DOI: https://doi.org/10.46354/i3m.2019.dhss.007

AGENT-BASED SIMULATION OF A FIRE DEPARTMENT'S RESPONSE TO EMERGENCY INCIDENTS: AN UPDATED MODEL

Adriano O. Solis[a], Jenaro Nosedal-Sánchez[b], Ali Asgary[c], Francesco Longo[d], Deryn Rizzi[e], Kevin Plested[f], Antonio Briga[g], Antonella Castagna[h], Beatrice Zaccaro[i]

[a][c] School of Administrative Studies, York University, Toronto, Ontario, Canada
[b] Cátedra Conacyt, Facultad de Ingeniería, Universidad Autónoma del Estado de México, Ciudad Universitaria Toluca, México
[d][g][h] DIMEG, University of Calabria, Rende (CS), Italy
[e][f] Vaughan Fire and Rescue Service, Vaughan, Ontario, Canada
[i] DIME, University of Genoa, Genoa (GE), Italy

[a] asolis@yorku.ca, [b] jnosedal@conacyt.mx, [c] asgary@yorku.ca, [d] francesco.longo@unical.it,
[e] deryn.rizzi@vaughan.ca, [f] kevin.plested@vaughan.ca, [g] anto94b@gmail.com, [h] antonella-castagna@virgilio.it,
[i] zaccarobeatrice@gmail.com

ABSTRACT
A modelling and simulation (M&S) approach was earlier developed, following statistical analysis of the emergency incident database of the Vaughan Fire & Rescue Service covering eight years of consecutive incident records from January 2009 to December 2016. The M&S framework, which could potentially be replicated for fire departments across Canada, involved two different simulation models running on separate platforms: (i) an *Incident Generation Engine*, which simulates the 'arrival' of emergency incidents, and (ii) a *Response Simulation Model*. The current report covers only an update of the Response Simulation Model, an agent-based model developed using AnyLogic. Two issues associated with the earlier Response Simulation Model have specifically been addressed and resolved by the updated model. We report on findings from our simulation experiments based on the updated model.

Keywords: Fire department, fire response, emergency response, discrete event simulation, agent-based simulation, Vaughan Fire & Rescue Service

1. INTRODUCTION

Solis *et al.* (2018a, 2018b) reported on modelling and simulation (M&S) of a fire department's responses to emergency incidents. The M&S project involved two simulation models running on separate platforms:

1. *Incident Generation Engine* – a discrete-event simulation model developed using CPNTools 4.0 (CPNTools 2017), generating the incidents used as inputs for the second model; and
2. *Response Simulation Model* – an agent-based model developed using AnyLogic.

1.1. Vaughan Fire & Rescue Service

The above models were created following statistical analysis of emergency incident and responding unit data of the Vaughan Fire & Rescue Service (VFRS) covering eight years of consecutive incident records from January 2009 through December 2016, and based upon VFRS operating policies and procedures. The City of Vaughan is the 17th largest city in Canada with a population currently estimated to be just over 330,000 (Canada Population 2019). It is located north of Toronto, the capital of the province of Ontario and the largest Canadian city with more than 3,000,000 inhabitants.

The research team had initially been commissioned to conduct, on behalf of the Canadian Association of Fire Chiefs (CAFC), research aimed at developing a simulation engine leveraging the National Fire Information Database (NFID) of Canada (Solis *et al.* 2018a). The NFID, which was first made available to the researchers in April 2017 and updated in July 2017, covered 11 years (2005-2015) of fire incident records across Canada. However, serious data gaps were found in the NFID by Solis *et al.* (2018a). Moreover, the NFID involves only fires and fire-related incidents, which generally do not account for the majority of emergency incidents that fire departments across Canada respond to. For example, in the case of the cities of Toronto and Vaughan in 2016, only 28.1% and 25% of all incidents responded to by Toronto Fire Services and VFRS, respectively, were fire and fire-related incidents (Solis *et al.* 2018b).

The NFID was, therefore, deemed to preclude a meaningful modelling and simulation of a fire department's responses to emergency incidents. It was in this context that the research team approached the VFRS Senior Command Team in order to seek advice and explore an appropriate way for moving forward with the M&S effort. The VFRS – recognizing an opportunity to gain potential strategic, tactical, and operating insights – offered to quickly make available its 2009-2016 emergency incident and responding unit dataset.

1.2. VFRS Emergency Incidents: 2009-2016

VFRS' yearly numbers of emergency responses over the 8-year period from 2009 to 2016 are presented in Figure 1.

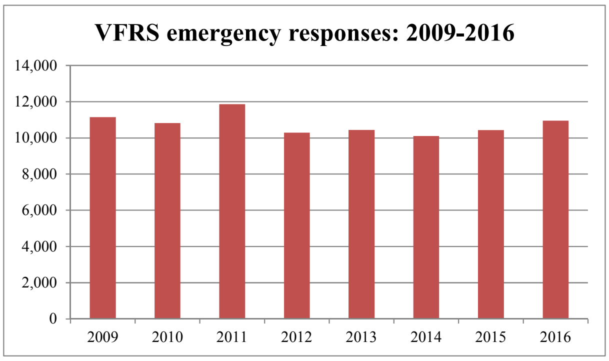

Figure 1: VFRS Emergency Responses per Year in 2009-2016
(Sources: Vaughan Fire & Rescue Service 2009-2016.)

According to census data (Table 1), Vaughan's population grew from 238,866 in 2006 to 306,233 in 2016, representing a growth rate of 2.5% per annum over the 10-year period. The numbers of emergency incidents do *not* appear to exhibit a corresponding rate of growth, apparently as a result of fire safety education and prevention initiatives of the VFRS.

Table 1: Population of the City of Vaughan

Census Year	Population
2006	238,866
2011	288,301
2016	306,233

(Source: City Population 2019.)

The annual breakdowns of emergency incidents in 2009-2016 according to major categories are summarized in Table 2. Fires and fire-related incidents (including false alarms) have accounted for between 25% and 36% of all VFRS emergency responses during the 8-year period from 2009 to 2016. Medical emergencies, on the other hand, have been between 34% and 42% each year during the same period. According to its latest annual report, VFRS responded to a total of 11,834 emergency incidents throughout the year 2018 (Vaughan Fire & Rescue Service 2018), of which 47% were medical emergencies.
In the 2009-2016 dataset, however, a more specific incident type is assigned to each incident in an 'Incident Code' field. There have been 83 such incident codes in use, which form part of the data inputs into the Incident Generation Engine. Each incident generated by this first model includes the incident code as one of the key incident features.

1.3. Incident Generation Engine

The first simulation model, the Incident Generation Engine, was implemented as a discrete event simulation with CPNTools 4.0 as the platform. This model produces a list of emergency incident occurrences, each with an incident ID and the following five key incident features (Solis *et al.* 2018a, 2018b):

1. incident 'arrival' time,
2. incident code (indicating type of incident),
3. incident location (Latitude and Longitude GIS coordinates, based upon a discrete partitioning of the entire geographical region covered by VFRS, using a lattice granularity of 500 m × 500 m),
4. APPTOT (or Alarm Processing Plus TurnOut Time, corresponding to Roll-out Time stamp minus Alarm Receipt Time stamp), and
5. on scene time (for the first responding unit at the scene of the incident).

Table 2: Breakdowns of VFRS Emergency Incidents: Years 2009 to 2016

Year	2009	2010	2011	2012
No. of incidents	11,147	10,814	11,864	10,286
Property fires/explosions	7%	8%	8%	7%
False alarm/non-fire calls	25%	28%	25%	23%
Rescues	11%	15%	16%	15%
Public hazards	4%	4%	3%	4%
Medical	42%	34%	36%	38%
Other responses	11%	11%	12%	13%
Total (%)	100%	100%	100%	100%
Year	**2013**	**2014**	**2015**	**2016**
No. of incidents	10,447	10,099	10,428	10,950
Property fires/explosions	6%	8%	7%	9%
False alarm/non-fire calls	24%	23%	24%	16%
Rescues	16%	17%	17%	18%
Public hazards	4%	5%	5%	4%
Medical	36%	38%	36%	41%
Other responses	14%	9%	11%	12%
Total (%)	100%	100%	100%	100%

(Sources: Vaughan Fire & Rescue Service 2009-2016.)

The chronological list of incidents output by the Incident Generation Engine is the set of inputs that are simulated in the Response Simulation Model. The Incident Generation Engine has already been presented and described in detail by Solis *et al.* (2018a, 2018b), and is accordingly only summarized here.

2. UPDATED RESPONSE SIMULATION MODEL

The current report covers only an updated version of the Response Simulation Model that was developed earlier (Solis *et al.* 2018a, 2018b).
While the Incident Generation Engine is a discrete event simulation model, we used agent-based modelling (ABM) to develop the Response Simulation Model, using the AnyLogic simulation platform. The agents in the model consist of the entities as summarized in Table 3.

Table 3: Agents in the Response Simulation Model

Agent	Description
Dispatcher	Representing the VFRS communications centre, which receives an emergency call and alerts the appropriate fire station or stations to respond to the incident
Emergency Point	Representing the location of an emergency incident, which changes its status based on the actions of other agents
Station	An agent that receives the call from the Dispatcher, and changes its status according to availability of resources (vehicles/crews)
Vehicle	An entity (responding unit) that receives the dispatch order from the Station, and uses the GIS subsystem within AnyLogic to determine and use the appropriate street route

Two issues associated with the earlier model have specifically been addressed and resolved by the updated model:

- an inaccurate representation of VFRS' fire districts and stations, and
- a model simplification that allows only either one or two responding units being dispatched to an emergency incident.

2.1. VFRS Fire Districts and Stations

The proper representation of VFRS' fire districts, with their corresponding geographical areas, and the locations of their respective fire stations (shown in Figure 2) are now incorporated as a shapefile in the updated Response Simulation Model.

The nine fire stations and current numbers of responding units are presented in Table 4. The actual number of vehicles located at each station is greater than the reported number of responding units, the latter being dependent upon the number of firefighting crews assigned to the station. Each responding vehicle is assigned a four-person firefighting crew. The addition of one responding unit at a station, therefore, requires one additional 24-hour firefighting crew, which corresponds to an incremental labour cost for VFRS of around CAD 2.5 million per year.

2.2. VFRS Incident Response Protocol

Current VFRS operating protocol calls for 1, 2, or 4 responding units depending upon the type of incident (entered as 'incident code'). Out of a list of 83 incident codes, the protocol requires four vehicles to respond to each of 15 codes, as summarized in Table 5. On the other hand, 24 incident codes require only one responding unit, while another 44 incident codes call for two responding units. The incident code assigned by the Incident Generation Engine to an incident accordingly determines the number of responding units (1, 2, or 4) that the Dispatcher agent "sends" to the scene of that incident.

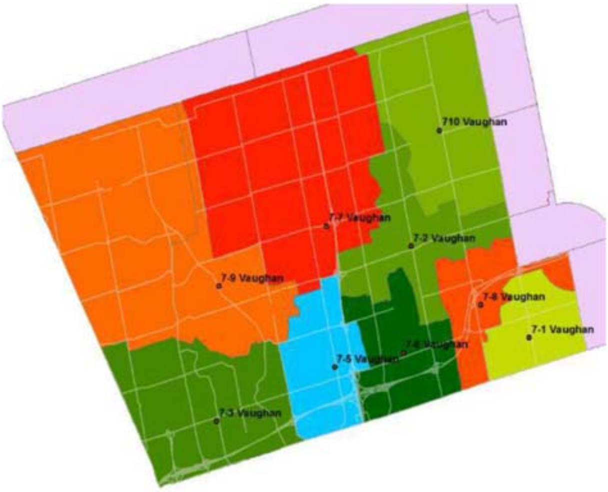

Figure 2: VFRS' Nine Fire Districts and Fire Station Locations

Table 4: VFRS Current Number of Responding Units per Station

District/Station	No. of Responding Units
71	2
72	2
73	2
75	2
76	1
77	1
78	1
79	1
710	1

Table 5: Incident Codes Calling for Four Responding Units per Current VFRS Response Protocol

Incident Code	Incident Description	No. of Trucks (Protocol)
1	Fire	4
2	Combustion Explosion (including during fire)	4
11	Overpressure Rupture (no fire - e.g., steam boilers)	4
12	Munition Explosion - (no fire - e.g., bombs, dynamite)	4
13	Overpressure Rupture - gas pipe (no fire)	4
21	Overheat (no fire - e.g., engines, mechanical device)	4
22	Pot on Stove (no fire)	4
24	Other Cooking/toasting/smoke/steam (no fire)	4
25	Lightning (no fire)	4
26	Fireworks (no fire)	4
29	Other pre fire conditions (no fire)	4
51	Bomb, Explosive Removal, Standby	4
63	Building Collapse	4
601	Trench rescue (non fire)	4
602	Confined space rescue (non fire)	4

In developing the initial Response Simulation Model, the research team recognized the fairly complicated, and apparently tedious, treatment within the AnyLogic model of dispatching four responding units coming from 2, 3, or 4 different fire stations that may have available vehicles/crews.

Based on the initial statistical analysis, it was determined that only 5.3% of the total number of incidents in the 8-year dataset would have required dispatching four responding units per response protocol, as seen in Table 6. However, when considering total number of responding units, such incidents would have, in fact, required 14.2% of all vehicles needing to be dispatched. Given this fairly significant proportion, it was believed appropriate for the research team to redouble its efforts in incorporating into the Response Simulation Model within AnyLogic the dispatching of four responding units whenever any of the 15 incident codes listed in Table 5 arises.

Table 6: Expected Distribution of Number of Responding Units per Response Protocol: 2009-2016

No. of Responding Units Required per Protocol	No. of Incidents	% of Total No. of Incidents	Total No. of Responding Units Required per Protocol	% of Total Responding Units
1	50,108	60.5%	50,108	40.3%
2	28,264	34.1%	56,528	45.5%
4	4,426	5.3%	17,704	14.2%
Total	82,798	100.0%	124,340	100.0%

However, the actual number of responding units dispatched to an incident may vary from the number specified per protocol, depending upon various factors – in particular, the actual situation as reported by the first responding unit arriving at the scene of the incident. We looked into the numbers of responding units, as reported in the 2009-2016 Incident Responding Units file, and derived the actual distribution shown in Table 7. We see that, in fact, only 71.4% of all responding units were either the lone unit or one of only two units responding to an incident. In the earlier version of the Response Simulation Model, of course, 100% of all simulated responding units would have fallen into either of the two categories (lone unit or one of two units).

Table 7: Distribution of Actual Number of Responding Units: 2009-2016

Actual # of Vehicles Dispatched per Incident	No. of Incidents	% of Total No. of Incidents	Total No. of Responding Units	% of Total Responding Units
1	57,494	69.4%	57,494	45.0%
2	16,819	20.3%	33,638	26.4%
3	2,864	3.5%	8,592	6.7%
4	1,712	2.1%	6,848	5.4%
More than 4	3,909	4.7%	21,055	16.5%
Grand Total	82,798	100.0%	127,627	100.0%

3. NEW SIMULATION RESULTS

With the model having been updated, we conducted, and collected statistics from, 365 replications of the experiment, with each replication simulating one day of VFRS responses to emergency incidents (corresponding to a one-year period from January 1 to December 31). The *Incident Generation Engine* was used to produce 365 days of incidents, and the resulting incident list was used as input for the *Response Simulation Model*.

Table 8 summarizes the number of emergency incidents throughout a simulated year, by district, and the corresponding number of responding units required. It may be worth noting that the average number of responding units per incident is highest, at 1.76, in the case of District 76, which is predominantly an industrial district.

Table 8: Simulated Number of Emergency Incidents and Required Responding Units

District	No. of emergency incidents	No. of responding units required	Average no. of responding units per incident
71	1,692	2,501	1.48
72	1,586	2,290	1.44
73	1,648	2,435	1.48
75	1,201	1,888	1.57
76	635	1,120	1.76
77	1,900	2,719	1.43
78	850	1,283	1.51
79	1,061	1,586	1.49
710	690	994	1.44
Overall	11,263	16,816	1.49

One of the interesting statistics arising from the simulation is the utilization of responding units at each fire station. For instance, Station 77 is currently allocated one responding unit. In our 365-day simulation experiment, this station has no available responding unit 12% of the time (see Figure 3).

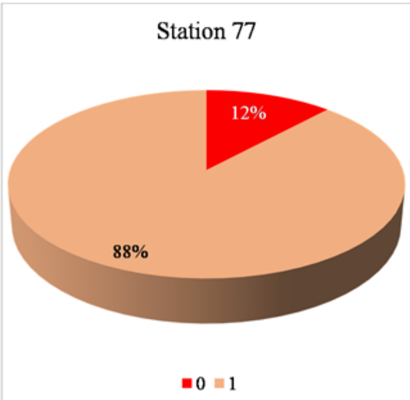

Figure 3: VFRS Station 77 – Simulated Responding Unit Utilization/Availability

Table 9 shows that, of the 1,900 incidents occurring in District 77 in the simulated year, just over 62% of the

2,719 required responding units are provided by its own station, Station 77, while close to 38% are units coming from other stations. Stations 72, 79, and 75 respond to around 19%, 8%, and 7%, respectively, of incidents in District 77. This would appear to make sense, particularly given the close geographical proximity of these three stations to District 77 as seen in Figure 2.

Table 9: Simulated Responses by Various Fire Stations to Incidents in District 77

Responding Station	Responses to District 77 Incidents	% to Total
71	0	0.0%
72	515	18.9%
73	3	0.1%
75	182	6.7%
76	21	0.8%
77	1,695	62.3%
78	1	0.0%
79	220	8.1%
710	82	3.0%
Total	2,719	100.0%

Station 75, on the other hand, with two responding units, does not have an available vehicle and crew only 5% of the time, while having two available responding units 89% of the time (see Figure 4).

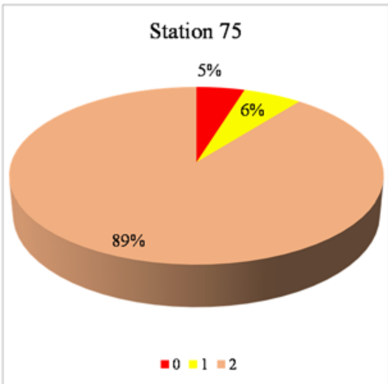

Figure 4: VFRS Station 75 – Simulated Responding Unit Utilization/Availability

As expected, when distances traveled to incident locations are much longer, we find that average response times are very significantly greater when fire stations respond to incidents outside their own district than when the incidents are within the district (Table 10). It is, therefore, desirable to see a fire station being able to respond as much as possible to its own district's incidents. We accordingly considered looking further into the situation where Station 77 responds to only 62% (refer back to Table 9) of the emergency incidents within District 77.
We considered two modifications to the current assignment of responding units (as summarized in Table 4), giving rise to the following three Scenarios:

Scenario 1. Current number of responding units at each fire station (Table 4).
Scenario 2. A second responding unit added to Station 77 (all other responding unit assignments remain the same).
Scenario 3. Move one responding unit from Station 75 to Station 77 (all other responding unit assignments remain the same).

Table 10: Average Response Times per Fire Station

Station	Responses within own District	Responses outside own District	Responses Overall
71	00:05:40	00:11:03	00:06:27
72	00:07:21	00:11:24	00:07:59
73	00:08:13	00:14:40	00:08:40
75	00:07:22	00:11:47	00:08:24
76	00:07:30	00:12:41	00:08:31
77	00:07:33	00:12:42	00:08:27
78	00:08:16	00:10:54	00:08:38
79	00:07:24	00:12:33	00:08:23
710	00:07:45	00:13:32	00:08:18

Table 11 provides a summary of responding unit assignments to the nine VFRS fire stations corresponding to each of these three scenarios. It must be noted that Scenario 2 would require a 14th responding unit for VFRS and entail a significant incremental operating cost.

Table 11: Number of Responding Units per Station Under Scenarios 1-3

District/Station	Scenario 1	Scenario 2	Scenario 3
71	2	2	2
72	2	2	2
73	2	2	2
75	2	2	1
76	1	1	1
77	1	2	2
78	1	1	1
79	1	1	1
710	1	1	1
Total No. of Responding Units	13	14	13

Figures 5, 6, and 7 show (for Scenarios 1, 2, and 3, respectively) the simulated responses by individual fire stations to incidents occurring within their own districts. Based upon the numbers reported in Figures 5-7, Table 12 shows the percentages, under each scenario, of the responding units required by incidents occurring in each district that are responded to by the district's own fire station. This table, therefore, allows a comparison of the percentages resulting under the alternative Scenarios 2 and 3 with the percentages under Scenario 1. With Stations 76, 77, 78, 79, and 710 each having only one responding unit currently assigned (under Scenario 1), Districts 76, 77, 78, 79, and 710 all have much lower percentages of own station's response (between 53%

and 66%) in comparison with Districts 71, 72, 73, and 75 (between 86% and 88%) which each have two responding units.

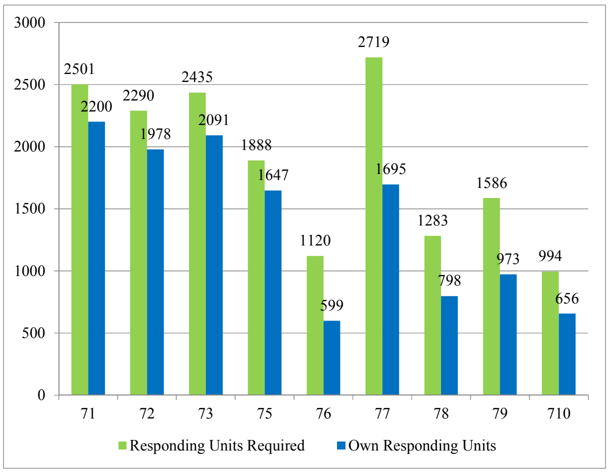

Figure 5: Responding Units Under Scenario 1

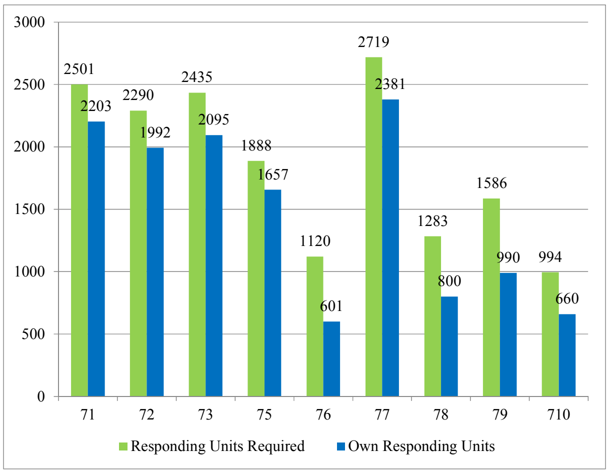

Figure 6: Responding Units Under Scenario 2

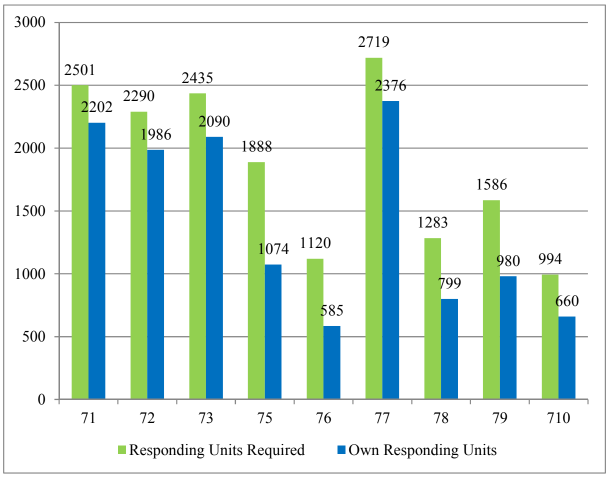

Figure 7: Responding Units Under Scenario 3

Understandably, under Scenario 3 where one responding unit is reassigned from Station 75 to Station 77, the percentage of own station's response to incidents decreases from 87% to only 57% of 1,888 in the case of District 75, while increasing from 62% to 87% of 2,719 in the case of District 77. On the other hand, under Scenario 2 where an additional responding unit is assigned to Station 77, the percentage of own station's response increases from 62% to close to 88% in the case of District 77, while the other districts' percentages either remain the same or marginally improve by up to one percentage point. Overall, Scenario 3 gives rise to only a 0.7 percentage point increase in own stations' responses to incidents, while Scenario 2 yields a heftier 4.4 percentage point improvement.

Table 12: Percentages of Required Responding Units Provided by Own Station Under Scenarios 1-3

District	Responding units required by incidents in the district	%-age of required responding units provided by own station		
		Scenario 1	Scenario 2	Scenario 3
71	2,501	88.0%	88.1%	88.0%
72	2,290	86.4%	87.0%	86.7%
73	2,435	85.9%	86.0%	85.8%
75	1,888	87.2%	87.8%	56.9%
76	1,120	53.5%	53.7%	52.2%
77	2,719	62.3%	87.6%	87.4%
78	1,283	62.2%	62.4%	62.3%
79	1,586	61.3%	62.4%	61.8%
710	994	66.0%	66.4%	66.4%
Overall	16,816	75.1%	79.6%	75.8%

Consistent with the comparisons of percentages in Table 12, we see that Table 13 shows average response times improving by 14 seconds overall under Scenario 2. In fact, under Scenario 2, the average response times improve by between 11 and 16 seconds in every district (except for District 71 with only a one second improvement). We do see an improvement in overall response times under Scenario 3, but only by 3 seconds. However, the effects on average response times in individual districts are inconsistent, with some districts showing improvements while other districts show increases in average response times.

Table 13: Comparison of Average Response Times Under Scenarios 1-3

District	Scenario 1	Scenario 2	Scenario 3
71	00:06:27	00:06:26	00:06:27
72	00:07:59	00:07:48	00:07:41
73	00:08:40	00:08:28	00:09:03
75	00:08:24	00:08:10	00:09:06
76	00:08:31	00:08:19	00:08:30
77	00:08:27	00:08:14	00:08:18
78	00:08:38	00:08:22	00:09:06
79	00:08:23	00:08:09	00:10:06
710	00:08:18	00:08:03	00:09:19
Overall	00:08:30	00:08:16	00:08:27

We see, therefore, that the impact of adding another responding unit (under Scenario 2) to Station 77, which currently is assigned only one responding unit, is significantly greater than just transferring one responding unit to Station 77 from Station 75 (under Scenario 3).

4. CONCLUSION AND FURTHER WORK

4.1. Conclusion

This study shows that using the proposed M&S approach combining discrete event and agent-based simulation models makes it possible to investigate in detail the dynamics and impacts of various resource allocation and reallocation scenarios on key performance indicators (KPIs) of a fire department.

Combining the results with cost-benefit analyses will provide decision makers with tools that they need to enhance a fire department's decisions regarding adding and equipping new or existing fire stations in their operational areas.

4.2. Further Work

Investigation of other alternative scenarios associated with assignment/reassignment of responding units (vehicles/crews) to existing fire stations is ongoing. Further work may also include looking into effects on KPIs of either new or relocated VFRS fire stations.

As indicated by the district/station numbers, a District/Station 74 had previously been in existence. The researchers plan to investigate the effects on KPIs of a proposed reintroduction in the near future of District/Station 74. The analysis will, of course, take into consideration District 74 boundaries in relation to other districts, as well as the location of Station 74 and any possible reassignment of responding units.

ACKNOWLEDGMENTS

This research work is conducted under the umbrella of the Advanced Disaster, Emergency and Rapid Response Simulation (ADERSIM) program at York University. The Modeling and Simulation Center–Laboratory of Enterprise Solutions (MSC-LES) of the University of Calabria, Italy, is an international collaborator of the ADERSIM program.

The work was initially supported by a grant from the Canadian Association of Fire Chiefs (CAFC) in support of a research project on 'Developing a fire response test bench based on NFID'. The project had sought to develop a simulation engine leveraging the National Fire Information Database (NFID).

We wish to acknowledge partial financial support from Dr. Jianhong Wu, University Distinguished Research Professor and Canada Research Chair in Industrial and Applied Mathematics, York University.

The participation of Dr. Jenaro Nosedal-Sánchez has been sponsored, since July 2018, through the Mexican Cátedras-Conacyt program (project 2354).

The research work has been undertaken in collaboration with the Vaughan Fire & Rescue Service, and has been incorporated in a VFRS project entitled "Igniting Insight: Using GIS and Analytics in the Fire Service" which has received the 2019 IPAC Innovative Management Bronze Award from the Institute of Public Administration of Canada.

REFERENCES

Canada Population, 2019. Population of Vaughan 2019. https://canadapopulation2019.com/population-of-vaughan-2019.

City Population, 2019. Population of the City of Vaughan, Ontario, Canada. Accessed at https://www.citypopulation.de/php/canada-ontario-admin.php?adm2id=3519028.

CPNTools, 2017. CPNTools 4.0. Downloaded from http://cpntools.org/.

Solis, A.O., Asgary A., Nosedal-Sánchez, J., and Zaccaro, B., 2018a. Developing a fire response test bench based on NFID. Project report submitted to the Canadian Association of Fire Chiefs, 1 March 2018. Accessible at https://cjr.ufv.ca/developing-a-fire-response-test-bench-based-on-nfid/.

Solis, A.O., Nosedal-Sánchez, J., Asgary, A., Longo, F., and Zaccaro, B., 2018b. Modelling and simulation of a fire department's response to emergency incidents. Proceedings of the 8th International Defence and Homeland Security Simulation Workshop, pp. 73-80. September 17-19, Budapest, Hungary.

Toronto Fire Services, 2018. Toronto Fire Services 2018 Annual Report. Accessible at https://www.toronto.ca/wp-content/uploads/2019/04/8e80-A1902231_TFSAnnualReport2018_WEB.pdf

Vaughan Fire & Rescue Service, 2009. Vaughan Fire & Rescue Service 2009 Annual Report. Accessible at https://www.vaughan.ca/services/residential/fire_and_rescue/annual_reports/General%20Documents/VFRS_2009_Annual_Report.pdf.

Vaughan Fire & Rescue Service, 2010. Vaughan Fire & Rescue Service 2010 Annual Report. Accessible at https://www.vaughan.ca/services/residential/fire_and_rescue/annual_reports/General%20Documents/VFRS_2010_Annual_Report.pdf.

Vaughan Fire & Rescue Service, 2011. Vaughan Fire & Rescue Service 2011 Annual Report. Accessible at https://www.vaughan.ca/services/residential/fire_and_rescue/annual_reports/General%20Documents/VFRS_2011_Annual_Report.pdf.

Vaughan Fire & Rescue Service, 2012. Vaughan Fire & Rescue Service 2012 Annual Report. Accessible at https://www.vaughan.ca/services/residential/fire_and_rescue/annual_reports/General%20Documents/VFRS_2012_Annual_Report.pdf.

Vaughan Fire & Rescue Service, 2013. Vaughan Fire & Rescue Service 2013 Annual Report. Accessible at https://www.vaughan.ca/services/residential/fire_and_rescue/annual_reports/General%20Documents/VFRS%202013%20Annual%20Report.pdf.

Vaughan Fire & Rescue Service, 2014. Vaughan Fire & Rescue Service 2014 Annual Report. Accessible at https://www.vaughan.ca/services/residential/fire_a

nd_rescue/annual_reports/General%20Documents/2014%20VFRS%20Annual%20Report.pdf.
Vaughan Fire & Rescue Service, 2015. Vaughan Fire & Rescue Service 2015 Annual Report. Accessible at https://www.vaughan.ca/services/residential/fire_and_rescue/annual_reports/General%20Documents/2015%20VFRS%20Annual%20Report.pdf.
Vaughan Fire & Rescue Service, 2016. Vaughan Fire & Rescue Service 2016 Annual Report. Accessible at https://www.vaughan.ca/services/residential/fire_and_rescue/annual_reports/General%20Documents/2016%20VFRS%20Annual%20Report.pdf.
Vaughan Fire & Rescue Service, 2018. Vaughan Fire & Rescue Service 2018 Annual Report. Accessible at https://www.vaughan.ca/services/residential/fire_and_rescue/annual_reports/General%20Documents/2018%20VFRS%20Annual%20Report%20-%20Final.pdf.