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Alternative police response models to crisis calls

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Abstract

A crisis call is when one or more individuals suffer from a mental- or behavioral health-related issue that may require a police response. Many police departments have introduced specially trained crisis response teams to replace the traditional police response with new response paradigms that may involve sending different or multiple types of vehicles to a crisis call. We introduce queueing models and performance measures to capture the dynamics of new response paradigms. We evaluate the queueing models using discrete event simulation with a case study based on data from Madison, Wisconsin, and we compare the crisis response to a traditional response to elucidate performance across a range of input parameters.

Keywords
Crisis Response, Discrete Event Simulation, Predictive Policing, Public Service Systems, Queueing Modeling.

1. Introduction
Crisis calls involve mental- or behavioral- health-related emergencies that may require a physical police response. Crisis calls are common and are typically more resource-intensive (e.g., longer amounts of service time) than non-crisis calls [1]. Police departments have traditionally responded to crisis calls using the basic Police Response Model (PRM) of sending law enforcement officers to all calls for service, with response times, crime rates, and the number of resulting citations and arrests being primary police performance measures [2]. There are several drawbacks to using traditional performance measures. For example, arrests, citations, and response times can be poorly defined or differ between municipalities. Additionally, crime rates can fluctuate over time and space, independent of policing operations. For crisis calls, slower response times may be preferred if crisis-trained officers respond to the call.

Some jurisdictions in the United States and the United Kingdom allow crisis calls to be co-responded with or alternatively responded to by mental and behavioral health workers (i.e., crisis servers) [3]. However, there are no best practices for crisis-responsive models, nor are there rigorous analytical frameworks to evaluate crisis care response models or provide guidance in designing crisis-responsive models that elucidate trade-offs across multiple criteria. Therefore, this paper seeks to address the knowledge gap by introducing two crisis-response models as queueing models—one static and one dynamic model—as well as new performance measures for evaluating the models. We also introduce a PRM for comparison. We evaluate the models using discrete event simulation with a case study based on data from Madison, WI, which sheds light on tradeoffs between the models.

2. Literature Review
A stream of papers in the operations research literature studies how queueing theory and optimization inform the design and operation of police patrolling problems. We describe the most relevant papers here and refer readers to the review paper by Samanta et al [4] for a more comprehensive overview. Most models in the literature study traditional PRMs of only sending sworn officers to all calls for service. Queueing theory has been widely used in the police response literature to understand how dispatching decisions affect response times and vehicle utilization associated with traditional PRMs [2, 5]. Queueing models have additionally been used to analyze systems with multiple types of vehicles [6]. Simulation modeling has been used to decide which police vehicle to send and the route to assign when incorporating call priority levels [7]. However, each of these studies uses traditional performance measures that do not capture the full complexity of crisis calls. In contrast, we simulate a variety of queueing models in the literature and evaluate each model with the crisis-specific performance measures introduced later in this paper.

3. Queueing Models

In this section, we introduce three queueing models used for police dispatching. The models include a PRM, a static crisis response model, and a dynamic crisis response model. In the following section, we introduce the performance measures used to evaluate the models.

For all models, calls have one of two main types: crisis calls (C) and non-crisis calls (P) and we assume that the call types are known upon arrival. Type C calls occur with probability q, which a crisis vehicle may serve. Type P calls occur with probability $p = 1 - q$ and must be served by a police vehicle. Arrivals occur via a Poisson process with arrival rate λ, and therefore, Type P and C calls arrive with Poisson rates $\lambda_P = p\lambda$ and $\lambda_C = q\lambda$, respectively. We assume infinite-length queues. We consider a queueing system with n_P general-purpose police vehicles and n_C crisis vehicles, with $n = n_P + n_C$ total vehicles (i.e., servers). In practice, a crisis vehicle can take one of three possible forms. A crisis vehicle can represent (1) a crisis intervention trained (CIT) police officer, (2) a mental and behavioral health specialist, or (3) a co-responding team where a police officer or CIT officer is co-located in a vehicle with a mental and behavioral health specialist. Service times for police and crisis servers are exponentially distributed with rates μ_P and μ_C, respectively. Service is non-preemptive, and calls enter service in order of arrival (i.e., FIFO). Individuals seeking service are impatient and may abandon the queue when they wait for service. However, a vehicle is still dispatched to the call since, in practice, vehicles are dispatched and attempt to find the individual at the scene.

Next, we introduce the three queueing models, which are illustrated in Figure 1. The first, as shown in Figure 1a, is the Police Response Model (PRM), which reflects the traditional PRM where a single type of server (i.e., police vehicle) responds to all call types. We model PRM as a $M/M/n_P$ queue and use it for comparison against the other two models.

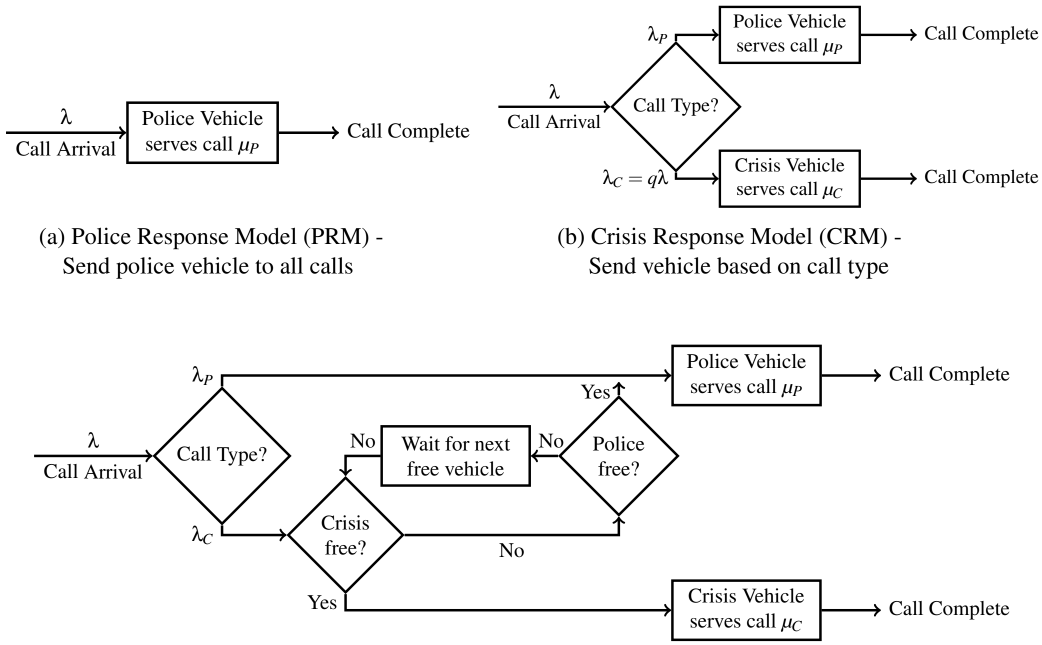
The second model, as shown in Figure 1b, is the Crisis Response Model (CRM), where police and crisis servers operate separately and respond to type P and C calls, respectively. Therefore, we model the response to non-crisis and crisis calls using two separate queues, $M/M/n_P$ and $M/M/n_C$, respectively. In practice, this model may apply where a crisis hotline and emergency response dispatching are siloed and, therefore, have separate operations and communication. CRM is a static model in that the responding vehicle type is always the same for each call type.

The third model, as shown in Figure 1c, is the Conditional Crisis Response Model (C-CRM), where dispatch decisions are dynamic such that either vehicle type may serve a crisis call and police vehicles serve non-crisis calls. The main difference between CRM and C-CRM is the allowance of non-crisis servers to serve crisis calls if all crisis servers are busy. Similar to the queuing model in Green [6], all calls arrive in a general queue with infinite length. If the first call in the general queue is of type C, then one of three possibilities could occur. First, if a crisis vehicle is free, the call is immediately served by the crisis vehicle. If all crisis vehicles are busy and a police vehicle is free, then the call is immediately served by a police vehicle. If all vehicles are busy, the call waits in the general queue until either a police vehicle becomes available and there are no calls of type P ahead of it (i.e. FIFO) or a crisis vehicle becomes available. If the first call in the general queue is of type P, the call moves to the police queue to be served by a police vehicle. In Green [6], when calls arrive, and the finite police queue is full, the call is assumed to change to a crisis call and would follow the rules of a waiting crisis call in the general queue. This is unrealistic for our context since a crisis vehicle cannot serve non-crisis calls. Therefore, we lift the limiting assumption of having a finite police queue made by Green [6] by simulating this queueing model to allow both the general and police queues to be infinite.

4. Performance Measures

We consider a common set of performance measures for evaluating all three models. We use the traditional queueing measures of vehicle utilization, expected delay (in hours), and the proportion of calls with a positive delay. Vehicle utilization is important for understanding working conditions and the availability of vehicles. Note that when an individual becomes impatient and abandons the queue before receiving service, a vehicle is later dispatched. Therefore, measuring both the probability a crisis call has to wait for an available server and the average time a crisis call is waiting for a response are important.

Additionally, we introduce two types of new performance measures for crisis response paradigms: quality and call outcome. Quality has two measures. First, crisis service quality (CSQ) is defined as the proportion of crisis calls that are responded to by a type C server. In practice, having the appropriate crisis vehicle type sent to crisis calls is important since if the individuals reporting the call expect a non-police response, they should receive a response by a crisis vehicle. A police vehicle responding to crisis calls can erode community trust and potentially escalate the situation by leading to citations and/or arrests that were unintentional to the call reporter [8]. Community perception of police is difficult to measure directly, and therefore, measuring CSQ can help jurisdictions better understand how to



(a) Police Response Model (PRM) - Send police vehicle to all calls

(b) Crisis Response Model (CRM) - Send vehicle based on call type

(c) Conditional Crisis Response Model (C-CRM) - Send one vehicle based on call type and availability

Figure 1: Response paradigms as queueing models

improve their community perceptions of police. However, *CSQ* does not factor in long queue lengths, which results in crisis vehicles not being dispatched in a timely manner. As a result, we introduce an alternative quality measure, the conditional crisis service quality (*CCSQ*), which is defined as the proportion of crisis calls that are responded to by a type *C* server, given that a vehicle is dispatched.

The second type of metric is call outcome, which we subdivide into six mutually exclusive possible outcomes: arrest, emergency department (ED) transport, other transport, no transport with referral, completed on-site with no referral, and no contact made. A summarized description of all performance measures is as follows:

- *Crisis service quality* $(CSQ) :=$ The proportion of all crisis calls that are responded to by a type C vehicle.
- *Conditional crisis service quality* $(CCSQ) :=$ The proportion of crisis calls that are responded to by a type C vehicle given that a vehicle is dispatched.
- *Crisis call outcome*. The resulting outcomes of a crisis call are subdivided into the following six mutually exclusive possible outcomes:
  - *Arrest* $(d_a) :=$ The proportion with an arrest.
  - *ED transport* $(d_e) :=$ The proportion with an emergency department (ED) transport.
  - *Other transport* $(d_t) :=$ The proportion with a non-ED transport.
  - *No transport, referral* $(d_r) :=$ The proportion with a referral for future services and no transport happens.
  - *Completed on-site, no referral* $(d_c) :=$ The proportion completed on-site with no transport or referral.
  - *No contact made* $(d_n) :=$ The proportion where the dispatched vehicle cannot locate the crisis call.
- *Vehicle utilization* $(\rho_P, \rho_C) :=$ The proportion of time a vehicle of type (P, C) is busy.
- *Expected Delay.* $(W_{q_q}) :=$ The conditional expected delay (in hrs) for a crisis call, given that the delay is positive.
- *Proportion of calls with a delay* $(P_{delay}) :=$ The proportion that a crisis call experiences a positive delay.

In the next sections, we use these performance measures to evaluate a case study.

5. Case Study

We introduce a case study based on the Community Alternative Response Emergency Services (CARES) program in Madison, WI. CARES deploys mobile response teams that consist of a paramedic and a crisis worker to address non-violent behavioral health emergencies such as suicidal thoughts, depression, anxiety, and agitation. CARES offers an alternative to police involvement, prioritizing calming situations, immediately addressing patient needs, and arranging referrals or transportation to other services as required. Currently, CARES has two vehicles that offer services working a 12-hour shift from 8 AM to 8 PM [9]. The parameters used for this case study are based on CARES [9], with missing information regarding non-crisis related outcomes supplemented by 2021 computer-aided dispatch (CAD) data provided by the Seattle Police Department (PD). Seattle PD has its own crisis response program and has well-documented available data; therefore, its vehicle call outcomes are reasonably representative of Madison police.

From the CARES report [9], we estimate that crisis calls arrive at a rate of 2.81 calls/hour. However, due to the nature of the CARES team, only around 26% of all crisis calls are eligible for CARES response, resulting in $\lambda_C = 0.73$ (calls/hour). Additionally, we estimate a CARES service rate of $\mu_C = 0.58$ and initially assume $\mu_P = \mu_C$ [9]. We assume there are $n_P = 60$ police vehicles on duty at a given time, with an overall police utilization of 0.75. We then estimate $\lambda = 0.75 \times \mu_P \times n_P = 26.1$ and $p = {}^{\lambda_C}/_{\lambda} = 0.028$. We additionally account for the small proportion (i.e., 0.03) of CARES-served calls that are reassigned to police, which can occur in both CRM and C-CRM. This is incorporated by inflating λ_P such that $\lambda_P = \lambda - (0.97 \times \lambda_C) = 25.84$. We vary the number of crisis vehicles n_C between one and eight. We assume impatient customers (i.e., calls) leave the system following a random amount of time distributed according to a uniform distribution between zero and two hours. When the call abandons the queue, service to the call results in “no contact made” between the vehicle and the customer involved.

Table 1 reports the inputs for the crisis call outcomes conditional on the responding vehicle type. The input parameters are represented as conditional probabilities and are reported when there is no delay, and the call does not abandon the queue. These conditional probabilities are used for calls with no delay and patient customers. These values are used to compute the performance measures. The CARES report was used to derive the crisis vehicle probabilities, and the Seattle PD CAD data was used to derive the police vehicle probabilities.

Table 1: Input parameters for crisis call outcomes (conditional probabilities) given the responding vehicle type

	Probability of arrest	Probability of ED transport	Probability of other transport	Probability of no transport & referral	Probability of completed on site	Probability of no contact made
Police vehicle	0.033	3.97×10^{-05}	2.87×10^{-05}	3.53×10^{-4}	0.74	0.22
Crisis vehicle	0.003	0.18	0.13	0.24	0.22	0.22

6. Results

We evaluate each model using discrete event simulation. All queueing model simulations are coded in Python using the SimPy Package. Each model has a warm-up period of 12 hours, a simulation length of 24 hours, and 100 replications.

Table 2 reports the 95% mean confidence intervals (CIs) of *CSQ*, *CCSQ*, crisis call outcome, ρ_P, ρ_C, P_{delay}, and W_{q_q} for PRM, CRM, and C-CRM (see Figure 1) as we vary p and n_c. We select $q = 0.028, 0.053$, and 0.108 to consider the cases where CARES could respond to $26\%, 50\%$, and 100% of all crisis calls, respectively. Note that only 26% of all crisis calls were eligible for CARES response [9]. Table 2, shows that ρ_P is lower for models CRM and C-CRM than PRM. We also notice that C-CRM has equal or lower values of ρ_C to CRM at any crisis number of vehicles. This means that depending on the number of eligible crisis calls in a jurisdiction, CARES can reduce police vehicle utilization, freeing up police for other tasks, such as community outreach, training, and prevention. For crisis vehicles, allowing for the dynamic dispatching decisions of C-CRM between police and crisis vehicles can make crisis utilization more manageable. In each instance shown in Table 2, we see that d_a and d_c drastically decrease for CRM and C-CRM as compared to PRM, while with d_e, d_t, and d_r increase as compared to PRM. This means that as more crisis vehicles respond to crisis calls, we can expect fewer arrests and calls completed on-site and more access to relevant services such as ED transports, transports to other services such as detox centers, and referrals for future service.

Additionally, in Table 2, P_{delay} is zero for some CRM and C-CRM instances with higher values of n_C. In contrast, CRM can have long wait times for calls (i.e., $W_{q_q} > 0.5$ hours) if there are not enough crisis vehicles to consistently have an immediate response. The wait times are especially long where crisis vehicles cannot keep up with demand, making the queue unstable (i.e., ${}^{\lambda_c}/_{n_C \mu_C} > 1$, which occurs for instances where $W_{q_q} > 2$ hours). However, CRM can offer higher service quality (i.e., *CSQ* and *CCSQ*) than PRM and C-CRM, even with an unstable queue at the cost of significantly more calls resulting in "no contact made" or d_n making up 75% or more of all crisis call outcomes given a response was sent.

Table 2: Performance measures' 95% CIs by model, q, and n_C, for: $\lambda = 26.1$, $n_P = 60$, and $\mu_P = \mu_C = 0.58$

					Crisis Call Outcome						Vehicle Measures		Crisis Call Measures	
Model	q	n_C	CSQ	$CCSQ$	d_a	d_e	d_t	d_r	d_c	d_n	ρ_P	ρ_C	P_{delay}	W_{q_q}
PRM	0.028	0	0.00 ± 0.00	0.00 ± 0.00	0.0304 ± 0.009	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.69 ± 0.03	0.21 ± 0.02	0.76 ± 0.01	-	0.03 ± 0.01	0.12 ± 0.02
CRM	0.028	1	**0.65 ± 0.05**	**1.00 ± 0.00**	**0.0006 ± 0.001**	**0.03 ± 0.01**	**0.02 ± 0.01**	**0.05 ± 0.01**	**0.04 ± 0.01**	**0.45 ± 0.03**	**0.74 ± 0.01**	0.92 ± 0.02	**0.88 ± 0.03**	**6.30 ± 0.93**
CRM	0.028	2	**0.96 ± 0.02**	**1.00 ± 0.00**	**0.0013 ± 0.002**	**0.11 ± 0.02**	**0.10 ± 0.02**	**0.17 ± 0.02**	**0.14 ± 0.02**	**0.37 ± 0.04**	**0.74 ± 0.01**	0.59 ± 0.03	**0.41 ± 0.05**	**1.50 ± 0.27**
CRM	0.028	3	**0.99 ± 0.00**	**1.00 ± 0.00**	**0.0037 ± 0.003**	**0.14 ± 0.02**	**0.13 ± 0.02**	**0.20 ± 0.02**	**0.18 ± 0.02**	**0.26 ± 0.03**	**0.74 ± 0.01**	0.40 ± 0.03	**0.14 ± 0.03**	**0.74 ± 0.12**
CRM	0.028	4	**1.00 ± 0.00**	**1.00 ± 0.00**	**0.0033 ± 0.003**	**0.16 ± 0.02**	**0.13 ± 0.02**	**0.22 ± 0.02**	**0.19 ± 0.02**	0.22 ± 0.02	**0.74 ± 0.01**	0.30 ± 0.02	0.04 ± 0.02	**0.45 ± 0.08**
CRM	0.028	5	**1.00 ± 0.00**	**1.00 ± 0.00**	**0.0033 ± 0.003**	**0.16 ± 0.02**	**0.13 ± 0.02**	**0.22 ± 0.02**	**0.20 ± 0.02**	0.21 ± 0.02	**0.74 ± 0.01**	0.24 ± 0.02	**0.01 ± 0.01**	0.33 ± 0.07
CRM	0.028	6	**1.00 ± 0.00**	**1.00 ± 0.00**	**0.0033 ± 0.003**	**0.17 ± 0.02**	**0.13 ± 0.02**	**0.22 ± 0.02**	**0.20 ± 0.02**	0.21 ± 0.02	**0.74 ± 0.01**	0.20 ± 0.01	**0.00 ± 0.00**	0.38 ± 0.07
CRM	0.028	7	**1.00 ± 0.00**	**1.00 ± 0.00**	**0.0033 ± 0.003**	**0.17 ± 0.02**	**0.13 ± 0.02**	**0.22 ± 0.02**	**0.20 ± 0.02**	0.21 ± 0.02	**0.74 ± 0.01**	0.17 ± 0.01	**0.00 ± 0.00**	0.62 ± 0.00
CRM	0.028	8	**1.00 ± 0.00**	**1.00 ± 0.00**	**0.0033 ± 0.003**	**0.17 ± 0.02**	**0.13 ± 0.02**	**0.22 ± 0.02**	**0.20 ± 0.02**	0.21 ± 0.02	**0.74 ± 0.01**	0.15 ± 0.01	**0.00 ± 0.00**	0.31 ± 0.00
C-CRM	0.028	1	**0.47 ± 0.02**	**0.47 ± 0.02**	0.0210 ± 0.007	**0.08 ± 0.01**	**0.05 ± 0.01**	**0.11 ± 0.02**	**0.47 ± 0.02**	0.19 ± 0.02	**0.75 ± 0.01**	0.54 ± 0.02	**0.01 ± 0.01**	**0.12 ± 0.02**
C-CRM	0.028	2	**0.77 ± 0.02**	**0.77 ± 0.02**	**0.0089 ± 0.004**	**0.13 ± 0.02**	**0.09 ± 0.01**	**0.17 ± 0.02**	**0.31 ± 0.02**	0.21 ± 0.02	**0.74 ± 0.01**	0.45 ± 0.02	**0.01 ± 0.01**	**0.07 ± 0.01**
C-CRM	0.028	3	**0.91 ± 0.02**	**0.91 ± 0.02**	**0.0060 ± 0.004**	**0.16 ± 0.02**	**0.10 ± 0.02**	**0.22 ± 0.02**	**0.24 ± 0.02**	0.20 ± 0.02	**0.74 ± 0.01**	0.37 ± 0.02	**0.00 ± 0.00**	0.11 ± 0.01
C-CRM	0.028	4	**0.97 ± 0.01**	**0.97 ± 0.01**	**0.0030 ± 0.003**	**0.16 ± 0.02**	**0.13 ± 0.02**	**0.21 ± 0.02**	**0.22 ± 0.02**	0.20 ± 0.02	**0.74 ± 0.01**	0.29 ± 0.02	**0.00 ± 0.00**	0.13 ± 0.01
C-CRM	0.028	5	**0.99 ± 0.01**	**0.99 ± 0.01**	**0.0031 ± 0.003**	**0.16 ± 0.02**	**0.13 ± 0.02**	**0.22 ± 0.02**	**0.20 ± 0.02**	0.21 ± 0.02	**0.74 ± 0.01**	0.24 ± 0.02	**0.00 ± 0.00**	0.18 ± 0.00
C-CRM	0.028	6	**1.00 ± 0.00**	**1.00 ± 0.00**	**0.0037 ± 0.003**	**0.16 ± 0.02**	**0.13 ± 0.02**	**0.22 ± 0.02**	**0.20 ± 0.02**	0.21 ± 0.02	**0.74 ± 0.01**	0.20 ± 0.01	**0.00 ± 0.00**	0.13 ± 0.00
C-CRM	0.028	7	**1.00 ± 0.00**	**1.00 ± 0.00**	**0.0033 ± 0.003**	**0.17 ± 0.02**	**0.13 ± 0.02**	**0.22 ± 0.02**	**0.20 ± 0.02**	0.21 ± 0.02	**0.74 ± 0.01**	0.17 ± 0.01	**0.00 ± 0.00**	NA
C-CRM	0.028	8	**1.00 ± 0.00**	**1.00 ± 0.00**	**0.0033 ± 0.003**	**0.17 ± 0.02**	**0.13 ± 0.02**	**0.22 ± 0.02**	**0.20 ± 0.02**	0.21 ± 0.02	**0.74 ± 0.01**	0.15 ± 0.01	**0.00 ± 0.00**	NA
PRM	0.054	0	0.00 ± 0.00	0.00 ± 0.00	0.0284 ± 0.006	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.70 ± 0.01	0.20 ± 0.01	0.76 ± 0.01	-	0.02 ± 0.01	0.09 ± 0.01
CRM	0.054	1	**0.23 ± 0.03**	**1.00 ± 0.00**	**0.0000 ± 0.000**	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	**0.00 ± 0.00**	0.20 ± 0.03	**0.72 ± 0.01**	1.00 ± 0.00	**1.00 ± 0.00**	**14.88 ± 0.94**
CRM	0.054	2	**0.71 ± 0.04**	**1.00 ± 0.00**	**0.0000 ± 0.000**	**0.04 ± 0.01**	**0.02 ± 0.01**	**0.04 ± 0.01**	**0.03 ± 0.01**	**0.52 ± 0.03**	**0.72 ± 0.01**	0.94 ± 0.02	**0.90 ± 0.03**	**5.20 ± 0.70**
CRM	0.054	3	**0.94 ± 0.02**	**1.00 ± 0.00**	**0.0007 ± 0.001**	**0.10 ± 0.01**	**0.08 ± 0.01**	**0.13 ± 0.01**	**0.14 ± 0.02**	**0.42 ± 0.03**	**0.72 ± 0.01**	0.76 ± 0.03	**0.56 ± 0.05**	**1.71 ± 0.31**
CRM	0.054	4	**0.99 ± 0.01**	**1.00 ± 0.00**	**0.0019 ± 0.002**	**0.13 ± 0.01**	**0.11 ± 0.01**	**0.20 ± 0.02**	**0.18 ± 0.01**	**0.29 ± 0.03**	**0.72 ± 0.01**	0.59 ± 0.03	**0.27 ± 0.04**	**0.74 ± 0.12**
CRM	0.054	5	**1.00 ± 0.00**	**1.00 ± 0.00**	**0.0016 ± 0.001**	**0.15 ± 0.01**	**0.12 ± 0.01**	**0.22 ± 0.02**	**0.20 ± 0.01**	**0.23 ± 0.02**	**0.72 ± 0.01**	0.48 ± 0.02	**0.11 ± 0.03**	**0.50 ± 0.07**
CRM	0.054	6	**1.00 ± 0.00**	**1.00 ± 0.00**	**0.0026 ± 0.002**	**0.16 ± 0.01**	**0.12 ± 0.01**	**0.23 ± 0.01**	**0.19 ± 0.01**	0.22 ± 0.02	**0.72 ± 0.01**	0.40 ± 0.02	0.04 ± 0.01	**0.38 ± 0.06**
CRM	0.054	7	**1.00 ± 0.00**	**1.00 ± 0.00**	**0.0023 ± 0.002**	**0.16 ± 0.01**	**0.13 ± 0.01**	**0.23 ± 0.01**	**0.20 ± 0.01**	0.21 ± 0.01	**0.72 ± 0.01**	0.34 ± 0.02	0.01 ± 0.01	0.27 ± 0.04
CRM	0.054	8	**1.00 ± 0.00**	**1.00 ± 0.00**	**0.0023 ± 0.002**	**0.16 ± 0.01**	**0.13 ± 0.01**	**0.23 ± 0.01**	**0.20 ± 0.01**	0.21 ± 0.02	**0.72 ± 0.01**	0.30 ± 0.02	**0.00 ± 0.00**	0.31 ± 0.03
C-CRM	0.054	1	**0.31 ± 0.02**	**0.31 ± 0.02**	0.0231 ± 0.004	**0.05 ± 0.01**	**0.04 ± 0.01**	**0.07 ± 0.01**	**0.54 ± 0.02**	0.21 ± 0.01	**0.75 ± 0.01**	0.70 ± 0.02	**0.01 ± 0.01**	0.09 ± 0.01
C-CRM	0.054	2	**0.55 ± 0.02**	**0.55 ± 0.02**	**0.0146 ± 0.004**	**0.10 ± 0.01**	**0.06 ± 0.01**	**0.12 ± 0.01**	**0.43 ± 0.02**	0.20 ± 0.01	**0.74 ± 0.01**	0.64 ± 0.02	**0.01 ± 0.00**	0.07 ± 0.01
C-CRM	0.054	3	**0.74 ± 0.02**	**0.74 ± 0.02**	**0.0117 ± 0.004**	**0.12 ± 0.01**	**0.08 ± 0.01**	**0.18 ± 0.01**	**0.33 ± 0.02**	0.21 ± 0.01	**0.73 ± 0.01**	0.59 ± 0.02	**0.00 ± 0.00**	0.12 ± 0.01
C-CRM	0.054	4	**0.87 ± 0.02**	**0.87 ± 0.02**	**0.0063 ± 0.003**	**0.14 ± 0.01**	**0.10 ± 0.01**	**0.20 ± 0.01**	**0.28 ± 0.02**	0.20 ± 0.01	**0.72 ± 0.01**	0.52 ± 0.02	**0.00 ± 0.00**	0.07 ± 0.01
C-CRM	0.054	5	**0.94 ± 0.01**	**0.94 ± 0.01**	**0.0025 ± 0.002**	**0.14 ± 0.01**	**0.12 ± 0.01**	**0.22 ± 0.01**	**0.24 ± 0.02**	0.21 ± 0.01	**0.72 ± 0.01**	0.44 ± 0.02	**0.00 ± 0.00**	0.09 ± 0.00
C-CRM	0.054	6	**0.98 ± 0.01**	**0.98 ± 0.01**	**0.0020 ± 0.002**	**0.16 ± 0.01**	**0.12 ± 0.01**	**0.23 ± 0.01**	**0.21 ± 0.01**	0.20 ± 0.01	**0.72 ± 0.01**	0.39 ± 0.02	**0.00 ± 0.00**	NA
C-CRM	0.054	7	**0.99 ± 0.00**	**0.99 ± 0.00**	**0.0029 ± 0.002**	**0.15 ± 0.01**	**0.13 ± 0.01**	**0.23 ± 0.01**	**0.21 ± 0.01**	0.21 ± 0.01	**0.72 ± 0.01**	0.34 ± 0.02	**0.00 ± 0.00**	NA
C-CRM	0.054	8	**1.00 ± 0.00**	**1.00 ± 0.00**	**0.0025 ± 0.002**	**0.16 ± 0.01**	**0.12 ± 0.01**	**0.23 ± 0.01**	**0.20 ± 0.01**	0.21 ± 0.01	**0.72 ± 0.01**	0.30 ± 0.01	**0.00 ± 0.00**	NA
PRM	0.108	0	0.00 ± 0.00	0.00 ± 0.00	0.0319 ± 0.004	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.68 ± 0.01	0.22 ± 0.01	0.76 ± 0.01	-	0.02 ± 0.01	0.07 ± 0.01
CRM	0.108	1	0.03 ± 0.01	**1.00 ± 0.00**	**0.0000 ± 0.000**	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	**0.00 ± 0.00**	**0.02 ± 0.01**	**0.68 ± 0.01**	1.00 ± 0.00	**1.00 ± 0.00**	**21.55 ± 0.35**
CRM	0.108	2	**0.19 ± 0.02**	**1.00 ± 0.00**	**0.0000 ± 0.000**	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	**0.00 ± 0.00**	**0.16 ± 0.02**	**0.68 ± 0.01**	1.00 ± 0.00	**1.00 ± 0.00**	**16.56 ± 0.83**
CRM	0.108	3	**0.48 ± 0.03**	**1.00 ± 0.00**	**0.0002 ± 0.000**	**0.00 ± 0.00**	**0.00 ± 0.00**	**0.00 ± 0.00**	**0.01 ± 0.00**	**0.42 ± 0.03**	**0.68 ± 0.01**	1.00 ± 0.00	**0.99 ± 0.00**	**9.46 ± 0.81**
CRM	0.108	4	**0.74 ± 0.03**	**1.00 ± 0.00**	**0.0008 ± 0.001**	**0.02 ± 0.01**	**0.02 ± 0.01**	**0.03 ± 0.01**	**0.03 ± 0.01**	**0.58 ± 0.03**	**0.68 ± 0.01**	0.97 ± 0.01	**0.94 ± 0.02**	**4.71 ± 0.55**
CRM	0.108	5	**0.91 ± 0.02**	**1.00 ± 0.00**	**0.0012 ± 0.001**	**0.07 ± 0.01**	**0.06 ± 0.01**	**0.10 ± 0.01**	**0.10 ± 0.01**	**0.51 ± 0.03**	**0.68 ± 0.01**	0.90 ± 0.02	**0.76 ± 0.04**	**2.05 ± 0.31**
CRM	0.108	6	**0.98 ± 0.01**	**1.00 ± 0.00**	**0.0020 ± 0.001**	**0.13 ± 0.01**	**0.08 ± 0.01**	**0.17 ± 0.01**	**0.16 ± 0.01**	**0.36 ± 0.03**	**0.68 ± 0.01**	0.79 ± 0.02	**0.48 ± 0.05**	**0.97 ± 0.15**
CRM	0.108	7	**0.99 ± 0.00**	**1.00 ± 0.00**	**0.0021 ± 0.001**	**0.15 ± 0.01**	**0.11 ± 0.01**	**0.21 ± 0.01**	**0.18 ± 0.01**	**0.27 ± 0.02**	**0.68 ± 0.01**	0.68 ± 0.02	**0.27 ± 0.04**	**0.56 ± 0.09**
CRM	0.108	8	**1.00 ± 0.00**	**1.00 ± 0.00**	**0.0023 ± 0.001**	**0.16 ± 0.01**	**0.12 ± 0.01**	**0.22 ± 0.01**	**0.20 ± 0.01**	0.23 ± 0.01	**0.68 ± 0.01**	0.60 ± 0.02	**0.13 ± 0.03**	**0.35 ± 0.05**
C-CRM	0.108	1	**0.18 ± 0.01**	**0.18 ± 0.01**	0.0276 ± 0.003	**0.03 ± 0.00**	**0.02 ± 0.00**	**0.04 ± 0.00**	**0.60 ± 0.01**	0.21 ± 0.01	**0.74 ± 0.01**	0.83 ± 0.01	**0.01 ± 0.01**	0.07 ± 0.01
C-CRM	0.108	2	**0.33 ± 0.01**	**0.33 ± 0.01**	**0.0220 ± 0.004**	**0.05 ± 0.01**	**0.04 ± 0.00**	**0.08 ± 0.01**	**0.54 ± 0.01**	**0.20 ± 0.01**	**0.73 ± 0.01**	0.81 ± 0.01	**0.01 ± 0.01**	0.07 ± 0.01
C-CRM	0.108	3	**0.49 ± 0.01**	**0.49 ± 0.01**	**0.0165 ± 0.003**	**0.08 ± 0.01**	**0.06 ± 0.01**	**0.12 ± 0.01**	**0.45 ± 0.01**	**0.20 ± 0.01**	**0.72 ± 0.01**	0.78 ± 0.01	**0.01 ± 0.00**	0.07 ± 0.01
C-CRM	0.108	4	**0.62 ± 0.01**	**0.62 ± 0.01**	**0.0105 ± 0.002**	**0.11 ± 0.01**	**0.08 ± 0.01**	**0.14 ± 0.01**	**0.38 ± 0.01**	0.22 ± 0.01	**0.71 ± 0.01**	0.74 ± 0.01	**0.00 ± 0.00**	0.06 ± 0.01
C-CRM	0.108	5	**0.74 ± 0.01**	**0.74 ± 0.01**	**0.0105 ± 0.003**	**0.12 ± 0.01**	**0.09 ± 0.01**	**0.17 ± 0.01**	**0.32 ± 0.01**	0.21 ± 0.01	**0.70 ± 0.01**	0.71 ± 0.01	**0.00 ± 0.00**	0.05 ± 0.01
C-CRM	0.108	6	**0.83 ± 0.01**	**0.83 ± 0.01**	**0.0079 ± 0.002**	**0.13 ± 0.01**	**0.10 ± 0.01**	**0.19 ± 0.01**	**0.29 ± 0.01**	0.21 ± 0.01	**0.69 ± 0.01**	0.66 ± 0.01	**0.00 ± 0.00**	0.04 ± 0.00
C-CRM	0.108	7	**0.90 ± 0.01**	**0.90 ± 0.01**	**0.0049 ± 0.002**	**0.15 ± 0.01**	**0.11 ± 0.01**	**0.20 ± 0.01**	**0.25 ± 0.01**	0.21 ± 0.01	**0.68 ± 0.01**	0.61 ± 0.01	**0.00 ± 0.00**	0.03 ± 0.00
C-CRM	0.108	8	**0.94 ± 0.01**	**0.94 ± 0.01**	**0.0037 ± 0.002**	**0.16 ± 0.01**	**0.11 ± 0.01**	**0.21 ± 0.01**	**0.23 ± 0.01**	0.20 ± 0.01	**0.68 ± 0.01**	0.56 ± 0.01	**0.00 ± 0.00**	0.03 ± 0.00

Note: NA indicates that no crisis calls were queued and all received immediate vehicle dispatch
Boldface values for CRM and C-CRM indicate p-values ≤ 0.05 for mean difference paired t-test compared to the corresponding PRM instance

We assume that $\mu_P = \mu_C$ in Table 2. However, existing case studies suggest that service rates for crisis calls can be slower than those for a typical police response [1]. Therefore, we test the situation where crisis vehicles have two-thirds the service rate of police vehicles (i.e., $\mu_P = (2/3)\mu_C$). Table 3 reports the 95% mean CIs of the performance measures for PRM, CRM, and C-CRM with $\mu_C = 0.39$, $\mu_P = 0.58$, $q = 0.028$, and n_C varying between one and eight crisis vehicles. Table 3 shows that when crisis vehicles have longer service times than police vehicles, more crisis vehicles are needed to obtain the same benefits observed in Table 2. Specifically, compared to the results of Table 2, CRM needs at least one additional crisis vehicle to create a stable queue (i.e., $n_C = 3$ vs. $n_C = 2$) or to obtain $CSQ = 1$ (i.e., $n_C = 5$ vs $n_C = 4$). Also, CRM needs two additional crisis vehicles (i.e., $n_C = 7$ versus $n_C = 5$) to obtain a P_{delay} that is statistically significantly less than that of PRM.

7. Conclusion

This paper discusses how queueing theory and discrete event simulation can inform the design and operation of alternative police response paradigms for crisis calls, such as crisis intervention teams. We introduce three queueing models and two new types of performance metrics that can be used to evaluate the models. All models are evaluated using discrete event simulation with a case study based on data from Madison, WI. The results demonstrate that alternative response paradigms can lead to better outcomes and service quality for crisis calls while decreasing police work. Additionally, allowing police to respond to calls when crisis response vehicles are busy allows for better traditional queueing measures such as reduced crisis vehicle utilization, a smaller proportion of crisis calls with a delay, and reduced wait time when there is a delay among crisis calls, with a potential trade-off of reduced crisis service quality

Table 3: Performance measures' 95% CIs by model and n_C, for: $\lambda = 26.1$, $q = 0.028$, $n_P = 60$, $\mu_C = 0.39$, and $\mu_P = 0.58$

				Crisis Call Outcome						Vehicle Measures		Crisis Call Measures	
Model	n_C	*CSQ*	*CCSQ*	d_a	d_e	d_t	d_r	d_c	d_n	ρ_P	ρ_C	P_{delay}	W_{q_q}
PRM	0	0.00 ± 0.00	0.00 ± 0.00	0.0304 ± 0.009	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.69 ± 0.03	0.21 ± 0.02	0.76 ± 0.01	-	0.03 ± 0.01	0.12 ± 0.02
CRM	1	**0.42 ± 0.04**	**1.00 ± 0.00**	**0.0000 ± 0.000**	**0.01 ± 0.01**	**0.01 ± 0.01**	**0.01 ± 0.00**	**0.01 ± 0.00**	**0.33 ± 0.04**	**0.74 ± 0.01**	0.99 ± 0.01	**0.97 ± 0.01**	**10.0 ± 0.94**
CRM	2	**0.85 ± 0.03**	**1.00 ± 0.00**	**0.0000 ± 0.000**	**0.07 ± 0.01**	**0.06 ± 0.01**	**0.10 ± 0.02**	**0.08 ± 0.01**	**0.43 ± 0.04**	**0.74 ± 0.01**	0.80 ± 0.03	**0.66 ± 0.05**	**3.18 ± 0.54**
CRM	3	**0.97 ± 0.02**	**1.00 ± 0.00**	**0.0009 ± 0.002**	**0.13 ± 0.02**	**0.09 ± 0.01**	**0.17 ± 0.02**	**0.15 ± 0.02**	**0.30 ± 0.03**	**0.74 ± 0.01**	0.58 ± 0.03	**0.30 ± 0.05**	**1.48 ± 0.28**
CRM	4	**0.99 ± 0.00**	**1.00 ± 0.00**	**0.0009 ± 0.002**	**0.16 ± 0.02**	**0.10 ± 0.01**	**0.19 ± 0.02**	**0.18 ± 0.02**	**0.24 ± 0.03**	**0.74 ± 0.01**	0.45 ± 0.03	**0.13 ± 0.03**	**0.94 ± 0.15**
CRM	5	**1.00 ± 0.00**	**1.00 ± 0.00**	**0.0009 ± 0.002**	**0.17 ± 0.02**	**0.11 ± 0.02**	**0.20 ± 0.02**	**0.19 ± 0.02**	0.22 ± 0.02	**0.74 ± 0.01**	0.36 ± 0.02	0.04 ± 0.02	0.78 ± 0.13
CRM	6	**1.00 ± 0.00**	**1.00 ± 0.00**	**0.0009 ± 0.002**	**0.17 ± 0.02**	**0.11 ± 0.02**	**0.20 ± 0.02**	**0.20 ± 0.02**	0.20 ± 0.02	**0.74 ± 0.01**	0.30 ± 0.02	0.02 ± 0.01	0.78 ± 0.12
CRM	7	**1.00 ± 0.00**	**1.00 ± 0.00**	**0.0009 ± 0.002**	**0.17 ± 0.02**	**0.11 ± 0.02**	**0.20 ± 0.02**	**0.20 ± 0.02**	0.20 ± 0.02	**0.74 ± 0.01**	0.26 ± 0.02	**0.00 ± 0.00**	0.65 ± 0.08
CRM	8	**1.00 ± 0.00**	**1.00 ± 0.00**	**0.0009 ± 0.002**	**0.17 ± 0.02**	**0.11 ± 0.02**	**0.21 ± 0.02**	**0.20 ± 0.02**	0.20 ± 0.02	**0.74 ± 0.01**	0.23 ± 0.02	**0.00 ± 0.00**	0.47 ± 0.05
C-CRM	1	**0.37 ± 0.02**	**0.37 ± 0.02**	0.0202 ± 0.007	**0.06 ± 0.01**	**0.05 ± 0.01**	**0.09 ± 0.01**	**0.51 ± 0.02**	0.19 ± 0.02	**0.75 ± 0.01**	0.65 ± 0.02	**0.02 ± 0.01**	**0.09 ± 0.01**
C-CRM	2	**0.66 ± 0.03**	**0.66 ± 0.03**	**0.0153 ± 0.005**	**0.11 ± 0.02**	**0.08 ± 0.01**	**0.14 ± 0.02**	**0.35 ± 0.03**	0.22 ± 0.02	**0.75 ± 0.01**	0.57 ± 0.02	**0.01 ± 0.01**	**0.07 ± 0.01**
C-CRM	3	**0.84 ± 0.03**	**0.84 ± 0.03**	**0.0067 ± 0.004**	**0.14 ± 0.02**	**0.09 ± 0.01**	**0.18 ± 0.02**	**0.28 ± 0.02**	0.19 ± 0.02	**0.74 ± 0.01**	0.50 ± 0.02	**0.00 ± 0.00**	0.09 ± 0.01
C-CRM	4	**0.93 ± 0.02**	**0.93 ± 0.02**	**0.0019 ± 0.002**	**0.16 ± 0.02**	**0.09 ± 0.01**	**0.19 ± 0.02**	**0.23 ± 0.02**	0.22 ± 0.02	**0.74 ± 0.01**	0.42 ± 0.02	**0.00 ± 0.00**	0.10 ± 0.00
C-CRM	5	**0.97 ± 0.01**	**0.97 ± 0.01**	**0.0019 ± 0.002**	**0.17 ± 0.02**	**0.11 ± 0.02**	**0.20 ± 0.02**	**0.20 ± 0.02**	0.20 ± 0.02	**0.74 ± 0.01**	0.35 ± 0.02	**0.00 ± 0.00**	0.18 ± 0.00
C-CRM	6	**0.99 ± 0.01**	**0.99 ± 0.01**	**0.0018 ± 0.002**	**0.16 ± 0.02**	**0.11 ± 0.02**	**0.20 ± 0.02**	**0.20 ± 0.02**	0.20 ± 0.02	**0.74 ± 0.01**	0.30 ± 0.02	**0.00 ± 0.00**	0.13 ± 0.00
C-CRM	7	**1.00 ± 0.00**	**1.00 ± 0.00**	**0.0009 ± 0.002**	**0.17 ± 0.02**	**0.11 ± 0.02**	**0.21 ± 0.02**	**0.20 ± 0.02**	0.19 ± 0.02	**0.74 ± 0.01**	0.26 ± 0.02	**0.00 ± 0.00**	NA
C-CRM	8	**1.00 ± 0.00**	**1.00 ± 0.00**	**0.0009 ± 0.002**	**0.17 ± 0.02**	**0.11 ± 0.02**	**0.21 ± 0.02**	**0.20 ± 0.02**	0.20 ± 0.02	**0.74 ± 0.01**	0.23 ± 0.01	**0.00 ± 0.00**	NA

Note: NA indicates that no crisis calls were queued and all received immediate vehicle dispatch
Boldface values for CRM and C-CRM indicate p-values ≤ 0.05 for mean difference paired t-test compared to the corresponding PRM instance

and crisis call outcomes. We find that adding additional crisis vehicles can mitigate any reduced system performance. More work is needed to identify and evaluate alternative response paradigms that can be used to support crisis response operations that co-respond with police vehicles.

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References

[1] Charette, Y., Crocker, A. G., and Billette, I, 2014, "Police Encounters Involving Citizens With Mental Illness: Use of Resources and Outcomes," Psychiatric Services, 65(4), 511–516.

[2] Green, L. V., and Kolesar, P. J., 2004, "Anniversary Article: Improving Emergency Responsiveness with Management Science," Management Science, 50(8), 1001–1014.

[3] Hashmi, T., Thomas, D., and -dan, M., 2021, "Mental Health Call Triage: Coding Systems and Opportunities for Research," Proc. of the Conference on Information Systems Applied Research, November 3-6, Washington, DC (2167), 1508-1518.

[4] Samanta, S., Sen, G., and Ghosh, S. K., 2022, "A literature review on police patrolling problems," Annals of Operations Research, 316(2), 1063–1106.

[5] Green, L., and Kolesar, P., 1984, "A comparison of the multiple dispatch and m/m/c priority queueing models of police patrol," Management Science, 30(6), 665–670.

[6] Green, L., 1985, "A queueing system with general-use and limited-use servers," Operations Research, 33(1), 168–182.

[7] Dunnett, S., Leigh, J., and Jackson, L., 2019, "Optimising police dispatch for incident response in real time," Journal of the Operational Research Society, 70(2), 269–279.

[8] Bureau of Justice Assistance, "Measuring Performance," Bureau of Justice Assistance. Accessed: Nov. 19, 2021. [Online]. Available: https://bja.ojp.gov/program/pmhc/measuring-performance

[9] Public Health Madison and Dane County, Journey Mental Health Center, and Madison Fire, 2022, "Madison CARES: A New Approach to Behavioral Health," Technical report, November.