

RESEARCH

Comparing the number of Emergency Medical Dispatchers (EMDs) scheduled based on the judgment of the managers with predictions of the Erlang C formula: a brief report

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Abstract

Introduction: Currently, at Tehran Emergency Medical Service (EMS) centre, Emergency Medical Dispatchers (EMDs) are scheduled based on the managers' experimental estimates. In this study, we planned to evaluate the conformity of managers' predictions with the Erlang C formula estimates in scheduling EMDs.

Methods: First, the Emergency Medical Communication Centre (EMCC) performance was evaluated over one week. Afterwards, the number of required EMDs was calculated using the Erlang C formula. Finally, the predictions of the Erlang C formula were compared with those of managers' judgments.

Results: During the study period, 79,583 calls were received by the Tehran EMCC. The average number of EMDs per hour ranged between 9.5 and 22.7. The actual number of EMDs was more than Erlang C formula predictions during the 24 hours in all but three time points, i.e. 14:00–14:59, 15:00–15:59 and 18:00–18:59. In all hours, 90% of calls were answered in less than 10 seconds, and the average waiting time for a total of one week was 7.3 seconds. Also, only 2.1% of all calls were answered after 10 seconds.

Conclusion: In the current study, we found that the number of EMDs scheduled based on the managers' experimental estimates was higher than that of the Erlang C formula calculations. Also, it was found that the waiting time for emergency calls was lower than the defined standards. Although the primary results of the current study indicated that, at least on paper, the Erlang C formula has the potential to be used as a predicting model in the Tehran EMCC, further research is required to evaluate its effect on the actual performance of the EMCCs.

Keywords

Emergency Medical Dispatcher; Erlang C formula; Emergency Medical Services

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INTRODUCTION

Call response protocols are required for all Emergency Medical Service (EMS) centres. Therefore, all Emergency Medical Dispatchers (EMDs) in Emergency Medical Communication Centres (EMCCs) must be well-trained, and their performance must meet these standard protocols (1,2). Additionally, an EMCC must have specific disaster forecasting protocols (3,4). One of the crucial issues in any EMCC is scheduling the EMDs' working shifts. The common method for such planning is called the stationary independent period by period (SIPP) approach, which means dividing the workload per day or week into shifts, then constructing a queuing model for those shifts (5). The problem is that this method may lead to inappropriate staffing levels (6). In other words, because of the unsteady arrival rates of the

incoming calls to the EMCCs, EMDs may have too much free time during one shift, while in another shift they find themselves struggling with higher loads of incoming calls (7,8).

The EMDs of the Tehran EMCC are registered nurses experienced in handling emergency calls. They are also able to give instructions to the first responders and laypeople on the scene. Moreover, they guide the missions of emergency medical technicians (EMTs) all day long.

According to the National Emergency Number Association (NENA) standards, 90% of 911 calls must be answered within 10 seconds, and 95% must be picked up within 20 seconds (9). In the Tehran EMS centre, calls that are not automatically connected in less than 8

seconds are transferred to a separate server and are considered as on-hold calls.

There are different models for calculating the number of EMDs needed to meet these standards. For instance, the Erlang formula, which was introduced by Anger Krarup Erlang, describes the probability of queueing for an incoming call. This formula has different models, including Erlang B and C. These Erlang calculators estimate the number of operators needed to run a call centre for any predefined service level (10).

Tehran EMCC is supervised by three managers. Despite introducing different formulas for scheduling EMDs, such as using the Erlang formulas (10), at this time there is no specified method for scheduling the EMDs at the Tehran EMS centre, and they are still scheduled based on the managers' experimental estimates.

In this study, we planned to evaluate the conformity of the number of EMDs scheduled by the Tehran EMS centre managers with the Erlang C formula predictions.

METHODS

Study design and setting

This cross-sectional study was conducted from 22 to 28 May 2020 in the EMCC of Tehran EMS, in Iran. Due to resource restrictions, simple sampling was applied to include all incoming calls over the seven days. Also, there were no exclusion criteria.

The EMCC operations include receiving calls, dispatching EMTs and providing health information to callers. About 45 EMDs are working at the EMCC, covering eight-hour shifts.

Procedure

First, the actual performance of the EMCC was evaluated over seven days using the output of a logging server at the EMCC. Then the number of required EMDs was calculated using the Erlang C formula (Figure 1) (10).

The formula predictions were then compared with the actual number of EMDs. Also, the number of incoming calls, number of on-hold calls, waiting time, number of working EMDs and Erlang C predictions were recorded. The call centre's database output was used to gather all the information. In addition, Erlang C predictions were calculated using an Excel spreadsheet.

$$P_w = \frac{\frac{A^N}{N!} \frac{N}{N-A}}{\left(\sum_{i=0}^{n-1} \frac{A^i}{i!} \right) + \frac{A^N}{N!} \frac{N}{N-A}}$$

Figure 1. The Erlang C formula (10). P_w: call waits, A: traffic intensity, N: number of agents

Data analysis

The quantitative data were reported as mean and standard deviation (SD), while qualitative data were described in terms of frequency and percentage. Also, we reported the distribution of data with bar charts and tables, as appropriate. The mean duration of the incoming calls at day and night was compared with an independent t-test. All statistical analyses were conducted with SPSS version 25, and p-value <0.05 was considered statistically significant.

Ethics

The local ethics committee of the Tehran University of Medical Sciences, in coordination with the head of the Tehran EMS centre, approved the research's conduct (IR.TUMS.VCR.REC.1398.718).

RESULTS

During the seven days, 79,583 calls were received by the Tehran EMCC. The lowest numbers of calls were on 25

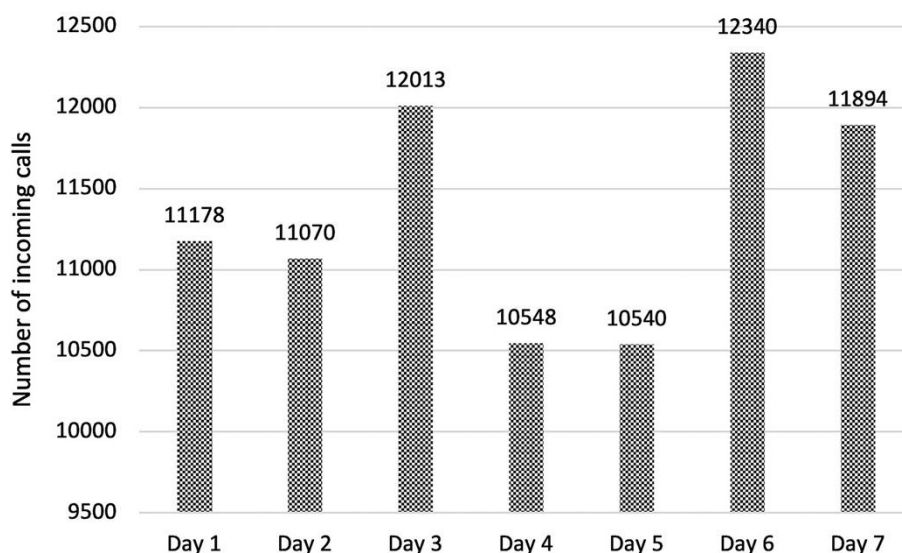


Figure 2. Frequency of incoming calls to the Tehran Emergency Medical Communication Centre over seven days

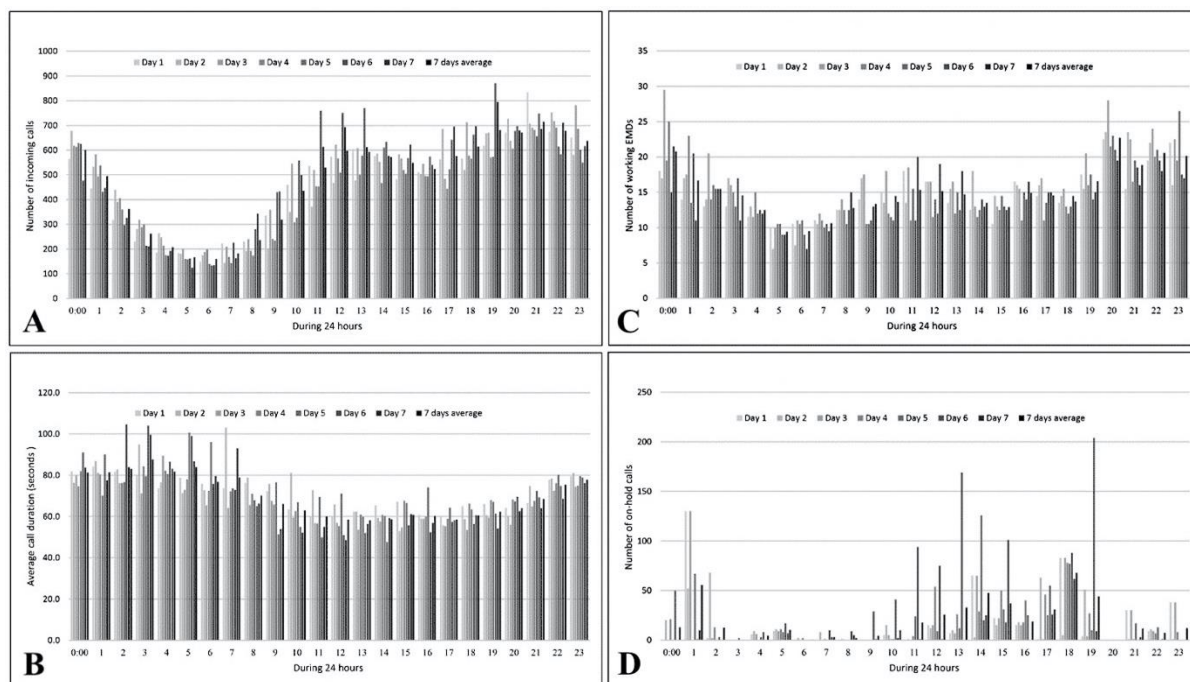


Figure 3. A: distribution of incoming calls, B: average duration of incoming calls, C: number of working EMDs, D: number of on-hold calls during 24 hours by day.

and 26 May (the Eid al-Fitr holiday; 10,548 and 10,540 calls, respectively), followed by on 22 and 23 May (Thursday and Friday; 11,178 and 11,070 calls, respectively) (Figure 2).

As Figure 3A depicts, the distribution of incoming calls followed a steady pattern, with the lowest number between 5:00 and 7:00 when there were fewer than 200 calls an hour. The average call duration followed a steady trend over the seven days, ranging between 58.2 (at 13:00) and 87.6 seconds (at 3:00). The overall duration of calls was longer at night (Figure 3B). So, the average duration over 6724 calls during the week was 61.6 seconds (SD = 3.5) during the day (8:00 to 20:59), while at night (21:00 to 7:59) it was 79.7 seconds (SD = 5.1) (p -value < 0.001).

Although the number and duration of calls saw a steady pattern, the numbers of EMDs (active stations) and of on-hold calls were somewhat erratic. The average number of EMDs ranged between 9.5 and 22.7 over the study period (Figure 3C, D).

Of the 79,583 calls, there were 3294 on-hold calls (4.1%), of which the waiting time for 1701 cases (51.6%) was more than the standard 10 seconds. The lowest average number of on-hold calls during the day (2:00–3:00 and 20:00–21:00) was zero, whereas the highest was 68 (18:00–19:00). Also, the lowest and highest mean waiting times of 8 seconds and 23 seconds were

recorded from 20:00 to 21:00 and 23:00 to 0:00, respectively (Figure 4).

During the one-week study, the number of working EMDs in the EMCC was more than Erlang C formula predictions. The time periods in which the number of EMDs was lower than Erlang C predictions were 14:00–14:59, 15:00–15:59, 18:00–18:59, and the differences between the number of EMDs and the Erlang C predictions in those periods were -0.1, -0.64 and -1, respectively. The largest difference between the number of EMDs and the Erlang C predictions during 24 hours was observed between 20:00 and 20:59 (Figure S1 and Table 1).

The distribution of the average number of on-hold calls, the average waiting time, the Erlang C calculations for the number of required EMDs and the actual number of EMDs during 24 hours is presented in Table 1. Based on the Erlang predictions, the number of EMDs in most hours was less than the actual number of working EMDs. In all hours, 90% of calls were answered in less than 10 seconds, with the average waiting time being 7.3 seconds; also, there were variations at different hours (between 7.0 seconds at 22:00 and 8.2 seconds at 18:00). In other words, 2.1% of calls were answered after 10 seconds. On the occasions when the actual number of EMDs was equal to the Erlang formula estimations, the ideal waiting time goal (less than 10 seconds) was achieved (Table 1).

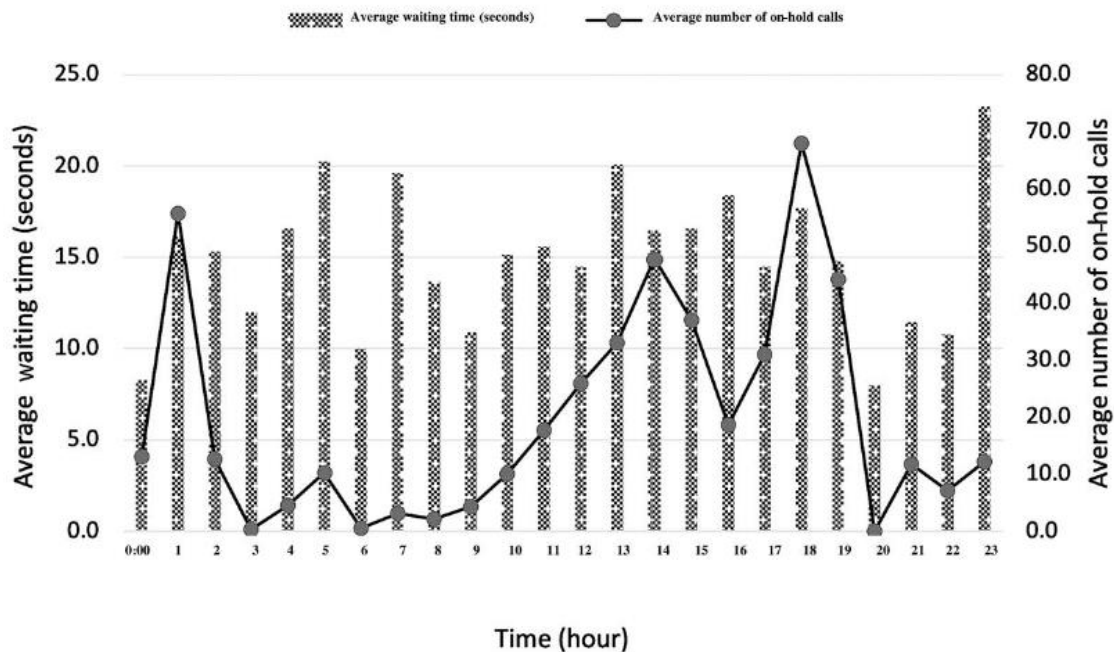


Figure 4. The average number of on-hold calls and average waiting times over the one-week study period

DISCUSSION

Predicting the volume of incoming calls in any public safety and health service call centre is of undisputed value. These call centres have to deal with unpredicted fluctuations in their workload, such as day-to-day and seasonal variations in the number of incoming calls. Furthermore, the demand is increased even more in the face of large-scale emergencies such as mass-casualty road traffic accidents, plane crashes, building collapses and epidemics. As a result, their schedules might suffer from overcapacity (6).

Appropriately forecasting these variations in demands boosts managers' planning, modelling and scheduling abilities to use available resources wisely. When it comes to an EMCC, the issue becomes even more crucial as their instant response is life-saving in many cases, such as heart attacks, strokes and traumas (4). In addition to the Erlang C formula, Erlang A and B can also be beneficial in this regard (11). However, each formula has its pros and cons; for instance, some researchers argue that Erlang C provides a pessimistic estimate and may cause extreme phone traffic congestion during peak hours (12).

Our study found that the number of working EMDs scheduled based on managers' experimental estimates was higher than the Erlang C formula predictions. Considering the average waiting time (7 seconds) of incoming calls to the Tehran EMCC, only 2.1% of all calls were answered beyond the standard waiting time (10 seconds). These findings suggest that the Tehran EMS centre might be able to utilise the Erlang C formula to estimate and forecast weekly or monthly active EMD numbers to increase the productivity of its staff. The

calculated average waiting time of the Tehran EMCC (7 seconds), even with a higher rate of incoming calls, is comparable with the reported averages in developed countries (13,14).

Although there are many forecasting models using a combination of algorithms and simulations, the precision of these models in different call centres is still in dispute. Therefore, any centre should carefully evaluate its resources and work volume during different time intervals throughout the year to find the best model which is consistent with their unique needs. Maintaining such standards is even more critical in disasters and disease outbreaks, like the COVID-19 pandemic, where there is a significant increase in incoming calls and a limited number of human resources. Nonetheless, the efficiency and applicability of such formulas in these situations are still under question. For instance, some argue that once an EMCC faces a heavy workload despite limited staff resources, implementing other policies like two-level filtering may be required (15).

Limitations

The current study has several limitations. First, due to the lack of resources available in the Tehran EMCC, we conducted this study in a short period, and this may affect our results. Second, this was just a prediction model, so work shifts did not plan in a real situation to see the true effect of such planning on the performance of Tehran EMCC. Third, only the Erlang C formula was used, and other prediction models and simulations did not apply, which prevents any comparison between the predicting models. Last but not least, this study was conducted in the EMCC of Tehran EMS, and other parts of the country were not involved in the research.

Table 1. Frequency of the average number of on-hold calls, average waiting time, actual number of working EMDs and number of EMDs calculated by Erlang C

Time of day	Number of non-standard on-hold calls n (%)	Average waiting time (seconds)	Average time of on-hold calls (seconds)	Number of on-hold calls (mean)	Actual number of EMDs (mean)	Erlang-predicted number of EMDs (mean)	Difference between actual and Erlang-predicted number of EMDs	Service level based on Erlang prediction (%)
0:00–1:00	42 (1.0)	7.0	8.3	13.0	20.8	18.7	2.1	94.1
1:00–2:00	131 (3.8)	8.0	16.2	55.7	16.6	16.0	0.6	93.0
2:00–3:00	47 (1.9)	7.3	15.3	12.6	15.5	12.7	2.8	94.3
3:00–4:00	1 (0.1)	7.0	12.0	0.3	14.6	10.4	4.1	90.3
4:00–5:00	17 (1.2)	7.2	16.6	4.6	12.5	8.3	4.2	91.2
5:00–6:00	38 (3.2)	7.8	20.3	10.3	9.4	7.1	2.3	91.6
6:00–7:00	1 (0.1)	7.0	10.0	0.6	9.5	6.6	2.9	95.7
7:00–8:00	22 (1.7)	7.2	19.6	3.1	10.6	7.4	3.2	90.8
8:00–9:00	8 (0.5)	7.1	13.7	2.1	12.8	8.0	4.8	93.0
9:00–10:00	12 (0.5)	7.1	10.9	4.3	13.4	9.6	3.8	95.3
10:00–11:00	43 (1.4)	7.2	15.2	10.0	13.6	11.4	2.2	94.8
11:00–12:00	77 (2.1)	7.3	15.6	17.7	15.4	12.9	2.5	93.0
12:00–13:00	79 (1.9)	7.3	14.5	25.9	15.1	14.0	1.1	93.5
13:00–14:00	143 (3.4)	7.7	20.1	33.0	14.7	13.7	1.0	93.9
14:00–15:00	243 (6.1)	7.8	16.5	47.6	13.5	13.6	-0.1	94.7
15:00–16:00	105 (2.7)	7.6	16.6	37.0	12.9	13.6	-0.6	94.8
16:00–17:00	65 (1.8)	7.4	18.4	18.7	14.9	12.9	2.1	93.6
17:00–18:00	117 (2.9)	7.4	14.5	31.0	14.6	13.6	1.0	94.4
18:00–19:00	247 (5.7)	8.2	17.7	68.0	13.7	14.7	-1.0	93.7
19:00–20:00	167 (3.5)	7.5	14.8	44.1	16.6	16.1	0.4	91.1
20:00–21:00	0 (0.0)	7.0	8.0	0.0	22.7	16.6	6.1	94.5
21:00–22:00	47 (0.9)	7.1	11.5	11.7	18.9	18.6	0.3	90.6
22:00–23:00	28 (0.6)	7.0	10.8	7.1	20.6	19.4	1.1	91.7
23:00–00:00	21 (0.5)	7.3	23.3	12.1	20.1	18.7	1.4	93.0

EMDs: Emergency Medical Dispatchers

CONCLUSION

The current study found that the number of EMDs in the EMCC based on managers' experimental estimates was higher than the Erlang C formula predictions. Also, it was found that the waiting time for emergency calls at all hours of the day and night was lower than the defined standards. The preliminary results of the current study indicated that, at least on paper, the Erlang C formula has the potential to be used as a predicting model in the Tehran EMCC and enables managers to forecast demand at different hours of the day and to engage more dispatches to answer higher volumes of calls at these times. Further research is needed in order to assess the effect of the Erlang C formula in real situations.

COMPETING INTERESTS

The authors declare no competing interests. Each author of this paper has completed the ICMJE conflict of interest statement.

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SUPPLEMENTARY MATERIALS

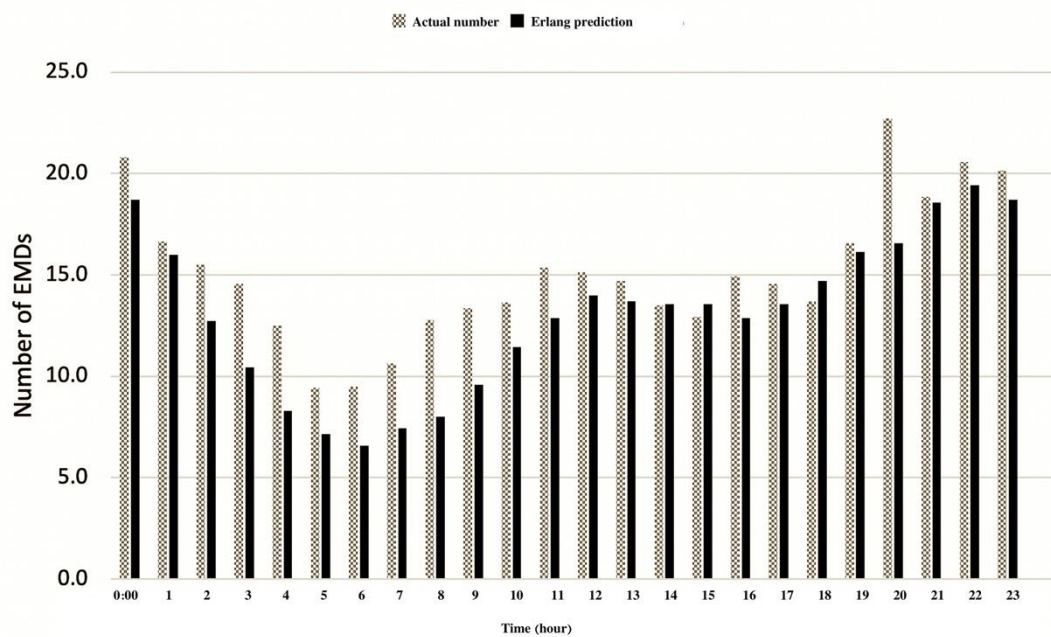


Figure S1. Frequency of working EMDs in the Tehran Emergency Medical Communication Centre (EMCC) over the one-week study compared with the Erlang C formula predictions