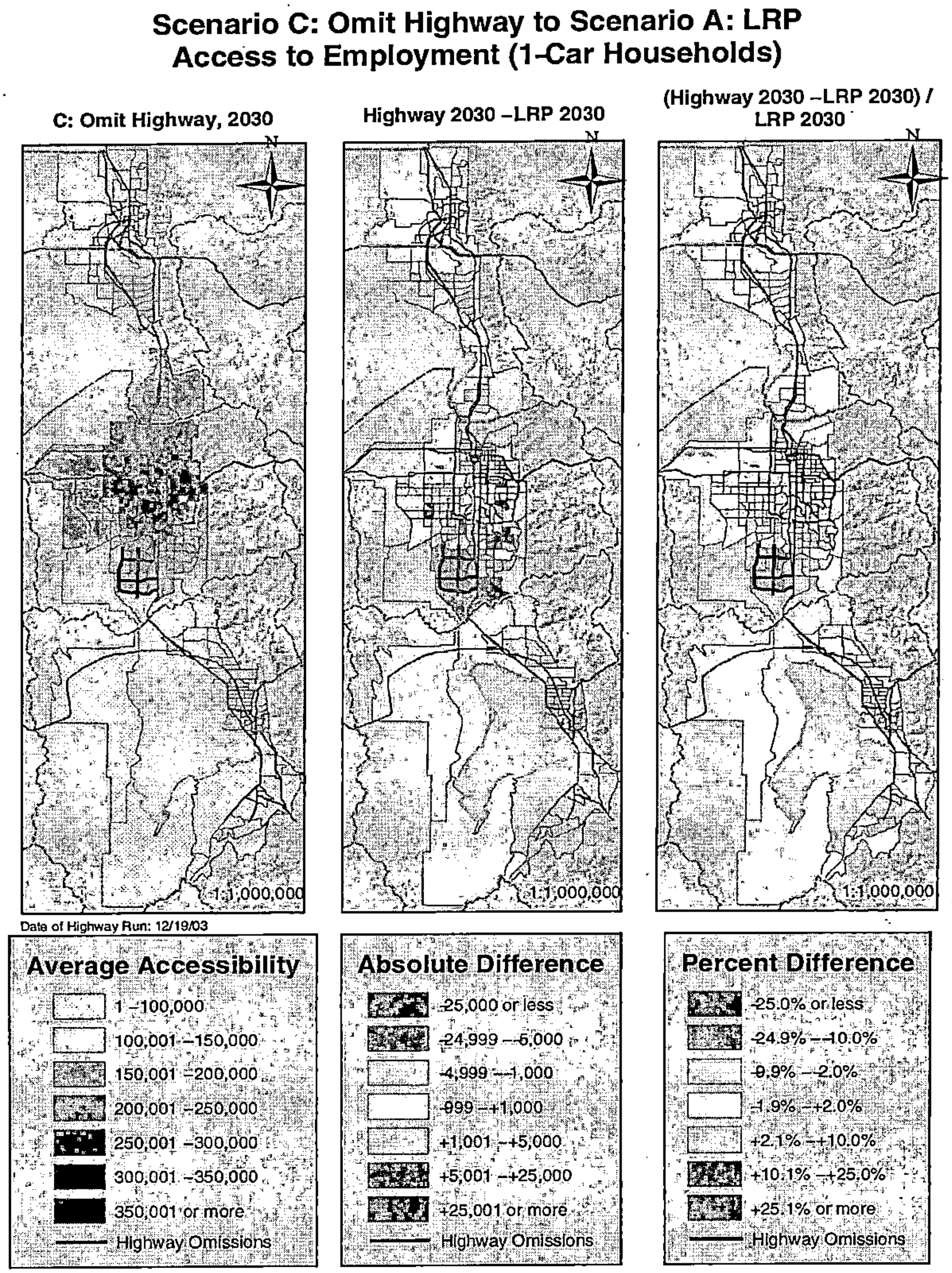

Figure 6.36: Comparison of Highway Scenario Accessibility to Employment in 2030 to LRP

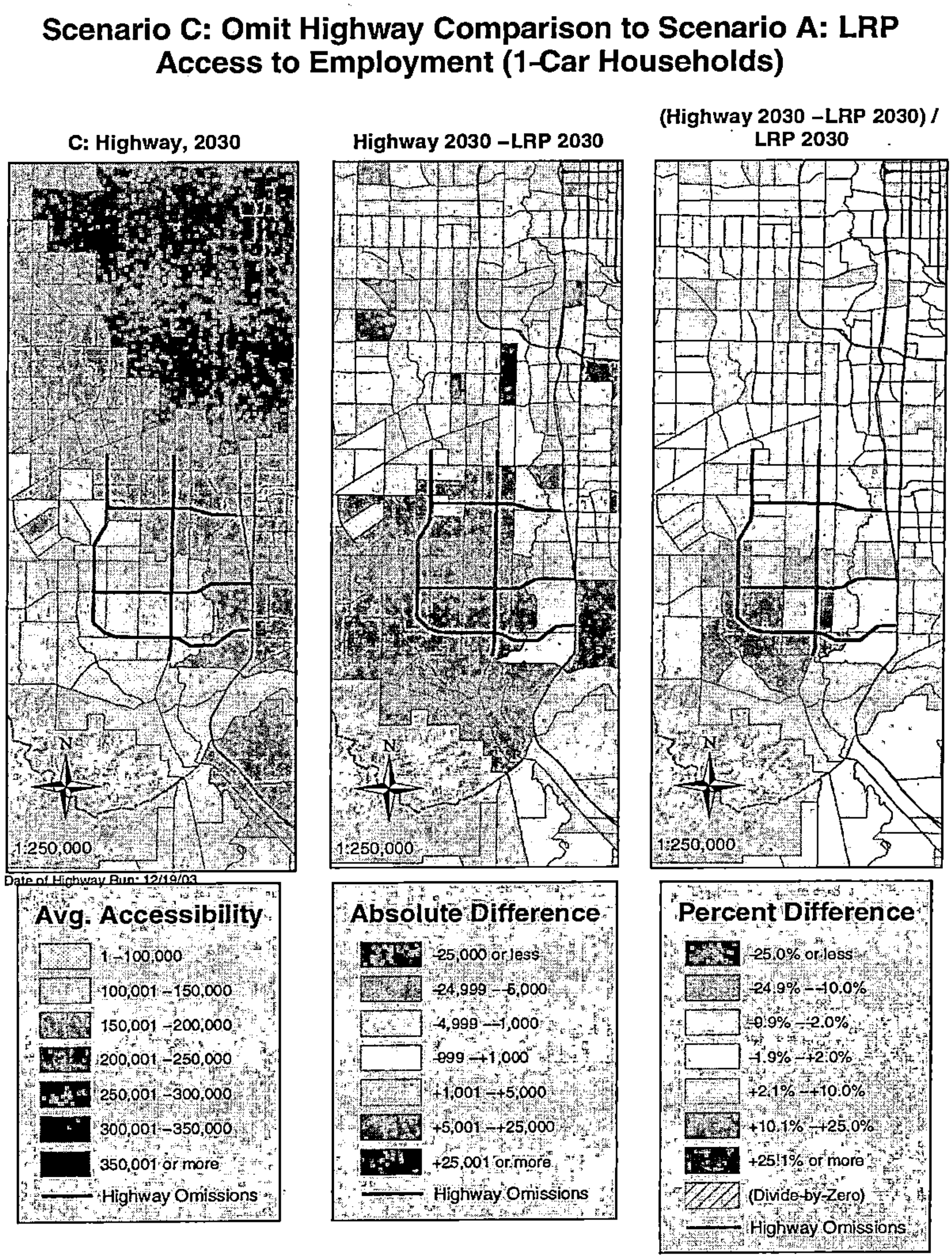

Figure 6.37: Comparison of Highway Scenario Accessibility to Employment in 2030 to LRP (Zoomed In)

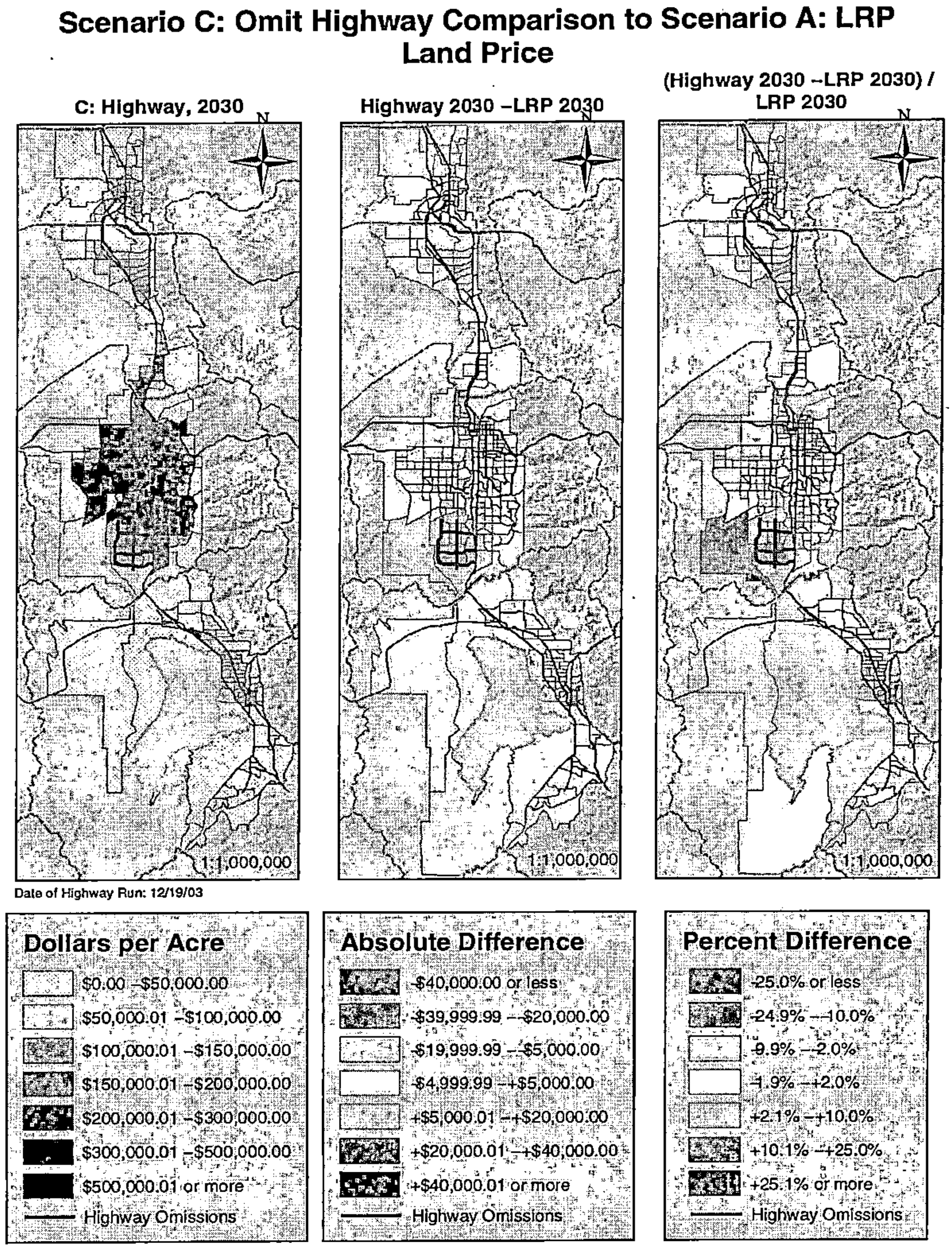

Figure 6.38: Comparison of Highway Scenario Land Price in 2030 to LRP

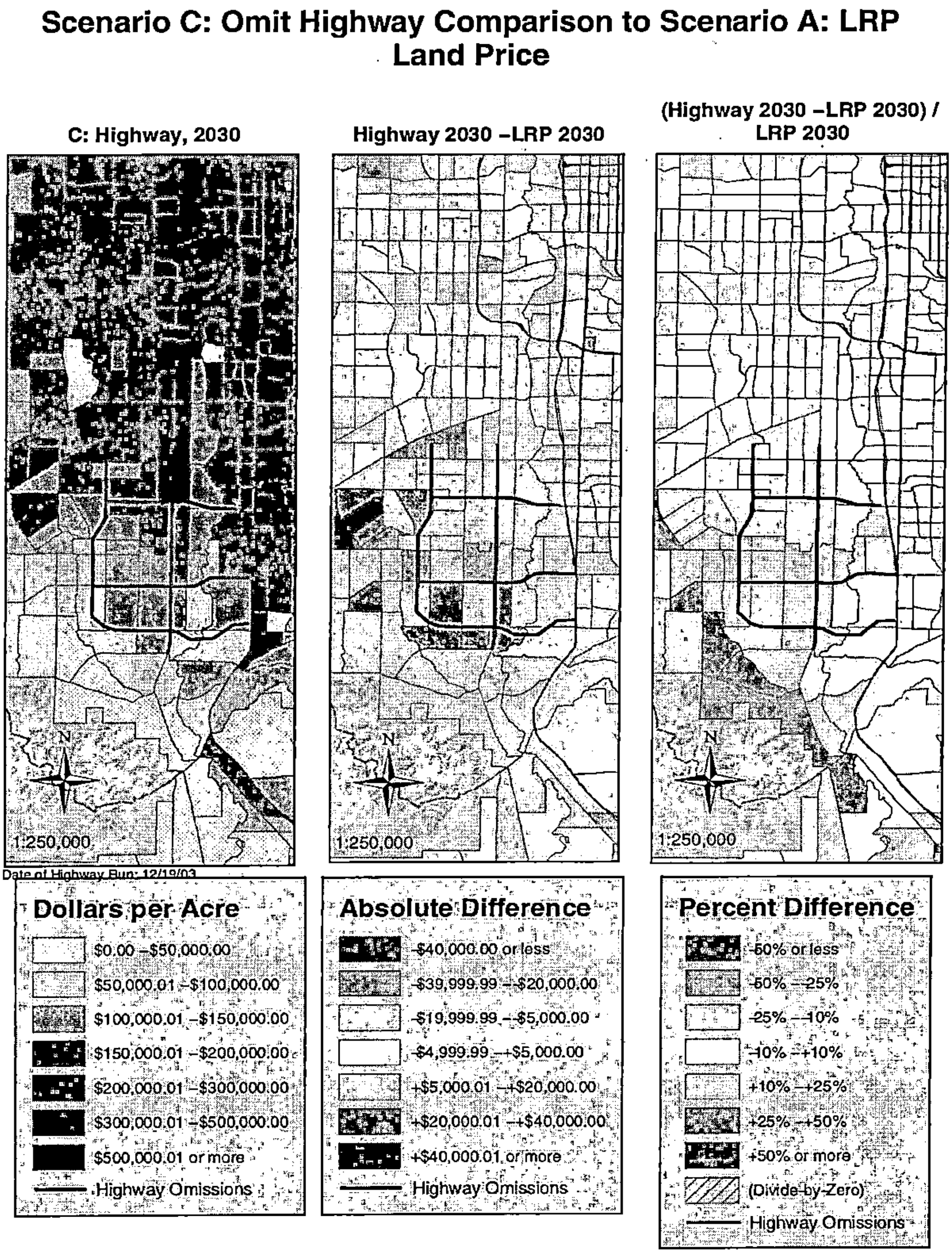

Figure 6.39: Comparison of Highway Scenario Land Price in 2030 to LRP (Zoomed In)

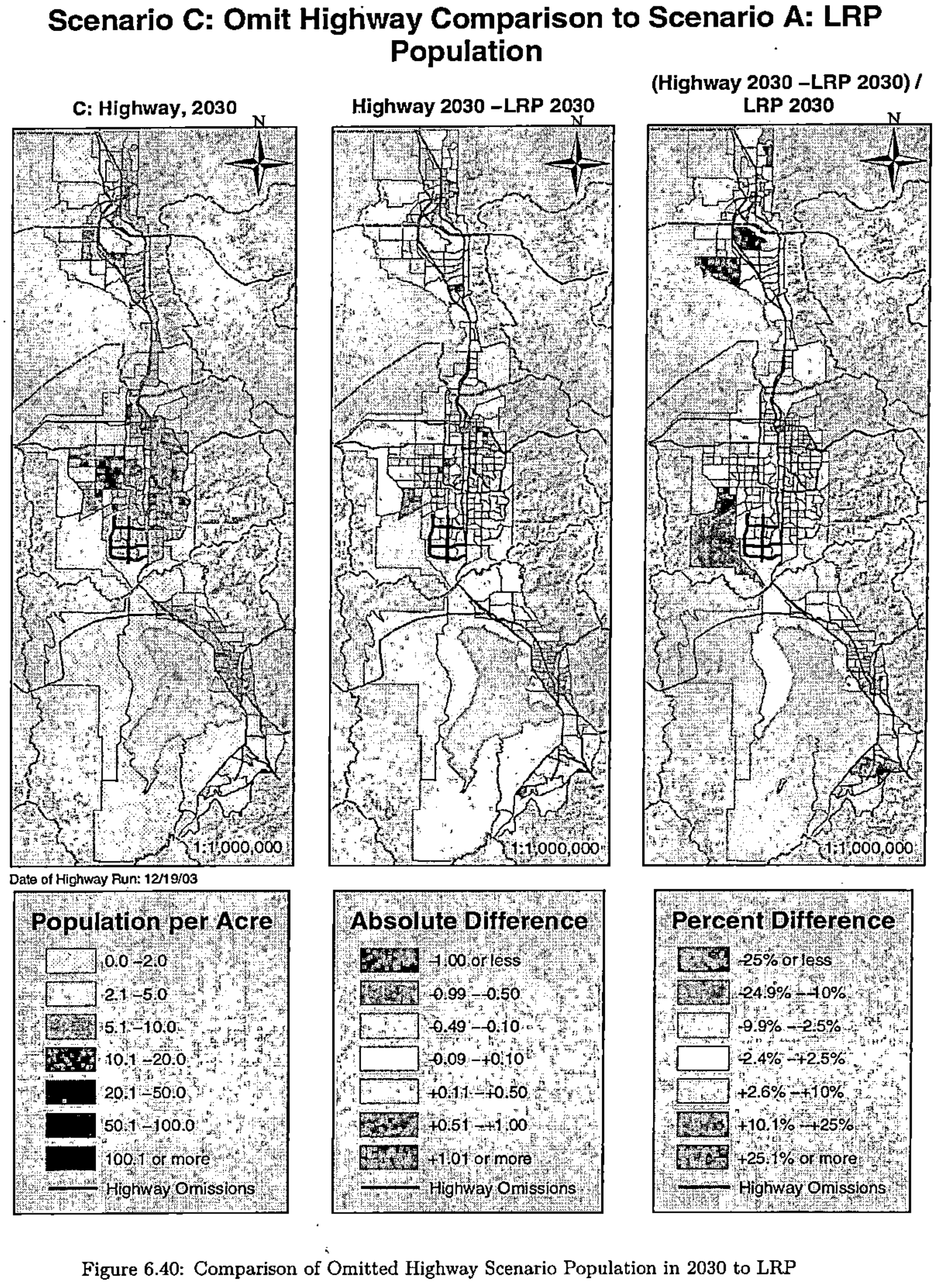

Figure 6.40: Comparison of Omitted Highway Scenario Population in 2030 to LRP

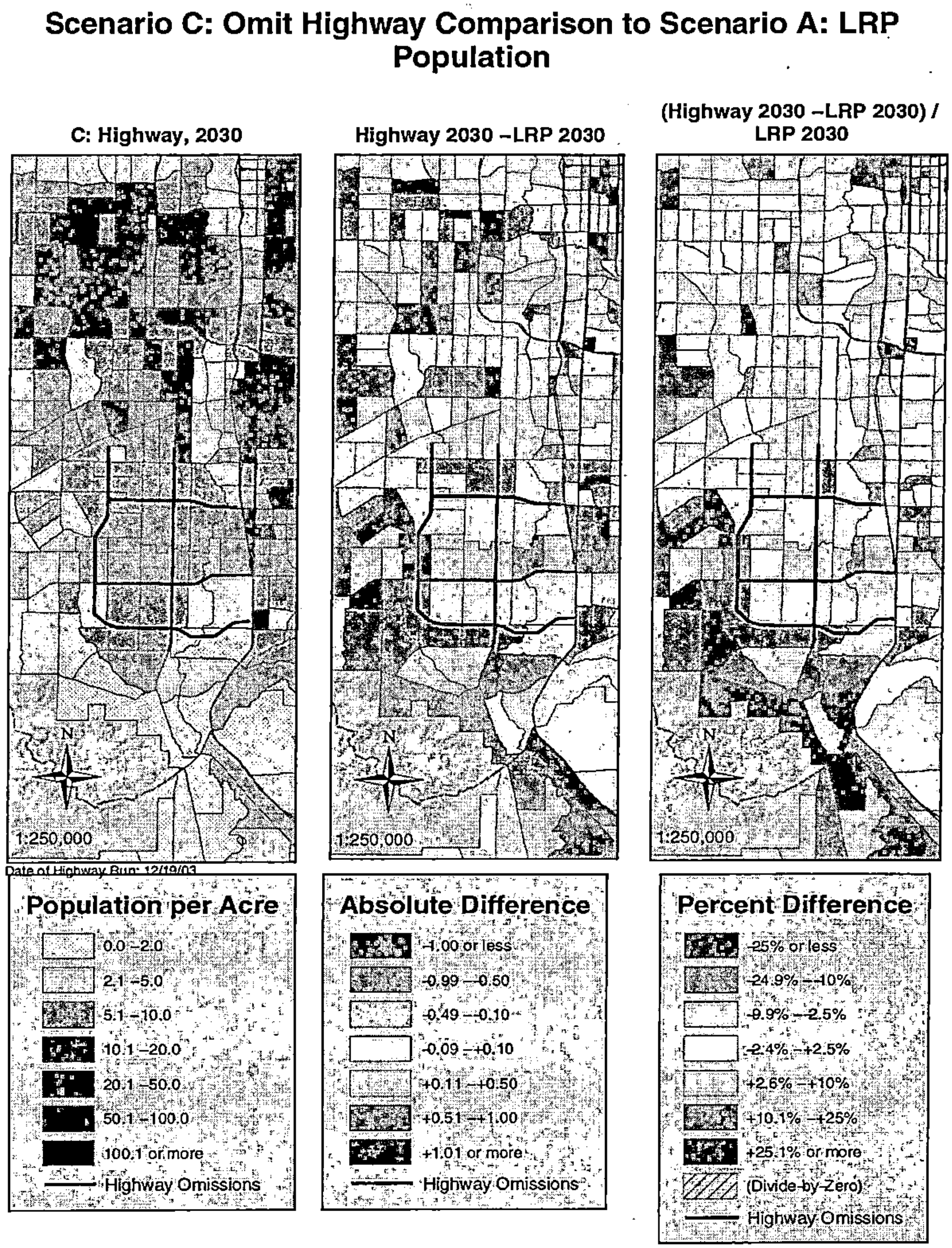

Figure 6.41: Comparison of Omitted Highway Scenario Population in 2030 to LRP (Zoomed In)

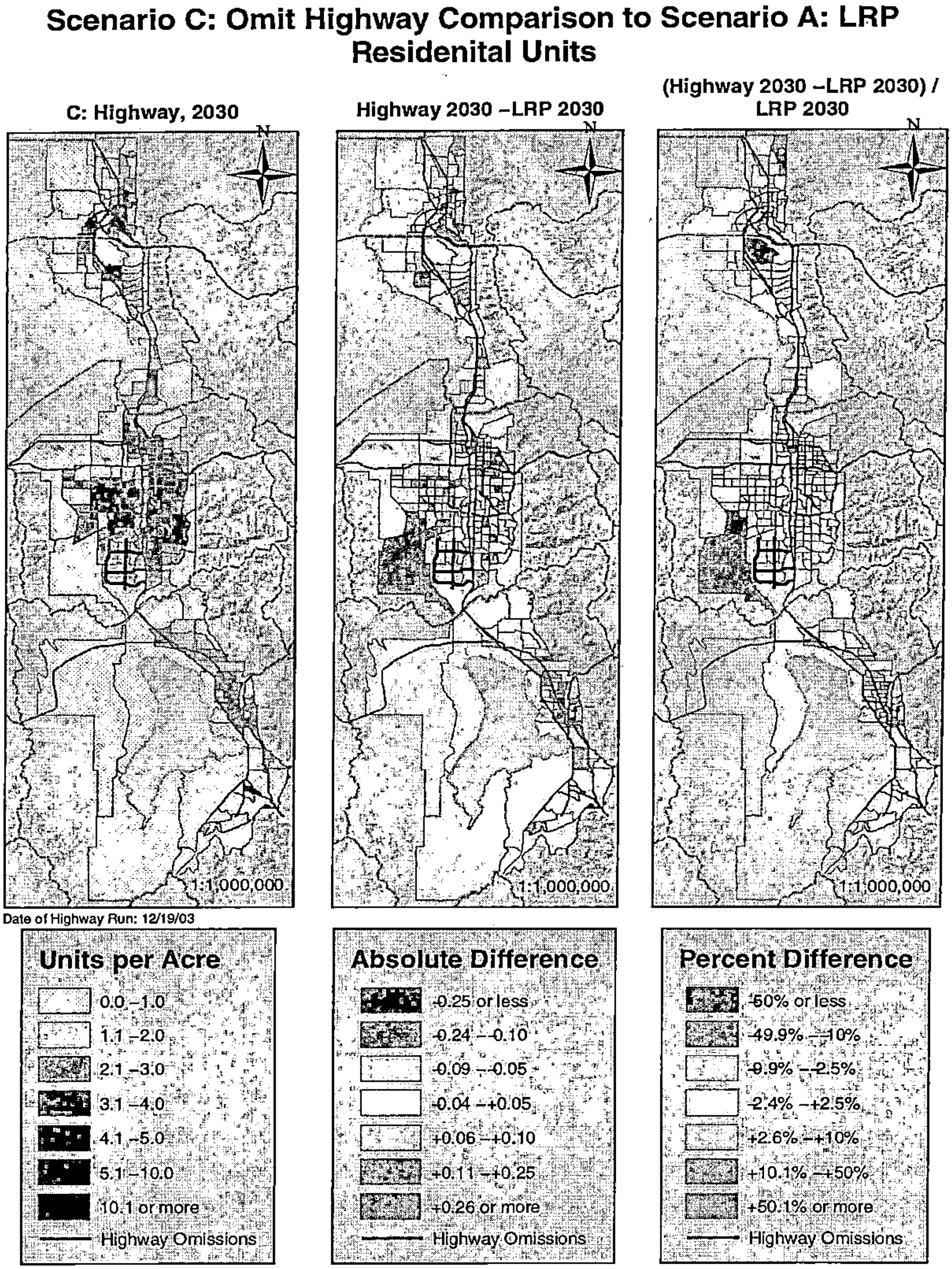

Figure 6.42: Comparison of Omitted Highway Scenario Housing Units in 2030 to LRP

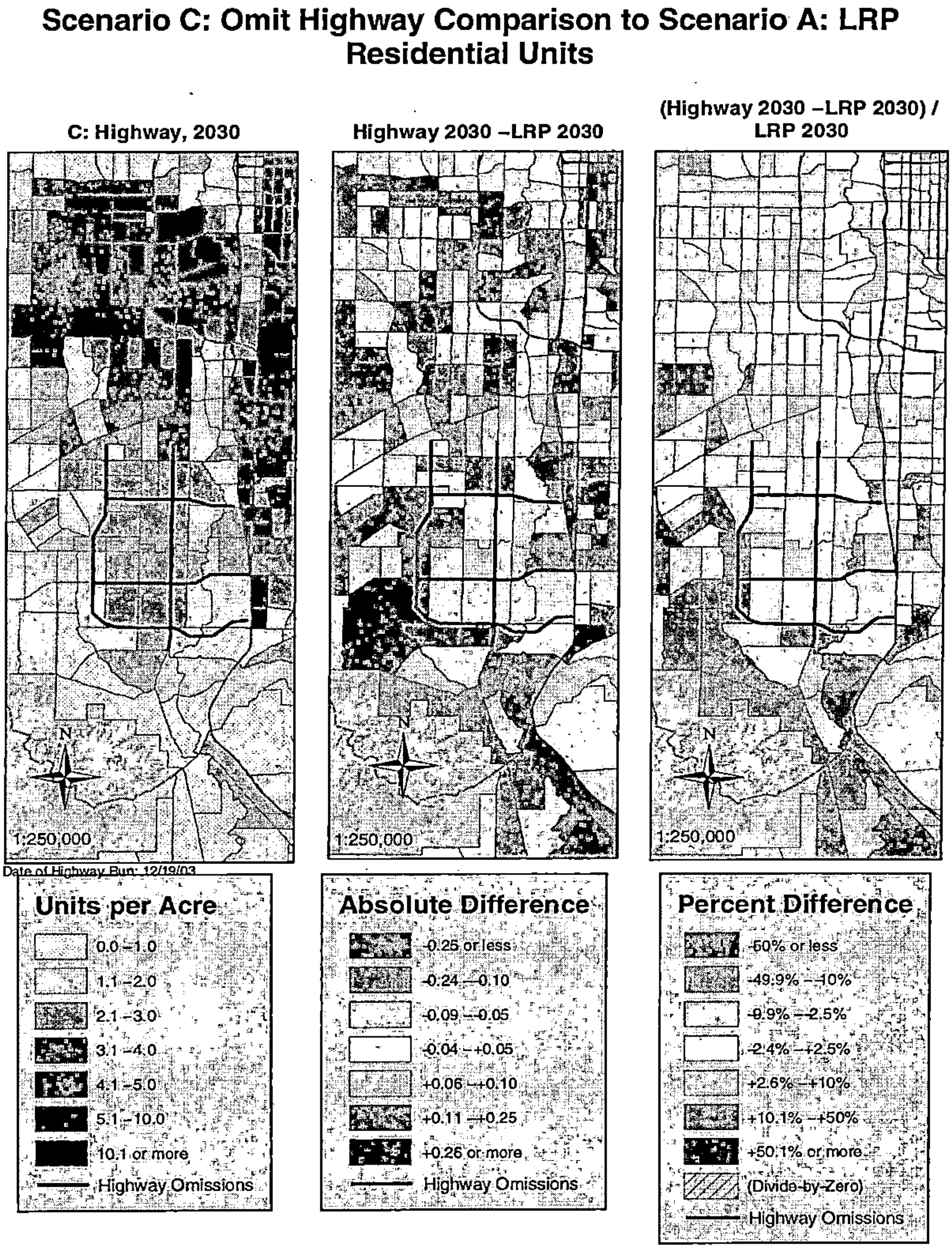

Figure 6.43: Comparison of Omitted Highway Scenario Housing Units in 2030 to LRP (Zoomed In)

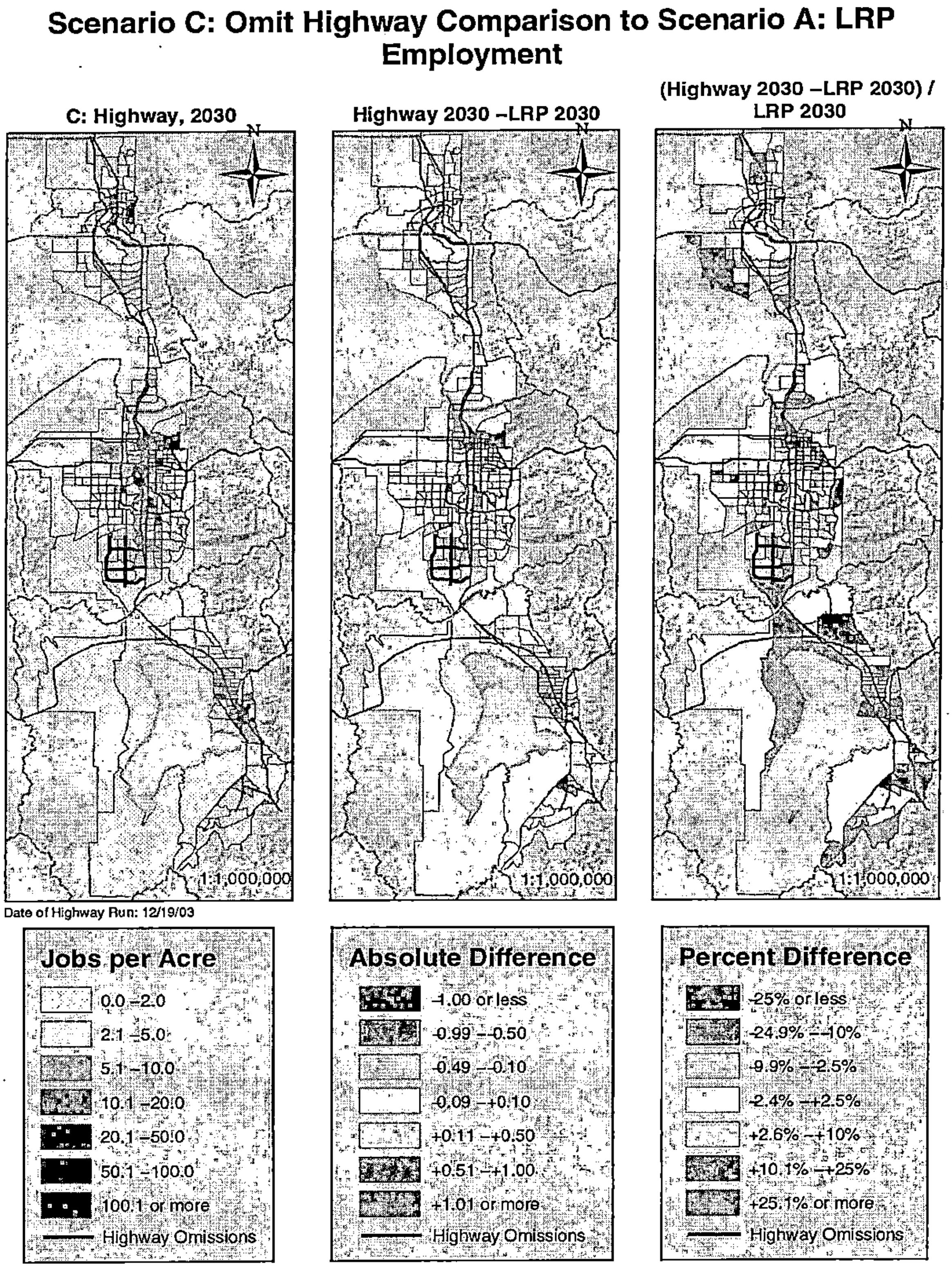

Figure 6.44: Comparison of Omitted Highway Scenario Jobs in 2030 to LRP

Scenario C: Omit Highway Comparison to Scenario A: LRP Employment

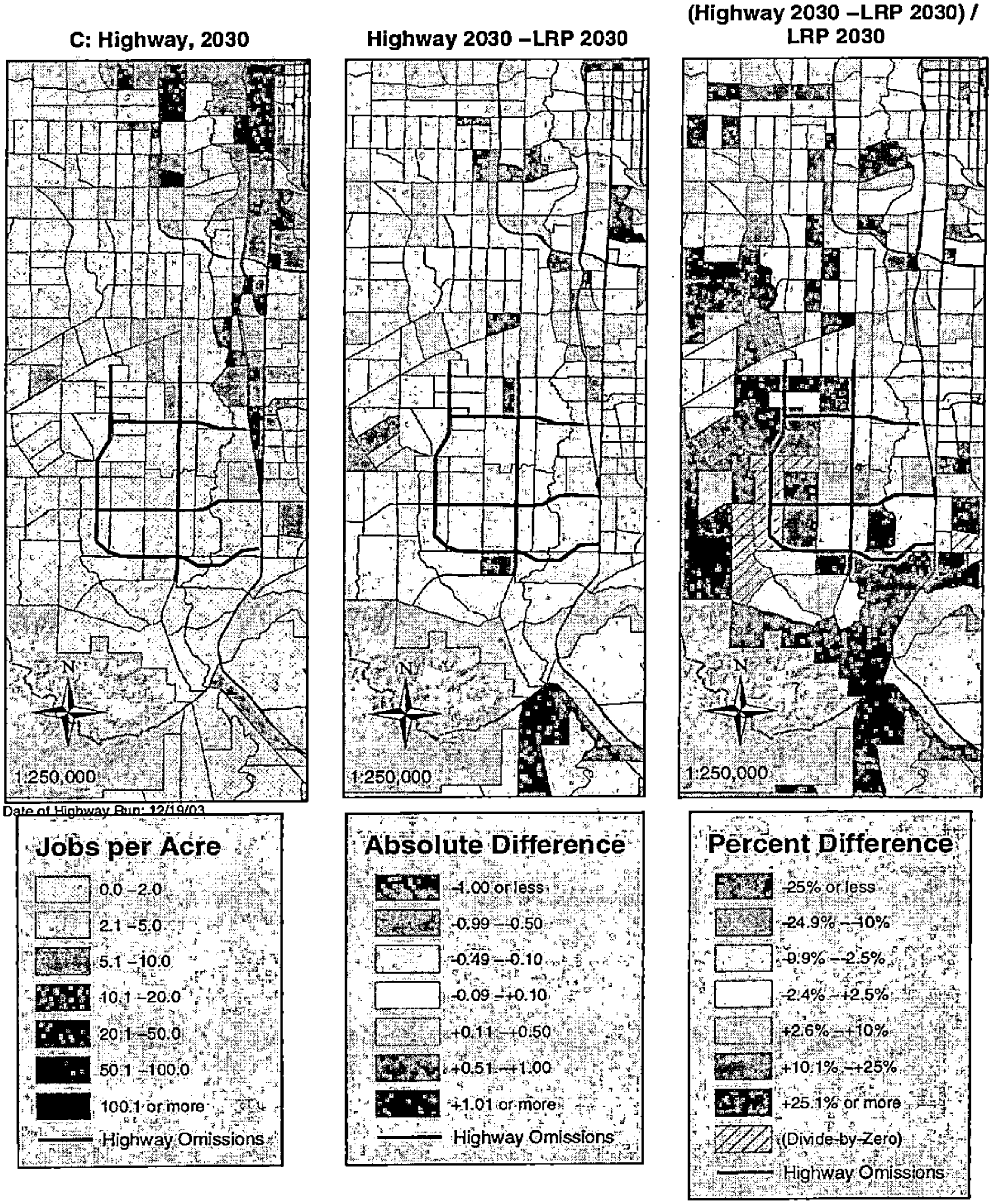

Figure 6.45: Comparison of Omitted Highway Scenario Jobs in 2030 to LRP (Zoomed In)

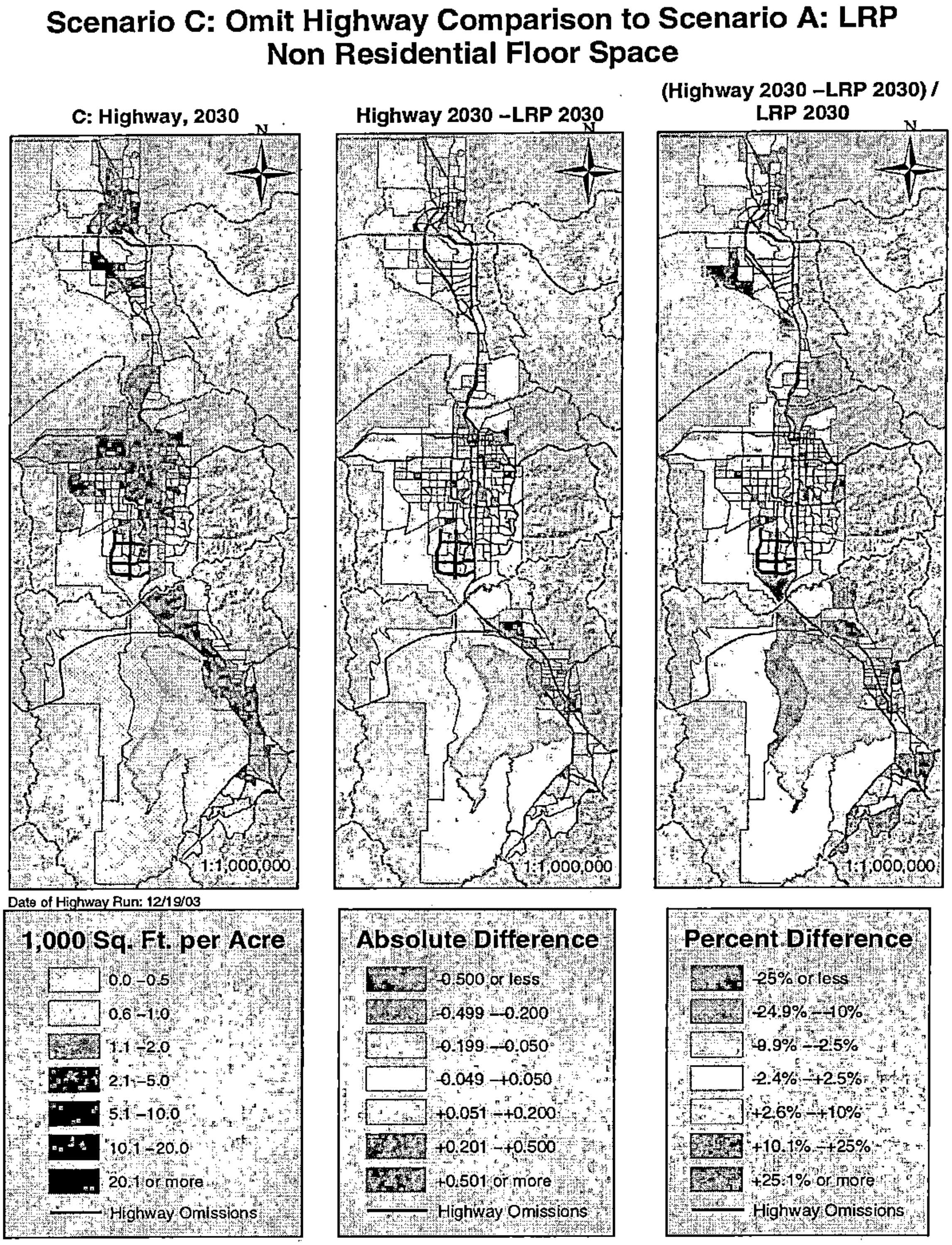

Figure 6.46: Comparison of Omitted Highway Scenario Non-residential SQFT in 2030 to LRP

Scenario C: Omit Highway Comparison to Scenario A: LRP Non-Residential Floor Space

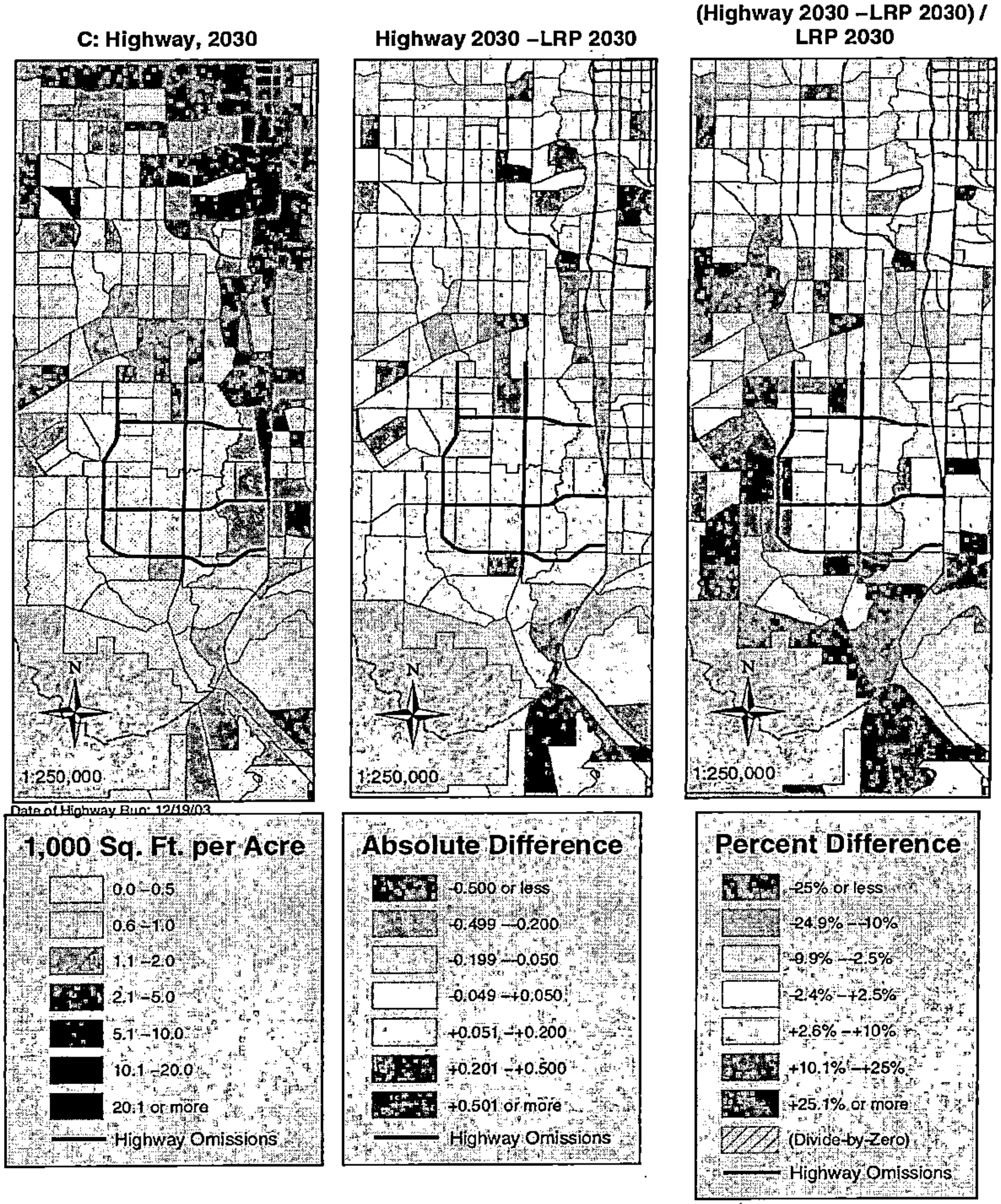

Figure 6.47: Comparison of Omitted Highway Scenario Non-residential SQFT in 2030 to LRP (Zoomed In)

6.5 Transit Alternative

This scenario removes a proposed transit facility from the LRP. The facility removed in this scenario is referred to locally as the mid-Jordan light rail extension. The line is shown in Figure X. Part of the line operates on track that currently has no service (southwest piece) and part on track with existing service. The extension (i.e. new track) is about 10 miles long (heading from southwest SL County to the existing light rail system in the center of the valley), but the entire length of the line is 25 miles long (heading ultimately to downtown SLC and the airport). We removed the entire line, not just the extension, which has the effect of providing poorer service where other lines exist (i.e. Norht/South through the center of the valley, and west from downtown to the airport). The mid-Jordan line is planned to operate at a 15-minute headway all day. In this scenario, where we remove the entire line, light rail service through the center of the valley will operate at 15-minute headways (instead of 7.5 with the mid-jordan line), and service to the airport will be at 15 minutes instead of 7.5.

Removing this line is expected to have affects both within the southwest corridor (where the extension is planned) and beyond (to a lesser extent) due to poorer rail service on track with existing service.

The results of removing the Mid-Jordan rail line are presented in Figures 6.48 through 6.59, and again with a zoomed-in view of the area immediately surrounding the projects in question in Figures 6.50 through 6.60.

The results of removing the Mid-Jordan LRT line show modest effects generally in the direction one would expect. Large effects would be unlikely from a single rail line extension where the mode share for transit is relatively low, and with the LRP containing extensive highway improvements in the same area. The key results observed in this scenario are:

- Lower accessibility along the corridor, and in the areas near the remainder of the LRT system to which this segment would have added ridership.
- Land price effects were diffuse, and not clearly evident.
- Differences in housing and population growth were modest, compared to the LRP scenario, and the net effect is not very clear. Some areas near the omitted Mid-Jordan line grew less than in the LRP run, but other zones nearby grew more.
- Employment growth appeared less in the core areas of Salt Lake County served by the remainder of the LRT line, and the zoomed-in map in Figure 6.45 shows a pattern of moderately lower job gains near the omitted Mid-Jordan line, compared to the LRP run.

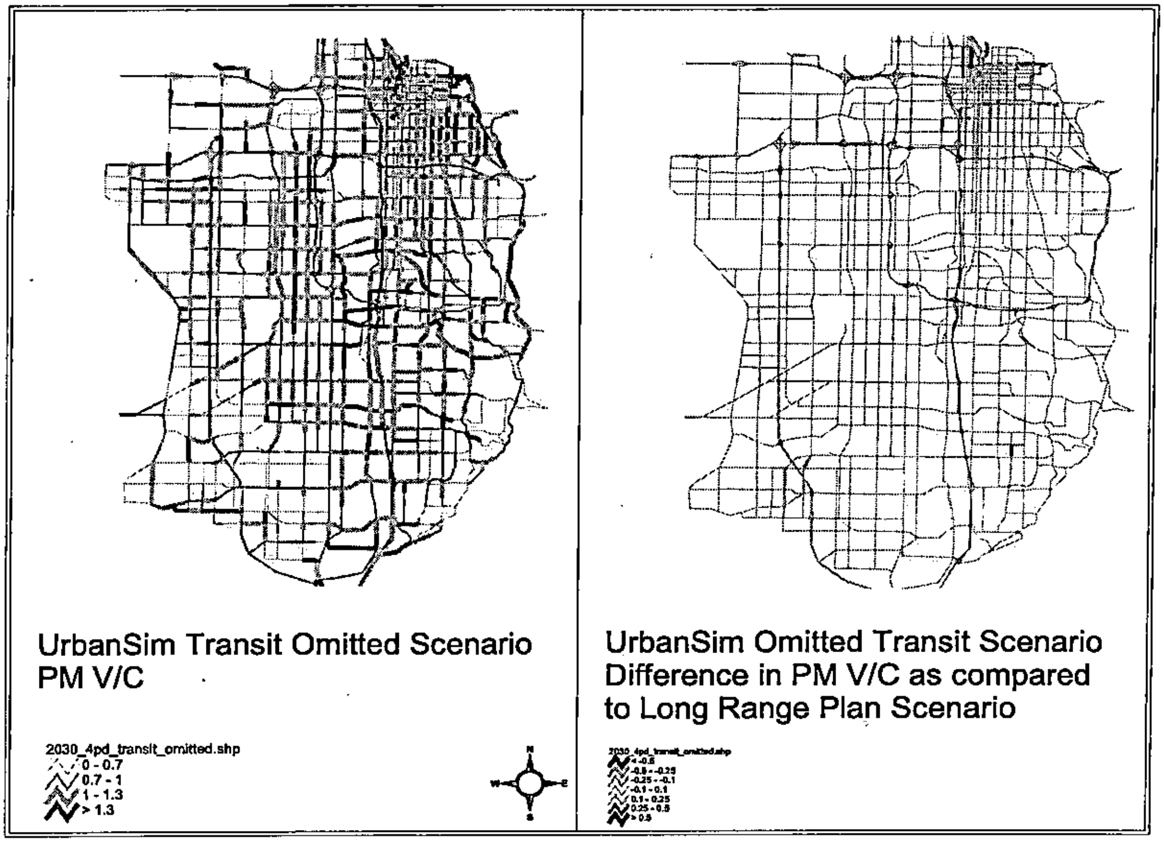

Figure 6.48: Comparison of Transit Scenario PM Peak Volume to Capacity Ratio to LRP

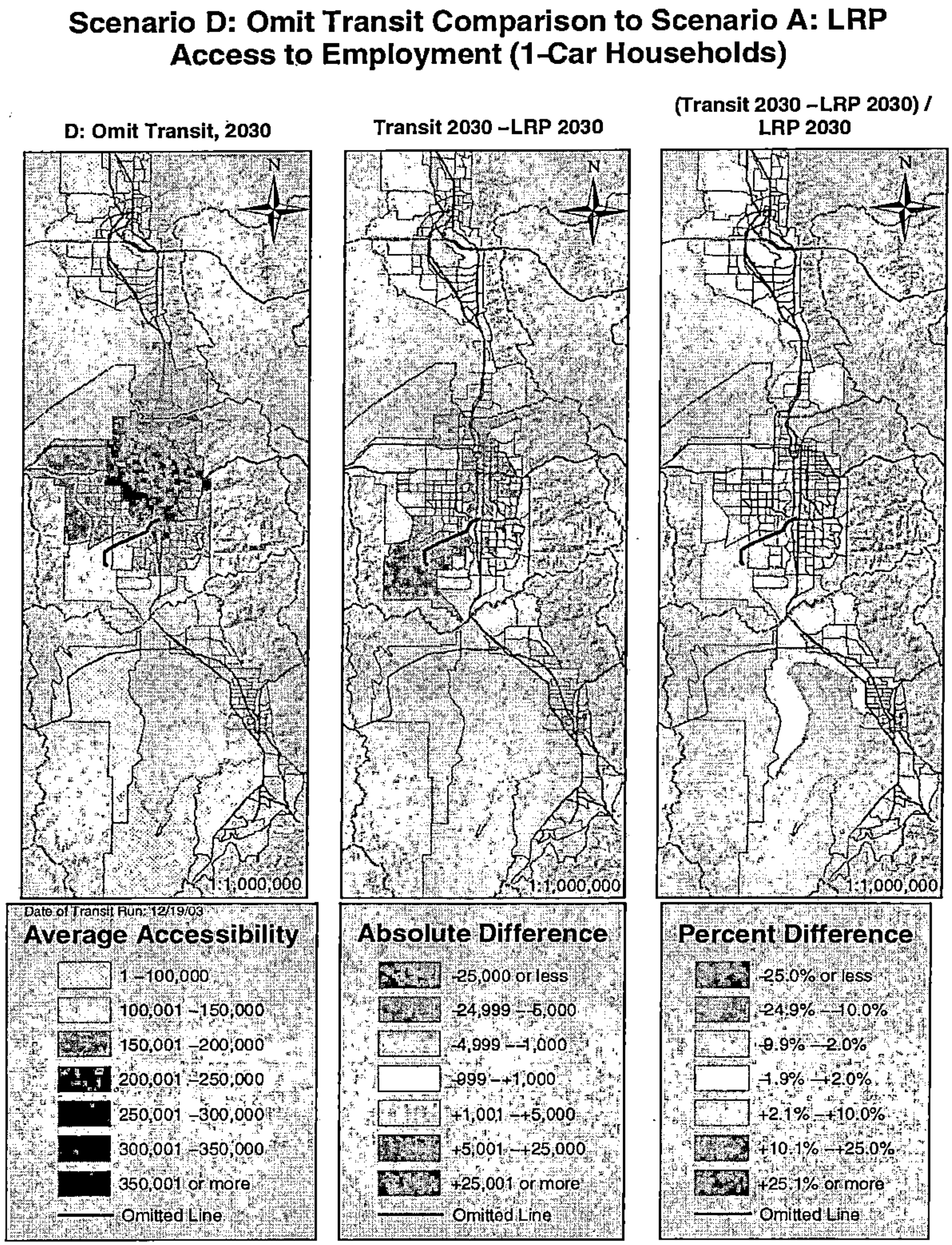

Figure 6.49: Comparison of Transit Scenario Accessibility to Employment in 2030 to LRP

Scenario D: Omit Transit Comparison to Scenario A: LRP Access to Employment (1-Car Households)

D: Transit, 2030 | Transit 2030 – LRP 2030 | (Transit 2030 – LRP 2030) / LRP 2030

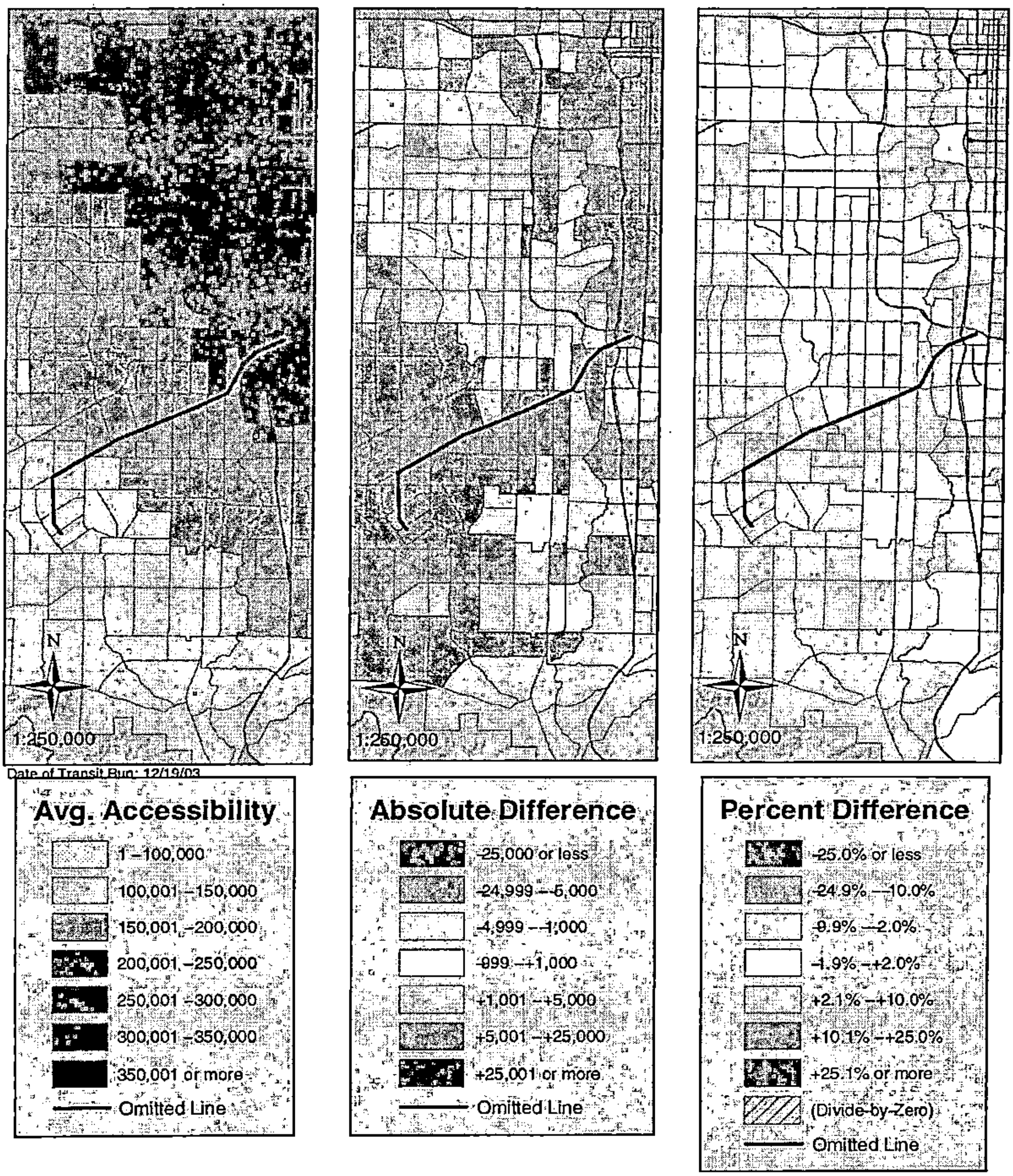

Figure 6.50: Comparison of Transit Scenario Accessibility to Employment in 2030 to LRP (Zoomed In)

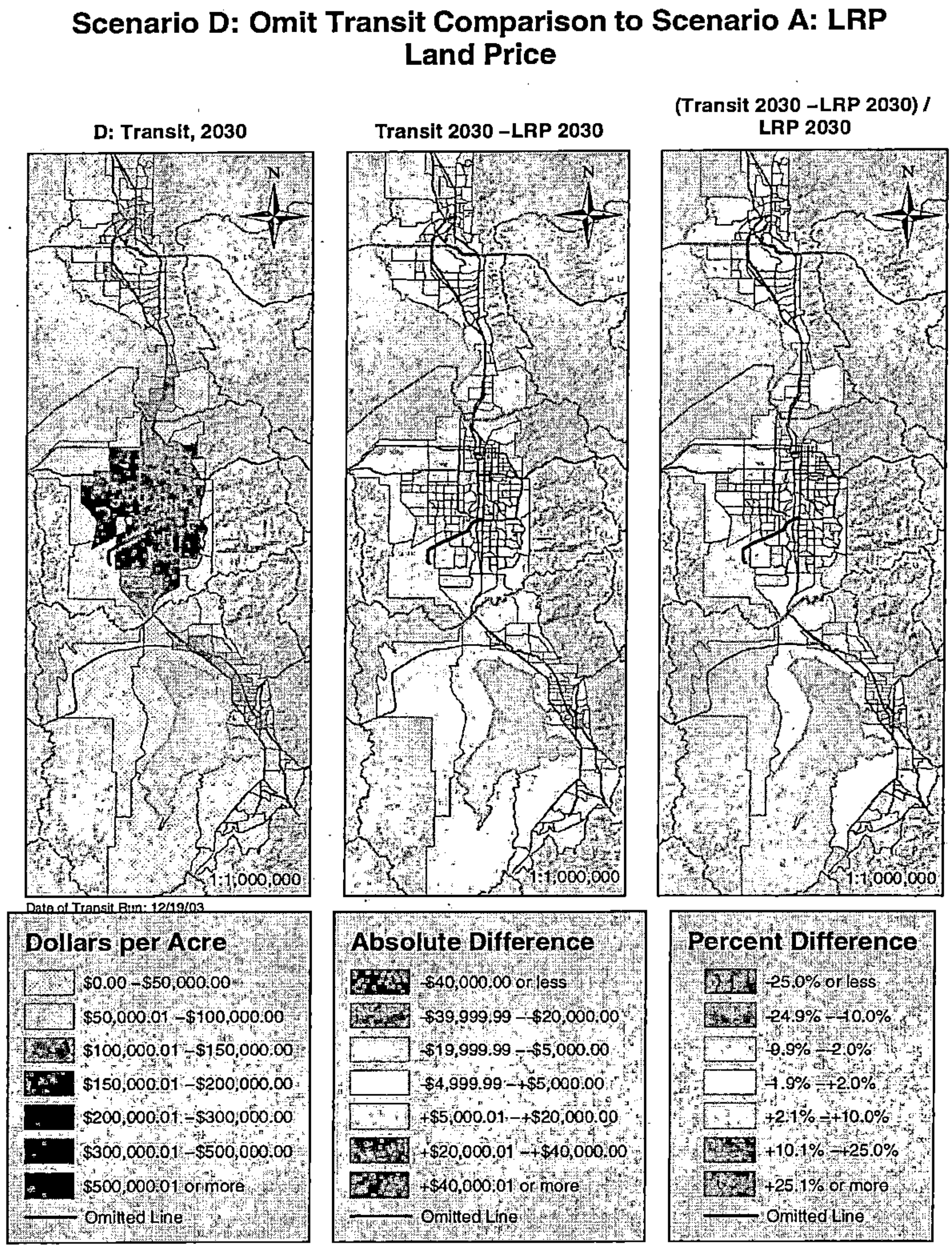

Figure 6.51: Comparison of Transit Scenario Land Price in 2030 to LRP

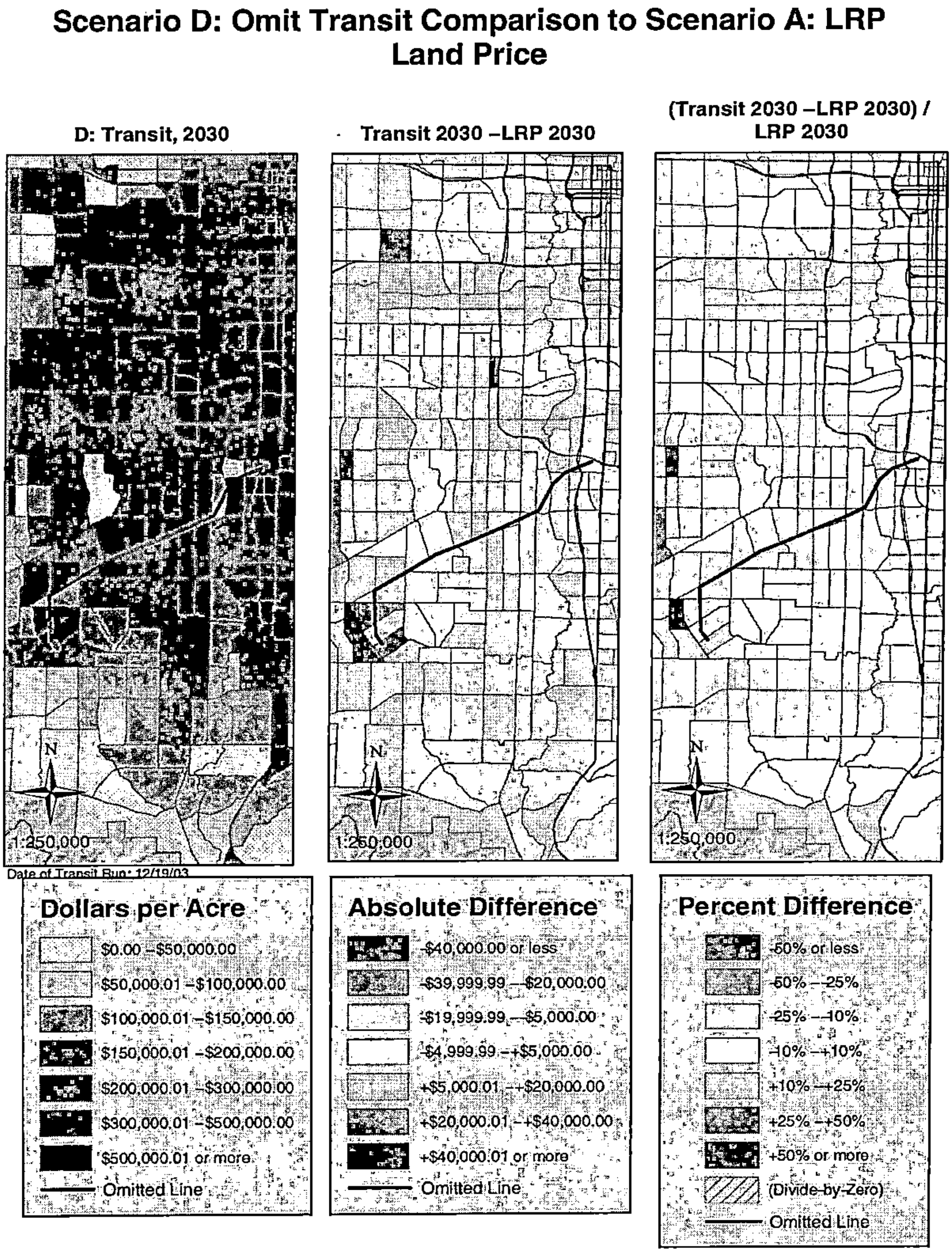

Figure 6.52: Comparison of Transit Scenario Land Price in 2030 to LRP (Zoomed In)

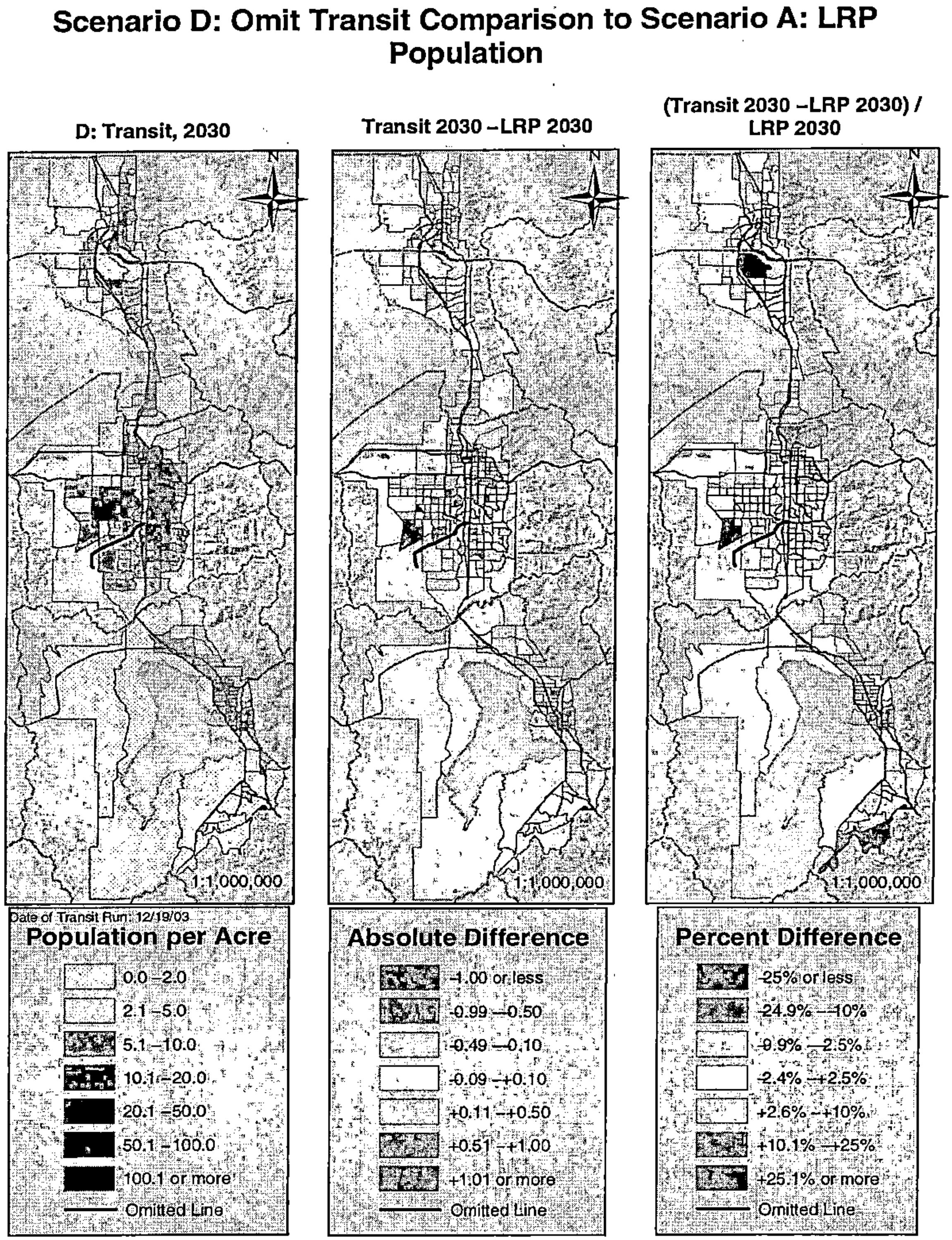

Figure 6.53: Comparison of Transit Scenario Population in 2030 to LRP

Scenario D: Omit Transit Comparison to Scenario A: LRP Population

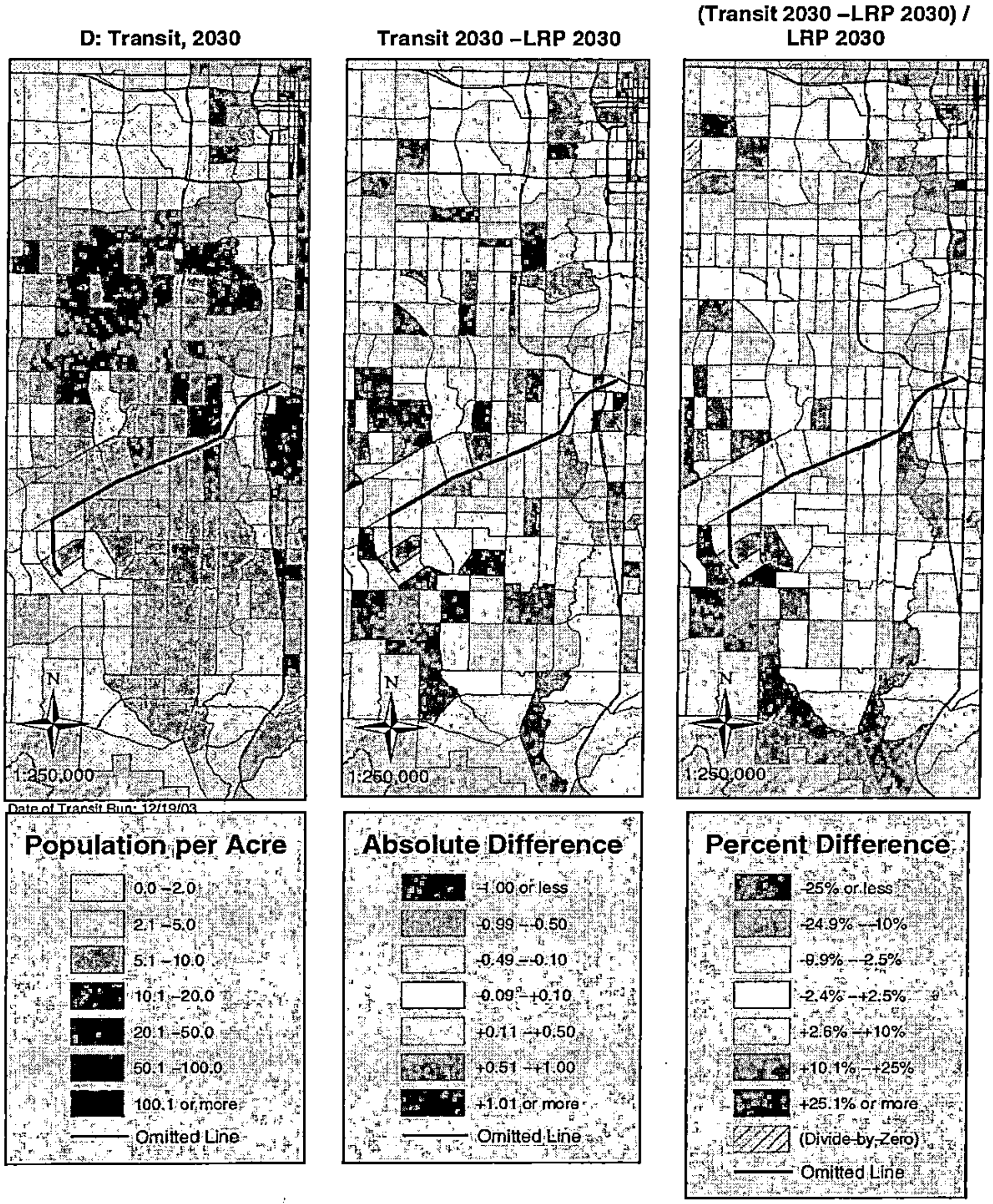

Figure 6.54: Comparison of Transit Scenario Population in 2030 to LRP (Zoomed In)

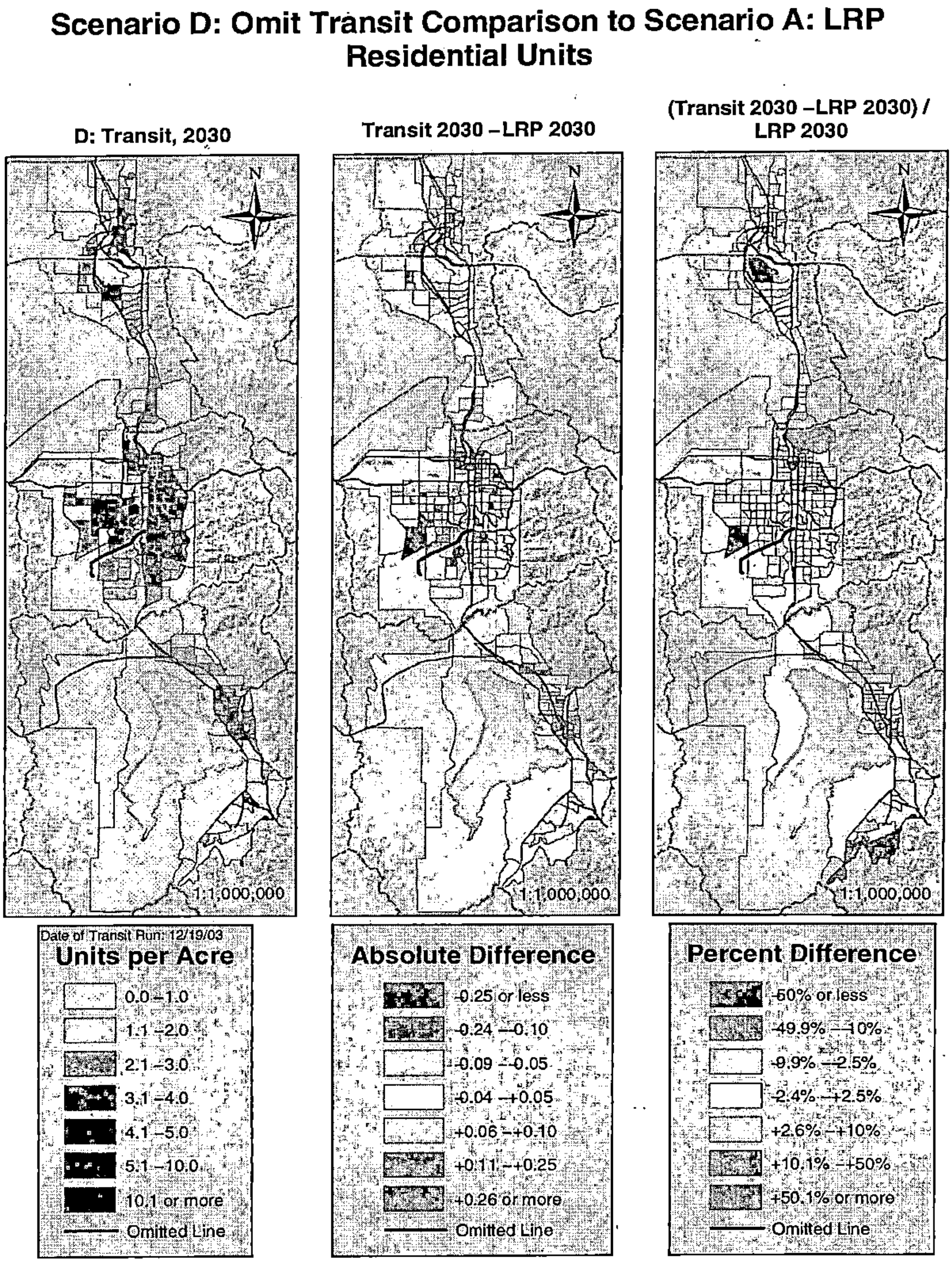

Figure 6.55: Comparison of Transit Scenario Housing Units in 2030 to LRP

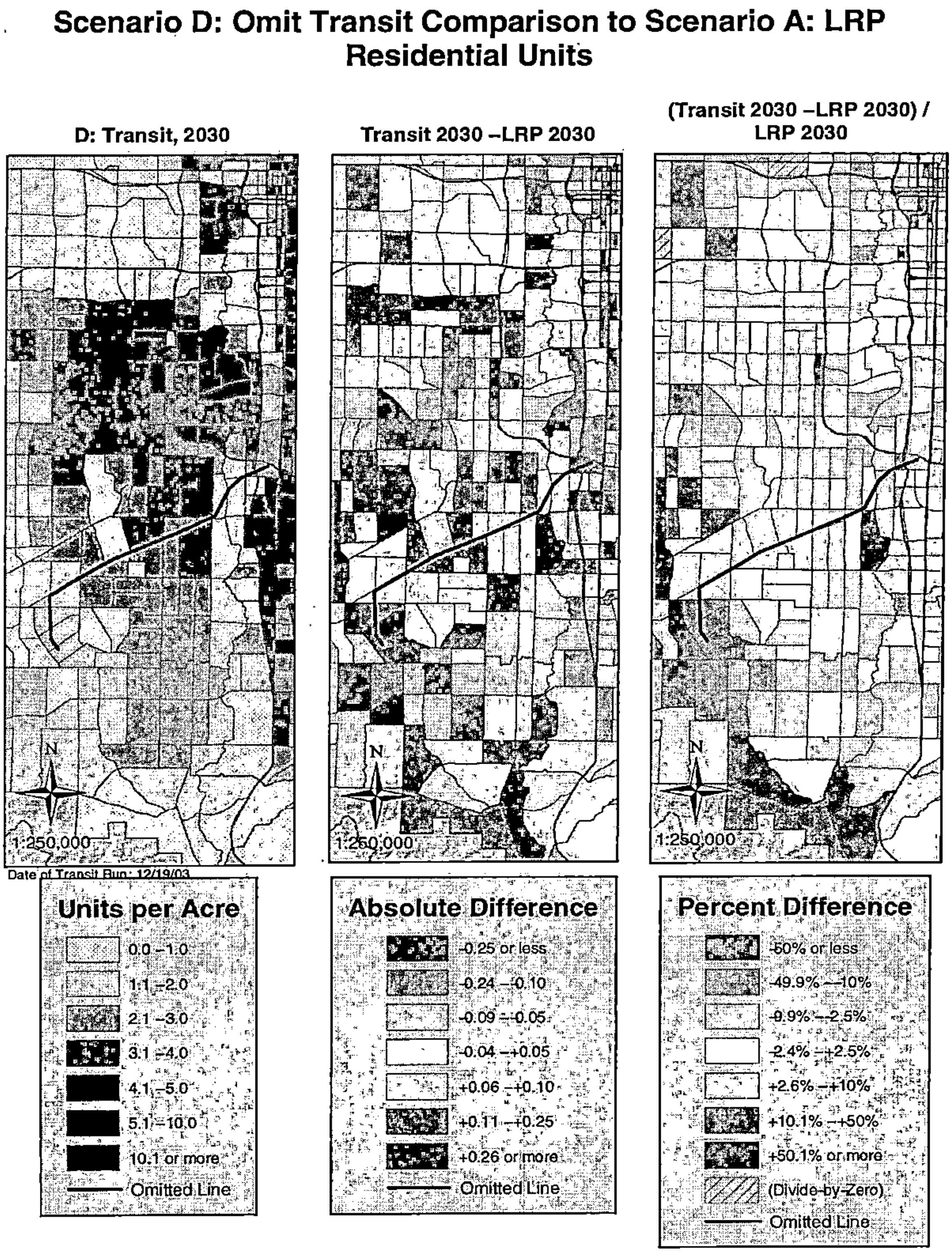

Figure 6.56: Comparison of Transit Scenario Housing Units in 2030 to LRP (Zoomed In)

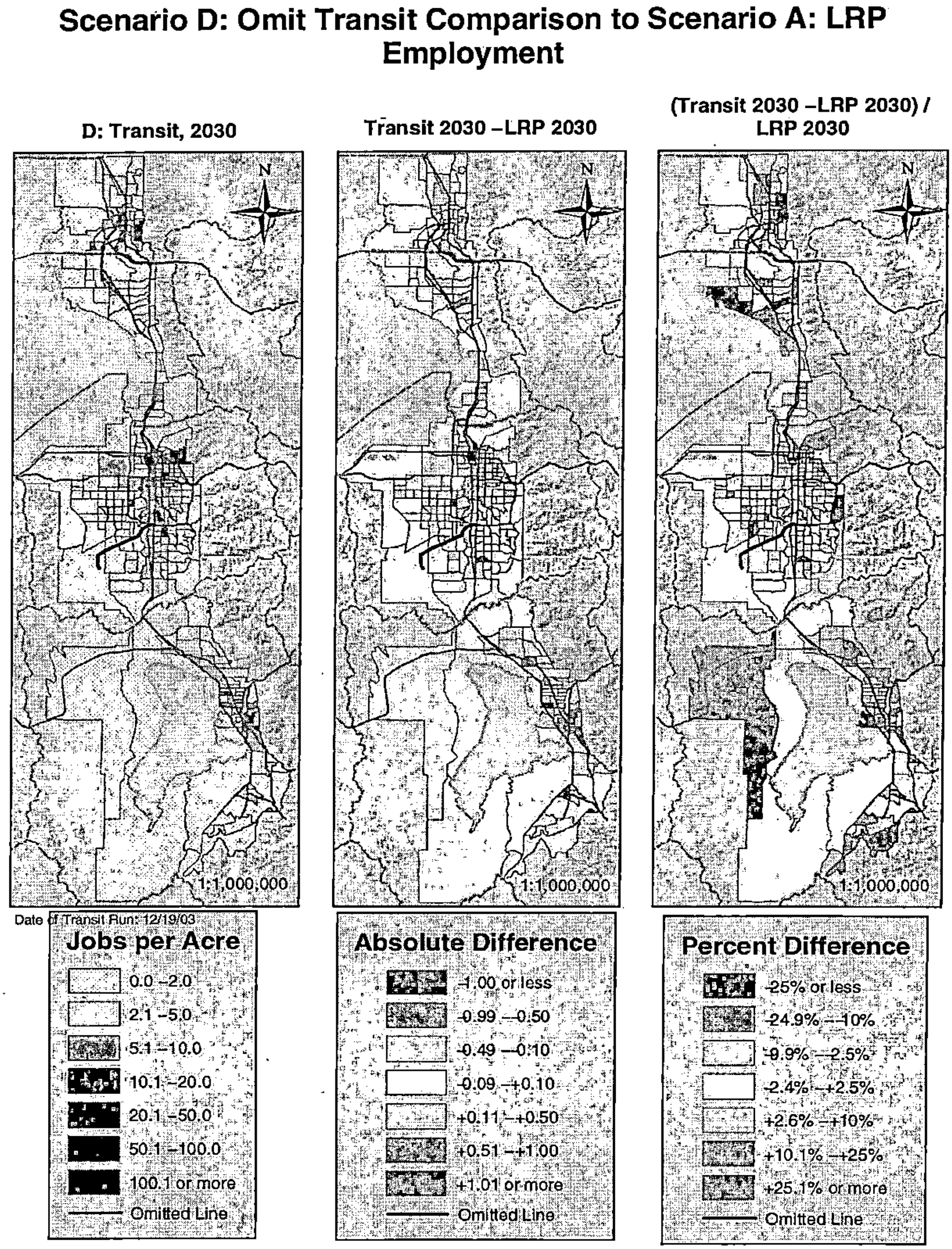

Figure 6.57: Comparison of Transit Scenario Jobs in 2030 to LRP

Scenario D: Omit Transit Comparison to Scenario A: LRP Employment

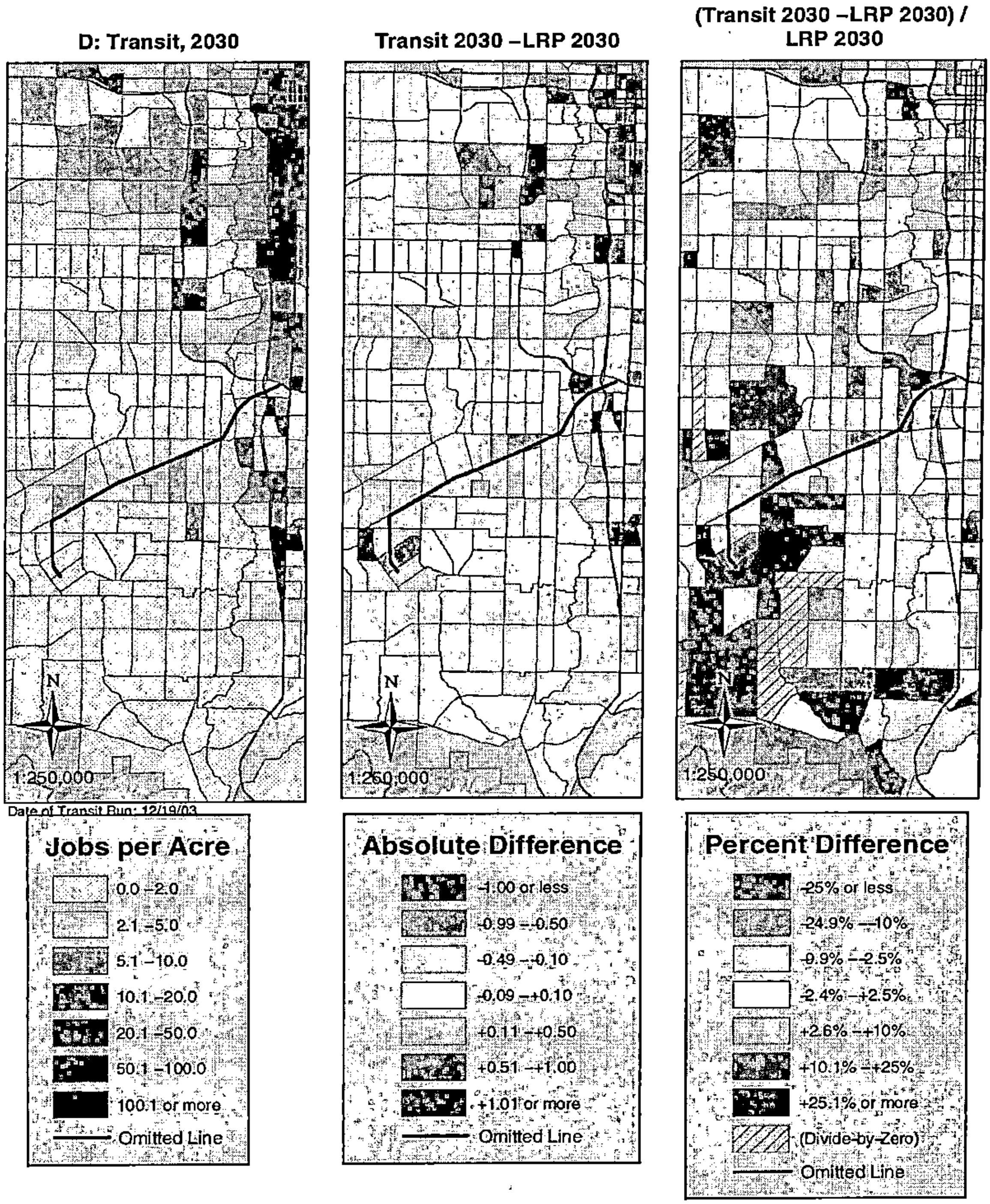

Figure 6.58: Comparison of Transit Scenario Jobs in 2030 to LRP (Zoomed In)

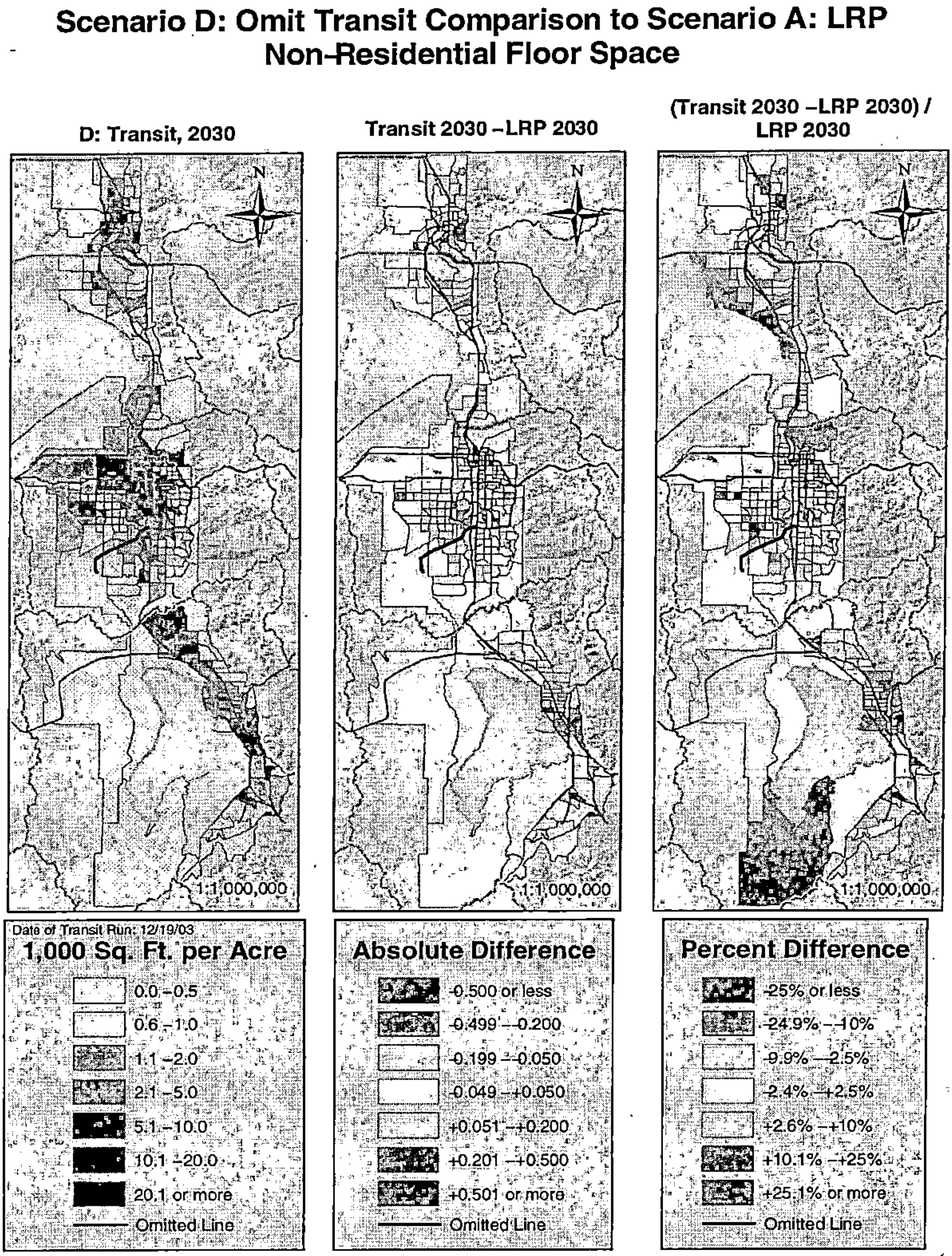

Figure 6.59: Comparison of Transit Scenario Non-residential SQFT in 2030 to LRP

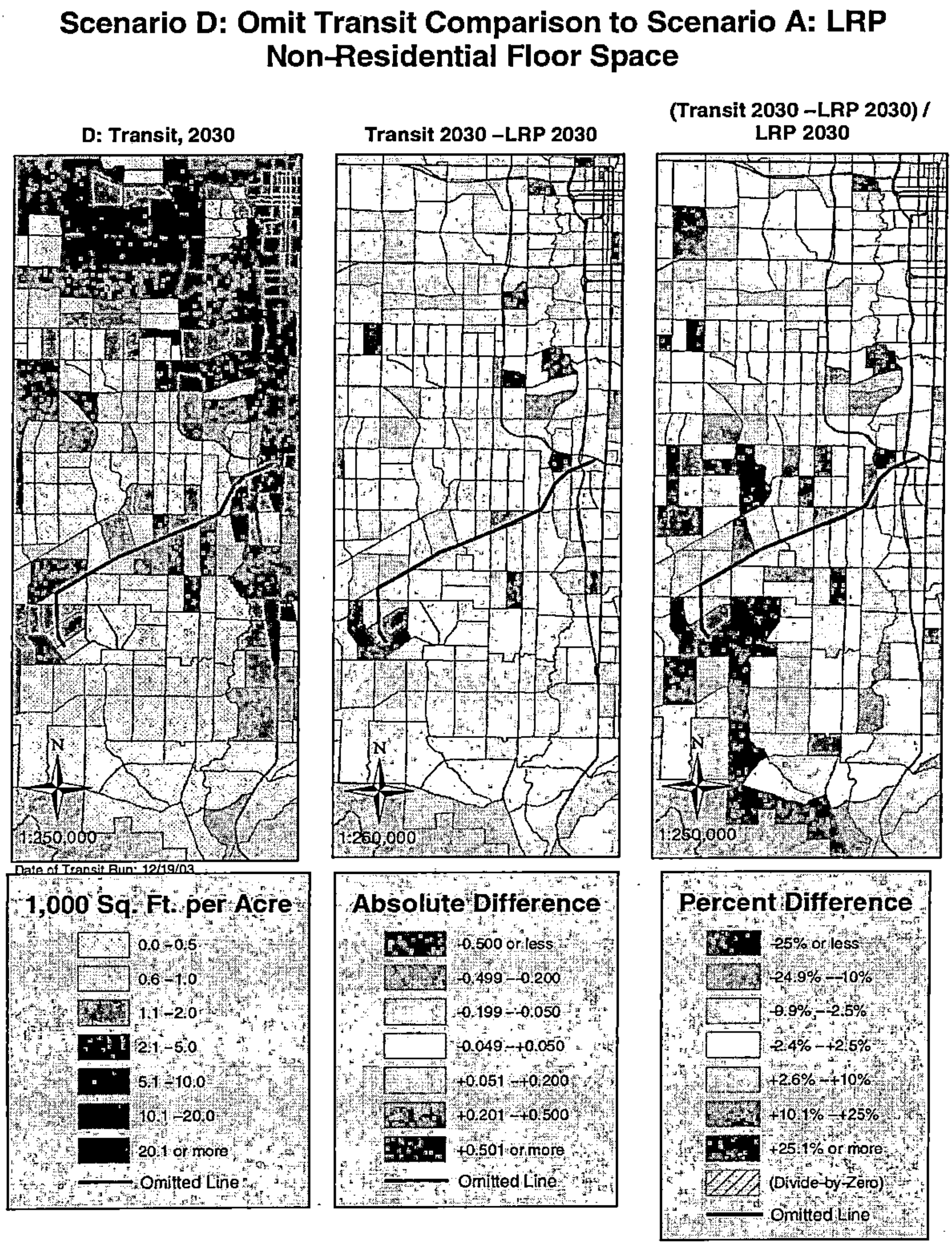

Figure 6.60: Comparison of Transit Scenario Non-residential SQFT in 2030 to LRP (Zoomed In)

6.6 Parking Cost Alternative

Data on downtown SLC workers travel behavior from a recent WFRC survey indicates that only 50% of downtown workers have to pay for parking (including those who did not drive). For those who have to pay for parking, the cost of parking varies from \$60-100/month, or roughly \$3-5 per day. This is a very low parking cost, compared with other cities. To apply the mode choice model, the average daily parking cost is divided by 2 (to get a per trip cost), and those that do not have to pay for parking are afctored in to get an average per-trip parking cost that varies from \$1.25-\$1.80 for zones with parking costs (some entire zones have free parking).

This scenario assumed a \$1.50 per trip increase in parking cost for all zones in the Salt Lake City CBD, even if the current cost for parking is 0. This approximates a doubling of parking costs (\$60 per month) for work trips.

For non-work trips, a \$1.00 per trip increase in parking cost is assumed in all zones. In reality, there are many zones without parking fees and a couple downtown malls offer free parking for the first 1-2 hours. Further, the mayor of SLC has added several hundred free parking spaces in downtown in the past year.

The results of imposing these parking costs are presented in Figures 6.61 through 6.72, and again with a zoomed-in view of the area immediately surrounding the projects in question in Figures 6.63 through 6.73.

The results of this scenario show modest response to the imposition of higher parking costs, generally in the direction that would be expected:

- Accessibility was modestly reduced in the areas affected by parking cost increases.
- Land price effects were not clearly visible.
- There is less population growth in the core area of Salt Lake City, and greater growth in population and residential units in south and southwest Salt Lake County than in the LRP, suggesting that some residential location is being pushed out from high-cost parking areas.
- Employment within downtown is also lower than in the LRP scenario.
- As with other alternatives that reduced accessibility, there was a diffused reduction in real estate development in this scenario.
- The parking cost scenario showed generally similar travel results to the LRP, but the transit mode share is higher than all but the UGB scenario over most of the forecast horizon.

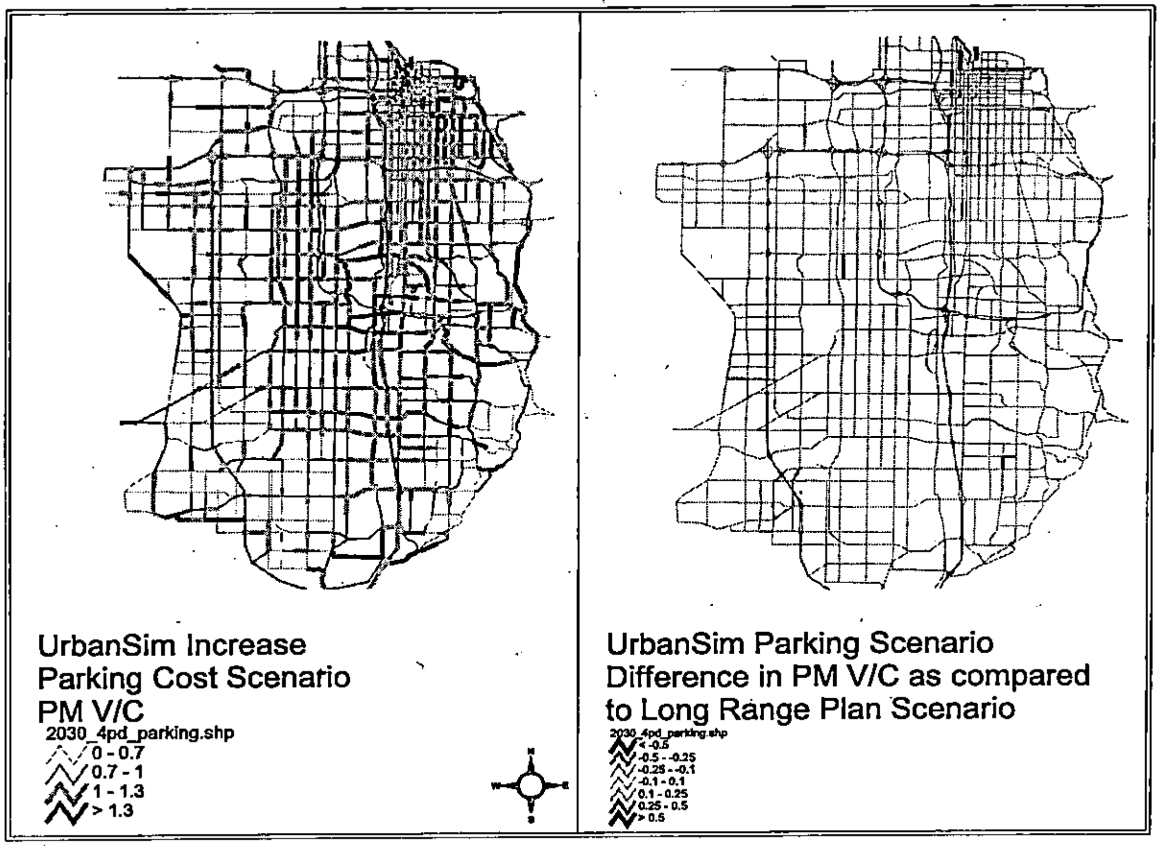

Figure 6.61: Comparison of Parking Scenario PM Peak Volume to Capacity Ratio to LRP

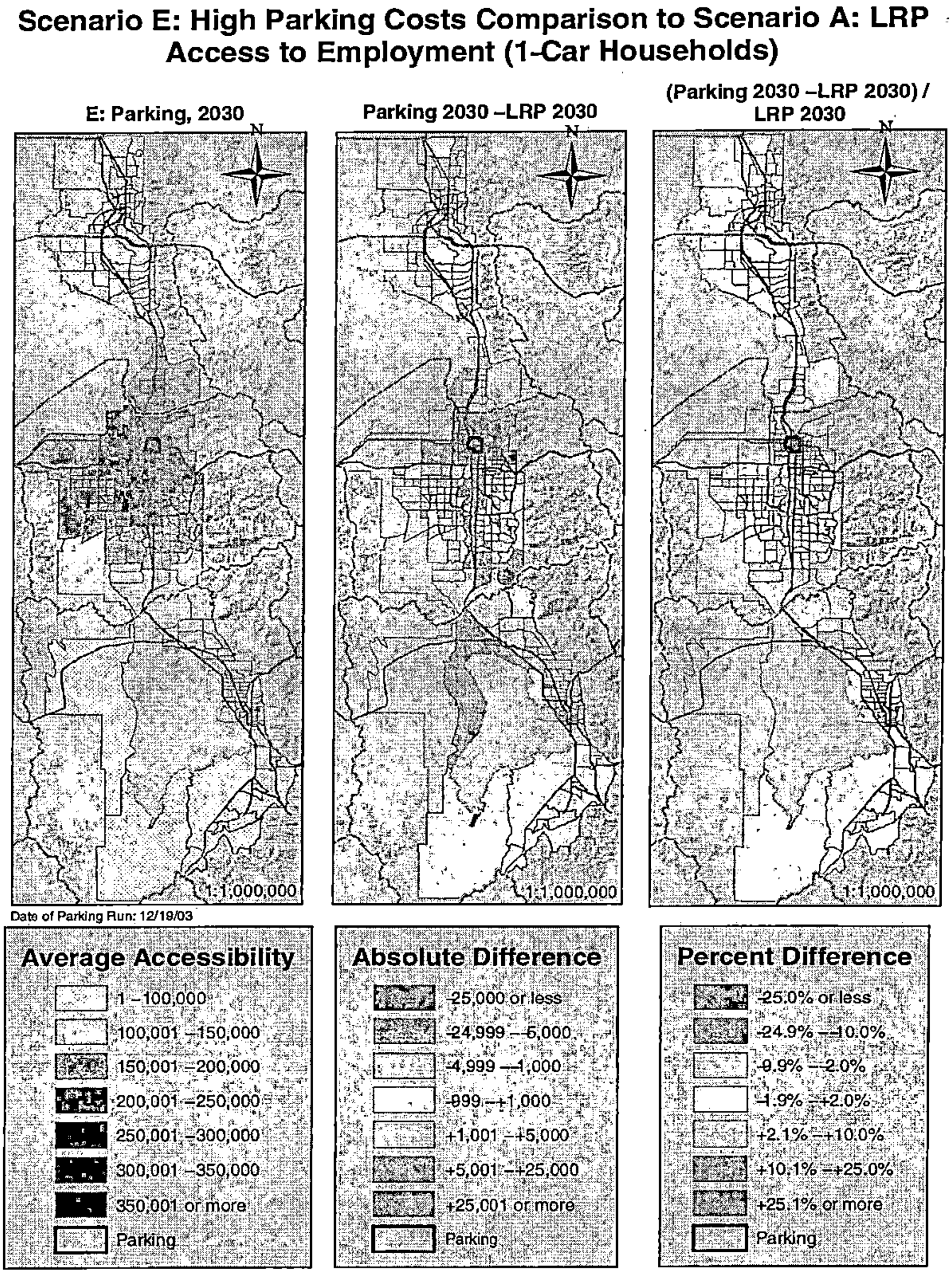

Figure 6.62: Comparison of Parking Scenario Accessibility to Employment in 2030 to LRP

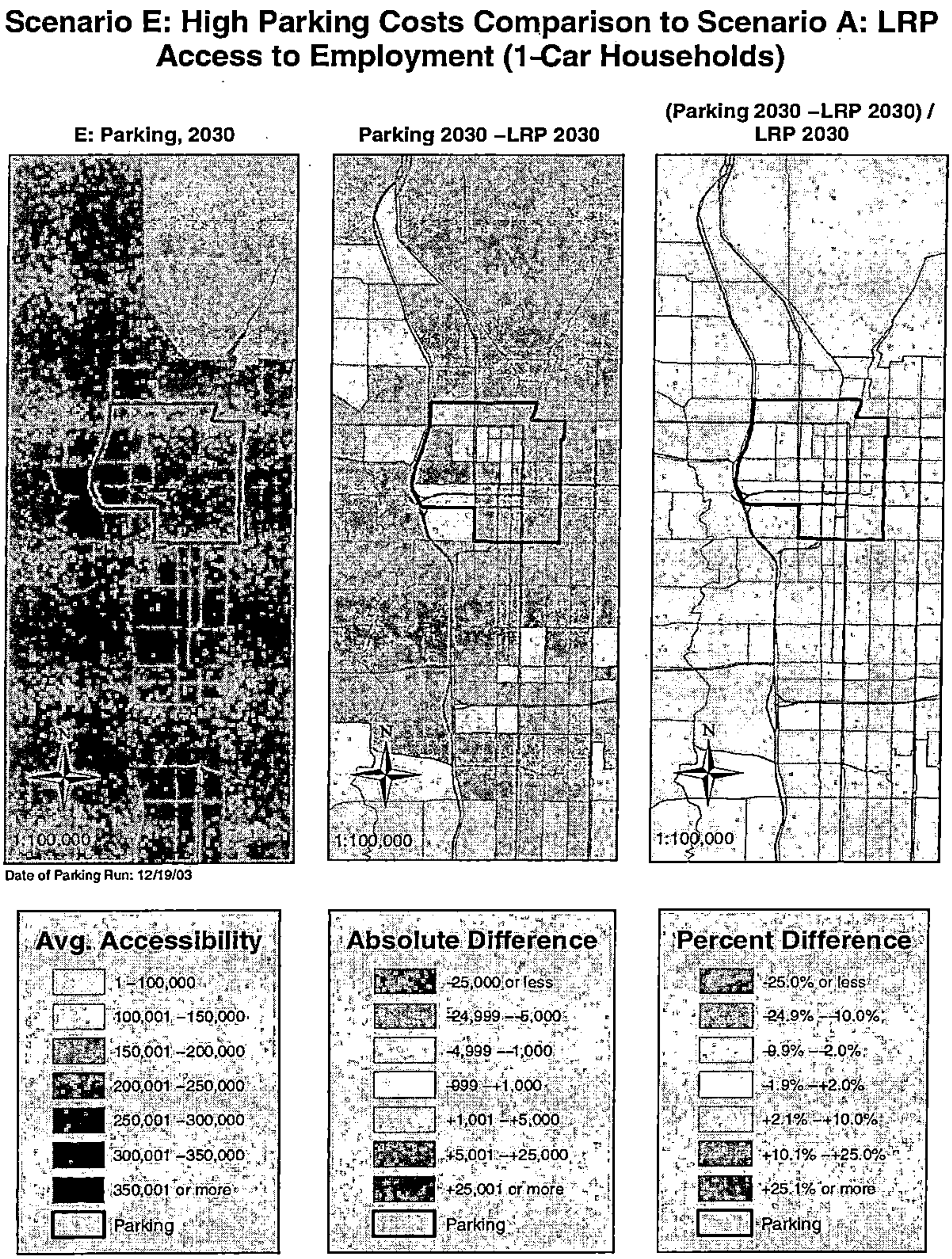

Figure 6.63: Comparison of Parking Scenario Accessibility to Employment in 2030 to LRP (Zoomed In)

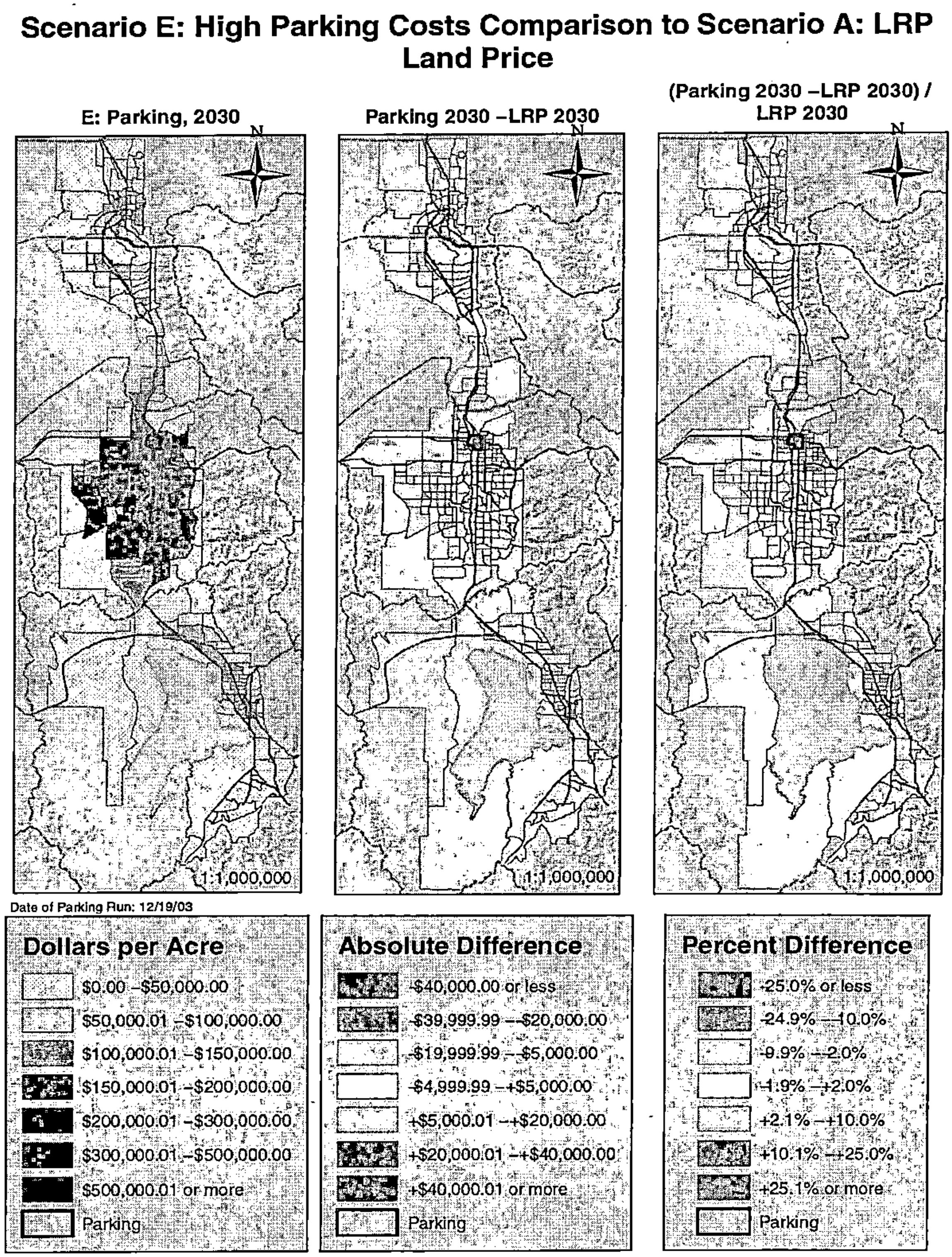

Figure 6.64: Comparison of Parking Scenario Land Price in 2030 to LRP

Scenario E: High Parking Costs Comparison to Scenario A: LRP Land Price

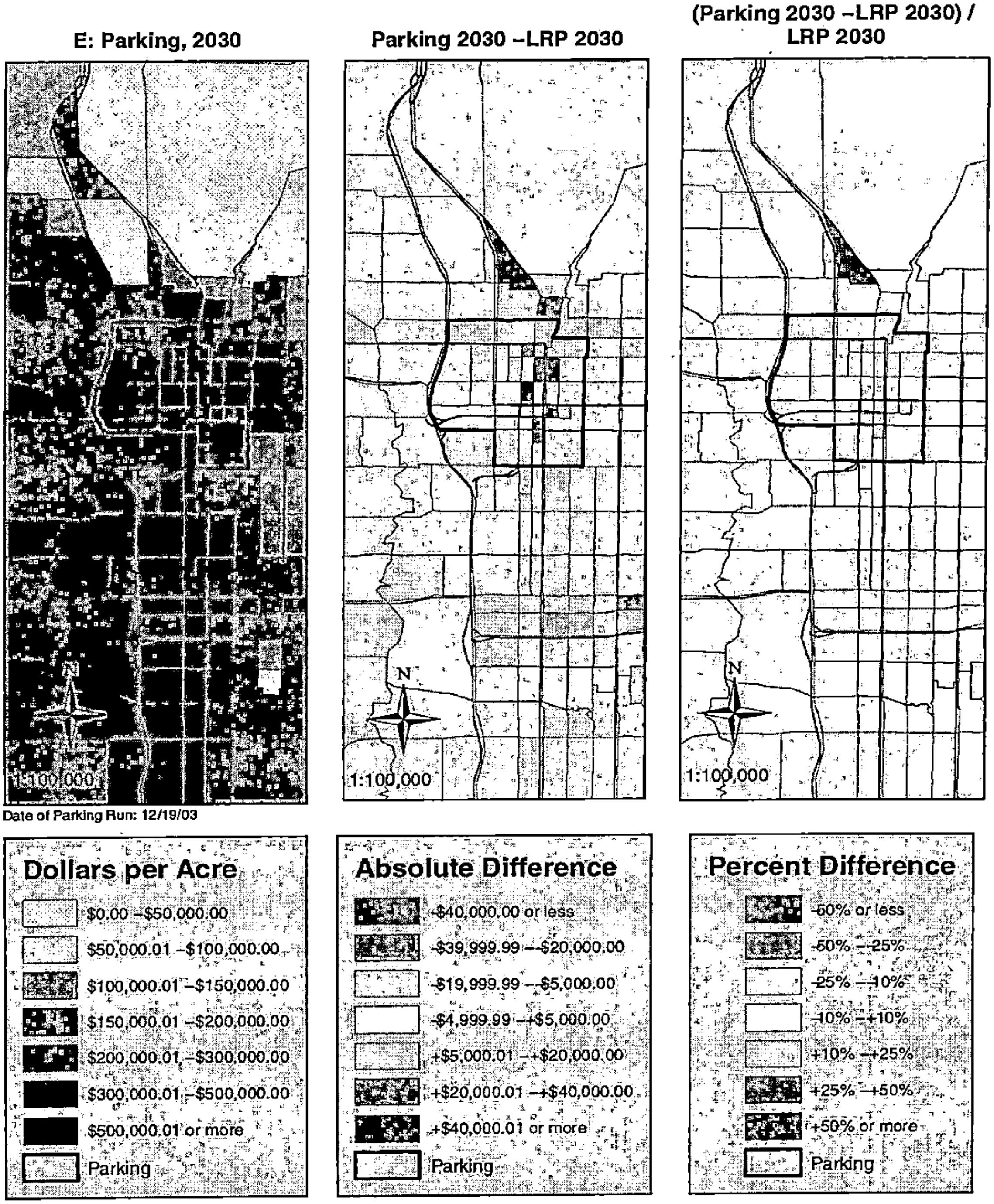

Figure 6.65: Comparison of Parking Scenario Land Price in 2030 to LRP (Zoomed In)

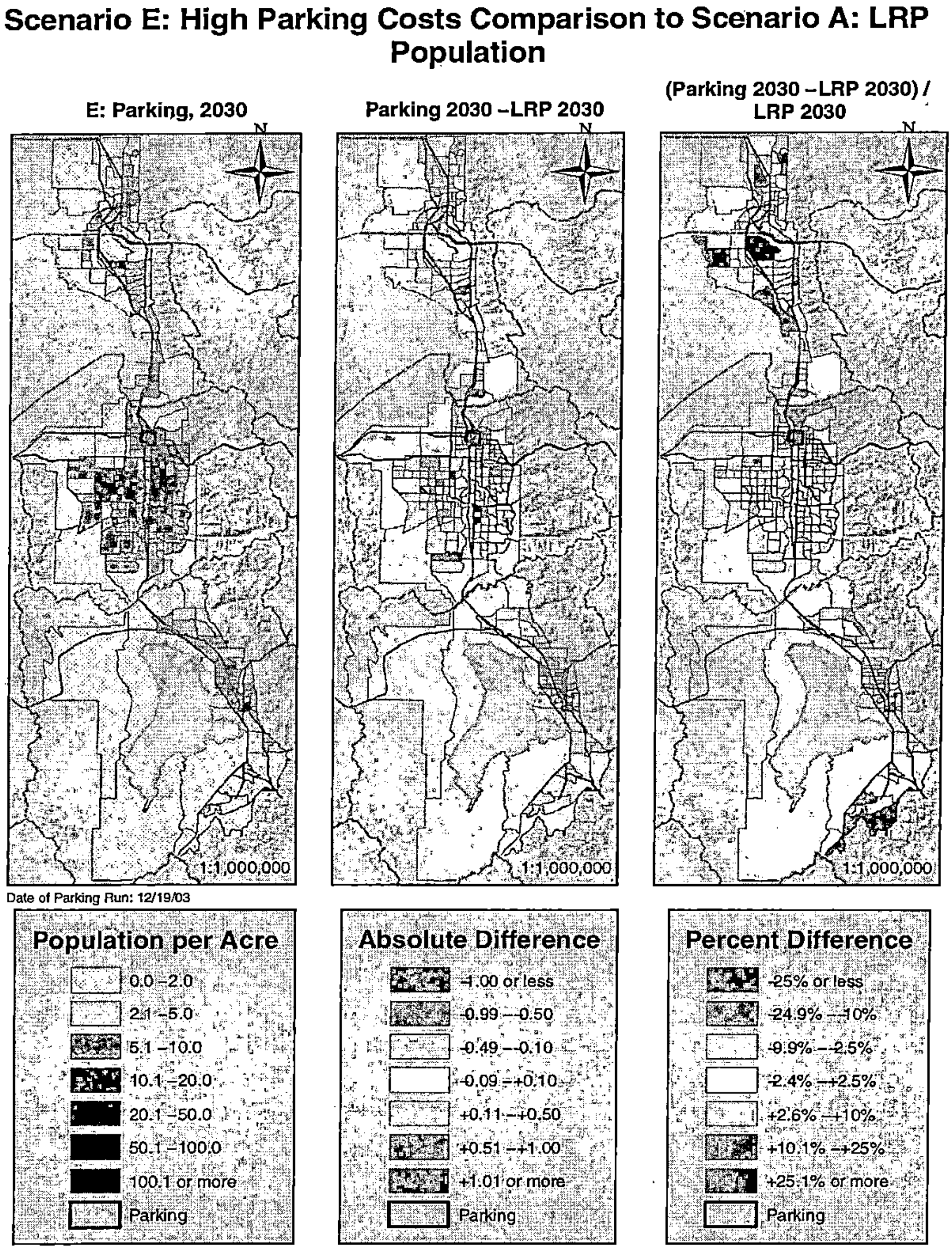

Figure 6.66: Comparison of Parking Cost Scenario Population in 2030 to LRP

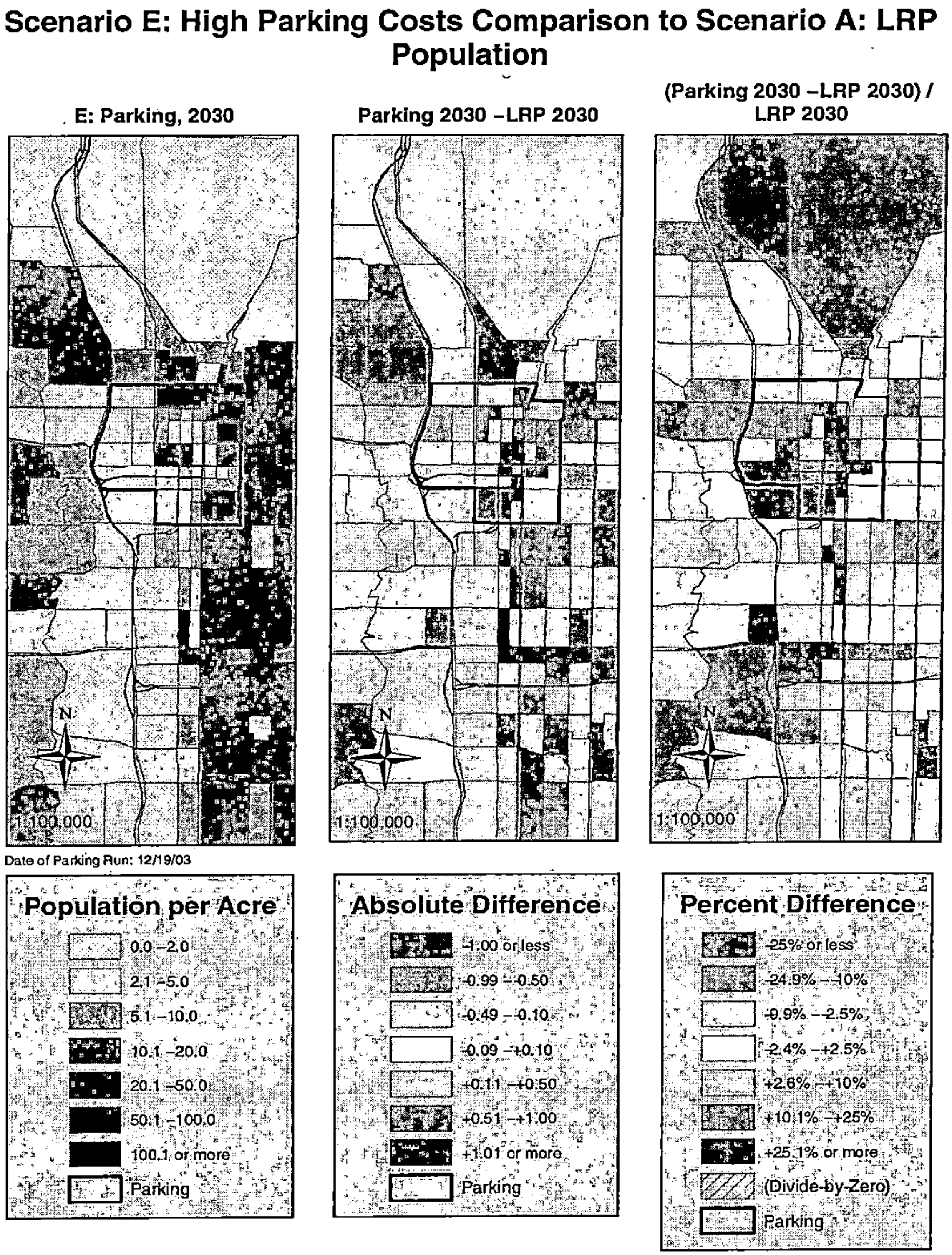

Figure 6.67: Comparison of Parking Cost Scenario Population in 2030 to LRP (Zoomed In)

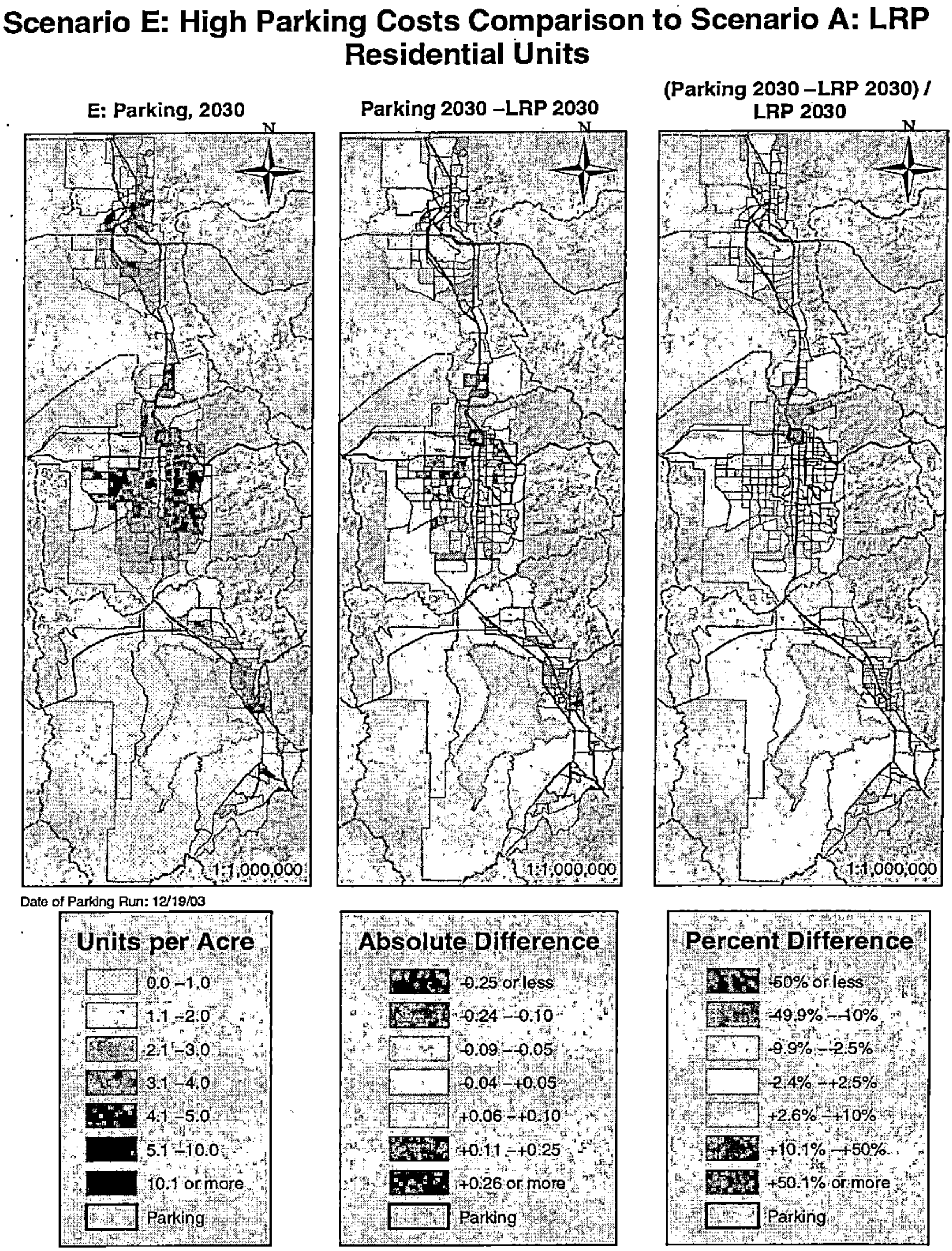

Figure 6.68: Comparison of Parking Cost Scenario Housing Units in 2030 to LRP

Scenario E: High Parking Costs Comparison to Scenario A: LRP Residential Units

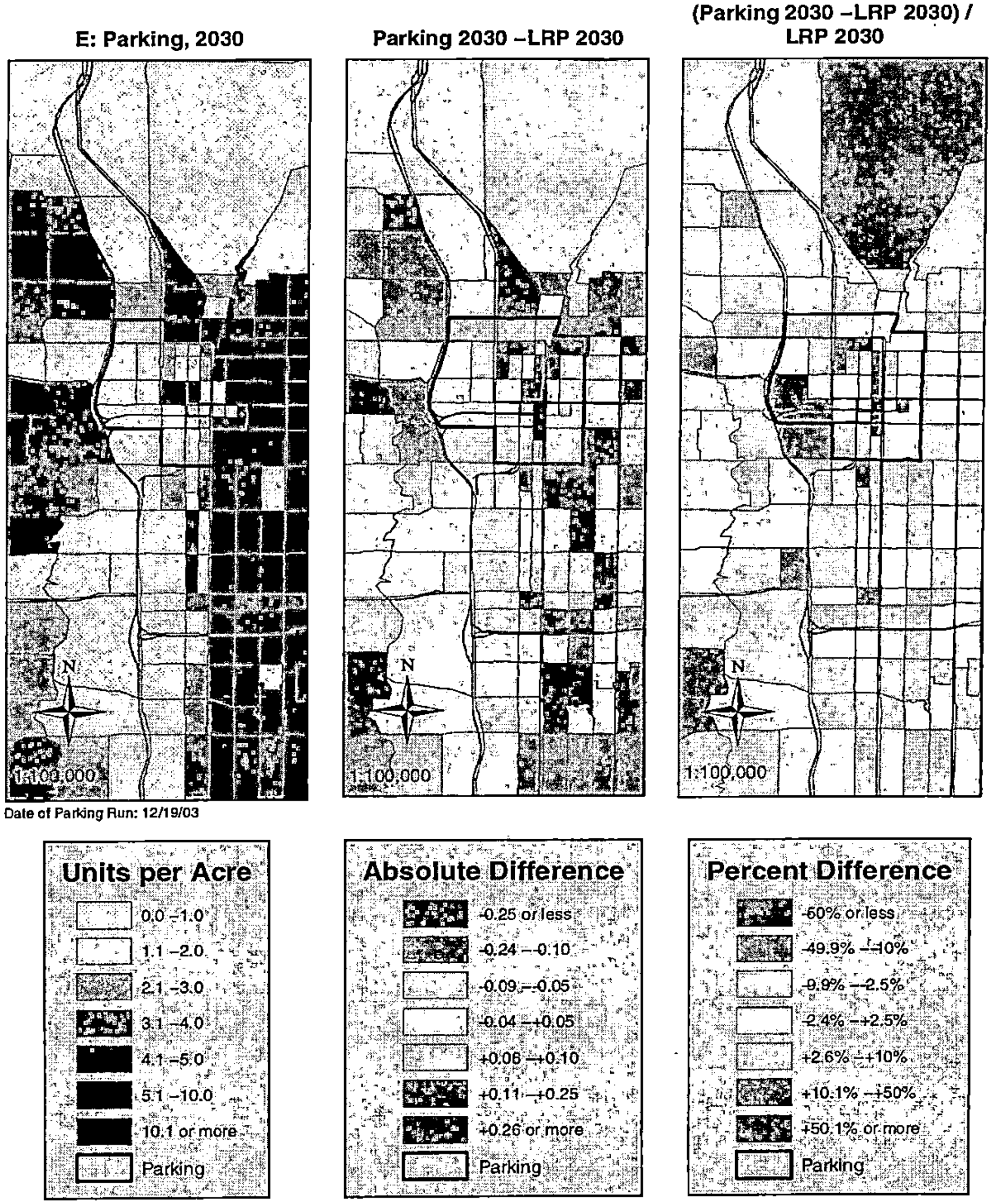

Figure 6.69: Comparison of Parking Cost Scenario Housing Units in 2030 to LRP (Zoomed In)

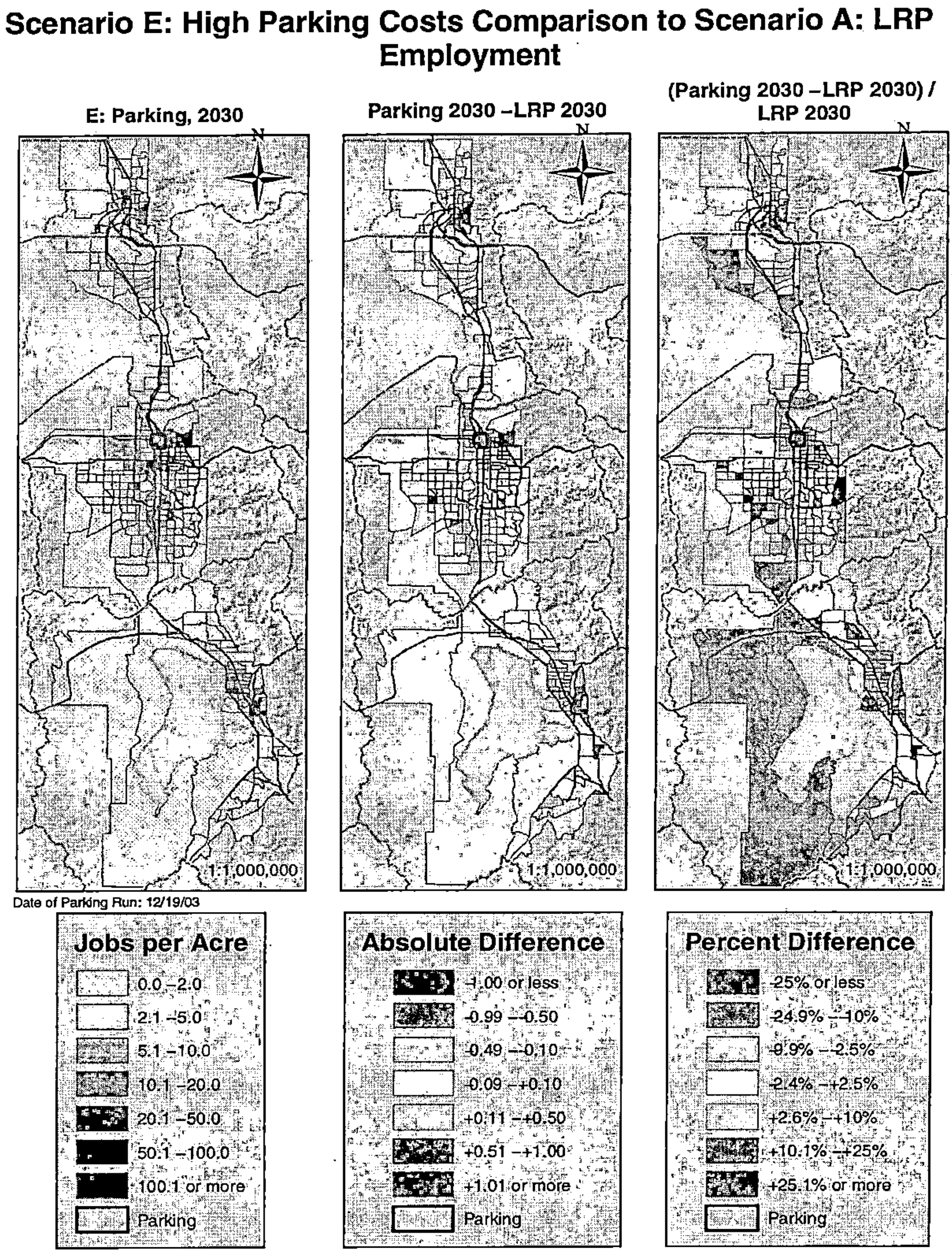

Figure 6.70: Comparison of Parking Cost Scenario Jobs in 2030 to LRP

Scenario E: High Parking Costs Comparison to Scenario A: LRP Employment

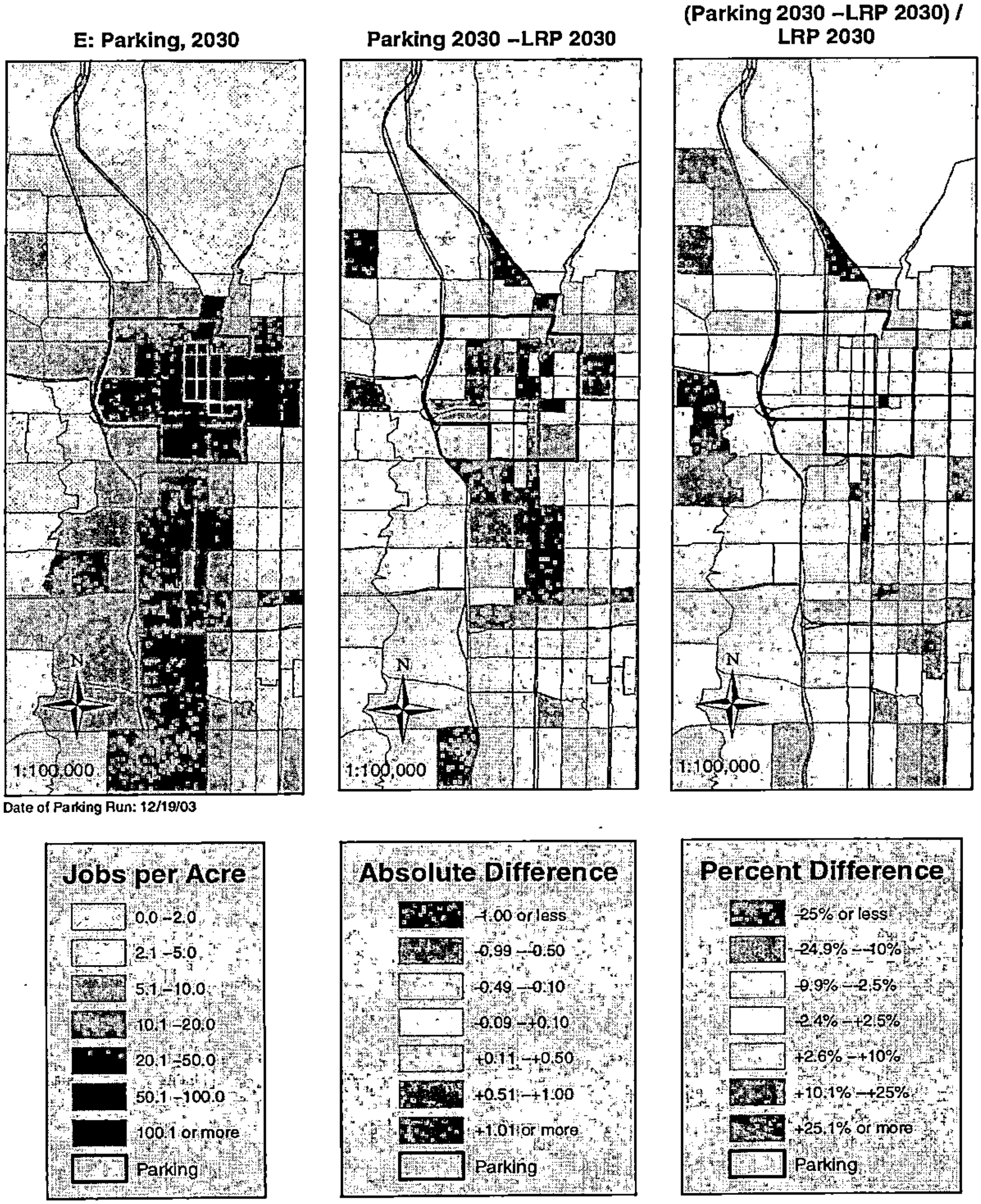

Figure 6.71: Comparison of Parking Cost Scenario Jobs in 2030 to LRP (Zoomed In)

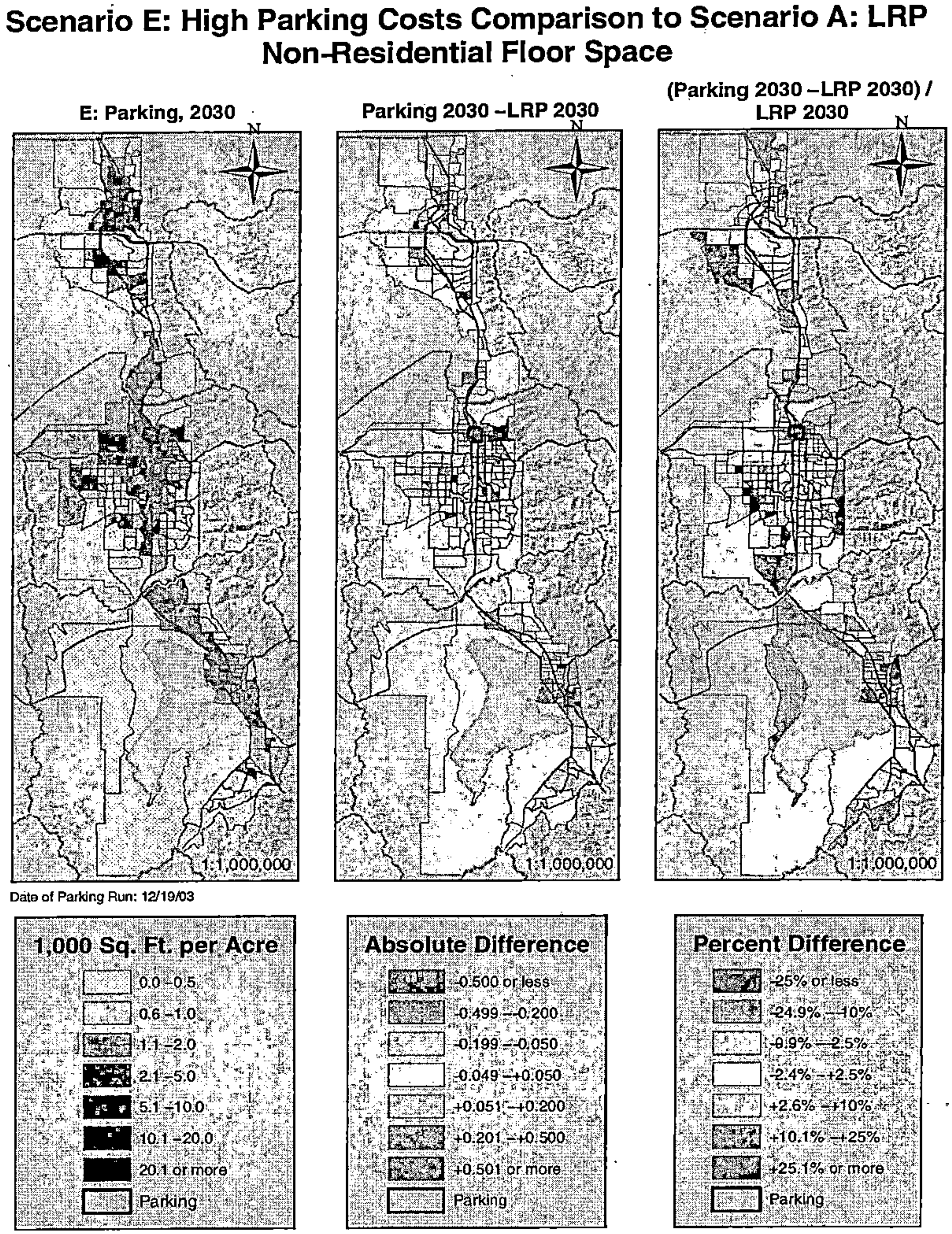

Figure 6.72: Comparison of Parking Cost Scenario Non-residential SQFT in 2030 to LRP

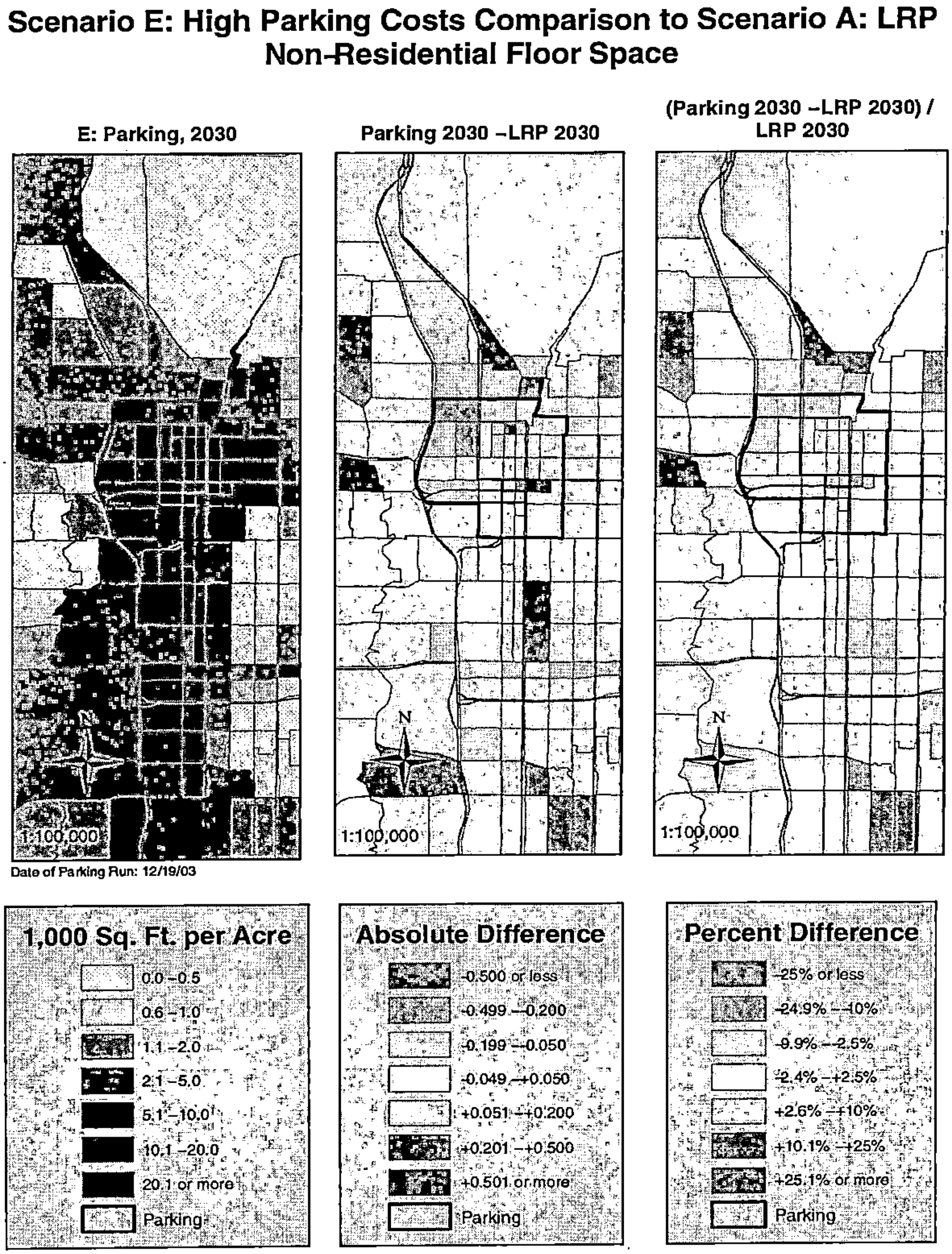

Figure 6.73: Comparison of Parking Cost Scenario Non-residential SQFT in 2030 to LRP (Zoomed In)

6.7 Urban Growth Boundary Alternative

In this scenario, an Urban Growth Boundary is imposed, restricting development at urban densities to those areas that fall within the boundary shown on the map, and imposing development constraints consistent with more rural land uses outside the boundary.

Since there were substantial land use plan changes associated with the Kennecott development in Salt Lake County, this scenario removes all land use plan changes associated with Kennecott development outside of the boundary but leave those land use plan changes that are within it. Outside the boundary, development constraints were set to allow R1, R2, M1, C1, and Government development.

The results of imposing an Urban Growth Boundary are presented in Figures 6.74 through 6.80.

The results of imposing an Urban Growth Boundary are obvious, and clearly reflect the fact that the model explicitly used development constraints to reflect this land policy test. Results for development, population and housing location, and land prices all show expected patterns. Accessibility results are more difficult to interpret, due to the combined effects of constraining population and employment growth to occur in areas principally served by existing infrastructure, and not allowing areas in which there is considerable planned expansion of the transportation system in the LRP. The transportation plan in this case is clearly not consistent with the land use policy of this sort, but it was not the intention of this analysis to evaluate a more realistic policy.

- Urban development was considerably greater inside the boundary than in the LRP, and was substantially lower outside the UGB.
- The UGB scenario produced the lowest Vehicle Hours Travelled of all the scenarios tested.
- The UGB scenario produced the lowest Total Hours of Congestion Delay of all the scenarios tested.
- The UGB scenario produced the highest transit mode share of all the scenarios tested.

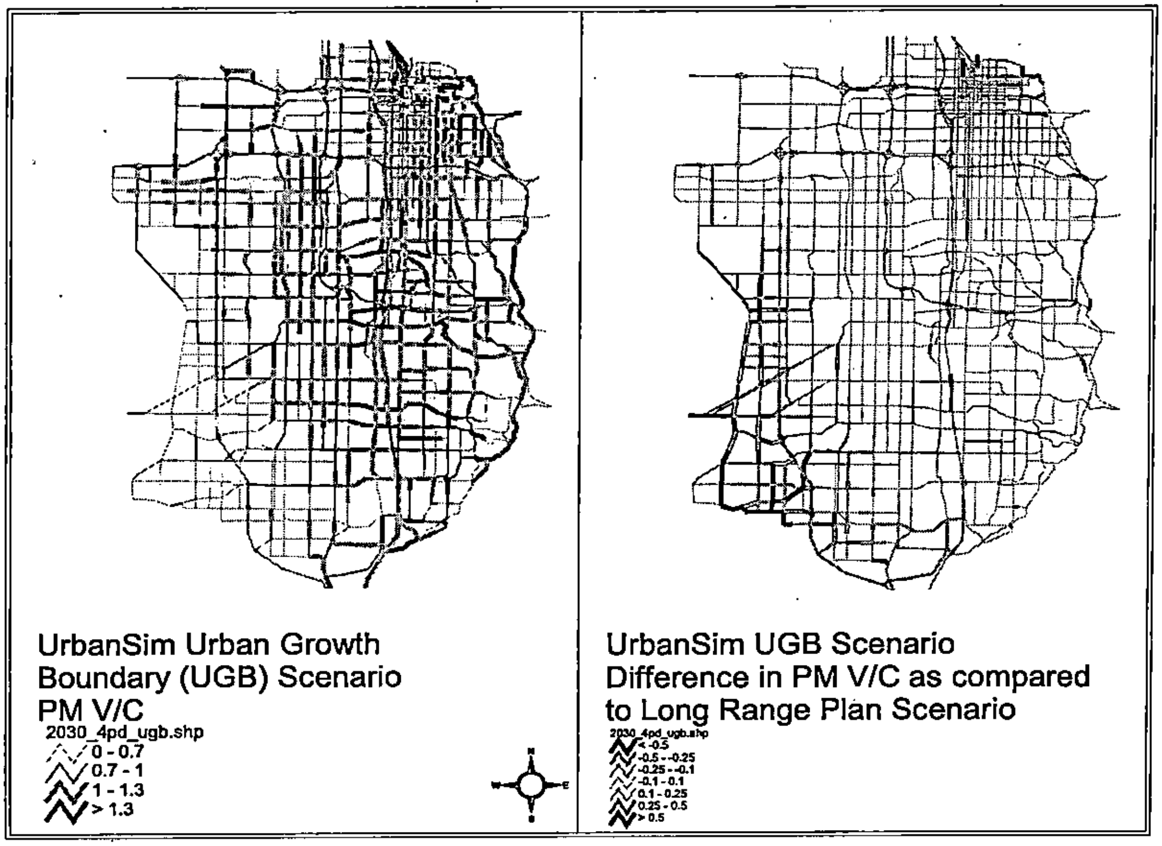

Figure 6.74: Comparison of UGB Scenario PM Peak Volume to Capacity Ratio to LRP

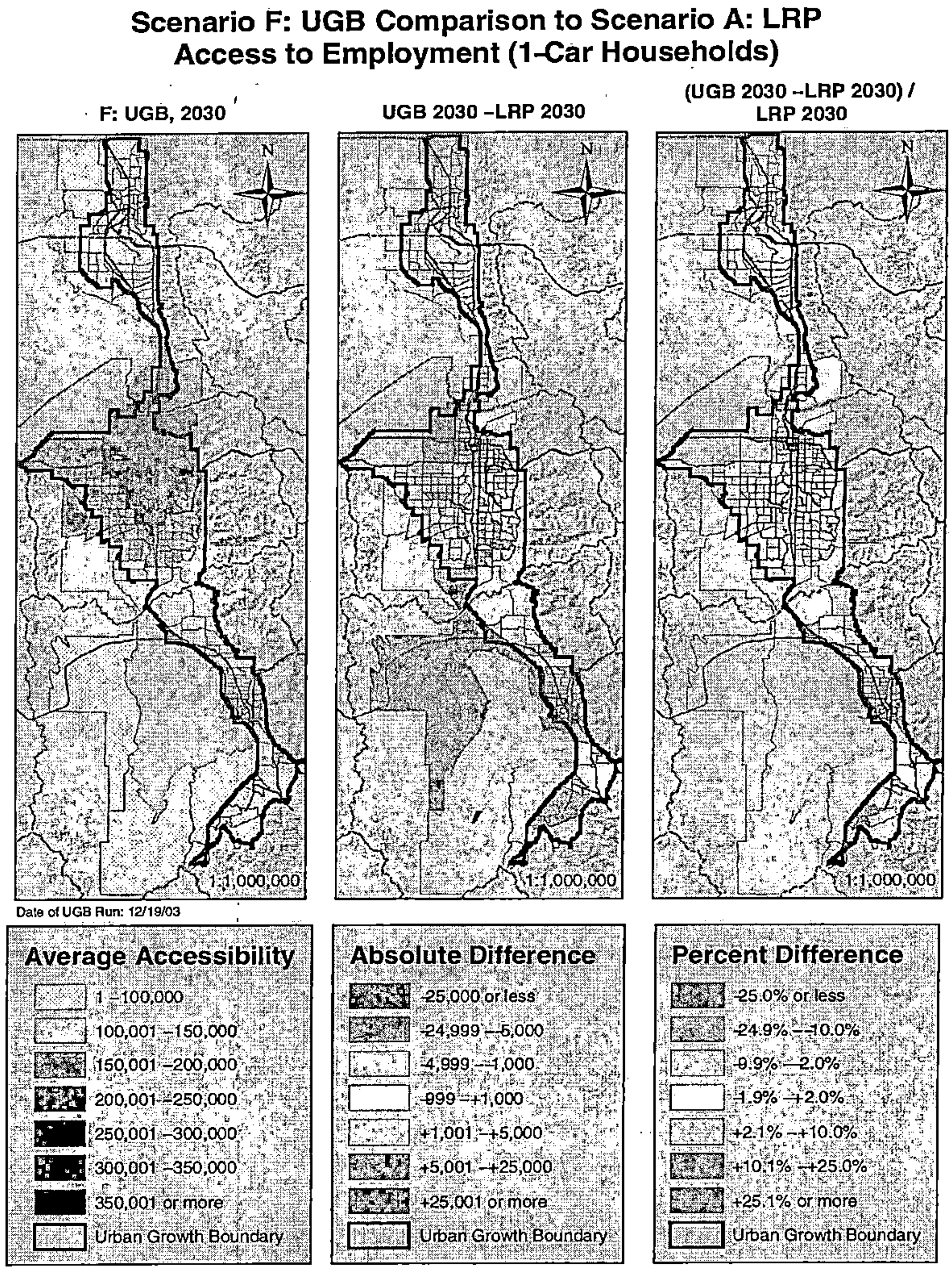

Figure 6.75: Comparison of UGB Scenario Accessibility to Employment in 2030 to LRP

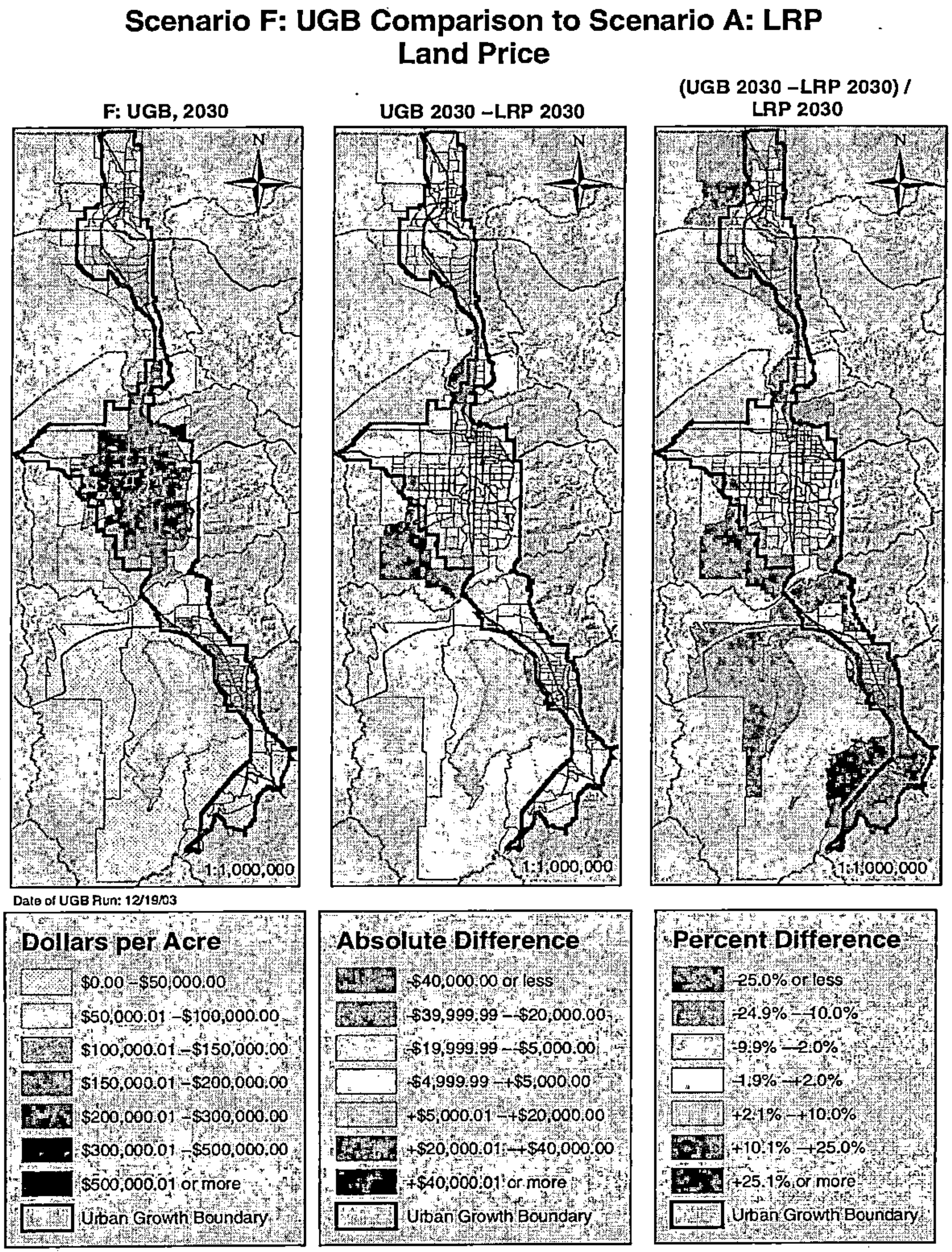

Figure 6.76: Comparison of UGB Scenario Land Price in 2030 to LRP

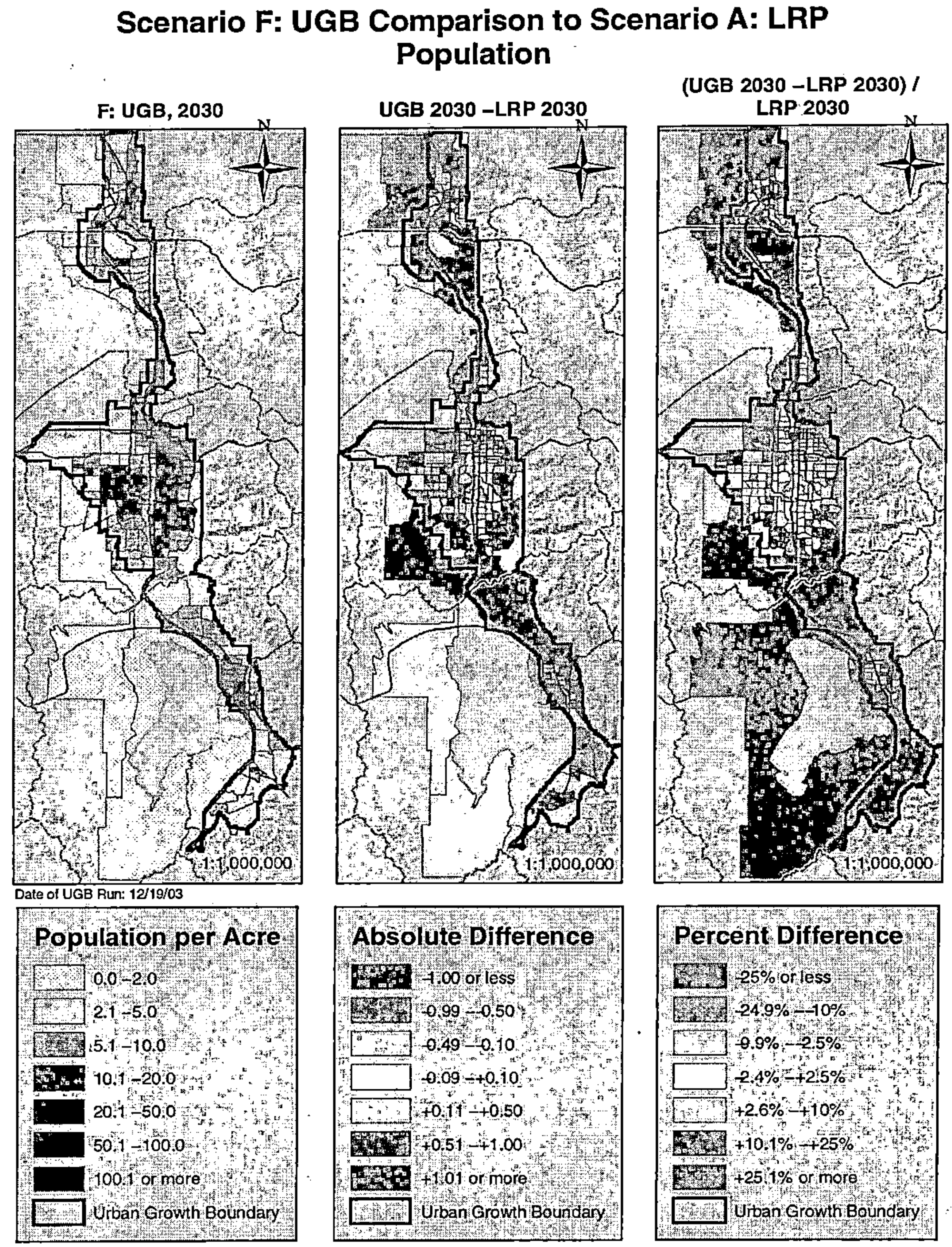

Figure 6.77: Comparison of UGB Scenario Population in 2030 to LRP

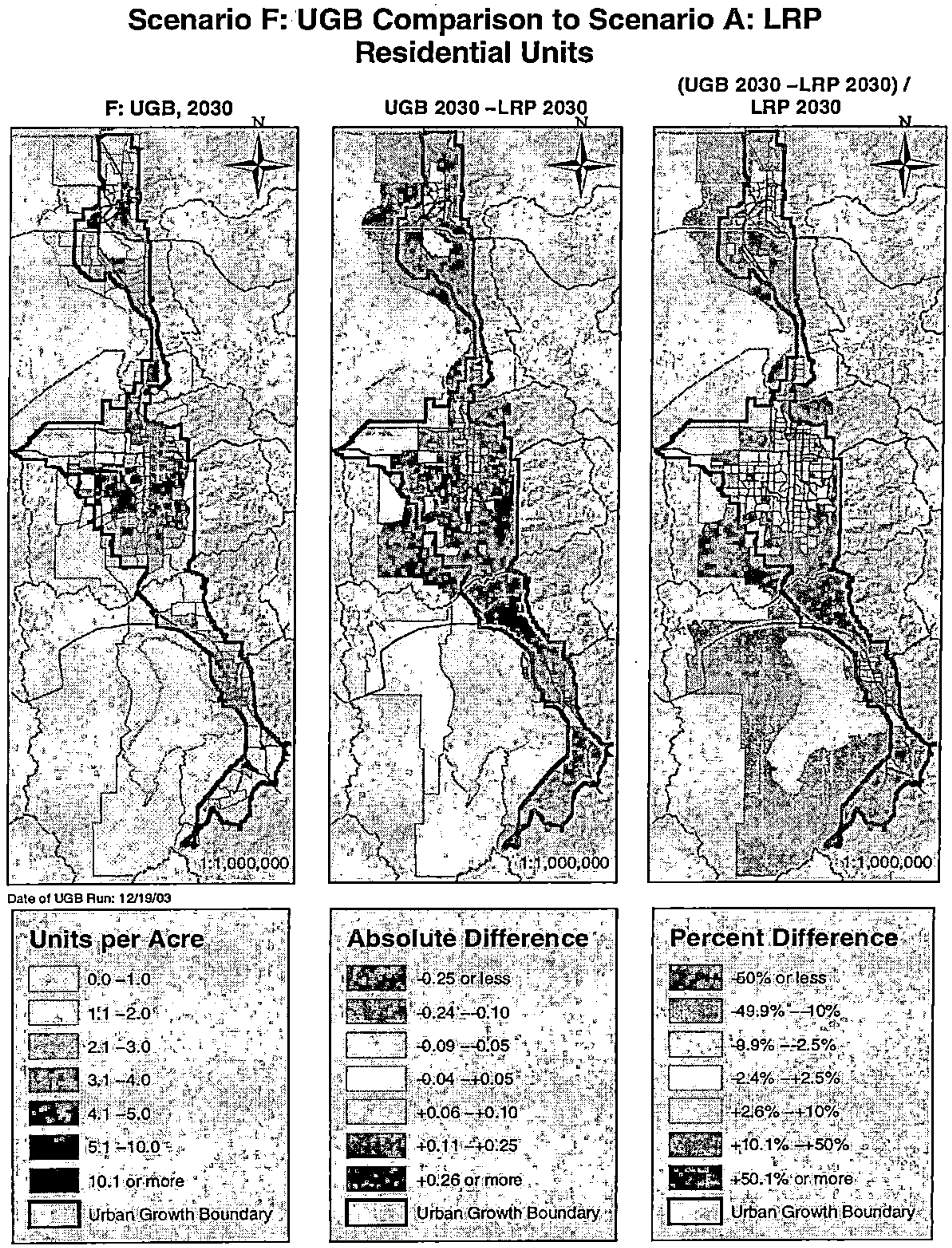

Figure 6.78: Comparison of UGB Scenario Housing Units in 2030 to LRP

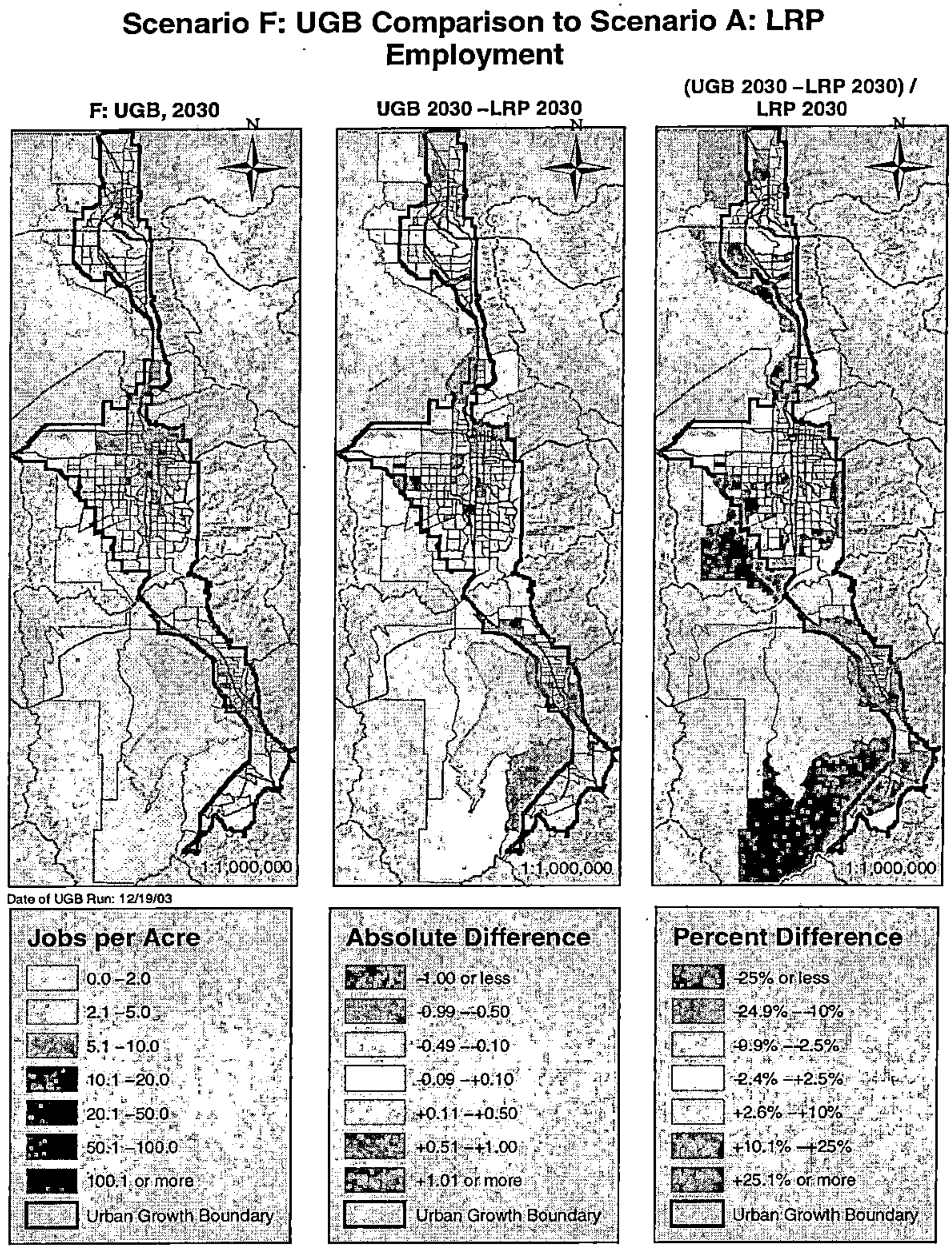

Figure 6.79: Comparison of UGB Scenario Jobs in 2030 to LRP

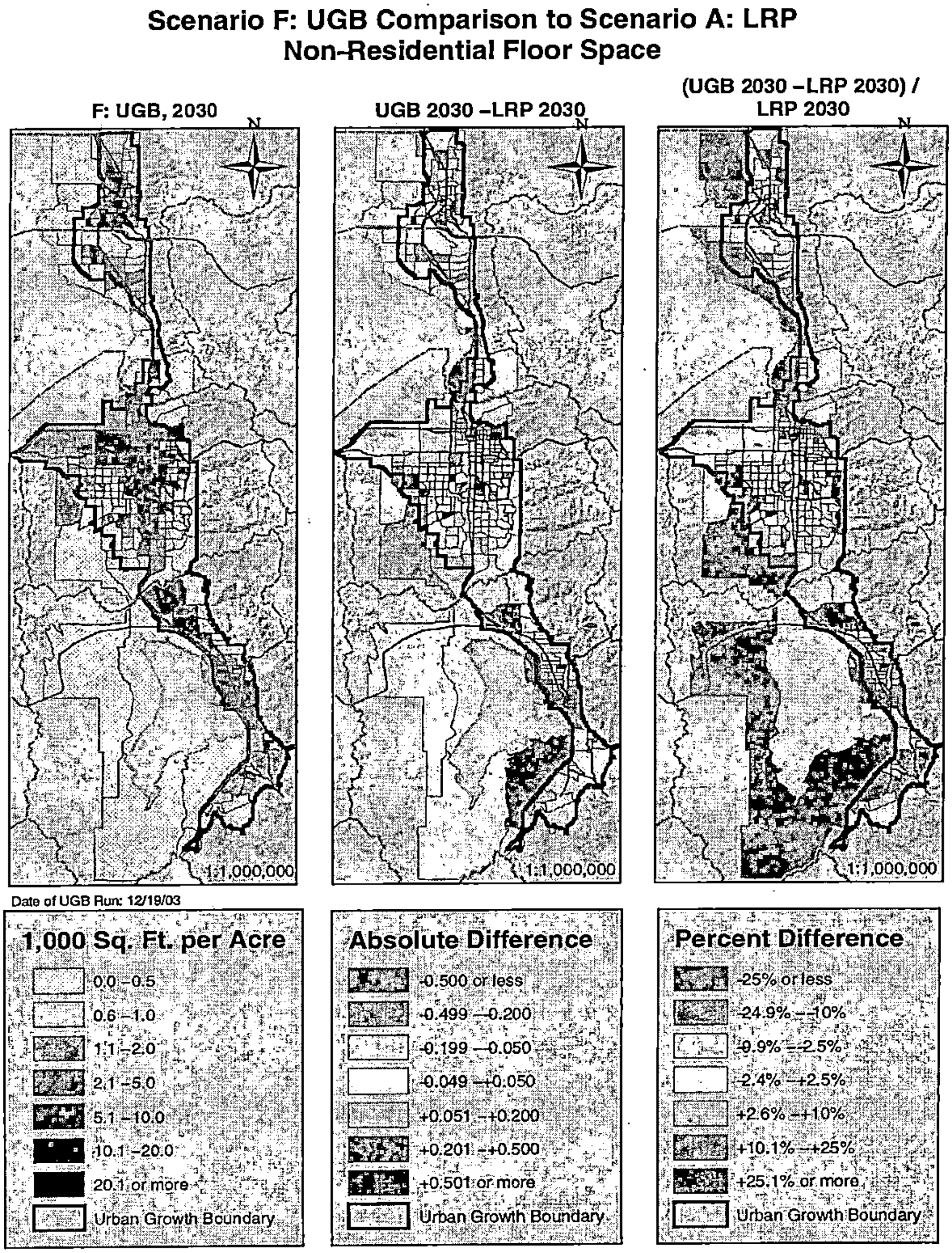

Figure 6.80: Comparison of UGB Scenario Non-residential SQFT in 2030 to LRP

6.8 Comparison of Scenarios

In this section, we provide comparisons across the full set of scenarios. The results are grouped into tables of indicators from UrbanSim (along with a table of results from the adopted forecasts for comparison), and charts comparing key indicators from the travel model.

6.8.1 Travel Model Indicators

Figures 6.81 through 6.84 compare the scenarios based on indicators from the travel model. Most of the scenarios are fairly tightly clustered on these indicators, with the exception of the No-build scenario, which shows considerably higher vehicle hours travelled and total hours of congestion delay, and lower vehicle miles travelled and transit mode share.

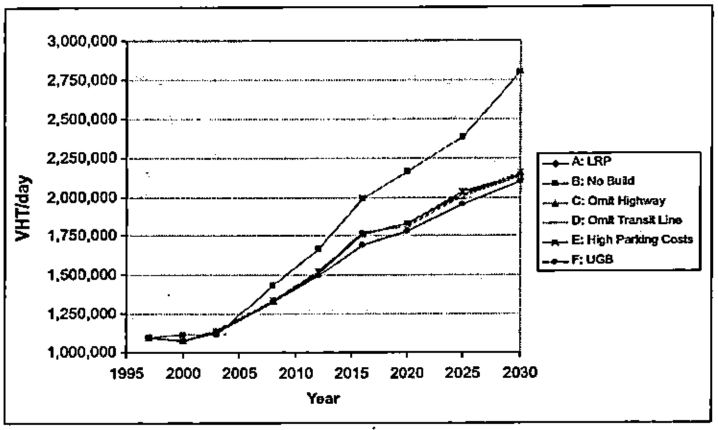

Figure 6.81: Vehicle Hours Travelled by Scenario

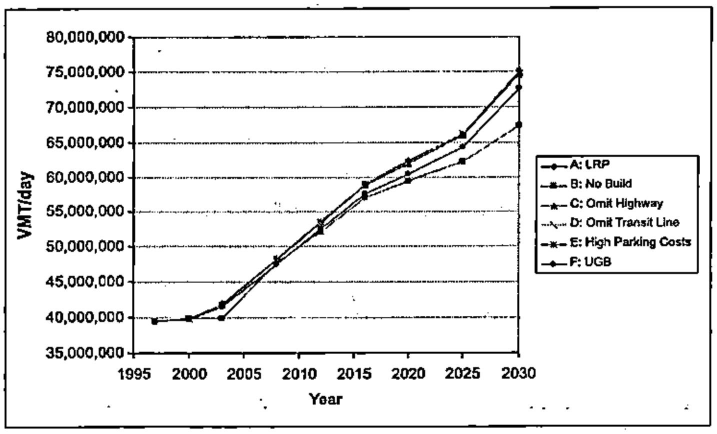

Figure 6.82: Vehicle Miles Travelled by Scenario

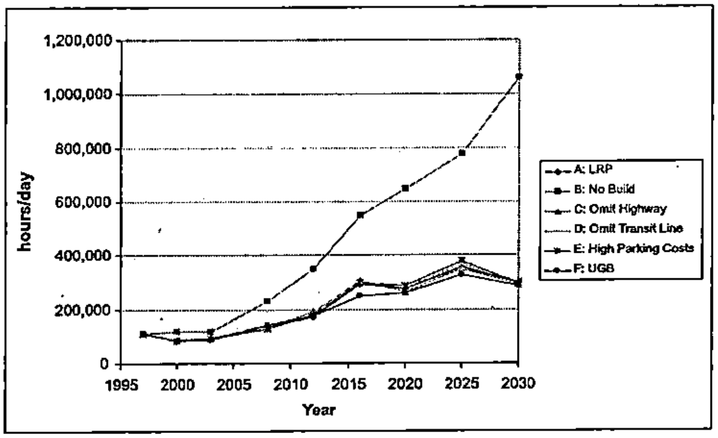

Figure 6.83: Hours of Delay by Scenario

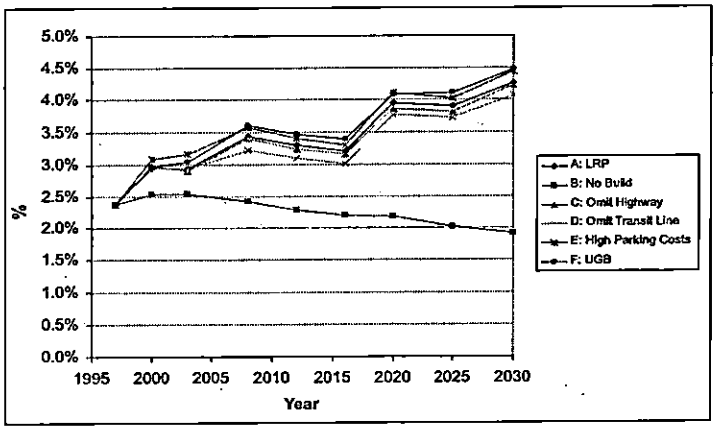

Figure 6.84: Transit Mode Share by Scenario

6.8.2 UrbanSim Indicators by City and County

Table 6.4: Currently Adopted WFRC Forecasts

Jurisdiction	Households	Population	Employment
County			
Weber	103902	312986	145089
Davis	131431	386669	135655
Salt Lake	498029	1429212	808183
Utah	209198	687926	255172
Total	942560	2816793	1344099
City			
Alpine	3555	13808	1222
American Fork	10573	35337	13950
Buffdale	14681	45754	10222
Bountiful	17984	46691	12404
Ceader fort	3291	11512	887
Cedar Hills	2206	9147	651
Centerville	5350	16069	5658
Clearfield	9646	26424	18221
Clinton	9376	28453	4561
Draper	17678	62934	20882
Eagle Mountain	15431	55108	2940
Farmington	6595	22400	6604
Farr West	2395	7187	6222
Fruit Heights	2945	9930	885
Genola	929	3553	271
Harrisville	2271	7136	1937
Highland	4228	17419	1713
Hill Airforce Base	1789	5840	16750
Kaysville	11842	39638	7680
Layton	29072	77652	23129
Lehi	15175	50211	15600
Mapleton	3302	11869	1745
Midvale	12465	29774	19482
Murray	21677	53006	42645
North Ogden	8576	30335	1689
North Salt Lake	2248	5319	11291
Ogden	39190	104455	74520
Orem	32868	105226	48610
Payson	12060	39349	10439
Plain City	2427	8964	1122
Plesant Grove	9547	33095	10083
Plesant View	2346	7579	3372
Provo	42309	127364	86468
Riverdale	3786	10353	7757
Riverton	17043	64747	13914
Roy	9104	27862	8475
Salem	2467	8442	2055
Salt Lake City	90971	199498	313504
Sandy	35757	116465	46175
Santaquin	5409	17924	1228
South Jordan	25380	86077	32378
South Ogden	8271	23014	4797
South Salt Lake	14028	29635	47625
Spanish Fork	12831	40571	17502
Springville	13266	39451	15764
Sunset	2113	5238	1357
Syracuse	6418	21045	1140
Vinyard	482	1561	4122
Washington Terrace	4705	13364	3468

Table 6.4: Currently Adopted WFRC Forecasts

Jurisdiction	Households	Population	Employment
West Bountiful	1855	5476	2193
West Haven	5434	19396	7132
West Jordan	43283	135649	52813
West Point	4303	13580	2052
West Valley City	43553	139112	108049
Woodland Hills	1232	4741	50
Woods Cross	3349	9917	6508
Other Unincorporated	16560	53578	21129
Taylorsville	29618	90830	21311
Herriman	6158	21161	5598
Holladay	12086	31849	5054
Hooper	2422	8615	1140
Marriott-Slaterville	1571	5284	2965
Kearns	12033	43782	5431
South Weber	3666	11441	1091
West Weber County Unincorporated	3013	11152	2771
East Weber County Unincorporated	2215	7705	1258
West Davis County Unincorporated	7553	24947	11247
East Davis County Unincorporated	1377	4420	686
Kennecott West Salt Lake County	36687	112765	16181
East Salt Lake County Unincorporated	61832	156413	45085
Cedar Valley	2678	8532	1308
Saratoga Springs	6884	23537	5304
Lindon	4057	15354	11612
Lakeshore-Benjamin	1120	3883	1015

Table 6.5: Comparison of Residential Units by Scenario

Jurisdiction	1997	LRP	No-build	Highway	Transit	Parking	UGB
County							
Salt Lake	312,900	530,500	526,800	526,500	531,900	529,200	526,100
Utah	91,200	197,000	195,600	197,100	197,600	195,000	207,800
Davis	62,900	137,800	138,700	138,800	136,100	139,100	134,500
Weber	61,700	121,100	122,400	121,400	119,500	119,100	114,800
Total	404,200	986,300	983,400	983,700	985,100	982,400	983,200
City							
Alpine	1,400	5,700	5,100	5,500	5,900	5,300	7,100
American Fork	5,800	13,100	13,000	13,100	13,200	13,000	14,100
Bluffdale	1,500	11,800	10,100	10,300	11,800	11,500	3,900
Bountiful	11,900	19,400	19,900	19,400	19,500	19,600	18,100
Cedar Fort	100	500	400	500	500	500	300
Cedar Hills	500	1,700	1,700	1,900	1,800	1,600	2,200
Cedar Valley	1,300	3,700	3,700	3,400	3,200	3,100	2,900
Centerville	3,400	6,800	7,000	7,100	6,800	6,800	6,800
Clearfield	6,600	10,900	10,700	10,900	10,800	10,800	11,800
Clinton	2,500	6,600	6,400	6,200	6,400	6,400	7,300
Draper	6,800	25,100	25,300	25,400	25,000	24,200	30,200
Eagle Mountain	200	1,900	1,400	1,600	1,600	2,100	1,100
East Davis County Unincorporated	100	900	900	1,000	1,000	1,000	1,200
East Salt Lake County Unincorporated	45,300	59,400	61,000	59,800	59,600	59,300	63,500
East Weber County Unincorporated	1,000	2,700	2,900	2,800	2,700	2,700	3,500
Elk Ridge	400	800	800	900	900	800	1,400
Farmington	2,800	7,500	7,500	7,500	7,400	7,700	7,900
Farr West	1,200	3,300	3,200	3,300	3,400	3,200	2,600
Fruit Heights	1,100	2,600	2,900	2,800	2,600	2,600	3,100
Genola	2,000	2,700	2,700	2,600	2,700	2,900	2,400
Goshen	400	500	500	500	500	500	400
Harrisville	1,100	2,400	2,700	2,500	2,200	2,600	3,000
Herriman	1,100	7,500	6,200	6,800	7,600	7,600	3,100
Highland	1,500	7,600	7,800	7,500	7,700	7,600	9,300
Hill Air Force Base	-	-	-	-	-	-	-
Holladay	8,000	12,700	13,200	12,600	12,600	12,900	13,900
Hooper	1,200	7,000	7,000	7,100	7,200	6,600	3,500
Kaysville	4,800	10,600	10,200	10,300	10,500	10,900	9,600
Kearns	9,900	12,100	12,200	12,100	12,100	12,100	12,600
Kennecott West Salt Lake County	9,100	32,400	30,000	30,400	31,700	32,100	24,900
Lakeshore/Benjamin	800	2,900	3,300	3,200	3,000	2,900	2,400
Layton	17,600	30,300	30,800	30,500	29,900	30,200	33,200
Lehi	4,800	21,800	21,200	21,600	21,400	21,400	19,300
Lindon	1,800	7,200	7,000	7,600	7,600	7,100	8,400
Mapleton	1,300	3,200	3,500	3,300	3,500	3,300	4,300
Marriott-Slaterville	400	3,600	3,100	3,700	3,200	3,200	2,400
Midvale	11,100	14,500	14,600	14,300	14,200	14,100	14,900
Murray	17,800	25,700	25,700	25,800	25,500	25,700	27,000
North Ogden	4,400	7,500	7,700	7,400	7,300	7,400	8,300
North Salt Lake	2,500	6,100	6,100	6,100	6,000	6,000	4,700
Ogden	23,500	34,500	34,900	34,300	34,500	34,300	36,900
Orem	20,700	31,900	32,300	31,700	31,800	31,800	34,200
Other Unincorporated	4,500	12,000	11,700	12,400	11,600	11,900	12,100

Table 6.5: Comparison of Residential Units by Scenario

Jurisdiction	1997	LRP	No-build	Highway	Transit	Parking	UGB
Payson	3,900	7,600	7,200	7,500	7,600	7,400	8,400
Plain City	1,000	2,500	2,500	2,800	2,500	2,500	1,400
Pleasant Grove	5,400	12,200	12,300	12,300	12,600	12,500	14,400
Pleasant View	2,100	5,300	5,300	5,100	5,200	5,100	6,100
Provo	23,300	33,200	33,900	33,500	33,100	33,100	35,200
Riverdale	2,600	4,900	4,900	4,900	4,800	5,000	5,500
Riverton	7,100	17,700	17,100	17,000	17,500	18,100	14,900
Roy	10,900	14,500	14,900	14,600	14,500	14,500	15,500
Salem	1,200	3,300	3,100	3,600	3,400	3,400	4,500
Salt Lake City	73,800	102,300	103,800	102,900	102,700	102,900	104,600
Sandy	26,000	42,000	42,300	41,800	41,900	41,500	45,500
Santaquin	1,300	2,200	2,500	2,400	2,400	2,400	1,900
Saratoga Springs	500	5,700	4,900	5,500	6,100	5,900	3,100
South Jordan	8,000	25,100	24,200	24,900	25,500	25,000	24,500
South Ogden	6,000	8,000	8,000	8,100	8,000	8,100	8,500
South Salt Lake	8,600	11,500	11,400	11,600	11,500	11,500	11,700
South Weber	1,000	3,400	3,500	3,300	3,100	3,300	4,300
Spanish Fork	5,300	10,900	10,500	10,800	10,700	10,400	11,500
Springville	7,200	14,100	13,700	13,800	13,700	13,700	16,200
Sunset	1,500	2,100	2,300	2,300	2,100	2,300	2,400
Syracuse	1,900	7,600	7,900	8,200	7,700	7,600	8,200
Taylorsville	21,300	27,800	28,300	28,100	27,900	27,800	29,300
Uintah	400	900	900	1,000	900	1,100	1,200
Vineyard	100	1,400	1,400	1,400	1,400	1,400	100
Washington Terrace	3,000	3,700	3,700	4,000	3,700	3,800	4,000
West Bountiful	1,200	3,600	3,600	3,600	3,600	3,500	2,800
West Davis County Unincorporated	200	7,000	6,900	7,300	6,800	7,600	2,800
West Haven	1,400	8,700	8,800	8,300	8,400	8,300	5,300
West Jordan	21,100	43,000	41,500	43,300	44,800	42,900	41,700
West Point	1,300	5,100	5,100	5,100	5,000	5,400	3,500
West Valley City	33,200	54,200	54,200	53,500	54,200	54,200	56,200
West Weber County Unincorporated	1,100	9,200	9,600	9,300	8,800	8,600	4,600
Woodland Hills	200	500	600	500	600	500	700
Woods Cross	1,600	4,300	4,200	4,100	4,200	4,100	3,100

Table 6.6: Comparison of Population by Scenario

Jurisdiction	1997	LRP	No-build	Highway	Transit	Parking	UGB
County							
Salt Lake	860,400	1,443,500	1,434,300	1,432,800	1,446,000	1,435,300	1,417,200
Utah	295,200	523,500	521,800	526,200	527,400	523,600	568,600
Davis	193,700	376,500	381,600	381,000	372,400	385,400	373,400
Weber	169,100	321,400	327,200	324,900	319,200	320,600	305,700
Total	1,155,600	2,664,900	2,664,900	2,664,900	2,664,900	2,664,900	2,664,900
City							
Alpine	4,900	15,400	13,800	15,100	16,000	15,000	21,100
American Fork	18,900	36,500	36,500	36,600	37,200	36,800	40,600
Bluffdale	5,900	32,800	28,600	28,800	33,200	32,700	6,500
Bountiful	35,500	55,100	56,400	55,000	55,100	55,700	50,500
Cedar Fort	500	1,100	1,100	1,100	1,100	1,100	400
Cedar Hills	1,600	4,800	4,700	5,200	4,700	4,400	6,600
Cedar Valley	3,900	8,800	9,000	8,100	7,700	7,200	5,700
Centerville	11,200	19,400	20,100	20,300	19,300	19,800	19,900
Clearfield	18,800	29,100	28,500	29,500	29,100	29,200	32,400
Clinton	8,900	18,500	18,000	17,300	17,800	18,000	21,300
Draper	20,500	71,900	73,800	72,800	72,100	70,300	88,700
Eagle Mountain	800	4,100	3,100	3,400	3,600	4,800	1,000
East Davis County Unincorporated	300	2,500	2,500	2,600	2,700	2,800	3,600
East Salt Lake County Unincorporated	118,000	164,200	168,000	164,700	163,200	162,200	175,000
East Weber County Unincorporated	3,100	7,100	8,000	7,400	7,000	7,000	10,200
Elk Ridge	1,400	2,000	1,900	2,000	2,100	1,800	3,800
Farmington	9,600	20,900	21,000	20,600	20,900	22,000	22,200
Farr West	3,400	8,700	8,500	8,400	9,000	8,100	6,000
Fruit Heights	3,600	7,200	8,100	7,800	7,400	7,400	9,200
Genola	6,700	6,400	6,300	6,200	6,200	7,000	5,000
Goshen	1,000	1,200	1,300	1,300	1,400	1,400	1,000
Harrisville	3,400	6,300	7,200	6,600	5,800	7,000	8,700
Herriman	3,700	20,200	16,700	18,000	20,600	20,500	4,700
Highland	6,000	20,600	21,900	20,500	21,400	21,400	27,500
Hill Air Force Base	-	-	-	-	-	-	-
Holladay	20,700	36,100	37,500	35,900	36,000	36,800	39,600
Hooper	4,200	16,600	17,400	17,800	17,400	16,300	5,300
Kaysville	16,000	29,100	29,100	28,700	29,300	31,200	26,100
Kearns	32,800	34,300	34,900	34,400	34,300	33,900	35,400
Kennecott West Salt Lake County	28,400	85,800	79,700	81,200	84,500	85,300	61,000
Lakeshore/Benjamin	2,800	5,100	5,900	5,800	5,100	5,000	2,500
Layton	52,200	83,700	85,900	85,000	82,600	84,200	94,700
Lehi	16,300	60,500	59,100	59,600	58,900	59,900	53,300
Lindon	6,300	20,200	19,500	21,500	21,400	20,500	24,800
Mapleton	4,400	7,000	8,200	7,500	8,300	7,700	11,400
Marriott-Slaterville	1,300	9,100	7,900	9,800	8,200	8,200	5,400
Midvale	27,400	37,800	38,200	37,100	36,900	36,300	38,100
Murray	44,400	69,500	69,500	69,100	68,300	68,600	72,600
North Ogden	14,400	21,000	22,100	20,800	20,700	21,100	24,900
North Salt Lake	7,000	15,400	15,200	15,100	14,900	15,000	11,900
Ogden	56,100	93,600	93,100	92,700	92,900	93,100	102,200
Orem	69,300	90,200	91,100	89,600	90,300	90,400	97,500
Other Unincorporated	14,900	33,100	33,100	34,400	32,400	33,600	34,300
Payson	12,900	19,600	17,900	19,400	19,500	18,700	23,200
Plain City	3,300	6,200	6,500	7,400	6,200	6,700	2,700

Table 6.6: Comparison of Population by Scenario

Jurisdiction	1997	LRP	No-build	Highway	Transit	Parking	UGB
Pleasant Grove	17,400	34,700	35,000	34,900	35,900	35,800	42,400
Pleasant View	6,000	13,400	14,000	13,100	13,600	13,800	17,200
Provo	69,300	85,200	87,600	87,000	85,400	85,200	92,700
Riverdale	7,200	14,000	13,600	13,600	13,500	14,500	15,900
Riverton	24,600	51,200	49,800	49,400	51,100	53,500	41,700
Roy	32,900	41,100	42,100	41,300	41,500	41,300	44,500
Salem	4,300	7,800	7,400	8,900	8,300	8,300	12,200
Salt Lake City	159,100	251,400	255,200	256,100	253,200	251,500	258,100
Sandy	86,700	123,200	123,500	121,900	121,700	120,400	132,900
Santaquin	4,100	5,500	6,500	6,000	6,100	6,100	4,600
Saratoga Springs	1,600	14,900	13,100	14,500	16,400	15,800	6,000
South Jordan	28,400	72,100	70,700	71,400	73,800	72,900	70,900
South Ogden	15,900	22,300	22,100	22,800	22,600	22,600	23,800
South Salt Lake	18,400	26,200	25,800	26,800	26,100	26,100	27,200
South Weber	3,300	9,100	9,300	9,000	8,300	9,000	12,600
Spanish Fork	17,200	28,600	27,600	28,500	28,100	27,100	32,100
Springville	22,800	37,500	36,300	37,000	36,200	36,600	45,500
Sunset	4,300	6,100	6,400	6,400	6,000	6,500	6,800
Syracuse	6,400	20,400	21,500	22,800	20,700	20,900	23,200
Taylorsville	61,700	77,000	78,400	78,100	77,000	76,700	80,700
Uintah	300	2,400	2,300	2,700	2,400	3,000	3,400
Vineyard	200	3,100	3,200	3,100	3,100	3,300	100
Washington Terrace	8,100	10,200	10,300	10,900	10,100	10,400	11,500
West Bountiful	4,200	10,400	10,000	10,300	10,300	10,100	7,800
West Davis County Unincorporated	800	17,000	16,800	17,800	16,200	18,600	3,300
West Haven	4,300	22,900	23,500	21,600	22,200	21,900	12,400
West Jordan	70,200	122,700	119,300	123,200	128,000	122,100	115,800
West Point	4,600	13,100	13,200	13,300	13,000	14,800	8,400
West Valley City	98,200	149,100	147,900	146,500	148,000	147,800	157,400
West Weber County Unincorporated	3,800	20,700	22,900	22,000	20,700	20,100	5,100
Woodland Hills	600	700	1,100	1,100	1,200	1,000	1,900
Woods Cross	5,000	12,000	11,700	11,000	11,600	11,500	8,300

Table 6.7: Comparison of Non-Residential Square Footage by Scenario (in 1,000s)

Jurisdiction	1997	LRP	No-build	Highway	Transit	Parking	UGB
County							
Salt Lake	309,900	497,500	496,800	500,600	497,900	499,800	489,000
Utah	83,500	257,300	258,100	256,300	261,500	254,300	243,500
Davis	40,100	97,700	98,500	97,300	95,800	99,600	76,200
Weber	47,700	97,100	98,000	96,600	97,300	97,400	98,000
Total	393,300	949,600	951,400	950,800	952,500	951,100	906,700
City							
Alpine	500	2,600	2,400	2,400	2,400	2,300	2,500
American Fork	4,400	16,300	16,500	17,500	16,900	16,600	17,400
Bluffdale	400	2,600	2,600	3,100	2,600	2,900	1,400
Bountiful	6,000	8,800	8,800	8,300	8,400	8,700	8,700
Cedar Fort	-	-	-	-	-	-	-
Cedar Hills	-	1,000	1,200	1,100	900	1,000	1,000
Cedar Valley	4	5,300	5,300	3,300	4,800	3,400	7,400
Centerville	1,600	6,800	7,400	6,700	6,700	7,500	1,900
Clearfield	6,500	11,300	11,500	11,800	11,200	11,700	12,100
Clinton	400	900	900	900	900	900	900
Draper	5,500	10,300	10,700	10,400	10,100	10,700	10,800
Eagle Mountain	-	-	-	-	-	-	-
East Davis County Unincorporated	17	-	-	-	-	-	-
East Salt Lake County Unincorporated	17,500	20,500	20,300	20,700	20,100	20,100	20,800
East Weber County Unincorporated	100	400	500	400	500	300	500
Elk Ridge	5	-	-	-	-	-	-
Farmington	1,800	3,700	3,700	3,400	3,300	3,100	4,200
Farr West	800	2,900	2,900	2,400	2,900	2,800	2,600
Fruit Heights	100	200	200	200	200	300	200
Genola	8	-	-	-	-	-	-
Goshen	-	900	900	900	1,000	800	500
Harrisville	200	2,000	2,100	2,500	2,400	1,900	2,300
Herriman	7	-	-	-	-	-	100
Highland	1,000	11,300	11,200	11,300	11,400	11,200	12,500
Hill Air Force Base	5,100	5,100	5,100	5,100	5,100	5,100	5,100
Holladay	3,000	4,000	4,100	4,100	4,100	4,100	4,700
Hooper	100	300	200	200	300	200	300
Kaysville	1,800	3,400	3,400	3,500	3,500	3,800	3,600
Kearns	1,400	2,600	2,600	2,500	2,700	2,800	2,800
Kennecott West Salt Lake County	4,200	43,300	42,200	44,500	43,700	44,200	37,200
Lakeshore/Benjamin	100	200	200	200	200	200	200
Layton	8,600	17,300	17,500	17,100	17,100	17,300	17,500
Lehi	10,600	29,500	28,900	29,700	29,900	29,100	31,500
Lindon	2,400	8,600	8,700	8,400	8,500	8,300	7,900
Mapleton	200	2,000	2,200	2,300	2,100	1,900	2,300
Marriott-Slaterville	700	3,600	3,400	3,600	3,700	3,400	3,000
Midvale	8,900	11,800	11,600	11,500	11,800	11,900	11,700
Murray	21,600	27,100	27,200	27,300	27,500	27,300	28,800
North Ogden	700	1,600	1,500	1,400	1,500	1,500	1,600
North Salt Lake	4,700	16,600	16,900	16,800	16,400	16,800	10,900
Ogden	30,700	48,200	49,300	48,100	48,800	48,900	49,900
Orem	20,900	29,800	29,800	30,800	30,500	30,200	31,200
Other Unincorporated	3,200	12,000	12,200	11,800	11,600	11,500	12,200
Payson	2,000	17,400	16,500	17,200	17,900	16,600	4,800

Table 6.7: Comparison of Non-Residential Square Footage by Scenario (in 1,000s)

Jurisdiction	1997	LRP	No-build	Highway	Transit	Parking	UGB
Plain City	100	200	200	200	200	200	200
Pleasant Grove	1,600	4,900	5,100	5,000	5,200	5,000	5,000
Pleasant View	1,000	5,000	4,500	5,100	5,200	5,500	5,000
Provo	31,200	67,800	68,600	66,800	69,000	68,400	74,600
Riverdale	3,900	5,100	5,000	5,100	4,900	5,100	5,000
Riverton	900	1,400	1,500	1,400	1,400	1,600	1,200
Roy	2,500	6,600	6,500	6,100	6,200	6,100	6,100
Salem	400	4,100	4,400	4,400	4,300	3,700	4,900
Salt Lake City	151,200	221,900	222,800	224,200	222,000	221,400	228,900
Sandy	17,900	22,000	21,600	21,700	21,900	21,900	22,100
Santaquin	100	200	100	200	200	200	200
Saratoga Springs	6	2,900	3,000	2,800	3,100	3,000	3,400
South Jordan	2,300	10,300	9,400	10,400	10,800	10,200	6,900
South Ogden	1,900	4,000	3,800	4,000	3,800	4,100	4,500
South Salt Lake	28,800	30,900	30,900	30,900	30,800	30,900	31,200
South Weber	100	1,800	1,800	1,700	1,700	1,700	1,700
Spanish Fork	3,300	29,700	29,900	29,000	30,000	30,000	21,800
Springville	4,600	13,600	13,600	13,100	13,600	13,100	14,200
Sunset	400	600	600	600	600	600	600
Syracuse	300	1,200	1,200	1,500	1,300	1,600	1,500
Taylorsville	7,500	14,300	14,300	13,700	13,500	13,900	14,700
Uintah	100	200	200	200	200	200	200
Vineyard	200	9,200	10,000	10,100	9,500	9,700	200
Washington Terrace	1,100	3,000	3,200	2,900	3,000	3,100	3,300
West Bountiful	500	1,200	1,500	1,300	1,600	1,300	1,400
West Davis County Unincorporated	200	11,400	10,500	11,400	10,600	11,800	1,900
West Haven	900	4,900	5,300	5,200	4,900	5,300	4,100
West Jordan	8,700	18,800	18,800	18,900	19,100	20,100	17,100
West Point	500	500	500	500	500	500	500
West Valley City	29,200	51,400	51,900	51,600	51,900	51,900	45,500
West Weber County Unincorporated	1,000	1,600	1,900	1,800	1,600	1,600	1,100
Woodland Hills	100	100	100	100	100	100	100
Woods Cross	1,100	5,900	6,100	5,900	6,000	6,300	2,800

Table 6.8: Comparison of Jobs by Scenario

Jurisdiction	1997	LRP	No-build	Highway	Transit	Parking	UGB
County							
Salt Lake	505,100	764,200	767,900	771,100	755,900	761,100	764,400
Utah	132,600	384,300	377,600	375,600	392,400	383,200	399,200
Davis	77,400	145,900	147,200	146,300	143,900	147,800	126,100
Weber	87,400	151,600	153,300	153,000	153,900	154,000	156,400
Total	637,700	1,446,000	1,446,000	1,446,000	1,446,000	1,446,000	1,446,000
City							
Alpine	1,000	3,800	3,600	3,800	3,600	3,300	3,900
American Fork	8,700	25,000	25,000	27,200	25,500	24,500	26,800
Bluffdale	900	3,600	3,600	4,300	3,600	4,300	2,200
Bountiful	12,900	16,100	16,200	15,700	15,600	16,200	15,700
Cedar Fort	1	-	-	-	-	-	-
Cedar Hills	22	1,100	1,100	1,300	1,200	1,200	1,200
Cedar Valley	38	7,900	7,600	4,300	7,000	4,800	13,800
Centerville	3,200	8,800	9,400	8,600	8,600	9,500	4,000
Clearfield	10,900	16,700	16,800	17,300	16,900	16,700	18,000
Clinton	1,000	2,300	2,500	2,200	2,400	2,400	2,500
Draper	9,000	21,500	22,500	22,000	21,200	22,100	22,600
Eagle Mountain	-	-	-	-	-	-	-
East Davis County Unincorporated	28	-	-	-	-	-	-
East Salt Lake County Unincorporated	33,600	39,300	39,800	39,800	39,300	38,600	39,900
East Weber County Unincorporated	200	700	700	600	700	600	700
Elk Ridge	35	100	-	-	-	-	100
Farmington	3,900	7,100	7,200	6,800	6,400	6,200	8,100
Farr West	2,000	5,100	5,300	4,300	5,100	4,800	4,600
Fruit Heights	300	600	600	500	600	700	600
Genola	47	-	-	-	-	-	-
Goshen	8	1,000	800	1,100	1,100	800	800
Harrisville	600	3,300	3,700	4,300	4,000	3,200	3,900
Herriman	37	-	-	-	-	-	-
Highland	2,000	12,300	12,100	12,800	12,600	11,800	13,300
Hill Air Force Base	9,500	4,700	4,700	4,700	4,700	4,700	4,700
Holladay	7,000	8,300	8,700	8,700	8,800	8,700	9,200
Hooper	300	700	500	600	500	600	600
Kaysville	3,700	5,800	5,900	6,200	6,000	6,700	5,900
Kearns	2,300	4,000	4,300	4,200	4,200	4,500	4,500
Kennecott West Salt Lake County	4,700	48,800	47,000	49,800	49,000	49,000	43,100
Lakeshore/Benjamin	200	300	300	300	400	300	300
Layton	16,500	32,300	32,700	32,400	32,600	32,100	33,000
Lehi	3,300	41,800	40,900	42,800	41,800	40,800	41,500
Lindon	3,400	13,800	13,500	13,800	13,700	13,100	13,500
Mapleton	400	3,000	3,200	3,400	3,300	2,800	3,700
Marriott-Slaterville	1,000	5,300	5,100	5,400	5,300	5,000	4,800
Midvale	15,000	19,800	20,300	19,800	19,800	19,600	20,400
Murray	39,900	46,200	47,400	46,300	46,600	47,200	49,100
North Ogden	1,700	3,000	2,900	2,900	3,200	3,000	3,300
North Salt Lake	7,000	19,800	20,000	20,000	19,500	19,900	14,000
Ogden	54,100	71,400	74,600	71,600	72,100	72,700	76,900
Orem	35,700	52,700	53,000	54,600	54,000	52,800	55,800
Other Unincorporated	6,700	20,200	19,600	20,300	19,600	20,200	19,000
Payson	3,800	21,900	20,400	21,600	22,200	20,300	9,200
Plain City	400	400	400	400	400	400	400

Table 6.8: Comparison of Jobs by Scenario

Jurisdiction	1997	LRP	No-build	Highway	Transit	Parking	UGB
Pleasant Grove	3,100	10,100	10,300	10,300	11,100	10,500	10,900
Pleasant View	1,100	6,700	6,300	6,800	7,300	6,900	7,200
Provo	55,400	104,900	100,300	95,600	109,900	111,700	132,200
Riverdale	8,100	9,600	9,900	9,600	9,800	9,500	10,000
Riverton	2,300	2,600	2,800	2,600	2,600	2,900	2,300
Roy	5,300	9,900	9,600	10,300	10,100	10,100	9,700
Salem	700	5,300	5,600	5,900	5,500	4,900	6,500
Salt Lake City	239,600	332,600	332,100	336,200	327,000	327,700	345,000
Sandy	34,200	42,300	43,000	41,900	42,900	41,800	41,200
Santaquin	200	400	300	400	400	300	400
Saratoga Springs	6	6,700	6,700	6,600	7,400	6,500	6,700
South Jordan	4,100	17,200	15,700	17,200	17,800	17,100	13,600
South Ogden	3,600	8,000	7,400	8,000	8,100	8,700	8,300
South Salt Lake	38,000	42,000	43,300	42,100	39,700	41,100	42,800
South Weber	200	1,900	1,900	1,800	1,700	1,800	1,700
Spanish Fork	6,200	40,000	39,800	37,500	39,700	39,800	32,700
Springville	7,800	23,000	23,100	21,900	22,800	23,000	25,400
Sunset	1,100	1,500	1,500	1,400	1,500	1,400	1,400
Syracuse	900	2,400	2,500	2,900	2,600	2,800	2,800
Taylorsville	16,300	25,600	26,700	25,400	24,200	25,300	26,600
Uintah	200	500	400	500	400	500	500
Vineyard	200	9,500	10,300	10,400	9,700	10,000	500
Washington Terrace	2,000	3,900	3,500	4,200	4,200	4,400	3,900
West Bountiful	1,300	2,200	2,500	2,300	2,500	2,200	2,500
West Davis County Unincorporated	400	12,900	11,700	12,800	11,800	13,300	3,700
West Haven	2,000	8,000	8,500	8,100	7,800	8,300	7,000
West Jordan	15,100	32,300	32,200	32,700	33,100	33,900	30,400
West Point	1,300	1,200	1,200	1,200	1,200	1,100	1,200
West Valley City	41,000	70,100	70,600	70,800	69,000	69,800	65,600
West Weber County Unincorporated	1,300	3,400	3,700	3,600	3,400	3,300	2,900
Woodland Hills	300	300	300	300	300	300	300
Woods Cross	2,400	8,200	8,500	8,200	8,300	8,800	4,900

6.9 Vacancy Rate Sensitivity

Based on a recommendation from the first Peer Review meeting, two scenarios were run as variations on the LRP scenario, in which a parameter on the vacancy rate variàble in the land price model was set at values of -0.5 and -1.0. This coefficient could not be estimated along with the other coefficients due to lack of historical data on vacancy rates. The results of these tests are summarized in Figure 6.85, and indicate that the effects of using non-zero coefficients on the vacancy variable is to modestly lower the trend in land prices over time.

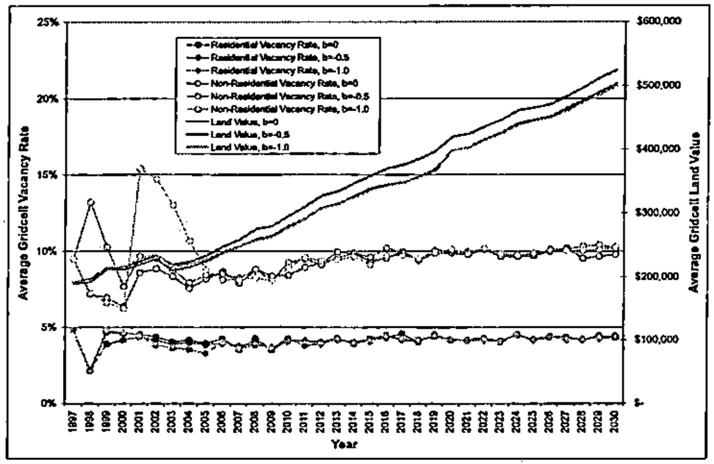

Figure 6.85: Land Price Sensitivity to Vacancy Rate Coefficient

6.10 Random Variation

UrbanSim uses random sampling to implement discrete choices from the probability distributions predicted by the multinomial logit equations in the model system. Since the models predict a probability of making each available choice, in order to implement one specific choice we use a random sampling procedure as follows. Assume that we predict the probability of making choices among 3 alternatives, with a probability of .3, .5, and .2 for the alternatives 1, 2 and 3 respectively. We construct a cumulatice probability distribution for these alternatives, as .3, .8, and 1, which define the probability ranges for each of these alternatives as being less than or equal to .3 for alternative 1, greater than .3 to .8 for alternative 2, and greater than .8 for alternative 3. We then sample a random number from a uniform distribution between 0 and 1, and determine which alternative the random number falls within. This is the selected alternative.

One question that arises is how random sampling in this approach might impact the stability of the model results. We conducted a test of this by running 10 model runs with identical inputs, over 10 years, allowing only the random seed, or starting value for the random number generator, to vary. We then computed the standard deviation for each grid cell on a series of quantities predicted by the model, and summarized these across all grid cells at different levels of geography. Not surprisingly, the degree of variation reduces as the level of geography becomes more aggregate, at the limit of the region, approaching zero since the regional totals are constraints imposed on the model. What is notable is that the level of uncertainty, or randomness, does not appear to significantly increase over time, and in some cases the trend is actually down over time. Figures 6.86 and 6.87 depict these trends for several levels of geography. Figures 6.88 and 6.89 depict these patterns from random variation in map form on three levels of geography: grid cells, traffic analysis zones, and small districts. The maps were produced from an earlier test of the model, over 5 years.

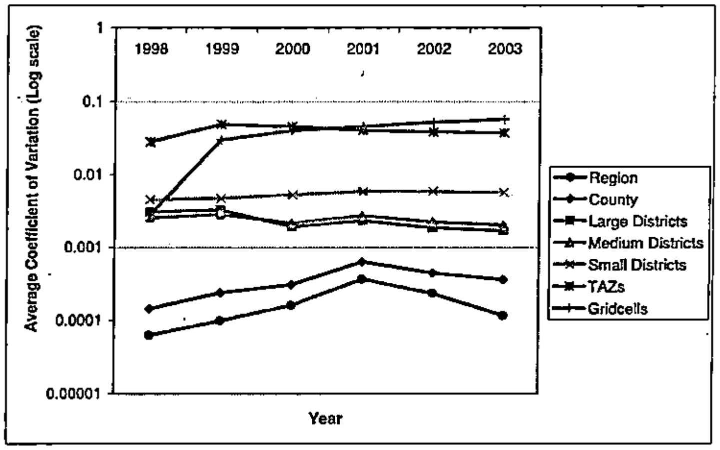

Figure 6.86: Random Variation in Nonresidential Floorspace by Geographic Level

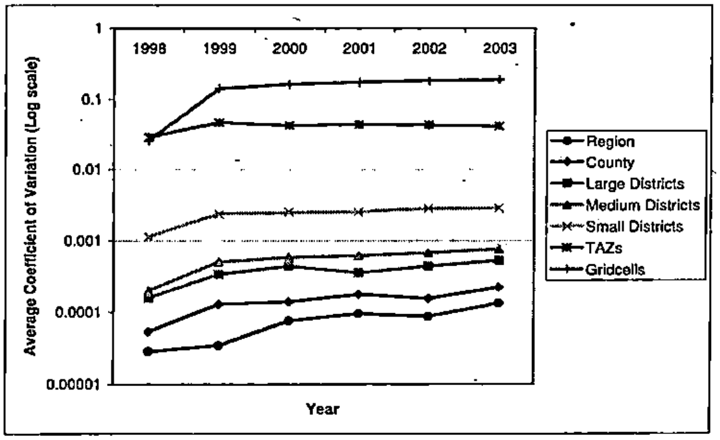

Figure 6.87: Random Variation in Residential Units by Geographic Level

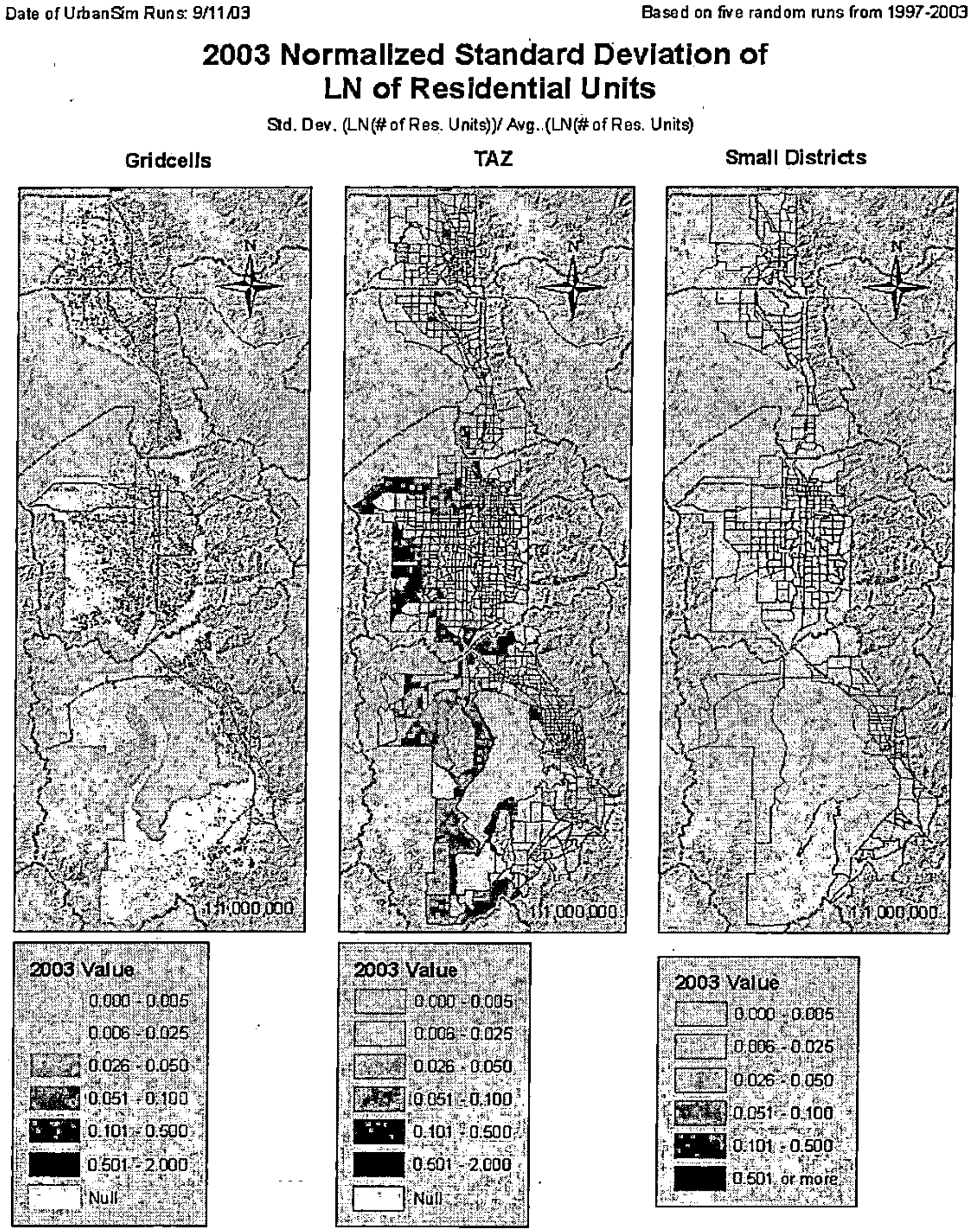

Figure 6.88: Random Variation in Residential Units Over 5 Years

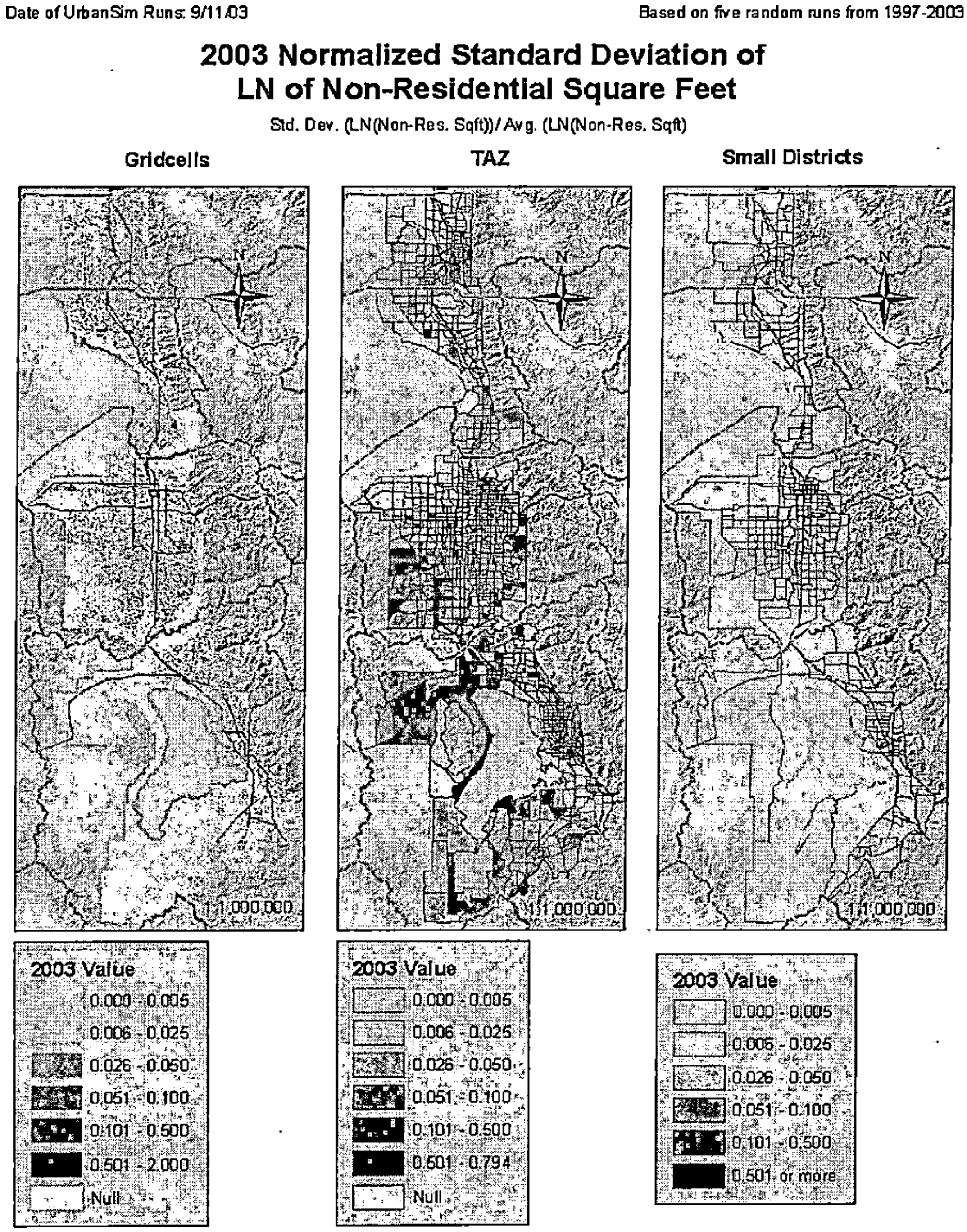

Figure 6.89: Random Variation in Non-residential Sqft Over 5 Years

Chapter 7

Conclusions

In Chapter 2, a set of evaluation criteria were proposed for the assessment of the appropriateness of UrbanSim (or other models) for use in operational metropolitan planning for land use and transportation. We return briefly to these evaluation criteria in this concluding chapter, commenting on each based on the results of this project. Considerable effort has been made to respond to concerns and issues that arose during the process of completing this project, and much progress has in fact been made. Not every issue has been fully addressed, however, and more effort would be valuable to invest in improving the inputs to the model, in particular in updating the base year database, and in further refining the model specifications based on lessons learned from this application.

7.0.1 Model Validity

Is the model structure theoretically sound? The theoretical validity of the model is a topic which the Peer Review Panel may address, but the theoretical basis of the model has been published in a variety of peer-reviewed journals, and the model has been extensively reviewed by studies conducted through the National Cooperative Highway Research Program, the Transit Cooperative Highway Research Program, and the EPA.

Are the quantitative methods used in the model appropriate? The principal methods used in UrbanSim are standard discrete choice models that have received widespread use in mode choice models, and increasingly in destination choice models.

Are the estimation results valid? The estimation results are generally statistically significant, though more needs to be done to integrate the model estimation to account for endogeneity across all the model equations. This is an area of considerable research focus within the UrbanSim project.

Are the simulation results reasonable? The patterns of results from the simulation of the alternative scenarios presented in this report appear plausible, and reasonable in terms of direction of effects. It is not possible to say definitively how accurate the results are in an absolute sense, given the nature of the testing and the limitations of observed historical data for use in validation.

Is the model appropriately sensitive to constraints and policies of interest? The direction of effects appeared generally reasonable, and the magnitudes were clearly larger for the alternatives that were expected to have a larger effect: the no-build scenario and the urban growth boundary scenario produced considerably larger differences from the Long Range Plan scenario than did the other scenarios.

Does it integrate well with the regional travel model system? A process for automating the interaction between the Wasatch Front Regional Travel model system, in TP+, with UrbanSim, was developed and used for unattended processing of 8 travel model runs for different years within each scenario. This process managed the summary of results from the MySQL database containing UrbanSim results, formatting the results for the Trip Generation model, launching the travel model, post-processing its results to incorporate them into the UrbanSim scenario database, and launching the next time period of UrbanSim simulation. It was written using the Perl scripting language, and includes Standard Query Language (SQL) for processing database queries.

7.0.2 Model Usability

Does it have an effective user interface? Although a user interface has been developed to interact with the model, create scenarios, and compute and examine indicators, the processing done for this project made extensive use of scripting and therefore bypassed the user interface. Considerable additional effort is being currently made to improve and extend the user interface and to facilitate scripting within this interface.

Is the computing performance adequate? UrbanSim runs the Wasatch Front model on a high end desktop (3.2 Ghz Pentium) at approximately 10 minutes per year. The travel model runs in approximately 2 hours per year, but is not run for every year. A combined simulation such as the runs executed for this testing, covering 33 years and 8 runs of the travel model, completed in just over one day.

Are requirements for data and expertise manageable? Data requirements of detailed models such as UrbanSim are high, including parcel data and employer data. Much progress has been made in the past year by the UrbanSim team in developing new tools to manage the database development process for the Puget Sound region, and these tools would be available at no cost to use in updating the WFRC database. Preliminary investigation suggests that the component data for updating the database are readily available. Moreover, much the same level of data would be required for almost any integrated land use and transportation model system. As for requirements for expertise, the requirement for UrbanSim is not substantially different than the expertise required to support a travel model system. If a user is involved in developing the database, expertise in database management and GIS would be required. For the model estimation phase, expertise in the specification and estimation of multinomial logit models would be required. For operating the model, a technical planner should be able to operate the model and examine results.

Does it produce needed indicators for diagnosis and evaluation? A set of over sixty indicators have been coded into UrbanSim at this point, and this set can be readily extended by users. A small subset was used in the evaluation of the scenarios in this report due to space constraints.

Does it integrate adequately into the institutional and political context? The integration of the model into the local institutional and political context ultimately must be managed by the relevant organizations. The model design recognizes that the role of the MPO or regional planning agency is very distinct from the role of local cities and counties, who manage land use policies and are generally the most knowledgeable sources of information on planned developments. By explicitly including land use policies as inputs, and providing a capacity to represent user-specified events, local input can be readily accommodated.

How useful is it in different use cases? The results to date suggest that once the concerns about input assumptions, and potential refinements in model specifications are addressed, it should be usable for the development of a baseline forecast, and for examination of the effects of large-scale projects or policies. It is less likely to be suitable for projects that are small in scope or effect, such as improvements to highways that are relatively small.

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Appendix A

Terms of the Settlement

SETTLEMENT AGREEMENT AND RELEASE

This Settlement Agreement and Release ("Agreement") is entered into by and among the Sierra Club, the United States Department of Transportation ("USDOT"), Secretary of the USDOT Norman Mineta, Federal Highway Administration ("FHWA"), FHWA Administrator Mary Peters, Division Administrator of FHWA Utah Division David Gibbs, Federal Transit Administration ("FTA"), FTA Administrator Jennifer Dorn, Regional FTA Administrator Lee Waddleton, United States Army Corps of Engineers ("COE"), District Engineer of COE Sacramento District Michael J. Walsh, COE Intermountain Regulatory Section Chief Brooks Carter, and the State of Utah ("Utah") this ___ day of ___________, 2002. WHEREAS, on or about January 31, 2001, Sierra Club filed a complaint in the United States District Court for the District of Utah against USDOT, Secretary Mineta, FHWA, Administrator Peters, Division Administrator Gibbs, FTA, Administrator Dorn, Regional Administrator Waddleton, COE, District Engineer Walsh, and Intermountain Regulatory Section Chief Carter (collectively "the Federal Defendants"), Civil No. 1:01 CV0014 J, which it amended on or about February 14, 2002 ("the Sierra Club Lawsuit"); WHEREAS, on or about May 9, 2001, the Sierra Club Lawsuit was consolidated with a lawsuit filed by Utahns for Better Transportation in the United States District Court for the District of Utah, Civil No. 1:01 CV0007 J ("the UBT Lawsuit"); WHEREAS, the UBT Lawsuit was filed against the same Defendants and alleges inadequacies in the environmental review and permitting of, and decision making concerning, the Legacy Parkway, a road proposed to be constructed in Davis County, Utah (the "Legacy Parkway Claims"); WHEREAS, on May 16, 2001, Utah intervened as a defendant in the UBT Lawsuit and the Sierra Club Lawsuit; WHEREAS, the Sierra Club Lawsuit contains the same Legacy Parkway Claims as the UBT Lawsuit as well as additional allegations set forth in the first through tenth counts in the Sierra Club's First Amended Complaint challenging FHWA and FTA decisions concerning Clean Air Act conformity, including findings of FHWA and FTA related to the Wasatch Front Regional Council's ("WFRC") 1998-2020 and 2030 Long Range Plans and 2001-2005 Transportation Improvement Program (the "Conformity Claims");

WHEREAS, the court has severed its consideration of the Conformity Claims from its decision on the Legacy Parkway Claims. The Legacy Parkway Claims were decided by the District Court in August 2001 and the Conformity Claims are scheduled to be heard in late summer 2002; WHEREAS the Defendants in the Sierra Club Lawsuit, including Intervenor Defendant Utah, have denied the truth of the allegations concerning the review and permitting of the Legacy Parkway and decision- making concerning the Legacy Parkway and WFRC conformity and transportation planning; and WHEREAS, Sierra Club, the Federal Defendants, and Utah (collectively, "the Parties") are desirous of resolving their disputes related to the Conformity Claims in the Sierra Club Lawsuit. NOW, THEREFORE, the Parties hereto agree as follows: 1. Within 7 days of the execution of this Agreement by the final signatory, FHWA, FTA and

WFRC will enter into a Memorandum of Agreement ("MOA") that conforms in substance to the draft attached hereto as Exhibit 1. 2. Within 7 days of the execution of this Agreement by the final signatory, Utah and WFRC will enter into a MOA that conforms in substance to the draft attached hereto as Exhibit 2. 3. Within 10 days of execution of this Agreement by the final signatory, the Parties will file a stipulation pursuant to Federal Rule of Civil Procedure 41(a)(1) dismissing, without prejudice, Counts 1 through 10 of the Sierra Club Lawsuit. 4. Nothing in the terms of this Agreement shall be construed to limit or modify the discretion accorded FHWA and FTA by the Clean Air Act, the Federal-Aid Highway Act and the Federal Transit Act or by general principles of administrative law. 5. The Parties agree to pay their own costs, individual expert fees and attorneys' fees they incurred or may incur in connection with the Sierra Club Lawsuit.

6. In the event that FHWA, FTA, WFRC and Utah accomplish the items specified in paragraphs 1 and 2 above and the MOAs referenced in those paragraphs, Sierra Club does hereby forever and fully discharge and release Federal Defendants and Utah, including, where applicable, their successors from any and all liability, claims, demands, actions, causes of action, suits, grievances, arbitrations, proceedings, costs, disbursements, attorneys' fees and all other claims of every kind and nature whatsoever, known or unknown, whether in law or equity, and however arising, against the Federal Defendants and Utah that it ever had or now has, concerning or arising out of the Conformity Claims in the Lawsuit, including any challenges to conformity findings made by FHWA or FTA prior to the date of this Agreement. This release, when effective, shall survive the termination of this Agreement. 7. In the event that FHWA, FTA, WFRC and Utah accomplish the items specified in paragraphs 1 and 2 above and the MOAs referenced in those paragraphs, Sierra Club agrees not to challenge future conformity findings made prior to January 31, 2004 by FHWA or FTA in the Wasatch Front region on any of the following grounds: (1) adequacy of land use modeling in the travel demand models used for the conformity findings; (2) adequacy of induced travel modeling in the travel demand models used for the conformity findings; and (3) adequacy of the empirical data on speed distributions in the travel demand models used for the conformity determinations. These limitations on Sierra Club challenges to future conformity findings shall apply to all conformity findings made prior to January 31, 2004. 8. In the event FHWA, FTA, WFRC and Utah do not accomplish the items specified in paragraphs 1 and 2 and the MOAs referenced in those paragraphs, the Sierra Club's sole remedies shall be the right to re-file Counts 1 through 10 of the Sierra Club Lawsuit and/or initiate litigation to seek review of any future conformity findings made by FHWA and FTA. 9. Except as expressly provided in this Agreement, none of the parties waives or relinquishes any legal rights, claims or defenses it may have. Nothing in this Agreement shall waive or affect in any manner whatsoever the Legacy Parkway Claims, nor shall anything in this Agreement affect in any matter whatsoever the appeal of the Legacy Parkway Claims

now docketed in the Tenth Circuit Court of Appeals as case number 01-4117. 10. It is understood and agreed that the Parties are settling disputed claims and that nothing set forth in this Agreement is intended to or may be construed or utilized as an admission of fault, liability or wrongdoing of any party. 11. This Agreement sets forth the entire agreement and understanding of the Parties and supersedes all prior agreements, arrangements and understandings between the parties, whether oral or written, with respect to the subject matter of the Sierra Club Lawsuit. 12. This Agreement shall not be amended or modified except in writing signed by all the parties. 13. The parties agree that they have fully consulted with their counsel regarding the effect of this Agreement.

14. The undersigned signatories on behalf of the respective parties are duly authorized to execute this Agreement as a document fully binding upon the entity on behalf of which it is signed. 15. This Agreement may be executed in Counterparts, with each fully enforceable as the other. 16. The Parties to this Agreement recognize and acknowledge that the obligations of FHWA and FTA under the MOA can only be paid from appropriated funds legally available for such purpose. Nothing in this Agreement shall be interpreted or construed as a commitment or requirement that FHWA or FTA obligate or pay funds in contravention of the Anti-Deficiency Act, 31 U.S.C. ? 1341, or any other applicable provision of law.

Sierra Club

By

Title

Date

United States Department of Transportation ("USDOT"), Secretary of the USDOT Norman Mineta, Federal Highway Administration ("FHWA"), FHWA Administrator Mary Peters, Division Administrator of FHWA Utah Division David Gibbs, Federal Transit Administration ("FTA"), FTA Administrator Jennifer Dorn, Regional FTA Administrator Lee Waddleton, United States Army Corps of Engineers ("COE"), District Engineer of COE Sacramento District Michael J. Walsh and COE Intermountain Regulatory Section Chief Brooks Carter

By

Title

Date

State of Utah

By

Title

Date

MEMORANDUM OF AGREEMENT

This Memorandum of Agreement ("MOA") is entered into this _____ day of _______, 2002 between the Federal Highway Administration ("FHWA"), the Federal Transit Administration ("FTA"), and the Wasatch Front Regional Council ("WFRC").

WHEREAS, on or about January 31, 2001, Sierra Club filed a Complaint in the United States District Court for the District of Utah against USDOT, Secretary Mineta, FHWA, Administrator Peters, Division Administrator Gibbs, FTA, Administrator Dorn, Regional Administrator Waddleton, COE, District Engineer Walsh, and Intermountain Regulatory Section Chief Carter (collectively "the Federal Defendants"), Civil No. 1:01 CV0014 J, which it amended on or about February 14, 2002 ("the Sierra Club Lawsuit"); WHEREAS on May 16, 2001, the State of Utah ("Utah") intervened as a defendant in the Sierra Club Lawsuit;

WHEREAS, Sierra Club, the Federal Defendants, and Defendant Intervenor Utah (collectively, "the Parties") have entered into a Settlement Agreement and Release in order to resolve their disputes related to the Sierra Club Lawsuit; and

WHEREAS one element of the Settlement Agreement and Release was that FHWA and WFRC enter into this MOA.

NOW, THEREFORE, FHWA, FTA and WFRC agree as follows:

1. WFRC has an interest in the UrbanSim model and previously began data collection in preparation for an application of UrbanSim to the Salt Lake City region. The FHWA Travel Model Research Program would like to document an application of UrbanSim to the region. Pursuant to an agreement on a Scope of Work between the University of Washington, FHWA and WFRC, the FHWA research program will provide 50,000 for data preparation for UrbanSim and for documentation of the results of the testing of UrbanSim by WFRC. WFRC shall complete the work under the 50,000 grant by January 1, 2004. The primary purpose for the provision of these funds is the documentation of results in a manner which will allow FHWA to assess the applicability of UrbanSim to the Salt Lake City region.

2. Following testing, WFRC will, in conjunction with other information required by law, (a) use the UrbanSim Modeling software for producing future-year socioeconomic and development forecasts that are necessary inputs to the travel demand forecasting process; and (b) use UrbanSim in conjunction with its travel modeling needs (i.e., WFRC's Long-Range Transportation Plan, Transportation Improvement Program and corridor studies) in an integrated fashion, provided that: a. WFRC need not use UrbanSim to test the possible effects of land-use policies unless required by law or separate agreement of the parties; b. UrbanSim is considered suitable for operational use in the Wasatch Front

area by: i. A majority of the WFRC board after evaluation by a peer review panel; ii. A peer review panel selected by WFRC which includes one qualified expert designated by the Sierra Club; and iii. FHWA; c. The scope of work outlined in the contract between FHWA and the University of Washington is completed. The peer review panel will issue a public report explaining its findings and recommendations.

3. Concurrent with FHWA review of any travel model output, such as conformity decisions for the long-range transportation plan and transportation improvement program, FHWA will request, and WFRC will provide it with, a named and dated version of the WFRC travel demand model, along with documentation that enables a user to run the model. Similarly, WFRC will provide FHWA, prior to the commencement of any public comment period on a Long Range Plan or Transportation Improvement Program, a named and dated version of the WFRC travel demand model, along with documentation that enables a user to run the model. FHWA will provide this documentation to third parties upon written request so that the third party can operate the model, but FHWA shall not be obligated to provide or otherwise be responsible for the cost of obtaining the software needed to run the model.

4. Beginning six months after the execution of this MOA, FHWA and FTA will request that any WFRC submission to FHWA and FTA for a conformity finding include a conformity analysis based upon application of MOBILE6. Prior to January 29, 2004, WFRC's submission of a conformity analysis based on MOBILE6 shall not preclude WFRC from submitting a conformity analysis, and FHWA and FTA from making a conformity finding, based upon MOBILE5 if the relevant area is not governed by an EPA-approved state implementation plan based upon MOBILE6.

5. WFRC will gather highway speed information in partnership with UDOT to check consistency with the empirical speed data used in its travel models and will provide to FHWA the highway speed information it gathers. Such data gathering and consistency review shall be completed on or before January 1, 2004. FHWA will provide this information to third parties upon written request. WFRC will input speed data into the MOBILE model consistent with EPA guidance.

6. This Agreement and the requirements imposed hereunder will expire on January 31, 2004.

Federal Highway Administration

By

Title

Date

Federal Transit Administration

By

Title

Date

Wasatch Front Regional Council

By

Title

Date

MEMORANDUM OF AGREEMENT

This Memorandum of Agreement ("MOA") is entered into this _____ day of _______, 2002 between the Utah Department of Transportation ("UDOT") on behalf of the State of Utah ("Utah") and the Wasatch Front Regional Council ("WFRC").

WHEREAS, on or about January 31, 2001, Sierra Club filed a Complaint in the United States District Court for the District of Utah against USDOT, Secretary Mineta, FHWA, Administrator Peters, Division Administrator Gibbs, FTA, Administrator Dorn, Regional Administrator Waddleton, COE, District Engineer Walsh, and Intermountain Regulatory Section Chief Carter (collectively "the Federal Defendants"), Civil No. 1:01 CV0014 J, which it amended on or about February 14, 2002 ("the Sierra Club Lawsuit"); WHEREAS on May 16, 2001, Utah intervened as a defendant in the Sierra Club Lawsuit;

WHEREAS, Sierra Club, the Federal Defendants, and Defendant Intervenor Utah (collectively, "the Parties") have entered into a Settlement Agreement and Release in order to resolve their disputes related to the Sierra Club Lawsuit; and

WHEREAS one element of the Settlement Agreement and Release was that Utah and WFRC enter into the following MOA.

NOW, THEREFORE, WFRC and UDOT agree as follows:

1. If adjustments to parameters or inputs are made to WFRC's travel demand model for specific UDOT projects, UDOT, with WFRC's assistance, will fully document and explain any such adjusted parameters or inputs.

2. By January 1, 2004, UDOT will undertake sensitivity testing of the WFRC travel demand model. UDOT will conduct a sensitivity test that indicates the model's representation of induced travel by simulating a no-build scenario and a highway-build scenario and calculating the elasticity of VMT with respect to lane miles of freeway and travel time. UDOT will also conduct sensitivity tests of the WFRC travel demand submodels? representation of induced travel. This can be done by holding constant the following components of induced travel from the future base case scenario to the highway-build scenario: (1) land use, (2) auto ownership, (3) trip generation, (4) trip distribution, (5) mode choice, and (6) traffic assignment.

3. Following the sensitivity testing described in paragraph 2 above, UDOT will provide to WFRC and the Parties a report documenting the results of the sensitivity testing provided for in this MOA. This report shall be issued prior to January 1, 2004.

4. This Agreement and the requirement imposed hereunder will expire on January 31, 2004.

State of Utah

By

Title

Date

Wasatch Front Regional Council

By

Title

Date

Appendix B

Report of the First Peer Review Meeting, June 26-27, 2003

WFRC Urbansim Application Peer Review Panel Report June 26-27, 2003

Recommendations - Immediate action (accomplish prior to Fall, 2003 meeting of panel)

- Establish a detailed work plan and schedule within two weeks, showing personnel deployment, confirm with participants (WFRC, UW), distribute to peer review panel (PRP), WRFC management, and participants. Make current version of the plan available to PRP and others on a secure website, and report significant deviations from plan and schedule to participants, WFRC management, and PRP.
- Make minor adjustments to Urbansim, re-estimate component models as necessary, and lock the model for use without further change for remainder of validation testing. This will be referred to as the validation model. Ongoing research may use parallel research versions of Urbansim.
- Model adjustments should include introduction of a mechanism to adjust floor space prices as a function of vacancy rate. Set initial parameter values to zero in anticipation of sensitivity testing in the evaluation process.
- Document this model, including statistical estimation parameters, goodness of fit measures, parameters adjusted during calibration (e.g. the developers' response to vacancy rate), and interpretation of the estimation and calibration, in a single, brief written report to the PRP . Goodness of fit measures should include tabular, graphed, and mapped comparison of calibration data and base year model results for principal outputs - population, households, housing units, prices and jobs. In collaboration with local stakeholders, identify and assess key differences, their potential causes and implications.
- Conduct, document and report model validation tests, as outlined below.
- In the iterative forecasting applications, rerun the transportation model package at least every 5 years, using the most appropriate network, but (for validation tests) not building new networks.

Recommendations - Future development of model system (accomplish after December 31, 2003 deadlines have been met).

- Introduce accessibility measures in Urbansim that are theoretically-consistent with the destination choice model used in the travel forecasting process and with standard assumptions of random utility theory.
- Develop and implement a more realistic strategy for generating location choice sets, i.e., influenced by household income, household size, etc.
- Calibrate and test a floor space price model that is sensitive to vacancy rates.
- Introduce and test travel impedance measures in all components of Urbansim to explore the sensitivity of location choices to local accessibility rather than to density measures alone. Based on results, introduce these improved accessibility measures into the travel models as well.
- Formulate and test truly dynamic version of Urbansim, i.e., a version calibrated with data on movers rather than estimated with cross-sectional data on the entire population sample.

Validation studies

- Use the validation version of Urbansim to forecast the 2002 housing, employment, land use, prices, and travel characteristics from the 1997 base year. Use the best available, appropriate networks, e.g., the 1997 network to forecast to 2000, and then the 2000 network including Trax to forecast to 2002. If feasible, also prepare a 2002 forecast using current procedures to measure relative accuracy of Urbansim. Compare results with best available data using these measures:

- Map and tabular comparison of Urbansim and current method results and objective data for population, households, housing units, jobs and prices. Provide similar comparisons for selected outputs of the travel models, e.g., vehicle miles of travel, vehicle hours of travel, average speeds, and other congestion measures. Report data for at least two levels of spatial aggregation.
- Results of comparisons by local stakeholders to identify and interpret key differences, their potential causes and implications.
- Graphs of time trends of key aggregate measures for Urbansim, the current forecasting procedure (if feasible), and travel models.
- Document data preparation procedures, assess data quality, and discuss implications for future applications of Urbansim (e.g., limitations, improvements, resource requirements).
- Use the validation version of Urbansim to produce two forecasts for 2030, the baseline using the current network, and a test forecast in which the long range transportation plan (LRP) is introduced in stages.
- Conduct a series of sensitivity tests by forecasting to 2030, making the following changes individually and in sequence:
    1. Remove a major highway link included in the LRP.
    2. Remove a major transit link included in the LRP.
    3. Significantly increase parking prices in downtown Salt Lake City (e.g., 50% increase in daily rates).
    4. Introduce a significant urban growth policy, e.g., an urban growth boundary or substantial cost increase in a rapidly developing part of the region.
    5. Test two different values of vacancy rate price sensitivity parameter.
- Forecasting and sensitivity test outputs should follow the same pattern as described above, i.e.:
- Map and tabular results from Urbansim for population, households, housing units, jobs and prices.
- Selected outputs of the travel models, e.g., vehicle miles of travel, vehicle hours of travel, average speeds, and other congestion measures, and mode shares by trip purpose (regionally and by subarea).
- Report tabular data for at least two levels of spatial aggregation.
- Assessment of the logic of forecasts by regional and local stakeholders to identify anomalies, their potential causes and implications.
- Graphs of time trends of key aggregate measures for both Urbansim and travel models.
- All evaluation results should be delivered in a single, integrated report at least two weeks prior to the fall meeting of the PRP.

This evaluation plan is subject to negotiated revisions to assure feasibility and effectiveness.

The PRP:
John Abraham (University of Calgary)
Gordon Garry (SACOG)
Eric Miller (University of Toronto)
Joseph Schofer (Northwestern University)
Jeff Tayman (SANDAG)
July 7, 2003

Appendix C

Documentation of Existing WFRC Land Use Forecasting Procedures

C.1 Overview of the Projections

Process The methodology used for this round of projections is similar to the process used in previous versions. It uses the same principles found in the WFRC MSID model as documented in Technical Report 39, though several enhancements have been made to the basic structure. There are four basic components to the projections methodology, base data: control totals, projections process, and review. These are discussed below.

C.1.1 Base Data

Base data for population and households come from the 2000 Census SF1 dataset at the block level. Blocks are summed to the TAZ and Tract levels. The TAZ structure in southwest Salt Lake County has been altered from the TIGER version to be more consistent in TAZ sizes with the rest of the region, as well as to give more detail to several transportation planning studies underway in the area.

Base employment data come from the 3rd Quarter, 2001 Utah Department of Workforce Services ES 202 database. The database was provided with site address, NAICS code, and number of employees. These records were then geocoded and assigned to TAZs. Once the records had been assigned to a TAZ, zone level totals were calculated for Total (non-construction, non-agricultural) employment, as well as various industry categories.

C.1.2 Control Totals

Control totals for the years 2002-2030 for population, households, and employment were provided at the county level by the Governor's Office of Planning and Budget (GOPB), as published in the 2003 Economic Report to the Governor. Both GOPB and WFRC staffs collaborate on the review of these county level totals before their publication. The Utah Process Economic and Demographic Model (UPED) is a hybrid economic-demographic model. A detailed discussion of the UPED model process is included below. These will be the final set of projections produced using the UPED model. All subsequent projections will be made using an econometric model called REMI Policy Insight.

C.1.3 City Projections

Like the previous version of projections, city level population projections were done separately from the TAZ projections. This was done to address comments from cities that the previous city level projections were not representative of their city, primarily because of TAZ boundaries not following city boundaries exactly. Undeveloped land and master plan land use were used as inputs, as were historical growth rates.

C.1.4 TAZ Projections

TAZ projections were made using the Modified Stratified Iterative Disaggregation (MSID) process described below, with some enhancements since the last set of projections. This method works on the theory developed by Dr. Bruce Newling[1] in 1969 that as distance from the central city increases, density decreases, and growth rates increase. The growth rates used in this set of projections were derived from analyzing historical growth trends from 1980 to 2000. The density calculation is performed every five years and the growth rate recalculated. Review Process The projections were subject to several rounds of review and revision. The projections are reviewed by individual jurisdictions for consistency

[1] Newling, Bruce, The Spatial Variation of Urban Population Densities, Geographical Review, Vol. 59, No. 2 (April , 1969), 242-252

with boundaries, land use element of the Master Plan, and reasonableness of the city and TAZ level projections. An expert panel made up of local jurisdictions, academia, state government, and interest groups reviews the methodology, assumptions, and results.

C.1.5 Base Data

Starting Point for Projections

The base data for the projections include initial population, dwelling units, and employment, as well as developable land. Data from the 2000 Census formed the base for the city and TAZ projections. The Utah Department of Workforce Services provided the 2001 employment data. These data, from their ES 202 database, included site address, NAICS code, and employment, and were geocoded and assigned to the proper TAZ.

Developable land

Once base population and employment were prepared, the land supply was examined and mapped. The data were from satellite imagery, analyzed using a procedure for identifying developed land created by the University of Utah's Energy and Geoscience Institute (EGI). Also used was a dataset showing environmental constraints, including steep slopes, flood plains, stream buffers, and wetlands. The amount of land in a TAZ or city that was not subject to environmental constraints was used in the density calculations. Land that was deemed undevelopable due to environmental constraints was taken out of the total and density was calculated using the total land available for development. The undeveloped land was further classified as residential or commercial using the master plans from each city and county.

C.1.6 Control Totals

UPED Model Overview

The following description of the UPED model is condensed from the GOPB website[2] and outlines the model that produces inputs to the WFRC projections. For a complete description of the UPED model and its equation structure, see the GOPB website.

UPED integrates a cohort-component demographic model with an economic base employment model. It generates long term demographic (population) and economic (employment) forecasts. The demographic component of UPED produces projections of births, deaths, and non-employment related in- and out-migration, while the economic component generates projections of employment and employment related net in-migration. The single most important driver of growth or decline in this model is the growth rate of employment associated with a region's economic base.

Demographic Component of UPED

The model employs the cohort survival population projection technique combined with econometric techniques for projecting the migration portion of population change. The UPED model begins with a census count base year population distributed by age and sex. The model then incorporates specific assumptions with regard to survival and fertility rates for each age and sex group and projects the population change over the next five-year period. This produces a natural increase in population disregarding in or out migration. Non-employment related in-migrants, such as retirees or students, are added and non-employment out-migrants are subtracted such that the result is a first approximation

[2] http://www.governor.state.ut.us/dea/publications/model/ch3a.htm

of the end of period population, that is, the expected end of period population in the absence of employment related migration. This value becomes input to the economic side of the model.

Economic Component of UPED

The economic component of UPED is an economic base employment model with the organizing concept of a labor market, which in disequilibrium, controls net in- or out- employment related migration. The central premise of this model is that external demand for a region's exports is the primary driving force behind the region's economic and demographic growth or decline. This demand is registered in the model as basic employment, which is used to produce goods and services for export. Estimates and projections of basic employment by industry sector are input to the model.

The population in the region also demands goods and services. Local production of goods and services for local consumption requires labor. The demand for labor is represented in the model as residentiary or population dependent employment. As the population of the region changes, this residentiary employment will change in a like direction. In the model, factors determining the level of this category of employment are 1) the population size and age structure, 2) trends in national per capita employment by industry reflecting changes in national consumption patterns and productivity, and 3) the local structure of production, reflecting regional differences, as compared with the U.S., in consumption patterns and the region's import structure. The total demand for labor, measured in jobs, is the sum of basic and residentiary employment.

Population, its age and sex composition, labor force participation rates and multiple job holding rates determine the supply of labor, again measured in terms of the number of jobs. Given the population from the demographic component of the model, if the supply of labor exceeds the demand for labor in sufficient numbers to yield an unemployment rate, which exceeds the equilibrium rate, employment related net out-migration occurs. On the other hand, if the unemployment rate is less than the equilibrium rate, employment related net in-migration results. If the labor market is in equilibrium, i.e., the unemployment rate is sufficiently close to the equilibrium rate, no migration occurs and the model proceeds to the next projection year. Nonemployment related out-migration is also projected in this section of the model, since the population base for this category of migration is the natural increase population plus employment related net in-migration.

In the event of migration, the size and composition of the population changes, which, in turn, affects the residentiary demand for labor, thus inducing further migration. This is solved iteratively. When equilibrium is achieved, the model proceeds to the next projection year. The ending population of the current year becomes the beginning population of the following year.

UPED makes projections at the multi-county district (MCD) level. GOPB and WFRC then disaggregate the MCD projections to counties based on growth trends, available land, etc. UPED does not have a land supply component as part of the model structure, thus that part of the review process becomes more important. Final products from UPED include population by age and sex, components of population change, households, household size, and 66 sectors of employment.

C.1.7 Projections Process and Enhancements

City Projections

City level projections of population were made using a growth rate method. The median growth rate for each city from 1990-1998 was calculated from US Bureau of the Census estimates and was applied to the 1998 Census estimate of each city's population. The decade of the 90s included periods of both slow and rapid growth. It was assumed that the growth rate would continue into the future until a city's population reached 90% of calculated buildout, at which point growth was assumed to slow. In that year the growth rate was halved and in each subsequent year, halved again. For each year, city population totals and the projection for unincorporated county land were controlled to the county total from GOPB using a factor applied across all cities.

A buildout population was calculated using the most current city boundaries available, satellite imagery estimating built/non-built environment, environmental constraints, and generalized master plan land use designations. The environmentally constrained land (steep slope, wetlands, etc.) was removed from the total area of a city. The 1998 population was divided by the estimate of built land to get an estimate of population per built acre. This density was then applied to the remaining residentially planned land within a city.

City level household and employment projections were made by summing the TAZ level projections to approximate the city boundaries.

TAZ Projections

For each TAZ the beginning point is the population and employment, as well as the zonal density for each data item. Using the density, a growth rate for each variable is selected based on the rates shown in Table 1. The annual growth rates are applied for five years. At each five-year interval densities are recalculated using the new population and employment and new growth rates are selected. The new growth rate is then applied for five years. This process in repeated until the horizon year (2030) is reached.

Table C.1: WFRC Density Assumptions

Population Minimum Density	Rate	Employment Minimum Density	Rate
0.00	0.0100	0.00	0.010
0.10	0.1472	0.14	0.156
0.51	0.0716	0.24	0.120
1.00	0.0731	0.48	0.100
2.45	0.0559	0.59	0.065
3.15	0.0487	0.93	0.050
4.13	0.0251	2.54	0.035
4.63	0.0269	4.35	0.025
5.40	0.0230	7.89	0.015
7.24	0.0118	58.31	0.0025
9.40	0.0090	10.50	0.0068
12.42	0.0014	14.00	0.0012
15.00	0.0037		

Once raw population, dwelling units, and employment are projected, the TAZ population data are controlled to the city level using the city level population projections. This is done using only the TAZs whose centroids fall within the city boundaries. After controlling to the city level, the TAZs are controlled to the county level using the control totals from GOPB. Zone totals may not sum to city totals, as the TAZ boundaries do not coincide with city boundaries. Some hand adjusting was performed, as well a check for reasonableness. Summing TAZs that form the tract calculates totals for each Census Tract. All TAZs nest within census tracts. Revision of density specific growth rates was undertaken to take advantage of the accessibility of the 2000 Census data. Analysis of data from the 1980, 1990, and 2000 censuses was undertaken in SPSS and the average growth rates from 1980-2000 were used.

Enhancements to the Projections Process

For this round of projections, some enhancements were made to the TAZ level projections process to better reflect the realities of development.

- Growth rate densities were calculated using only developable, residentially or commercially planned land, rather than all developable land in a TAZ.
- A buildout flag was incorporated into the population and employment projections to designate when a TAZ is considered "built out". This flag reduces the growth rate regardless of the density. It prevents already developed, low density zones from experiencing high projected growth based solely on the density. The flag activates when the overall population density (population / developable, residentially planned acres) reaches 1.2 times the existing density in the base data (base population / base developed, residentially planned acres). The buildout threshold for employment is 2 times existing density.
- The ability to add and track "seeds" in both population and employment was added. This is the ability to add known developments that the model would not otherwise pick up. An example of this is the Daybreak development in South Jordan.
- Employment was divided into more sub-categories to enhance WFRC's ability to model travel demand. Sub-categories are Government (including public education), Industrial, Retail, Service, and Wholesale.

The WFRC projections are currently maintained in an Excel spreadsheet and produce Population, Households, Total (non-agricultural, non-construction) Employment, Government Employment (including public education), Industrial Employment, Retail Employment, Service Employment, and Wholesale Employment projections for each year from 2002 to 2030. Projections are available at the TAZ, Census Tract, City, and County levels.

Review Process

Local governments were asked to review the projections at two stages in the development process. A final notification was sent to each city and county. An expert panel was formed to review the projections, as well as the methodology. Table 2 below lists committee members and their affiliations. The Working Group met in July, 2003 and, with the exception of the Sierra Club representative, concluded that the methodology was sound and that the results were reasonable at the regional level.

Table C.2: WFRC Review Committee

Name	Representing
Craig Barker	Weber County
Barry Burton	Davis County
Nina Dougherty	Sierra Club
Russ Fox	Envision Utah
Glen Graham	Town of Herriman
Spence Greer	Homebuilders Association of Greater Salt Lake
Mike Kaczorowski	Utah Department of Transportation
GJ Labonty	Utah Transit Authority
Neil Olsen	Salt Lake City Data Center
Mike Ostermiller	Greater Ogden Area Board of Realtors
Steve Pastorik	West Valley City
Pam Perlich	Bureau of Economic and Business Research
James Sorenson	Sandy City
Robert Spendlove	Governor's Office of Planning and Budget

Appendix D

Model Estimation Tables

D.1 Household Location Choice

Table D.1: Estimation Results for Household Location Model

Variable	Coefficient	Standard Error
Log of the quantity (household income minus one tenth of the gridcell's average price per residential unit) if positive, otherwise this is set to Log of .0000001 to indicate a budget constraint	0.0544	(0.0098)††
Interaction between income and log of improvement value per residential unit	0.2094e-04	(0.3797e-05)††
Household income interacted with percent of the gridcell that is residential land	0.2255e-06	(0.1121e-06)††
Log of the distance to nearest highway	-0.1091	(0.0129)††
Log of accessibility to employment in the cell's TAZ, given that it is a zero-vehicle household	0.4299	(0.2161)††
Log of accessibility to employment in the cell's TAZ, given that it is a one-vehicle household	0.8374	(0.5111)
Log of accessibility to employment in the cell's TAZ, given that it is a two-vehicle household	0.634	(0.588)
Log of the quantity household income times accessibility to employment for one-car households	-1.3968	(0.5069)††
Log of the number of residential units in the grid cell	-0.462	(0.0346)††
Log of quantity of retail within walking distance	0.159	(0.0139)††
Percent of households within walking distance that are designated as high-income, given that the decision-making household is high-income	0.0277	(0.0048)††
Percent of households within walking distance that are designated as low-income, given that the decision-making household is low-income	0.0438	(0.0032)††
Percent of development type group residential within walking distance	0.0091	(0.0023)††
Number of residential units in the cell, given that the decision-making household has children.	-0.0075	(0.0011)††
Indicator for a young head of household in a high density residential cell	0.3213	(0.0834)††

D.2 Employment Location Choice

Separate models are estimated for each sector of employment. Parameter estimates and standard errors for each equation are provided in the Tables D.2 through D.8 on the following pages.

Table D.2: Estimation Results for Employment Location Model - Sectors 1-2

Sector:	1: Resource Extraction		2: Construction	
Variable:	Coefficient	Std. Error	Coefficient	Std. Error
Indicator for development type 17	0	(0)	-0.2007	(0.0742)††
Indicator for development type 18	0.5556	(0.0658)††	-0.3292	(0.0798)††
Indicator for development type 19	0.9576	(0.0575)††	-0.2047	(0.0784)††
Indicator for development type 20	0	(0)	0	(0)
Indicator for development type 21	0	(0)	0	(0)
Indicator for development type 22	0	(0)	0	(0)
Indicator for development type 23	0	(0)	0	(0)
Indicator for development type group mixed use	0.7343	(0.052)††	0	(0)
Indicator for industrial or governmental development type	0	(0)	-0.566	(0.0685)††
Indicator for employment sector 10	0	(0)	0	(0)
Indicator for employment sector 11	0.0004	(0.7299e-04)††	-0.0001	(0.581e-04)††
Indicator for employment sector 12	0	(0)	-0.0003	(0.9163e-04)††
Indicator for employment sector 13	0	(0)	-0.0004	(0.0001)††
Indicator for employment sector 14	-0.0003	(0.439e-04)††	-0.0002	(0.3714e-04)††
Indicator for employment sector 1	0.0207	(0.0006)††	0.0036	(0.0009)††
Indicator for employment sector 2	0.0004	(0.0002)††	0.0042	(0.0001)††
Indicator for employment sector 3	-0.0009	(0.9026e-04)††	0	(0)
Indicator for employment sector 4	0	(0)	0	(0)
Indicator for employment sector 5	0	(0)	-0.0002	(0.8927e-04)†
Indicator for employment sector 6	-0.0019	(0.0001)††	-0.0004	(0.0001)††
Indicator for employment sector 7	0.0006	(0.0001)††	-0.0005	(0.0001)††
Indicator for employment sector 8	-0.0006	(0.0003)††	0	(0)
Indicator for employment sector 9	-0.0012	(0.0001)††	0	(0)
Log of the average land value per acre within walking distance	-0.1017	(0.02)††	-0.1049	(0.0182)††
Log of commercial sq.ft. in the grid cell	-0.5632	(0.0153)††	-0.4352	(0.0117)††
Log of the distance to nearest highway	0.0047	(0.0088)	0	(0)
Log of improvement value per residential unit within walking distance	0.0473	(0.0069)††	0.0205	(0.0074)††
Log of the number of residential units in the grid cell	0	(0)	0.0694	(0.023)††
Log of the number of residential units within walking distance	0	(0)	0.0318	(0.0153)††
Log of total value of the cell	0.1827	(0.0303)††	0	(0)
Log of work accessibility to employment for one vehicle households in the cell's TAZ	-5.7959	(0.4217)††	-1.3328	(0.2197)††
Log of work accessibility to population for one vehicle households in the cell's TAZ	4.1516	(0.3177)††	1.4062	(0.2533)††
AM peak hour travel time by single-occupancy vehicle from the cell's TAZ to the CBD's TAZ (or a representative TAZ for the CBD)	-0.0271	(0.009)††	0	(0)
AM peak hour travel time by single-occupancy vehicle from the cell's TAZ to the airport TAZ	-0.0297	(0.0089)††	0	(0)

Table D.3: Estimation Results for Employment Location Model - Sectors 3-4

Sector:	3: Manufacturing		4: Transp/Comm/Utilities	
Variable:	Coefficient	Std. Error	Coefficient	Std. Error
Indicator for development type 17	-1.1117	(0.1528)††	-1.5907	(0.2115)††
Indicator for development type 18	-0.8695	(0.1576)††	-1.7084	(0.2154)††
Indicator for development type 19	-0.8084	(0.1641)††	-1.3377	(0.2141)††
Indicator for development type 20	0	(0)	0	(0)
Indicator for development type 21	0	(0)	0	(0)
Indicator for development type 22	0	(0)	0	(0)
Indicator for development type 23	0	(0)	0	(0)
Indicator for development type group mixed use	-0.813	(0.1475)††	-0.7992	(0.1976)††
Indicator for industrial or governmental development type	-1.2662	(0.158)††	-1.7666	(0.2162)††
Indicator for employment sector 10	0	(0)	0	(0)
Indicator for employment sector 11	0.0002	(0.5911e-04)††	0	(0)
Indicator for employment sector 12	-0.0002	(0.7061e-04)††	-0.9474e-04	(0.4703e-04)††
Indicator for employment sector 13	0	(0)	-0.0002	(0.3558e-04)††
Indicator for employment sector 14	-0.0003	(0.3182e-04)††	-0.0002	(0.2386e-04)††
Indicator for employment sector 1	0.0034	(0.0005)††	-0.0008	(0.0005)†
Indicator for employment sector 2	0.0007	(0.0001)††	0	(0)
Indicator for employment sector 3	0.0014	(0.3586e-04)††	0	(0)
Indicator for employment sector 4	0	(0)	0.001	(0.2132e-04)††
Indicator for employment sector 5	-0.0002	(0.5452e-04)††	0.0002	(0.4318e-04)††
Indicator for employment sector 6	-0.0007	(0.7811e-04)††	0.0004	(0.6219e-04)††
Indicator for employment sector 7	0	(0)	-0.0004	(0.8547e-04)††
Indicator for employment sector 8	-0.0011	(0.0002)††	-0.0025	(0.0002)††
Indicator for employment sector 9	-0.0003	(0.9099e-04)††	0	(0)
Log of the average land value per acre within walking distance	-0.1218	(0.0157)††	-0.1236	(0.0227)††
Log of commercial sq.ft. in the grid cell	-0.1929	(0.0151)††	-0.2107	(0.0229)††
Log of the distance to nearest highway	0.0151	(0.0078)†	-0.0316	(0.008)††
Log of improvement value per residential unit within walking distance	0.025	(0.0058)††	0.0187	(0.004)††
Log of the number of residential units in the grid cell	0	(0)	-0.1258	(0.026)††
Log of the number of residential units within walking distance	-0.0243	(0.0115)††	0	(0)
Log of total value of the cell	0	(0)	0.2429	(0.0368)††
Log of work accessibility to employment for one vehicle households in the cell's TAZ	0.9413	(0.448)††	4.4435	(0.2425)††
Log of work accessibility to population for one vehicle households in the cell's TAZ	-1.592	(0.3233)††	-4.3165	(0.2871)††
AM peak hour travel time by single-occupancy vehicle from the cell's TAZ to the CBD's TAZ (or a representative TAZ for the CBD)	0.0202	(0.0079)††	0	(0)
AM peak hour travel time by single-occupancy vehicle from the cell's TAZ to the airport TAZ	-0.024	(0.0071)††	0	(0)

Table D.4: Estimation Results for Employment Location Model - Sectors 5-6

Sector:	5: Trucking/Wareh/Wholes		6: General Retail	
Variable:	Coefficient	Std. Error	Coefficient	Std. Error
Indicator for development type 17	-1.0665	(0.1765)††	0	(0)
Indicator for development type 18	-1.1349	(0.1852)††	0.2296	(0.0535)††
Indicator for development type 19	-0.9896	(0.1921)††	0.225	(0.0493)††
Indicator for development type 20	0	(0)	0	(0)
Indicator for development type 21	0	(0)	0	(0)
Indicator for development type 22	0	(0)	0	(0)
Indicator for development type 23	0	(0)	0	(0)
Indicator for development type group mixed use	-0.678	(0.1571)††	0	(0)
Indicator for industrial or governmental development type	-1.2767	(0.1847)††	-0.5146	(0.0536)††
Indicator for employment sector 10	0.0006	(0.0001)††	-0.0004	(0.8753e-04)††
Indicator for employment sector 11	0.0004	(0.6366e-04)††	-0.0002	(0.4592e-04)††
Indicator for employment sector 12	-0.0003	(0.8021e-04)††	0	(0)
Indicator for employment sector 13	0	(0)	0.0003	(0.3641e-04)††
Indicator for employment sector 14	-0.0003	(0.36e-04)††	-0.0002	(0.3034e-04)††
Indicator for employment sector 1	0.0011	(0.0005)††	-0.0064	(0.0006)††
Indicator for employment sector 2	0.001	(0.0001)††	0.0005	(0.0002)††
Indicator for employment sector 3	0.0001	(0.4889e-04)††	0	(0)
Indicator for employment sector 4	-0.0003	(0.5585e-04)††	0.0002	(0.4069e-04)††
Indicator for employment sector 5	0.0011	(0.4385e-04)††	-0.0003	(0.7815e-04)††
Indicator for employment sector 6	0	(0)	0.0015	(0.5183e-04)††
Indicator for employment sector 7	-0.0007	(0.0001)††	0.0007	(0.8893e-04)††
Indicator for employment sector 8	0.0006	(0.0002)††	0	(0)
Indicator for employment sector 9	-0.0006	(0.0001)††	0	(0)
Log of the average land value per acre within walking distance	-0.0445	(0.019)††	-0.1555	(0.0199)††
Log of commercial sq.ft. in the grid cell	-0.3102	(0.0167)††	-0.3303	(0.014)††
Log of the distance to nearest highway	-0.0256	(0.008)††	-0.02	(0.0069)††
Log of improvement value per residential unit within walking distance	0.0141	(0.0059)††	-0.0207	(0.008)††
Log of the number of residential units in the grid cell	-0.0705	(0.0246)††	0	(0)
Log of the number of residential units within walking distance	-0.05	(0.0131)††	0.1342	(0.0148)††
Log of total value of the cell	0	(0)	0.2249	(0.0301)††
Log of work accessibility to employment for one vehicle households in the cell's TAZ	2.4106	(0.492)††	3.0323	(0.4782)††
Log of work accessibility to population for one vehicle households in the cell's TAZ	-2.5001	(0.3688)††	-1.276	(0.3324)††
AM peak hour travel time by single-occupancy vehicle from the cell's TAZ to the CBD's TAZ (or a representative TAZ for the CBD)	0.0441	(0.0084)††	0.0667	(0.0086)††
AM peak hour travel time by single-occupancy vehicle from the cell's TAZ to the airport TAZ	-0.0476	(0.0074)††	-0.0061	(0.0084)

Table D.5: Estimation Results for Employment Location Model - Sectors 7-8

Sector:	7: Restaurants/Food Stores		8: Auto Sales/Services	
Variable:	Coefficient	Std. Error	Coefficient	Std. Error
Indicator for development type 17	0.3129	(0.074)††	0.9986	(0.1902)††
Indicator for development type 18	0.4751	(0.0718)††	0.8632	(0.1961)††
Indicator for development type 19	0.3549	(0.0756)††	0.7486	(0.2032)††
Indicator for development type 20	0	(0)	0	(0)
Indicator for development type 21	0	(0)	0	(0)
Indicator for development type 22	0	(0)	0	(0)
Indicator for development type 23	0	(0)	0	(0)
Indicator for development type group mixed use	0	(0)	0.5298	(0.1822)††
Indicator for industrial or governmental development type	-0.3138	(0.0748)††	0.4336	(0.2015)††
Indicator for employment sector 10	-0.0007	(0.7818e-04)††	-0.0005	(0.0001)††
Indicator for employment sector 11	-0.0004	(0.5914e-04)††	-0.0002	(0.6224e-04)††
Indicator for employment sector 12	-0.0003	(0.5919e-04)††	0	(0)
Indicator for employment sector 13	-0.0002	(0.3558e-04)††	-0.0004	(0.69e-04)††
Indicator for employment sector 14	-0.0002	(0.2842e-04)††	-0.0003	(0.3393e-04)††
Indicator for employment sector 1	0.0013	(0.0006)††	0.0039	(0.0007)††
Indicator for employment sector 2	-0.0011	(0.0002)††	0.0003	(0.0002)††
Indicator for employment sector 3	-0.0004	(0.6934e-04)††	-0.0004	(0.6596e-04)††
Indicator for employment sector 4	0	(0)	0.0001	(0.3854e-04)††
Indicator for employment sector 5	-0.9869e-04	(0.7618e-04)	0	(0)
Indicator for employment sector 6	-0.0002	(0.6604e-04)††	-0.0003	(0.7167e-04)††
Indicator for employment sector 7	0.0023	(0.8567e-04)††	0	(0)
Indicator for employment sector 8	0	(0)	0.0051	(0.0001)††
Indicator for employment sector 9	0.0003	(0.0001)††	0.0003	(0.0001)††
Log of the average land value per acre within walking distance	0	(0)	0	(0)
Log of commercial sq.ft. in the grid cell	-0.3742	(0.0146)††	-0.4983	(0.0247)††
Log of the distance to nearest highway	-0.0225	(0.0067)††	-0.0525	(0.0069)††
Log of improvement value per residential unit within walking distance	0	(0)	0.0646	(0.0089)††
Log of the number of residential units in the grid cell	0.0699	(0.0213)††	0.1221	(0.0227)††
Log of the number of residential units within walking distance	0.2189	(0.0136)††	0.0516	(0.0147)††
Log of total value of the cell	0.1814	(0.0316)††	0.1956	(0.0383)††
Log of work accessibility to employment for one vehicle households in the cell's TAZ	0	(0)	1.7104	(0.4626)††
Log of work accessibility to population for one vehicle households in the cell's TAZ	0	(0)	-1.7358	(0.3297)††
AM peak hour travel time by single-occupancy vehicle from the cell's TAZ to the CBD's TAZ (or a representative TAZ for the CBD)	0.0185	(0.0069)††	0.0468	(0.009)††
AM peak hour travel time by single-occupancy vehicle from the cell's TAZ to the airport TAZ	-0.0123	(0.007)†	-0.0356	(0.0089)††

Table D.6: Estimation Results for Employment Location Model - Sectors 9-10

Sector:	9: Finance		10: Insurance/Real Estate	
Variable:	Coefficient	Std. Error	Coefficient	Std. Error
Indicator for development type 17	-0.5391	(0.082)††	-1.094	(0.1871)††
Indicator for development type 18	0	(0)	-0.7367	(0.1868)††
Indicator for development type 19	0	(0)	-0.8122	(0.191)††
Indicator for development type 20	0	(0)	0	(0)
Indicator for development type 21	0	(0)	0	(0)
Indicator for development type 22	0	(0)	0	(0)
Indicator for development type 23	0	(0)	0	(0)
Indicator for development type group mixed use	-0.4465	(0.0721)††	-0.7329	(0.1709)††
Indicator for industrial or governmental development type	-1.104	(0.0578)††	-1.8345	(0.1973)††
Indicator for employment sector 10	0.0002	(0.6181e-04)††	0.0013	(0.4981e-04)††
Indicator for employment sector 11	0	(0)	0	(0)
Indicator for employment sector 12	-0.0004	(0.554e-04)††	-0.0002	(0.4536e-04)††
Indicator for employment sector 13	0.0002	(0.2405e-04)††	0	(0)
Indicator for employment sector 14	-0.0002	(0.3015e-04)††	-0.0002	(0.2466e-04)††
Indicator for employment sector 1	-0.0077	(0.0004)††	-0.0019	(0.0004)††
Indicator for employment sector 2	0	(0)	0	(0)
Indicator for employment sector 3	-0.0005	(0.6577e-04)††	-0.0005	(0.7343e-04)††
Indicator for employment sector 4	-0.0004	(0.5204e-04)††	0	(0)
Indicator for employment sector 5	-0.0009	(0.0001)††	-0.0004	(0.0001)††
Indicator for employment sector 6	0	(0)	-0.0003	(0.6772e-04)††
Indicator for employment sector 7	0	(0)	0	(0)
Indicator for employment sector 8	0	(0)	-0.001	(0.0002)††
Indicator for employment sector 9	0.002	(0.5761e-04)††	0	(0)
Log of the average land value per acre within walking distance	0	(0)	0.6515	(0.0547)††
Log of commercial sq.ft. in the grid cell	-0.267	(0.0147)††	-0.3129	(0.0215)††
Log of the distance to nearest highway	-0.0578	(0.0075)††	-0.0963	(0.0073)††
Log of improvement value per residential unit within walking distance	-0.0408	(0.0099)††	0.036	(0.0083)††
Log of the number of residential units in the grid cell	0.1798	(0.0221)††	0.1447	(0.0224)††
Log of the number of residential units within walking distance	0.0882	(0.0182)††	0	(0)
Log of total value of the cell	0.3861	(0.0326)††	0.2916	(0.0404)††
Log of work accessibility to employment for one vehicle households in the cell's TAZ	5.7796	(0.5418)††	-0.7749	(0.2202)††
Log of work accessibility to population for one vehicle households in the cell's TAZ	-3.3324	(0.3649)††	1.1773	(0.2555)††
AM peak hour travel time by single-occupancy vehicle from the cell's TAZ to the CBD's TAZ (or a representative TAZ for the CBD)	0.159	(0.0092)††	0	(0)
AM peak hour travel time by single-occupancy vehicle from the cell's TAZ to the airport TAZ	-0.0791	(0.0089)††	0	(0)

Table D.7: Estimation Results for Employment Location Model - Sectors 11-12

Sector:	11: Business/Prof. Services		12: Health Services	
Variable:	Coefficient	Std. Error	Coefficient	Std. Error
Indicator for development type 17	-0.0654	(0.0837)	0	(0)
Indicator for development type 18	0.1581	(0.0673)††	-0.1567	(0.0766)††
Indicator for development type 19	0.5633	(0.0491)††	0.3975	(0.0626)††
Indicator for development type 20	0	(0)	-1.12	(0.24)††
Indicator for development type 21	0	(0)	-0.3113	(0.1395)††
Indicator for development type 22	0	(0)	-0.4635	(0.1119)††
Indicator for development type 23	0	(0)	0.255	(0.0699)††
Indicator for development type group mixed use	0.2726	(0.0704)††	0	(0)
Indicator for industrial or governmental development type	0	(0)	0	(0)
Indicator for employment sector 10	0.0002	(0.6684e-04)††	-0.0012	(0.0001)††
Indicator for employment sector 11	0.0011	(0.4267e-04)††	0.0003	(0.4651e-04)††
Indicator for employment sector 12	-0.0002	(0.4803e-04)††	0.0009	(0.3256e-04)††
Indicator for employment sector 13	-0.0002	(0.3031e-04)††	-0.0002	(0.4155e-04)††
Indicator for employment sector 14	-0.0003	(0.2804e-04)††	-0.0003	(0.2989e-04)††
Indicator for employment sector 1	-0.001	(0.0005)††	0.0068	(0.0007)††
Indicator for employment sector 2	0	(0)	0	(0)
Indicator for employment sector 3	0	(0)	-0.0008	(0.9449e-04)††
Indicator for employment sector 4	0	(0)	0	(0)
Indicator for employment sector 5	0	(0)	-0.0017	(0.0002)††
Indicator for employment sector 6	0	(0)	-0.0008	(0.0001)††
Indicator for employment sector 7	-0.0005	(0.7632e-04)††	-0.0004	(0.0001)††
Indicator for employment sector 8	0.0007	(0.0001)††	0.0009	(0.0002)††
Indicator for employment sector 9	-0.0006	(0.7174e-04)††	0	(0)
Log of the average land value per acre within walking distance	-0.2133	(0.0167)††	-0.0783	(0.0292)††
Log of commercial sq.ft. in the grid cell	-0.397	(0.0135)††	-0.2874	(0.0127)††
Log of the distance to nearest highway	-0.0422	(0.0069)††	0.0368	(0.0085)††
Log of improvement value per residential unit within walking distance	0	(0)	-0.0468	(0.0132)††
Log of the number of residential units in the grid cell	0.0482	(0.0217)††	0.1187	(0.0192)††
Log of the number of residential units within walking distance	0.077	(0.011)††	0.3434	(0.0226)††
Log of total value of the cell	0.6711	(0.029)††	0.3723	(0.0307)††
Log of work accessibility to employment for one vehicle households in the cell's TAZ	-0.1612	(0.2062)	0.1326	(0.51)
Log of work accessibility to population for one vehicle households in the cell's TAZ	-0.111	(0.2449)	0.1066	(0.3697)
AM peak hour travel time by single-occupancy vehicle from the cell's TAZ to the CBD's TAZ (or a representative TAZ for the CBD)	0	(0)	-0.0769	(0.0091)††
AM peak hour travel time by single-occupancy vehicle from the cell's TAZ to the airport TAZ	0	(0)	0.0875	(0.0094)††

Table D.8: Estimation Results for Employment Location Model - Sectors 13-14

Sector:	13: General Services		14: Government/Education	
Variable:	Coefficient	Std. Error	Coefficient	Std. Error
Indicator for development type 17	0	(0)	-1.2362	(0.1958)††
Indicator for development type 18	0	(0)	-1.3323	(0.1984)††
Indicator for development type 19	0	(0)	-0.7546	(0.1941)††
Indicator for development type 20	0	(0)	-2.3423	(0.2897)††
Indicator for development type 21	0	(0)	-2.2407	(0.2602)††
Indicator for development type 22	0	(0)	-1.4694	(0.2103)††
Indicator for development type 23	0	(0)	0.3987	(0.1941)††
Indicator for development type group mixed use	0	(0)	-0.889	(0.1837)††
Indicator for industrial or governmental development type	-0.3439	(0.0434)††	0	(0)
Indicator for employment sector 10	-0.0003	(0.8462e-04)††	-0.0002	(0.9291e-04)††
Indicator for employment sector 11	0.0002	(0.4354e-04)††	0.0006	(0.4006e-04)††
Indicator for employment sector 12	-0.0003	(0.4841e-04)††	-0.0004	(0.3694e-04)††
Indicator for employment sector 13	0.0004	(0.3167e-04)††	-0.0002	(0.397e-04)††
Indicator for employment sector 14	-0.7934e-04	(0.2257e-04)††	0.0003	(0.1303e-04)††
Indicator for employment sector 1	0.0011	(0.0005)††	0.0028	(0.0005)††
Indicator for employment sector 2	-0.0012	(0.0002)††	-0.0013	(0.0002)††
Indicator for employment sector 3	-0.0005	(0.6554e-04)††	-0.0005	(0.7323e-04)††
Indicator for employment sector 4	-0.0004	(0.5501e-04)††	-0.0005	(0.5991e-04)††
Indicator for employment sector 5	0.0004	(0.6312e-04)††	0	(0)
Indicator for employment sector 6	0.0002	(0.6581e-04)††	0	(0)
Indicator for employment sector 7	-0.0003	(0.9393e-04)††	-0.0011	(0.9962e-04)††
Indicator for employment sector 8	0	(0)	0	(0)
Indicator for employment sector 9	0	(0)	0	(0)
Log of the average land value per acre within walking distance	-0.0836	(0.0196)††	-0.0815	(0.0209)††
Log of commercial sq.ft. in the grid cell	-0.3958	(0.0133)††	-0.2513	(0.0213)††
Log of the distance to nearest highway	-0.0214	(0.007)††	0.0259	(0.0082)††
Log of improvement value per residential unit within walking distance	0.0467	(0.0062)††	0.065	(0.008)††
Log of the number of residential units in the grid cell	0.0598	(0.0138)††	0	(0)
Log of the number of residential units within walking distance	0	(0)	0.1076	(0.0149)††
Log of total value of the cell	0.3081	(0.0274)††	0.2801	(0.0313)††
Log of work accessibility to employment for one vehicle households in the cell's TAZ	0	(0)	-2.2422	(0.4516)††
Log of work accessibility to population for one vehicle households in the cell's TAZ	0	(0)	1.2822	(0.3343)††
AM peak hour travel time by single-occupancy vehicle from the cell's TAZ to the CBD's TAZ (or a representative TAZ for the CBD)	-0.0758	(0.0067)††	-0.0609	(0.0086)††
AM peak hour travel time by single-occupancy vehicle from the cell's TAZ to the airport TAZ	0.0691	(0.0069)††	0.0223	(0.0094)††

D.3 Land Price

Table D.9: Estimation Results for Land Price Model

Variable	Coefficient	Standard Error
Constant	-6.386	(0.1081)‡
Indicator for development type 1	-0.4364	(0.0357)‡
Indicator for development type 10	0.1871	(0.0686)‡
Indicator for development type 11	0.2523	(0.052)‡
Indicator for development type 12	0.2806	(0.0928)‡
Indicator for development type 13	0.4827	(0.0845)‡
Indicator for development type 14	0.0841	-0.0801
Indicator for development type 15	0.19	-0.1277
Indicator for development type 16	0.6722	(0.1232)‡
Indicator for development type 17	0.4012	(0.0357)‡
Indicator for development type 18	0.7084	(0.0425)‡
Indicator for development type 19	0.9124	(0.0449)‡
Indicator for development type 2	-0.2433	(0.0369)‡
Indicator for development type 20	0.2733	(0.0411)‡
Indicator for development type 21	0.2782	(0.047)‡
Indicator for development type 22	0.6078	(0.0472)‡
Indicator for development type 23	0.1141	(0.0155)‡
Indicator for development type 3	-0.181	(0.0413)‡
Indicator for development type 4	-0.0932	(0.0451)‡
Indicator for development type 5	-0.1507	(0.0475)‡
Indicator for development type 6	-0.3116	(0.0514)‡
Indicator for development type 7	-0.612	(0.0563)‡
Indicator for development type 8	-0.7599	(0.0806)‡
Indicator for development type 9	-0.0833	(0.0299)‡
Indicator for cells near a highway	0.1347	(0.0145)‡
Log of the average total value per residential unit within walking distance	-0.0042	(0.001)‡
Log of commercial sq.ft. in the grid cell	-0.0668	(0.0032)‡
Log of commercial sq.ft within walking distance	3.03E-05	-0.0012
Log of the distance to nearest highway	0.0581	(0.0027)‡
Log of accessibility to employment for one-vehicle households in the cell's TAZ	-0.8286	(0.0317)‡
Log of accessibility to population for one-vehicle households in the cell's TAZ	2.0242	(0.0356)‡
Log of the percent of development type group commercial within walking distance	0.0333	(0.0044)‡
Log of the percent of development type group governmental within walking distance	0.0549	(0.0027)‡
Log of the percent of development type group industrial within walking distance	0.0563	(0.0049)‡
Log of the percent of development type group mixed use within walking distance	0.0066	-0.0042
Log of the number of residential units in the grid cell	0.1861	(0.0122)‡
Log of the number of residential units within walking distance	0.1634	(0.0032)‡
Log of total employment within walking distance	0.0493	(0.0032)‡
Log of total improvement value in the cell	0.1195	(0.0031)‡
Percent of cell covered by floodplain	-0.0055	(0.0003)‡
Percent of cell covered by open space	0.0052	(0.0002)‡

Table D.9: Estimation Results for Land Price Model

Variable	Coefficient	Standard Error
Percent of cell covered by public space	-0.0043	(0.0002)‡
Percent of cell covered by roads	-0.0021	(0.0002)‡
Percent of cell covered by slope	-0.0139	(0.0002)‡
Percent of cell covered by stream buffers	-0.0099	(0.0008)‡
Percent of cell covered by water	-0.0054	(0.0004)‡
Percent of cell covered by wetland	-0.0099	(0.0004)‡
Indicator for plantype 1	-0.0092	-0.021
Indicator for plantype 10	-0.143	(0.0415)‡
Indicator for plantype 2	0.4768	(0.0112)‡
Indicator for plantype 3	0.6788	(0.0165)‡
Indicator for plantype 4	0.5646	(0.014)‡
Indicator for plantype 5	0.8113	(0.1268)‡
Indicator for plantype 6	0.5654	(0.0202)‡
Indicator for plantype 7	0.3854	(0.0221)‡
Indicator for plantype 8	1.6278	(0.0258)‡
Indicator for plantype 9	-0.4824	-0.4814

D.4 Real Estate Development

Table D.10: Estimation Results for Developer Model - Development Type 1: R1

Alternative:	No-build		1: R1		2: R2		2: R3	
Variable	Coeff.	Std. Err.	Coeff.	Std. Err.	Coeff.	Std. Err.	Coeff.	Std. Err.
Constant(Calibrated)	0.1336	()	-8.7425	()	-15.5508	()	-21.6353	()
Constant	0	(0)	-6.5855	(1.2942)††	-13.9995	(0.9062)††	-20.8178	(0.9793)††
Indicator for cells near an arterial	0	(0)	0.4884	(0.2745)†	0	(0)	0	(0)
Indicator for cells near a highway	0	(0)	0	(0)	-0.6633	(0.1196)††	-0.6633	(0.1196)††
Log of accessibility to population for one-vehicle households in the cell's TAZ	0	(0)	0.3293	(0.0936)††	0.3293	(0.0936)††	0	(0)
Log of the total land value in the grid cell	0	(0)	-0.1652	(0.0891)†	0.7839	(0.0387)††	1.5156	(0.0778)††
Percent of development type group commercial within walking distance	0	(0)	-0.0454	(0.0065)††	-0.0454	(0.0065)††	-0.0454	(0.0065)††
Percent of development type group industrial within walking distance	0	(0)	0	(0)	-0.0639	(0.0139)††	0	(0)

Alternative:	4: R4		5: R5		9: M1	
Variable	Coeff.	Std. Err.	Coeff.	Std. Err.	Coeff.	Std. Err.
Constant(Calibrated)	-41.7624	()	-26.878	()	-7.3471	()
Constant	-40.7242	(5.0711)††	-26.0935	(3.1501)††	-5.2884	(0.2133)††
Indicator for cells near an arterial	-0.377	(0.2726)	-0.377	(0.2726)	1.0521	(0.3081)††
Indicator for cells near a highway	0	(0)	0	(0)	0	(0)
Log of accessibility to population for one-vehicle households in the cell's TAZ	1.7866	(0.5008)††	0	(0)	0	(0)
Log of the total land value in the grid cell	1.211	(0.2087)††	1.7448	(0.2455)††	0	(0)
Percent of development type group commercial within walking distance	-0.0454	(0.0065)††	0	(0)	0.0539	(0.0171)††
Percent of development type group industrial within walking distance	0	(0)	0	(0)	0.0376	(0.0363)

Table D.11: Estimation Results for Developer Model - Development Type 2: R2

Alternative:	No-build		2: R2		3: R3		4: R4	
Variable	Coeff.	Std. Err.	Coeff.	Std. Err.	Coeff.	Std. Err.	Coeff.	Std. Err.
Constant(Calibrated)	0.9142	()	-12.5403	()	-15.0809	()	-28.2783	()
Constant	0	(0)	-12.0371	(0.7144)††	-14.8487	(0.7369)††	-28.2176	(2.3068)††
Indicator for cells near an arterial	0	(0)	-0.2826	(0.0437)††	-0.2826	(0.0437)††	-0.4662	(0.1661)††
Indicator for cells near a highway	0	(0)	-0.5438	(0.072)††	-0.5438	(0.072)††	-0.8881	(0.2897)††
Log of accessibility to population for one-vehicle households in the cell's TAZ	0	(0)	0.5841	(0.0763)††	0.2091	(0.0773)††	0.8273	(0.2167)††
Log of the total land value in the grid cell	0	(0)	0.3135	(0.0385)††	0.9052	(0.0433)††	1.1757	(0.098)††
Percent of development type group commercial within walking distance	0	(0)	-0.0318	(0.0041)††	-0.0318	(0.0041)††	-0.0187	(0.0107)†
Percent of development type group industrial within walking distance	0	(0)	-0.0534	(0.0107)††	-0.0225	(0.0085)††	0	(0)
Percent of development type group residential within walking distance	0	(0)	-0.0037	(0.0011)††	-0.0037	(0.0011)††	-0.0037	(0.0011)††

Alternative:	5: R5		6: R6		9: M1		17: C1	
Variable	Coeff.	Std. Err.	Coeff.	Std. Err.	Coeff.	Std. Err.	Coeff.	Std. Err.
Constant(Calibrated)	-18.5818	()	-6.6598	()	-3.4385	()	-7.6679	()
Constant	-18.6131	(1.2102)††	0	(0)	-2.8536	(1.8371)	0	(0)
Indicator for cells near an arterial	-0.8733	(0.355)††	0	(0)	0.4495	(0.2911)	0	(0)
Indicator for cells near a highway	-1.177	(0.5911)††	0	(0)	0	(0)	0	(0)
Log of accessibility to population for one-vehicle households in the cell's TAZ	0	(0)	0	(0)	0	(0)	0	(0)
Log of the total land value in the grid cell	1.1757	(0.098)††	0	(0)	-0.1847	(0.184)	0	(0)
Percent of development type group commercial within walking distance	0	(0)	0	(0)	0.0588	(0.019)††	0	(0)
Percent of development type group industrial within walking distance	0	(0)	0	(0)	-0.0685	(0.0676)	0	(0)
Percent of development type group residential within walking distance	-0.0125	(0.0057)††	0	(0)	-0.0133	(0.0095)	0	(0)

Table D.12: Estimation Results for Developer Model - Development Type 3: R3

Alternative:	No-build		3: R3		4: R4		5: R5	
Variable	Coeff.	Std. Err.	Coeff.	Std. Err.	Coeff.	Std. Err.	Coeff.	Std. Err.
Constant(Calibrated)	0.9846	(0)	-7.9398	(0)	-11.2755	(0)	-21.7854	(0)
Constant	0	(0)	-7.7332	(0.556)††	-11.0894	(0.7598)††	-21.75	(2.1566)††
Indicator for cells near an arterial	0	(0)	-0.2103	(0.0406)††	-0.2103	(0.0406)††	-0.2103	(0.0406)††
Indicator for cells near a highway	0	(0)	-0.4474	(0.064)††	-0.4474	(0.064)††	-0.4474	(0.064)††
Log of accessibility to population for one-vehicle households in the cell's TAZ	0	(0)	0.1305	(0.0575)††	0.1396	(0.0757)†	0.9232	(0.1804)††
Log of the total land value in the grid cell	0	(0)	0.4884	(0.0397)††	0.6557	(0.0521)††	0.6557	(0.0521)††
Percent of development type group commercial within walking distance	0	(0)	-0.0505	(0.0041)††	-0.0245	(0.0047)††	-0.0394	(0.0108)††
Percent of development type group industrial within walking distance	0	(0)	-0.0459	(0.0081)††	-0.027	(0.0098)††	0	(0)
Percent of development type group residential within walking distance	0	(0)	-0.0146	(0.0012)††	-0.0099	(0.0016)††	-0.0254	(0.0032)††

Alternative:	6: R6		7: R7		9: M1	
Variable	Coeff.	Std. Err.	Coeff.	Std. Err.	Coeff.	Std. Err.
Constant(Calibrated)	-21.1299	(0)	-5.8814	(0)	-6.2691	(0)
Constant	-20.868	(5.7762)††	0	(0)	0	(0)
Indicator for cells near an arterial	0	(0)	0	(0)	0	(0)
Indicator for cells near a highway	0	(0)	0	(0)	0	(0)
Log of accessibility to population for one-vehicle households in the cell's TAZ	1.1935	(0.462)††	0	(0)	0	(0)
Log of the total land value in the grid cell	0	(0)	0	(0)	0	(0)
Percent of development type group commercial within walking distance	0.0378	(0.0161)††	0	(0)	0	(0)
Percent of development type group industrial within walking distance	0	(0)	0	(0)	0	(0)
Percent of development type group residential within walking distance	0	(0)	0	(0)	0	(0)

Table D.13: Estimation Results for Developer Model - Development Type 4: R4

Alternative:	No-build		4: R4		5: R5		6: R6	
Variable	Coeff.	Std. Err.	Coeff.	Std. Err.	Coeff.	Std. Err.	Coeff.	Std. Err.
Constant(Calibrated)	0.7314	(0)	-4.1228	(0)	-4.2887	(0)	-21.6913	(0)
Constant	0	(0)	-3.3896	(0.669)††	-3.5821	(0.4539)††	-20.9741	(5.0544)††
Indicator for cells near an arterial	0	(0)	-0.2155	(0.049)††	-0.2155	(0.049)††	-0.5046	(0.3832)
Indicator for cells near a highway	0	(0)	-0.5283	(0.0737)††	-0.5283	(0.0737)††	-0.5283	(0.0737)††
Log of accessibility to population for one-vehicle households in the cell's TAZ	0	(0)	0.0216	(0.0583)	0	(0)	1.386	(0.4029)††
Log of the total land value in the grid cell	0	(0)	0.2445	(0.0378)††	0.2445	(0.0378)††	0	(0)
Percent of development type group commercial within walking distance	0	(0)	-0.0353	(0.0035)††	-0.0353	(0.0035)††	-0.0269	(0.0207)
Percent of development type group industrial within walking distance	0	(0)	-0.0344	(0.0084)††	0	(0)	0	(0)
Percent of development type group residential within walking distance	0	(0)	-0.0124	(0.0015)††	-0.0162	(0.0017)††	-0.0162	(0.0017)††

Alternative:	7: R7	
Variable	Coeff.	Std. Err.
Constant(Calibrated)	-7.264	(0)
Constant	0	(0)
Indicator for cells near an arterial	0	(0)
Indicator for cells near a highway	0	(0)
Log of accessibility to population for one-vehicle households in the cell's TAZ	0	(0)
Log of the total land value in the grid cell	0	(0)
Percent of development type group commercial within walking distance	0	(0)
Percent of development type group industrial within walking distance	0	(0)
Percent of development type group residential within walking distance	0	(0)

Table D.14: Estimation Results for Developer Model - Development Type 5: R5

Alternative:	No-build		5: R5		6: R6		7: R7	
Variable	Coeff.	Std. Err.	Coeff.	Std. Err.	Coeff.	Std. Err.	Coeff.	Std. Err.
Constant(Calibrated)	0.7955	(0)	-0.9804	(0)	-9.4943	(0)	-7.5283	(0)
Constant	0	(0)	0.3615	(0.8256)	-8.1767	(1.7243)††	0	(0)
Indicator for cells near an arterial	0	(0)	-0.2666	(0.0616)††	-0.2666	(0.0616)††	0	(0)
Indicator for cells near a highway	0	(0)	-0.558	(0.0985)††	-0.558	(0.0985)††	0	(0)
Log of accessibility to population for one-vehicle households in the cell's TAZ	0	(0)	-0.1533	(0.0792)†	0.676	(0.1392)††	0	(0)
Log of the total land value in the grid cell	0	(0)	0.1968	(0.0556)††	0	(0)	0	(0)
Percent of development type group commercial within walking distance	0	(0)	-0.0468	(0.0041)††	-0.0468	(0.0041)††	0	(0)
Percent of development type group industrial within walking distance	0	(0)	-0.0207	(0.0083)††	-0.0343	(0.0147)††	0	(0)
Percent of development type group residential within walking distance	0	(0)	-0.0211	(0.0019)††	-0.0334	(0.0028)††	0	(0)

Table D.15: Estimation Results for Developer Model - Development Type 6: R6

Alternative:	No-build		5: R5		6: R6	
Variable	Coeff.	Std. Err.	Coeff.	Std. Err.	Coeff.	Std. Err.
Constant(Calibrated)	0.3225	(0)	-7.4837	(0)	-6.0984	(0)
Constant	0	(0)	-5.0552	(1.7161)††	-3.6422	(2.0692)†
Indicator for cells near an arterial	0	(0)	-0.2806	(0.1266)††	0	(0)
Indicator for cells near a highway	0	(0)	-0.4483	(0.1858)††	0	(0)
Log of accessibility to population for one-vehicle households in the cell's TAZ	0	(0)	0.5145	(0.1402)††	0	(0)
Log of the total land value in the grid cell	0	(0)	0	(0)	0.2826	(0.1664)†
Percent of development type group commercial within walking distance	0	(0)	-0.0309	(0.0072)††	-0.0309	(0.0072)††
Percent of development type group industrial within walking distance	0	(0)	-0.0355	(0.0109)††	-0.0355	(0.0109)††
Percent of development type group residential within walking distance	0	(0)	-0.0274	(0.0035)††	-0.0355	(0.0063)††

Table D.16: Estimation Results for Developer Model - Development Type 7: R7

Alternative:	No-build		7: R7	
Variable	Coeff.	Std. Err.	Coeff.	Std. Err.
Constant(Calibrated)	0.3291	(0)	-5.4724	(0)
Constant	0	(0)	-2.8999	(0.8104)††
Indicator for cells near an arterial	0	(0)	0	(0)
Indicator for cells near a highway	0	(0)	-0.5964	(0.1903)††
Log of accessibility to population for one-vehicle households in the cell's TAZ	0	(0)	0	(0)
Log of the total land value in the grid cell	0	(0)	0.1086	(0.0718)
Percent of development type group commercial within walking distance	0	(0)	0.0119	(0.0091)
Percent of development type group industrial within walking distance	0	(0)	0.0175	(0.0164)
Percent of development type group residential within walking distance	0	(0)	0.0114	(0.0053)††

Table D.17: Estimation Results for Developer Model - Development Type 8: R8

Alternative:	No-build		8: R8	
Variable	Coeff.	Std. Err.	Coeff.	Std. Err.
Constant(Calibrated)	0.3305	(0)	-3.4703	(0)
Constant	0	(0)	-0.4692	(11.4473)
Indicator for cells near an arterial	0	(0)	-0.5738	(0.4333)
Indicator for cells near a highway	0	(0)	0	(0)
Log of accessibility to population for one-vehicle households in the cell's TAZ	0	(0)	2.0328	(0.9599)††
Log of the total land value in the grid cell	0	(0)	-2.0481	(0.5821)††
Percent of development type group commercial within walking distance	0	(0)	0.0296	(0.0246)
Percent of development type group industrial within walking distance	0	(0)	-0.1378	(0.0512)††
Percent of development type group residential within walking distance	0	(0)	0.019	(0.0169)

Table D.18: Estimation Results for Developer Model - Development Type 9: M1

Alternative:	No-build		4: R4		9: M1	
Variable	Coeff.	Std. Err.	Coeff.	Std. Err.	Coeff.	Std. Err.
Constant(Calibrated)	0.5617	(0)	-11.8772	(0)	0.9658	(0)
Constant	0	(0)	-9.6054	(6.5697)	3.607	(2.1568)†
Indicator for cells near an arterial	0	(0)	0	(0)	-0.1352	(0.1317)
Indicator for cells near a highway	0	(0)	-1.0982	(0.6438)†	-0.9135	(0.198)††
Log of accessibility to population for one-vehicle households in the cell's TAZ	0	(0)	-0.5816	(0.6944)	-0.7182	(0.2356)††
Log of the total land value in the grid cell	0	(0)	0.9074	(0.4437)††	0.316	(0.1219)††
Percent of development type group commercial within walking distance	0	(0)	-0.0405	(0.0295)	-0.0231	(0.0084)††
Percent of development type group industrial within walking distance	0	(0)	0.0311	(0.0225)	-0.019	(0.0086)††
Percent of development type group residential within walking distance	0	(0)	0.056	(0.0133)††	0.0313	(0.004)††

Alternative:	10: M2		17: C1	
Variable	Coeff.	Std. Err.	Coeff.	Std. Err.
Constant(Calibrated)	-5.8777	(0)	-6.2663	(0)
Constant	0	(0)	0	(0)
Indicator for cells near an arterial	0	(0)	0	(0)
Indicator for cells near a highway	0	(0)	0	(0)
Log of accessibility to population for one-vehicle households in the cell's TAZ	0	(0)	0	(0)
Log of the total land value in the grid cell	0	(0)	0	(0)
Percent of development type group commercial within walking distance	0	(0)	0	(0)
Percent of development type group industrial within walking distance	0	(0)	0	(0)
Percent of development type group residential within walking distance	0	(0)	0	(0)

Table D.19: Estimation Results for Developer Model - Development Type 10: M2

Alternative:	No-build		10: M2	
Variable	Coeff.	Std. Err.	Coeff.	Std. Err.
Constant(Calibrated)	0.3419	(0)	-11.4033	(0)
Constant	0	(0)	-8.758	(4.3912)††
Indicator for cells near an arterial	0	(0)	-0.3571	(0.2791)
Indicator for cells near a highway	0	(0)	-1.1555	(0.3929)††
Log of accessibility to population for one-vehicle households in the cell's TAZ	0	(0)	1.3144	(0.4512)††
Log of the total land value in the grid cell	0	(0)	-0.6671	(0.2908)††
Percent of development type group commercial within walking distance	0	(0)	0	(0)
Percent of development type group industrial within walking distance	0	(0)	0	(0)
Percent of development type group residential within walking distance	0	(0)	0.0112	(0.0072)

Table D.20: Estimation Results for Developer Model - Development Type 11: M3

Alternative:	No-build		11: M3	
Variable	Coeff.	Std. Err.	Coeff.	Std. Err.
Constant(Calibrated)	0.3269	(0)	-4.0055	(0)
Constant	0	(0)	-1.3573	(0.5753)††
Indicator for cells near an arterial	0	(0)	-0.2592	(0.207)
Indicator for cells near a highway	0	(0)	-0.8216	(0.2468)††
Log of accessibility to population for one-vehicle households in the cell's TAZ	0	(0)	0	(0)
Log of the total land value in the grid cell	0	(0)	0	(0)
Percent of development type group commercial within walking distance	0	(0)	0.0139	(0.0114)
Percent of development type group industrial within walking distance	0	(0)	0	(0)
Percent of development type group residential within walking distance	0	(0)	0.0139	(0.0071)†

Table D.21: Estimation Results for Developer Model - Development Type 12: M4

Alternative:	No-build		12: M4	
Variable	Coeff.	Std. Err.	Coeff.	Std. Err.
Constant(Calibrated)	0.6686	(0)	-3.3043	(0)
Constant	0	(0)	0	(0)
Indicator for cells near an arterial	0	(0)	0	(0)
Indicator for cells near a highway	0	(0)	0	(0)
Log of accessibility to population for one-vehicle households in the cell's TAZ	0	(0)	0	(0)
Log of the total land value in the grid cell	0	(0)	0	(0)
Percent of development type group commercial within walking distance	0	(0)	0	(0)
Percent of development type group industrial within walking distance	0	(0)	0	(0)
Percent of development type group residential within walking distance	0	(0)	0	(0)

Table D.22: Estimation Results for Developer Model - Development Type 14: M6

Alternative:	No-build		14: M6	
Variable	Coeff.	Std. Err.	Coeff.	Std. Err.
Constant(Calibrated)	0.6054	(0)	-4.3763	(0)
Constant	0	(0)	0	(0)
Indicator for cells near an arterial	0	(0)	0	(0)
Indicator for cells near a highway	0	(0)	0	(0)
Log of accessibility to population for one-vehicle households in the cell's TAZ	0	(0)	0	(0)
Log of the total land value in the grid cell	0	(0)	0	(0)
Percent of development type group commercial within walking distance	0	(0)	0	(0)
Percent of development type group industrial within walking distance	0	(0)	0	(0)
Percent of development type group residential within walking distance	0	(0)	0	(0)

Table D.23: Estimation Results for Developer Model - Development Type 17: C1

Alternative:	No-build		11: M3		17: C1	
Variable	Coeff.	Std. Err.	Coeff.	Std. Err.	Coeff.	Std. Err.
Constant(Calibrated)	0.1875	(0)	-19.6081	(0)	-7.5107	(0)
Constant	0	(0)	-16.7849	(3.4013)††	-4.7558	(1.5272)††
Indicator for cells near an arterial	0	(0)	-0.8375	(0.3018)††	-0.6236	(0.1709)††
Indicator for cells near a highway	0	(0)	-1.1434	(0.3972)††	-0.779	(0.2055)††
Log of accessibility to population for one-vehicle households in the cell's TAZ	0	(0)	0	(0)	0	(0)
Log of the total land value in the grid cell	0	(0)	1.0382	(0.2612)††	0.3283	(0.1371)††
Percent of development type group commercial within walking distance	0	(0)	0	(0)	-0.0339	(0.0093)††
Percent of development type group industrial within walking distance	0	(0)	0	(0)	-0.0436	(0.0141)††
Percent of development type group residential within walking distance	0	(0)	0.0336	(0.0066)††	0.0192	(0.0055)††

Table D.24: Estimation Results for Developer Model - Development Type 18: C2

Alternative:	No-build		12: M4		18: C2	
Variable	Coeff.	Std. Err.	Coeff.	Std. Err.	Coeff.	Std. Err.
Constant(Calibrated)	0.7396	(0)	-5.7994	(0)	-3.5966	(0)
Constant	0	(0)	0	(0)	-1.0394	(0.6861)
Indicator for cells near an arterial	0	(0)	0	(0)	0	(0)
Indicator for cells near a highway	0	(0)	0	(0)	-0.9975	(0.3428)††
Log of accessibility to population for one-vehicle households in the cell's TAZ	0	(0)	0	(0)	0	(0)
Log of the total land value in the grid cell	0	(0)	0	(0)	0	(0)
Percent of development type group commercial within walking distance	0	(0)	0	(0)	-0.0402	(0.0148)††
Percent of development type group industrial within walking distance	0	(0)	0	(0)	-0.03	(0.0252)
Percent of development type group residential within walking distance	0	(0)	0	(0)	0.0354	(0.0091)††

Table D.25: Estimation Results for Developer Model - Development Type 19: C3

Alternative:	No-build		19: c3	
Variable	Coeff.	Std. Err.	Coeff.	Std. Err.
Constant(Calibrated)	0.1468	(0)	-6.7876	(0)
Constant	0	(0)	-2.4996	(1.2262)††
Indicator for cells near an arterial	0	(0)	-0.7628	(0.4857)
Indicator for cells near a highway	0	(0)	0	(0)
Log of accessibility to population for one-vehicle households in the cell's TAZ	0	(0)	0	(0)
Log of the total land value in the grid cell	0	(0)	0	(0)
Percent of development type group commercial within walking distance	0	(0)	-0.0206	(0.0201)
Percent of development type group industrial within walking distance	0	(0)	-0.1556	(0.1235)
Percent of development type group residential within walking distance	0	(0)	0.0626	(0.0177)††

Table D.26: Estimation Results for Developer Model - Development Type 20: I1

Alternative:	No-build		20: I1	
Variable	Coeff.	Std. Err.	Coeff.	Std. Err.
Constant(Calibrated)	0.1057	(0)	-5.024	(0)
Constant	-0	(0)	-1.6004	(0.5685)††
Indicator for cells near an arterial	0	(0)	0	(0)
Indicator for cells near a highway	0	(0)	0	(0)
Log of accessibility to population for one-vehicle households in the cell's TAZ	0	(0)	0	(0)
Log of the total land value in the grid cell	0	(0)	0	(0)
Percent of development type group commercial within walking distance	0	(0)	0.0248	(0.0154)
Percent of development type group industrial within walking distance	0	(0)	-0.0197	(0.0134)
Percent of development type group residential within walking distance	0	(0)	0.0552	(0.0118)††

Table D.27: Estimation Results for Developer Model - Development Type 21: I2

Alternative:	No-build		21: I2	
Variable	Coeff.	Std. Err.	Coeff.	Std. Err.
Constant(Calibrated)	0.3511	(0)	-4.2068	(0)
Constant	0	(0)	0	(0)
Indicator for cells near an arterial	0	(0)	0	(0)
Indicator for cells near a highway	0	(0)	0	(0)
Log of accessibility to population for one-vehicle households in the cell's TAZ	0	(0)	0	(0)
Log of the total land value in the grid cell	0	(0)	0	(0)
Percent of development type group commercial within walking distance	0	(0)	0	(0)
Percent of development type group industrial within walking distance	0	(0)	0	(0)
Percent of development type group residential within walking distance	0	(0)	0	(0)

Table D.28: Estimation Results for Developer Model - Development Type 23: GV

Alternative:	No-build		23: GV	
Variable	Coeff.	Std. Err.	Coeff.	Std. Err.
Constant(Calibrated)	0.1209	(0)	5.5063	(0)
Constant	0	(0)	10.7947	(3.2172)††
Indicator for cells near an arterial	0	(0)	0	(0)
Indicator for cells near a highway	0	(0)	0	(0)
Log of accessibility to population for one-vehicle households in the cell's TAZ	0	(0)	-1.6038	(0.3203)††
Log of the total land value in the grid cell	0	(0)	0.6517	(0.1109)††
Percent of development type group commercial within walking distance	0	(0)	0	(0)
Percent of development type group industrial within walking distance	0	(0)	-0.0313	(0.0285)
Percent of development type group residential within walking distance	0	(0)	0.0301	(0.005)††

Table D.29: Estimation Results for Developer Model - Development Type 24: VC

Alternative:	No-build		1: R1		2: R2		3: R3	
Variable	Coeff.	Std. Err.	Coeff.	Std. Err.	Coeff.	Std. Err.	Coeff.	Std. Err.
Constant(Calibrated)	0.4359	(0)	-11.9333	(0)	-19.1815	(0)	-22.6244	(0)
Constant	0	(0)	-9.0493	(0.8675)††	-17.2645	(0.9549)††	-21.2086	(1.3638)††
Indicator for cells near an arterial	0	(0)	0.3017	(0.0656)††	0.3017	(0.0656)††	0	(0)
Indicator for cells near a highway	0	(0)	-0.5791	(0.127)††	-0.9701	(0.1697)††	-1.2203	(0.2364)††
Log of accessibility to population for one-vehicle households in the cell's TAZ	0	(0)	-0.4431	(0.0874)††	-0.4431	(0.0874)††	-0.5956	(0.136)††
Log of the total land value in the grid cell	0	(0)	0.941	(0.0391)††	1.5787	(0.0521)††	1.9992	(0.0685)††
Percent of development type group commercial within walking distance	0	(0)	-0.0583	(0.0065)††	-0.0583	(0.0065)††	-0.0583	(0.0065)††
Percent of development type group industrial within walking distance	0	(0)	-0.0799	(0.0114)††	-0.0554	(0.0107)††	-0.0361	(0.0095)††
Percent of development type group residential within walking distance	0	(0)	0.0255	(0.0015)††	0.0255	(0.0015)††	0.0255	(0.0015)††
A measure of proximity to development	0	(0)	3.3962	(0.2501)††	3.3962	(0.2501)††	3.3962	(0.2501)††

Alternative:	4: R4		5: R5		6: R6		7: R7	
Variable	Coeff.	Std. Err.	Coeff.	Std. Err.	Coeff.	Std. Err.	Coeff.	Std. Err.
Constant(Calibrated)	-22.6244	(0)	-22.6244	(0)	-9.1408	(0)	-30.9526	(0)
Constant	-21.2086	(1.3638)††	-21.2086	(1.3638)††	0	(0)	-29.4624	(2.6746)††
Indicator for cells near an arterial	0	(0)	0	(0)	0	(0)	1.2555	(0.2738)††
Indicator for cells near a highway	-0.6689	(0.2992)††	-0.8025	(0.4271)†	0	(0)	0	(0)
Log of accessibility to population for one-vehicle households in the cell's TAZ	-0.5956	(0.136)††	-0.5956	(0.136)††	0	(0)	0.3303	(0.1561)††
Log of the total land value in the grid cell	1.914	(0.0687)††	1.8634	(0.0689)††	0	(0)	1.5407	(0.1927)††
Percent of development type group commercial within walking distance	-0.0583	(0.0065)††	-0.0583	(0.0065)††	0	(0)	0.0335	(0.0135)††
Percent of development type group industrial within walking distance	-0.0361	(0.0095)††	-0.0361	(0.0095)††	0	(0)	-0.0361	(0.0095)††
Percent of development type group residential within walking distance	0.0255	(0.0015)††	0.0255	(0.0015)††	0	(0)	0.0079	(0.0034)††
A measure of proximity to development	3.3962	(0.2501)††	3.3962	(0.2501)††	0	(0)	3.3962	(0.2501)††

Table D.30: Estimation Results for Developer Model - Development Type 24: VC (Continued)

Alternative:	9: M1		17: C1		20: I1		21: I2	
Variable	Coeff.	Std. Err.	Coeff.	Std. Err.	Coeff.	Std. Err.	Coeff.	Std. Err.
Constant(Calibrated)	-15.9004	(0)	-18.6251	(0)	-19.2185	(0)	-18.3953	(0)
Constant	-12.0521	(1.6546)††	-15.404	(1.2117)††	-15.3901	(1.2597)††	-15.3859	(1.2575)††
Indicator for cells near an arterial	0.8231	(0.1437)††	0.8065	(0.2412)††	1.1959	(0.2699)††	1.6097	(0.3049)††
Indicator for cells near a highway	0.86	(0.1624)††	1.7233	(0.2258)††	0	(0)	0	(0)
Log of accessibility to population for one-vehicle households in the cell's TAZ	0.3303	(0.1561)††	0	(0)	0	(0)	0	(0)
Log of the total land value in the grid cell	0.1943	(0.0509)††	0.7464	(0.1028)††	0.8855	(0.0994)††	0.8855	(0.0994)††
Percent of development type group commercial within walking distance	0.0598	(0.0078)††	0.0479	(0.0115)††	0.0314	(0.0139)††	0.0452	(0.015)††
Percent of development type group industrial within walking distance	0.0297	(0.0076)††	0	(0)	0.0559	(0.0081)††	0.0241	(0.0119)††
Percent of development type group residential within walking distance	0.0079	(0.0034)††	0	(0)	-0.0553	(0.0104)††	-0.1073	(0.0188)††
A measure of proximity to development	3.3962	(0.2501)††	3.3962	(0.2501)††	2.3141	(0.6857)††	2.3141	(0.6857)††

Alternative:	22: C3	
Variable	Coeff.	Std. Err.
Constant(Calibrated)	-7.524	(0)
Constant	0	(0)
Indicator for cells near an arterial	0	(0)
Indicator for cells near a highway	0	(0)
Log of accessibility to population for one-vehicle households in the cell's TAZ	0	(0)
Log of the total land value in the grid cell	0	(0)
Percent of development type group commercial within walking distance	0	(0)
Percent of development type group industrial within walking distance	0	(0)
Percent of development type group residential within walking distance	0	(0)
A measure of proximity to development	0	(0)