unavailable companies (U_i).[23] The constant depended on the average velocity of the companies, and Rand *assumed* this to be 20 miles per hour during the early application of this model because they had no actual data. Of course, fire alarms are not uniform in time and peak sharply during the day, during certain days of the week, and seasonally. Average peak unavailability thus had to be calculated separately from average offpeak.

Unavailability depended on alarm rate and number of units sent to alarms. Because they did not bother to analyze fire records, the Rand fire project staff simply *assumed* that average offpeak alarm rate was 40% that of average peak and that two engines and two ladders were sent to alarms, although at that time three engines and two ladders were the standard alarm assignment until late 1974.[24] Several times in their reports, the Rand staff members explain that they calculated a number, made an assumption, or constructed a relationship because analyzing the real data would have been "too laborious"![25]

Rand then sorted the neighborhoods of the City into seven hazard categories. By use of the Resource-Allocation Model, they equalized response time between areas of like hazard designation. If an area had a lower-than-average response time for its hazard designation, it lost one company or more to bring it close to the average.[26] This process is known to engineers as suboptimalization because it degrades the better areas, rather than improving the worse ones.

For the 1975 cuts and thereafter, the Department coupled this Resource-Allocation Model with another model, the Firehouse-Siting Model. The Resource-Allocation Model determined which areas would lose companies, and the Firehouse-Siting Model determined which company or companies would be cut from each designated area. The Firehouse-Siting Model also uses nothing more mathematically difficult than the square root:

$$T(D) = 2\sqrt{D/a} \qquad \text{if } D \le 2D_c$$
$$= V_c/a + D/V_c \qquad \text{if } D > 2D_c$$

where a = acceleration, V_c = cruise velocity, D = distance, T = travel time, D_c = distance to cruise velocity

In words, travel time for a given distance is two times the square root of the distance divided by acceleration rate if the distance is less than or equal to twice the distance needed to get to cruise velocity. Travel time is cruise velocity divided by the acceleration rate plus the distance divided by cruise velocity if the distance is more than twice the distance needed to get to cruise velocity. Distances were calculated by simple geometry and represent those between firehouses and *alarm boxes.*[27]

The Firehouse-Siting Model would look at each area on the Resource-Allocation Model's "hit list" and estimate average travel times for the area before any cuts and after hypothetical cuts and redrawing of the remaining companies' service areas to fill the service hole(s). The company whose removal resulted in the lowest average travel time of the hypothetical removals would be the one to be closed or permanently relocated.

Both Rand models contain many flaws of early ecological models: simplistic assumptions, omission of other simultaneous impacts, baseless assigning of a value distribution to a phenomenon, and the combination of an inadequate data base with inappropriate analysis and interpretation of the data. Table 2-2 contrasts Rand's simplistic assumptions with the complicated realities. Table 2-3 lists some of the neighborhood-specific variables Rand omitted from its models as well as typical workload policies which confounded the models. Finally, table 2-4 includes many of the policy changes in New York City from 1972–1976 which increased firefighting time per fire- or real-fire-alarm rate. Each of the factors in these tables held the potential for affecting company availability, velocity, distance, and effective service-area geometry.

The models projected only the time required to get from the firehouse to the alarm box, not to the burning building, and certainly not to the first stream of water on the fire. The difference in time between arrival at the alarm box and the first stream of water on a fire may range from two to ten minutes. Table 2-5 highlights the differences between fighting a fire in a tenement and fighting one in a one-family home. Longer additional times characterize overcrowded, poor neighborhoods, for obvious reasons, and the potential for both loss of life and loss of homes is greater in these areas than in others, partly because of fire-spread rate and partly because of the greater fuel loads due to the overcrowding.

"RAND LACKED REAL DATA"

To implement even these simple models, Rand should have acquired real data. The Resource-Allocation Model depended on the system of hazard regions and the seven hazard classes. The classes are:

1. valuable commercial
2. fireproof high-rise office
3. large industrial with lumberyards and oil tanks
4. high-density high fire-hazard residential

5. lower-density less-hazardous residential
6. mixed multi-story and one- or two-story frame
7. one- or two-story frame

Assignment to the classes allegedly depended on the fire and explosion hazards presented by the neighborhoods. Yet when the neighborhoods assigned by Rand to the same hazard class are considered, the data on which these class assignments were based aren't obvious. East Flatbush in Brooklyn and Astoria in Queens were placed in the same hazard class as Riverdale in the Bronx although the prevalent housing types, population densities, and presence of special hazards such as oil-tank farms were quite different in the three neighborhoods. Greenwich Village and Chelsea-Murray Hill (wealthy areas) were placed in hazard class 1 (valuable commercial) although the buildings and population densities were similar to the Westside and Inwood. The data on the likelihood and potential severity of fire and explosion hazard in the various neighborhoods were either not acquired, or not used properly for an objective hazard classification.

Rand's hazard regions were vast and so heterogeneous as to be essentially meaningless. The classification scheme failed to take spatial heterogeneity into account and led to underservice of areas of greater-than-average fire-incidence ("hot spots") within each region. Fire service cannot be designed for either geographic or temporal averages.

The only real data Rand acquired was firefighting-unit response time. In order to develop the formulae for the Firehouse-Siting Model, time and distance data were needed. Rand timed 2,000 responses by 15 units.[28] That sounds like a lot of data. However, eleven of the fifteen were in Lower Manhattan below 14th Street and two each in Brooklyn and Queens. Thirteen were ladder trucks and two battalion-chiefs' cars. No data were acquired on engines. Thus, both the geography and the unit types failed to sample the City properly.

What Rand then did with this non-representative data further guaranteed that whatever model was developed could not adequately serve the neighborhoods: Rand smoothed the data by plotting average response times against distance. This kind of smoothing is only acceptable during the exploratory phase of data analysis to get the basic underlying shape of the data. It is not an acceptable basis on which to build a prescriptive model for a life-support-system-like fire-control service. The Fire Department itself had timed several units just before Rand intruded into the scene and had seen that the velocity and response time of each timed unit depended on time of day and season and on incidents, accidents, and events which change traffic-flow rate.[29]

The entire Rand system of allocating fire-control service for New York City in the early-to-mid-1970's involved averaging and suboptimalization. Hazard regions of below-average response time for their classification were targeted for cuts by the Resource-Allocation Model; these response times were averaged over huge hazard regions which were in reality nonhomogeneous both in their demand for fire control service and in their potential for serious fire spread and explosion. This model used average and peak-average availabilities and never the smallest credible availability or smallest historic availability. The Firehouse-Siting Model was based on average response times for given distances and yielded average travel times for an area. Creation of a system based on such averages is not acceptable even for something as frivolous as delivery of beauty-parlor supplies, let alone delivery of fire-control service, for the simple reason that any area above average will be underserved. By the statistical Law of Large Numbers, if there are a large number of areas (over 200 engine response areas, for example), approximately half of the areas will be at least slightly above average and some will be outside the broad crest of the "bell-shaped" curve (well above average). Rand's use of averages in this way ensured gross underservice to a large number of neighborhoods. In particular, all neighborhoods at the boundaries of fire-company response areas necessarily suffered underservice due to their above average distances.

Rand's use of these models also ensured that the neighborhoods with the densest placement of firefighting resources would be the losers. These neighborhoods had dense resources because of the historic and projected demand for fire service, based on global measures such as fire incidence, lives lost, households de-housed, and firefighter workload. The Rand models, based largely on calculated internal measures of fire service, prescribed policy and actions opposite to those prescribed by the analysis of global measures.

The Rand staff itself knew that what they were doing was both bad policy science and unethical. In 1972 or 1973, Rand's Ed Ignall wrote an undated memo to ten people in the Rand Fire Project and the Fire Department (Arthur Swersey, Richard Urbach, Ken Rider, Mei Ling, Joan Held, Elmer Chapman, Frank Ronan, Homer Bishop, Ed Blum, and Hope Wong) with copies to seven other Rand or Fire Department staff members of note (Grace Carter, Warren Walker, Pete Kolesar, Jack Hausner, Tom Crabhill, Sandy Stevenson, and Rae Archibald) in which he proposed using actual fire records which report property damage and correlating the damage with the response distance. He wanted to construct the relationships between distance and damage with 1968–1969 data and validate them with 1970–71 data. Uneasy with the Resource-Allocation Model and purely internal measures of fire service, he asked the essential question: what is a minute of response time worth?

Ignall listed difficulties in relating damage to distance:

> First: we do not have response times. The best we can do are Euclidean distances

> from an alarm box near the incident(s) to the house of the first arriving engine and the house of the first arriving ladder. . . .
>
> Second: we do not have good measures of the extent of fire when fire companies arrive. . . .
>
> Third: Delays in discovering fires are sometimes long, sometimes short. . . .
>
> Fourth: Some fires grow quickly, others grow slowly. . . .

He discussed in great detail how local conditions influence unit speed and how a unit is not always in its house when its alarm comes in. He concluded: "Effects like these can cripple a naive approach to estimating the value of response time." Then he further detailed local conditions which may influence the speed with which alarms are turned in.

Thus, although nearly everyone of importance within the Rand Fire Project and the Fire Department knew of the technical and ethical objections to use of calculated average response time and of the need to correlate it with some global measure of fire service, fire-company permanent relocations and closings proceeded on the basis of the unvalidated Resource Allocation Model and, later, on the unvalidated Firehouse Siting Model. The Resource Allocation Model provided the sole basis for the first round of fire-company eliminations and permanent relocations in November 1972. The affected companies (Table 2.1) served high fire incidence, overcrowded, poor minority neighborhoods such as Brownsville and the South Bronx. Both rounds of cuts in 1974 also relied solely on the Resource-Allocation Model and again targeted the neighborhoods in greatest need of fire-control service. Rand Institute and the Fire Department seduced many local minority politicians, such as then Manhattan Borough President Percy Sutton into supporting the cuts by telling them that the ERS fireboxes would make up for the reduced resources by allowing more efficient use of the remaining resources and by "proving" that the resource reduction would not reduce response time significantly. This proof relied solely on constructions of response time by the Resource-Allocation Model. Because of the antipathies between minority communities and the uniformed services, laying off firefighters did not receive much resistance from local politicians who lumped firefighters together with police.

The 1975, 1976, and 1988–89 cuts relied on both the Resource-Allocation and the Firehouse-Siting Models. Again, the great majority of the cut or moved companies lay in poor minority neighborhoods, but a few were in integrated areas in the process of gentrifying. Some of these integrated neighborhoods, unlike the resource-poor neighborhoods before them, had the political clout and the nose for "something rotten" to fight the cuts and to enlist experts to expose the inadequacies of the Rand models and their implementation. Thus, the only fire companies reopened were those closed in the post-1974 rounds of cuts and were primarily in racially integrated areas of economic diversity that promised gentrification.

HUD EXPERIMENTS ON HUMAN POPULATIONS

By 1974, the Rand Institute had achieved close ties with the U.S. Department of Housing and Urban Development (HUD) and received grants for creation and refinement of models such as the Firehouse-Siting Model. In return, the models were turned over to HUD to "sell" to municipalities. Another thinktank, Public Technologies Inc., had developed similar models for emergency service deployment under HUD funding, which were also "sold" to municipalities.[30]

The message from HUD to the cities was "Less is more." Cities learned how to target minority neighborhoods and break civil-service unions behind a shield of equations and graphs which "proved" that emergency service would not suffer from the resource reductions. A large number of cities bought into these models and implemented them: Denver, Wilmington, Hartford, Yonkers, Jersey City, St. Louis, Hoboken, Tacoma, Washington, and Tampa, and others. The City Hall of Jersey City burned down after implementation of the models, as did major portions of its poor neighborhoods.

This HUD approach continued through the Nixon, Ford, and Carter administrations and beyond. Under the Democratic administration of Jimmy Carter, the Assistant Commissioner of HUD for Science and Public Policy was Donna Shalala, who later became the Secretary of Health and Human Services in the Clinton Administration. In the mid-1970s, Dr. Shalala had been the director of the Municipal Assistance Corporation, the New York State entity which oversaw the budget cuts during the New York city fiscal crisis of 1975. She had encouraged Fire Department cuts along with cuts in garbage collection and housing-code enforcement (all interacting to accelerate destruction of low-cost housing) and espoused the idea of the City as a laboratory for innovative sweeping experiment in government and services. According to a 1982 *Report of the President's Commission for the Study of Ethical Problems in Medicine and Biomedical and Behavioral Research*, never in her brief tenure at HUD did Dr. Shalala acknowledge that the public policies which she promulgated and implemented could constitute experiments on human populations:

> The Department of Housing and Urban Development (HUD) is the only other Federal agency conducting research with human subjects that does not have formal

> regulations for the protection of human subjects. In HUD's initial response to the Commission's inquiry, Donna Shalala (Assistant Secretary for Policy Development and Research) stated that except for a study co-sponsored with HEW, involving the testing of an aversive additive in paint to deter children from eating paint chips, HUD 'has never sponsored any human-subject or biomedical studies.' Moreover, Dr. Shalala challenged the statement in the National Commission's report that HUD's 'housing-allowance experiment' constituted research with human subjects.[31]

When confronted with criticisms of the inadequate fire-service models being sold to municipalities by HUD, Shalala's response was:

> The Rand work has been recognized by awards from several professional societies. The Office of Policy Development and Research has had the Rand work independently evaluated. These evaluations found the research of high quality and useful for some local government decision-makers.[32]

She also had the Urban Institute perform a routine hatchet job on the criticisms, and because a seemingly technical "answer" was rendered, she decided to put the issue to bed. The models promoted by Shalala continued their mass destruction. Indeed, Alan Siegel, Director of HUD's Division of Community Development and Management Research, wanted no discussion of the quality of the Rand work by policy and decision-makers and wrote to us in 1976: "Concerning the final issue of the models' scientific quality, I believe the proper forum for challenging scientific quality exists in organizations of technical and scientific peers."[33] Thus did HUD dispose of the troublesome question of the potential harm of its prescribed treatments for sick cities.

The Rand/HUD experiment on human subjects makes the famous Tuskegee Institute study on syphilis seem humane and small. The Rand/HUD team would directly and indirectly kill thousands and permanently disable millions of metropolitan residents across the country.

Table 2-1 FIRE COMPANY CLOSINGS, 1972-1991

BOROUGH	NEIGHBORHOOD	NO. OF REMOVED COMPANIES
Manhattan	Lower East Side	4
	Lower West Side	3 (2 restored)
	Times Square	1
	Upper West Side	2
	Harlem	3
Brooklyn	Brownsville	6
	Bedford-Stuyvesant	2
	Crown Heights	1
	Greenpoint	2 (1 restored)
	Park Slope	2 (1 restored)
	Red Hook	1
	Brooklyn Heights	1
Bronx	South Bronx	7 (1 restored)
	City Island	1 (restored)
Queens	Flushing	1
	Richmond Hills*	1
	Rockaway	2
	Stapleton	1
	Tottenville	1 (restored)

Total: 42 areas affected, 34 permanently.
(Only one of the restored companies was in a poor area.)

*This company was closed and reopened twice.

Table 2-2 MODEL ASSUMPTIONS VS. REALITY

ASSUMPTION 1: Unchanging ratios of types of alarms.
REALITY: Rapid changes both citywide and within areas. Physical and social instability leads to rapid changes
MODEL: Resource allocation

ASSUMPTION 2: Predictable alarm rates.
REALITY: Rates highly variable from year to year
MODEL: Resource allocation

ASSUMPTION 3: Service times independent of each other and of state of system.
REALITY: Relocation of units to alien areas increases service times. Exhaustion of firefighters increases service times. Dispatching delays occur during peaks
MODEL: Resource allocation

ASSUMPTION 4: Availability is stable.
REALITY: Massive changes in availability with cuts
MODEL: Both resource allocation and firehouse siting

ASSUMPTION 5: Very low probability of all units busy in area.
REALITY: Even boroughwide unavailability has occurred since April 1975
MODEL: Both resource allocation and firehouse siting

ASSUMPTION 6: All alarms answered from firehouse.
REALITY: Alarms regularly answered from field, especially during peaks in high-alarm area
MODEL: Both resource allocation and firehouse siting

Table 2-3 LOCAL VARIABLES OMITTED FROM THE MODELS

1. Potential for fires to spread between buildings
2. Hydrant pressure and maintenance
3. Design of the streets
4. Parking customs (double parking, parking at hydrants)
5. Presence of special hazards (natural gas tanks, pipelines, etc,)
6. Variable traffic patterns
7. Arson rate
8. Age structure of population: the very old and very young are especially susceptible to fire-injury and death
9. Special seasonal fire characteristics such as brush fires on Staten Island and use of heaters and stoves in areas of many heating violations
10. Access to means of turning in alarms reliably
11. Population density and changes in population density
12. Spatial and temporal patterns of fire occurrence on the neighborhood level. For example: Harlem and the affluent Upper West Side were lumped into a single "hazard region."

WORKLOAD POLICIES CONFOUNDING THE MODELS

1. In busy areas, the nearest fire company was not always the one dispatched to the alarm. A less busy one may have been sent
2. Companies are not available during their two-hour rest after a big fire or after a rapid series of small ones
3. "Interchange" exchanged busy with less busy companies to even out the workload. This resulted in degraded service because of lack of familiarity with the area
4. In mid-1970s, relocation mainly between ghettos

Table 2-4 POLICY CHANGES WHICH INCREASED SIZE OF FIRES OR ALARM RATE, 1972-1976

1. Closing or permanently relocating companies from high-fire areas
2. No-voice contact on ERS boxes gets at most one engine
3. 1972–1974: Less than standard responses to ghetto alarms
4. 1975 manning reduction: 5 to 4 on engines; 6 to 5 on ladders
5. Reliance on firefighters tired from mandatory overtime
6. Understaffing in dispatch centers delays response
7. 1974: reduction by one engine in standard response
8. Dispatchers and battalion chiefs can no longer call automatic higher alarms but are pressured to "special-call" units one by one
9. Cuts in trash collection lead to more trash fires
10. Cuts in building inspections lead to more fire violations
11. Understaffing of fire marshals hampers arson investigation
12. No more inspection for repair of fire damage led to building abandonment
13. Cuts in hydrant inspection and repair led to a high percentage of defective hydrants

Table 2-5 FIREFIGHTING AT TENEMENT AND 1-FAMILY HOME

FACTOR	TENEMENT	1-FAMILY HOME
	5-story, 20-family 35'x75' attached	25'x35' detached
1st engine arriving	3 minutes	4 minutes
Hose stretch	6–10 lengths	3 lengths
Forcible entry	many locks steel door	one lock window or wood door
Time from arrival to water on fire	3–8 minutes*	1–2 minutes
Life hazard	several families	1 family
Escape	cannot jump	can jump to ground
Spread potential	between apartments between buildings	none
Laddering problems	no rear rescue double park or overhead cables prevent front rescue	none
Inhabitants per engine (1975)	34–44,000	17–25,000
Special problems	frequent building collapse	none

*Delays common in multiple-dwelling areas from blocked hydrants, defective hydrants, and delayed forcible entry.

Figure 2-1 THE 59 COMMUNITY DISTRICTS OF NEW YORK

The important neighborhoods which these districts comprise are as follows:

MANHATTAN

1: Lower West Side
3: Lower East Side
4 & 5: Times Square
7: Upper West Side
10: Central Harlem
11: East Harlem

BRONX

1, 2 , 3, 6: South Bronx
10: City Island
4, 5: West Bronx

QUEENS

7: Flushing
8,9,12 junction: Richmond Hills
14: Rockaway
4: East Elmhurst/Corona
1: Astoria

BROOKLYN

1: Greenpoint/Williamsburg
3: Bedford-Stuyvesant
4: Bushwick
6: Red Hook/Park Slope
2: Brooklyn Heights
8: Crown Heights North
16, W. 5: Brownsville

STATEN ISLAND

1: Stapleton/New Brighton
3: Tottenville