Sensitivity Analysis for Land Use, Transportation, and Air Quality

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The effect on air quality of a higher-density alternative land use scenario that concentrates a high percentage of the employment growth expected between 1989 and 2010 along transit corridors, was compared with that for the expected lower-density suburban development typical in the Denver region. The lower-density suburban growth development pattern was served by a circumferential highway, whereas in the higher-density scenario the circumferential was deleted with the exception of those segments already constructed or reasonably committed. Both scenarios included a rapid transit system. A high-occupancy vehicle lane system was also substituted for other freeway improvements proposed as part of the regional transportation plan. Although transit patronage increased significantly in the higher-density scenario, vehicle miles of travel remained relatively unchanged. Carbon monoxide levels increased under the higher-density land use case, but remained well below the federal standard. Other pollutant levels did not vary significantly between the two scenarios. Concentrating much of the 1989 to 2010 regional employment growth along transit corridors did not improve air quality.

In order to provide insight as to the degree to which changes in land development patterns could affect air quality, a sensitivity analysis of the air quality effects of concentrating development growth along major rapid transit corridors, minimizing new highway construction, and adding a substantial bus and high-occuancy vehicle (HOV) network was conducted for the Denver region. The methodology used in conducting this analysis and the resulting effects on carbon monoxide (CO), O_3, NO_2, and particulate matter less than 10 μm in diameter (PM10) pollutants are described.

A higher-density development pattern alternative was defined. Although the regional control totals on population and employment growth were maintained, more of the new growth was concentrated in the rapid transit corridors. The rapid transit corridors defined in the 2010 regional transportation plan (RTP) are shown in Figure 1. It was estimated that market forces would lead to approximately 40 percent of new employment and 20 percent of new population locating within 1 mi of a rapid transit alignment or 1½ mi of a rapid transit station. For the air quality sensitivity test, it was assumed that growth in the transit corridors would double to include approximately 80 percent of new employment and 40 percent of new population. This higher-density alternative scenario was matched with a transportation system comprising a much reduced highway network, the rapid transit system adopted as part of the 2010 RTP, and a supplemental HOV lane network on major freeways. The major facilities assumed in the two highway systems are shown in Figure 2. The same transportation systems management actions were modeled for the alternative case as was modeled for the 2010 RTP case. Higher parking costs under the alternative scenario in the Denver central business district (CBD) reflected higher employment densities expected. Suburban parking costs were generally not assumed to be in place. No changes in other parameters such as automobile operating costs or trip generation were made. The regional travel model, a traditional four-step Urban Transportation Planning System (UTPS) based model, was run and the resultant highway assignment was used in projecting ambient air quality levels associated with the land use test case for the higher-density sensitivity. Pollutants tested included CO, O_3, NO_2, and PM10.

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DEVELOPMENT SCENARIOS

Lower-Density Suburban Development Pattern

Two alternative development patterns were defined. The base case was the currently adopted market driver development scenario. This land use pattern is typified by

- The majority of new growth occurring outside the City and County of Denver.
- Growth in the City and County of Denver occurring in a few areas such as the CBD, the Platte Valley, and the new airport area, and the Stapleton site.
- Suburban residential development occurring at low densities (typically single-family dwellings at three and four dwelling units per acre).
- Approximately 40 percent of the employment growth and 20 percent of the population growth occurring within the transit corridors.

Higher-Density Transit Corridor Development Pattern

The alternative-scenario land use pattern located approximately 80 percent of the employment growth from 1985 to 2010 within the seven major rapid transit corridors. Population growth within the transit corridors was assumed to about double from 20 percent of the growth to 40 percent. This required that 195,000 future residents and 226,600 future employees be shifted from other locations into the transit corridors.

The relatively short (20-year) time horizon used in this study did not allow for major redevelopment to occur. As such, it was assumed that the existing urban fabric would remain in place and the study dealt only with the growth increment.

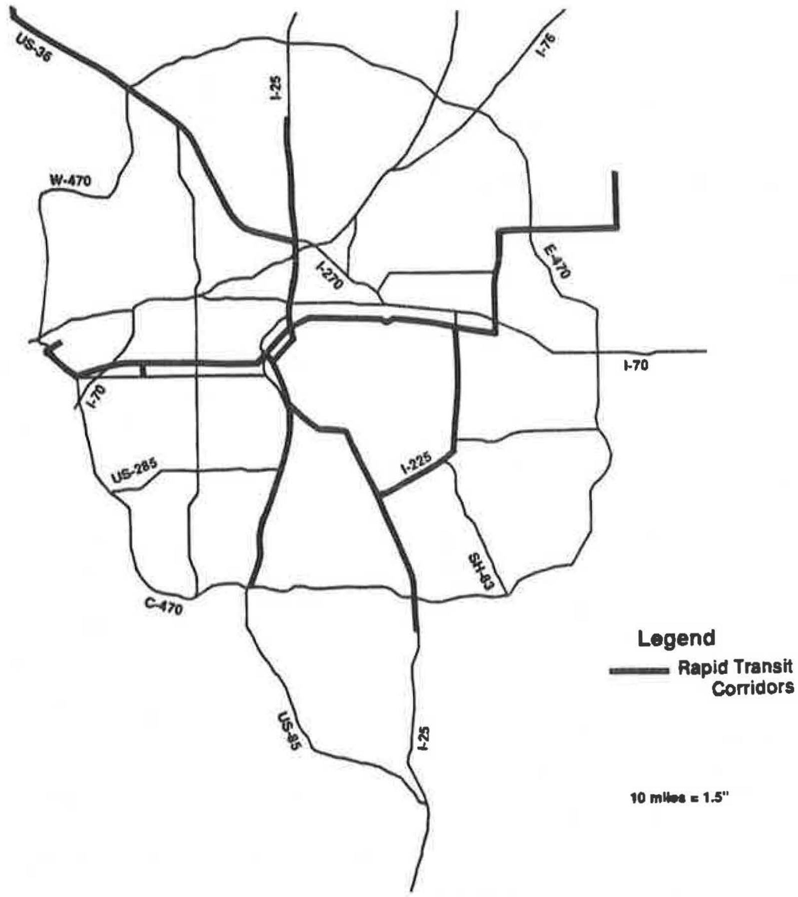

FIGURE 1 Rapid transit corridors.

Not moving existing residences or jobs to the transit corridors had a substantial effect on how much impact the alternative scenario would have, in that 69 percent of the population anticipated in 2010 is already in place, as are 59 percent of the employment locations. Therefore, the percent of 2010 total development actually transferred to the transit corridor zones was only 7 percent of the population and 13 percent of the employment. The majority of development was assumed to be in the same location for both scenarios.

The assumption to place 80 percent of the new employment and only 40 percent of the new residential development in the transit corridors had the effect of concentrating employment much more strongly than residential population in transit corridors. This distribution was based on the assumption that there would be a greater possibility of concentrating employment in higher-density nodes and strips than of concentrating residential development.

Comparison of Development Scenarios

Table 1 presents the net effect on land use distribution by analysis areas between the low density 2010 RTP scenario and the higher density alternative scenario. Development within the rapid transit corridors increased by 20.5 and 22.0 percent for population and employment, respectively. The Denver CBD population was increased by 31.1 percent and employment by 23.3 percent. CBD employment is critical in that it is a major determinant of transit patronage. The percent of population and employment living outside of transit corridors declined by 12 and 32.7 percent, respectively.

In general, future development growth was removed from the 470 beltway corridor and from areas beyond the beltway and in outlying communities such as Longmont and Castle Rock and moved to the transit corridors. Figure 3 shows the concentration of additional growth in the central area. The zonal data sets reveal that the population changes were somewhat more compact, whereas some employment increases were assumed at the end of the major corridors. The population reductions clearly occurred in a ring around the region. The employment reductions were more evenly dispersed and less focused on the ring.

After the redistribution process, a check was made of population and employment densities. The highest population densities do not exceed 50 persons per acre or about 18 housing units per acre. This density is approximately that of one of Denver's oldest and most transit-dependent area: Capitol Hill. Employment densities used were similar to those occurring in the suburban, campus-style, Denver Technological Center. An examination of current land use patterns found many areas along the rapid transit corridors that could be developed at higher densities. Significant development opportunities exist as the planned rapid transit corridors avoid currently developed areas in favor of alignments along existing

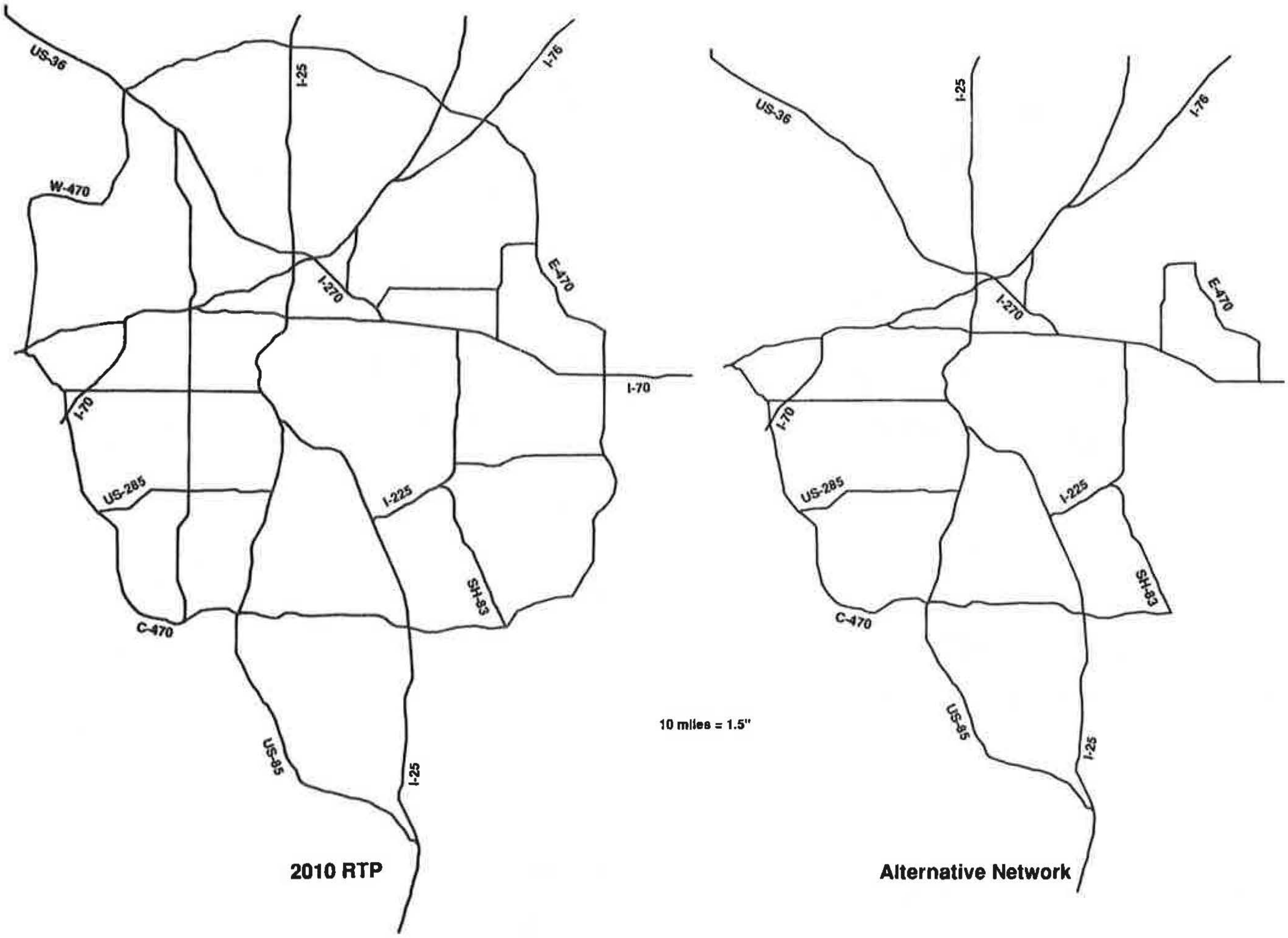

FIGURE 2 Alternative highway systems.

TABLE 1 DEVELOPMENT BY ANALYSIS AREAS OF POPULATION AND EMPLOYMENT

	2010 Plan		2010 LU/AQ Alternative		% Change	
Geographic Area	Pop.	Empl.	Pop.	Empl.	Pop.	Empl.
Rapid Transit Corridors	950,890	1,028,007	1,145,741	1,254,617	20.5	22.0
Denver CBD	14,971	164,650	19,628	202,975	31.1	23.3
Remainder of Transit Corridors	935,919	863,357	1,126,113	1,051,642	20.3	21.8
Outside of Rapid Transit Corridors	1,629,010	692,693	1,434,166	466,305	-12.0	-32.7
TOTAL	2,579,900	1,720,700	2,579,907	1,720,922	0.0	0.0

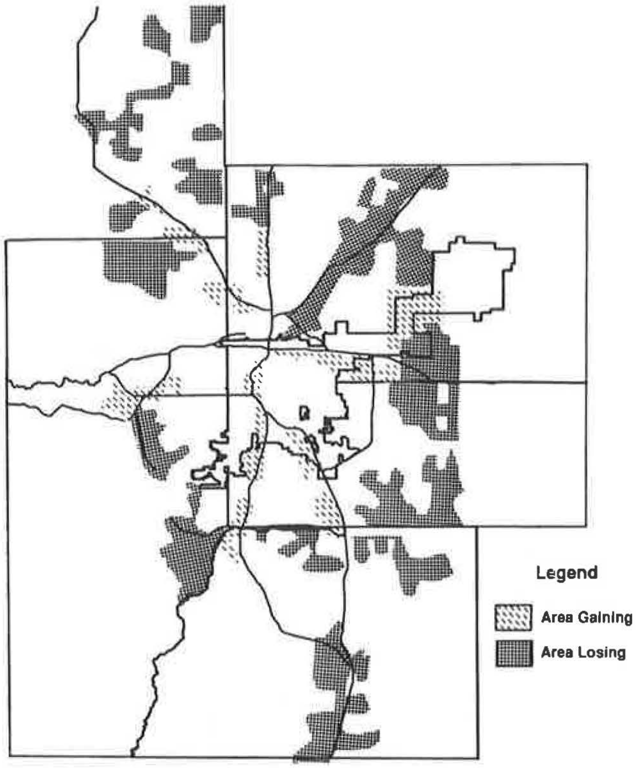

FIGURE 3 Distribution shift from 2010 RDF to alternative scenario.

railroad tracks or freeway facilities where tracts of open land exist.

EFFECT ON TRANSPORTATION DEMAND

Transportation System Supply Characteristics

In order to develop travel demand estimates, it is necessary to make a number of basic assumptions concerning the transportation system supply characteristics. These supply characteristics include the extent and layout of the rapid transit system as well as the background bus system, the extent and layout of the highway system, and similar information concerning the HOV lane system.

The highway system used in testing the higher-density alternative scenario is based on the former year 2000 RTP thoroughfare network and modified on the basis of current knowledge or recent construction, in revised alignments of some roadways and inclusion of new roads to serve the new Denver International Airport. In addition, a minimal number of lane improvements were assumed for the inner freeway system.

The transportation networks assumed for each scenario are shown in Figure 2. The major differences between the networks are (a) the 2010 RTP includes a full circumferential freeway whereas the alternative includes only those portions currently open, under construction, or well along in the planning process; (b) the 2010 RTP includes improvements to the existing freeway network to increase the number of lanes to 8 or 10—in contrast, the alternative network includes minimal improvements to the existing freeway network, and (c) further widening of existing arterials and provision of new arterials in the 2010 RTP are planned—in contrast, widening and new roadways are minimized under the alternative.

The transit system was based on the currently adopted year 2010 RTP transit element. It consisted of approximately 100 mi of light-rail transit (LRT) system supplemented by a large background bus network. Additional stations were identified on the planned rapid transit system to maximize transit development potential. The light-rail system was assumed to have a minimum of 3-min headways and the acceleration, deceleration, and maximum speeds of LRT vehicles.

Transit fare assumptions mimic current-day average transit fares by service type. Rapid transit lines were assumed to have a fare similar to existing express bus fare (i.e., $1.25). Automobile operating costs were those in place during the early 1980s. As such, no additional gaseoline taxes or other vehicle taxes were assumed to be in place under the alternative scenario as compared with the base case. It was also assumed that future increases in gasoline prices will be offset by improvements in fuel efficiency.

Parking costs in the Denver CBD were estimated in direct relation to employment density: the higher the employment density, the higher the parking cost. The average all-day parking costs in the Denver CBD were calculated as 1985, $4.11; 2010 RTP, $6.60; and 2010 alternative, $7.24. The higher CBD employment densities projected in the alternative scenario resulted in a 10 percent increase in projected parking costs over the 2010 RTP scenario. Parking costs were not assumed in suburban areas (except for the new airport) as the employment density was too low to justify parking costs under either scenario.

Transportation Modeling Process

The regional travel model set is a standard four-step model set using the programs and procedures recommended within the UMTA-FHWA-developed UTPS. The model set, originally developed on the basis of a 1971 home interview survey, has been updated extensively using the 1980 Census Urban Transportation Planning Package (UTPP) and information from the 1985 small-sample household survey and 1986 on-board bus survey.

Trip Generation

The total number of internal person-trips in the modeling area increased by roughly ½ percent from 8,453,300 to 8,491,600 between the 2010 plan case and the alternative scenario. This increase occurred as the result of moving development from the small outlying growth centers and rural areas (outside the modeling area) into the Denver urbanized area. Table 2 presents assumed population and employment within the modeling area, as well as the resultant work and total internal person-trips. The increase in trip making occurs mainly in the home-based work trip purpose that is most susceptible to diversion to transit or carpooling. Trip making per person per day decreased slightly (0.7 percent) from 3.83 to 3.80.

The total number of internal person-trips was relatively insensitive to changes in the development pattern. The trip

TABLE 2 REGIONAL TRIP GENERATION

	2010 RTP LU	LU/AQ Alternative	Percent Change
Population	2,206,000	2,232,000	1.2%
Employment	1,527,000	1,575,000	3.1%
Home-Based Work Person Trips	2,227,000	2,300,000	3.3%
Total Internal Person Trips*	8,453,300	8,491,600	0.5%

*Excludes truck trips and internal/external trips.

generation model used assumes that the total number of trips generated per family can be explained by the income and household size of the family. Some individuals have speculated that automobile trips can be converted to walk trips at high enough densities. This relationship is not included in the trip generation model because of the following:

- The quantitative relationship between density and trip making is only speculative; no quantitative relationships have been established.
- Increased density in and of itself may not decrease trip making. In addition to increased density, a diversity of land uses on a microscale would appear necessary. Current land use patterns are centralizing and separating land uses rather than integrating them. For example, in the 1950s the corner grocery store disappeared making way for the supermarket. Recently, some supermarkets are disappearing, being replaced by a few mega-grocery stores. The same trends can be seen in hardware stores and other land uses. The impact on VMT of this change in marketing is unknown. The megastores are often grouped together, providing opportunities to shop for a diversity of items (groceries, drugs, books, hardware) in one general location. This may make trip chaining more likely, offsetting some of the additional distance driven. In order to convert the entire shopping trip for automobile back to walking, it would be necessary to return to the corner grocery store. This implies a change in lifestyle, in which individuals would need to be willing to give up the diversity of goods and low prices associated with mass marketing. It also implies extremely high densities at the residential end to have sufficient numbers of families within easy walking distance of stores.

Trip Distribution

A set of gravity models was used to distribute trips between origins and destinations. Person-trips are distributed for both peak and off-peak periods on the basis of composite impedance measures of spatial separation of zones. The composite impedance is a function of automobile and transit travel times and costs.

The average trip length of 8.5 mi did not change between the two land use scenarios. However, this lack of change on a daily basis masks changes by time of day. The rearrangement of development and congestion in the peak periods caused trip lengths to decrease by 4.1 percent during the a.m. peak period (from 9.4 to 9.0 mi) and 4.8 percent during the p.m. peak period (from 8.4 to 7.9 mi). These decreases indicate that gains were made in reducing the length of the work trip. They were offset by an increase of 3.6 percent (from 8.3 to 8.6 mi) during the off-peak period. The increase during the off-peak may be reflective of a greater separation of activity areas and residents under the alternative scenario than the 2010 RDF/RTP scenario. For example, the ratio of population to employment in the non-rapid-transit corridors increases substantially from 2.3 to 3.0. This increase is not offset by a large corresponding decrease within the transit corridors (the ratio changes only from 0.94 to 0.92). Longer trips may be necessary for those remaining in the areas outside the rapid transit corridors.

The travel model used bases its estimates of travel destinations partially on employment locations. The trip attraction model uses estimates of retail and total employment. In moving employment into rapid transit corridors, the model assumed that service jobs were also being concentrated. Differentiating service jobs and redistributing them separately might have reduced nonwork travel.

Tables 3 and 4 present the trip distribution between analysis areas. Work trips destined to the Denver CBD and the remainder of the transit corridors increase by 29.6 and 20.4 percent, respectively. Work trips destined outside the rapid transit corridors decreased 32.1 percent. Nonwork trips to transit corridors not in the CBD increased 21.3 percent, whereas trips to areas outside rapid transit corridors decreased 22.5 percent. However, the increased work trips are only 3.2 percent for the entire modeling area.

Mode Split

The mode split model was used to divide the trips into mode-specific trips (transit, drive alone, and shared ride—2 and 3 plus carpools) based on the alternative transportation network description. The mode split model is a three-dimensional logit model (drive alone, shared ride, and transit). The mode split model takes into account in- and out-of-vehicle travel time, and monetary costs such as parking fees, transit fares, and automobile operating costs.

Out-of-vehicle travel time is weighted by 2.5. The implied value of travel time between home and work is $5.60 per hour. The mode split model is run for both peak and off-peak periods.

Changing land use assumptions from the 2010 Regional Development Framework (RDF) to the alternative scenario increased the potential for walk access to transit. Households with walk access to either bus or rail transit increased from 58.3 to 63.6 percent, or a gain of 61,900 households having walk access. Employment locations with access increased from 66 to 71.3 percent or a gain of 112,300 employees having

TABLE 3 TRIP DISTRIBUTION (THOUSANDS)

Home-Based Work

Trip Origin	Trip Destination: Denver CBD 2010 Plan	Denver CBD LU/AQ	Rapid Transit Corridors Outside CBD 2010 Plan	Rapid Transit Corridors Outside CBD LU/AQ	Outside Rapid Transit Corridors 2010 Plan	Outside Rapid Transit Corridors LU/AQ	Total Modeling Area 2010 Plan	Total Modeling Area Alternative
Denver CBD	3	4	5	7	2	2	10	13
Rapid Transit Corridors Outside CBD	105	154	543	743	231	194	879	1,092
Outside Rapid Transit Corridor	133	153	668	714	540	329	1,340	1,196
Total Modeling Area	240	311	1,216	1,464	773	535	2,229	2,300

Non Work

Trip Origin	Trip Destination: Denver CBD 2010 Plan	Denver CBD LU/AQ	Rapid Transit Corridors Outside CBD 2010 Plan	Rapid Transit Corridors Outside CBD LU/AQ	Outside Rapid Transit Corridors 2010 Plan	Outside Rapid Transit Corridors LU/AQ	Total Modeling Area 2010 Plan	Total Modeling Area Alternative
Denver CBD	45	52	86	100	50	43	181	195
Rapid Transit Corridors Outside CBD	141	150	1,718	2,239	661	602	2,520	2,991
Outside Rapid Transit Corridor	130	118	976	1,033	1,947	1,416	3,053	2,567
Total Modeling Area	316	320	2,779	3,372	1,658	2,060	5,753	5,752

TABLE 4 PERCENT CHANGE IN TRIP DISTRIBUTION FOR ALTERNATIVE COMPARED WITH 2010 PLAN

Home-Base Work:

Trip Origin	Trip Destination: Denver CBD	Rapid Transit Corridors Outside CBD	Outside Rapid Transit Corridors	Total Modeling Area
Denver CBD	36.5%	44.0%	-4.8%	31.3%
Rapid Transit Corridors Outside CBD	47.5%	36.8%	-4.8%	31.3%
Outside Rapid Transit Corridor	15.3%	6.9%	-39.0%	-10.8%
Total Modeling Area	29.6%	20.4%	-32.1%	3.2%

Non-Work:

Trip Origin	Trip Destination: Denver CBD	Rapid Transit Corridors Outside CBD	Outside Rapid Transit Corridors	Total Modeling Area
Denver CBD	15.9%	16.1%	-13.3%	8.0%
Rapid Transit Corridors Outside CBD	6.5%	30.4%	-9.0%	18.7%
Outside Rapid Transit Corridor	-9.3%	5.8%	-27.3%	-15.9%
Total Modeling Area	1.3%	21.3%	-22.5%	0.0%

access. In-vehicle travel times were calculated to test how long it would take for area residents to go to work or other destinations using transit. The reported travel times do not include time to walk to a line, wait for a bus, or transfer between transit lines. This test indicated that in the alternative scenario, 34 percent of the work trips and 35 percent of all trips could be completed in under 40 minutes by walking to a bus or rail transit line.

Transit patronage increases 26.9 percent from 316,000 to 402,000 daily between the 2010 RTP case and the 2010 alternative scenario. A significant proportion of the increase is additional work trips taking place on transit, which increases from 149,000 to 216,400, or 44.8 percent. Overall mode share increases from 4.0 to 4.8 percent. Work trip mode share increases from 6.7 to 9.4 percent. The patronage estimates for the 2010 RTP and the 2010 alternative both exhibit significant increases from the current-day transit ridership of approximately 135,000 patrons per day, or roughly 2.6 percent of internal trip making. Ridership on the rapid transit system has increased from 110,300 under the 2010 RTP case to 185,000 under the 2010 land use–air quality (LU–AQ) scenario. Table 5 indicates that most of the increase in transit usage occurred in trips to non-CBD destinations in rapid transit corridors, implying that the rapid transit system is better serving non-CBD trips in the alternative scenario.

Annual transit trips per capita were compared with data from other cities to confirm the reasonableness of the forecasts (see Table 6).

In order to estimate the effects of the HOV system on automobile occupancy, the work mode choice module was supplemented with an HOV choice model. Surveys in other cities having HOV lanes supported this approach, because little use of HOV lanes by nonworkers actually takes place. In addition, nonwork automobile occupancy is most highly affected by family size, because these are mostly families traveling together. The work mode choice model incorporates drive-alone, HOV, and transit travel times and costs into its probability function, and divides work trips into drive alone, shared ride 2, shared ride 3-plus, and transit modes. Time savings using an HOV lane as compared to a general purpose lane are factored into the decision-making process. After incorporating the effects of the HOV system, it was found that the HOV system did not have a significant effect on regional work automobile occupancy; however, the HOV system did increase the number of persons in 3-plus person work-purpose carpools by 11.5 percent over the 2010 RTP, from 152,200 to 169,700 persons per day.

Network Assignment and Analysis

The federally released computer programs were used for building and processing both the highway and transit networks at the traffic zone level. On the highway side, diversion off freeway facilities onto arterials is accomplished using congestion diversion curves to calculate travel times under congested circumstances. Congested speeds from the peak highway assignments are compared to initial estimates of the speeds used in trip distribution and mode split calculations. This typically results in two to three model reruns before highway-side equilibration is reached. Similarly, a check was made to ensure adequate transit capacity for projected demand.

Vehicle miles of travel (VMT) between the two scenarios is effectively unchanged despite the slight increase in population and employment in the alternative scenario. Both scenarios generated approximately 63.5 million VMT daily. VMT in the alternative was 0.2 percent higher than in the 2010 RTP scenario. This can be compared with the increase of population of 1.3 percent and increase in employment of 3.1 percent in the modeling area in the alternative. Table 7 presents the percent of the system operating over capacity. The percent of VMT experiencing congestion increases from 32 to 45.1 percent. The average speeds decrease by 9 to 10 percent during the peak periods. This result increases daily vehicle hours of travel (VHT) by approximately 8 percent.

TABLE 6 ANNUAL TRANSIT TRIPS PER CAPITA

Houston (1985)	21
Denver (1985)	37
Miami (1985)	39
Portland (1985)	49
Seattle (1985)	49
Atlanta (1985)	65
San Francisco (CMSA)(1985)	84
Chicago (1985)	105
San Francisco (Central)(1985)	232
New York (1985)	309
Denver (2010 RTP)	65
Denver (2010 LU/AQ)	83

EFFECT ON AIR QUALITY

Carbon Monoxide

The levels of carbon monoxide associated with each scenario are indicated below:

2010 RTP (ppm)	*Alternative Scenario (ppm)*	*Standard (ppm)*
4.8	6.5	9

TABLE 7 HIGHWAY OPERATING CHARACTERISTICS

Percent of System Operating over Capacity[1]			
% of Roadway Mileage	14.6%	17.2%	
% of VMT	32.0%	45.1%	
AM Peak Avg. Speed	23.8 mph	21.4 mph	-10.1%
PM Peak Avg. Speed	22.3 mph	20.3 mph	- 9.0%
All Day Avg. Speed	26.7 mph	24.7 mph	- 7.3%
Daily VHT	2,382,000	2,575,500	+ 8.1%

(1) Level of Service E and E during the peak period.

TABLE 5 TRANSIT PATRONAGE BY ANALYSIS AREA

Area	2010 RTP	2010 LU/AQ Alternative	Change
Rapid Transit Corridors			
Denver CBD	130,300	164,400	+ 26%
Rapid Transit Corridors Outside CBD	75,600	151,900	+109%
Outside Rapid Transit Corridor	110,100	85,700	- 22%
TOTAL	316,000	402,000	+ 27%

The Denver CBD remains the site with the highest concentrations. The alternative LU–AQ scenario results in significantly higher levels of CO because there is more congestion in the Denver CBD under this scenario than with the 2010 RTP scenario. However, neither scenario violates the federal standard.

Ozone

The currently available O_3 model does not allow prediction of specific levels of O_3; however, it does predict the hydrocarbon (HC) emissions that must be reduced to achieve the standard, or the amount of HC emissions that can be tolerated until a violation is expected in a specific corridor between the CBD and an outlying area. These corridors are called trajectories.

Three trajectories were modeled in this exercise; from the CBD to Boulder, from the CBD to the new airport, and from the CBD to Highlands Ranch. Below is a comparison of the likelihood of a violation, if any, in each trajectory for the 2010 RTP and the alternative LU–AQ scenario. In both cases where a violation is possible, the expected violation would be marginal.

	Possibility of O_3 Violation CBD to:		
Scenario	*Boulder*	*Airport*	*Highlands*
2010 RTP	No	Yes	No
Alternate Scenario	No	No	Yes

PM10

Model results are often best used to compare one scenario with another scenario instead of predicting absolute values. The PM10 (small particulate) model calibration indicates that the model significantly overpredicts the annual average concentration by approximately 50 percent. The model calibration also indicates that the 24-hr concentrations are about 10 percent higher than actual 1986 monitored concentrations. The results should thus be viewed as indications of a problem needing further exploration rather than as an identification of specific predicted results.

The PM10 (small particulate) modeling completed for this exercise resulted in no significant difference in concentrations between the alternatives. The alternative scenario resulted in a 2 percent higher maximum concentration than the 2010 RTP; however, such a small difference is less than the range of accuracy of the model. The modeled 24-hr and average annual concentrations are presented below. Both the 2010 RTP and the alternative scenario result in significant violations of the 24-hr standard; however, the area that experiences violations is slightly larger in the 2010 RTP than in the alternative scenario.

	2010 RTP (mg/m^3)	*Alternative Scenario (mg/m^3)*	*Standard (mg/m^3)*
24-hr average	272	278	150
Annual average	90	91	50

Nitrogen Dioxide

Using a conservative rollback modeling technique, the projected NO_2 concentrations for the two transportation data sets at the CBD monitoring station were modeled. The annual average results are summarized below:

2010 RTP (ppm)	*Alternate Scenario (ppm)*	*Standard (ppm)*
0.058	0.059	0.053

The rollback technique is not sensitive to differences in spatial distribution; therefore, the effects of the spatial difference between the two transportation data sets are not adequately analyzed. Also, because the two data sets produce concentrations that are only slightly higher than the standard, a more detailed modeling technique would be required to determine if either of these two scenarios would cause an actual exceeding of the standard.

CONCLUSIONS

- Changing development patterns by concentrating employment growth along transit corridors to the degree used in this study, restructuring highway capacity improvements, and providing an extensive bus and HOV system did not improve air quality.
- The relatively short (20-year) time horizon used in this study did not allow for major redevelopment to occur. The existing urban fabric was assumed to remain in place and the study dealt only with the growth increment. Not moving existing residences and jobs minimized the air quality difference measured between the two scenarios. Because 69 percent of residential locations and 59 percent of the job locations in 2010 are already in place, the relative impact of even large changes in the location of projected growth is minimized.
- Even though 40 percent of the expected population growth was concentrated in the transit corridors under the alternative scenario, the larger concentration of 80 percent of employment growth in the transit corridors led to an imbalance of population-to-employment ratios. It appears that both population and employment need to be concentrated in the transit corridors. In the alternative higher-density development pattern tested, because substantial employment growth was allocated to the transit corridors without equivalent redistributed population, a greater spatial separation between population and employment resulted than in the base 2010 RDF/RTP planned suburbanization case. This spatial separation led to increased miles of travel (i.e., longer trip lengths) for non-peak-period, nonwork trips, which eliminated much of the benefit gained in transferring peak-period, drive-alone work trips to transit and carpooling.
- Transit patronage increased significantly—from 316,000 to 402,000 riders per day between the 2010 RDF/RTP and 2010 LU–AQ alternative. Overall, 4.8 percent of trips in the LU–AQ alternative use transit. Factors that mitigated against a larger transit mode share included

  —Increased congestion resulting from the assumed constrained capacity roadway network and higher land use densities in the LU–AQ alternative was of limited benefit in increasing transit patronage. In both scenarios, the bulk of transit service is provided by buses operating on-street. These buses operating in mixed traffic flow were slowed proportionately because of increased arterial traffic congestion. Bus services affected by traffic congestion included on-street feeder services to the rail facility. Only for the rail line-haul portion of the transit trip was traffic congestion a benefit in inducing travelers to use transit.

—Placing development within 1 mi of a rapid transit line did not ensure good transit access. The resulting densities were too low to ensure walk access to the rapid transit system. Most of the development in the corridors was still beyond walking distance to a station. Many of the residents and employees within the rapid transit corridor were dependent on feeder buses or park-and-ride lots to access the rail system. Moving more employment to the immediate vicinity of a transit station (i.e., within ⅓ mi, the assumed maximum walking distance) or provision of small-area circulator buses feeding the transit station might increase transit ridership.

—The rapid transit and HOV systems were radial in nature, mainly serving trips to and from the central area.

—Provision of transit improvements is a necessary but not sufficient condition to cause a large increase in transit ridership. Incentives to use transit, such as employer subsidized bus passes and bus priority lanes intersecting a rapid transit corridor, and disincentives to use the private automobile, such as increased parking costs and higher fuel costs, appear necessary if a large shift to alternative modes is to occur.

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