Proceedings of the 2012 Winter Simulation Conference
C. Laroque, J. Himmelspach, R. Pasupathy, O. Rose, and A.M. Uhrmacher, eds

REDUCING AMBULANCE RESPONSE TIME USING SIMULATION: THE CASE OF VAL-DE-MARNE DEPARTMENT EMERGENCY MEDICAL SERVICE

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ABSTRACT

The French Emergency Medical service, known as SAMU, is responsible for providing permanent phone support and dispatching the proper response for emergency requests. The response time required for an ambulance's arrival at the scene following a call is an important performance indicator in determining the quality of the SAMU system since this may be directly related to patient's survival. In this paper, discrete simulation techniques are used to model the SAMU of the Val-de-Marne department (France) in order to investigate several alternative configurations for potential improvements. Scenarios consist of adding more resources, relocating existing teams and reducing processing times in order to improve response time. We found that repositioning part of the existing teams into potential stations increased average percentage of calls covered within the 20-minutes criterion up to 4.8%. This improvement in coverage reaches 5.2% when reducing the regulation processing time by 20%.

1 INTRODUCTION

The emergency medical service (EMS) system in France is known as the SAMU system which stands for the French acronym of "Urgent Medical Aid Service". It was established in 1968 to coordinate the activity of the "Mobile Emergency and Resuscitation Services", named SMUR, which are mobile response vehicles staffed with one or more physicians and operated by public hospitals. The law n°86-11 of 6 January 1986, relating to emergency medical care and medical transport, defined SAMU mission as "hospital based services providing permanent phone support, choosing and dispatching the proper response for a phone call request". The phone support is performed in a reception and regulation (R&R) center and the response to each call depends on patient need: it can be a simple care advice over the phone, or a prompt dispatch of the most appropriate mobile care resource (SMUR teams, cross-trained firefighters, private ambulance…) to perform emergency medical assistance. The main objective of the SAMU system is to provide a high level of service on the scene of accidents performed by a physician. This is the main characteristic of the French system in comparison with some other EMS worldwide, especially in Anglo-Saxon countries, where care is mainly given by paramedics, whereas advanced life support (well-equipped ambulance staffed with physicians) is involved only in the most critical cases.

The SAMU is responsible for providing service for two types of phone call requests: primary calls that require immediate medical assistance outside of the hospital (e.g., cardiac arrest, accident injuries,

978-1-4673-4782-2/12/$31.00 ©2012 IEEE

childbirth...) and secondary calls which correspond to the transport of patients from one hospital to another, in case medical staff assistance is needed during the transfer. As primary calls are considered to be absolute emergencies, an available SMUR team is immediately dispatched to the call in order to perform the rescue. In case of secondary calls, the most serious cases are considered to be as urgent as primary calls and thus require the immediate assignment of a SMUR team whereas less urgent emergencies are postponed and served within a reduced activity period according to an appointment system. Between rescues, SMUR teams are placed in fixed positions called stations.

The French territory is organized according to three administrative division levels: 27 regions (e.g.: region of Ile-de-France) subdivided into 101 departments (e.g.: department of Val-de-Marne), in turn divided into more than 36.000 districts (e.g.: district of Creteil). The SAMU system is structured at the department level. Each department is responsible for managing its own SAMU service. The current research results from a project named “Performance and Systemic Optimization of Emergency Medicine” funded by the French National Research Agency (ANR) in cooperation with the National Geographic Institute (IGN) and the SAMU 94 which is responsible for the emergency medical and pre-hospital care within the Val-de-Marne department. This project aims to develop the SAMU 94 procedures in a cost-effective way that meets the population’s needs in emergency situations under limited resources. Since we know of no prior optimization model that deals with the French legislation regarding emergency medical services, the purpose of our work is to improve the system’s effectiveness through the use of a discrete-event simulation model implemented in ARENA software. The main performance measures used to evaluate such improvement are related to response time (i.e. waiting time of a patient for an ambulance arrival in order to answer a call) and the SMUR teams utilization.

The paper is organized as follows: Section 2 briefly describes the literature review on the use of optimization models in emergency medical services management. In Section 3, we describe the emergency medical service process of the Val-de-Marne department, the available data , the details of our simulation model and the steps of verifying and validating the initial configuration of the model. We detail the results of alternative scenarios in Sections 4. Finally, Section 5 provides conclusions and presents some perspectives for future research.

2 LITERATURE REVIEW

Emergency service operations have been studied using a variety of tools such as mathematical programming models and queuing theory (See the comprehensive literature review of Brotcorne, Laporte, and Semet (2003)). In this paper, we discuss ambulance emergency medical services using computer simulation. This approach refers to the process of designing and creating a computerized model of a system to imitate its operations or characteristics in order to better understand the behavior of that system for a given set of conditions (Kelton, Sadowski, and Sturrock (2007)). It offers a less expensive, less disruptive and more timely means of evaluating several process changes on the studied system (Benneyan (1997)). In the context of emergency medical services, simulation has been used for various purposes since it allows to describe a high degree of detail without simplifying assumptions that are otherwise needed to obtain performance measure predictions when using other methods (Henderson and Mason (2004)).

Savas (1969) was one of the early users of computer simulation to analyze the possible improvements in New York emergency ambulance service when changing the number and location of ambulances. Peleg and Pliskin (2003) developed a simulation model of Israeli EMS that uses a geographic information system (GIS) to construct geographic areas (polygons) of at most 8 minutes response time. By positioning ambulance within the modeled polygons, the calls responded within the criterion of 8 minutes increased from 34% and 62% in the Camel (urban) and Lachish (rural) districts respectively to more than 94%. Ingolfson, Erkut, and Budge (2003) used a model based on discrete simulation to estimate the impact of several changes on Edmonton EMS operations such as different shift scheduling and the use of a single start station where ambulances would begin and end their shifts instead of a multiple start system in order to simplify management and supervision. Silva and Pinto (2010) studied the case of the EMS of Belo Horizonte in Brazil using a simulation model implemented in ARENA Software to evaluate scenarios of an increased demand and to analyze the number of ambulances needed at each station. The simulation environment ARENA had also been used by Sullivan (2008) to analyze an EMS response in case of mass casualty disaster, such as terrorist attack, and natural disaster and by Koch and Weigl (2003) to develop a model that analyzes the transport logistics of the Austrian Red Cross rescue organization and compares the alternative of a decentralized planning with central coordination. Aringhieri, Carello, and Morale (2007) dealt with the problem of locating ambulance locations in Milano(Italy) city area using some static deterministic integer linear programming models to find optimal post locations and then validating the proposed solutions with a simulation framework.

In this paper, we propose a simulation model that captures several detailed aspects of the real system (such as time-dependent arrival rate and travel times) and aims to improve the response by the SAMU 94 system through alternative configurations related to the three components of response time that are waiting times, processing times and travel times.

3 THE EMERGENCY SERVICE SYSTEM OF THE VAL-DE-MARNE DEPARTMENT

3.1 Process Description

Val-de-Marne is a French department located in the south east of the city of Paris in the region of Ile de France. It has a total area of 227 km², a population of approximately 1,300,000 inhabitants and is divided into 47 districts. The emergency service of the department (SAMU-94) is available 24 hours a day, every day of the year and is currently operated by two stations where on-duty vehicles wait between calls: one central station located at Henri-Mondor Hospital (HM) in the district of Creteil and an auxiliary station located in Villeneuve-Saint-Georges Hospital (VSG).

The number of ambulances in each station is fixed. Altogether there are 8 vehicles including 6 well-equipped ambulances called Mobile Intensive Care Units (MICU) and 2 medical vehicles (MV) which are usually dispatched for the most serious calls because faster than MICU but do not allow for the transport of the patient . The 2 MV's and 5 of the MICU's are located in the main station of HM and 1 MICU in the auxiliary station of VSG. Each of these vehicles is staffed by a SMUR team consisting of one qualified physician, one nurse and/or one emergency medical technician. There is one SMUR team on duty at VSG station 24 hours a day and between 3 to 5 teams on duty at HM station scheduled as follows: 3 teams between 10:30pm and 10:30am, 4 teams between 7:30pm and 10:30pm and 5 teams between 10:30am and 7:30pm.

The basic process for regulating calls and deploying the SMUR teams is illustrated in Figure 1. This process is triggered when a call is first received in a reception and regulation (R&R) center located in the central station HM. In this center, a medical team performs a triage called regulation to decide the best solution for the patient. There are two types of resources in the R&R center: assistants and regulator physicians. Assistants are responsible for the initial selection to identify inappropriate calls or to create a medical file and record the basic information on the nature of the request such as the patient's name and age, the address and the reason for the call. The number of assistants on duty varies between 4 (9pm-7am), 5 (7am-2pm) and 6 (2pm-9pm). Depending on the potential severity of the call, the assistant chooses to redirect the call to an emergency physician named "SAMU regulator" for high priority calls, or to a general practitioner named "PDS regulator" otherwise. The regulator performs a medical evaluation which can lead to three possible decisions: (1) The call is not urgent: in this case, a simple advice is given to the patient or a private ambulance is dispatched; (2) The request is a relative emergency: if it is a primary call, it is transferred to a basic life support system (firefighters, red-cross…). In case of a secondary call, an appointment is taken with the origin hospital in order to send a SMUR team when more than one team is available in the central station; (3) The request is an absolute emergency: a SMUR team is immediately dispatched to the call location. There are between 1(8am-12:30pm) and 2(12:30pm-8am) SAMU regulators and 1 PDS regulator 24 hours a day.

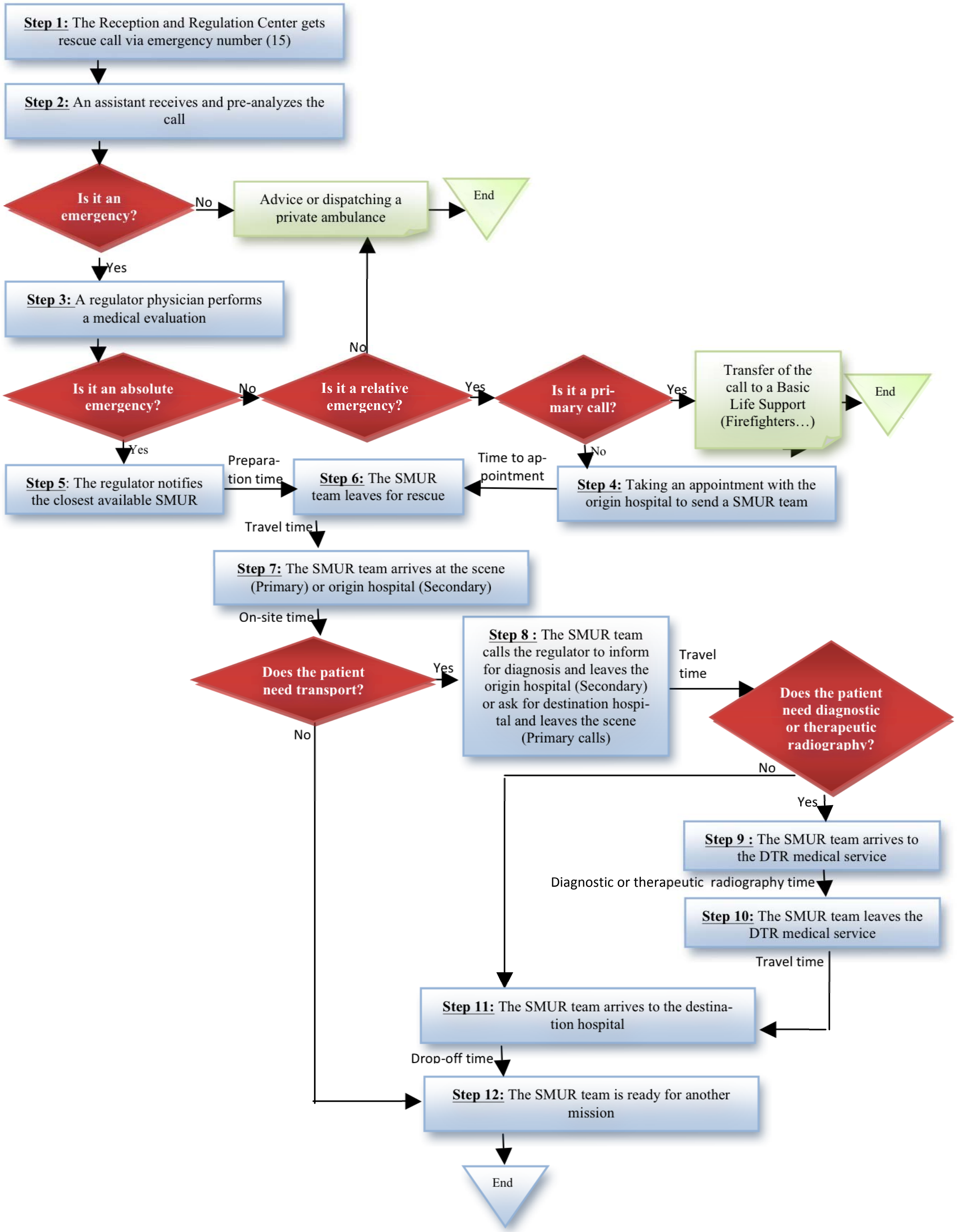


Figure 1: Process flowchart

In the case that the regulator decides to send a care team, he notifies the closest available SMUR team. The team prepares the rescue by getting the information relative to the call and rushing to the vehicle. Once at the call location, the SMUR team reaches the patient (find the right building, climb the stairs ,etc.), stabilize the patient, call the SAMU regulator to brief him about the updated diagnosis and, if needed, prepare the patient for transport to the destination hospital chosen by the regulator. The choice of destination hospital is determined by several factors: the proximity and the available capacity of the hospitals, the hospitals having appropriate facilities for the patient and the patient wishes. The patient may need a diagnostic or therapeutic radiography (DTR) such as MRI, X-ray, etc. In this case, the SMUR team takes the patient to the medical service where the DTR is performed. The patient is then transported to the destination hospital where the SMUR team spends some time 'handing over' the patient to hospital staff and completing paperwork. Finally, the SMUR team becomes available and can travel for another rescue or return to the station to which it is assigned for the next mission.

Based on the different steps in this rescue process (See Figure 1), the following processing times were identified:

- Regulation time: interval between the time the R&R center gets the rescue call (Step1) and the time the regulator notifies the nearest available SMUR team to perform the rescue (Step 5). It includes the assistant pre-analysis time (Step 2), the regulator medical evaluation time (Step 3) and eventually, the duration to achieve the appointment time to send a SMUR team in case of secondary relatively urgent calls (Steps 4 to 6)
- Preparation time: interval between the time the regulator notifies the SMUR team and the time it leaves for rescue (Steps 5 to 6)
- On-site time: time interval between the SMUR team arrives at the scene and the time it leaves the scene (Steps 7 to 8)
- Diagnostic or therapeutic radiography time: time interval between the SMUR team arrives at the DTR medical service and the time it leaves this service (Steps 9 to 10).
- Drop-off time: time interval between the SMUR team arrives at destination hospital and the time it leaves the hospital (Steps 11 to 12)

3.2 Performance Measures

The response time, defined as the period between receipt of a call and first arrival of an ambulance at the scene, is an important benchmark to evaluate the quality of emergency medical services (Peleg and Pliskin (2003)). It is an important performance measure since the prompt arrival of the rescue on the scene saves lives, reduces suffering and produce confidence in the service from the population point of view (Savas (1969)). The response time can be calculated as an average time (Inakawa, Furuta, and Suzuki (2010), Silva and Pinto (2010)) or as a percentage of calls responded to within a target time T (e.g.: responding to at least 90% of the most serious calls in 9 min or less in North America's EMS department (Ingolfsson, Erkut, and Budge (2003)).

Other performance measures have been used in the literature such as: (1) the round trip time, defined as the period between the receipt of a call and the arrival of the ambulance with the patient to the destination hospital, which is an important parameter in case the patient requires prompt professional medical treatment (Savas (1969)) and (2) the ambulance utilization rate that should be balanced among human resources (teams) to insure social equity.

In this paper, we used the response time performance measure to validate the simulation model since it is the main variable of interest that the model has been developed to minimize. In Section 4, a response time of 20 minutes or less was set as a target time and used together with the SMUR teams utilization rate per station to evaluate and compare the different alternative configurations.

3.3 Data Generation

The 12th version of the discrete event simulation software ARENA (Rockwell Automation, Milwaukee, Wisconsin) was used to develop the simulation model. This system uses the SIMAN processor and simulation language and is fully hierarchical. It combines the ease of use found in high-level simulators that provide graphical simulation modeling and analysis modules, with the flexibility of simulation languages accessed in low-level modules and even general-purpose procedural languages like Visual Basic or C/C++ to model any desired level of detail and complexity.

This section aims at presenting how data used in the simulation model is generated, based on observed values. The data concerns mainly the characterization of calls (i.e. distribution of calls arrival, typology and priorities), processing times and travel times.

3.3.1 Calls

We analyzed data on call volume over 6 months (June 8th 2010 to December 31st 2010), broken down by hour of the day and day of the week (see Figure 2). We can notice that the number of calls per hour is relatively stable during weekdays (Monday through Friday) and tends to significantly increase on the weekend (Saturday and Sunday) by 23% on average. During weekdays, we identified 3 time periods : the “busy period” from 7pm to 11pm (more than 17 calls per hour), a “reduced activity period ” from 1am to 8am (less than 10 calls per hour) and a “regular activity period” otherwise. On the weekend, reduced activity period remains the same, while the busy period is longer (from 9am to 11pm). According to this preliminary analysis, we used the input analyzer module from ARENA 12 software to fit a probability distribution to the call data and to estimate this distribution parameters at the accurate level of hour of the day by distinguishing between weekdays and weekends. Kolmogorov-Smirnov and Chi-Square goodness-of-fit tests were applied to choose the “most fitting” theoretical arrival distribution and to verify the hypothesis of its fitting to the call data. These tests were unable to reject such hypothesis with 5% of significance.

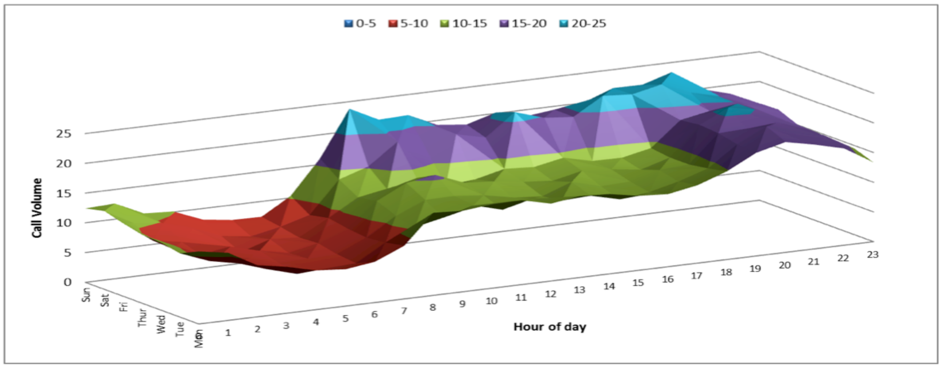


Figure 2: Average call volume by hour of the day and day of the week

The generated calls in the simulation model were then classified into two types according to their occurrence in the call database: primary (98,87%) and secondary (1,13 %). Among the primary calls, only 4,32% required the dispatch of a SMUR team. In order to determine the response priorities for different categories of requests and the allowed travel speeds of vehicles during the rescue, both primary calls that require the dispatch of a SMUR team and secondary calls were categorized according to their degree of severity at two levels of evaluation: the first level is performed by the regulator after his medical analysis on the phone (i.e. Step 3 on Figure 1), and the second level by the SMUR team once at the call location(i.e. Step 7 on Figure 1). At first level (Priority level I), priority 1 is assigned to the most serious calls that include life-threatening emergencies (e.g. cardiac arrests, serious trauma…). Priority 2 is assigned otherwise. This level affects the order of queued calls waiting for the dispatch of an available SMUR team, the preparation time and the travel time to the scene. At second level(Priority level II), a scale of 0 to 3 is established: Priority 0 is assigned when the patient is not transported to a destination hospital(e.g. case of patient’s death). Priority 1 indicates the highest priority (urgent medical assessment required at the destination hospital). Priority 3 indicates the lowest priority (non-urgent calls). This level affects the on-site, the travel time to the destination hospital and the drop-off times.

In order to spatially model the distribution of calls, the Val-de-Marne department was divided into units of equal size known as "IRIS", the French acronym for "aggregated units for statistical information". Each IRIS is a basic unit of 2000 residents developed by the French National Institute for Statistics and Economic Studies (INSEE) to divide the territory for the dissemination of the population census. The Val-de Marne is composed of 527 IRIS . Hence, the main advantage of this division for the present study is to aggregate calls into small areas (i.e. basic units) without having a significant travel time within a given such area .

3.3.2 Processing Times

The rescue records of the SAMU 94 dated from October 1st, 2010 to August 31st,2011 (6658 calls) were collected for analysis. This database over 11 months, hereafter referred to as "regulation database", included for each call the following data: (1) The time and date of the call; (2) The type of call (primary/secondary); (3) The origin of the call (the district); (4) The priority of the call established by the regulator; (5) The priority of the call after the SMUR team evaluation, (6) The name of the response vehicle performing the rescue; (7) Patient destination; (8) The timing of the different steps in the rescue process: SMUR team notified, SMUR team leaves for the rescue, SMUR team arrives at the scene, SMUR team leaves the scene, SMUR team arrives at the diagnostic or therapeutic radiography service, SMUR team leaves the diagnostic or therapeutic radiography service, SMUR team arrives at the hospital, SMUR team finishes the rescue. Table 1 represents the data relative to this period . Based on this data, the processing times (See Section 3.1) are evaluated for all arriving calls. An average value is then calculated for calls associated with a given couple (type of call; priority), except for the DTR time which is calculated regardless of the call priority because of its low occurrence in the database (3% of rescues). This corresponds to the "Real" columns of Table 1.

Table 1: Average processing times comparison for different call types and priorities (minutes)

Type of call	Priority level I	Average regulation time			Average preparation time		
		Real	Simulated	Relative difference	Real	Simulated	Relative difference
Primary	1	6.5	6.3	4%	3.3	3.3	0%
	2	12.8	12.9	-1%	3.8	3.8	0%
Secondary	1	22.8	22	4%	4.9	5.2	-5%
	2	53.8	51.8	4%	6	6.1	-1%

Type of call	Priority level II	Average on-site time			Average DTR time			Average drop-off time		
		Real	Simu-lated	Relative difference	Real	Simu-lated	Relative difference	Real	Simu-lated	Relative difference
Primary	0	45.9	46.6	-1%						
	1	52.1	52.9	-2%	60.2	59.6	1%	38.9	38.9	0%
	2	56.4	57.2	-1%				31.8	31.8	0%
	3	49.1	49.6	-1%				21.9	22.0	-1%
Secondary	0	46.6	45.6	2%						
	1	33.3	34.5	-4%	63.1	62.2	1%	32.2	32.2	0%
	2	35.6	35.8	-1%				29.4	29.3	0%
	3	34.6	34.5	0%				24.9	24.8	1%

We used the input analyzer module to fit the processing times probability distributions to the data using Kolmogorov-Smirnov and Chi-Square goodness-of-fit tests. As the obtained p-values of these tests when fitting the data to the theoretical distributions available in the software (Beta, Erlang, Exponential, Gamma, Johnson, Lognormal, Normal, Poisson, Triangular, Uniform and Weibull) were low (less than 0.05), we chose to use the empirical distributions to better capture the characteristics of the data (See Kelton, Sadowski, and Sturrock (2007)). Empirical distributions simply divide the actual data into groupings and calculate the proportion of values in each group. These distributions were used as input data to build the simulation model. They provided predictions of the model within 5% of the observed processing times (See "simulated" columns of Table 1).

3.3.3 Travel Times

Travel times is essentially a function of the distance travelled, the traffic conditions (rush hours, weekdays vs. weekends, daytime vs. night time…) and the weather conditions (Zaki and Cheng (1997)). They are also correlated to the rescue degree of severity since rescue teams can use lights and sirens for the most urgent calls, and travel at standard traffic speeds otherwise (Henderson and Mason (2004)).

For purposes of this study, the National Geographic Institute pre-computed average travel times for every possible combination of origin IRIS, destination IRIS, hour of the day, day of the week, call type and priority. By comparing the regulation database to the GPS traces of the SAMU-94 vehicles (a set of points recorded each 10 seconds), the "relevant paths" that correspond to routes of effective rescues were identified. Based on these paths, an average travel time was assigned to each section of the road network of the Val-de-Marne department according to its typology (motorway, main road, minor road, local street). For each hour of the day, day of the week, rescue type and priority, this travel time was calculated by dividing the section length by the average speed observed in the GPS data.

The average travel time for a given combination of origin and destination IRIS is then obtained by summing up the average travel times associated with the sections that form the shortest path between these two IRIS. We used an API (Applications Programming Interface) and a Visual Basic for Applications (VBA) function to make the simulation model communicate with the travel time calculation module by providing the input parameters (origin and destination IRIS that can correspond to a call, station or hospital location, the hour, the day, the type and the priority of the call) and getting the resulting average travel time.

3.3.4 Verification and Validation of the Simulation Model

The simulation model verification was performed by showing the model to the SAMU-94 specialists to ensure that the conceptual model has been implemented according to the real world system behavior. We traced the movement of calls to check that the closest available ambulance responded to them and we checked that the travel times computed by the travel time calculation module were realistic.

The operational validation, defined as determining that the model's output behavior has sufficient accuracy (Sargent (2007)), was performed by comparing the response time statistics obtained from the simulation model to the corresponding statistics observed in the real system. We ran the simulation model for 502.560 minutes (corresponding to 11 months of operations which is the regulation database period and 15 days as a warm up period), using different random number seeds to replicate the model 10 times. Overall, the model's average response time predictions (32.32 min) are quite close to the real system average response time (32.06 min). The corresponding distribution, shown in Figure 3, indicates that model outputs are within 7.5% of the observed cumulative response time distribution.

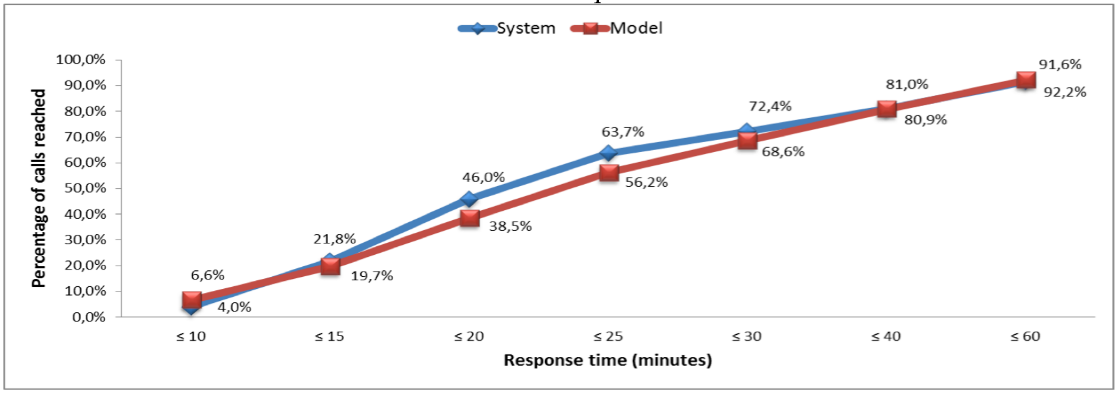


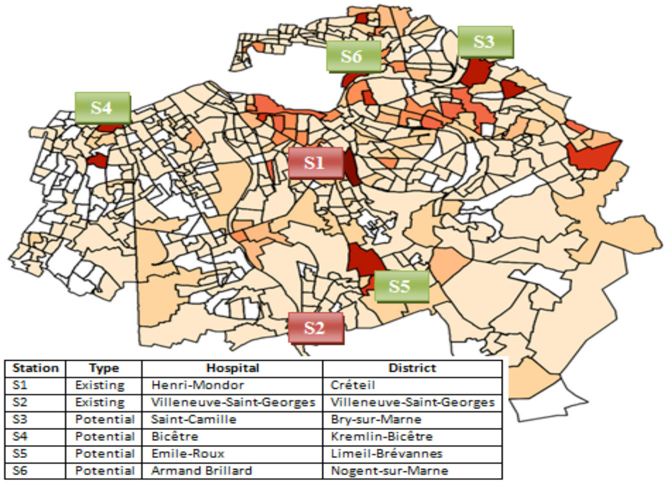
Figure 3: The cumulative distributions of real and simulated response time

4 SCENARIOS AND RESULTS

In this section, we changed some of the simulation model parameters to investigate the impact of such variations on the present SAMU-94 system operations (i.e. the original model). Since the general purpose of the simulation model is to achieve a substantial improvement in response time, three simulation experiments were tested in order to reduce the three main components of this time which are waiting times, travel time and regulation processing time. In the first experiment, we assume that new resources (assistant, regulator or SMUR teams) are added to the original model in order to reduce the waiting times for the assignment of these resources. The second experiment consists in changing the locations of stations and the associated number of available SMUR teams in order to reduce the distance travelled and to achieve call locations more quickly. Finally, the third experiment tests the impact of a reduction of regulation processing time. This reduction could take place by performing some tasks of the process more efficiently or concurrently (e.g. part of medical evaluation with preparation tasks). A target response time of 20 minutes for absolute emergency calls (primary calls and priority 1 secondary calls) was set as a working performance indicator. Since relative emergency calls (priority 2 secondary calls) are based on an appointment system, it is not relevant to include them into this performance indicator. The 95% confidence intervals of percentage of calls reached within this target time as well as SMUR teams utilization rate per station were calculated from 5 independent replications based on 11 simulated months for each scenario.

Under the original model, we noticed that the waiting times for the assignment of resources were low (0.20 min, 0.74 min and 0.48 min on average for assistants, regulators and SMUR teams respectively), which suggested no significant improvement in performance when adding new resources. In order to verify such an assumption, we performed the first experiment by adding a new SMUR team to the system located in the busiest station of HM. Not surprisingly, we found that the average SMUR teams utilization decreased by 4.1% ± 1.1%, while the percentage of absolute emergency calls reached in 20 min remained almost the same (44% ± 1.0%). Thus, further analysis of adding resources to the system can be expected to have no potential gain , which suggests that the current number of the SAMU-94 is quite sufficient.

In the second experiment, a visual study of Val-de-Marne demand map suggested where new stations would be needed. We identified one potential station (S5) where the VSG station (S2) SMUR team could be moved and three potential station (S3, S4 and S6) where one of HM station (S1) SMUR teams could be located 24 hours a day (See Figure 4). We tested the relocation of one SMUR team from S2 to S5 (scenario 1), from S1 to S3(scenario 2), from S1 to S4 (scenario 3) and from S1 to S6 (scenario 4). We also tested the relocation of two SMUR teams by combining scenarios 1 and 2 (scenario5), scenarios 1 and 3 (scenario 6) and scenarios 1 and 4 (scenario 7).



Station	Type	Hospital	District
S1	Existing	Henri-Mondor	Créteil
S2	Existing	Villeneuve-Saint-Georges	Villeneuve-Saint-Georges
S3	Potential	Saint-Camille	Bry-sur-Marne
S4	Potential	Bicêtre	Kremlin-Bicêtre
S5	Potential	Emile-Roux	Limeil-Brévannes
S6	Potential	Armand Brillard	Nogent-sur-Marne

Figure 4: Spatial distribution of calls using IRIS, existing stations and possible new stations

When comparing results of the original model and scenarios 1 to 4 (See Table 2), we found that the optimal replacement of one SMUR team among the potential stations is that from S1 to S4 (scenario 3). This relocation improved the percentage of absolute emergency calls reached in 20 min by 3.5% ± 0.6%. Note that the obtained improvement interval under this scenario is quite precise, which suggests that the prediction by the simulation model can be expected to be correct within 0.6%, 95% of the time. This improvement can entirely be attributed to the reduction of travel time by an average of 6.7%. On the other hand, if the advantage of a single move of one SMUR team from S2 to S5 (scenario 1) can be neglected (0.6 ± 0.6), combining this change to scenarios 2 to 4 improved the average performance of these scenarios. Particularly, the advantage of the optimal replacement of one SMUR team(scenario 3) on the average percentage of absolute emergency calls reached in 20 min was even greater (4.8% ±1.2%) when combined to a second move of a SMUR team from S2 to S5 (scenario 6), providing the optimal replacement of two SMUR teams among the potential stations. Finally, we observed that all the scenarios tested in this experiment provided a balanced utilization rate of SMUR teams with a difference at most equal to 4% on average among stations on duty.

Table 2: 95% confidence intervals for performance measures of the original model and scenarios 1 to 7

Scenarios	**Used stations**	**Number of SMUR teams on Duty**	**SMUR teams utilization rate/station**	**Percentage of calls reached in 20 min** *(absolute emergency calls)*
Original Model	S1	3 *(10:30pm-10:30am)*,4 (07:30pm-10:30pm) or 5 (10:30am-07:30pm)	23.4% ± 1.7%	44% ± 1.8%
	S2	1 (24 h/day)	21.3% ± 1.0%	
Scenario 1	S1	3 *(10:30pm-10:30am)*,4 (07:30pm-10:30pm) or 5 (10:30am-07:30pm)	24.0% ± 2.4%	44.5% ± 2.1%
	S5	1 (24 h/day)	20.4% ± 2.1%	
Scenario 2	S1	2 *(10:30pm-10:30am)*,3 (07:30pm-10:30pm) or 4 (10:30am-07:30pm)	24.3% ± 1.1%	45.3%± 1.8%
	S2	1 (24 h/day)	21.3% ± 1.4%	
	S3	1 (24 h/day)	21.1% ± 1.5%	
Scenario 3	S1	2 *(10:30pm-10:30am)*,3 (07:30pm-10:30pm) or 4 (10:30am-07:30pm)	24.3% ± 2.2%	47.5% ± 1.6%
	S2	1 (24 h/day)	21.4% ± 1.9%	
	S4	1 (24 h/day)	20.6% ± 2.0%	
Scenario 4	S1	2 *(10:30pm-10:30am)*,3 (07:30pm-10:30pm) or 4 (10:30am-07:30pm)	22.6% ± 1.0%	46.4% ± 2.0%
	S2	1 (24 h/day)	21.0% ± 1.2%	
	S6	1 (24 h/day)	24.1% ± 1.3%	
Scenario 5	S1	2 *(10:30pm-10:30am)*,3 (07:30pm-10:30pm) or 4 (10:30am-07:30pm)	25.1% ± 1.9%	45.8% ± 1.8%
	S5	1 (24 h/day)	21.6% ±1.5%	
	S3	1 (24 h/day)	21.9% ± 2.0%	
Scenario 6	S1	2 *(10:30pm-10:30am)*,3 (07:30pm-10:30pm) or 4 (10:30am-07:30pm)	23.6% ± 0.7%	48.8% ± 0.9%
	S5	1 (24 h/day)	21.0% ± 1.5%	
	S4	1 (24 h/day)	20.3% ± 1.7%	
Scenario 7	S1	2 *(10:30pm-10:30am)*,3 (07:30pm-10:30pm) or 4 (10:30am-07:30pm)	22.4% ± 0.7%	47.3% ± 1.8%
	S5	1 (24 h/day)	20.1% ± 1.8%	
	S6	1 (24 h/day)	24.1% ± 1.6%	

The third experiment evaluates the performance of the system when the regulation processing time is decreased. However, we were interested in evaluating the impact of such a change compared to that of relocating stations. We found that a 10% decrease in regulation time for all call types and priorities provided a percentage of absolute emergency calls reached in 20 min of 47% ± 2.1%, i.e. an improvement of 3% ± 1.1% compared to the original model, which is slightly lower on average than the benefit of the optimal relocating scenario of one SMUR team in experiment 2 (scenario 3). With a 20% decrease in regulation time, the increase in coverage attained 5.2% ± 0.7% (49.2% ± 1.6%), i.e. an additional 0.4% average coverage compared to the optimal relocating scenario of two SMUR teams in experiment 2 (scenario 6). However, such a large decrease in regulation processing time may be hard to implement in comparison with the relocating scenarios.

5 CONCLUSION

The objective of this paper is to provide the French emergency medical service of the Val-de-Marne department decision-makers with an efficient and flexible tool that allow them to identify potential problems in the flow of operations, to test and investigate the effects of proposed policy changes and to quantify the resulting improvements regarding some chosen performance measures. For this purpose, we developed a simulation model using ARENA software that integrates: (1) time-dependent arrival rate, (2) small calls aggregation areas (less than 0.5 km^2 on average), (3) processing times related to call type and severity, (4) a travel time calculation module for every possible origin and destination with consideration to traffic conditions (hour of day and day of the week) and calls priority, (5) various resources and their scheduled shifts, as well as (6) the current dispatching policy (nearest available team). This model was validated regarding the response time performance measure and used to evaluate several changes to the SAMU-94 operations. Computational results show that the average percentage of absolute emergency calls reached in 20 min was improved continuously when moving one or two SMUR teams to potential station(s) from 44% in the current system up to 48.8% with two teams relocated. The 20-min coverage attained greater improvement(49.2%) when the regulation processing time was decreased by 20%.

Further research will take place according to three directions. First, we will investigate scenarios on the relocation of a larger number of teams into several combinations of potential stations. A second direction is to study the possible implementation of reducing regulation time as well as other processing times and to evaluate the impact of this decrease on the total time (from the receipt of the call until the end of the rescue). Finally, it is possible to achieve more considerable improvements by integrating a dynamic ambulance redeployment system to the simulation model in order to optimally locate the SMUR teams after every service start or completion.

ACKNOWLEDGMENTS

The financial support from the French National Research Agency (ANR) is gratefully acknowledged. The authors would like to thank the SAMU-94 managers and physicians for their support of this project. We are also very grateful to the National Geographic institute team for their work on the travel times model.

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