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## Deaths Expected from Delayed Emergency Response Due to Neighborhood Traffic Mitigation

Submitted to the City Council of Boulder, Colorado

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### Background

During the 11 June 1996 City Council Study Session for Boulder's neighborhood traffic mitigation program (NTMP), several members requested additional quantitative information so that they could better understand the issues. In particular, Councilman Mock asked for data that would allow a comparison of the impacts of delayed emergency response time versus the putative increases in neighborhood safety. His question can be answered well enough by considering cardiac arrest emergencies, for which reasonably good data exists, and then making a crude estimate to allow for the other critical emergencies. Data on the following are required: traffic accident deaths, cardiac arrest emergencies and survivals, emergency response times, and delays from traffic mitigation devices. Fairly accurate numbers exist for all of these items. They are certainly accurate enough for reasonable "risk assessment", which often involves far worse vagaries and rough estimates than in the present case.

### Traffic Deaths in Boulder

Transportation staff member Bill Cowern supplied data showing that deaths from traffic accidents for the entire City averaged about 2.8 per year for 1991 through 1996. However, only one death, about 0.17 deaths per year, occurred on streets slated for treatment under the NTMP. So, assuming that this mitigation actually would save lives from reduced vehicle speeds, the improvement could not possibly be dramatic. Because the mitigation devices themselves present some direct hazards, they could possibly cause *more* deaths by accidents rather than *fewer*. For discussion purposes, I assume that mitigation city wide would reduce the present traffic death rate on mitigated streets by about 0.1 person per year on average. This is believed to be a generous assumption.

Obviously, the 0.1 death per year estimate could be considerably in error. Perhaps the one neighborhood death in the past six years was from some cause that could not be cured by planned mitigation devices; or it could be argued that a death at 13<sup>th</sup> and College should be included because there may be some traffic mitigation applied there under another program. When lives are at stake, it is best not to make optimistic assumptions, so I do not think it is wise to use an estimate higher than about 0.1 for the assumed lives saved by the NTMP. In any case, doubling or even tripling this number would not change the important conclusions drawn in the last section.

## Deaths Caused by Delayed Emergency Response from The NTMP

From the NTMP planning documents, I estimate that emergency response runs will suffer roughly 14 % delay in a sizable area, or over the whole city, if the program is fully applied to the streets in that area. This amounts to about 30 seconds typically and about one minute or more on long runs. Though the NTMP presently includes a condition that the delays must not exceed 30 seconds for any run, it is obvious from measured delays from individual traffic circles and speed humps that only sparse application of these devices would be possible under this criterion. So, the BFD is being pressured to allow a relaxation of original emergency response delay condition. The analysis presented here shows this move to be ill-advised. Even the original allowance of a maximum of 30 seconds involves an intolerable trade-off - lives will be lost due to a large risk/benefit ratio.

Sudden cardiac arrest (SCA, or simply CA) is the most common critical emergency needing prompt intervention. It strikes more than 350,000 people a year in the U. S. ("Sudden Cardiac Arrest", a Communicore publication). Scaled to Boulder, this indicates roughly 140 SCAs per year. About 90% of those treated within two minutes survive; while only about 10% survive if treated after 6 minutes. Survivors have a good long term outlook - about 80% are alive at one year and about 57% are alive at five years. This is impressive because the average age of victims is 65. (However, many victims are much younger, in their 30s and 40s).

Some statistics for Boulder roughly confirm the above scaled value of 140 CAs per year. Brad Baker of AMR, Boulder's ambulance service, informed me that they had "worked and delivered", to the hospital, 30 cardiac arrest victims in Boulder in 1996. Regardless of whether AMR or the BFD reached the victim first, both have roughly the same response times. So, the calculated present average survival probability of 30% for Boulder (see Appendix), if naively applied, indicates that the 30 "successful" resuscitations correspond to roughly 100 CAs. However, the calculations assume that defibrillation equipment is always available with the responding vehicle, which is not true at present; so the present success rate may be well below 30%. This consideration, taken by itself, indicates that substantially more than 100 CAs occur in Boulder each year. Also, not all CAs are reported as emergencies because the persons are found obviously dead or are reported too late for successful initial intervention, which further indicates there are considerably more than 100 CA's per year for Boulder. On the other hand, not all of the 30 victims delivered to the hospital survive long enough to be considered true survivors, which, by itself, would indicate fewer than 100 CAs per year for Boulder.

What is needed here is the number of CA emergencies that were either reported promptly or that were given CPR along with reasonably quick reporting. These "fortunate" victims would approximately follow the CA survival curve used in the calculations in the Appendix. From the discussion in the previous paragraph, 60 to 80 is a reasonable, perhaps conservative, estimate of the number of good prospects for successful resuscitation. In the Appendix, I have used 60. The final conclusions will not be changed even if these estimates are much in error.

The relevant CA survivability curves and the BFD response time curves are fairly well known. This allows a calculation of the number of survivals out of the "fortunate" victims for both the current response times as well as degraded or improved response times, as detailed in

the Appendix. The Appendix also has a written confirmation of the calculation procedure from Dr. Irving Weiss, who is a retired math professor and who specializes in statistical analysis.

From my estimate of 60 "fortunate" CA victims per year, the calculations in the Appendix indicate that roughly 5.3 additional deaths per year in Boulder can be expected if full neighborhood traffic mitigation is implemented. This assumes that the one minute response time improvement target of the BFD is not accomplished. If their goal is met, only to be negated by the NTMP, then roughly 6.5 additional CA deaths can be expected from the NTMP. I believe the BFD improvement goals are realistic and will be achieved. Therefore, I offer the 6.5 additional CA deaths as the best guess as determined by the present analysis.

But what about other time-critical, life-threatening emergencies? I have not been able to find sufficient data on these to make a satisfactory estimate. However, the worst possible assumption would be that there are *no* additional deaths from response delays for burn victims, heavy traumas, choking children, drowning victims, ruptured appendices, child birth emergencies, shock victims (electric, toxic, etc.), severe asthma attacks, and other critical emergencies. It is lamentable that better data is not kept with respect to these emergencies. As a gross guess, I estimate that at least two additional non-CA deaths per year would result from a one minute degradation in response times, for a total of roughly 8.5 lives per year.

## Discussion

To put the predicted consequences from a fully implemented NTMP in perspective, I note that 8.5 lives per year is three times larger than the usual 2.8 traffic deaths per year for the entire city. Further, these predicted additional deaths are very large compared to the 0.1 life per year assumed to be saved by this program. The present analysis indicates a risk/benefit ratio of 85 to 1, in terms of human lives (property loss risks are ignored here but are probably quite sizable). Over time, 85 additional deaths are predicted from delayed emergency response for each life saved, if any, by the NTMP.

Of course, the above comparisons are very rough due to the lack of precise data and the assumptions involved. Assuming a wildly optimistic posture, if the estimate for lives saved by the NTMP is low by a factor of three, giving 0.3 lives saved per year; and if the estimate for the lives lost due to delayed emergency response is high by a factor of three, then only about three additional lives lost per year are foreseen. Even with these rather absurd allowances, nearly 10 lives are predicted to be lost, over time, for each one saved by full implementation of the NTMP.

The risk/benefit ratio will be the same in mitigated *portions* of the city as for the *whole city*, as long as the mitigation is extensive enough to cause, on average, the same proportional delays in the emergency response curve. However, different models and analyses are needed for projects of limited extent - for example, a few obstructions on a cul-de-sac. Given the large risk/benefit ratios for extensive mitigation, it is likely that such local mitigation also involves significantly increased risk. *For the few special situations where obstructive mitigation appears possibly beneficial, the city should conduct the proper engineering studies rather than blindly allowing mitigation projects that might endanger the affected residents.*

## Appendix

### To: "Deaths Expected from Delayed Emergency Response Due to Neighborhood Traffic Mitigation"

## Cardiac-Arrest Emergencies in Boulder, CO Lives Saved or Lost Versus Emergency Response Times

### The Basic Data

The Boulder Fire Department (BFD) Master Plan contains data on the survival probability for cardiac arrest (CA) emergencies in terms of the time delay before treatment occurs (from textbook data). Histograms of responses of Boulder's fire trucks to emergency calls are also given (the fire department provides the early medical treatment). Along with data for the yearly number of CA emergencies, reasonable estimates can be made for expected survivals not only for the present situation but also for several relevant scenarios, such as delayed responses due to traffic mitigation or quicker responses due to anticipated improvements in equipment and protocol.

Pages A3 and A4 are copies from the BFD Master Plan that show the three key curves in Figures 7 and 10 from that plan: (1) the smoothed BFD response histogram (Figure 7); (2) the cumulative arrival time curve (Fig 10), which is simply an integration of the smoothed response histogram; and (3) the survival probability for CA emergencies as a function of time. The survival curve relates to victims who are given defibrillation treatment. This curve does apply to the BFD as they are now purchasing defibrillators.

Page A5 shows a spreadsheet and some graphs of the pertinent data. The data in the leftmost 6 columns was scaled from Fig. 10 on Page A4. There are three additional hypothetical response time data sets, each proportional to the present response data:

- "0.14 quicker" than present, which amounts to a one minute improvement in the present 90% response time of 7 minutes and is BFD's goal for the near future
- "0.14 slower" than present, which is an estimate for response delays within and beyond any area effected by full mitigation according to the original Boulder NTMP (eventually, the area effected could be most of the city)
- "90% within 4 minutes", which is the response-time goal of Boulder's peer cities

The hypothetical curves were formed by applying proportional changes to the time axis of the "present" curve. For the mitigation-delayed response curve, a proportional change assumes that the mitigation obstructions are, on average, spread uniformly along the routes. The proportional degradation or improvement is also applied to the roughly one minute time interval between notice of the emergency and leaving the station. While it is appropriate to assume that the "roll out" times will be shorter for the improved response scenario, the mitigation devices will not degrade the roll out times. So, there is a small error in proportionally increasing roll-out times for the degraded scenario.

## Integrating the Probabilities to Determine the Survivors

While there is no arrival time histogram for CA emergencies alone, it is reasonable to assume that the arrival time histogram for CA emergencies is the same as that in Figure 7, which is for all fire and medical emergency calls.

To have symbols for the ordinates of the curves in Figures 7 and 10, let  $F$  represent the smoothed arrival time histogram of Figure 7, let  $S$  represent the survivability curve of Figure 10, let  $A$  represent the cumulative arrival time curve of Figure 10.

To perform an approximate integration using these curves, we will need some approximate formulas that are well within the accuracy of the data base for the curves. Let  $X$  be the number of "fortunate" (Page 2, main text) CA emergencies per year. Since  $F$  is the fraction of total arrivals per minute interval at a given arrival time, the number of CA emergencies per year reached within a time interval  $DT$  ("delta"  $T$ ) centered at a given arrival time is  $DT * F * X$ . Then, the number of lives saved for the given arrival time period is  $DT * F * X * S$ . To carry out the approximate integration over all arrival times, it is convenient to make some substitutions in this formula.

Now refer to the graph on Page A5, where a  $DT$  of one-half minute is shown. Because the cumulative arrival time curve,  $A$ , is simply the integral of  $F$ , it follows that  $DT * F$  for a given time interval is equal to  $(A_E - A_B)$  for the corresponding time interval. ("E" refers to the end of a time period and "B" refers to the beginning). Further,  $S$  expressed in terms of the beginning and ending values is  $(S_E + S_B)/2$ , the average value for the interval. So, the number of lives saved for any given time interval is  $0.5 * (S_E + S_B) * X * (A_E - A_B)$ . For a given number of cases per year, the sum of these formulas for all half-minute intervals from 1 to 10 minutes gives the predicted total number of lives saved per year.

The formulas in the rightmost four columns of the spreadsheet are  $0.5 * (S_E + S_B) * (A_E - A_B)$ . The  $X$  has been factored out and applied later, as shown in the area just below the column sums. Each column sum is the average survival probability for randomly reported CA emergencies in Boulder for the corresponding arrival time curve.

From the discussion in the main text,  $X=60$  is an estimate of the "fortunate" emergencies. This estimate is for the "most probable" case rather than either end of a range of reasonably likely possibilities. The approximate integrations performed here show that roughly 10% of these "fortunate" CA victims are saved or lost by one minute changes in the present 90% response time.

Dr. Irving Weiss has supplied a formal derivation along with a confirmation of the integration procedure (See Page A6). The integration procedure has also been verified by using some simple postulated probability distributions that have obvious results.

Figure 7

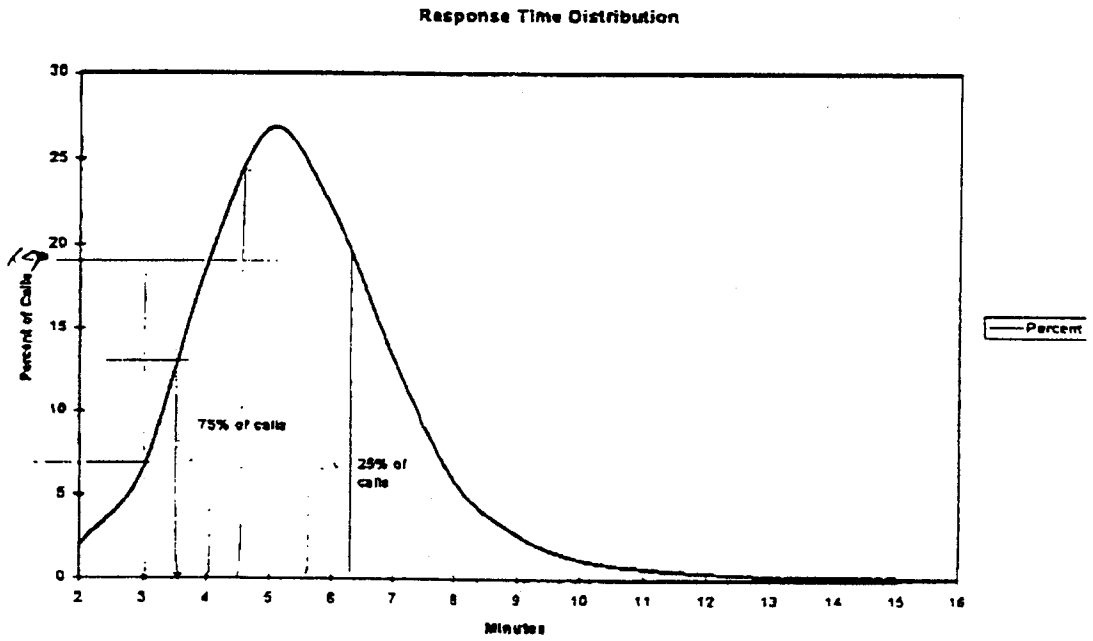


Figure 8

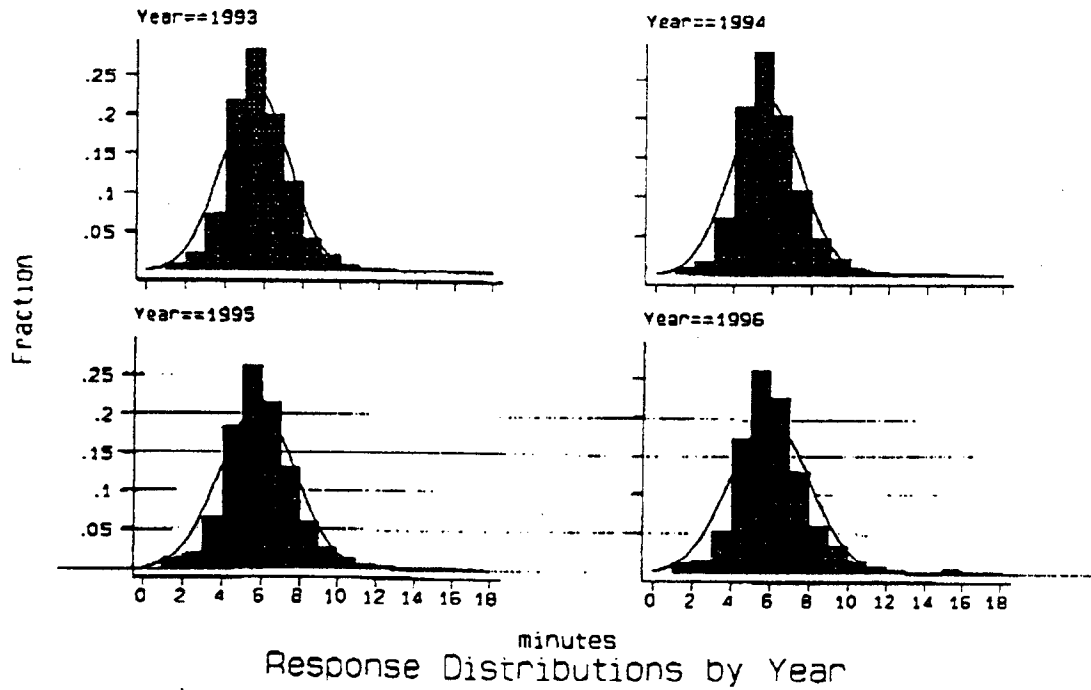
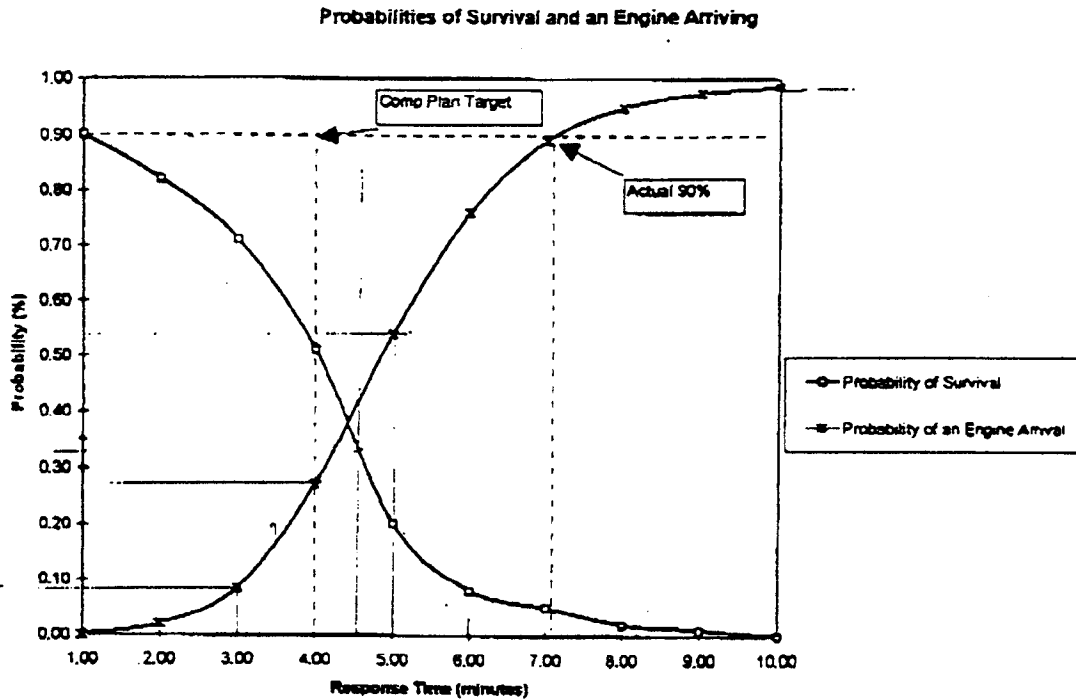


Figure 10



A=19

**Why Are The Response Times Increasing?**

Boulder currently delivers emergency services with six engine companies and a ladder company based out of six fire stations located throughout the city. This configuration of stations and apparatus was developed in response to Resolution 208, Report of the Joint Fire Study Committee in 1976. Since the 1976 adoption of Resolution 208, Boulder has changed dramatically. The population has increased, the geographic boundaries have expanded due to annexation, the density of the City has increased due to in-fill, and Boulder has evolved into a regional business and retail center. Today, in-commuting far exceeds out-commuting resulting in a large daytime population.

These changes in Boulder's character and size impacted three major factors related to response time: 1) demand and capacity related issues; 2) travel distance; and 3) traffic congestion and mitigation.

**Demand and Capacity Issues — Two Boulder Fire Stations Are Beyond Their Capacity**

Over the last twenty years, Boulder's population increased approximately 25 percent, while fire department calls increased approximately 425 percent. Most of this increase in calls for service is attributed to the advent of emergency medical responses in 1976. However, a recent trend analysis of the rate of change in service demand and population shows the rate of change in demand dramatically exceeding the rate of change in population, Figure 11 (also see Figure 1).

A4

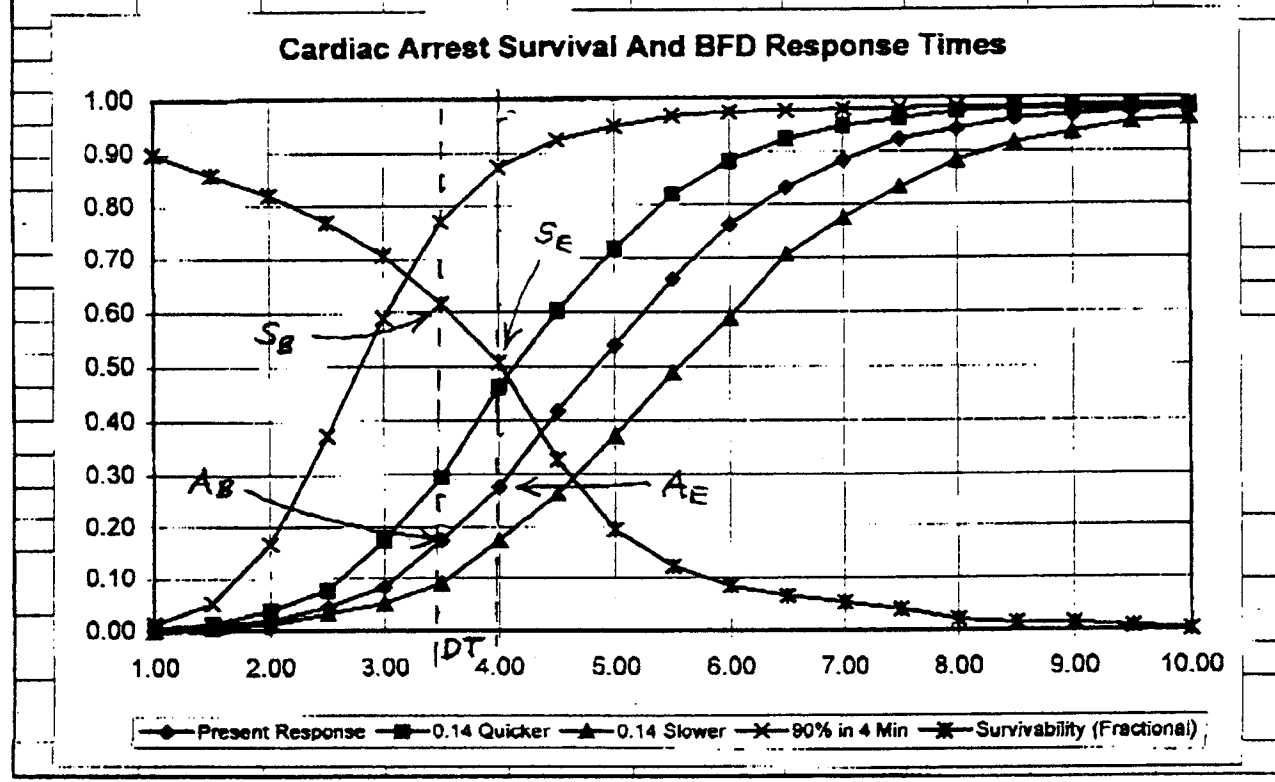
## Consequences of Emergency Response on Cardiac Arrest Survival

R. Bowman & W. Hultquist 3 April 1997

Arrival Time	Fraction Within Arrival Time				Survivability (Fractional)	Survival Predictions for X Cases			
	Present Response	0.14 Quicker	0.14 Slower	90% in 4 Min		60.00 Present	60.00 14 % Imp	60.00 14 % Del	60.00 4-min/90
1.00	0.00	0.00	0.00	0.01	0.90				
1.50	0.01	0.01	0.01	0.05	0.86	0.01	0.01	0.01	0.03
2.00	0.02	0.04	0.01	0.17	0.82	0.01	0.02	0.01	0.10
2.50	0.04	0.08	0.03	0.37	0.77	0.02	0.03	0.02	0.16
3.00	0.08	0.17	0.05	0.59	0.71	0.03	0.07	0.01	0.16
3.50	0.17	0.29	0.09	0.77	0.62	0.06	0.08	0.03	0.12
4.00	0.28	0.46	0.17	0.87	0.51	0.06	0.09	0.05	0.06
4.50	0.42	0.60	0.26	0.92	0.33	0.06	0.06	0.04	0.02
5.00	0.54	0.72	0.37	0.95	0.19	0.03	0.03	0.03	0.01
5.50	0.66	0.82	0.49	0.97	0.12	0.02	0.02	0.02	0.00
6.00	0.76	0.88	0.59	0.97	0.08	0.01	0.01	0.01	0.00
6.50	0.83	0.92	0.71	0.98	0.06	0.01	0.00	0.01	0.00
7.00	0.88	0.95	0.78	0.98	0.05	0.00	0.00	0.00	0.00
7.50	0.92	0.96	0.83	0.98	0.04	0.00	0.00	0.00	0.00
8.00	0.94	0.97	0.88	0.98	0.02	0.00	0.00	0.00	0.00
8.50	0.96	0.98	0.92	0.98	0.01	0.00	0.00	0.00	0.00
9.00	0.97	0.98	0.94	0.99	0.01	0.00	0.00	0.00	0.00
9.50	0.97	0.98	0.96	0.99	0.01	0.00	0.00	0.00	0.00
10.00	0.98	0.98	0.96	0.99	0.00	0.00	0.00	0.00	0.00
					Totals	0.31	0.42	0.22	0.66

X= 60	Lives Saved Out of X Cases:	18:79	25:29	13:47	39:76
	Change from Present:		6:51	-5:31	20:97



A5



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1635 Mariposa Ave.  
 Boulder, Colorado 80202  
 March 19, 1997

Mr. Ray Bowman  
 Pacemark Inc.  
 5455 Spine Rd.  
 Boulder, Colorado 80301

Dear Ray:

I have checked your method for estimating the probability of surviving a heart attack when treated by the emergency services of the Boulder Fire Department and have found it to be correct. Your use of numerical integration is formalized below.

Let  $S$  = the event that a person survives a heart attack due to emergency action of the BFD.

$T_1$  = time interval in which the BFD arrives.

$$\text{Now } S = (S \cap T_1) \cup (S \cap T_2) \cup \dots \cup (S \cap T_n)$$

I am using a discrete model rather than a continuous one to avoid curve fitting and to simplify calculations.

Let  $P(S)$  = Probability that a given individual survives due to BFD action.

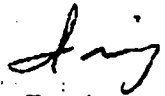
$$\text{Then } P(S) = P(S/T_1)P(T_1) + \dots + P(S/T_n)P(T_n)$$

This equation corresponds to the righthand four columns in your table: "Consequences of Emergency Response on Cardiac Arrest Survival".

To obtain the average or expected number of survivors,  $E(S)$ , multiply the number of cases,  $n$ , by  $P(S)$ .  $E(S) = nP(S)$ . Let  $Q(S)$  be the probability that one does not survive emergency treatment; is is fatality. Then the expected number of fatalities,  $E(F)$  is

$$E(F) = nQ(S) = n - E(S).$$

Sincerely yours,



Irving Weiss, PhD