DEPLOYMENT ANALYSIS UNDER PUBLIC SCRUTINY

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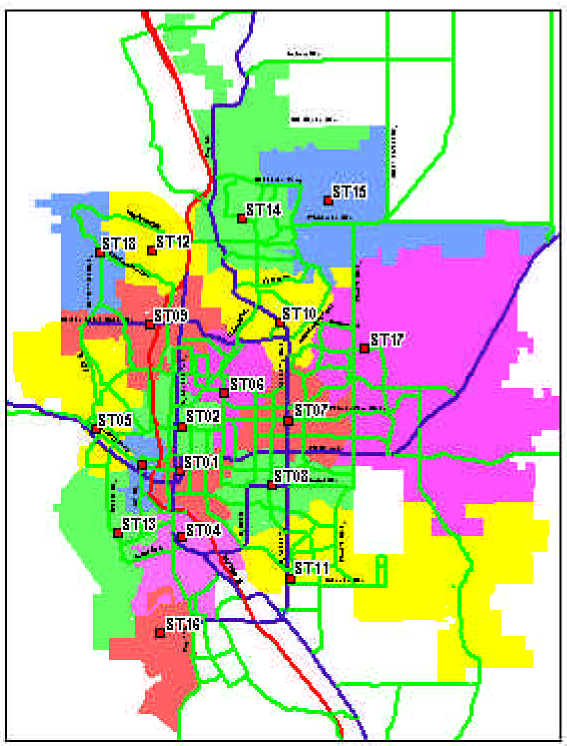
1.0 Background

Rapid growth and tight budgets have driven the interest of the Colorado Springs Fire Department in deployment analysis. In 1960, the population of Colorado Springs was 70,194, living in an area of 16.5 square miles. Today, more than 374,000 people live in approximately 120 square miles of the city's total land area of 186 square miles. In a little over forty years, Colorado Springs has increased 433% in population and 1027% in land area. In the same time period it has gone from five fire stations to eighteen with 378 uniformed firefighters and 54 civilian employees.

The old stations located downtown or in areas adjacent to downtown are close together, but the newer stations that have been built as the city has grown have been located farther apart. While the average number of square miles covered by a station is 10.3, actual still districts range in size from 2.6 square miles to 45.3 square miles. This has resulted in significant inequities in service.

Figure 1.1 Colorado Springs Fire Station Locations



Response to fires is only one part of the service equity issue. Over the years, the Colorado Springs Fire Department has taken on additional missions, including BLS and ALS medical response (but not transport which is provided by a private ambulance company), hazardous materials response, and a variety of forms of special rescue.

Fires make up only 3% of the incidents to which the CSFD responds. Structure fires account for less than 1%. Medical incidents, on the other hand, constitute 70%. Hazardous materials incidents and rescue operations represent another 2.3 percent of the emergency incidents. The remainder of the incidents are malicious and non-malicious false alarms, service calls, and good intent calls.

Over 44,000 residential addresses lie in a wildland/urban interface zone characterized by steep slopes and thick vegetation. While the fire department recognizes that there is a risk of a catastrophic fire, much of the interest of citizens in fire department resource levels and deployment is focused on medical response.

2.0 Public Controversy over Fire Department Deployment

In 1992, voters passed amendments to the Colorado Springs City Charter and the Colorado State Constitution limiting both expenditures and tax revenue. Under the state amendment, which is the more restrictive of the two, the following provisions apply.

- Voter approval is required in advance for any new tax, tax rate increase, mill levy increase, valuation for assessment ratio increase, extension of an expiring tax, or a tax policy change that increases net tax revenue. There is a limited exception for emergencies.
- No new or increased property transfer tax can be imposed and no new state real property tax or local district income tax can be imposed.
- The maximum annual percentage change in each local district's fiscal year spending (including increases to reserves) equals inflation in the prior year plus local growth, defined as "the net percentage change in actual value of all real property in a district from construction of taxable real property, minus destruction of similar improvements, and additions to, minus deletions from, taxable real property."[1]
- Excess revenue must be refunded to the taxpayers.

At the same time that the local and state amendments were passed, local voters chose to phase out a city sales tax of ½ cent on the dollar that had been dedicated to capital improvements. In the years following the passage of the amendments, the city experienced significant growth. Funds from the general budget were diverted to pay for the most critical capital improvements, imposing significant budgetary constraints on operating budgets.

In the 1990s, the city grew by 80,460 residents. By 1997, Colorado Springs had 17 engines and 4 trucks operating from 17 fire stations, a dedicated hazardous materials team, and a 3-person medical squad to enhance medical coverage along a busy corridor. Coverage was good in the core areas of the city, but due to the spacing of stations, it was barely adequate in outlying areas. Aerial truck coverage presented a special challenge. Three of the department's four aerial trucks were located south of the geographic center of the city, but rapid growth was occurring to the north and east. Furthermore, in the northwest section of the city there were multistory hotels and other large commercial structures located far from the nearest aerial truck—as much as twelve to fifteen minutes in travel time. To address this deficiency, funding for an additional truck company was requested by the fire department during the 1997 budget process, but this request was ultimately denied.

After considering a number of alternatives, the fire department decided that the best option available for staffing a truck company in the northwest was to close one of the stations in the core of the city where there was good coverage from adjacent stations. Once the proposal was made public, there was protest from the residents in the area surrounding the station to be closed. A number of accusations were leveled against the fire department, from not caring about the health and welfare of residents in the area to conducting inaccurate and distorted deployment analysis.

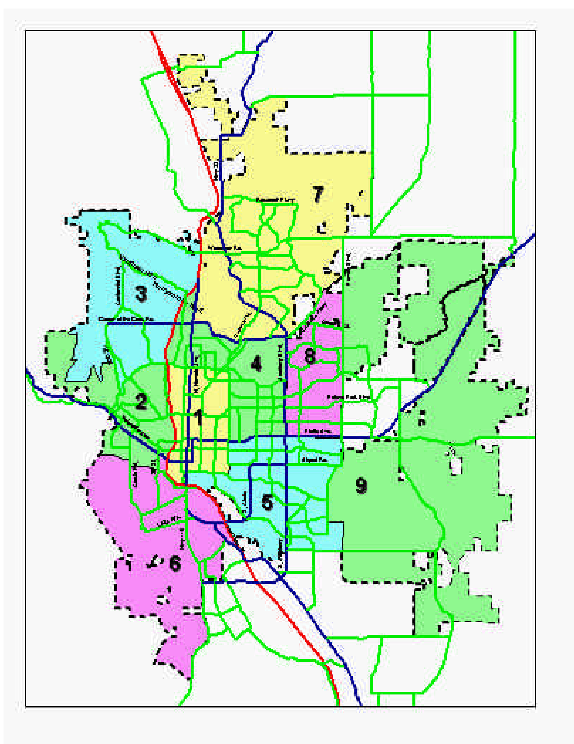
Three significant events occurred in April 1998. The city council appropriated funds to begin staffing a new truck company in late fall. At the same time, hoping that expert counsel would help resolve the deployment controversy, it approved funding for a comprehensive study of the fire department. Shortly after that, the council approved as interim standards of coverage the response levels that the fire department was achieving on a city-wide basis. However, the interim standards specified that the response objectives were to be achieved in each of the nine geographic regions used in the city's comprehensive plan (Figure 2.1).

> *Fire Department response times for the first arriving fire company, defined as the time elapsed from when the call is received at the Communications Center until the first unit arrives on scene, shall be 8 minutes or less for 90% of the incidents annually in each of the 9 Planning Evaluation Zones.*
>
> *Fire Department response times for the minimum effective fire fighting force, defined as the time elapsed from when the call is received at the Communications Center until two engines and a ladder truck have arrived on the scene, shall be 12 minutes or less for 90% of the incidents involving such an effective force annually in each of the 9 Planning Evaluation Zones.*

In January of 1999, TriData Corporation completed its comprehensive study of the fire department and presented the final report to the Colorado Springs City Council. This report affirmed that the deployment analysis conducted by the Colorado Springs Fire Department was sound. The report recommended the addition of a truck company in the northwest while retaining all of the existing stations and fire companies. This recommendation was identical to the original fire department proposal submitted during the 1997 budget process.

Voters approved bonds for capital improvements in April of 1999. However, the bonds were to be repaid from the existing tax revenue stream. While the bonds provided funding for needed capital projects, including an eighteenth fire station, it made a long-term commitment to taking additional money from the revenue stream that funds operating budgets to pay for capital improvements. Thus, the financial situation remained bleak.

Figure 2-1. Planning Evaluation Zones



In August 1999, the city council adopted by resolution (not ordinance, which would have had the force of law) the interim standards of coverage as permanent standards, but inserted after the standard for first arrival the following statement:

> *The Fire Department will strive to achieve a goal of 6 minutes or less response time in 90% of incidents within 5 years.*

In subsequent discussions with the city council, this goal was clarified as applying to medical incidents only, to the arrival of a unit by either the fire department or the private ambulance company that transports (currently American Medical Response (AMR)), and to the city as a whole, not individual planning evaluation zones.

The public controversy that stemmed from the proposal to close a fire station contributed to the Fire Department's securing a fifth truck company. The discussions of fire service and inequities in coverage opened the door for the fire department to propose formal standards of coverage. The publicity surrounding the controversy may have assisted in garnering public approval for the bond issue that passed in 1999, which allowed the eighteenth station to be built. Furthermore, it may have helped gain support for a public safety sales tax that was approved by voters in November, 2001, that will fund the construction and staffing of a few additional stations and units.

3.0 The Colorado Springs Fire Department Simulation System

The initial budget request for an additional truck company in the northwest section of the city was supported by drive-time analysis. The resulting maps clearly indicated a deficiency in truck coverage in the northwest. However, the focus of citizen groups and city management was not on travel time to an emergency scene from fire stations; they were interested in emergency response times. Although drive-time analysis was initially useful, it was incapable of addressing many of the questions regarding actual response times within the city. Specifically, drive-time analysis has the following limitations.

- Drive-time analysis does not provide an adequate estimate of the distribution of travel times, only an estimate of the typical travel time. In order to model performance relative to standards based on a percentile benchmark, an estimate of the dispersion of travel times about the typical value is needed.
- Drive-time does not include dispatch and turnout time which are included within the city's standards of response coverage. While typical times for dispatching incidents and company turnout can be added to drive time estimates, this approach does not adequately model the typical variation in response time from all sources of variation.
- Drive-time analysis assumes that units are always available for calls. In Colorado Springs, the majority of our engine companies and squads are unavailable more than 10% of the time between 8 a.m. and midnight due to servicing previous calls and "overhead" activities, such as vehicle maintenance and training activities.

The adoption of the standards of response coverage created additional demands on the department's deployment analysis capabilities. Since drive-time analysis did not provide a suitable foundation for future deployment analysis efforts, the Colorado Springs Fire Department adopted a new approach based on computer simulation.

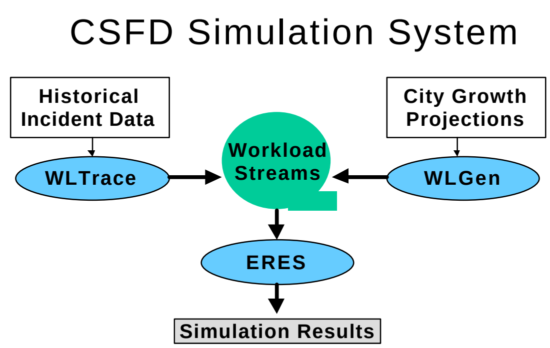
To meet the needs of future deployment analysis efforts, three critical design objectives were established for the simulation system: it had to model all aspects of fire department response in order to evaluate total response time and coverage; it had to be able to validate simulation results using historical incidents; and it had to be capable of projecting future fire service coverage by incorporating forecasts for growth. The overall system structure that was selected to fulfill these objectives is depicted in Figure 3.1.

The major application is the Emergency Response Evaluation Simulator (ERES). This computer application simulates emergency operations of the CSFD and, when desired, AMR. Although ERES provides the majority of the system's capabilities, it is dependent on other applications for input files containing workload streams. A workload stream is a time-ordered list of emergency incidents. These workload streams are used by ERES to drive the simulation of the fire department's emergency operations.

ERES simulates the response of emergency units to incidents based on the department's dispatching policies. The simulation software records the response time to individual incidents and maintains records of coverage levels by geographic area.

As noted in Figure 3.1, there are two distinct applications capable of producing workload streams. Workload Trace (WLTrace) produces a workload file from historical data. This provides the capability to simulate fire operations against the actual workload that occurred in prior years. The second application, Workload Generator (WLGen), produces synthetic workload streams based on typical workload characteristics and growth projections for the city. However, WLGen it not limited to the production of future workloads; it can also produce representative workloads for the current year and a limited number of prior years. One of the important properties of WLGen is its ability to produce multiple workload streams for the same year. Each of the workload streams produced by WLGen will be statistically similar, but each workload will have a different sequence of incidents. The time and location of structure fires, for example, will be different in each workload stream. This allows testing of deployment options under multiple workload scenarios.

Figure 3.1 CSFD Simulation System



3.1 ERES Inputs

The ERES application contains the majority of the simulation system's functionality and is the primary tool for performing deployment analysis. There are a number of configuration options available within this application. One of the most important options is the ability for the ERES user to select different workload streams. To setup a simulation run, the user selects one of the available workload streams produced by either WLGen or WLTrace. Each simulation run consists of simulating fire operations on a specified workload stream. A workload usually covers an entire year. However, to evaluate a specific year, ERES is usually run several times on multiple workload streams for the year to develop overall estimates. By performing several simulation runs on multiple workloads for a given year, point and interval coverage estimates are obtained. These provide an estimate of the average coverage achieved and the variation expected in each of the performance measures.

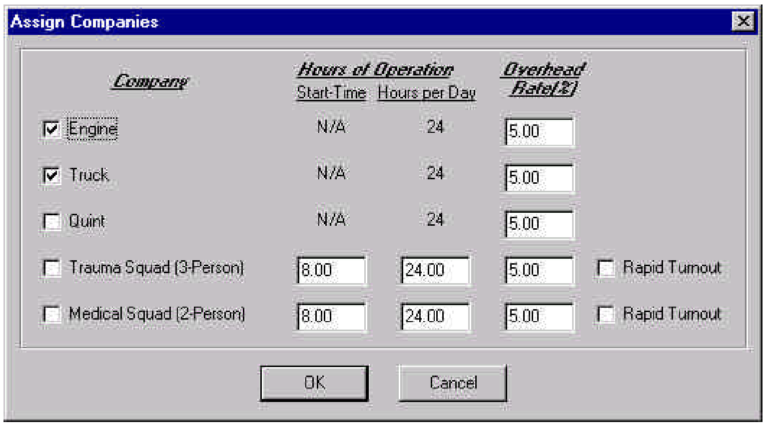
ERES also permits the user to configure the simulation according to the

- number and location of stations,
- equipment assigned to each station,
- hours of operations for special units,
- overhead (training, maintenance, administrative time) for each unit, and
- dispatching policy for each unit class.

The input screen for equipment options for a given station is shown in Figure 3.1.1. The ERES user determines the number and type of each unit at the station. Engines, trucks, and/or quints operate on a 24 X

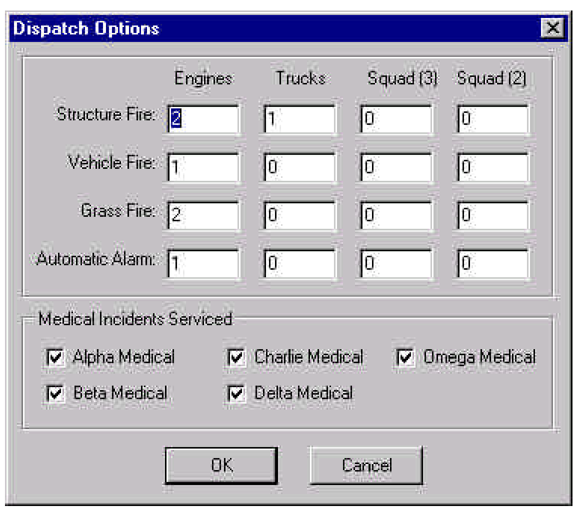
7 basis. Medical units may be in operation only a portion of the day, since they are used to supplement the basic coverage provided by fire apparatus. The overhead rate can be selected for individual units. This rate is used to indicate the amount of time the unit is out of service for training, equipment maintenance or repair, meetings, or other activities that take it out of service. In addition, there are two models for turnout time for medical units. The normal model is similar to other fire companies, while the rapid turnout model is similar to ambulances that are posted on the street. If the simulation includes units belonging to AMR, similar configuration choices are available.

Figure 3.1.1 ERES Station Equipment Options



Several dispatching options have been incorporated into ERES (Figure 3.1.2). These have been used to evaluate potential changes in fire department dispatching policy. For example, these options have been used to test the impact on fire service coverage of such options as not having the CSFD respond to low-priority medical calls and dispatching a complement of two engines and one truck to automatic alarms.

Figure 3.1.2 ERES Dispatching Options



In addition to the options shown previously, fire stations can be added or moved, as the user desires. To move a station, the user simply specifies new coordinates for the station. Adding a new station is also simple. The user specifies the coordinates of the new station and the equipment assigned to the station.

3.2 ERES Outputs

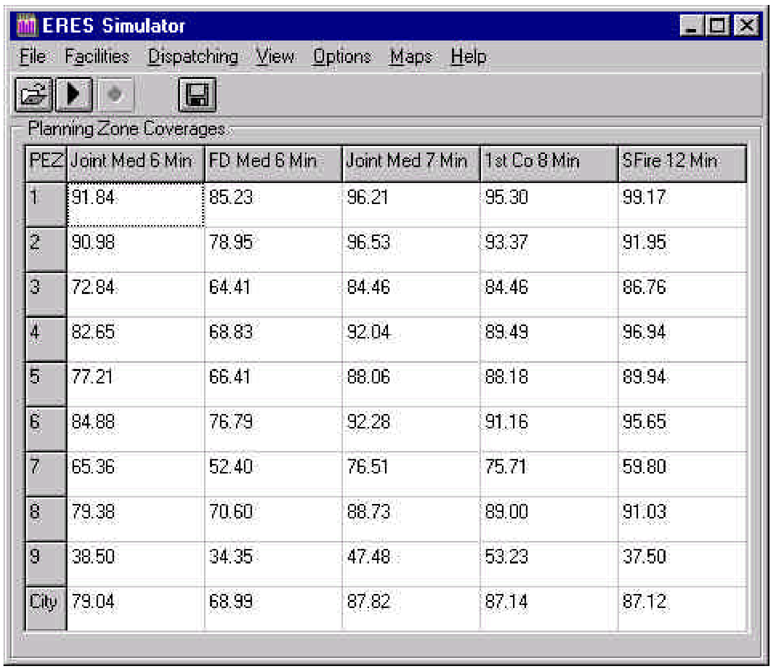
The primary output from a simulation run consists of five sets of coverage statistics. Coverage is reported on these five service measures for each planning evaluation zone (PEZ) and for the city as a whole. The five measures are:

- joint AMR/CSFD 6-minute medical coverage,
- CSFD 6-minute medical coverage,
- joint 7-minute medical coverage,
- first company 8-minute coverage for all emergency incidents, and
- 12-minute effective force coverage for all structure fires.

Figure 3.2.1 is an example of a display of coverage statistics produced by ERES. The numbers in the cells are the percentage coverage achieved. Thus, the number in the bottom right cell indicates that the effective force requirement for first response to a structure fire (two engines and a truck) was achieved within twelve minutes 87.12% of the time for this simulation run.

Each simulation run also produces statistics on the number of responses and utilization of each fire company and ambulance. Figure 3.2.2 is an example of an output screen for equipment responses. These numbers show how many responses were assigned to specific units during the simulation run. Figure 3.2.3 is an example of an output screen for equipment utilization. This shows that in this particular simulation run Engine 1 is busy and unavailable to respond to a new call 17.8% of the time between midnight and 1 a.m.

Figure 3.2.1 ERES Coverage Display



PEZ	Joint Med 6 Min	FD Med 6 Min	Joint Med 7 Min	1st Co 8 Min	SFire 12 Min
1	91.84	85.23	96.21	95.30	99.17
2	90.98	78.95	96.53	93.37	91.95
3	72.84	64.41	84.46	84.46	86.76
4	82.65	68.83	92.04	89.49	96.94
5	77.21	66.41	88.06	88.18	89.94
6	84.88	76.79	92.28	91.16	95.65
7	65.36	52.40	76.51	75.71	59.80
8	79.38	70.60	88.73	89.00	91.03
9	38.50	34.35	47.48	53.23	37.50
City	79.04	68.99	87.82	87.14	87.12

Figure 3.2.2 Response Display

Responses

Station	Engine	Truck	Quint	Squad(3)	Squad(2)
1	4184	1230			
2	2268				
3	2247				
4	2931	633			
5	1773				
6	2288				
7	2648			2359	
8	4872	1556			
9	2147	575			
10	2665	743			
11	2057			1535	
12	1317				
13	1000				
14	2058				

OK

Figure 3.2.3 Equipment Utilization Display

Utilization

Hour	Eng 1	Trk 1	Eng 2	Eng 3
0	17.80	4.93	8.90	8.14
1	15.82	3.69	8.38	7.25
2	13.37	3.95	6.65	6.10
3	9.96	2.17	5.81	6.08
4	8.47	2.23	4.23	3.50
5	7.17	1.66	3.09	3.92
6	8.47	2.68	4.41	4.13
7	12.15	2.40	6.88	6.36
8	15.57	2.83	9.21	8.51
9	21.61	5.21	10.30	10.98
10	19.41	6.25	10.60	10.17
11	22.20	8.14	11.55	13.12
12	25.57	6.90	13.33	12.00
13	24.51	6.70	13.49	13.26

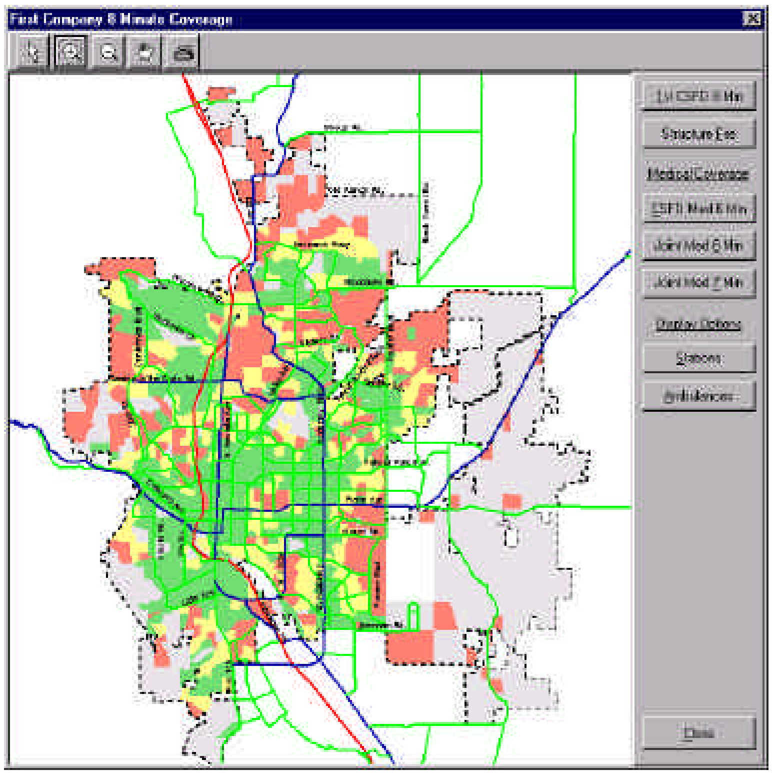
OK

Finally, ERES can produce coverage maps that indicate coverage levels throughout the city. Coverage maps can be displayed for each of the coverage statistics mentioned previously. ERES actually calculates coverage on small geographic regions called fire demand zones (FDZs) and coverage maps are derived from the FDZ coverage statistics. The FDZ coverage statistics can also be saved to a file for use with other applications.

An example of the maps available is shown in Figure 3.2.4. Areas in green indicate 90% or higher coverage, the yellow areas 80% to 89% coverage, and the red areas coverage of less than 80%. The areas in light grey are within the city limits but there were no incidents in these areas in this particular simulation run.

Any of the maps can be requested from the primary window in the simulator or the map can be changed from the geographic coverage display window as well by using the buttons on the right side of the window. Other options are to display the locations of fire stations and ambulance posting locations used in the simulation. Provisions exist for panning and zooming and for printing the maps.

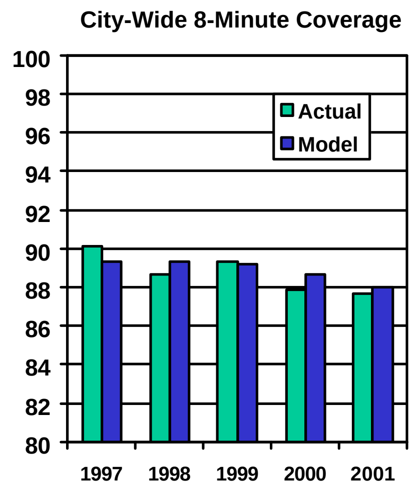
Figure 3.2.4 Geographic Coverage Display



3.3 Accuracy of ERES

Since ERES was developed to improve the accuracy of deployment analysis, an important question is *How accurate is ERES?* Figure 3.2.5 shows a graph comparing actual 8-minute first company response coverage for the past five years and the coverage estimated by ERES for these same years. The measured and simulated coverage is generally within one percent. Other measures based on smaller sample sizes, such as 12-minute structure fire coverage, produce acceptable results but with larger standard errors (and confidence intervals).

Figure 3.2.5 Comparison of Historical and Simulated Coverage



4.0 Summary and Conclusions

The ERES simulator has proven to be an excellent tool for projecting future needs based on growth and workload trends and projecting the impact of new development on fire service coverage. It is superior to drive-time analysis for determining the optimum locations of new stations and units since it incorporates information regarding unit availability. Also, ERES has proven indispensable for determining the appropriate time to open a new station or unit.

The ability to simulate fire operations has allowed the department to evaluate potential deployment policy changes relatively easily. In several cases, additional features were added to ERES to support these analysis projects. The functionality contained in this simulation system will continue to grow as additional questions are investigated and new options considered.

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[1] CO Const. Art X, §20(2)(g).

BIOGRAPHICAL SKETCHES

William Wallace is a Principal Analyst with the Colorado Springs Fire Department. He holds a B.S. in Mathematics for the University of Texas at Arlington and an M.S. in Mathematical Statistics from Southern Methodist University.

Nina Rikoski is the fire administration manager in Colorado Springs. She received a B. A. in philosophy from Beloit College and an M. A. in sociology from the University of Pennsylvania. Prior to working for the City of Colorado Springs she was engaged primarily in research in criminology and criminal justice. She first did work with fire service issues through Abt Associates, Inc., where she conducted research on arson investigation and prosecution for the U. S. Department of Justice and on the reporting of fire cause information for the U. S. Fire Administration, National Fire Data Center.

Brett Lacy is the fire marshal for the City of Colorado Springs. He holds a Bachelor's degree from Oklahoma State University and is a Professional Engineer and Certified Safety Professional. He has been an instructor for two community colleges and has been employed in the private sector as an HPR Loss Control Representative and Safety Engineer. He has over 19 years experience in the fire service, in both professional and volunteer capacities, as a nationally registered paramedic and firefighter as well as a fire protection engineer.