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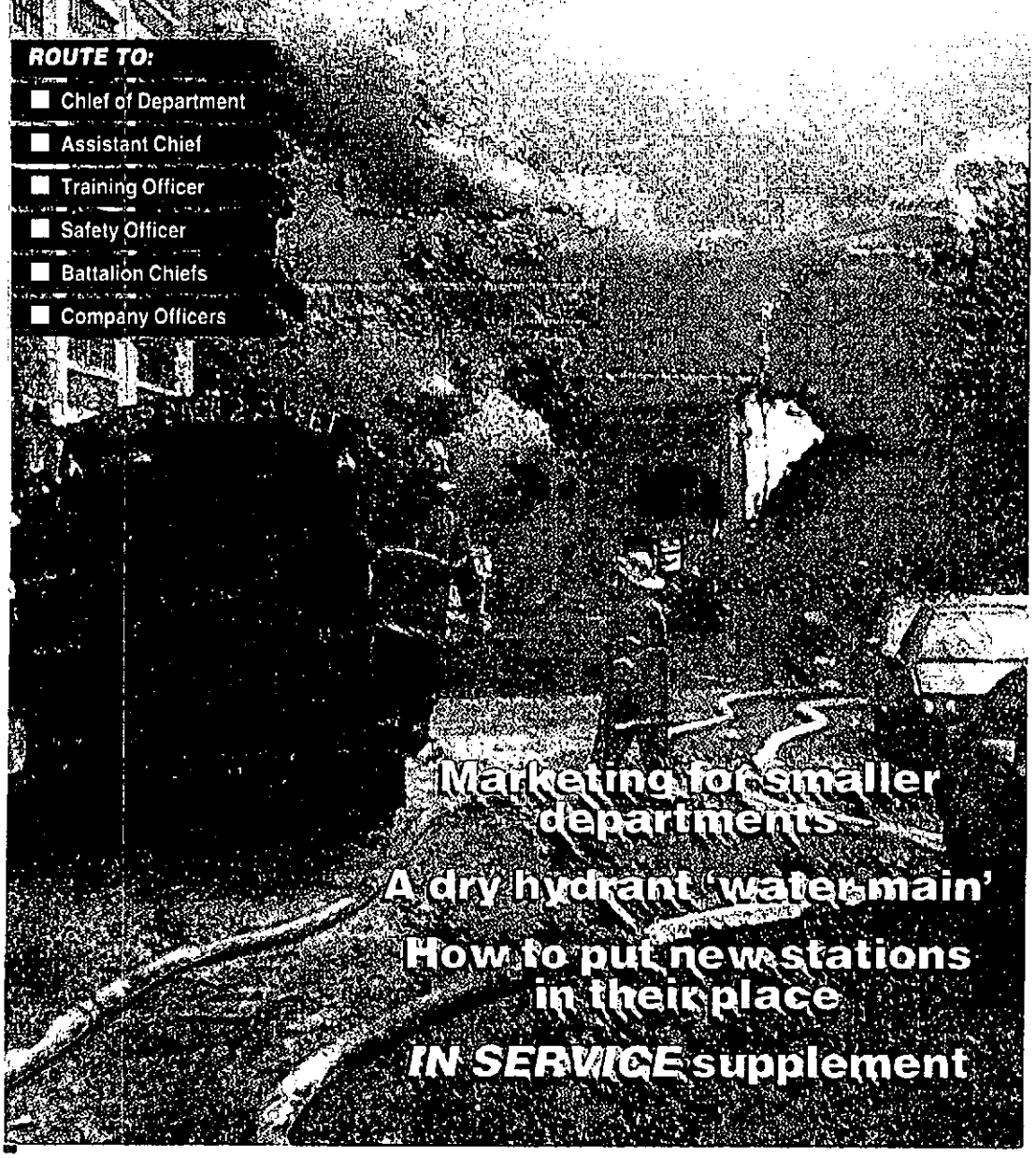


Marketing for smaller departments

A dry hydrant 'water main'

How to put new stations in their place

***IN SERVICE* supplement**

An equation for station location

Fire station locations don't have to be selected on the basis of guesswork or political pressure. This method quantifies all the factors that go into siting decisions, proving where stations are needed most.

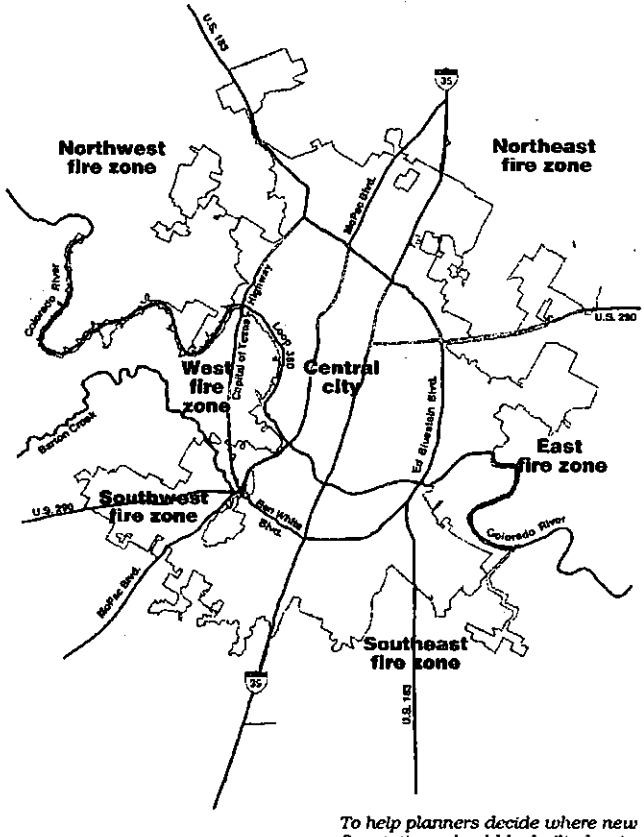
By Pieter Sybesma
Fire Contracts Administrator
City of Austin, Texas

As a fire executive, have you faced a situation in which you know from your professional experience that it's time to build a new fire station to serve a growing area, but had difficulty explaining to your board, commission or council the need and the timing for station construction? Such was the challenge the Austin (Texas) Fire Department faced after a booming economy and rapid growth in the 1980s.

The first step toward determining when to build a fire station is identifying future sites by constructing service area grids. In Texas, historically the service area boundaries of a fire station have been measured "as the crow flies" from a fire station site.

The Texas State Board of Insurance, the agency formerly charged with evaluating the effectiveness of Texas fire departments, used this approach as recently as 1991 when it established that the criteria for service area of a fire station were "1. Distance: Every structure should have a station within 1½ miles as the crow flies; 2. Response Time: a. Maximum three minutes to commercial, industrial and heavy residential (apartment complexes) areas; b. Maximum five minutes to single family residential areas."

The resulting service area of a fire station, using this method, is a circle with a response area of about seven square miles within a 1.5-mile radius of the fire station.



To help planners decide where new fire stations should be built, the city of Austin is divided into seven zones, based on natural and artificial features.

Diamonds, not circles

The problem with this approach is that fire engines and trucks must use the existing roadway network and can't reach an emergency scene "as the crow flies." Then Austin Fire Chief Bill Roberts decided that mapping the 1.5-mile distance on the roadway grid would be a more accurate method of calculating the response areas to determine the future location of fire stations. The resulting service area, using Chief Roberts' approach, is a diamond rather than a circle. (See Figure 1, page 56.)

The approach developed by Chief Roberts was affirmed by the work of Richard C. Larson and Keith A. Stevenson of the Massachusetts Institute of Technology in their study of fire response areas. The MIT study was supported in part by the National Science Foundation at the MIT Operations Research Center and by the U. S. Department of Housing and Urban Development at the New York City Rand Institute.

The approach described by Larson and Stevenson provides a minimum average response time by mobile emergency units responding from fixed locations where support is provided by neighboring units when the primary unit is unavailable for dispatch.

This approach works best in areas that are relatively flat, with perpendicular streets and few, if any, artificial or natural barriers. The distance from the center of the diamond to the outer corners is the response distance and correlates to the response time selected by the community. The unit responding from the station in the center of the diamond should be able to reach any location in the diamond within that response time.

Under city ordinance, the Austin Fire Department has an annual average response time goal of 3.5 minutes from receipt of the call to the time the first fire apparatus arrives at the scene of the emergency. Thirty seconds "scramble time" is allotted to allow personnel to react to the call, don the appropriate gear, and start the apparatus.

The travel speed is assumed to average 30 mph because of the need to drive prudently and to slow or stop at controlled intersections. Therefore, the ideal service area for an Austin fire station is the defined geographic area that the fire apparatus located at that station can cover in three minutes, about 1.5 miles.

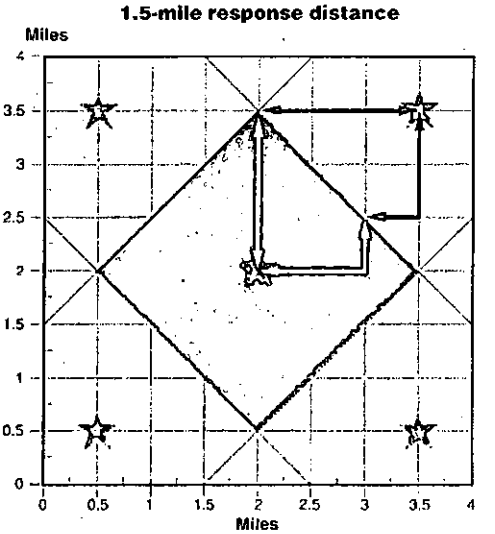
Each side of the diamond-shaped ideal response area measures 2.1213 miles, resulting in an area of 4.5 square miles. (Obviously, if your community has different response time criteria, the size of the diamond will vary.) The 4.5-square-mile response area of the diamond shape is less than two-thirds the size of the 7.065-square-mile circular "as the crow flies" response area that uses a 1.5 mile radius.

Developing a grid template of fire station diamond service areas, scaled to a map of the entire service area, allows the planner to identify future station locations. Although there are several fire station location computer programs on the market, using a grid template on a map can be almost as accurate, far less expensive and graphically illuminating.

Natural boundaries

When locating a fire station site, it's seldom possible to have the ideal situation. Natural and artificial barriers often challenge the planner selecting the fire station site. Reasonable siting adjustments must be made so that no area is too far outside the appropriate travel response distance of the fire station. Likewise, the planner must take care to minimize or avoid overlap of service area from an adjacent fire station's service area. And in certain areas, the planner must delete a potential station site because its service area can't or won't ever be developed, or adjust the grid system to fit the terrain.

Figure 1 — Fire station service area, 1.5-mile response distance



Rather than measuring a response district "as the crow flies," a circle with the station as the center and the desired response distance as the radius, the Austin Fire Department uses a diamond-shaped grid based on existing roadways and an ideal response distance of 1.5 miles. This makes the area smaller and travel times more realistic. Emergency responders can reach any part of the diamond in 3.5 minutes or less.

For instance, Austin is blessed with a variety of natural features, but this abundance can create challenges in the provision of emergency services. The western part of the city is divided by the Balcones Fault, with areas to the east of the fault geologically classified as prairies and areas west of the fault as plateaus. The prairie areas are flat and have creeks and streams running through them, but the plateau areas are hilly and rocky.

These natural barriers make it necessary to establish unique grid alignments within distinct areas. In reviewing the topography of Austin's extraterritorial jurisdiction, allowing for both natural and artificial barriers, six distinct fire zones were created. A three-minute response diamond grid template was prepared on clear acetate, superimposed on a map of each of the six areas and anchored to at least one existing fire station's service area. An example of the resulting grid pattern for one area is depicted on page 60.

Once the grid pattern is established for each area, the center of each grid is labeled as an ideal location for a fire station. Wherever 35% or more of a service area is in another municipality's city limits or extraterritorial jurisdiction, no fire station is planned for that diamond. Service to the remaining area of the diamond will be provided by adjacent fire stations.

All residents who live within Austin's city limits are taxed and receive complete fire and police services. Residents of Austin's extraterritorial jurisdiction area, however, receive fire protection from small volunteer departments. These departments are sometimes contracted by the city to provide first-responder services when areas are annexed, until the city builds its own stations.

Chief Roberts' judgment was that if 65% or more of the service area is in Austin's extraterritorial jurisdiction, then a fire station is appropriate, but if less than 65% of the area is in Austin's extraterritorial jurisdiction, building a station would not be fiscally justified.

Some of the "ideal locations" placed stations in the middle of pastures or fields on today's map, but as the areas develop and infrastructure is provided, the station locations can be adjusted to place the stations on streets which will allow the response area to reasonably represent the diamond shape after development has occurred.

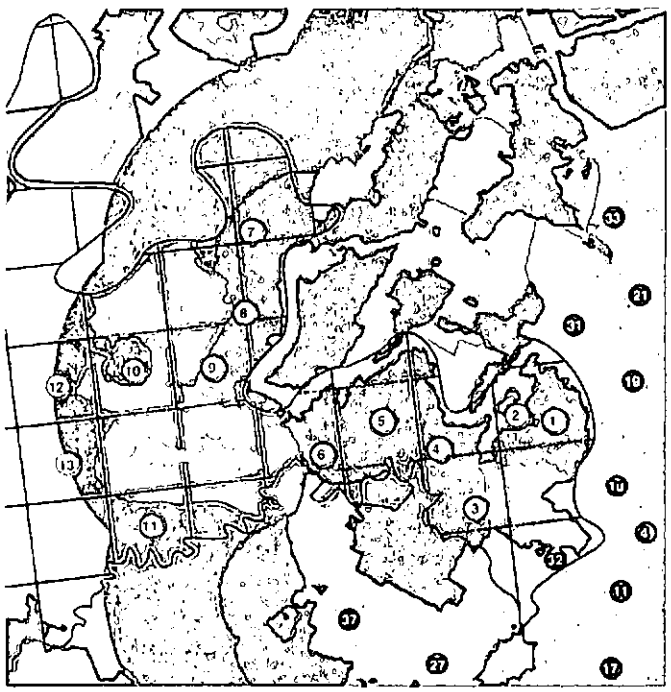
However, the stations should not

be sited more than a quarter-mile from their original locations, or the diamond shape will begin to shift.

For example, in areas to the west of Austin, the planned fire station locations are further apart than three roadway miles, because of winding streets in the hilly terrain.

Additionally, in the western areas biologically and environmentally sensitive sites will be or are being set aside so that no development will occur. As these sites are assembled into larger contiguous blocks of land, it will be necessary to adjust the locations of some of the proposed fire station sites and to eliminate others entirely.

Only a few such sites in the west and northwest fire zones have been adjusted, since the final configuration of the biological and environmental habitat land holdings has not yet been completed. One hundred twenty-five future fire station sites were identified for the five-mile extraterritorial jurisdiction of Austin as of Jan. 1, 1994.



This map shows the West Fire Zone established by fire department planners to decide where new stations should be located, using the diamond shaped grid system. The yellow areas are the city's jurisdiction; the blue and purple areas are the city's extraterritorial jurisdictions. Orange areas are other cities' jurisdictions. Red dots represent existing stations and white dots are planned stations. While a new station should ideally be located in the center of its square, natural features and land availability sometimes make it necessary to put a station somewhere else.

Some factors to consider

With the competition for public dollars becoming more intense and citizens expecting high levels of service throughout the community, the challenge to the fire chief or fire planner is knowing when an area has the right combination of development factors to require funding of a new fire station. Texas law requires that the fire protection service provided to newly annexed areas must not be less than the area received prior to annexation and *must be comparable to similarly situated parcels in other parts of the city* (emphasis added).

Traditionally, the factor compared for a pre-annexation service level and a post-annexation service level is response time. While the number of trained personnel, the diversity and number of equipment, and the ability to enforce a building or fire code are just as important, response time is the criterion most people look at for comparative purposes.

Fire protection is provided as a basic service of the City of Austin to areas inside the corporate limits. As areas are annexed, often the question of constructing a fire station to serve the newly annexed area is raised by the residents. With land costs for a fire station site ranging from $300,000 to $1.5 million, construction costs from $700,000 to $900,000, fire engine costs of $275,000, and annual operational costs of $500,000, a new fire station is expensive and a significant long-term service commitment.

The timing for the construction and operation of a new fire station is based on a demand threshold that is influenced by many factors, including:

- distance from existing stations;
- percent of the area developed;
- fire frequency in the area;
- daytime population (commercial and industrial areas);
- nighttime population (residential areas);
- square footage of industrial and commercial structures;
- value of improvements;
- conflagration potential;
- time since the area was annexed;
- exposures (such as hazardous materials, chemical manufacturing and combustibles);
- fire flow demand;
- citizen demand;
- other political pressures;
- topography;
- alarms responded to by the nearest fire station;
- amount of time the nearest station is out of service because of a run outside its territory or service area;
- volume and type of traffic on the roads;
- and the wildland/urban interface characteristics of the service area.

In another community, the factors affecting the level of demand might be different and should be determined by the fire chief.

Chief Roberts ranked the following factors in order of importance:

1) Distance from existing stations: 16%

2) Percentage of the area that is developed: 16%

3) Fire frequency in uncovered area: 15%

4) Nighttime population (residential

areas): 10%
5) Square footage of industrial and commercial structures: 10%
6) Value of improvements: 10%
7) Daytime population (commercial and industrial areas): 8%
8) Conflagration potential: 5%
9) Time since the area was annexed: 5%
10) Wildland/urban interface: 5%

The remaining factors were considered to be of secondary or minimal importance, and thus were not weighted.

Apples to apples

To demonstrate that newly developed areas of the community are comparable to areas that currently receive standard fire protection response time service, one must know the characteristics of the existing service areas. The first requirement is to determine what the decision analysis values are for the service areas of existing fire stations. Of the 10 previously mentioned factors, three are not applicable to the service area of an existing fire station: distance from existing stations, fire frequency in uncovered area, and time since the area was annexed.

The remaining seven factors are pertinent to determining a decision analysis value for the service areas of existing fire stations, but the percentage value for the combined seven factors no longer equals 100%. Accordingly, the percentage values were adjusted to account for the removal of the three non-pertinent factors.

The following values result from this adjustment: percentage of the area that is developed: 25%; daytime population (commercial and industrial areas): 12.5%; nighttime population (residential areas): 15.63%; square footage of industrial and commercial structures: 15.63%; value of improvements: 15.63%; conflagration potential: 7.81%; and wildland-urban interface: 7.81%.

After identifying the issues involved in deciding when to build a fire station, data gathering can begin. To make adequate comparisons, data from each factor is converted to a utility function numeric scale of 0.0–1.0. A brief discussion of each data factor follows.

Percentage of area developed

Aerial photographs were taken in March 1992, the service area of each station was outlined on the photographs, and an estimate of the amount of fully developed land area was made. This data changes with new construction and demolition, so development within each fire station service area must be reviewed each time an analysis is conducted. The utility value for each fire station service area was converted from the percentage of the area developed, i.e., 45% development equated to a .45 utility value.

Daytime population

Obviously, fires usually occur where people are, and during the day, most adults work away from their homes. The Austin Chamber of Commerce's Directory of Austin Area Major Employers (July 1993) was used to obtain a rough estimate of the number of working adults and their locations, though there are limits to this information, because not all employers report their employment data to the chamber. The data from this publication, plus the enrollment from public schools and the University of Texas, were combined to develop a daytime population figure.

The daytime population utility value for each fire station service area was determined by finding the ratio of actual daytime population in the service area to a daytime population of 55,000, a value above the highest population level found. For

example, if the daytime population in the service area of Station 1 is 27,618, that figure divided by 55,000 equals 0.5.

Nighttime population

1990 census data was used to determine the nighttime population. I identified the census blocks included within each fire station's service area, and the city planner used a census computer program to provide the population totals, breakdown by age and breakdown by households.

The nighttime population utility value for each fire station service area was determined by finding the ratio of actual nighttime population in the service area to a nighttime population of 25,000, a value above the highest population level found. For example, if Station 1 has a nighttime population of 2,452, that number divided by 25,000 is 0.098.

Square footage of industrial and commercial structures

Commercial and industrial construction techniques such as large open areas or metal truss-supported roofs can expose firefighters to a variety of safety hazards when fighting fires. In addition, fire load, processes, equipment and material stored in a commercial building differ significantly from those in a residential building. A quick response to a commercial or industrial structure fire will make a significant difference in how the fire will be fought and what can be saved of the structure and its contents.

Consequently, the square footage of industrial and commercial buildings within the service area of a proposed fire station is a factor in determining when to construct a new fire station. Determining the amount of square footage under roof was difficult, because these cumulative-type records are not available from the city.

> When locating a fire station site, it's seldom possible to have the ideal situation. Natural and artificial barriers often challenge the planner selecting the site.

Information was then sought from the Travis County Central Appraisal District. Tax maps for each service area were identified and data-processing personnel produced reports giving the square footage of all structures for each map. I then extracted data on all commercial and industrial buildings from each map report for each service area and totaled the square footage. Similar information was obtained from the Williamson County Central Appraisal District. This data changes annually and requires updating for each future analysis. Data was also obtained from public tax-exempt facilities, such as public schools, state land, universities, federal land and so on.

The utility value for each fire station service area was determined by finding the ratio of actual square footage of industrial and commercial structures in the service area to a value above the highest square footage of industrial and commercial structures level found. For example, if there are 22,218,547 square feet in the service area of Station 1, that number divided by 40 million square feet equals 0.56.

Value of improvements

I identified the tax parcel maps associated with each fire station ser-

vice area at the Travis and Williamson county central appraisal districts, and obtained computer tabulations of all property values associated with each service area. Since land does not burn, only the improvement values (structures) were considered. This data changes annually and requires updating for each future analysis.

The utility value for each fire station service area was determined by finding the ratio of actual improvement values in the service area to an improvement value of $700 million, a value above the highest improvement value level found. For example, if the Station 1 service area has an improvement value of $514 million, that number divided by $700 million equals 0.74.

Conflagration potential

The NFPA Fire Protection Handbook, 12th Edition, says: "There is no universally accepted exact definition of a conflagration. Some list as conflagrations all fires causing more than a specified amount of loss, irrespective of the extent of spread or the number of buildings involved. The best practice is to apply the term only to fires extending over a considerable area and destroying numbers of buildings."

In Austin, Chief Roberts identified buildings that are three stories or more in height, constructed of wood and in close proximity to each other as potential conflagrations. Apartment buildings often fall under this definition. Only if a conflagration condition does not exist in a fire station service area must a review be undertaken for any new construction which would change the condition for a future analysis.

> While this method of calculating fire station utility factors is comprehensive, it is not always applicable.

If the fire station service area has a conflagration potential, its utility value is 1.0. If the fire station service area does not have a conflagration potential, its utility value is 0.0.

Wildland/urban interface

Travis County and the central Texas area have many undeveloped areas with lots of fuel for fire, such as brush, tall grasses and trees. This is a significant firefighting problem for urban fire departments, because these departments are geared toward fighting structure fires and generally are equipped with fire apparatus that must stay on a paved roadway surface because of its weight, can't drive and squirt water at the same time, and depends on a readily available, large-volume water source.

To fight a wildland fire, fire departments use smaller brush trucks capable of moving and squirting a mixture of water and foam and water tankers with portable water tanks. Having a developed area with homes adjacent to an undeveloped wildland area is a significant problem whenever a wildland fire develops.

Areas of western Travis County have been compared to the Malibu, Calif., area which suffered massive losses in 1993 as a result of uncontrollable wildland brush and grass fires burning in canyons and across rolling hills where numerous homes had been built on ridge lines. The potential for a similar fire in western Travis County is acknowledged by the Federal Emergency Management Agency.

Sums of factors and their utility functions

Station	Taxable improvement values*	Square footage commercial*	Single-family dwellings (sq. feet)*	Utility function of improvement values	Utility function of commercial (sq. feet)	Daytime population	Nighttime population	Utility function of daytime population	Utility function of nighttime population
1	$514.711	$22.218	1.362	0.735	0.555	27,618	2,452	0.502	0.098
2	$205.894	$15.704	3.691	0.294	0.392	52,669	12,992	0.957	0.519
3	$291.747	$8.402	7.496	0.416	0.210	39,149	13,637	0.711	0.545
4	$135.610	$2.932	3.173	0.193	0.073	4,519	5,826	0.082	0.233
5	$64.796	$.813	3.295	0.092	0.020	9,450	9,506	0.171	0.380
6	$335.632	$5.714	9.181	0.479	0.142	9,729	16,165	0.176	0.646
7	$85.925	$2.856	4.397	0.122	0.071	6,378	16,261	0.115	0.746
8	$472.643	$11.403	9.764	0.675	0.285	6,335	18,665	0.115	0.650
9	$148.931	$1.411	4.551	0.212	0.035	7,250	10,447	0.131	0.417
10	$305.670	$2.304	8.199	0.436	0.057	1,339	11,411	0.024	0.457

* In millions

Above: Fire stations located in different areas can be compared in an equal manner through the use of utility functions calculated for a number of relevant factors. The utility functions for each station then are tallied and the station given an overall utility ranking. The chart shows figures for fire stations 1 through 10.

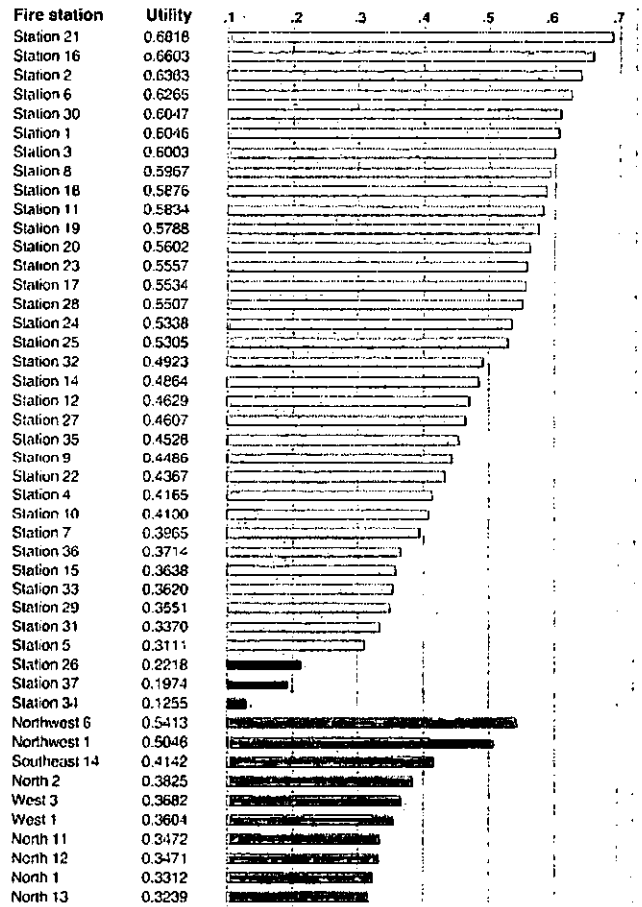
Right: Figure 2 shows how all existing or planned Austin fire stations compare to each other and how many meet the threshold utility value of 0.3. While 30 future fire station locations have been identified, the last 10 stations are the only ones that meet the utility value requirements at this time. Although stations 26, 34 and 37 do not meet the requirements, they are being built to extend the city service area in growth directions and/or to satisfy bond issue commitments.

Tall grasslands interspersed with brush in the prairie areas pose another significant danger in the northern, eastern and southern areas of Travis County. A quick and massive response to wildland fires is required for a reasonable control time. In some flat areas, the wildland/urban interface may diminish over time and be eliminated. If the fire station service area is in a wildland/urban interface area, its utility value is 1.0. If the fire station service area is not in a wildland/urban interface area, its utility value is 0.0.

How it all adds up

The three-minute/1.5-mile response areas for the 32 existing stations and four other stations in various degrees of construction (stations 34, 35, 36 and 37) were determined by using the grid template pattern on a map and LandTrak™ GIS software to

Figure 2 — Ranking of expected utility for existing and planned fire stations



more accurately measure the 1.5-mile roadway response distance. Data was collected from the previously referenced sources for each of the seven factors, as correlated to the existing and funded fire station areas.

Information about the daytime and nighttime populations, square footage of industrial and commercial structures, and the value of improvements was reported using Excel™. The data totals derived from Excel were entered into Logical Decisions™ software to calculate the utility factor values for each station as reported in Figure 2 on the facing page.

The same data collection and analysis was done for 30 future fire station service areas. Of the 30 future stations in areas that could be annexed in the next seven years, only 10 of the station service areas have a utility value that exceeds 0.3, the threshold number for fire station utility. These 10 fire station service areas, all of which meet the requirements of Texas annexation laws for funding and construction, are compared with existing stations in Figure 2.

This analysis can be used to determine and demonstrate the necessity of constructing a new fire station by comparing the utility factor values of a new fire station service area to the utility factor values for existing fire station service areas. Whenever 65% of a future fire station's service area is inside the corporate limits and the utility factor for that fire station service area equals or exceeds 0.3, construction of the new fire station is justified.

While this method of calculating fire station utility factors is comprehensive and allows for future planning, it is not always applicable to every situation. Three existing fire stations, Stations 26, 34 and 37, ranked below the 0.3 utility factor value.

However, stations 26 and 34 have been located in a leapfrog fashion to extend fire protection services further away from the contiguous service areas of the city. Infill of fire stations will be required to provide the three-minute/1.5-mile response services to the areas between these two outer fire stations and the existing contiguous fire service area of the bulk of the city.

The third fire station, Station 37, was included in the 1992 Bond Election because of requests from residents in the area to be served by this station, and because of commitments made during the 1987 annexation process.

Using these methods, the Austin Fire Department was able to chart the course of its growth for the next decade. The approach used to justify new stations can also be modified to assist in identifying a fire station relocation possibility or fire station consolidation options.

For other fire departments in Austin's situation, this type of analysis can provide the necessary justification for including new fire stations in bond elections, explain the cost to governmental leaders, and provide cost-effective fire protection to citizens when they need it. FC

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Pieter Sybesma has worked for the City of Austin (Texas) for 23 years, the last nine as a civilian member of the Austin Fire Department. Prior to joining the fire department, he served as the city's intergovernmental relations officer. Sybesma received a bachelor of arts degree in 1970 and a master's degree in business administration in 1994, both from the University of Texas at Austin.