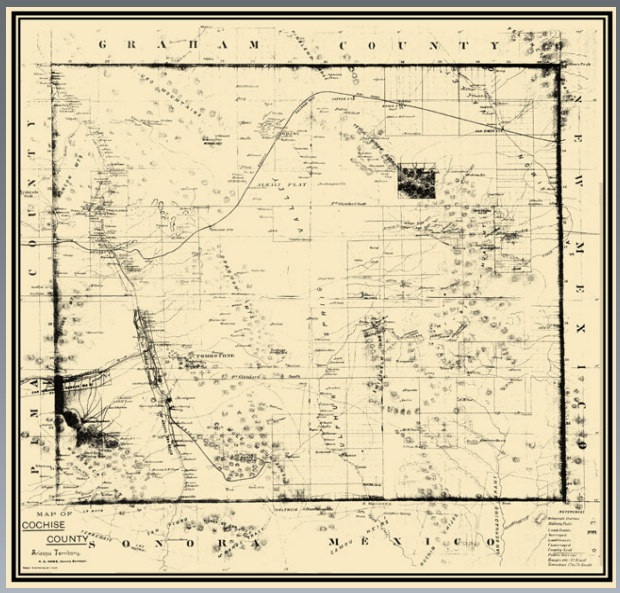
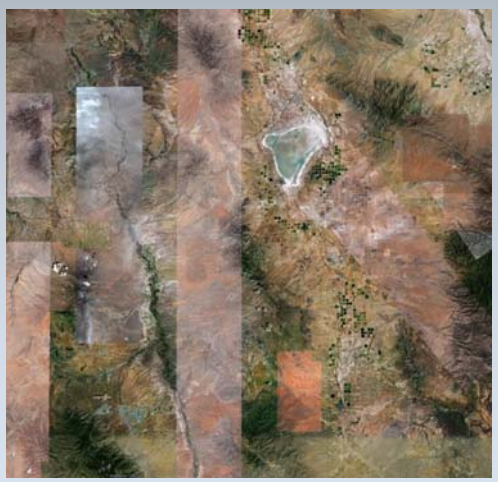
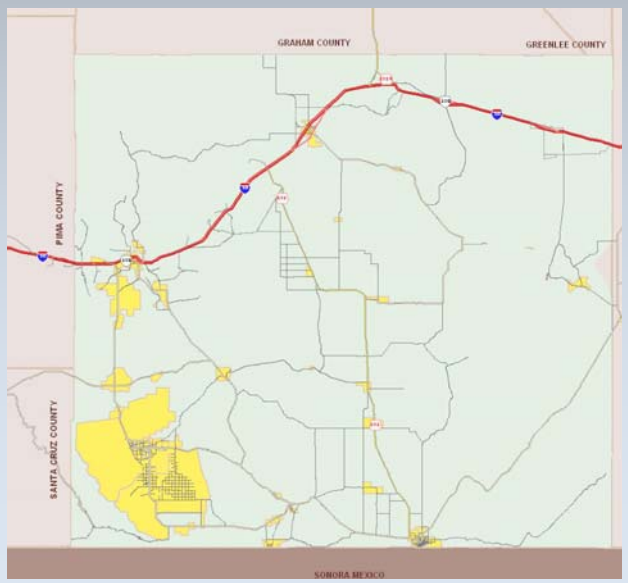
Cochise County & City of Sierra Vista Travel Demand Model Development







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Context of the Project

Following the Arizona Department of Transportation's Task Assignment MPD 12-09, Wilbur Smith Associates has been charged with developing a combined travel demand model for Cochise County and the City of Sierra Vista. The model was specified as being developed in the QRS-II modeling platform. The route for developing the model included Network and Traffic Analysis Zone (TAZ) development in TransCAD and ArcGIS shapefile formats for ease of display and analysis, with all modeling work being performed in QRS-II. The final model files were delivered in both QRS-II and in ArcGIS shapefile formats in June 2010. Following the development of the 2007 base year model, forecast TAZ data was input to develop models for the years 2020 and 2040.

The Wilbur Smith Associates model development team was lead by project manager, Dale Miller, PE. Tom Cooney served as the modeling task leader and developed much of the model input data. Charlie Sullivan performed the modeling work. Although not formally part of the modeling team, Karen Lamberton of Cochise County and Jeff Pregler of the City of Sierra Vista contributed to the process extensively, and verified the base year and developed the forecast demographic data for the entire County and for the City of Sierra Vista, respectively. Training and technical assistance was provided by Dr. Alan J. Horowitz of AJH Associates, the developer of the QRS-II platform.

The QRS-II model file is a network with associated nodes. Network data is provided in the line layer, while TAZ data for the model is contained in the nodes.

The network file for the model contains descriptive attributes and output modeled volumes. Autos and trucks are modeled separately, and their output volumes are reported separately in the network.

The TAZ data consists of the inputs which are used by the model to calculate the demand for trips. The data is aggregated to the TAZ level, and includes average autos per household, total occupied dwelling units, and employment in the three categories of basic, retail, and service. It should be noted that employment data was originally provided in the two categories of retail and non-retail; but the data was broken down into additional detail in order to use more precise attraction rates per employment category.

Base Year 2007 Model Network

Model network development began by extracting Cochise County highway network information from the ADOT statewide travel demand model and Cochise County and applicable city GIS files. Industry-standard GIS layers, street maps, aerial photos, and other databases were all used in network development. The complete network was designed to capture both regionally significant and local level roads in order to support realistic model loading patterns.

A full range of network attributes were developed to support both the needs of the travel demand model and the requirements of post-modeling display and analysis. The characteristics of the QRS-II platform specified for the Cochise County and City of Sierra Vista model impose limitations on the number and name of network data fields. Therefore, the model networks were ported into the ArcGIS shapefile format in order to provide for additional network fields.

The more extensive number of network fields, populated in the ArcGIS shapefile format, are shown in Table 1.

Table 1: Data Fields for the Shapefile Network

Data Fields for the ArcGIS Shapefile-Format Network		
Field	Description	Source
ID	Unique identification number for each link	Generated by TransCAD
Length	Length of the link in miles	Generated by TransCAD
Dir	Direction flag to identify 1-way and 2-way roads	Original file and review
NAME	Unique QRS-II name field for each link, independent of the link ID	Generated by QRS-II
QRSII Order	Line order of links used by QRS-II for extract and update functions	Generated by QRS-II
StreetName	Actual street name of the link	Original street file
TAZ	Traffic Analysis Zone of centroid connectors	Tagged from TAZ layer
AT	Area Type	Calculated
FUNCL	Standard functional classification	Derived from standards
CTL_Flag	Flag to identify links with continuous left turn lanes	Review of aerial photos
Paved_Flag	Flag to identify links as paved or not paved	Original file and review
PostedSpeed	Posted speed limit	Original file
Lanes	Number of lanes	Original file and review
AB_Cap	Hourly LOS E capacity	Derived from standards
BA_Cap	Hourly LOS E capacity	Derived from standards
Speed	Input operational speed, not the same as posted speed limit	Derived from standards per Area Type
Time	Input travel time based on input operational speed	Calculated
CountTot	2007 total traffic count	ADOT
CountAuto	2007 auto count	Factored to remove trucks
CountTruck	2007 truck count	Factored by truck percentage
TotalCountVMT	Total VMT based on 2007 counts	Calculated
RID	County ID number for the road section	Original street file
MaintID	County ID number for the road section	Original street file
H7SecID	County ID number for the road section	Original street file
CarVolxx	Assigned auto volume for the given year	Model output
TrkVolxx	Assigned truck volume for the given year	Model output
TotVolxx	Assigned total volume for the given year	Model output
TotVMTxx	Total VMT based on assigned total volume for the given year	Model output

The QRS-II platform's network fields, which are designed to be used only for direct modeling needs, are noted in Table 2.

Table 2: Data Fields for the QRS-II Network

Data Fields for the QRS-II - Format Network				
	Extract/Update Codes			
Field	1-way street	2-way street	Centroid Connector	Description
Name	B	B	B	Alphanumeric code generated by QRS-II
Approach Code	1	1		Model code controlling capacity, throughput, and delay at intersections
Speed	2	2	2	Input operational speed
Travel Time A to B	3	3	3	Input travel time based on input operational speed
Travel Time B to A		4	4	Input travel time based on input operational speed
Capacity A to B	5	7		Hourly LOS E capacity
Capacity B to A		9		Hourly LOS E capacity
Distance	8	a	5	Link length from the ArcGIS network
Ground Count A to B	g	p		2007 ground count from ADOT files
Ground Count B to A		q		2007 ground count from ADOT files
Assigned Volume A to B		s	8	Model output volume
Assigned Volume B to A	i	t	9	Model output volume

Two important considerations should be noted when working within the QRS-II modeling platform and extracting or updating attributes to ArcGIS. The first point is that QRS-II does not retain link ID's when importing. Rather, links are renumbered with a *Name* attribute based on their geographic order. All files used in QRS-II must list the links in the specified order. Second, QRS-II orders link variables by defined link types. Three link types are defined in the Cochise County and City of Sierra Vista model: 1-way street, 2-way street, and centroid connector. As shown in Table 2, the reference code for extracting or updating a given attribute varies depending on its link type. For example, the code to extract or update the link name and assigned volume from the QRS-II network would be Bi for 1-way streets, Bst for 2-way streets, and B89 for centroid connectors.

Ground traffic counts for area roadways were provided for the years 1998 through 2009. Most of the years had just a small number of counts focused on area collectors. The data for 2007 was both more comprehensive and more thorough, with a total of 1,239 counts provided on roads of all functional class. Only the 2007 counts were coded into the network.

Truck percentages from the file *SHSkdtFactors 2007-2008 ver2.xls* were used to factor total counts to develop counts for combination trucks. While these are factors rather than actual counts, and while the factors were constant over relatively large distances of roadway, they provided a useful and valuable measure to validate the truck model.

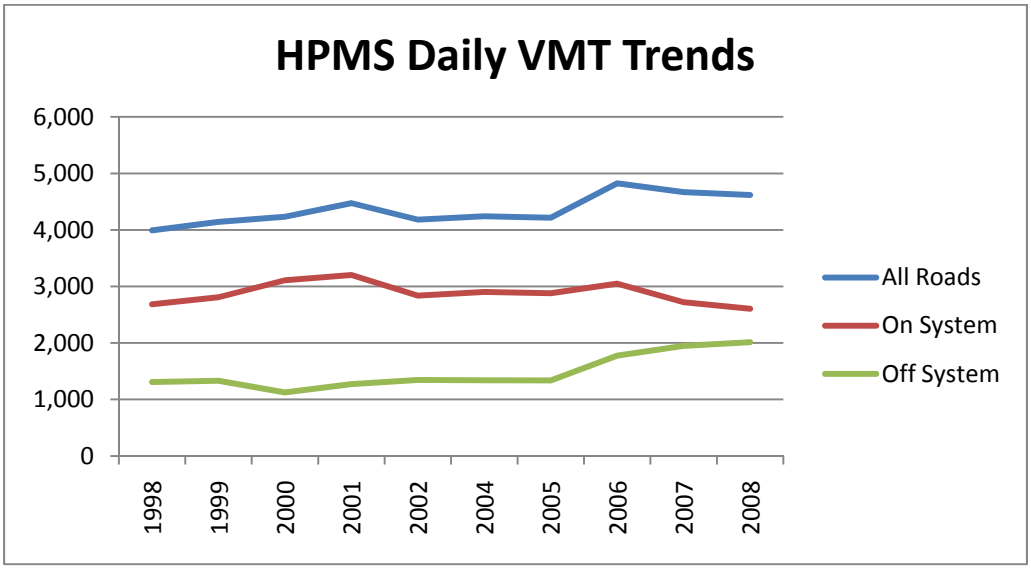
Complementing the ground count data, county-level HPMS VMT for the years 1998 – 2008 was available from the ADOT website to provide another measure of traffic activity. Table 3 shows the data for each year for Cochise County, along with the population trend data.

Table 3: Historic HPMS Daily VMT

HPMS Average Daily VMT for Cochise County				
Year	Total Pop	All Roads	On System	Off System
1998	123,750	3,991	2,684	1,307
1999	124,575	4,141	2,809	1,332
2000	117,755	4,233	3,108	1,125
2001	121,435	4,473	3,201	1,272
2002	124,040	4,182	2,836	1,346
2004	124,013	4,242	2,903	1,339
2005	131,790	4,217	2,879	1,338
2006	135,150	4,825	3,049	1,776
2007	137,200	4,669	2,721	1,948
2008	139,434	4,619	2,605	2,014

The same data is presented in a chart in Figure 1. It is interesting to note that on-system VMT is fairly stable throughout the period. Off-system VMT shows a slight but steady increasing trend.

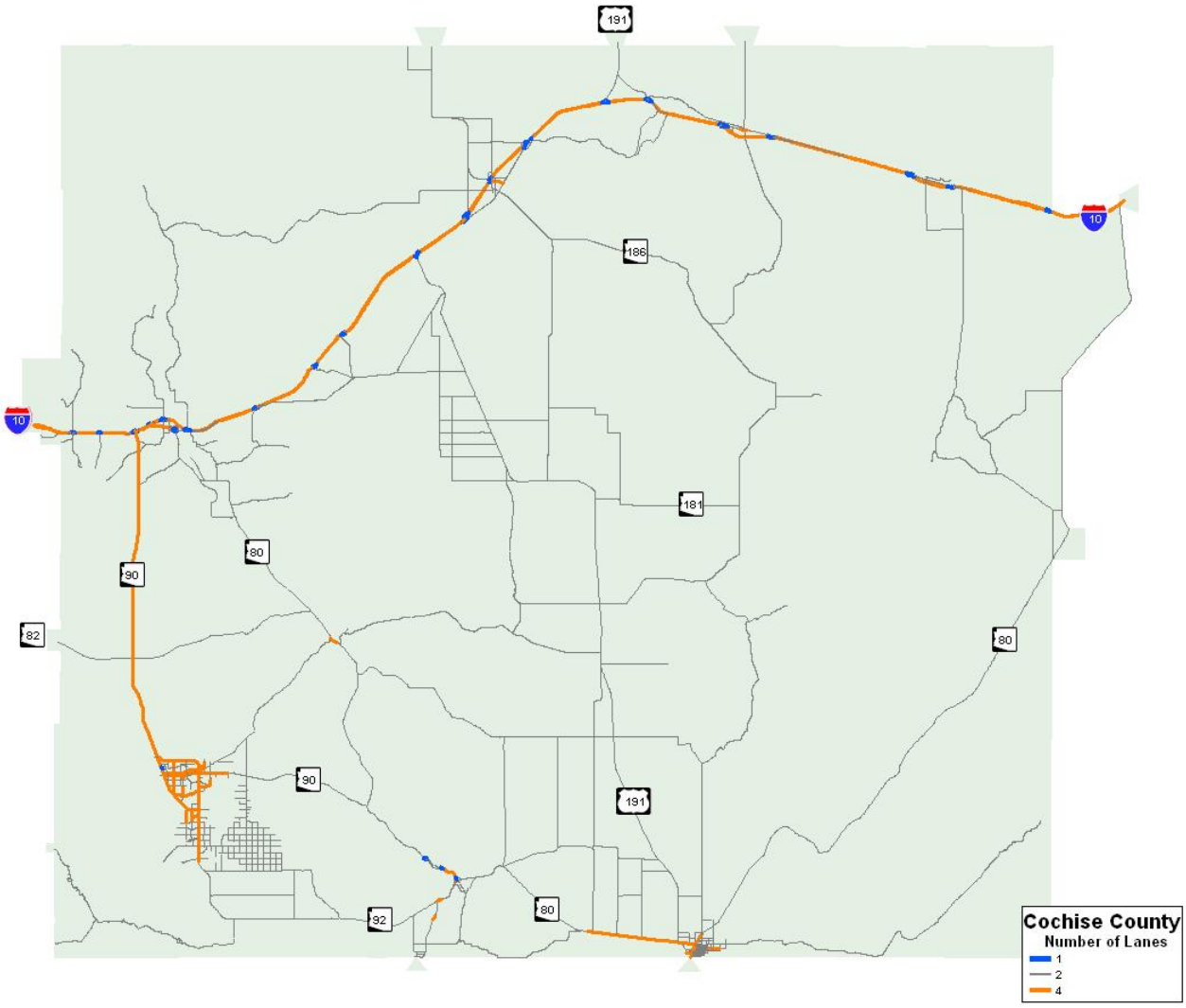
Figure 1: Historic HPMS Daily VMT Chart



Color-coded views of several network data fields are shown in Figures 2 through 6, with associated explanatory text and tables.

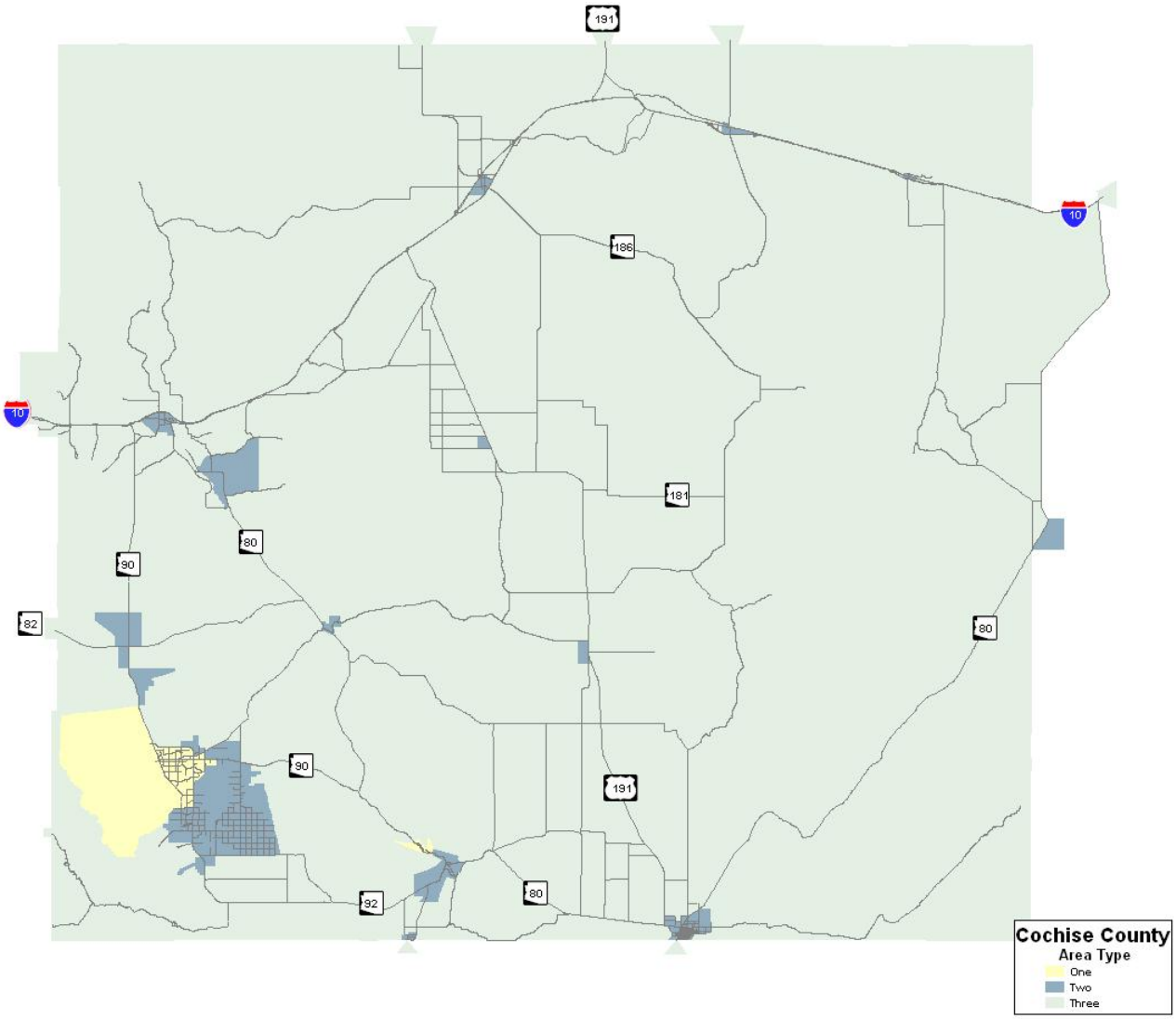
The number of lanes, shown in Figure 2, is based on the original street file and was verified using aerial photography. Links on I-10 are detail coded with separate lines for each direction; ramps and any frontage roads are included. It should be noted that there are some 2-way, 2-lane ramps along I-10, and also in the Bisbee area.

Figure 2: Number of Lanes



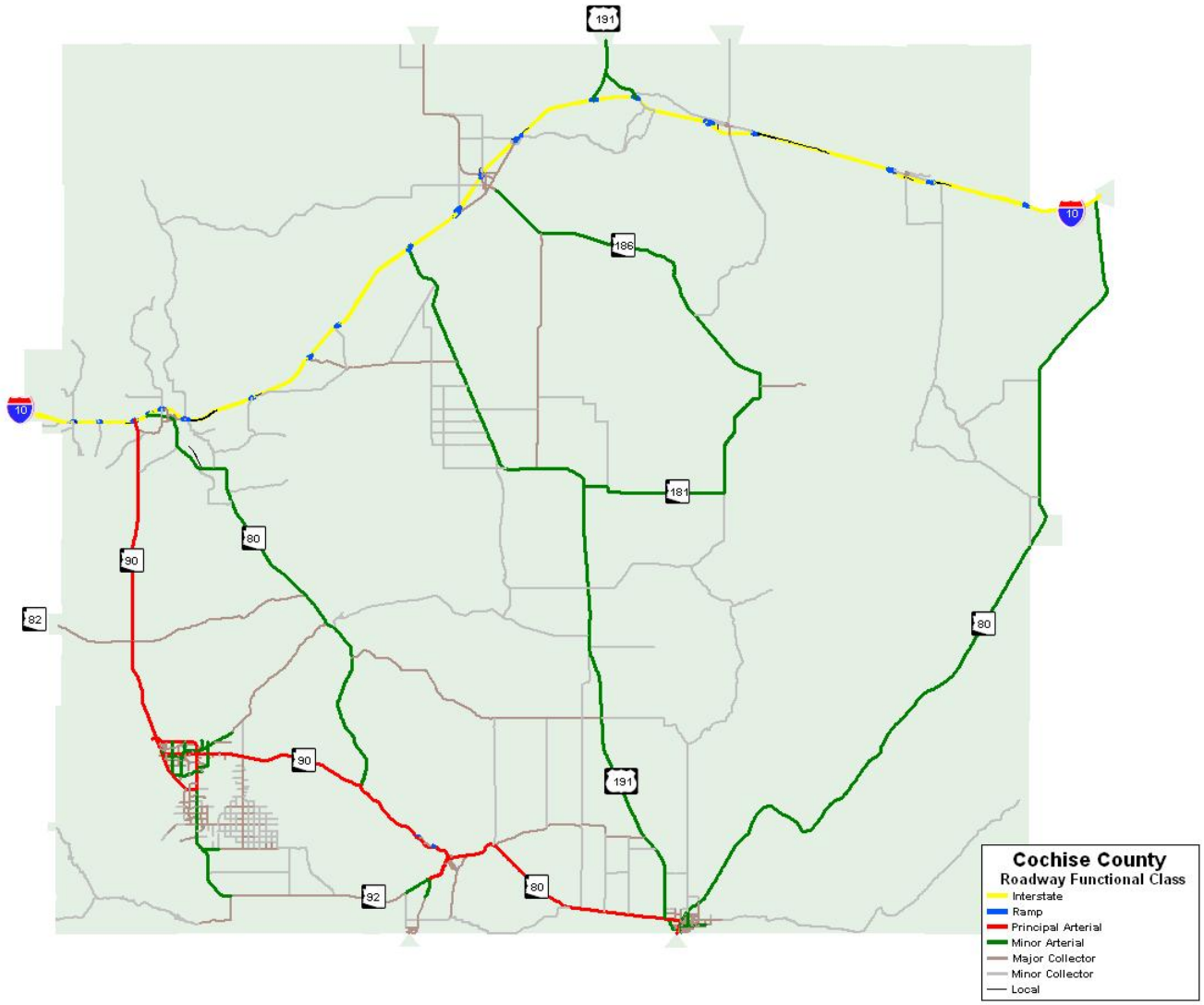
Area Types were defined for the Cochise County and City of Sierra Vista model based on a subjective evaluation of combined employment and dwelling unit density. Three defined area types were used to stratify the assignment of network speeds and capacities to links, and to stratify trip attraction rates. Area Type 1 represents the more dense urban areas such as portions of Sierra Vista, Bisbee, and Douglas. Smaller urbanized areas such as Benson, Bowie, etc. were classed as Area Type 2. Finally, the rural areas of the county were classified as Area Type 3. The general effect of the area types is to define higher network speeds, lower network capacities, and lower trip attraction rates for the more rural areas, while the more urbanized areas feature lower speeds and capacities and higher attraction rates. Area Types for the Cochise County and City of Sierra Vista model are shown in Figure 3.

Figure 3: Area Types



Functional classifications, shown in Figure 4, were defined and assigned based on the original street file, standard network coding practice, and on the requirements of the QRS-II program. Only a specific number of functional classifications are available within the QRS-II modeling platform. In general, the response to this was to implement area types, with stratification of functional class and other attributes replacing the original separate HPMS urban and rural coding scheme.

Figure 4: Functional Class



It should be noted that the same functional classes are described by QRS-II with different internal codes. The standard link functional classifications and the equivalent QRS-II codes are shown in Table 4. The standard link functional classifications are used in the ArcGIS shapefile format network, while the QRS-II codes are used in developing its *Approach Codes* to control intersection capacity, throughput, and delay. The standard classifications are the numbers zero through 8. The QRS-II codes are case-sensitive letters. Note that the Centroid Connector code is

the capital letter “O”, not the number zero, and that the code for a local street is a lower-case letter “L”, rather than the number 1.

Table 4: Functional Class Codes

Functional Classification Codes		
Description	Shapefile	QRS-II
Centroid Connector	0	O
Interstate	1	F
Principal Arterial	2	M
Minor Arterial	3	m
Major Collector	4	C
Minor Collector	5	c
Local	6	l
Slip Ramp	7	R
Tight Ramp	8	Q

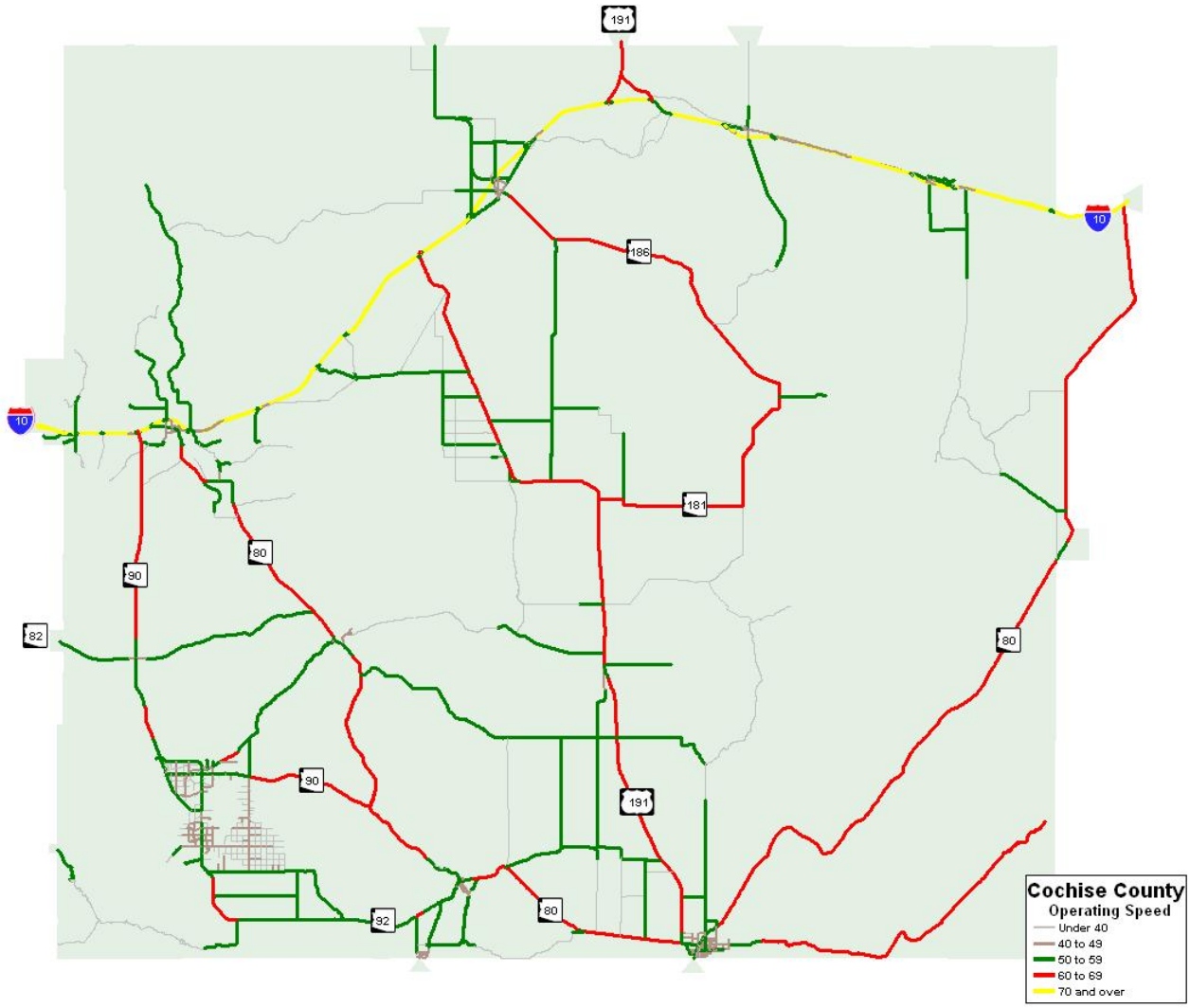
The scheme for estimating network speeds by Functional Class and Area Type is shown in Table 5. Two additional variables, the presence of continuous left turn lanes and the status of the road as paved or unpaved, also have an effect on the designated input speed. It should be noted that not all possible combinations are present for each stratification variable. For example, the Interstate Functional Class is present only in defined rural area type, no links in the rural area type have continuous left turn lanes, and there are no unpaved roads in the dense urban area type.

Table 5: Network Speed Stratification

Network Speeds by FUNCL by Area Type, CTL, and Pavement										
		Dense Urban			Urban			Rural		
	FUNCL	CTL	Paved	Unpaved	CTL	Paved	Unpaved	CTL	Paved	Unpaved
Centroid Connector	0	-	35	-	-	40	-	-	55	-
Interstate	1	-	-	-	-	-	-	-	75	-
Principal Arterial	2	53	50	-	58	55	-	-	65	-
Minor Arterial	3	48	45	-	53	50	-	-	65	-
Major Collector	4	-	35	-	43	40	-	-	55	-
Minor Collector	5	-	-	-	-	40	35	-	50	35
Local	6	-	-	-	-	-	-	-	45	35
Slip Ramp	7	-	40	-	-	40	-	-	50	-
Tight Ramp	8	-	35	-	-	35	-	-	35	-

The input network speeds are shown in Figure 5. These speeds represent the average operational speed, and are different from the posted speed limit. The purpose of the stratification is to allow the model to replicate the relative differences in observed driver behavior on different functional classes of roads under different conditions.

Figure 5: Input Network Speeds



The stratified capacities of roadway links by Functional Class, Area Type, and other attributes are shown in Table 6. To meet the requirements of the QRS-II model platform, the data is for hourly capacity, one-way, per lane, at Level of Service (LOS) E. LOS E is considered the saturation flow rate.

Table 6: Network Capacity Stratification

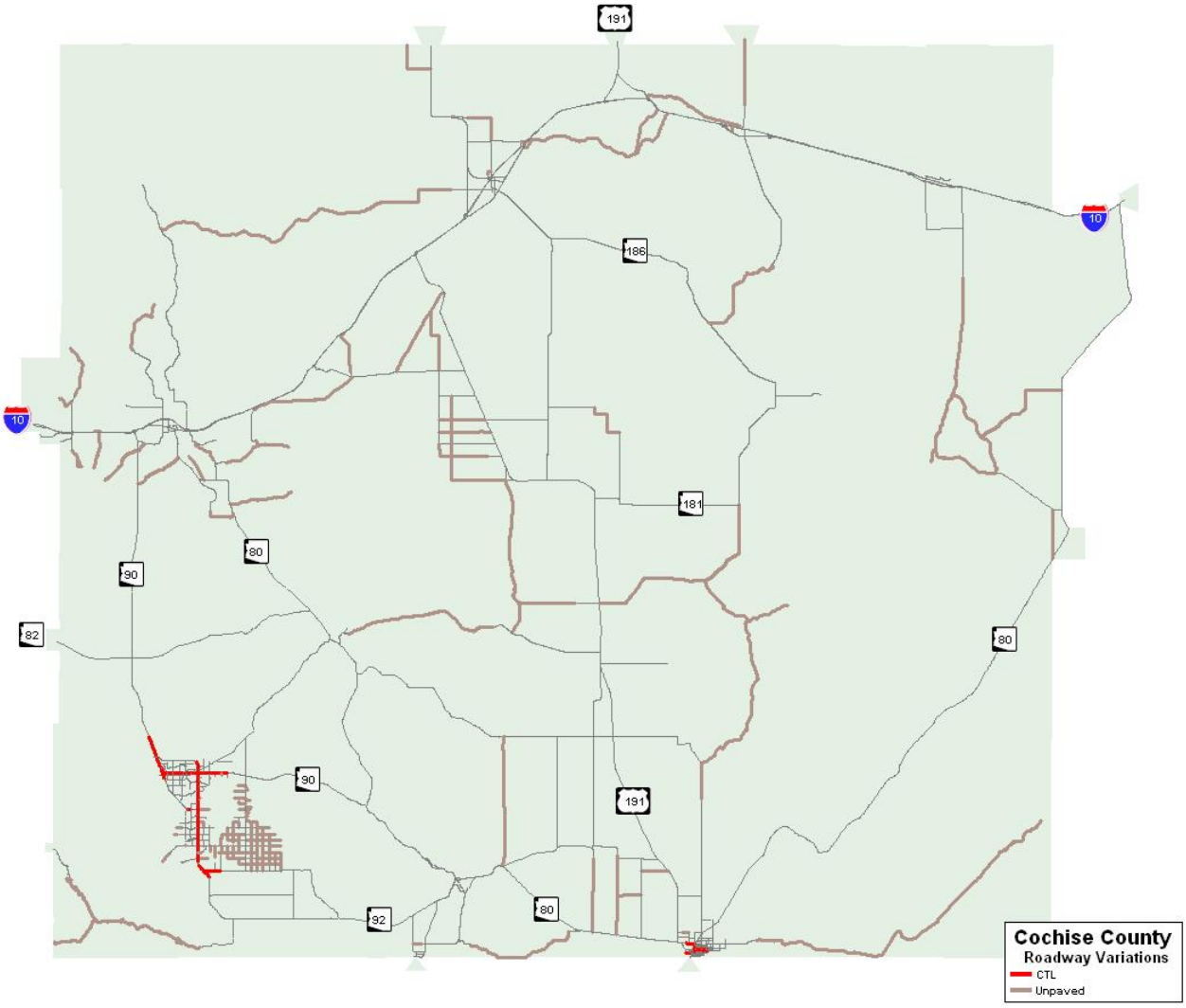
Hourly LOS E Capacity per Lane by FUNCL by Area Type, CTL, and Pavement										
		Dense Urban			Urban			Rural		
		CTL	Paved	Unpaved	CTL	Paved	Unpaved	CTL	Paved	Unpaved
Centroid Connector	0	-	1,170	-	-	1,020	-	-	780	-
Interstate	1	-	-	-	-	-	-	-	5,640	-
Principal Arterial	2	2,880	2,580	-	2,520	2,280	-	-	1,710	-
Minor Arterial	3	2,460	2,280	-	2,190	2,040	-	-	1,530	-
Major Collector	4	-	1,890	-	1,890	1,710	-	-	1,260	-
Minor Collector	5	-	-	-	-	1,380	1,080	-	1,050	840
Local	6	-	-	-	-	-	-	-	1,050	840
Slip Ramp	7	-	1,800	-	-	1,800	-	-	1,800	-
Tight Ramp	8	-	1,800	-	-	1,800	-	-	1,800	-

Stratified model total link capacities are shown in Figure 6.

Figure 6: Hourly LOS E Capacity

The two additional variations which affect link speeds and capacities are the presence of continuous left turn lanes and the status of the road as paved or unpaved. These variables are shown together in Figure 7. Note that continuous left turn lanes are present only in Sierra Vista and Douglas. Unpaved roads are found throughout the county, and some roads have both paved and unpaved segments.

Figure 7: Other Speed & Capacity Stratification Variations



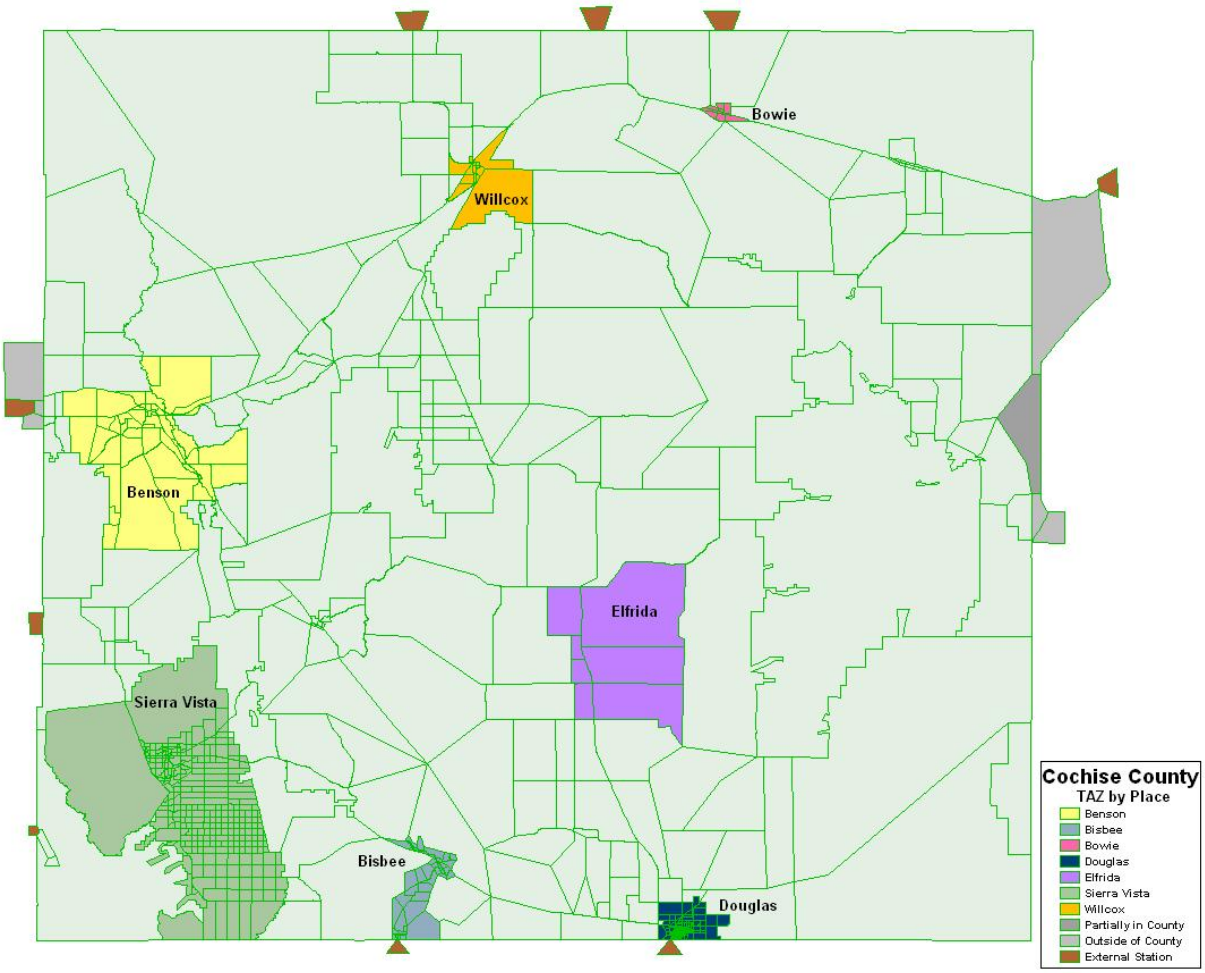
Forecast Years 2020 and 2040 Model Networks

In the initial stage of development of the Cochise County and City of Sierra Vista model, no future year network improvements have been defined. Planners have taken the eminently reasonable approach of using the model to forecast and analyze network deficiencies, and to use those results to generate potential network projects for further testing. It is expected that a number of alternative projects will be developed using this process, and that they will be tested in the model at a later time by County and City staff (or through a qualified consultant).

Cochise County TAZ Data

The TAZ structure developed for the Cochise County model features a total of 799 zones. Zone size and density varies throughout the county, with the more dense urbanized areas having a finer zone structure than the rural parts of the county. The TAZ structure is shown in Figure 8.

Figure 8: Cochise County TAZ Structure



Seven urbanized areas were identified as places in the original TAZ file; and these designations have been retained. These seven places have sometimes included several places in one. For example, the Sierra Vista place includes Sierra Vista, Huachuca City, Fort Huachuca, Sierra Vista Southeast, Hereford, Palominas, and Miracle Valley. The Elfrida place includes Elfrida and McNeal. In contrast, some smaller places, such as Tombstone, Gleeson, and Kansas Settlement, have not been specifically marked. In general, the seven designated places have a denser zone structure than the remainder of the county.

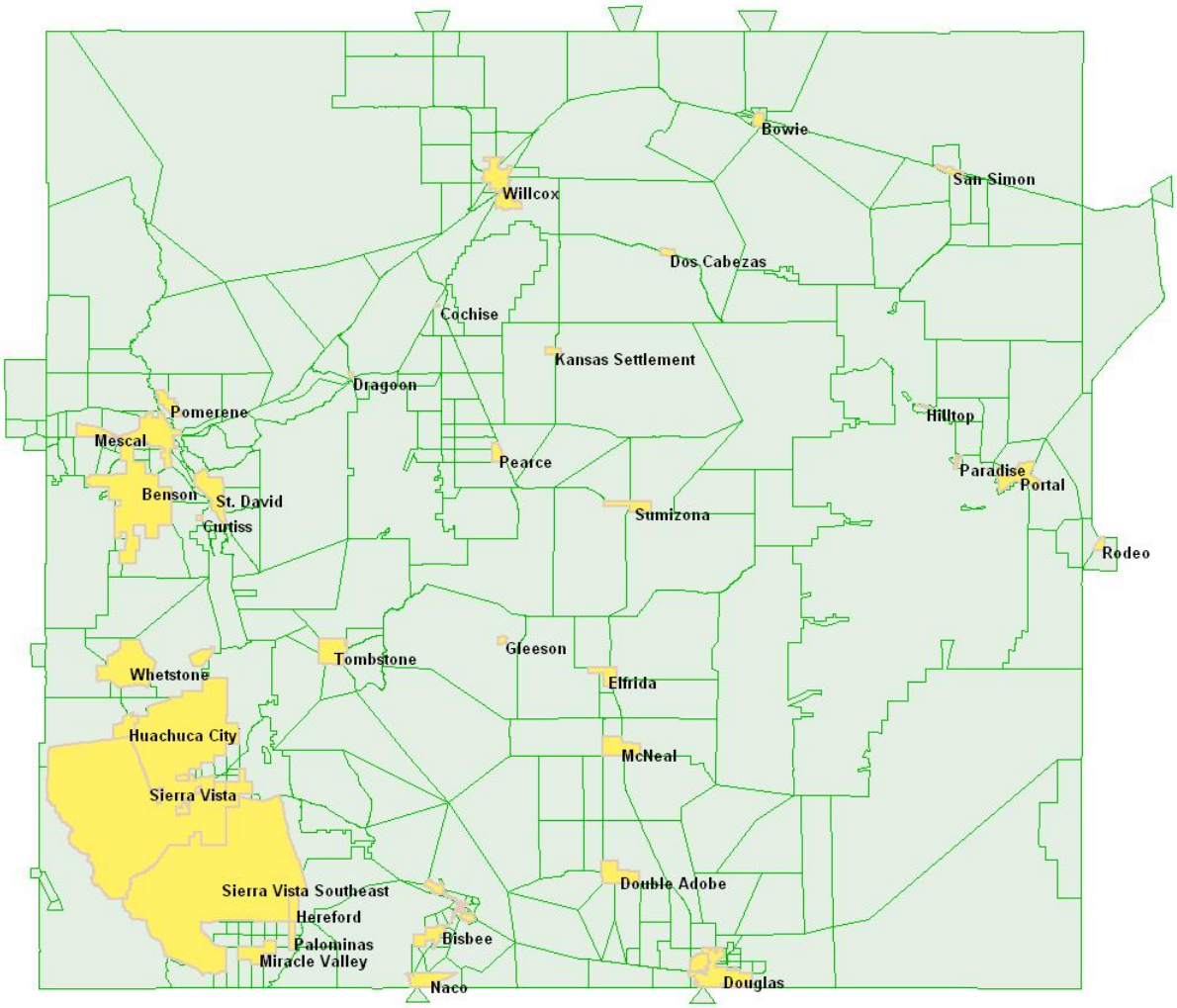
Table 7 shows the distribution of zones by place. Sierra Vista has the most zones with 304. There are three zones on the western edge of I-10 which are within Pima County. Four zones on the eastern side of the county are partially or totally in Hidalgo County, New Mexico, and include the community of Rodeo. There are nine external stations, including two ports of entry with Mexico at Naco and at Douglas.

Table 7: TAZ Structure by Place

Cochise County TAZ Structure by Place	
Place	Number of TAZ's
Benson	49
Bisbee	47
Bowie	10
Douglas	137
Elfrida	7
Sierra Vista	304
Willcox	14
Rural Area of Cochise County	215
Partially Within Cochise County	1
Outside Cochise County	6
External Station	9
Total Traffic Analysis Zones	799

Complementing the definition of places in the Cochise County model, Figure 9 shows the Census Designated Places (CDP) for 2000. There are a total of 34 CDP's in the county (plus one for Rodeo, New Mexico).

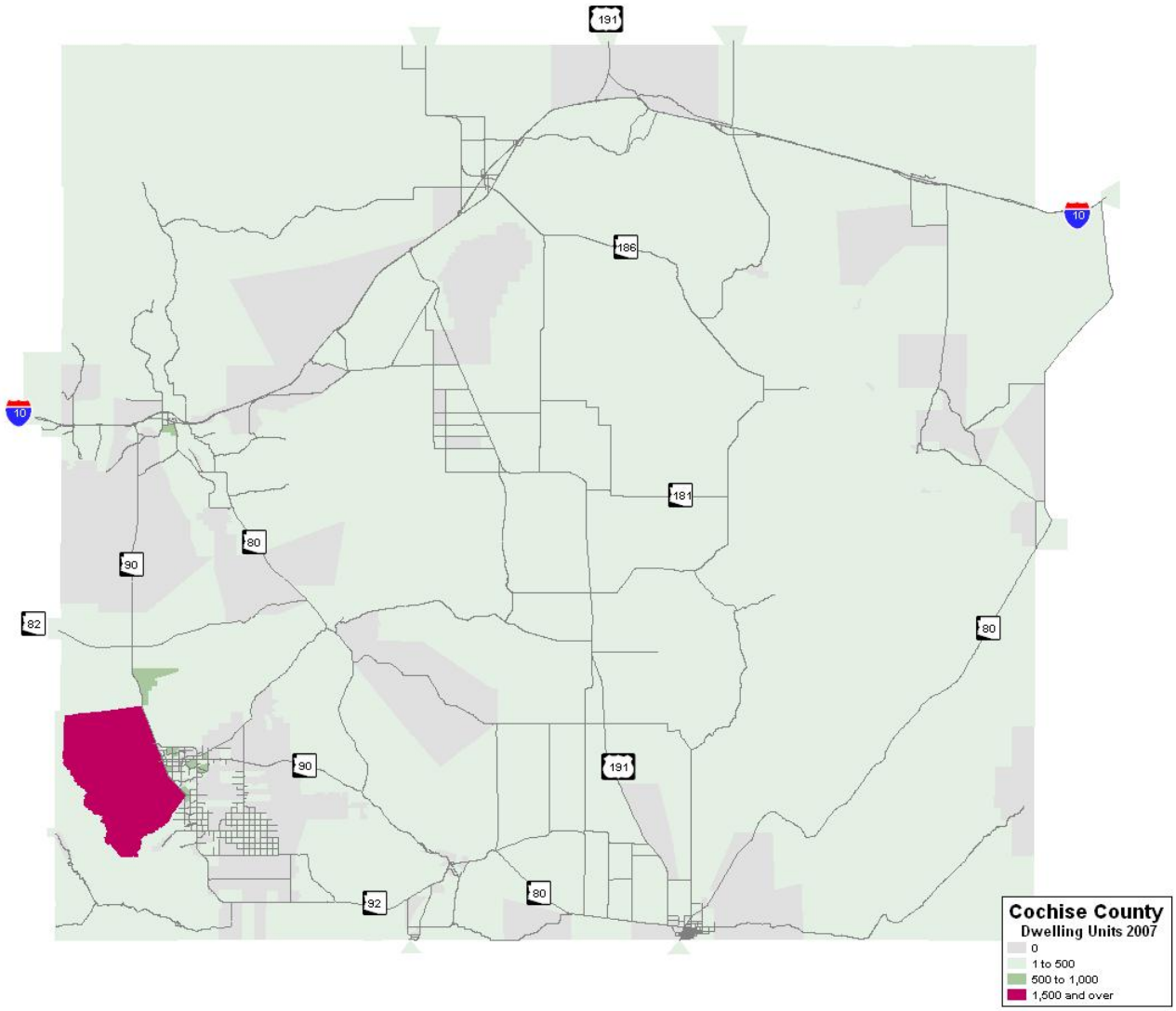
Figure 9: Census Designated Places



Population

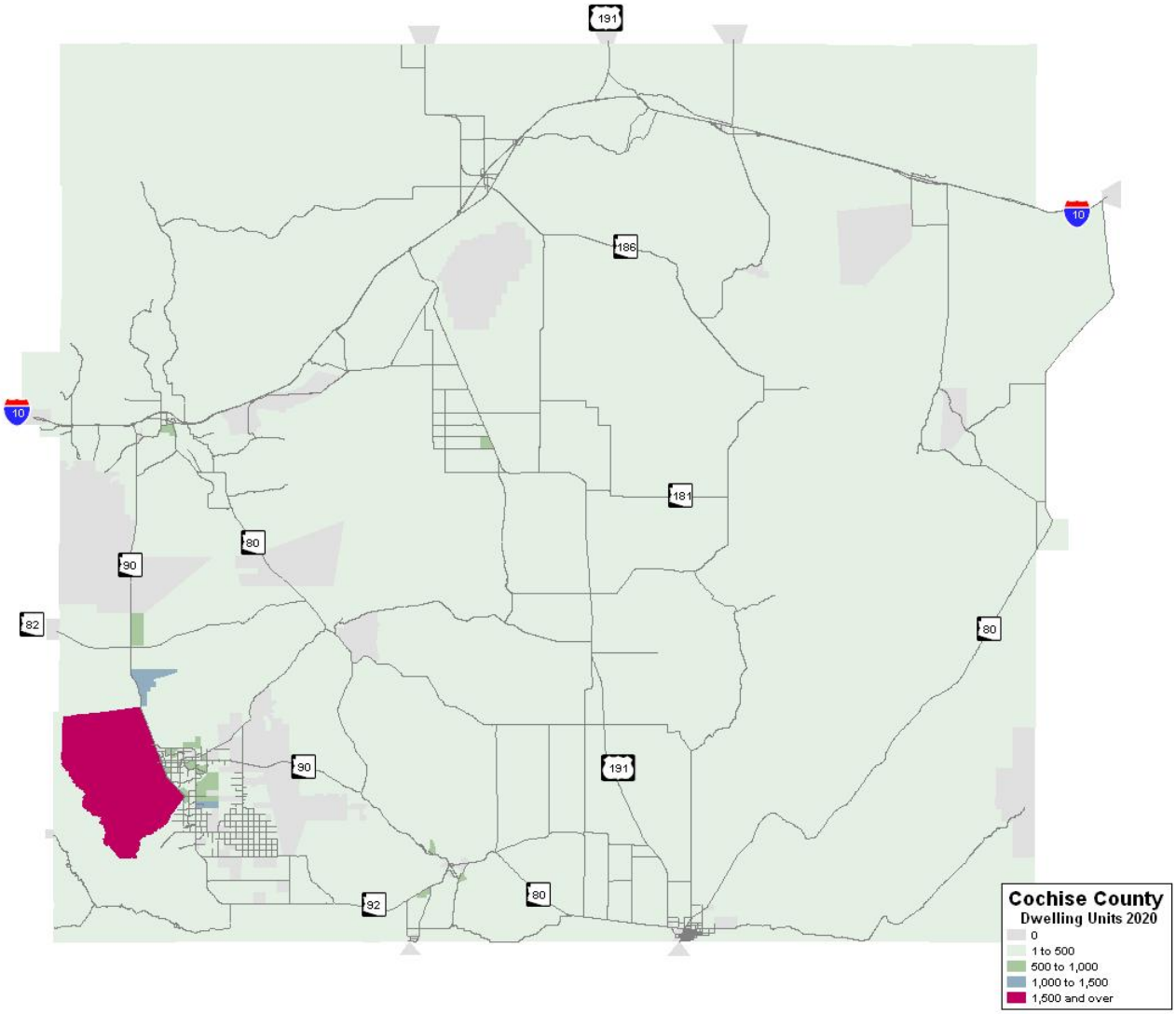
QRS-II trip modeling is based on households rather than population. As a result, occupied dwelling units (DU's) were the basis for the model and were calculated in the demographics files, rather than population. DU's for 2007, 2020, and 2040 are shown in Figures 10 to 12. For display purposes, Fort Huachuca in TAZ 18 is shown with over 1,000 DU's. However, in the model, it was actually treated as a special generator.

Figure 10: 2007 Occupied Dwelling Units



Occupied DU's for the 2007 model are shown in Figure 10. A total of 302 zones had no DU's in 2007. There were 474 zones, or 60% of the total, with less than 500 DU's. Only 14 zones had 500 or more DU's in 2007; 13 of these were in Sierra Vista. The other higher-population zone is TAZ 845 in Benson, south of 4th Street, between Ocotillo and Highway 80.

Figure 11: 2020 Occupied Dwelling Units



The forecast year 2020 DU's are shown in Figure 11. The number of zones with no DU's dropped to 110, as the population is anticipated to spread throughout the county. The populated zones with less than 500 DU's increased to 653, now making up 83% of the total. The 27 zones with 500 or more DU's now include zones in Sierra Vista, Huachuca City, Whetstone, Benson, Mescal, Pearce, and Bisbee.

Figure 12: 2040 Occupied Dwelling Units

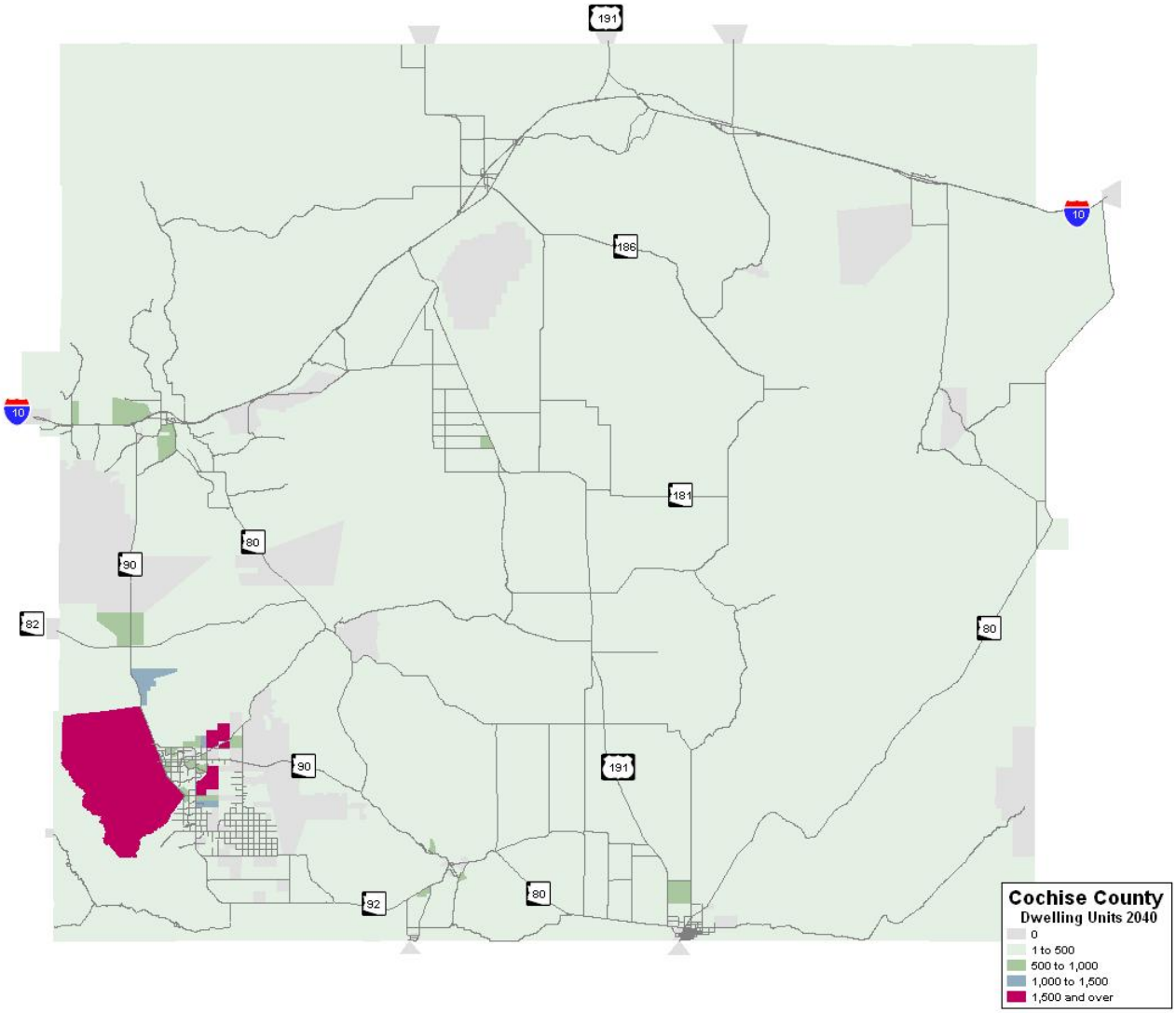
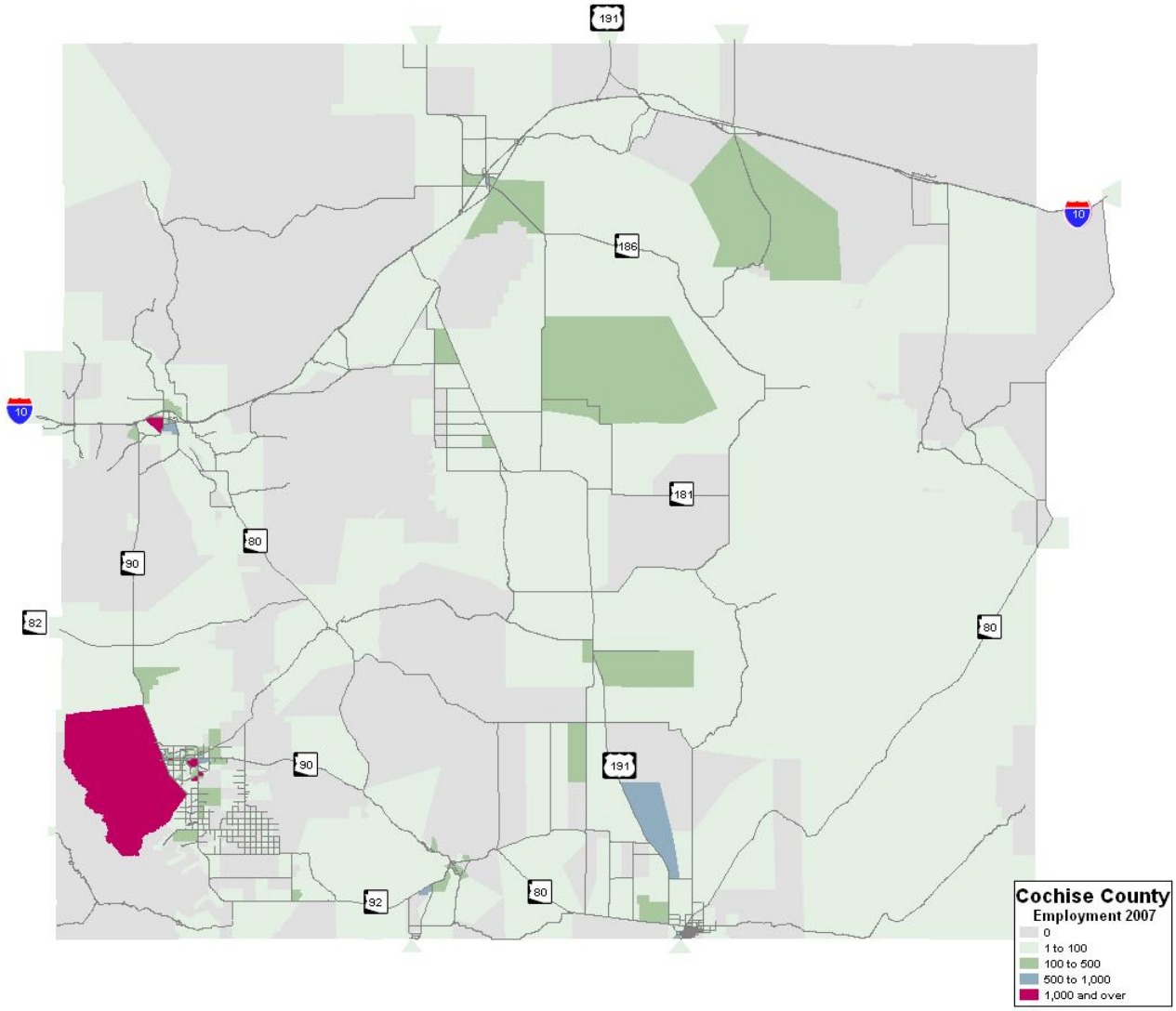


Figure 12 shows the 2040 DU's. Population is expected to continue to increase and to spread throughout the county for the forecast year 2040. The number of zones with no DU's dropped to 102. The populated zones with less than 500 DU's decreased slightly to 649 as more zones moved into higher population categories, but these are still 82% of the total. There are 39 zones with 500 or more DU's in 2040, which now include zones in Sierra Vista, Huachuca City, Whetstone, Benson, Pomerene, Mescal, Pearce, Bisbee, and Douglas.

Employment

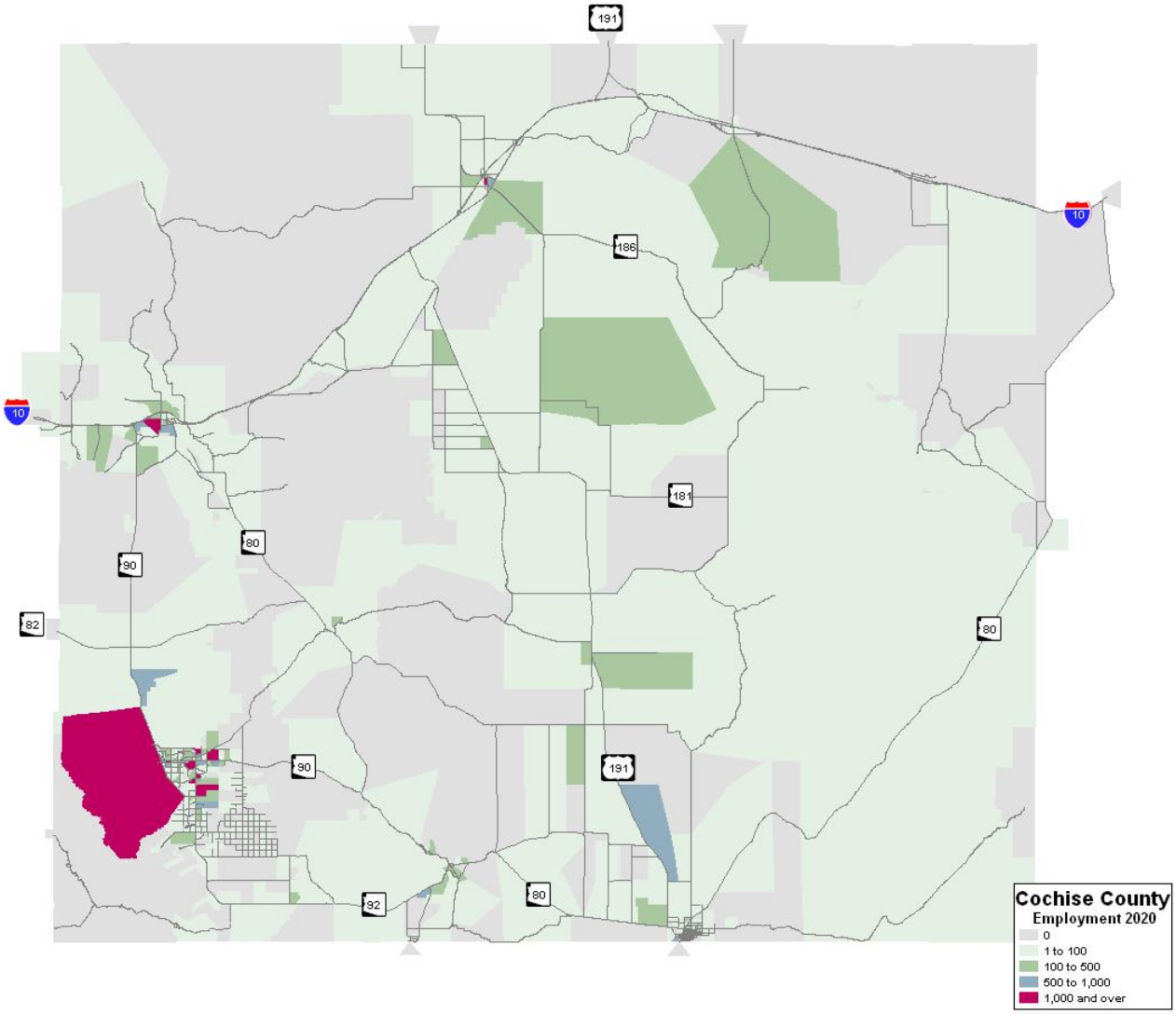
Employment is the main variable driving the trip attraction rates per zone. In contrast to population (represented by dwelling units), which increased and showed more spreading through the county, the increase in employment was more concentrated in the existing urbanized areas. Much of the employment increase was concentrated in the Sierra Vista / Fort Huachuca area.

Figure 13: 2007 Total Employment



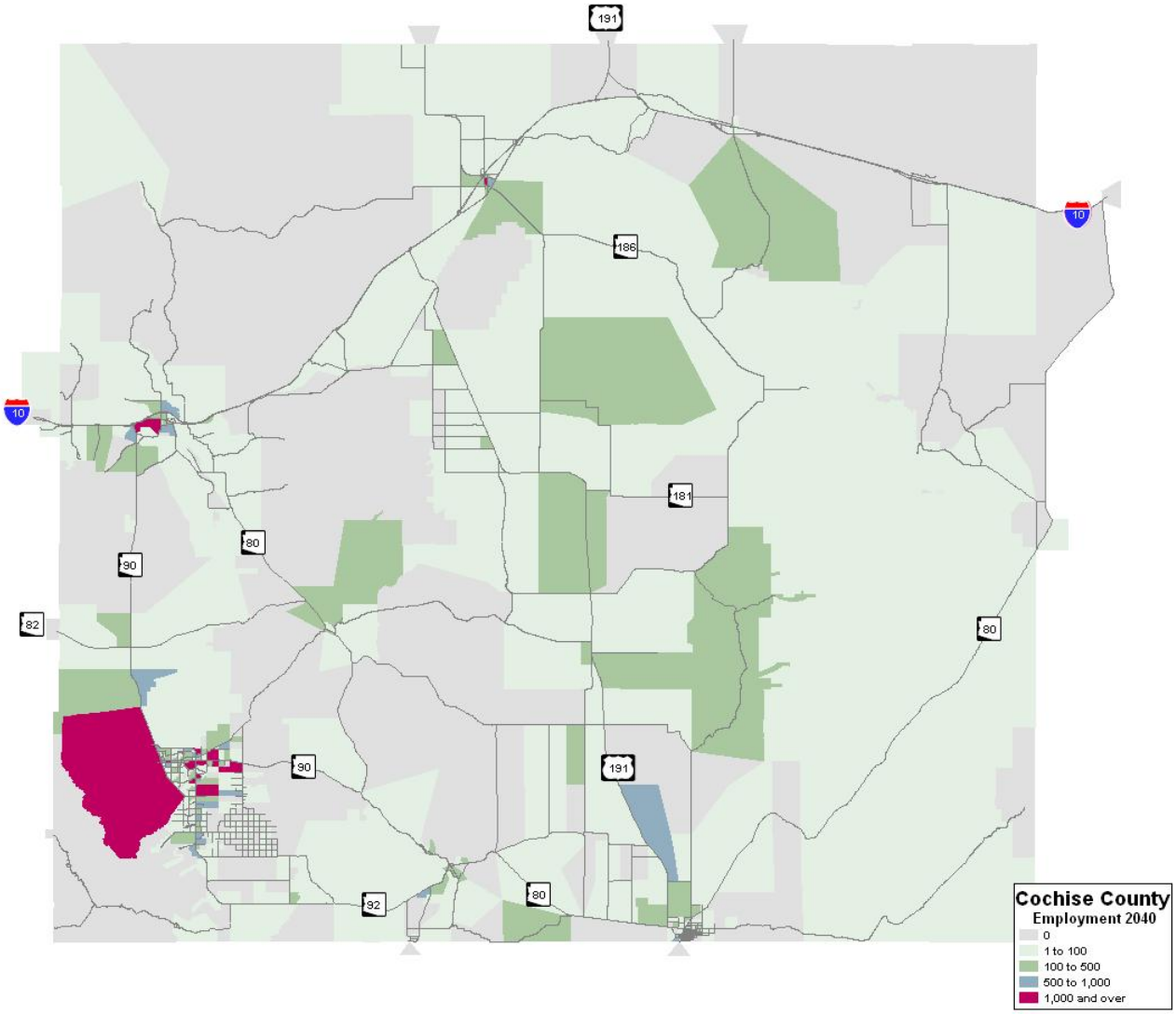
Total employment in 2007 was zero for 266 zones, as shown in Figure 13. A further 426 zones have less than 100 employees. Another 82 zones have up to 500 employees, and 10 have between 500 and 1,000. These 10 zones are in Benson, Sierra Vista, Bisbee, Douglas, and at the Bisbee-Douglas International Airport. There are 6 zones in Benson and Sierra Vista with over 1,000 employees in 2007, including Fort Huachuca.

Figure 14: 2020 Total Employment



For the forecast year 2020, the number of zones with no employment dropped slightly to 260. The next category of 0 to 100 zones also dropped slightly to 408, while 93 zones had up to 500 employees. The number of zones with between 500 and 1,000 employees increased to 18 and now include TAZ's in Willcox, Pomerene, Benson, Huachuca City, Sierra Vista, Bisbee, and Douglas. The 11 zones with more than 1,000 total employees are in Benson and Sierra Vista.

Figure 15: 2040 Total Employment



For the forecast year 2040, the number of zones with no employment dropped slightly to 247. The next category of 0 to 100 zones also dropped to 382. The zones with up to 500 employees again showed an increase, growing to 118. The number of zones with between 500 and 1,000 employees increased to 26 and include TAZ's in Willcox, Pomerene, Benson, Huachuca City, Sierra Vista, Sierra Vista Southeast, Bisbee, and Douglas. There are 17 zones with more than 1,000 total employees; and again all of these zones are in Benson and Sierra Vista.

Model Design

All model functions for the Cochise County model are performed entirely within the QRS-II platform. The platform design features extensive reliance on the state-of-the-art data, algorithms, and procedures, which are embedded within the platform. This feature, according to the QRS-II Reference Manual, "…permits elimination of unnecessary data and most calibration exercises." This feature makes QRS-II uniquely applicable for a range of studies, as it "…can be used as a sketch planning tool when time for more careful planning is unavailable, or [it] can be used for rigorous analysis…."

QRS-II was initially based on the parameters and procedures of *NCHRP 187: Quick-Response Urban Travel Estimation Techniques and Transferable Parameters.* It has been updated with the revision of that document to the 1998 *NCHRP 365: Travel Estimation Techniques for Urban Planning*. Both reports feature compatibility with the procedures used in the Highway Capacity Manual.

Trip Generation

Standard QRS-II procedures were used for trip generation. Production rates were modified during the validation to enable a closer match to observed total VMT. Autos per household were used as the chief production variable.

Attraction rates were varied by TAZ for the three defined area types. Employment was broken into the categories of Retail, Non-Retail (basic), and Demographic 4 (service).

Three special generators were defined:

Ft. Huachuca / Sierra Vista Municipal Airport in TAZ 18
Cochise College in TAZ 582
Bisbee – Douglas International Airport in TAZ 596

The predominantly residential zones lying outside Cochise County were considered for designation as special generators. However, after an examination of available counts in those areas, and of the preliminary model results, it was determined that the standard trip generation procedures in the model adequately captured their travel behavior. Therefore, these zones were modeled using standard trip generation.

For automobile travel, the three standard trip types of Home-Based Work (HBW), Home-Based Non-Work (HBNW), and Non-Home-Based (NHB) were used. Truck traffic was modeled as a separate trip type, with trucks defined as multi-unit trucks only.

Trip Distribution

Trip distribution was based on the negative exponential function. The initial average trip lengths for auto trips were set to the census journey-to-work figure of 21.45 minutes for HBW, with HBNW and NHB correspondingly set to 7.20 and 6.78 minutes, respectively, using standard relationships between the three trip types. However, during the validation and examination of county-wide VMT and trip paths, and consideration of the geography of the county, this lead to increasing the average trip length for HBNW and NHB to 15.28 and 14.36 minutes. For trucks, the average trip length was set to 34.22 minutes, based primarily on the length of through trips.

External Stations

There are nine external stations defined for Cochise County, located as shown in Figure 8. Tables of the total volumes, external-local volumes, and external-through volumes for autos and trucks for the years 2007, 2020, and 2040 are shown in Tables 8 – 10.

Table 8: 2007 External Station Volumes

2007 External Station Auto and Truck Total Volumes and External-Local & External-Through Volumes									
		Total Volume			Total		Auto		Truck	
TAZ	Description	Total	Auto	Truck	Local	Through	Local	Through	Local	Through
876	I-10 Tucson	29,242	23,688	5,554	18,852	10,390	18,852	4,836	4,420	1,134
878	SR-82 Santa Cruz Cnty	2,238	2,037	201	2,238	0	2,037	0	201	0
879	SR-83 Santa Cruz County	101	101	0	101	0	101	0	0	0
888	US 191 to Safford	2,309	2,125	184	2,309	0	2,125	0	184	0
893	Central Av to Graham Cnty	100	100	0	100	0	100	0	0	0
988	I-10 New Mexico	12,590	8,184	4,406	5,000	7,590	5,000	3,184	2,692	1,714
997	Naco POE	2,517	2,409	108	2,317	200	2,317	92	104	4
1001	Douglas POE	11,149	10,592	557	8,149	3,000	8,149	2,443	429	128
1011	To Ft Grant State Prison	200	200	0	200	0	200	0	0	0

Table 9: 2020 External Station Volumes

2020 External Station Auto and Truck Total Volumes and External-Local & External-Through Volumes									
				Total		Auto		Truck	
TAZ Description	Total	Auto	Truck	Local	Through	Local	Through	Local	Through
876 I-10 Tucson	38,240	30,964	7,276	24,653	13,587	26,936	4,028	5,477	1,799
878 SR-82 Santa Cruz Cnty	2,364	2,129	235	2,364	0	2,225	0	235	0
879 SR-83 Santa Cruz County	128	128	0	128	0	162	0	0	0
888 US 191 to Safford	2,728	2,511	217	2,728	0	2,967	0	217	0
893 Central Av to Graham Cnty	120	120	0	120	0	120	0	0	0
988 I-10 New Mexico	15,052	9,765	5,287	5,978	9,074	7,149	2,616	3,501	1,786
997 Naco POE	2,771	2,652	119	2,551	220	2,562	90	113	6
1001 Douglas POE	12,661	12,026	635	9,254	3,407	10,508	1,518	612	23
1011 To Ft Grant State Prison	239	239	0	239	0	286	0	0	0

Table 10: 2040 External Station Volumes

2040 External Station Auto and Truck Total Volumes and External-Local & External-Through Volumes									
				Total		Auto		Truck	
TAZ Description	Total	Auto	Truck	Local	Through	Local	Through	Local	Through
876 I-10 Tucson	62,416	50,561	11,855	40,239	22,177	43,912	6,649	8,030	2,830
878 SR-82 Santa Cruz Cnty	2,589	2,356	232	2,589	0	2,356	0	232	0
879 SR-83 Santa Cruz County	191	191	0	191	0	191	0	0	0
888 US 191 to Safford	3,600	3,313	287	3,600	0	3,313	0	287	0
893 Central Av to Graham Cnty	161	161	0	161	0	161	0	0	0
988 I-10 New Mexico	20,513	13,334	7,179	8,147	12,366	9,171	4,163	4,704	2,810
997 Naco POE	3,253	3,114	140	2,995	258	2,969	145	124	10
1001 Douglas POE	14,863	14,121	743	10,864	3,999	11,457	2,664	452	30
1011 To Ft Grant State Prison	322	322	0	322	0	322	0	0	0

Growth rates for most of the external stations were based on ADOT traffic log AADT projections. The two exceptions are the I-10 external stations. Their growth was expected to be higher based on recent development, especially the western station at the Cochise County/ Pima County border. For these stations, the higher growth rates from the I-10 reliever study of 2.46% at the western station and 1.56% at the eastern station were used.

Base Year 2007 Traffic Assignment and Validation

Following the guidelines of the *Model Validation and Reasonableness Checking Manual*, it is generally accepted that "…there are no absolute measures or thresholds that can be achieved to declare a travel model or its components 'validated'. The level of accuracy expected of a model is somewhat subjective, and ultimately depends on the time and resources available… The reliability of a model validation effort is always constrained by the quality and quantity of validation data available." The manual notes varying confidence levels for various model input data and output parameters, as shown in Table 11. The overall point of the table is that there is some level of uncertainty in model input parameters. As a result, the general practice is to be wary of over-validating a model by too rigorous adjustments to match specified criteria. It is generally preferable to have correct algorithms and behavioral trends that can be used with confidence to predict trends in future behavior; instead of mangling the model to match validation criteria which themselves have a range of error.

Table 11: Estimated Accuracy of Model Parameters

Estimate Accuracy of Model Parameters		
Parameter	Magnitude	Range
Zonal Generation	2,000	± 50%
Minor Link	5,000	± 55%
Average Link	20,000	± 27%
Major Link	50,000	± 17%

With that understanding, the target error ranges for an urban model validation is noted in the manual as shown in Table 12. It is generally accepted that lower-volume facilities are validated to lower standards. There are two reasons for this. First, following the concepts of Table 11, there is usually less confidence in the input data for lower-volume facilities, so there should be correspondingly less strict standards for their modeled outputs. Second, higher-volume facilities in a model draw their trips from a larger geographic range of zones and of network paths. This makes them more responsive to global model parameter adjustments, so that their trips may be modified without violating the validity of the modeling of overall traveler behavior.

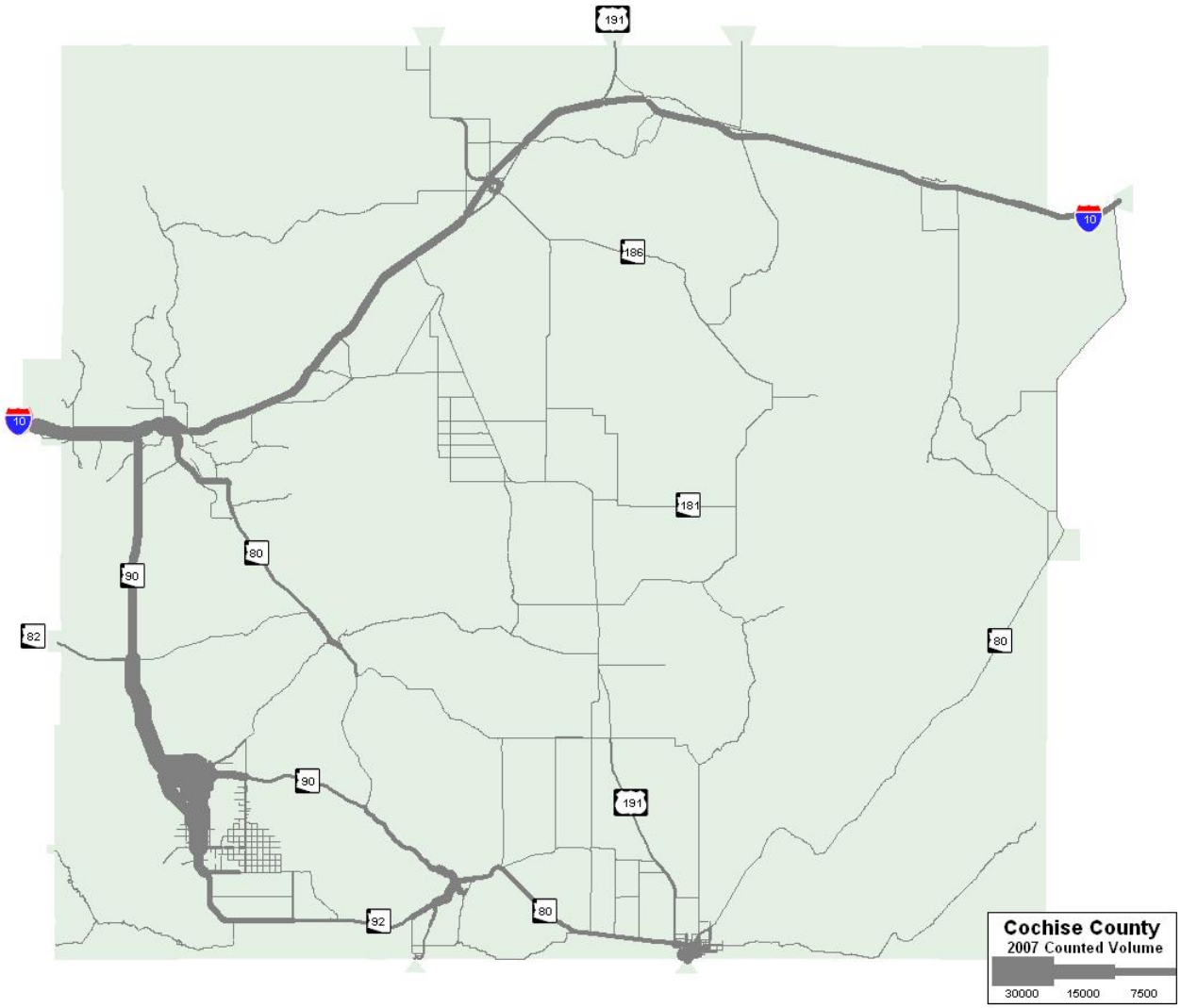
Table 12: Model Validation Targets

FHWA Validation Targets	
Facility Type	Target
Collector	± 25%
Minor Arterial	± 15%
Major Arterial	± 10%
Freeway	± 7%

This brings up a further point in a model validation. That these accepted ranges are for urban models with similar travel patterns and parameters within the geographic area. Cochise County is a larger geographic area with rural zones and a mix of urbanized areas ranging from isolated groups of houses like Paradise and Portal, to small clusters like Sumizona and St. David, to small cities like Benson and Bisbee, to full-scale cities like Sierra Vista and its surrounding suburbs. With the greater variability of the study area, there is a corresponding impact on the potential accuracy of the model.

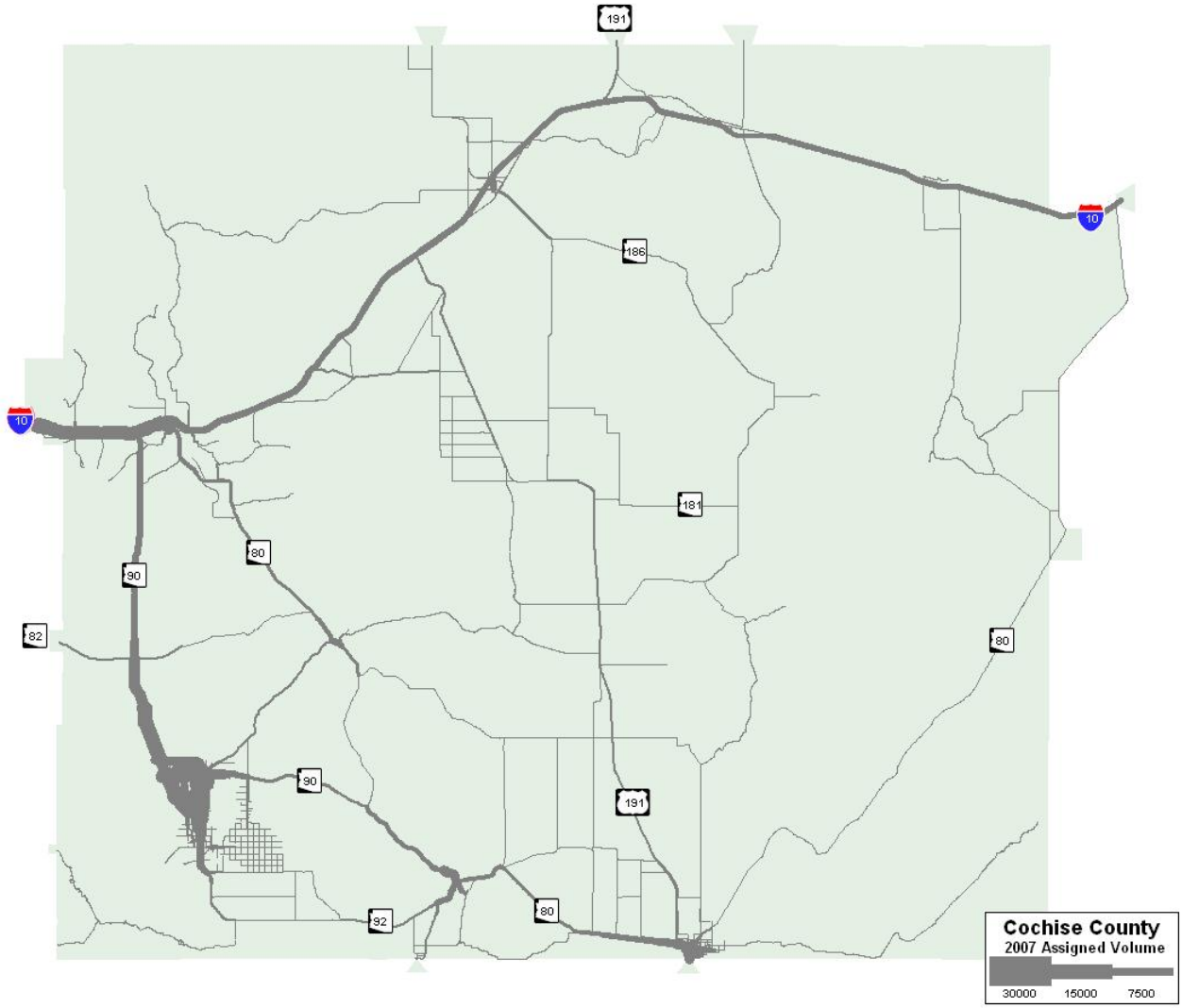
The overall flow of year 2007 counted traffic for Cochise County is shown in Figure 16. Through traffic on I-10 is evident. The county shows its strongest volumes on I-10 from the Cochise/Pima border to Benson and down Highway 90 to Sierra Vista. Traffic in the southern part of the county in the vicinity of Douglas and Bisbee is also strong.

Figure 16: 2007 Counted Volume Flows



In comparison, the flows of traffic from the Cochise County and City of Sierra Vista model are shown in Figure 17. The model has successfully generated the same overall patterns of traffic as are recorded in the 2007 ground traffic counts. This is only one measure, but it shows that the general operation of the model is correct.

Figure 17: 2007 Modeled Volume Flows



VMT by Area Type

Three area types were defined for Cochise County. Totaling the Vehicle Miles Travelled (VMT) for all the links within each area type provides a measure of the model's fit across various geographic areas. Area types are shown in Figure 3. Statistics for the total counted VMT, total modeled VMT, and their match for each Area Type is shown in Table 13.

Table 13: VMT Match by Area Type

2007 Model Results by Area Type			
	Area Type 1	Area Type 2	Area Type 3
Counted VMT	568,562	473,374	2,550,598
Assigned VMT	496,685	448,291	2,694,789
Ratio	0.87	0.95	1.06

Area Type 1 focuses on Sierra Vista, Bisbee, and Douglas. It covers slightly less than 1% of the total land area and 4.3% of its roadway mileage. The mean value for its match for individual links is 0.97, with a standard deviation of 0.57. The overall match is 0.87.

Area Type 2 has almost 2.1% of the county's area and 13.2% of its roadway mileage. Its model matches are 0.95 overall, with a mean match per link of 0.86 and a standard deviation of 0.82.

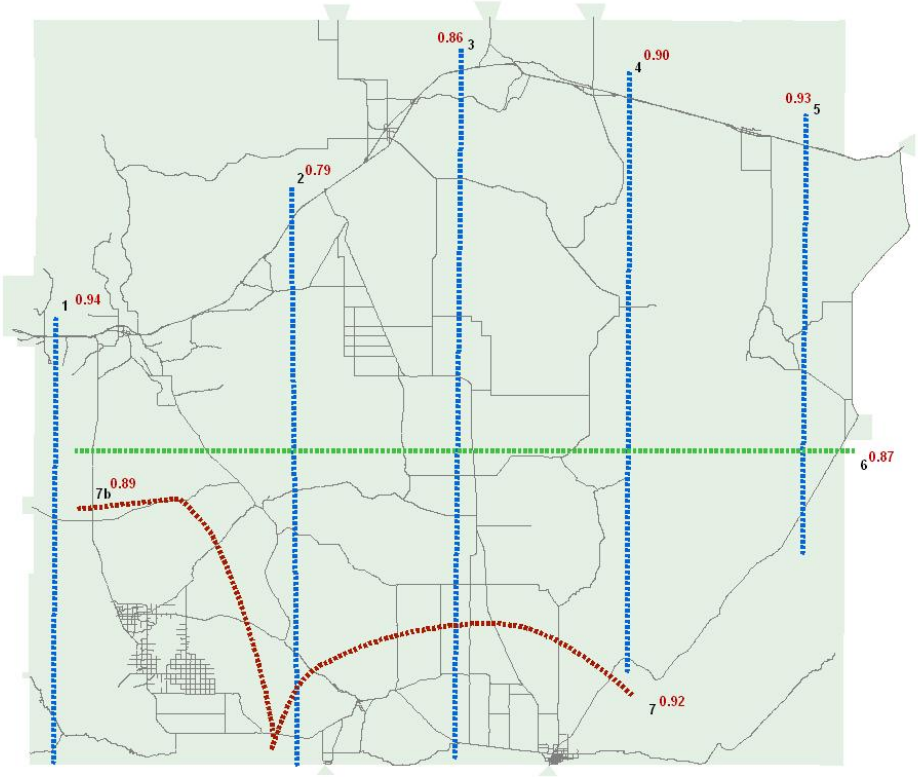
Area Type 3 constitutes 96.4% of the area of the county and 82.5% of its roadway mileage. The match of modeled VMT to counted VMT for individual links averaged 1.22, with a standard deviation of 1.30. Total modeled VMT to counted VMT is 1.06.

VMT by Screenlines and Cutlines

While the overall statistics for the model show a reasonably tight validation, the results of screenline and cutline analyses examine the validation in more detail. Screenlines and cutlines are collections of links used to aggregate the comparisons of modeled results to counts. Screenlines are typically defined as large lines cutting across significant travel movements in a study area. They present the big picture of the model. Cutlines are typically smaller, used to check the validation for smaller and more specific areas.

For the Cochise County and City of Sierra Vista model, eight screenlines were defined, as shown in Figure 18. Five screenlines capture east-west trips, one was defined to capture north-south movements through the middle of the county, and two screenlines curve around the Sierra Vista and the Bisbee-Douglas areas.

Figure 18: Screenlines and Cutlines



The higher-level view of the validation represented by the screenlines in Table 14 show the reasonableness of the validation. The overall modeled-to-count ratio is an average of averages, and so is not a rigorously valid statistic, but it is useful for comparison.

Table 14: Screenline Results

2007 Model Results by Screenline				
Screenline	Observations	Counted	Modeled	Ratio
1	4	69,351	65,087	0.94
2	6	182,362	144,540	0.79
3	7	146,681	126,117	0.86
4	4	151,730	135,927	0.90
5	5	113,044	105,368	0.93
6	4	62,428	54,442	0.87
7	6	38,022	34,882	0.92
7b	5	43,288	38,442	0.89
Totals	41	806,906	704,805	0.89

Complementing the screenlines, 42 smaller cutlines were defined throughout the county, with focus on Douglas and Sierra Vista. The overall statistic for the 140 observations is again an average of averages, but its value of 0.93 is generally reasonable and is comparable to the 0.89 average for the screenlines. However, a look at the individual cutlines shows some with much less accurate matches. Some of this is reasonable. For example, cutline 23 has 7 observations, yet the total counted VMT is less than 2,000. These are low-volume roads with lower expected accuracy. Table 16 aggregates cutline matches by counted VMT ranges, and again shows reasonable matches in the aggregate values of the larger model.

Table 16: Cutline Results by VMT Range

2007 Model Results by Cutline Range				
Range	Observations	Counted	Modeled	Ratio
50,000 - 100,000	11	376,618	312,093	0.82
25,000 - 50,000	28	276,937	236,123	0.85
10,000 - 25,000	30	116,451	96,729	0.85
5,000 - 10,000	18	40,977	46,195	1.11
Less than 5,000	53	41,445	40,800	0.98

The overall conclusion is clear that the validation is less precise in detail than it is in the larger picture.

Table 15: Cutline Results

2007 Model Results by Cutline				
Cutline	Observations	Counted	Modeled	Ratio
8	3	7,036	11,141	1.58
9	2	2,341	3,464	1.48
10	3	4,848	8,060	1.66
11	2	2,950	4,767	1.62
12	2	6,765	14,527	2.15
13	3	6,877	5,436	0.79
14	2	5,344	3,621	0.68
15	2	5,836	3,719	0.64
16	3	13,480	13,722	1.02
17	3	33,635	28,683	0.85
18	2	12,409	15,994	1.29
19	2	25,301	22,019	0.87
20	3	18,794	13,760	0.73
21	2	10,204	5,643	0.55
22	4	1,285	1,056	0.82
23	7	1,897	1,433	0.76
24	6	3,738	2,110	0.56
25	6	3,363	1,743	0.52
26	6	2,380	1,977	0.83
27	4	4,410	3,088	0.70
28	5	12,182	11,756	0.97
29	6	9,119	7,751	0.85
30	3	3,077	2,494	0.81
31	6	31,084	21,710	0.70
32	3	10,383	8,207	0.79
33	3	3,766	3,171	0.84
34	3	2,195	1,697	0.77
35	6	31,904	23,411	0.73
36	2	1,706	2,428	1.42
37	2	26,405	26,469	1.00
38	3	37,738	34,766	0.92
39	2	97,395	85,331	0.88
40	2	80,087	67,831	0.85
41	3	49,322	42,004	0.85
42	3	58,317	47,679	0.82
43	2	86,841	70,291	0.81
44	2	53,978	40,960	0.76
45	3	41,548	37,062	0.89
46	2	3,489	3,310	0.95
47	5	16,682	6,710	0.40
48	5	12,058	7,020	0.58
49	2	10,259	13,916	1.36
Totals	140	852428	731940	0.93

VMT by Functional Class

Aggregating model results by functional class provides another view of the validation and a diagnostic of the sources of the revealed imprecision. Table 17 shows the assigned VMT to counted VMT ratios and average volumes for five functional classes. (Note: Figure 4 shows the defined functional classes). It can be seen that the higher-volume facilities validated reasonably well. The obvious outlier is the minor collector functional class, which includes unpaved roads and very low volume roads. However, the statistics also show that the Minor Collector functional class accounts for less than 2% of the total counted VMT.

Table 17: Model Results by Functional Class

2007 Model Results by Functional Class					
	Interstate	Principal Arterial	Minor Arterial	Major Collector	Minor Collector
Observations	87	199	386	929	716
% of Total Mileage	12.9	6.0	18.3	18.4	44.5
% of Total VMT	43.3	25.5	18.5	11.1	1.6
Avg Volume	8,930	11,524	5,568	2,414	971
Counted VMT	1,554,745	916,830	663,645	399,372	57,055
Assigned VMT	1,470,640	761,854	649,512	457,866	282,251
Ratio	0.95	0.83	0.98	1.15	4.95

VMT by Volume Range

A final aggregate view of the validation in Table 18 shows the relative mileage, VMT, and match of the model by volume class. The lower match for the two categories of 20,000 – 25,000 and 25,000 – 30,000 are principally due to the functional class 2 roadways (primarily Highways 80, 90, and 92, Buffalo Soldier, and Fry).

Table 18: Model Results by Counted Volume Range

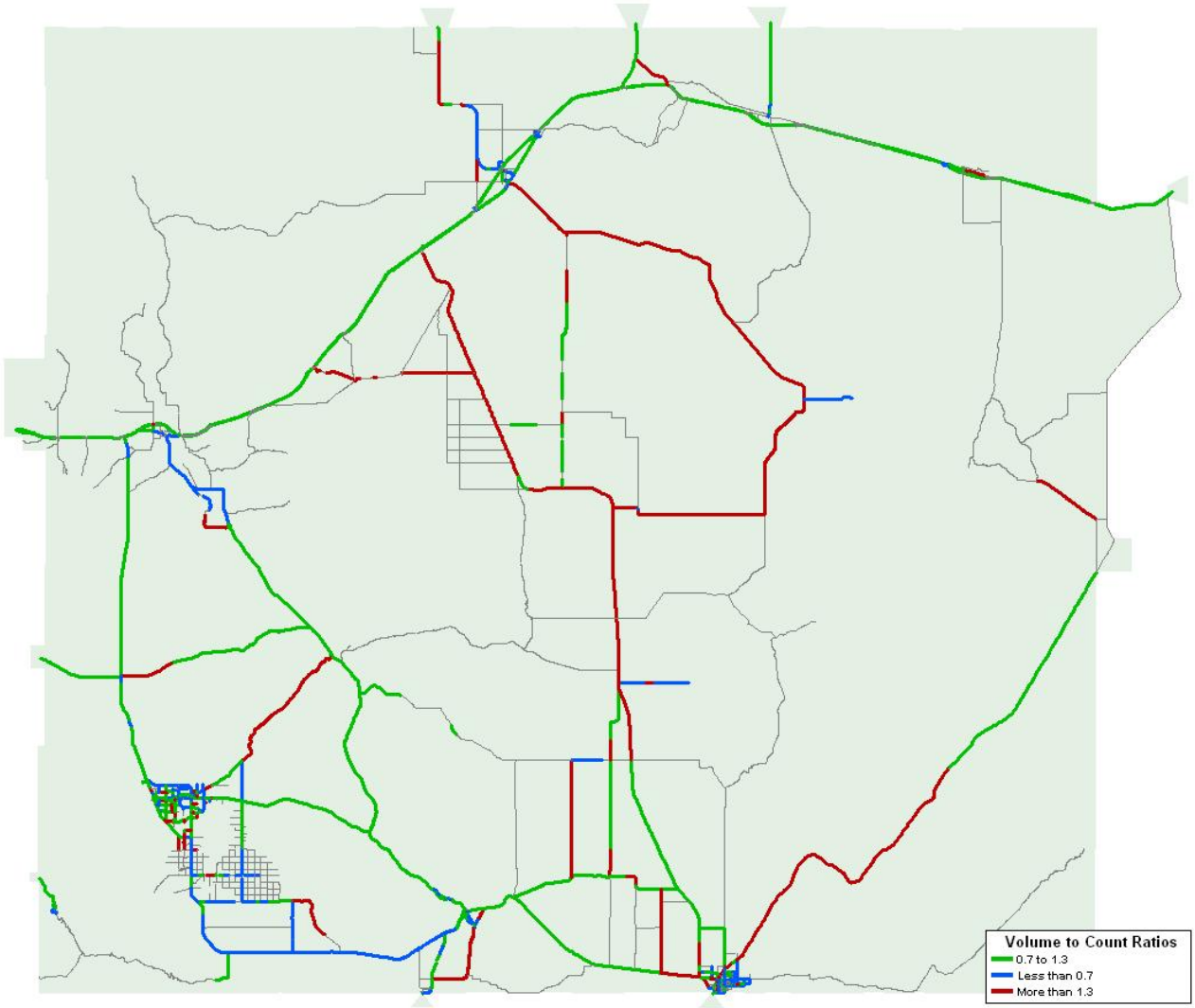
Results by Volume Range						
	0 - 5,000	5,000 - 10,000	10,000 - 15,000	15,000 - 20,000	20,000 - 25,000	25,000 - 30,000
Observations	803	262	59	31	32	15
% of Total Mileage	63.6	30.1	2.4	2.9	0.6	0.3
% of Total VMT	23.7	52.3	7.4	11.3	3.2	2.1
Counted VMT	850,632	1,879,394	265,023	407,302	115,416	74,767
Assigned VMT	893,316	1,548,953	235,348	327,356	78,482	51,102
Ratio	1.05	0.82	0.89	0.80	0.68	0.68

Assigned Volume to Count Ratio by Link

As a final graphic to show the model validation, Figure 19 shows the Volume to Count (V/C) ratios in three categories to clearly display the geographic distribution of the model's matches.

Overall, I-10 validated well. The model was somewhat high on the lower-volume roads in the center of the county, between Elfrida and I-10. The relatively high volume functional class 2 roads in the south and west of the county were generally modeled low. Local-level links within Sierra Vista and Douglas have mixed results.

Figure 19: Volume to Count Ratios



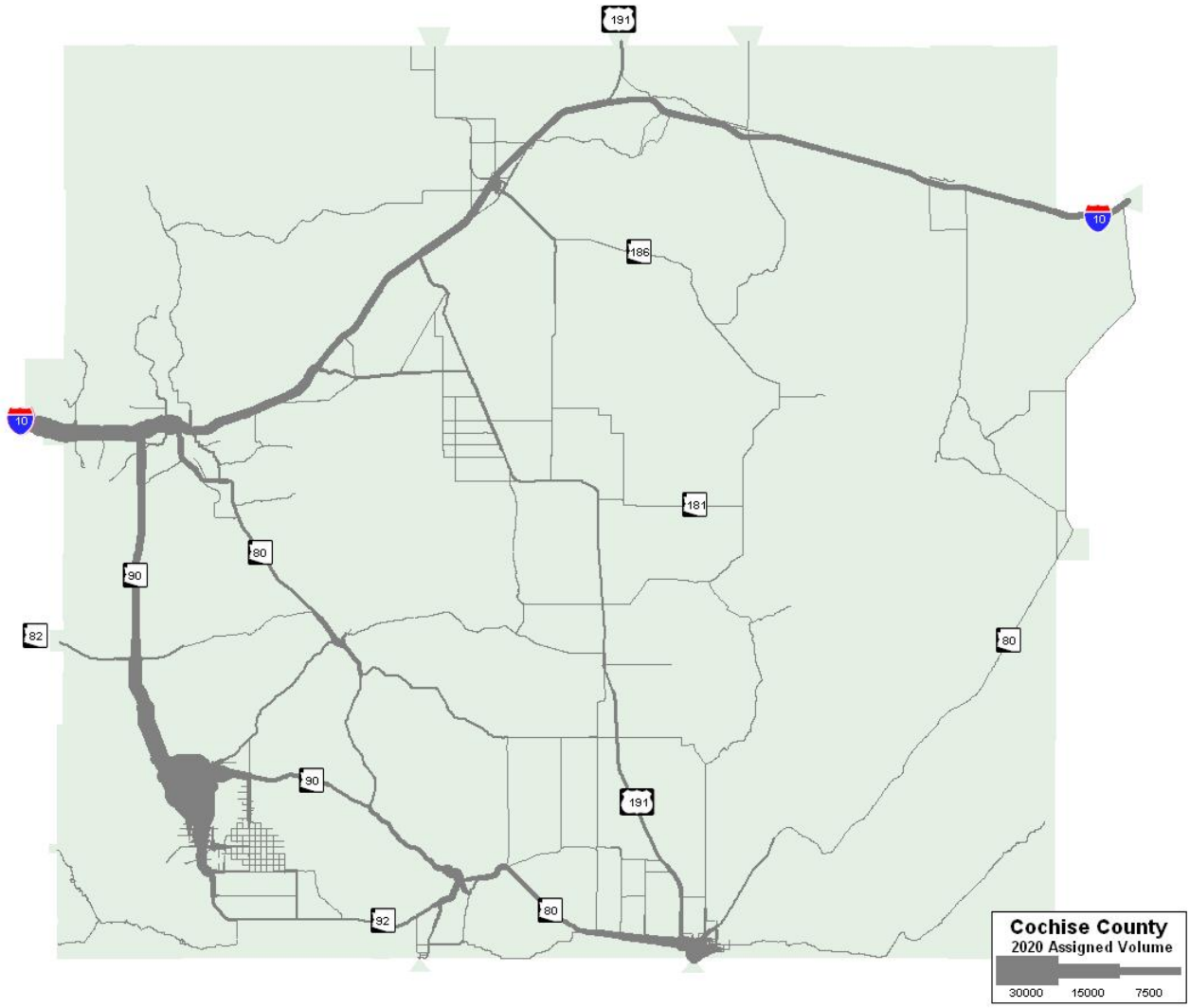
Overall, the 2007 model validation is not exemplary, but is generally reasonable for a full-county mixed urban and rural model given the time and the levels of confidence in the input demographics and counts. Any model could of course benefit from additional work, and this model is no exception. If additional time and resources became available, the model validation would benefit most from focusing on improving the following, in descending order of importance and impact:

- Highways 80 and 90 south of I-10
- Highways 80 and 92 between Douglas and Sierra Vista
- Localized roads in Sierra Vista
- Localized roads in Douglas
- Low-volume roads between Douglas and I-10
- Low-volume minor collectors

2020 Model Results

The overall flow of year 2020 modeled traffic for Cochise County is shown in Figure 20. Compared to the 2007 modeled flow shown in Figure 17, the same overall patterns of traffic as are recorded in the 2007 ground counts. This general cross-check shows that the overall operation of the 2020 forecast model is reasonable.

Figure 20: 2020 Modeled Volume Flows



2020 VMT by Area Type

The modeled VMT for 2020 is shown in Table 19, with a comparison made to the modeled 2007 data. The aggregate growth in VMT is greater in the more urbanized Area Types 1 and 2, as one would expect. The compound annual growth in VMT is 2.7% for Area Type 1, 2.6% for Area Type 2, and 1.8% for Area Type 3.

Table 19: 2020 VMT by Area Type

2020 Model Results by Area Type			
	Area Type 1	Area Type 2	Area Type 3
2007 Assigned VMT	496,685	448,291	2,694,789
2020 Assigned VMT	700,523	627,007	3,397,416
Ratio	1.41	1.40	1.26

2020 VMT by Functional Class

The 2020 Modeled VMT results by Functional Class are shown in Table 20. The compound annual growth rate in VMT ranges from 1.3% for Interstates to 3.0% for Minor Collectors. It is interesting to compare this trend of percent increase (not volume increase) with Figure 1, which shows HPMS daily VMT trends. In that figure, off-system roads are seen to have a stronger trend of increase than on-system. The match of the model to the HPMS trends indicate that the increase in input demographics for the model are reasonable.

Table 20: 2020 VMT by Functional Class

2020 Model Results by Functional Class					
	Interstate	Principal Arterial	Minor Arterial	Major Collecto	Minor Collector
Observations	87	199	386	929	716
% of Total Mileage	12.9	6.0	18.3	18.4	44.5
% of Total VMT	37.0	20.6	20.0	13.5	8.9
Avg Volume	9,122	12,976	6,127	2,362	830
2007 Assigned VMT	1,470,640	761,854	649,512	457,866	282,251
2020 Assigned VMT	1,739,405	967,668	941,916	632,274	416,981
Ratio	1.18	1.27	1.45	1.38	1.48

2020 VMT by Volume Range

Table 21 shows the 2020 modeled results by volume range, compared with the 2007 modeled results. As with the previous tables, the 2020 data shows reasonable increases. Similar to the higher off-system growth trend shown in Tables 19 and 20, Table 21 shows strong growth in the lower volume ranges. However, unlike the previous tables, the growth across volume ranges is more even across categories.

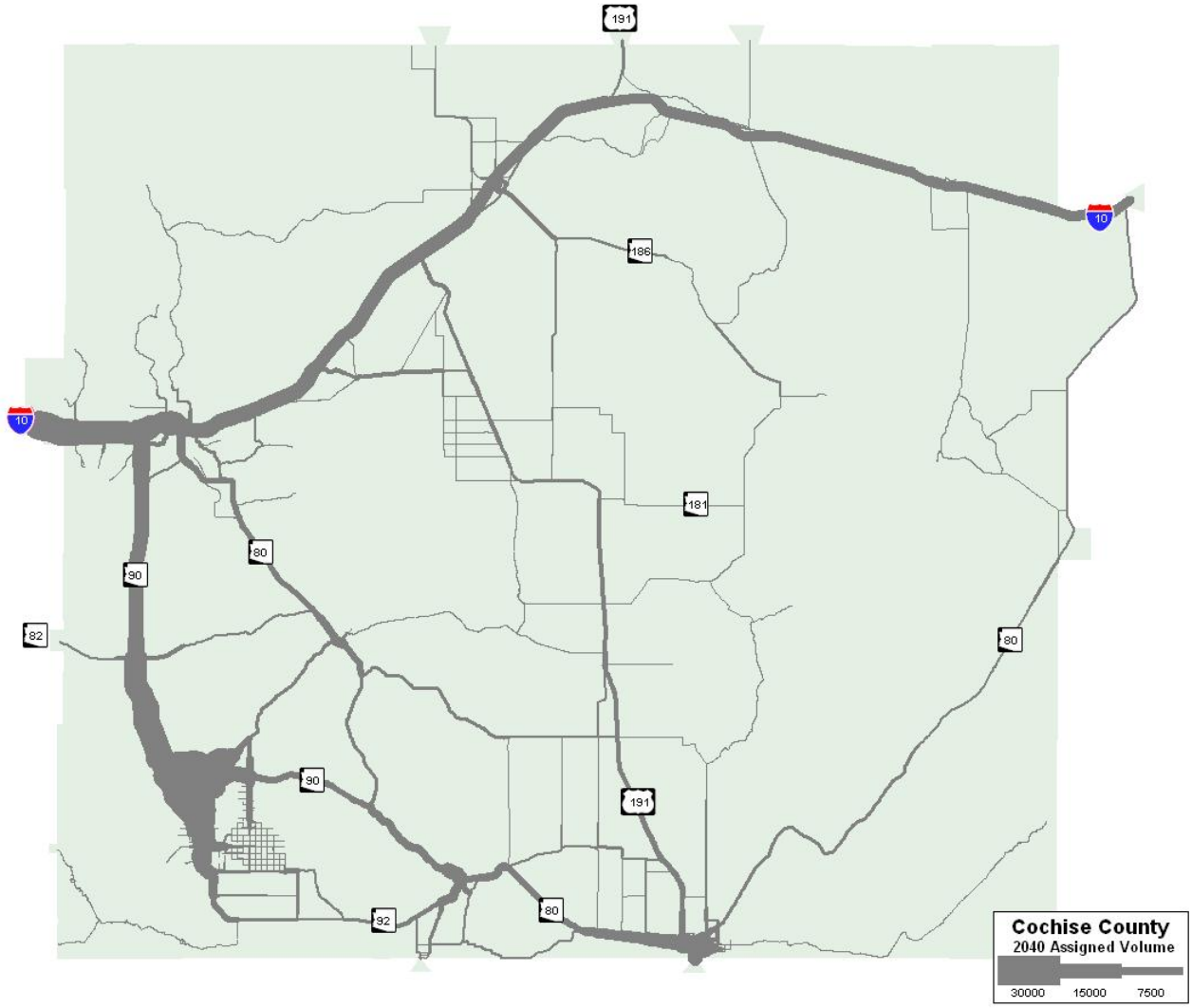
Table 21: 2020 VMT by Volume Range

2020 Results by Volume Range						
	0 - 5,000	5,000 - 10,000	10,000 - 15,000	15,000 - 20,000	20,000 - 25,000	25,000 - 30,000
Observations	803	262	59	31	62	15
% of Total Mileage	63.6	30.1	2.4	2.9	0.6	0.3
% of Total VMT	30.7	47.0	7.7	10.0	2.8	1.7
2007 Assigned VMT	893,316	1,548,953	235,348	327,356	78,482	51,102
2020 Assigned VMT	1,227,607	1,880,356	309,601	401,140	113,978	69,339
Ratio	1.37	1.21	1.32	1.23	1.45	1.36

2040 Model Results

The overall flow of year 2040 modeled traffic for Cochise County, shown in Figure 21, has similar patterns to the 2007 and 2020 models. The link volumes, however, are noticeably greater. Strong growth at the Cochise/Pima county external station on I-10 is a significant contributor to the increased volumes. This general cross-check shows that the general operation of the 2040 model is reasonable.

Figure 21: 2040 Modeled Volume Flows



2040 VMT by Area Type

Modeled results for 2040 are compared to the 2020 modeled results in Table 22. The trend of higher growth rates in the less urbanized areas continues, although Area Type 2 exhibits a relatively higher rate.

Table 22: 2040 VMT by Area Type

2040 Model Results by Area Type			
	Area Type 1	Area Type 2	Area Type 3
2020 Assigned VMT	700,523	627,007	3,397,416
2040 Assigned VMT	1,011,470	948,421	5,607,973
Ratio	1.44	1.51	1.65

2040 VMT by Functional Class

Data for 2040 modeled VMT by functional class is shown in Table 23. Trends are reasonable, with the compound annual growth rate for the 20-year period ranging from 1.9% for Major Collectors to 3.2% for Minor Collectors. By the year 2040, VMT on Interstate 10 is modeled to comprise almost 38% of the total VMT in Cochise County.

Table 23: 2040 VMT by Functional Class

2040 Model Results by Functional Class					
	Interstate	Principal Arterial	Minor Arterial	Major Collector	Minor Collector
Observations	87	199	386	929	716
% of Total Mileage	12.9	6.0	18.3	18.4	44.5
% of Total VMT	37.9	20.1	19.3	12.2	10.4
Avg Volume	14,566	19,025	8,716	3,298	1,397
2020 Assigned VMT	1,739,405	967,668	941,916	632,274	416,981
2040 Assigned VMT	2,854,067	1,515,701	1,453,322	920,181	784,921
Ratio	1.64	1.57	1.54	1.46	1.88

VMT by Volume Range

Fairly even growth, with slightly stronger growth in the lower volume categories, is a feature of the 2040 modeled VMT by volume ranges compared to the same categories for the 2020 model. Again, the trends and relationships compared to 2020 seem reasonable.

Table 24: 2040 VMT by Volume Range

2040 Results by Volume Range						
	0 - 5,000	5,000 - 10,000	10,000 - 15,000	15,000 - 20,000	20,000 - 25,000	25,000 - 30,000
Observations	803	262	59	31	62	15
% of Total Mileage	63.6	30.1	2.4	2.9	0.6	0.3
% of Total VMT	30.2	48.8	7.4	9.6	2.5	1.5
2020 Assigned VMT	1,227,607	1,880,356	309,601	401,140	113,978	69,339
2040 Assigned VMT	1,907,762	3,084,615	468,423	610,026	156,783	94,742
Ratio	1.55	1.64	1.51	1.52	1.38	1.37

End of Model Documentation Report