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Required Allocation of Police Patrols in a Public Safety Emergency Response System Using Stochastic Simulation

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ABSTRACT: *Our research focuses on the performance evaluation of a public safety Emergency Response System based on a geographical and information technology assisted model, used to allocate police patrols to attend phone calls for service. Usually, public safety receives insufficient amount of resources such as the number of police patrols geographically allocated. However, our research interest is to evaluate an ideal and required number of police patrols that would be sufficient to reach a given level of service, considering the key performance parameter of response time and an international reference ideal maximum value. This research incorporates a 9th police district to previously published results of eight police districts. Actual and proposed operating strategies are modeled using discrete event stochastic simulation based on real data from 23 continuous days of operation of the system. Results identify that required ideal levels of resource for all police districts could be considered realistic and affordable.*

Keywords: *Emergency Response System; Police Patrols Allocation; Public Safety; Response Time; Stochastic Simulation*

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I. INTRODUCTION

The new federal government in Mexico is considering the formation of a National Guard police under the administration of the national army. This type of militarized police, new to Mexico, conceptually would reinforce the national security as an allied organization to municipal and state police organizations, and it would substitute the Federal Police. The justification to the National Guard police proposal is based on the need to try different strategies to more efficiently combat high incidents of crime at the national level. As an example of this alarming national crime statistics, the 2018 Perception and Victimization National Poll (ENVIPE) (INEGI, 2018), conducted by the National Institute of Statistics and Geography (INEGI), can be cited. According to ENVIPE 2018, the perception of public insecurity levels in Mexico, among citizens of 18 years old and older, was 82.1% and 76.3% for women and men respectively with a total average of 79.4%. This statistic represents an average percent increment of 5.1% compared to its value of the previous year. An increasing trend of this statistic has been observed since 2013 with a total average of 72.3%.

According to Zhang and Brown (2012), deterring and preventing crimes are important roles performed by police patrols to preserve public safety. Likewise, Guo et al., (2010) establish that police patrol deployment not only contributes to deterring criminals and reducing crime, but also improves people´s sense of security. Moreover, Leigh et al., (2017), state that police patrolling, has the capacity of deterring crime in areas with high criminal incidence. More broadly, Zhang and Brown (2013) and Devia and Weber (2013), affirm that the mission of a police patrol system, similar to other emergency service system, relies on providing the proper level of service, at the proper time and at the proper place.

Average response time is one of the key performance parameter of Emergency Response Systems (ERS) including safety ERS (Piyadasun et al., 2017; van Barneveld et al., 2018), which is measured from the time a call is answered to the arriving time of the unit to the location of the reported event (D'Amico et al., 2002; Stevens, 1980). An ideal maximum response time of 3 minutes to service urgent events was identified by the National Advisory Commission on Criminal Justice (NACCJ, 1973) in the United States of America. Similarly, Guo et al., (2010) utilize a maximum response time of 3 minutes as a requirement for a 90% service level.

Even though there is a vast volume of literature focused on the principle of optimizing insufficient allocations of resources to ERS including safety (Saladin, 1983; Curtin et al., 2010; Zhang and Brown, 2012; Zhang et al., 2016; Leigh et al., 2017; Camacho-Collados and Liberatore, 2015), our research focus is based on sufficiency resource allocation principles by design, to meet the maximum response time of 3 minutes.

In our research, the analysis of a 9th police district of a city´s safety ERS is integrated. This analysis follows consistency of prior research, and similarly to the evaluation of the other police districts, this research follows the same sequence of analysis including: (1) characterization of demand for service and service performance parameters, (2) modeling ideal present conditions identified as Basic Proposal scenario, (3) modeling scenario with 3 minutes maximum response time restriction (NACCJ, 1973), (4) identify ideal patrol inventory levels for police quadrants, and (5) identify areas of opportunity for improvement. The simulation software utilized by our research was ProModel 2010.

Given that the 7th police district was divided in to two districts identified as 7(1) and 7(2), due to its double number of police quadrants for a regular police district, the 8th police district became the 9th police district for analysis purposes. However, this analyzed 9th police district is referred as the 8th police district. This 8th police district is located at the northwest of the city´s urban grid. It is composed by low density population settlements similar to a rural configuration, and its streets are mainly not paved.

In general, the allocation of police patrols in the city´s ERS sometimes does not meet the ideal allocation of at least one patrol per patrolling zone, generating longer response times due to larger traveling distances among inter patrolling zone coverage or intra police quadrants and districts services. The Emergency Response System of the city uses a nationwide common 911 phone number, where all emergency calls are served for a given city and geographical area´s highways and roads. Our research obtained historic data from the city´s ERS corresponding to 552 continuous hours of operation.

II. LITERATURE REVIEW

The problem of the optimum allocation of resources including personnel and equipment to an emergency response system that allows the minimization of the service response time, to or under a given time value, is identified in the literature by Zaki et al., (1997). A historic review of significant contributions made by the academic areas of Operations Research and Management Science to improve efficiency of emergency response systems since the 1960´s is presented by Green and Kolesar (2004), where queueing models and simulation methodologies have been used. An example of a seminal research is the hypercube queueing model for facility location and redistricting in urban emergency services by Larson (1974). In this research, the author focuses on problems associated with geographical allocation of resources observed in emergency response systems, and develops efficient computational algorithms in a computer model, which allows the behavior analysis of a multi-server queueing system with distinguishable servers. This model was capable of analyzing problems of vehicle location and evaluation of police district design based on performance parameters such as response time and workload. Additional examples or pioneering research include Chaiken and Larson (1972), and Kolesar and Walker (1975). Variations of queueing models continue to be a strong strategy of analysis of emergency response systems. Examples of these research developments include Atkinson et al., (2008); Camacho et al., (2015); Zhang et al., (2016), and Ansari et al., (2017). Similarly, Zaki et al., (1997), present an example on the utilization of a simulation model for the analysis and management of an ERS, which focuses on the study, evaluation, and optimization of the allocation of police patrols vehicles to zones with multiple demand patterns in Richmond, VA. Additional research examples using simulation models to evaluate and improve emergency response systems include Brooks et al., (2011), Devia and Weber, (2013); Zhang et al., (2016); Chen et al., (2017); Zhang and Brown, (2013; 2014), Wu et al., (2014), Guedes et al., (2015), and Karatas and Yakici, (2019).

Alternatively, there are also other methodologies for evaluating and improving the efficiency of emergency response systems including: (1) mathematical optimization (Misra, 2014; Yang et al., 2015; Karatas and Yakici, 2019), (2) heuristics (Camacho et al., 2015; Chen et al., 2017), and (3) geographic information systems (Curtin et al., 2005; Huang and Pan, 2007).

III. METHODOLOGY

Our research focuses on solving the problem identified in the literature by Zaki et al., (1997), using stochastic discrete simulation for the ERS of interest, in a large city in Mexico. However, a performance constraint of maximum response time of 3 minutes for a given service level, for all priority calls, is considered as a restriction, using excess capacity of response units to evaluate an ideal level of required resource to comply with the maximum response time restriction, in all patrolling zones of every police district evaluated. We believe this goal meets the equity and sufficiency resource allocation principles by design, considering particular service demands for every zone, quadrant, and police district of the ERS. This design strategy tries to prevent differentiated customer service levels depending on political, income, cultural, and ethnicity variations in the society.

The simulation models sequential activities integrated in the response time process for the geographical region of one police quadrant, which is composed by four patrolling zones, and it is applied to every one of the four quadrants in a police district. Results are then averaged by police district. Two scenarios are simulated: (1)

BP-Actual, which models current response times and strategies of operations, one dedicated police patrol P_{dj} per patrolling zone, and four backup police patrols B_{ij} used by priority in any patrolling zone of the quadrant when any dedicated patrol is busy, and (2) RT3M, which it only modifies the response time of the BP-Actual scenario to the maximum response time of 3 minutes. Given this resource configuration the following applies to both scenarios:

P_{dj} = Dedicated patrol d for patrolling zone j, d=1 to 4, and j=1 to 4, and
B_{ij} = Back up inventory patrol i assisting any patrolling zone j, i=1 to 4, and j=1 to 4
Back-up Patrol Usage Priority: i=1 > i=2 > i=3 > i=4

The ERS provided real data from 552 hrs of continuous operation. A simulation run time period of 552 hrs was defined using ten replicates, based on the real time period. As explained previously, this research integrates the analysis and evaluation of results of a 9th police district, corresponding to the real 8th police district, due to the division of the 7th police district into two districts, given its double number of quadrants compared to one regular district. Our simulation model utilizes probabilistically characterized sequential processes integrated in the response and service processes in the ERS service.

The model verification was conducted by verifying the reproducibility of the model dynamics compared to the real dynamics of the processes, and of the operating logic of scenarios. In relation to the validation of the model, we considered the following criteria: (1) all the probability distributions utilized were identified with p-values >= 0.05, (2) the total numbers of events of calls for service, generated by the utilized probabilistic distribution functions, were very similar to those of historic demands in every patrolling zone, and (3) simulation results reflect logical behavior based on the model design and patrols deployment strategy.

IV. RESULTS

This section integrates results of the probabilistic characterizations of the main processes involved in the service provided to the calls for service in the Emergency Response System, and results from the stochastic simulation model corresponding to the two scenarios considered. As a reference, we describe the ERS nomenclature for the geographic divisions and subdivisions. The major or 1st level division of the ERS is named a police district. The middle or 2nd level subdivision is identified as police quadrant and every police district has four quadrants. Lastly, the lower or 3rd level subdivision is defined as patrolling zone, and every police quadrant has four patrolling zones. In relation to the calls for service, the ERS utilizes three levels of priorities associated with the level of importance for a call to be attended. These priority levels are designated as urgent, medium importance, and low importance.

Although the ERS simulation unit is one police quadrant, we report consolidated results using averages of all four quadrants in the police districts to assist in the traceability of results. In Table 1 we present the accumulated probability distributions of the three main parameters of interest by police district that define the system´s input, or demand for service, and the system´s output, or service provided. These three describing parameters are: (1) interarrival time, (2) response time, and (3) patrol busy time at the location of the event. The interarrival times were characterized by patrolling zone and by priority of the call for service, generating 12 probability characterizations in a police quadrant and 48 in a police district. In relation to the response time and patrol busy time at location, it was decided to characterize their behaviors by police quadrant and by priority generating 3 probability distributions by quadrant and 12 by district. For the 1st police district, a mixed strategy was followed. This strategy change was due to data integration given small samples occasionally found. In general terms, including all police districts and the three describing parameters, we can observe that the probability distributions are integrated by 42.1% Lognormal, 30.9% Exponential, and 19.5% Gamma, contributing with a 92.6% from the total amount of distributions. However, evaluating each parameter individually we observe that interarrival time, is described by 41.2% Exponential, 23.3% Gamma, and 27.7% Lognormal probability distributions. Similarly, the response time parameter is composed by 85.4% Lognormal, and 5.9% Gamma probability distributions. Likewise, the parameter patrol busy time at location is described by 23% Exponential, 18.8% Gamma, and 52.1% Lognormal probability distributions. If we evaluate only the 8th police district, it can be observed that the composition of probability distributions for interarrival time is 41.6% Lognormal, Gamma 37.5%, Weibull 12.5%, and 8.3% Exponential. Correspondingly, for the response time parameter, the describing probability distributions are integrated by 91.6% Lognormal, and 8.3% Gamma. Equally, for the patrol busy time at location parameter we observe that 83.3% of its behavior is defined by Lognormal, 8.3% by Exponential, and 8.3% by Gamma probability distributions.

Table 1. Characterization of Arrivals and Service of the City's ERS

Parameter	D_k[1]	Probability Distributions (95% C.I.)							Total
		Exponential	Gamma	Loglogistic	Lognormal	Normal J-T	Normal	Weibull	
Interarrival Time	D_1	30	9		7			2	48
	D_2	41	6		1				48
	D_3	27	6		9			6	48
	D_4	36			12				48
	D_5	1	21		14			12	48
	D_6	17	16		15				48
	$D_{7(1)}$	6	19		17			6	48
	$D_{7(2)}$	16	6		25			1	48
	D_8	4	18		20			6	48
Response Time	D_1			3	13	3		2	21
	D_2				12				12
	D_3		3		9				12
	D_4	1	1		9		1		12
	D_5		1		11				12
	D_6				12				12
	$D_{7(1)}$				12				12
	$D_{7(2)}$		1		11				12
	D_8		1		11				12
Patrol Busy Time at L[2]	D_1	6	4	3	7	1			21
	D_2	6	2		4				12
	D_3	4	1		7				12
	D_4	2	7		3				12
	D_5	4			7			1	12
	D_6		1		11				12
	$D_{7(1)}$		1		11				12
	$D_{7(2)}$	4	5		1			2	12
	D_8	1	1		10				12
Total		206	130	6	281	4	1	38	666

[1] = (D_k) Police District k
[2] = (L) Location of Event

A Cumulative distribution Function (CDF) example for priority 1 calls for service in one police quadrant in the 8th police district reflects that 1.6% of these calls had a response time of 3.3 minutes or less. Additional analysis of the CDF curve to evaluate longer response times describe that 59.5% of the calls for service were attended with a response time of 10.3 minutes or less, 82.5% with a response time of 15.3 minutes or less, 92.8% with a response time of 21.3 minutes or less, and 97.6% with a response time of 28.4 minutes or less. Given these results of this sampled police quadrant, the opportunity for improving response times is apparent.

In Table 2 we present the simulation results of three performance parameters for police districts by simulation scenario. These results are police quadrant averages from averages of ten simulation replicates of 552 hrs of simulation run time. The performance parameters are: (1) Average Number of Times (a patrol is) Used, ANTU, (2) Average Time per (patrol) Usage, ATPU, and (3) Percent Average (patrol) Usage, %AU.

A general overview among all police patrol districts and both simulation scenarios for the performance parameter Average Number of Times Used (ANTU), allows to realize the apparent condition that dedicated patrols P_{dj} are not sufficient to serve all demand for service, not even under the ideal condition where maximum response time is used as a requirement in simulation scenario RT3M. This is evidenced by the ANTU values obtained for the backup patrols $B_{ij,}$ especially for B_{1j} and B_{2j}. With this resource utilization condition, we observe that backup police patrols are required, and their resource levels need to be adjusted depending on the police quadrant and its demand. In relation to the performance parameter Average Time per Usage (ATPU), we also observe a general condition of time reduction when BP-Actual and RT3M scenarios are compared.

Table 2. Simulation Results by Scenario: District Comparisons of Quadrant Averages by Performance Parameters

D_k[1]	Scenario	Parameter	Dedicated Patrols				Inventory Back up Patrols			
			P_{11}	P_{22}	P_{33}	P_{44}	B_{1j}	B_{2j}	B_{3j}	B_{4j}
D_1	BP-Actual	ANTU[2]	148.28	129.83	126.48	103.23	64.68	11.58	3.38	1.63
		ATPU[3]	24.70	24.41	23.87	24.23	24.05	25.12	22.38	27.83
		% AU[4]	10.83	9.43	9.01	7.36	4.66	0.83	0.22	0.13
	RT3M	ANTU	154.15	133.80	131.18	107.28	45.75	5.60	1.60	1.30
		ATPU	14.89	15.32	14.36	15.37	14.66	16.42	18.43	17.05
		% AU	6.91	6.17	5.64	4.91	2.02	0.25	0.08	0.07
D_2	BP-Actual	ANTU	131.10	139.70	157.38	161.65	64.33	7.45	2.03	1.68
		ATPU	22.82	22.91	22.51	22.49	22.52	25.06	26.74	27.19
		% AU	8.94	9.60	10.68	10.90	4.32	0.51	0.14	0.12
	RT3M	ANTU	136.33	145.23	165.38	170.38	45.15	3.53	1.70	1.58
		ATPU	14.26	14.54	14.38	14.18	14.48	16.76	15.13	16.59
		% AU	5.89	6.38	7.14	7.23	1.98	0.17	0.07	0.07
D_3	BP-Actual	ANTU	105.70	127.03	116.75	132.48	46.40	5.78	1.75	1.53
		ATPU	20.09	19.78	19.31	19.70	20.22	20.42	21.91	23.93
		% AU	6.28	7.53	6.69	7.71	2.71	0.33	0.11	0.10
	RT3M	ANTU	100.38	129.33	119.28	141.45	32.45	3.25	1.70	1.58
		ATPU	13.43	13.61	12.95	13.54	13.42	14.03	14.88	15.50
		% AU	3.97	5.27	4.66	5.61	1.27	0.13	0.07	0.07
D_4	BP-Actual	ANTU	36.00	30.60	46.93	37.93	5.78	1.53	1.65	1.55
		ATPU	28.16	29.93	29.18	31.09	31.28	32.12	32.07	27.16
		% AU	3.10	2.22	3.76	3.61	0.53	0.14	0.15	0.12
	RT3M	ANTU	35.45	32.83	48.38	39.98	4.73	1.45	1.65	1.40
		ATPU	21.77	19.13	19.73	19.12	17.70	22.50	22.02	19.56
		% AU	2.39	1.71	2.68	2.27	0.26	0.09	0.10	0.09
D_5	BP-Actual	ANTU	127.38	122.23	160.10	141.78	74.78	12.95	2.80	1.75
		ATPU	24.75	25.49	24.88	24.71	25.03	24.14	22.73	27.98
		% AU	9.54	9.47	12.04	10.62	5.67	0.93	0.18	0.13
	RT3M	ANTU	127.03	124.28	170.15	153.15	56.70	6.45	1.98	1.60
		ATPU	16.61	16.32	16.51	16.19	16.91	15.80	16.68	21.84
		% AU	6.34	6.15	8.45	7.45	2.93	0.33	0.09	0.09
D_6	BP-Actual	ANTU	95.70	93.63	95.60	92.83	39.85	4.98	2.03	1.55
		ATPU	33.93	33.08	33.52	34.34	34.84	32.24	36.04	41.26
		% AU	9.81	9.36	9.68	9.62	4.19	0.50	0.20	0.18
	RT3M	ANTU	100.98	95.20	93.55	97.13	24.73	2.80	1.73	1.55
		ATPU	19.12	18.81	18.69	19.33	19.82	24.34	18.53	26.74
		% AU	5.81	5.39	5.26	5.68	1.46	0.18	0.09	0.11
$D_{7(1)}$	BP-Actual	ANTU	117.48	105.23	86.45	102.70	41.08	5.08	1.78	1.70
		ATPU	26.79	27.17	27.01	27.93	28.27	27.60	35.28	31.38
		% AU	8.28	7.51	6.26	7.31	2.92	0.37	0.15	0.12
	RT3M	ANTU	118.30	110.55	91.75	106.00	27.28	2.90	1.63	1.55
		ATPU	14.89	15.12	15.71	15.28	15.37	18.40	20.55	23.08
		% AU	5.23	5.04	4.28	4.81	1.25	0.14	0.08	0.10
$D_{7(2)}$	BP-Actual	ANTU	115.58	108.05	112.23	126.73	34.33	3.65	1.60	1.58
		ATPU	24.35	24.88	24.10	24.09	24.11	26.19	30.76	27.92
		% AU	8.05	7.72	7.71	8.95	2.45	0.27	0.12	0.12
	RT3M	ANTU	119.30	104.95	110.75	131.03	22.38	2.48	1.60	1.50
		ATPU	14.79	14.99	13.98	14.52	15.62	15.86	20.56	17.58
		% AU	5.16	4.69	4.57	5.78	1.06	0.11	0.09	0.07
D_8	BP-Actual	ANTU	64.02	60.16	60.80	59.18	9.16	1.63	1.54	1.54
		ATPU	24.79	24.77	24.76	24.78	24.95	27.24	27.43	27.40
		% AU	4.79	4.50	4.54	4.44	0.69	0.12	0.12	0.12
	RT3M	ANTU	64.84	60.84	61.27	59.88	6.18	1.57	1.53	1.52
		ATPU	14.83	14.87	14.92	14.95	15.09	16.76	17.36	17.32
		% AU	2.90	2.73	2.75	2.71	0.28	0.07	0.07	0.07

[1] = (D_k) Police District k
[2] = (ANTU) Average Number of Times Used (From 4 Quadrants)
[3] = (ATPU) Average Time per Usage (From 4 Quadrants): Transportation Time + Service Time at Location
[4] = (%AU) Average Percent Utilization of Patrol Time (From 4 Quadrants)

This is attributed to the significantly smaller response times, which can be interpreted as minimizing insufficiency of police patrols in the patrolling zone, quadrant or district, and the need to request coverage support to other zones, quadrants, or districts. If sufficient police patrol capacity is maintained with dedicated and backup patrols, the traveling of longer distances can be prevented. The general evaluation of the performance parameter Percent Average Usage (%AU), also reflects a significant reduction when compared in BP-Actual and RT3M scenarios. Reduced response times are observed due to reduced transportation distances and transportation time. This elevated transportation time in BP-Actual scenario absorbs utilization time of the police patrol, and a reduced transportation time frees it in RT3M scenario, allowing each police patrol to be available for a potential incoming call for service. Even though significant response time reductions could be achieved by shorter transportation distances, it is important to recognize other opportunities for reducing response time since it also includes other processes including the information gathering on the phone and the dispatching of the police patrol.

If we focus on interpreting the results of the 8^{th} police district we observe that its demand for service is only larger to the demand observed for the 4^{th} police district. This condition allows all dedicated patrols to be more capable of servicing a call for service. However, even though this demand for service is not as large as the demand in other police districts, it is observed that it also required the use of backup police patrols B_{1j}, and B_{2j} to absorb most of its demand for service when the four dedicated patrols were busy. Their values for the performance parameter Average Number of Times Used (ANTU) in BP-Actual were 9.16 and 1.63 respectively, and 6.18 and 1.57 in the RT3M scenario. The performance parameter Average Time per Usage (ATPU) also reflects a time reduction when compared to its value in scenarios BP-Actual and RT3M, where the ANTU value in RT3M scenario reflects an average reduction of 10 minutes due to its constrained response time. Similarly, it can be observed that performance parameter Percent Average Usage (%AU), reflects a conservative reduction in the RT3M scenario compared to the BP-Actual scenario given the less saturated system in this police district.

The performance parameter Percent Average Utilization (%AU), illustrating graphical results of all police districts, is presented in Figure 1. In this figure we can observe a general behavior for two conditions. In the first condition the reduction of the patrol utilization time in the RT3M scenario compared to the BP-Actual scenario is observed for all dedicated P_{dj}, and backup patrols B_{ij}. This utilization time reduction allocates an increment in capacity in all patrols to be able to serve calls for service if presented. The second condition is the observed prevalence of the need of the backup patrols, as their %AU values are present and significant.

Likewise, the performance parameter Average Number of Times Used (ANTU) is shown in a graphical format in Figure 2 for all police districts. We also would like to comment on two relevant observable conditions in this figure. The first condition is related to the incremented value of the ANTU value for all dedicated police patrols P_{dj} in the RT3M scenario compared to its corresponding value in the BP-Actual scenario. This condition is achieved due the reduction in the %AU parameter due to a reduction in their response time that allows dedicated patrols to increase their service capacity. This incremental capacity reduces the level of dependency on backup police patrols B_{ij} to serve incoming calls for service when all dedicated patrols are busy. The second condition is directly related to the previous statement, which is that the ANTU values for backup patrols in the RT3M scenario are reduced given that in this scenario dedicated patrols have higher capacity of attending calls for service and absorb this demand for service instead of the backup police patrols.

Based on the simulation results obtained by the evaluation of two scenarios, we offer three potential criteria to determine the required allocation of police patrols. However, we recommend an allocation strategy for every police quadrant in every police district based on their particular simulation results. The first criterion to allocate police patrols may be based on a minimum value of ANTU per time unit. Alternatively, the second criterion could be based on a %AU value per time unit. Moreover, a third potential criterion would be based on a defined Customer Service Level (CSL), considering the cumulative service provided by incremental number of police patrols. Using the first criterion in the 8^{th} police district with the RT3M scenario and an ANTU value of >=2 for 552 hrs of operation, the required number of backup patrols would be one. If the second criterion is used with a %AU>=0.2%, the required value of backup patrols would be one as well. Applying the third criterion for a CSL>=98%, the required minimum number of backup patrols would be one, providing a 98.2% CSL.

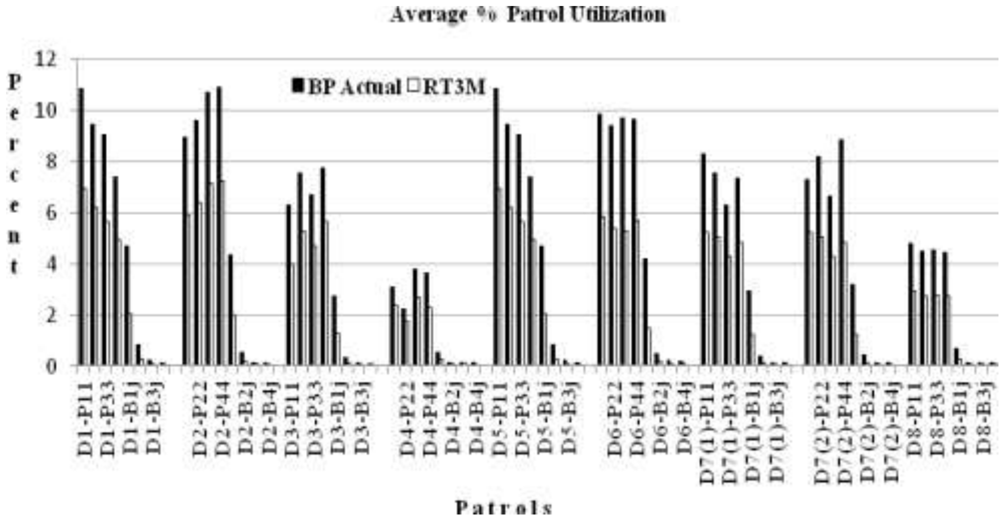

Figure 1. Average % Patrol Utilization by Patrol for Districts D_1, D_2, D_3, D_4, D_5, D_6, $D_{7(1)}$, $D_{7(2)}$, and D_8

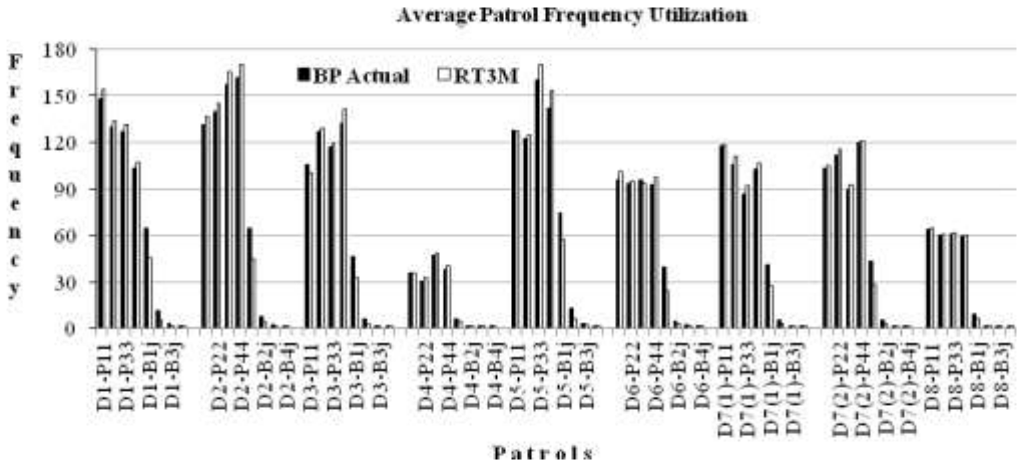

Figure 2. Average Frequency Utilization by Patrol for Districts D_1, D_2, D_3, D_4, D_5, D_6, $D_{7(1)}$, $D_{7(2)}$, and D_8

V. CONCLUSIONS

We concluded that stochastic discrete event simulation is a very valuable tool to consider in the evaluation and design of current and new ERS operating strategies. Moreover, simulation allows the in depth analysis required to understand complex dynamic and stochastic processes, as well as to evaluate proposed operating strategies. Our research has found that basic or dedicated as well as an adequate number of backup police patrols are required allocations in all police quadrants and in all police districts of the evaluated ERS of interest. In this case, we would recommend that the required allocation of police patrols be evaluated in every police quadrant in an individual basis, instead of providing allocations based on district averages. Also, it is recommended that a given reasonable service standard in terms of Customer Service Level (CSL) be defined for the complete ERS considering gradual increments and starting with 97% CSL. It is highly recommended that a design principle of equity and sufficiency be considered for all patrolling zones and quadrants of the ERS. We understand that these design principles will require cultural and budget adjustments.

Similarly, we found that one to three backup police patrols significantly and positively impact the performance of an ERS in terms of decreasing patrol response time. However, there are other ERS processes that impact this response time such as the time to process an incoming phone call for service and the time to develop an efficient dispatching strategy.

We would like to emphasize the key role of the utilization of Geographic Information Systems to have real time visualization of patrols´ locations, and tools that assist on an efficient decision making and accountability of resources. It is also fundamental to consider an adequate police district design strategy based on advanced design tools.

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