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CDE #31806

# Improve Your 9-1-1 Service by Answering the Phone

## USING ERLANG-C TO COMPARE PSAPS

BY MICHAEL LAFOND

PHOTO KEVIN LINK

Comm center performance can be predicted and pre-planned using models, such as *Erlang-C*. Referenced in the APCO/NENA ANS 1.102.2-2010, 3.2.15.1 Standard Criteria, the base standard for answering calls in 9-1-1 centers is prescribed by NENA:

> "**3.1 Standard for answering 9-1-1 Calls.** Ninety percent (90%) of all 9-1-1 calls arriving at the Public Safety Answering Point (PSAP) shall be answered within ten (10) seconds during the busy hour (the hour each day with the greatest call volume, as defined in the NENA Master Glossary 00-001). Ninety-five (95%) of all 9-1-1 calls should be answered within twenty (20) seconds."[1]

The standard is rigorous. Notice that averages are not even mentioned, because average numbers are too general to be effective measurements of performance. Of course, by assigning the standard for the "busy hour," the standard becomes the outer limit, the minimum level of acceptable service at all times. The performance of a PSAP in answering is a relatively direct function of providing enough calltakers for the number of calls to be received.

Random variables, such as those found in a 9-1-1 center, are the study of statistical analysis. Although individual 9-1-1 calls are unpredictable, large numbers of calls over time tend to form patterns that are describable and measurable. This fact becomes the basis for the NENA standard. Some people misunderstand the word "random" to mean entirely unpredictable; however, this is not correct in the study of probability and statistics. For mathematicians, a random variable is by its nature something that can be measured through specific techniques. We will be able to predict the necessary staffing to meet the NENA standard by examining the 9-1-1 service process statistically.

The maths required to do this type of analysis with maximum accuracy are quite complex. So much so that it would be inconvenient or impractical for most call centers to employ someone with the necessary expertise to evaluate the system from month to month. The level of accuracy requiring such expertise, however, is not really necessary

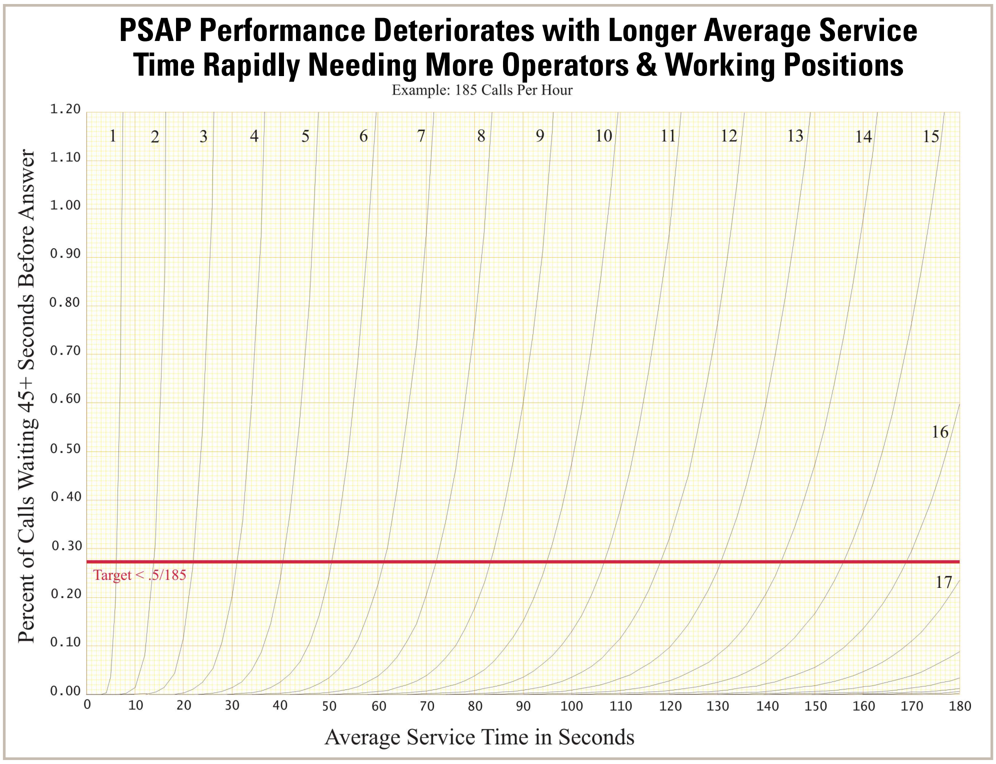


**Figure 1:** This graph is complicated because it is not just a graph; it is also an Erlang-C Calculator from 1996. It shows how many telecommunicators Erlang-C predicts are necessary to achieve a service goal of 99.73% calls answered within 45 seconds (here expressed in the negative as percentage of calls waiting 45+ seconds) for a call rate of 185 calls per hour. This goal happens by chance to be virtually identical in effect to the current NENA standard. To use the calculator, find the average service time that reflects the operation and follow the graph line up from 0 to the red target line 0.27%; at the intersection the necessary number of telecommunicators is the line to the right of this intersection. At the time, 185 calls per hour was the highest traffic intensity ever received in our PSAP, so it was a solid basis for estimating staffing needs. I have included this graph to visually show the relationship of service time to staffing needs and performance. Notice how simply increasing the service time, with all other factors remaining the same, mathematically demands additional personnel. Now follow a line representing the minimum number of telecommunicators from 0 upward and see how the decreasing performance is directly related to the increase in service time. Also, the effect of adding telecommunicators is non-linear, and the negative effect of increasing the service time is reduced as the number of telecommunicators is increased.

to manage a system. I am going to show how a 9-1-1 center manager can use the Erlang-C formula to estimate and achieve control of call loads and make key decisions on staffing, process and structure in the 9-1-1 system.[2]

In 2005, APCO International published a study that reported:

"Although Erlang calculations are often referred to as the most useful formula for determining appropriate staffing levels, only 15 percent of the large centers reported using it."[3]

This is probably due to the intimidating mathematics involved in Erlang calculations. Although the Erlang-C formula is complex, many inexpensive computer programs are available to do the calculations automatically. The only effort required is to learn how to use the information in a meaningful way, as I am going to demonstrate in this article.

The importance of having such a model of performance should be obvious, because staffing is, of course, critical to the performance of any 9-1-1 call center in meeting the call-answering standard. It is also useful in ensuring the overall performance and stability of the center as a whole:

"The absence of readily useable processes and formulas to determine appropriate staffing levels appears to be a major factor contributing to excessive use of overtime to compensate for lack of adequate staffing. Excessive use of overtime is widespread and is a major contributor to staffing and retention problems in the industry. And we conclude that excessive overtime requirements that result in the loss of control over personal time contribute more to employee 'burnout' than the emotionally demanding nature of the job."[4]

Consequently, although some of the concepts that we are about to discuss are difficult, it will be worthwhile to discuss them.

## PRELIMINARY CONSIDERATIONS

The NENA standard does not use the word "waiting," but waiting time limits are exactly what it prescribes. If 90% of calls are answered within 10 seconds, then 10% are waiting longer. The standard is stating that no more than 10% of calls may be allowed to wait longer than 10 seconds before answer. This is called a *service-level goal*.

To use the Erlang-C formula or computer program, some commonly available information must be gathered: The expected call-arrival rate must be known (i.e., the number of calls per hour or half hour). Most programs will require half-hour or one-hour increments. To get this number, simply examine the hour of the day in question for a month and use the average. A good practice is to also look at the average for the same month in the previous year and use whichever is the higher number.

Another key piece of information required by Erlang-C is the average call-processing time (aka, talk time or service time for the type of position). This average should be the quotient of all call times divided by the total number of calls for all calltakers, including extreme times. Some managers want to discard the very long times in police calltaking positions, because they don't feel they're representative; however, this is improper because those calls can happen anytime as well. To accurately predict, a true average is necessary.

The hold time (aka, wrap-up time) is also important. This is the time required to do the paperwork and whatever else is necessary to complete the processing of the call after the calltaking has finished. Some programs don't allow for this time; and in this case, the averaged number is simply added as part of the average service

time to fulfill the true total average service time. It's important to account in the service time for the total time the calltaker is occupied until ready to take the next call.

The expected service level is usually and most accurately expressed as the percentage of calls to be successfully answered within a specified waiting-time limit. Of course, an accredited 9-1-1 center will want to achieve the NENA standard or better. An obvious question is, "Why do we not answer all calls within 10 seconds?" It's possible to aim for perfection; however, in doing the calculations for the number of agents required to achieve such a level, the practical considerations will become clear. For goals to be useful, they need to be achievable.

Finally, of course, we are usually looking for the number of agents required to meet the specified service level goal. For the purposes of this article, I will always use the NENA standard as the service-level goal.

At a calltaking position, the Erlang-C formula describes the relationship between the call-arrival rate, the average service time (including the hold or wrap-up time), the service level, and the number of calltakers. If we know any three of these numbers, we can calculate the unknown factor. Generally, we are calculating the number of calltakers needed to achieve a service level or we are calculating the expected performance (service level) of a number of calltakers. With a program, of course, these calculations are easy to do.

The Erlang-C formula assumes a constant pace of traffic overall. Although the calls arrive at different intervals randomly, the rate is supposed to be pretty much constant and not increasing or decreasing. In reality, of course, the number might very well be increasing or decreasing during a given time period; however, this is usually not significant enough to invalidate the estimate, and as a practical matter all methods of estimation are inaccurate to some degree.

Another assumption of the Erlang-C formula is that 9-1-1 calls arrive in a truly random fashion. This is not a good assumption in a PSAP, because although many calls do arrive randomly, some kinds of incidents generate spurts of calls that are related to the same incident and so are not truly random. For example, a visible fire will usually generate many calls from the area. Calls will peak within several minutes and then ebb as the fire suppression units arrive. All of the calls will be related to the same incident, together with random calls also arriving interspersed among the fire calls. Many other kinds of incidents also generate multiple calls, creating a large spurt of call arrivals, and such effects demand more personnel to handle the influx. Moreover, it is not uncommon to see overlapping spurts, which further stresses the 9-1-1 system. Consequently, the Erlang-C formula, because it assumes truly random call arrivals and intervals, tends to underestimate the number of operators needed. However, this underestimate is more accurate for determining the minimum staffing needs than anything other than computer simulation models.

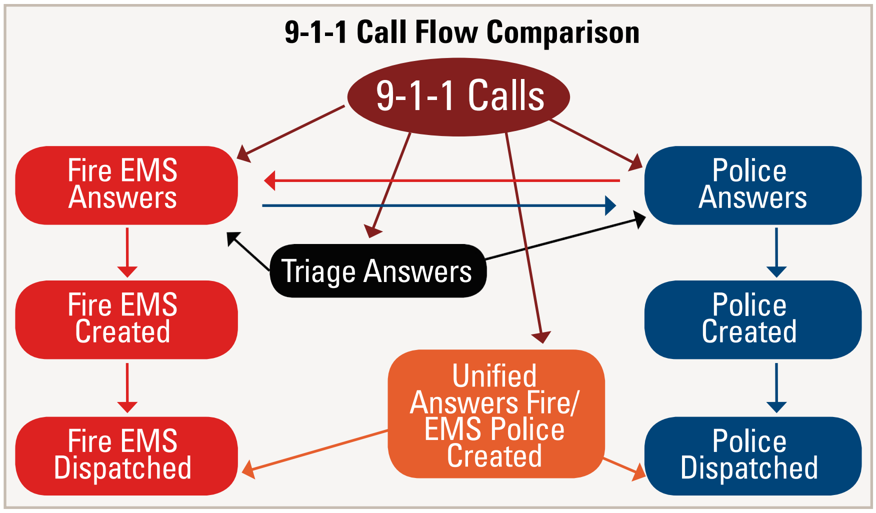


**Figure 2:** Four different directions for 9-1-1 calls represent different options for the structures of 9-1-1 centers.

After seeing how important the average service time number is to the efficiency and effectiveness of the calltaking position, most managers are tempted to try to reduce the number artificially through policy changes and applying pressure to calltakers. Such attempts, however, usually backfire with serious negative consequences and achieve little benefit. Because the average service time is the result of a large sample, it is by nature resistant to artificial efforts. Policies and the cooperation of the 9-1-1 callers are limiting factors. In reality, calltakers who are well-trained have limited immediate control over the length of any call.

Our goal is 95% of calls answered within 20 seconds, but many managers only have a number available for the average calls per hour. Thus, to know if the goal is being met, we must convert the average into the 95th percentile. If you have access to or can calculate the standard deviation (SD) for the data producing the average, then simply add two standard deviations to the average, which will return a value for wait-times just above the 95th percentile. If the SD is not available, we are going to have to make a crude estimate based upon general experience with call loads, which is that two standard deviations in a 9-1-1 call center is usually about 25% of the mean.

## BASIC PSAP FACTS

It should be obvious that having multiple calltakers receiving the same kind of calls from a common queue, first-in-first-out, is more efficacious than separate queues for separate calltakers. All systems answer with maximum and equal efficiency until the number of calls exceeds the number of calltakers for that system. One call at a time per calltaker with no holds is the safest and most efficient practice. Calltakers who are not ready are not available and cannot be counted (i.e., an operator on break or otherwise occupied has reduced the capacity of the system). Calltakers cannot be occupied with other tasks and still be considered ready, and so occupied calltakers have reduced the capacity of the system.

Even in a busy system, there will be significant idle time, and idle time is absolutely necessary to maintain stability of the operation. Non-emergency queries often take longer than emergency calls to process, because greater effort must be taken to avoid potential but unknown liability. Not all of these facts are entirely obvious, but with experience and study, these conclusions are borne out universally.

The four systems we will examine

apply mostly to 9-1-1 centers with large call loads, where efficiency and effectiveness are nearly synonymous. Smaller centers sometimes have to use creative alternatives that are usually more efficient in terms of cost but less effective in providing service; however, the principles discussed here may still be useful and suggest other approaches.

Although all centers have their own unique policies, community factors and idiosyncracies that contribute to some variation in average service time, enough similarities exist between call centers to generalize. For example, general police service times including all types of incidents will range from three to four minutes on average, including some very long calls in particular cases and very short calls in many cases. Fire and medical calls average shorter service times—around two minutes. Triage service times are much shorter, near 30 seconds. In addition, all systems require roughly 10 seconds for wrap-up or transfer.

Therefore, for this discussion, we will assume average service times: three minutes for police, two minutes for fire/medical and 30 seconds for triage, plus an additional 10 seconds for wrap-up/transfer. Also, we will be assuming that the dispatching of responders is handled at separate positions. Although communities may have different needs, most diverse communities generate roughly 70% law enforcement and 30% fire/medical calls. We will not further complicate matters by considering the transfers to agencies outside the primary PSAP jurisdiction.

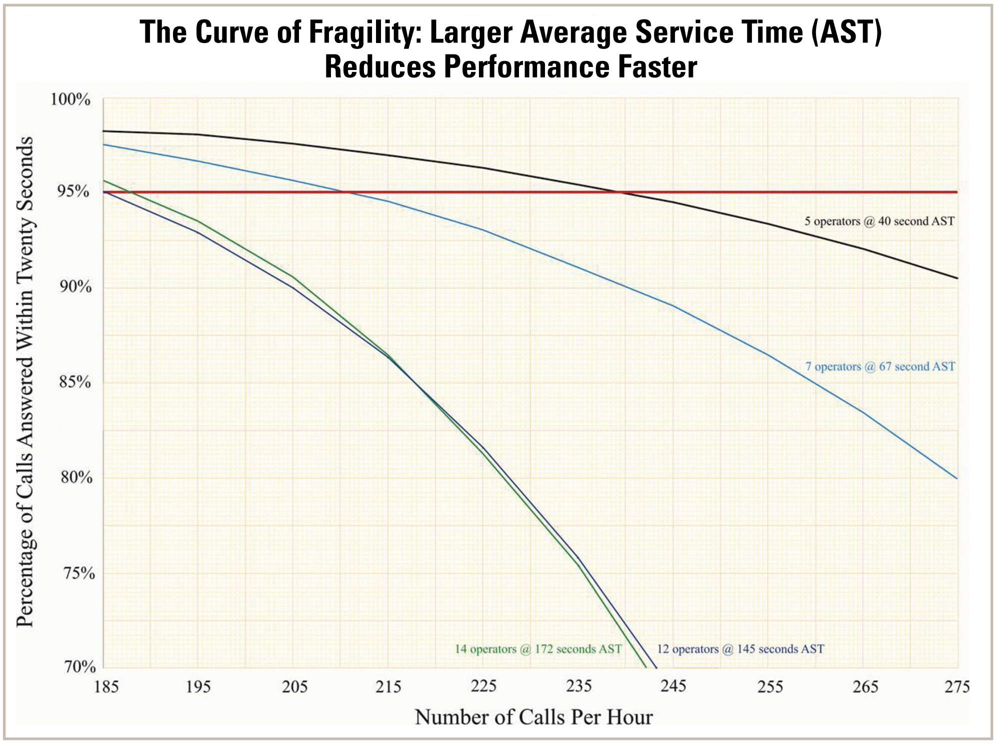


**Figure 3:** This graph demonstrates that higher service times make a calltaking position more vulnerable to increases in call load. The slope of the curve shows the fragility of the operation. Higher service times decrease service rapidly when call traffic increases.

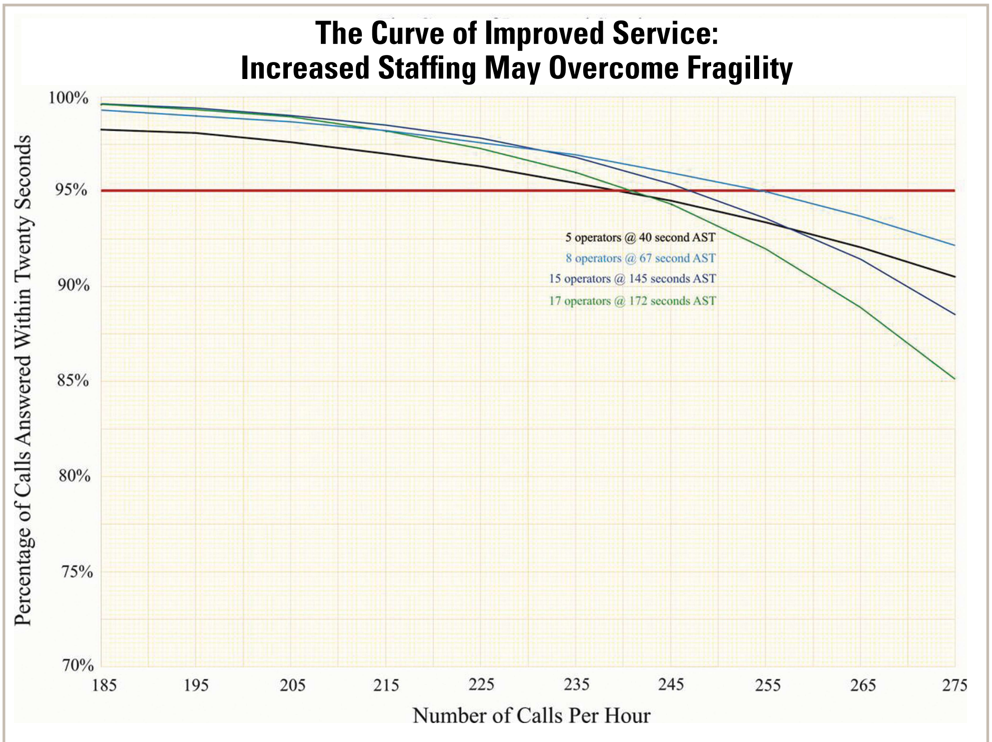


**Figure 4:** The triage PSAP has not changed in staffing at five telecommunicators. With staffing for 25% more calls to simulate the 95th percentile, all the slopes become more similar, suggesting that performance also would be similar. There's still reason for concern, however, because this does not account for the spikes of related calls. If anyone is able to test the effects under real call loads, please e-mail me at info@911serviceanalysis.com.

## BREAKS

As an arbitrary estimate, 10 minutes every two hours is reasonable for the triage PSAP. For the other more demanding calltaking positions, some have recommended 10 minutes every hour; however, this is based on continuous under-staffing and overworked operators. Taking into account that more than 50% of the time the workload will be quite low in a properly staffed system, 10 minutes every two hours becomes reasonable for all systems.

For staffing purposes, the natural conclusion is that one break person for every 10 calltakers is appropriate. Of course, if no one is on break, the performance of the system will be improved by the extra calltakers.

## CALCULATING PERFORMANCE & COMPARING PSAP STRUCTURES

Regarding the needs of emergency call centers, we have so far neglected mentioning secondary PSAPs, which should be included in any cost evaluation of the 9-1-1 systems. The secondary PSAPs can be measured in the same manner as primary PSAPs and added to calculate the costs of the total system.

We will assume, as an arbitrary example, that the busy hour call load for the primary PSAP is 185 calls per hour. Adding 25% as an estimate of two standard deviations to exceed the expected load of 95th percentile, the total number of calls expected will be 231 calls per hour.

The first system that we will examine is uncommon; it is the unified police/fire/medical calltaker with transfers only to outside jurisdictions. This system, of course, makes enormous training demands on operators and requires extraordinary cooperation between law enforcement and fire departments. It does have the advantage of making possible that all agencies in a jurisdiction are at least aware of all other incidents. All calls are potential reports and must be processed fully. Redundant calls may be screened but even redundant calls must be questioned as normal to determine that no significant new information is available on the call; this provides no significant reduction in the load. Consequently, the average service time will be the weighted average of 70% police and 30% fire/medical calls plus 10 seconds ([0.7 x 180] + [0.3 x 120] + 10), which equals 172 seconds. Therefore, 17 operators and two break persons is the total cost for 231 calls per hour at the 95th percentile level.

This is a very small base cost in terms of personnel, but it is also very dangerous, because this PSAP has no adaptability to unexpected increases in call loads (compare Figures 3 and 4). Training is demanding and costly; it may be difficult to find anyone who can master this position. Policy issues and separating the functions could create problems, because coordinating the competing demands of two customer agencies at the same time might be impossible. Of course, theoretically, if it is sufficiently staffed, it should work; however, it's difficult to know how many operators are really enough, because there is no tolerance for the unexpected. Yet, even with all of these negatives, it's still tempting because of the obvious advantage that no transferring is necessary.

For the police PSAP, we should assume that the 30% fire/medical calls must be transferred after determining through questioning that they are not by nature law enforcement calls. This is the same function as triage, so it's a good assumption that these calls will have an average service time of 30 seconds plus 10 seconds for transfer. Therefore, the average service time will be a weighted average of 70% law enforcement and 30% triage plus 10 seconds ([0.7 x 180] + [0.3 x 30] + 10), which equals 145 seconds. For 231 calls per hour, 15 operators and two break persons are needed; however, the fire/medical secondary PSAP will require six calltakers plus one break person for a total of 24 personnel. Training and retention and policies don't have any unusual pressures or conflicts. Ninety percent of emergencies are

transferred, and bottlenecks at the police primary PSAP mean that fire and medical emergency calls will be delayed.

For the third system, the fire/medical PSAP, which is less common but significantly represented in the U.S., 70% of the calls will be triaged and transferred to law enforcement and 30% will require full calltaking. Therefore, the average service time will be a weighted average of 70% triage and 30% fire/medical plus 10 seconds ([0.7 x 30] + [0.3 x 120] + 10), which equals 67 seconds. For a 95th percentile of 231 calls per hour, 185 calls per hour average, 8 calltakers and one break person is needed; but for the secondary police PSAP 13 operators and two break persons are required, for a total of 24 operators. Ninety percent of emergencies don't need to be transferred. Policy conflicts are possible but should not be crippling. Dispatching and calltaking functions should not be shared except in extreme conditions because of the intensity of call traffic and the need to keep calltakers immediately available. Additionally, preliminary basic prioritizing of police calls can produce further benefits.

The fourth system, the triage PSAP, transferring 100% of calls with an average service time of 30 seconds plus 10 seconds transfer for a total of 40 seconds. The triage PSAP needs five operators and one break person for a 95th percentile of 231 calls per hour. All calls can be screened for redundant and non-emergency calls. Preliminary basic prioritizing is available and useful. Assuming that 30% of all categories of calls can be screened, for 231 calls per hour, the secondary fire/medical PSAP should require five agents and one break person; however, some of these can be shared with dispatch positions, because the call traffic is low. The secondary police PSAP with no calls screened needs 11 agents and two break persons. Therefore, the total number of operators would be 25 for a 95th percentile 231 total calls per hour. All emergency calls are transferred. Training and retention and policies do not have any unusual pressures or conflicts. Much less training is required for the triage PSAP operators, and this can result in significant savings in cost. The short service times do allow surplus calls to be shared with other emergency and non-emergency positions on an *ad hoc* basis, greatly increasing the adaptability of this configuration.

## TOLERATING SPIKES

The greatest challenge to service in a properly staffed 9-1-1 center are heavy spikes or spurts of traffic. A community disaster is experienced as a sustained extreme spike in communication loads, so the same principle applies. Most of the traffic received in a 9-1-1 center is not strictly random; commonly spikes arrive as groups of calls and the groups are random, but the individual calls are bunched together in a manner that Erlang-C cannot account for. Measuring and accounting for the spikes would require a far more complex simulation program tailored to the specific set-up of the 9-1-1 call center.

If cost efficiency is important, then the best system is the most resilient system. The triage PSAP, with its short service times, is the most effective at withstanding sudden increases in call loads. Other systems run into difficulties as soon as a spike in traffic much exceeds the number of telecommunicators. For small 9-1-1 centers, the cost of the triage PSAP may be too high to be workable; however, the nature of this structure is such that several nearby 9-1-1 centers can easily share a triage PSAP efficiently, and sharing will greatly reduce costs.

## FINAL CONSIDERATIONS

It is reasonable and appears to comply with the NENA standard to adjust to the expected call load of each hour—at least that's how it was interpreted by L. Robert Kimball and Associates Architects and Engineers in their report published by NENA, although this may not have been the original intention of the NENA wording.[5] The standard is relatively new, however, and still evolving so that practical adjustments are necessary. It can be extremely wasteful to continually staff for peak hours during non-peak hours, when the fluctuations between them are significant. The same can be said for seasonal fluctuations in call load and unexpected growth. Consequently, it becomes imperative to monitor call loads continuously and to implement changes in expected optimum staffing from month to month for all hours of the day.

There's another formula, Erlang-B, that calculates the number of trunks needed from the same data. The result is the maximum total number of lines occupied, which means calltaking in progress plus the calls waiting in the queue. Every call needs to occupy a physical trunk. It is wise to double this Erlang-B number, so as to never run out of trunks, which would create busy signals. Of course, the percentage of cellular trunks to land lines should reflect the percentages in the call loads. Many Erlang-C calculators provide the Erlang-B number simultaneously.

The obvious conclusion from the above discussion is that large 9-1-1 call centers, with their unpredictable and sometimes extreme loads and conditions, would be better served by the triage system. In addition to the better service levels, the triage PSAP also has the additional advantages of being able to screen redundant calls and to rudimentarily prioritize some high-level calls. Yet in spite of these advantages, this system remains rare. The main objection to the triage PSAP over the years has been that the need to transfer every call creates a "delay" of 40 seconds on average, because no dispatches are created at the triage position. This objection is quite sensible if the call center is designed to receive only a specific number of calls at a time; however, as soon as the number of calls arriving exceeds the number of available operators, this assumption breaks down, and delays created in wait-times become far more devastating to service. Also, as previously mentioned, serious emergencies are usually shorter in processing time, because the need for immediate help is obvious to both the calltaker and the caller.

Another factor that should be considered is the number of actual emergencies contained in the respective call loads. While 95% of fire/medical calls require a lights-and-siren response, less than 5% of law enforcement calls are so urgent. This makes the police PSAP a very poor choice for the obvious reasons that about 90% of emergency calls will need to be transferred, even after waiting behind non-emergency calls, creating long but predictable delays in critical situations. Although the triage PSAP does require a transfer for these calls, it eliminates long waits before answer, ensuring faster

processing of emergency calls on a consistent basis.

Nothing destroys the credibility and effectiveness of a 9-1-1 system more than not answering promptly. Because every call is an unknown potential crisis situation, every call must be answered as fast as possible. A call ringing longer increases the possibility that the caller will give up, causing deadly delays, lost information, and dire consequences. The public expects us to answer promptly; answering promptly is critical to our mission; therefore, we should answer the phone promptly. ||PSC||

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## REFERENCES & END NOTES

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