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MEMORANDUM

Date: December 2, 2011

To: John Thomas, US EPA

From: Jeremy Klop & Nick VanderKwaak

Subject: Mixed Use Trip Generation in the Denver Region

DN11-0298

Fehr & Peers has completed the mixed-use development (MXD) trip generation estimate to analyze future land use for two sites in the Denver region. An analysis was also completed using a direct ridership forecasting model to show light rail ridership sensitivity to different land use scenarios near stations.

AREAS OF ANALYSIS

The Brighton Ave corridor just north of Downtown Denver and the Denver Federal Center in Lakewood were selected to have Mixed Use Trip Generation (MXD) applied. Criteria and specific locations were solicited at a project stakeholder meeting with agency representatives. The group discussed both specific locations and criteria such as potential for mixed use development and access to future rail stations. The site boundaries for the analysis areas were selected to correlate as closely as possible with Transportation Analysis Zones (TAZ) from the DRCOG regional travel demand model.

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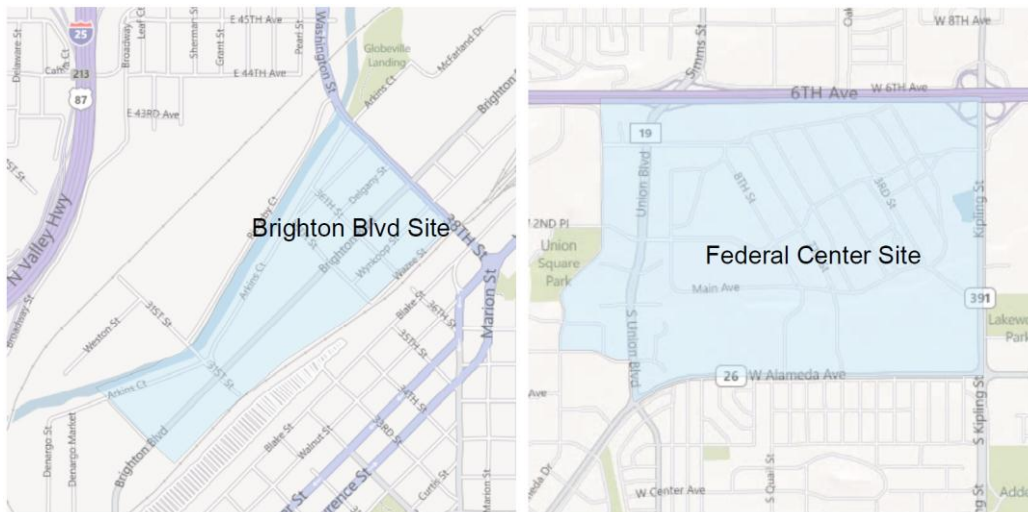
MXD ANALYSIS

The MXD model is based on a growing body of research, which focuses on the relationship between travel and the built environment. This method supplements conventional trip generation methods to capture effects related to built environment variables (known as the Ds) like **d**ensity, **d**iversity of land uses, **d**estinations (accessibility), **d**evelopment scale, pedestrian and bicycle **d**esign, and **d**istance to transit services, and **d**emographics. This method improves accuracy in estimating the number of vehicle trips that infill projects generate and provides a more reasonable picture of how travel characteristics change over time.

The MXD model development process used over 200 mixed-use development sites across the United States and the model was validated using data from 16 independent mixed use sites.   Hierarchical Linear Modeling (HLM) techniques were used to quantify relationships between characteristics of the MXDs and the likelihood that trips generated by those MXDs will stay internal and/or use modes of transportation other than the private vehicle.

MXD is sensitive to variables located in the site being analyzed but is also sensitive to regional factors and other adjacent employment not located directly in the site. The measurements adjusted specifically for each of the Denver sites include:

- Employment within one mile of the MXD,
- Employment within a 30 minute transit trip
- Total regional employment
- Average household size
- Average vehicle ownership

The MXD spreadsheet attempts to capture the vehicle traffic reduction effects of mixed-use developments and improve on current trip generation methods that rely on conventional travel demand models or rates and adjustments from the Institute of Transportation Engineers (ITE) Trip Generation Manual. This helps provide greater predictive power of internalization of trips and trips taken via transit, walking, and bicycle. A screenshot of the interface is shown below.

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MIXED USE TRIP GENERATION MODEL V6.1 - BASIC INPUT

All shaded cells are inputs	
Regular inputs (project-specific)	
Inputs that may depend on regional values from census data, travel demand model, etc...	

Section 1 - General Site Information

Site Name	Federal Center

Geographic

Developed Area (in acres)	894
Number of Intersections	53
Is Transit (bus or rail) present within the site or across the street?	Yes
Proportion of households within 1/4 mile of a transit stop	100%

Land Use - Surrounding Area

Is the site in a Central Business District and/or TOD?	Yes
Employment within one mile of the MXD	17,405
Employment within a 30 minute Transit Trip (Door-to-door)	54,146
Total Regional Employment	1,351,473

Site Demographics

Enter Population Directly?		No
	Population	
Average HH Size by type within MXD		
	Single Family	3.2
	Multi-Family	2.5
	Townhouse	2.5
	High Rise Condo	2.5
Use Census Block Group Data for Average HH Size?		Yes
Use Census Block Group Data for Average Vehicle Ownership?		Yes
Average Vehicles Owned per Dwelling Unit within site		

Surrounding Area (Block Group) Demographics

Average HH size near Site	2.08
Average Vehicles Owned per Dwelling Unit near Site	1.60

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Regional data and site specific data such as forecasted land use at the two sites was gathered from existing planning studies and the DRCOG regional model. Data for the Denver Federal Center site is listed in Table 1, and the data for the Brighton Blvd site is listed in Table 2. These calculated land use inputs are used as a base for the first land use Scenario in subsequent calculations.

TABLE 1. MXD PLANNED INPUTS FOR DENVER FEDERAL CENTER SITE		
Input Variable	**Input Value**	**Source**
Developed Area (in acres)	894	Calculated in GIS
Number of Intersections	53	Based on Federal Center Site Plan Study (2008)
Transit Available	Yes	
Proportion of households within ¼ mile of a transit stop	100%	
Central Business District or TOD?	Yes	
Employment within one mile of MXD	17,405	DRCOG 2035 Regional Model
Employment within a 30 minute Transit Trip (Door-to-door)	54,146	
Total Regional Employment	1,351,473	
Average Household (HH) Size for Single Family Dwelling Units	3.2	Project Estimate
Average Household (HH) Size for Multi-family Dwelling Units	2.5	
Average HH Size Near Site	2.08	2000 Census
Average Vehicles Owned per Dwelling Unit Near Site	1.60	
Multi-family Dwelling Units	2104	Proposed Campus Development Program by District from Denver Federal Center Site Plan Study (2008) / Existing and Future Employment and Residences within the Union Boulevard Corridor from Union Boulevard Corridor Connectivity Plan (2011)/ Planned Development along the West Corridor from Connecting the West Corridor Communities: An Implementation Strategy for TOD along the Denver Region's West Corridor (2011)
General Retail (1000 sq. ft.)	212	
Non Medical Office (1000 sq. ft.)	2193	
Medical Office (1000 sq. ft.)	1050	
Hotel Rooms	200	

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TABLE 2. MXD MODEL INPUTS FOR BRIGHTON BLVD SITE		
Input Variable	**Input Value**	**Source**
Developed Area (in acres)	138	Calculated in GIS
Number of Intersections	23	Calculated in GIS based on existing road network
Transit Available	Yes	
Proportion of households within ¼ mile of a transit stop	100%	
Central Business District or TOD?	Yes	
Employment within one mile of MXD	25,476	DRCOG 2035 Regional Model
Employment within a 30 minute Transit Trip (Door-to-door)	106,243	
Total Regional Employment	1,351,473	
Average Household (HH) Size for Single Family Dwelling Units	3.2	Project Estimate
Average Household (HH) Size for Multi-family Dwelling Units	2.5	
Average HH Size Near Site	2.27	2000 Census
Average Vehicles Owned per Dwelling Unit Near Site	1.5	
Single Family Dwelling Units	30	Medium Density Development Scenario from Brighton Corridor Design Guidelines (2008)
Multi-family Dwelling Units	720	
General Retail (1000 sq. ft.)	41	
Non Medical Office (1000 sq. ft.)	285	

Three additional land use scenarios were developed for each site to demonstrate MXD sensitivity to mix of land use changes. The additional scenarios utilize the same MXD inputs as the base scenario except for site specific land use. The scenarios were developed as follows for:

- Scenario 1: Planned Land Use (from Table 1 and Table 2)
- Scenario 2: Double Planned Land Use
- Scenario 3: More Residential and Less Commercial
- Scenario 4: Less Residential and More Commercial

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The land use inputs for the four Denver Federal Center scenarios are shown in Table 3, and the land use inputs for the four Brighton Blvd land use scenarios are shown in Table 4.

TABLE 3. DENVER FEDERAL CENTER SITE MXD SCENARIO LAND USE INPUTS				
Land Use	Scenario 1: Planned Land Use	Scenario 2: Double Planned Land Use	Scenario 3: More Residential and Less Commercial	Scenario 4: Less Residential and More Commercial
Multi-family Dwelling Units	2104	4208	4208	0
General Retail (1000 sq. ft.)	212	424	20	424
Non Medical Office (1000 sq. ft.)	2193	4386	100	4386
Medical Office (1000 sq. ft.)	1050	2100	500	2100
Hotel Rooms	200	400	0	400

TABLE 4. BRIGHTON BLVD SITE MXD SCENARIO LAND USE INPUTS				
Land Use	Scenario 1: Planned Land Use	Scenario 2: Double Planned Land Use	Scenario 3: More Residential and Less Commercial	Scenario 4: Less Residential and More Commercial
Single-family Dwelling Units	30	60	60	0
Multi-family Dwelling Units	720	1440	2500	0
General Retail (1000 sq. ft.)	41	82	10	100
Non Medical Office (1000 sq. ft.)	285	570	50	600

The MXD tool calculates the traditional ITE vehicle trip generation as well as a reduction based on external vehicle trips, external walk/bike, and external transit. VMT estimates are site specific using average trip length by trip type from the DRCOG regional model. Results of the calculations for Denver Federal Center are shown in Table 5, and results of the calculations for Brighton Blvd are shown in Table 6.

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TABLE 5. DENVER FEDERAL CENTER MXD DAILY TRIP GENERATION AND VMT ESTIMATES*				
	Scenario 1: Planned Land Use	Scenario 2: Double Planned Land Use	Scenario 3: More Residential and Less Commercial	Scenario 4: Less Residential and More Commercial
ITE External Vehicle Daily Trips	77,892	146,655	48,409	121,031
MXD External Vehicle Daily Adjusted Trips	64,113	118,959	36,940	106,456
MXD Reduction in External Vehicle Trips	18%	19%	22%	12%
MXD Internal capture	13%	13%	17%	8%
MXD External Walk / Bike	3%	4%	4%	2%
MXD External Transit	3%	3%	2%	3%
ITE Daily VMT	292,103	549,785	172,263	460,167
MXD Daily Adjusted VMT	244,495	454,401	137,488	408,482
MXD Reduction in Daily VMT	16%	17%	20%	11%
*VMT reflects half the VMT associated with total trips as other areas would be responsible for the other half Source: Fehr & Peers, August 2011				

TABLE 6. BRIGHTON BLVD MXD DAILY TRIP GENERATION AND VMT ESTIMATES*				
	Scenario 1: Planned Land Use	Scenario 2: Double Planned Land Use	Scenario 3: More Residential and Less Commercial	Scenario 4: Less Residential and More Commercial
ITE External Vehicle Daily Trips	11,622	20,565	18,226	12,092
MXD External Vehicle Daily Adjusted Trips	8,747	15,029	13,999	10,484
MXD Reduction in External Vehicle Trips	25%	27%	23%	13%
MXD Internal capture	12%	12%	9%	5%
MXD External Walk / Bike	10%	11%	10%	4%
MXD External Transit	5%	5%	5%	4%
ITE Daily VMT	37,611	66,293	56,600	40,555
MXD Daily Adjusted VMT	28,651	49,306	44,073	35,340
MXD Reduction in Daily VMT	24%	26%	22%	13%
*VMT reflects half the VMT associated with total trips as other areas would be responsible for the other half Source: Fehr & Peers, August 2011				

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All of the land uses were doubled between Scenario 1 and Scenario 2 for both Denver Federal Center and Brighton Blvd. This resulted in the total number of external trips generated using the ITE method to also increase at a similar rate. Twice the housing and employment density on the sites creates more internal accessibility which reduced external vehicle trips. External trips were reduced with MXD in both scenarios, but the reduction in external trips in Scenario 2 was even greater due to the increased density and accessibility. The Brighton Blvd site experienced a greater reduction in external vehicle trips than Denver Federal Center due to other variables such as proximity to downtown Denver. A greater external Walk/Bike access was also calculated for both the Denver Federal Center site and Brighton Blvd site in Scenario 2.

Scenario 3 has increased residential from Scenario 1 and a lot less Commercial. These changes result in a less mixed residential environment. Fewer external vehicle trips are generated in the Denver Federal Center site in Scenario 3 as there is a lot less retail and office, but there is a greater MXD reduction in external vehicle trips from the ITE method as the greater amount of residential is interacting with the hospital and other commercial land use. Scenario 3 for Brighton Blvd generates more trips than the base scenario and has less of a reduction in external vehicle trips from MXD as a lot more residential is present with far fewer commercial land uses.

Scenario 4 has less residential land use than Scenario 1 and more Commercial land uses. These changes in land use increase the total external vehicle trips for both sites, and the MXD internal capture is also a lot less than Scenario 1. Not having a lot of housing at the site causes this reduction in internal capture and also causes a reduction in External Walk/Bike and External Transit access.
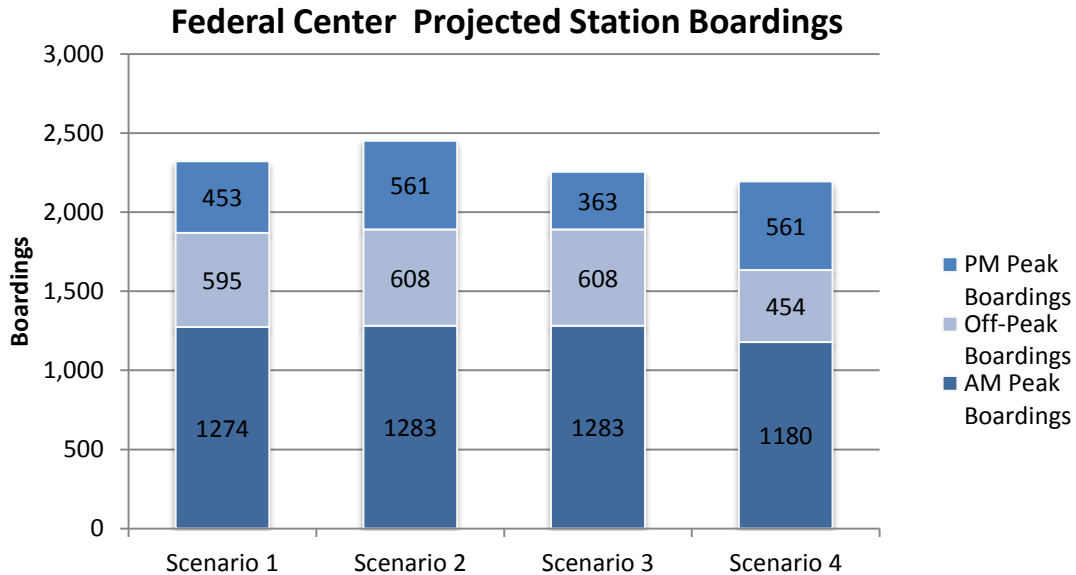
The four MXD scenarios demonstrate how changes in land use influence internal trip capture, walk/bike trips, transit trips, and VMT. Greater density and a greater mix of land uses result in higher internal capture. Increased external walk/bike trips and external transit trips are also influenced by these changes and other variables in MXD.

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DIRECT RIDERSHIP FORECAST ANALYSIS

A Direct Ridership Model was created by Fehr & Peers for the Regional Transportation District (RTD) in Denver. The primary purpose of the model is to explain how different land uses around light rail stations will affect light rail ridership. The model was developed to predict boardings at each station in the AM peak period (6-9 AM), the PM peak period (3-6 PM), and the off peak hours. The resulting ridership model is an effective and responsive means of forecasting the effect of individual station activities on ridership at various times of the day. It should be noted that the model is calibrated to the existing land use and ridership patterns in the Denver region, which are likely to change as the land use and ridership mature and potentially intensify around stations over time.

The four Federal Center land use scenarios developed for comparison using MXD were also applied to the RTD Direct Ridership Forecasting model. The following assumptions were made about the Federal Center Station based on the West Corridor EIS as the rail line through the station has not been built yet.

- Utilized parking for each scenario is 1000
- Daily, AM peak, and PM peak feeder bus service for each scenario utilized the same numbers as Belleview Station which has higher than average levels of bus service.
- Retail employment factor of 1.2 employees per 1,000 square feet of development
- Office employment factor of 3.3 employees per 1,000 square feet of development
- Industrial employment factor of 1.1 employees per 1,000 square feet of development
- Medical employment factor of 2.6 employees per 1,000 square feet of development
- Hotel employment of 1 employee per room

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Federal Center Projected Station Boardings

	PM Peak Boardings	Off-Peak Boardings	AM Peak Boardings
Scenario 1	453	595	1274
Scenario 2	561	608	1283
Scenario 3	363	608	1283
Scenario 4	561	454	1180

The RTD ridership forecasting model was developed using existing RTD light rail stations, and because of this it is most sensitive to utilized parking and feeder bus service. Both of these variables were held constant between the four scenarios, and the changes in ridership resulted due to station area land use changes.

Some significant findings of the ridership model include:

- Number of parking spaces is a key variable affecting boardings in the AM peak period
- Households also affect boardings in the AM period, but not as significantly as parking spaces
- Employment is a key variable affecting boardings in the PM and off-peak periods

Land use was doubled between Scenario 1 and Scenario 2, but the model predicts only a modest increase in ridership. A small reduction in ridership occurred with more residential and less commercial in Scenario 3. An even greater reduction in ridership occurred in Scenario 4 with more commercial and almost no residential. As transit oriented development continues to happen around station areas in the future, a recalibrated model will most likely become more sensitive to land use changes, especially if changing land uses around stations in the Denver region result in higher ridership.