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Tobias Andersson Granberg[a*], Sofie Pilemalm[b]
[a] *Dep Science and Technology, Linköping University, Sweden*
** Corresponding author: SE-60174 Norrköping, Sweden. tobias.andersson.granberg@liu.se*
[b] *Dep Management and Engineering, Linköping University, Sweden*

Abstract

By training and equipping human resources from other public service sectors than emergency response, to act as first responders, it is possible to reduce the first response times at a low cost. Before launching such an initiative, it is however important to evaluate the potential benefits. In this work, a method for doing this kind of evaluation is developed and applied to a potential initiative, utilizing fire service day personnel as new first responders. By developing a smartphone application and performing an experiment, sending alerts to potential first responders, and combining this with expert reviews of the possible value of their contribution, it is possible to estimate the response time reductions, as well as the monetary benefits of the initiative. The results show that there is a monetary benefit, even with a low number of new first responders, but that it is highly dependent on how quickly they can start travelling towards the emergency site.

Keywords: Emergency response; Accidents; Cross-sector collaboration; Samaritan response; Volunteers; Decreasing budgets; Semi-professionals

1 Introduction

In the public sector generally, as well as in emergency response and crisis management, shortages and cutbacks have made organizations seek help from other sectors, e.g. by introducing cross-sector collaborations (e.g. O'Leary and Bingham, 2009; Venema et al., 2010), i.e. combining resources from various sectors, including private organizations, various public organizations, non-governmental organizations and citizens (Agranoff and McGuire, 2007; Bryson, 2004; O'Leary and Bingham, 2009). An additional issue is the problem of recruiting part-time and volunteer fire-fighters (Degel et al., 2014), making it necessary to explore other ways of obtaining the necessary resources. This is true also for Sweden, where there exists a current trend where society-funded human resources are encouraged take on additional responsibilities within rescue and response, even if their primary occupation does not involve any rescue work. Two concrete examples are security guards who respond to fires and other accidents, and home care nurses who assist the fire services with additional medical competence (Sund and Jaldell, 2018; Weinholt and Andersson Granberg, 2015). These new types of resources are sometimes referred to as semi-professionals (Yousefi Mojir et al., 2019), a term most commonly used in relation to athletes and artists (Morgan and Herrington, 2014).

The semi-professional emergency responder concept stems from cross-organizational collaboration within emergency response, e.g. having firefighters performing first response to medical emergencies (Smith et al., 2001; Sund et al. 2012), but here, the new responders might have no previous experience from working with emergencies. To be able to efficiently utilize them, a large number of questions regarding, e.g. organizational, educational, technical, financial and legal issues have to be addressed, as has been pointed out in previous studies (Pilemalm et al. 2013; Yousefi Mojir and Pilemalm, 2016). However, it is equally important to be able to assess, in the best case quantitatively, the potential benefits of the cross-sector collaborations, before launching them. While it has been argued that the emerging initiatives have a good potential for adding capacity and value to the emergency response system (Yousefi Mojir et al., 2019), there exist few studies where this assessment is actually done before starting the collaboration. Thus, there is no established method for pre-evaluation of these initiatives. Furthermore, the effectiveness of an initiative is likely dependent on the specific profession of the people who are introducing emergency response into their daily routine, making a pre-evaluation of different types of professions valuable.

1.1 Study aim

The aim of this study is to develop a method for evaluating the potential benefits of a new, not yet existing, cross-sector collaboration, utilizing semi-professionals as first responders to daily emergencies, and to use this method on the specific case of fire service day personnel.

1.2 Related work and contributions

In recent years, the public sector has had to deal with increasing challenges, including natural disasters, increasing socio-economic gaps, depopulation of rural areas, an aging population, migration streams, war and terrorism (see e.g. Haddow et al., 2013). This has taken place against a background in which the sector has often experienced substantial financial cutbacks and resource shortages. One way to cope with these societal developments is to create cross-sector collaborations. This can be seen in a number of areas, with greater efficiency, reduced bias, higher quality of service, and improved organizational accountability being some examples of the perceived benefits (e.g. Alford and O'Flynn, 2012; Brinkerhoff, 2002). Meanwhile, in a number of studies it is also argued that achieving efficient cross-collaboration is difficult (Bryson, 2004; Greve and Hodge, 2005; Huxham and Vangen, 2000). Identified challenges include distrust, managerial complexity, cultural conflict, power imbalances, risk of dependence, and lack of incentive for collaboration (Babiak and Thibault, 2009; Gazley and Brudney, 2007; Young, 2000).

That the cross-sector collaborations work as intended and that they are carried out effectively, is of course crucial in emergency response, which is a highly dynamic activity intended to save lives, minimize suffering and damage to infrastructure and the environment. Thereby, the shortening of response times, and the provision of adequate help, become crucial to the collaborations. Related studies have focused on aspects such as medical issues (Weisfeldt et al., 2010), economics (Weinholt and Andersson Granberg, 2015), technological improvement (Jaeger et al., 2007), mainly in relation to large-scale emergencies and ad-hoc organization. Some studies have also included smaller scale accidents and collaboration opportunities and challenges, and related business and development processes (e.g. Pilemalm et al., 2013; Ramsell et al., 2017).

As for the evaluation of first response initiatives, there exist many studies evaluating the benefits of volunteer (or layperson) assistance in the case of cardiac arrest (e.g. Caputo et al. 2017; Ringh et al., 2011). Trials show that mobile dispatch of volunteers shortens the time to first response (Ringh et al., 2015). Publicly accessible AEDs might double the survival chance for the victims (Groeneveld and Owens, 2005). Using firefighters as first responders to medical emergencies has been shown to decrease response times (Smith et al., 2001) and having a positive benefit-cost ratio (Sund et al., 2012). For semi-professionals, Weinholt and Andersson Granberg (2015) analyzed two cases using cost-benefit analysis. The first case concerned security officers responding to fire service calls, like fires and traffic accidents, and the conclusion was that the initiative had positive economic effects. In the second case, home care nurses were dispatched to assist the fire services when they responded to medical emergencies, while waiting for the ambulance. In the second case, insufficient data existed to draw conclusions on the economic effects.

In the vast majority of the previous studies evaluating new first response initiatives, an ongoing initiative has been studied, using standard methodology, such as randomized studies or cost-benefit analysis. While this gives high quality data, it is also associated with a certain amount of risk as well as possibly high costs, e.g. if the initiative does not work as expected, or is very costly, or the benefits are negligible. Thus, it is interesting to be able to evaluate these kinds of initiatives before launching them.

Here, there is a clear gap in the current literature. Even if a few studies exist, there is no universal method for evaluating non-existing initiatives.

Two of the major challenges, compared to when an existing first response initiative is studied, are:

1. The number of responders and their response times are uncertain. Even if it is possible to determine how many new responders that will be available, the responses are made on a voluntary basis, and thus the responders might decline or not perceive the alert. Furthermore, the response is usually only valuable if the responder reaches the site before the regular emergency services.
2. The value of the first response is uncertain. It is a function of both the response time and the capability of the responder (Baker et al., 1984). Even if the responders are trained and equipped, a response from one volunteer or semi-professional is not as effective as a response from a full crew of firefighters or an ambulance.

In two previous studies, these challenges have been addressed. Khamelsky and Schwartz (2017) developed a simulation model for analyzing smartphone-based Samaritan response.

They focused on medical emergencies and the ability to compare the new initiatives to regular emergency medical services. The first challenge was addressed by scenario analysis, with three scenarios; worst, likely and best case, setting the probabilities for each case based on previous research. To estimate the probability that a responder will arrive before the emergency medical services, they used Monte Carlo simulation with random responder locations based on expected responder density, and compared this to real, historical ambulance response times.

Sund and Jaldell (2018) also used simulation coupled with cost-benefit analysis to evaluate a proposed initiative, having security officers responding to residential fires. The number of new resources were known, but since security officers patrol, their location varies. Thus, it is uncertain where they would be located when an event occurs. By studying historical data, and using expert opinions, they selected one specific location for each vehicle, at each point in time. This was compared to expected response time for fire services, assuming that they always are available at the stations.

The second challenge was addressed by Khamelsky and Schwartz (2017) using a success parameter, with a probabilistic chance that the intervention would be successful, that varied with each scenario, and for each medical condition. While a success/no-success evaluation might be appropriate for these events, in other cases, it may be possible to contribute to the response, without being able to fully take care to the emergency, e.g. it may be possible to help suppress a fire, preventing it from spreading, until the fire services arrive and can extinguish it. Sund and Jaldell (2018) estimated the effectiveness of a response by a security officer to a residential fire to be 25% of that of a unit of firefighters, based on previous research.

This study is similar to these two studies, in that we analyze a proposed, not yet existing initiative, but instead of volunteers or security officers, we study fire service day personnel (who are employed by the fire services but not part of the response organization). In response to the first challenge above, we use an experiment, where we send alerts to potential responders, giving us data for how many that will accept an alert, and how long time it will take them to get to the event site. This is compared to real, historical response times for the fire services. For the second challenge, we let experts estimate the potential effectiveness of semi-professional responses to real, historical events of four different types.

To summarize, there is a lack of knowledge about which benefits that will result from a new first response initiative. These benefits will differ depending on the local context, including the geographical area (distances, road access, etc), the demography and incident frequency, as well as the new responders and their availability and capability. Thus, studies are needed to give more insight into different variations of new first response initiatives, and also to provide new methods for analyzing them.

We partly close this gap by providing an analysis of the benefits of using day personnel at the fire services as semi-professional first responders, as this professional group has never been studied before in this particular context. We also describe a novel methodology for performing the analysis, which can be used for analyzing similar initiatives, in other geographical areas or for other resources.

2 Case study context, methods and data

2.1 Case study context

This work is part of the project Efficient communal use of municipal resources for increased safety and security (ESKORT) which ran between the years 2015-2017 and aimed to identify, train and equip semi-professionals in the cities of Norrköping and Linköping, Sweden, as well as evaluate the potential of such an initiative.

Norrköping and Linköping are neighboring municipalities in southern Sweden with about 300 000 inhabitants in total, and with a joint fire services organization. The project was supported by participation from the municipality and the fire services. The aim was to identify, train, equip, dispatch, and evaluate the potential benefits of using semi-professionals, e.g. facility service personnel, taxi drivers, security guards, fire service day personnel, or eldercare personnel. Within the project, a smartphone application prototype was also developed for the semi-professionals to enable them to receive alerts and be dispatched to emergency sites. Furthermore, the potential benefits of establishing this kind of initiative was quantitatively evaluated, which is the work that is reported in this paper.

Semi-professionals' primary jobs are not first response, but they are trained and equipped to act as first responders. In their regular jobs, they often travel around in the community, increasing the chance that they at times will be closer to upcoming emergency sites than professional response resources. Semi-professionals are alerted simultaneously with the fire services on certain pre-defined events, and can go to the emergency site to provide first response while waiting for the professional resources to arrive. In ESKORT, four potential semi-professional groups were selected and analyzed (this is described in detail in Yousefi Mojir et al., 2019). From these, fire service day personnel were selected as a test group for further analysis. They are employed by the municipal fire services but are not part of the response organization. Instead, they work daytime with e.g. teaching, material procurement, or office work.

2.2 Methods and data

The methods used are outlined in Figure 1. A survey was performed in order to investigate the general opinion in Sweden about performing first response on a voluntary or semi-professional basis, and receiving such help. With an answer rate of 66%, 1066 replies were received. The same survey was also sent to all fire service day personnel in the participating fire service organization, Räddningstjänsten Östra Götaland (RTÖG), and 10 answers were received, giving an answer rate of 62.5%. A literature study followed by a workshop gave a set of four potential semi-professional groups that were analyzed. From these, fire service day personnel was selected as a test group for further analysis.

A selection of possible events that semi-professionals can respond to was also performed, based on output from the workshop, as well as expert opinions from the fire services. From a full set of 250 different possible events that the fire services might respond to, 72 were deemed suitable for a semi-professional first response. The rest of the events were deemed too dangerous (e.g. risk for explosion) or the estimated benefits too small (e.g. water damage).

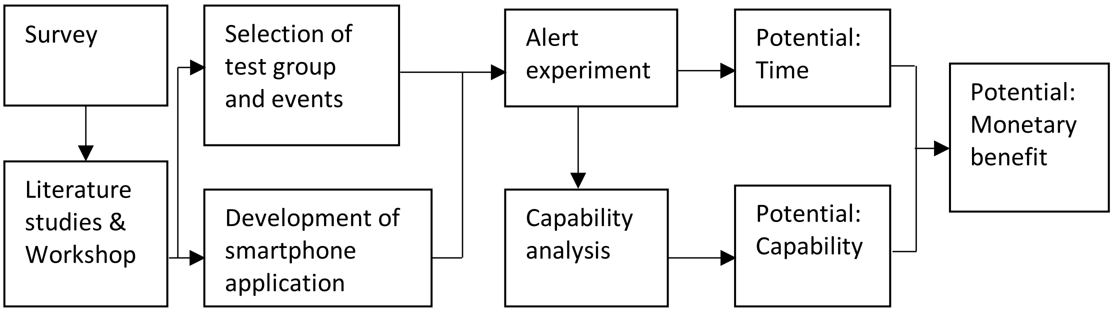

Figure 1: Methods used in the study

An Android-based smartphone application for the reception and acknowledgement of mission alerts was developed based on information from the workshop and the analysis of the different professional groups.

In the Alert experiment*,* nine potential first responders (fire service day personnel) were equipped with a smartphone, with the application installed. All day personnel within RTÖG (n=16) were asked to participate, and nine agreed. The responders could indicate in the application if they would accept the mission (should it have been a real situation), and the time of response and their location were noted. This made it possible to calculate their expected response time to the incident, using the GIS software ArcMap. As the mission alerts sent out were based on historical data from the fire services, the old, real response times by the fire services were known, making a comparison possible.

During two months, a total of 149 mission alerts were sent to the responders. The duration of the experiment was set partly from a practical perspective. The experiment started as soon as the application had been developed and initially tested, which was in the middle of October. Then it was ended in the middle of December, as the Christmas holiday was not deemed a representative period to gather data. Furthermore, we considered it a risk that the participants would grow tired and stop responding to the alerts if the experiment period was long.

In 141 cases, at least one responder indicated reception of the mission, and there existed historical travel times for the fire services, making it possible to compare the response times and find out in which cases the first response times could have been reduced using semi-professional responders. This made it possible to calculate the potential in terms of time. The results were generalized for the whole of 2015 (instead of just the two months covered by the experiment), giving an estimate for the yearly potential benefit.

In the 149 events, there were 42 cases where a semi-professional responder could have arrived before the fire services. These cases were evaluated in terms of the contribution that the semi-professionals could have made in each case, giving a Capability analysis. For each case, three experts from two different fire service organizations evaluated the contribution as 0 = No contribution, 1 = Small contribution, 2 = Medium contribution, 3 = Large contribution. By summing the experts' evaluations, a value for each case was obtained. The cases were then grouped by event type (e.g. fire, medical emergency, etc.), and a mean value for each event type was calculated. This was used as a base for a general evaluation of the benefit of a semi-professional response, for different event types, giving the potential in terms of capability.

Finally, by utilizing monetary values for response time reductions/increases from previous research (Jaldell, 2004), the monetary value of a semi-professional response could be calculated, giving the potential in terms of monetary benefits.

3 Results

The results in this section are presented according to the structure in Figure 1, first describing the results from the survey. This is followed by the calculated availability and expected response times for the semi-professionals, for the experiment data as well as generalized for an entire year (Potential: Time). Then the ability to help is evaluated (Potential: Capability) and finally the monetary benefits are reported (Potential: Monetary benefit).

3.1 Survey results

For an initiative utilizing semi-professional first responders to be successful, there must exist people willing to perform the responses, and the people affected by accidents and medical emergencies must be willing to accept the help they provide. The survey show that 64% of all men, and 53% of all women, above 18 years in Sweden would be willing to accept mission alerts on their mobile phones in order to act as a first responder in case of an emergency. Limiting the question to who would do this as part of their current employment, increased the numbers to 70% and 58% respectively. Another question in the survey, was if a voluntary first response would be appreciated, given that professional help is on its way. On this, 91% of all responders answered that they would appreciate this very much, and only 2% claimed that they would not appreciate this at all.

3.2 Potential: Time

During the two months long experiment, 149 mission alerts were sent to the participants, between 0 and 9 alerts per day, with an average of 3.0 alerts per day. The number of registered participants varied between 2 and 9 (fewer in the beginning), and the mean number of persons who received an alert was 7.8. The number of responses (accept or decline) also varied, between 0 and 7, with an average number of responses per alert of 3.4. In 126 cases, at least one participant accepted the mission.

As the position of the mission was known (all alerts were for events that happened the same time the previous year), and the position of the participants as well, the expected travel time could be calculated using ESRI ArcMap. The semi-professionals are expected to travel by car, adhering to current laws (e.g. speed limits). The travel time was thus calculated as the quickest path from the position of the semi-professional to the event site, using the Swedish National Road Database (NVDB, https://nvdb2012.trafikverket.se/) as the underlying road network and assuming that the maximum allowed speed was used on all road links. To get the response time for the participants, a call handling time (time from the alert is sent until the participant accepts or declines), and a preparation time (time from acceptance of the mission until start of travel) had to be added. While the call handling time easily could be calculated for each alert and participant, there was no way to determine the preparation time from the experiment data, since the participants not were expected to actually start traveling. Therefore, the analysis is made for a range of different possible preparation times.

By comparing the calculated response times for the experiment participants, with the historical response times for the fire services, it is possible to get an estimation of how often a semi-professional responder might be able to reach an event site quicker than the fire services, and how much the first response time might be reduced.

Table 1: Number of events and time savings, where a semi-professional could have acted as a first responder

Preparation time for semi-professionals	0s	90s	180s	300s
Share of the missions where a semi-professional would have arrived first	25.4%	17.5%	9.5%	3.2%
Average first response time reduction	167s	132s	120s	164s
Max first response time reduction	666s	576s	486s	366s

In Table 1, the share of missions, where a semi-professional responder might have reached the event site before the fire services is reported, given that the mission was accepted. Thus, if the semi-professionals had zero preparation time, they could have arrived first in 25.4%, i.e. 32 of the 126 events. This share decreases with an increasing preparation time; if a semi-professional needs 5 minutes before starting travelling, the share becomes only 3.2% (4 events). The average first response time reduction in Table 1 is calculated only based on the cases where a semi-professional arrives first, and varies between 120 and 167 seconds. The maximum first response time reduction for a single event is about 11 minutes, when a preparation time of zero seconds is assumed, and then decreases accordingly with increasing preparation time.

3.2.1 Generalization to one year

The result in Table 1 can be used to evaluate the benefits of semi-professional first responders during the specific period of the experiment. The result is then directly dependent on the missions that occurred during that time, and the availability of the experiment participants. In order to generalize the result to some extent, the experiment data was extrapolated to the whole year of 2015, using the following nomenclature:

R = The number of semi-professionals that will acknowledge (accept or decline) a mission

Z = The total number of alerts sent to semi-professionals

Y_{aj} = The share of missions where j semi-professional responders can arrive before the fire services, given preparation time a, if they accept the mission; j = 1, 2, 3, 4

T_a = Average response time reduction, given preparation time a

P = The probability that a mission will be accepted by a semi-professional

S_j = The probability that at least one semi-professional accepts the mission, of the j who can arrive before the fire services

R is set to 3.4 in accordance with the availability data from the experiment. In reality, the number of semi-professional resources would probably be higher, but there would also be a risk that they would not perceive the alert, or choose not to acknowledge.

Z is calculated to 919 missions, by starting with the total number of event that the fire services (RTÖG) responded to during 2015, removing the events that semi-professionals should not be dispatched to, and finally removing all missions between 7 pm and 7 am (i.e. those occurring during night time).

Y_{aj} states the share of the missions where 1-4 semi-professionals could have arrived before the fire services, given that everybody accepts the mission (see Table 2). For instance, in 11 events, out of the 126 (8.7%), two semi-professionals could have arrived before the fire services, had they had a preparation time of 90 seconds (Table 2: $j = 2$, $a = 90s$). In total, it was possible in 25.4% of the events, for 1, 2, 3 or 4 semi-professionals to perform a first response, assuming 90 seconds preparation time.

Table 2: Generalized result for 2015

j = number of semi-professionals who arrive before the fire services	Y_{aj} a = 0s	a = 90s	a = 180s	a = 300s	S_j =
1 semi-professional	17.5%	12.7%	7.1%	3.2%	69.5%
2 semi-professionals	13.5%	8.7%	5.6%	2.4%	90.7%
3 semi-professionals	3.2%	3.2%	1.6%	0.0%	97.2%
4 semi-professionals	1.6%	0.8%	0.0%	0.0%	99.1%
Sum of share before the fire services	35.7%	25.4%	14.3%	5.6%	
T_a = average response time reduction	158s	127s	119s	154s	
O_a = estimated number of events in 2015 where semi-professionals could have made a first response	267.0	189.6	106.2	40.1	

The average response time reduction, T_a, is calculated by first adding the measured call handling times and the assumed preparation time to the calculated travel times for each semi-professional response, and then comparing this to the historical response time for the fire services. The mean of the response time reduction is calculated over all occasions that a semi-professional response are quicker than the fire services'. Since the number of events where the semi-professionals would have been first on site decreases with increasing preparation time, the average reduction varies with a.

The probability that a mission will be accepted by a semi-professional is calculated as the accumulated number of calls accepted by the participants in the experiment (269), divided by the total number of answered calls (387). This gives the probability $P = 0.695$, that a semi-professional will accept the mission. The probability that at least one semi-professional accepts the mission, of the *j* who can arrive before the fire services, can then be calculated as (assuming that $S_0 = 0$):

$$S_j = 1 - (1 - P)^j$$

Thus, the probability that at least one semi-professional will arrive before the fire services increases if more than one semi-professional has a short travel time to the emergency site. For example, if there exist two semi-professionals who can arrive before the fire services, the probability that none of them will accept the mission, is $(1\text{-}0.695)^2$. The probability that at least one of them accepts (and thus arrives before the fire services) is $1 - (1\text{-}0.695)^2 = 0.907$ (see S_2 in Table 2).

The number of events during 2015, where semi-professionals could have served at first responders, given preparation time *a*, can then be calculated as:

$$O_a = \sum_{j=1}^{4} Z * Y_{aj} * S_j$$

For a given preparation time, the number of events to which semi-professionals could have been dispatched during 2015 ($Z = 919$) are multiplied by the calculated share of events where 1-4 semi-professionals would have reached the event site before the fire services, and finally multiplied with the probability that at least one of them accepts the mission. The total number of events, for each assumed preparation time, is presented in the final row of Table 2.

3.3 Potential: Capability

To assess the semi-professionals' ability to help, i.e. how much they could contribute to reducing the negative consequences at different events, three experts from two different fire service organizations (Räddningstjänsten Östra Götaland and Södertörns brandförsvarsförbund) evaluated 42 of the events in the experiment. The selected events were the ones where a semi-professional could have arrived before the fire services, given that the mission was accepted. For each event, the experts evaluated the ability to help as 0 = No contribution, 1 = Small contribution, 2 = Medium contribution, 3 = Large contribution from a semi-professional response. By summing up the experts evaluations, a score was obtained for each event. The events were classified according to their principal event types, and a mean score for each event type was calculated:

$$Mean\_score_e = \frac{\sum_{i=1}^{N_e} \sum_{k=1}^{3} score_{ki}}{N_e}$$

N_e is the number of events of type *e*, and $score_{ki}$ is the score by expert *k* for event *i*. It should be noted that some event types, like e.g. drowning accidents, where it would be possible for a semi-professional to make a contribution, were missing in the set of evaluated events.

The mean score varies between 0 and 9 (since there were three experts). The ability to help at medical emergencies has the largest mean score (7.0), and the ability to help at building fire, the lowest (2.4). For the medical emergencies, the majority of the cases concern cardiac arrest, and the professionals state that the semi-professionals can start cardiopulmonary resuscitation (CPR). Even if the first response time is only slightly reduced, this might have a positive effect on the survival chance. Out of the five building fires, only one actually turned out to be a real fire in an apartment when the fire services arrived. For that case, one professional argued that the semi-professional could help with the evacuation, while another did not believe that semi-professional would be able to do anything. For the other four cases, some of the professionals argued that a semi-professional could have made the assessment that no fire services are necessary and reported this, freeing up the professional resources for other assignments. For traffic accidents, the professionals thought that the semi-professionals could e.g. stabilize the neck and stop possible bleedings, manage traffic and make reports to the alarm services.

The effectiveness factor in Table 3 is an estimate of how effective the semi-professional response is, compared to a typical, professional fire response (with one fire truck and five fire fighters including one unit commander). It is calculated as the normalized mean score (e.g. for Outdoor fires, it is calculated as the mean score divided by the maximum possible mean score, i.e. 3/9=0.333). Thus, by design, the effectiveness factor can vary between 0 and 1, where 1 corresponds to an equal effectiveness.

Table 3: Evaluating the ability to help

Event type	Number of events	Mean score	Effectiveness factor	Time value (Euro/s)
Building fire	5	2.4	0.267	51.76
Outdoors fire	7	3.0	0.333	1.88
Medical emergency	11	7.0	0.778	19.19
Traffic accident	19	3.5	0.389	32.38

3.4 Potential: Monetary benefit

The effectiveness factor can be used to estimate the monetary benefits of a semi-professional response, based on monetary values for professional responses that already exist for the studied event types (Jaldell, 2004). The time values can be found in the last column in Table 3, and are adjusted for inflation from 2003 to 2015 price level, using an increase of 12.68%, based on the Swedish consumer price index. A conversion rate of 1 Euro = 10 SEK is used. The values are originally calculated from the mission reports given by the fire services, and can be used to estimate the cost/benefit of one second increased/reduced response time.

By calculating the number of events of different types during 2015 where a semi-professional could have arrived before the fire services, multiplying this with the average time difference (how long time before the fire services they arrive) and the time value, it is possible to calculate the monetary benefit. This is reported in Table 4; first the number of events of each type is calculated, where a semi-professional could have arrived before the fire services in 2015. This is done by multiplying the historical number of events of each type in 2015, and then multiplying this by the share of events where a semi-professional can be expected to respond first, given the assumed preparation time (i.e. O_a / Z).

The value of semi-professional responses for each event type is calculated by multiplying the number of events with the average time difference (i.e. how long before the fire services they arrive; T_a in Table 2), the effectiveness factor, and the time value in Table 3. As an example, for medical emergencies, and the assumed preparation time of 300s, the value is calculated as 10.4 * 154 * 0.778 * 19.19 / 1000 = 24.0 thousand Euro.

Table 4: Potential annual benefit of semi-professional resources

	Preparation time							
Event type	**0s**	**90s**	**180s**	**300s**	**0s**	**90s**	**180s**	**300s**
	Number of events 2015				**Value of semi-professional response [1000 Euro]**			
Building fire	52.3	37.1	20.8	7.6	113.9	65.2	34.2	16.7
Outdoors fire	39.2	27.9	15.6	5.9	3.9	2.2	1.2	0.6
Medical emergency	69.4	49.3	27.6	10.4	163.5	93.6	49.1	24.0
Traffic accident	100.8	71.6	40.1	15.2	200.2	114.6	60.2	29.4
Total	***267.0***	***189.6***	***106.2***	***40.2***	***481.5***	***275.7***	***144.7***	***70.7***

4 Discussion

In relation to emergency response and crisis management, over the past years, both natural large-scale disasters and man-made incidents, have become increasing threats to our society. At the same time, regular accidents on a smaller scale will continue to occur and the centralization of resource-strained response organizations leading to long distances between residents and response organizations – physically and socially – is also likely to continue. This combination means that the professional emergency response organizations responsible for delivering essential services are often placed under extreme pressure while having to meet increased demands for efficiency. To handle the challenges, emergency response cross-sector collaborations are becoming more common both from a global perspective (e.g. Barsky et al., 2007; Venema et al., 2010; Waugh and Streib, 2006), and in Sweden (e.g. Pilemalm et al., 2013; Weinholt and Andersson Granberg, 2015). In Sweden, the approach of using semi-professionals, in particular security guards, as first responders, has spread to several municipalities. In a more general perspective, it has been claimed that contemporary public challenges, e.g. climate change, environmental protection, natural resource management, natural disasters, the educational achievement gap, and emergency management are difficult to address without cross-sector understanding, agreement and collaboration (Vigoda, 2003). However, even though initiatives exist, since this trend is recent, corresponding research is needed. Above all, the potential usefulness and effectiveness should be quantitatively assessed, and this seems particularly important in a context where response times and short-term efficiency are in focus, as compared to other cross-sector collaborations, e.g. in public health, education and poverty management that are more directed towards long-term goals

(Agranoff and McGuire, 2010; Bryson, 2004; O'Leary and Bingham, 2009). This is important, not the least for decision-makers, politicians, public service planners, municipalities and others responsible for taking decisions on and carrying out real implementations. In this respect, this study contributes by providing a method that similar initiatives can use.

The results from the case study show that there exist a potential societal benefit in using semi-professional emergency response resources. This is an expected result, in line with previous research (e.g. Sund and Jaldell, 2018; Weinholt and Andersson Granberg, 2015). It is also trivial to realize that if more response resources exist, the average response times will decrease, at least as long as they are appropriately spatially and temporally distributed. As long as these new resources can contribute with some value in the response, the benefit will be positive. In the end, however, a trade-off has to be made against the cost for initializing and running the operations.

The cost for having semi-professional resources is nothing that is explicitly studied here. Weinholt and Andersson Granberg (2015) show that the use of security officers and home care nurses give rise to relatively low costs. Sund and Jaldell (2018) show that using security officers as first responders has positive economic effects. Qualitative results related to our study (e.g. as reported in Yousefi Mojir et al., 2019) give no indication that it should be different for fire service day personnel. This also mirrors the main idea with semi-professional resources – which is to use resources that are already available in society, and that can be equipped and trained at a low cost. Even if the number of events per year, where they make a major contribution, is low, the benefit/cost ratio might be positive. One single occasion, where a semi-professional response has a crucial impact, may cover the costs for the operations for several years onwards.

The results in Table 4 show that the monetary benefit for Norrköping and Linköping municipalities is somewhere between 70 000 and 480 000 Euro per year, depending on how long time it takes for the semi-professional resources to start their journey towards the emergency site, after they have received the mission alert. This would give a yearly benefit of between 0.23 and 1.6 Euro per inhabitant. While the calculations may not scale to larger cities, having the same benefit per inhabitant would mean a yearly benefit between 225 000 and 1.5 million Euros for Stockholm (the capital of Sweden) or 2 and 14 million Euros for London. These numbers are subject to a number of assumptions, some of which are discussed below.

One assumption is that there, at all times, exist 3.4 semi-professionals who will always accept or decline the mission. This is of course a simplification. Of the ten fire service day personnel who replied to the survey, all of them were willing to act as first responders, if it was practically feasible. Everyone who participated in the experiment, accepted at least three missions during the experiment period. This indicates that given a full implementation of the project, there would be more than 3.4 semi-professional resources available, which should lead to more accepted missions, and reduced first response times. However, it is not reasonable to assume that it is possible to achieve a mission alert answering rate of 100%, especially if the alert is received on a mobile phone. But with a well-designed application, installed on the phones that the semi-professionals use daily, it should be possible to reach an answering rate much higher than the one achieved during the experiment, which was 34.2%.

The average times and shares presented in Table 1 and 2 would have become more reliable if more mission alerts had been sent out during the experiment. Thus, it is important to realize that the results can be seen as indicators of what can be possible, and not proof of what would happen in a realization of the concept. The extrapolation of these times to the whole of 2015, introduces further error, as the alerts sent out during the experiment period might not be representative for the whole year. Incident frequency and location varies over the year, depending on e.g. weather, holidays, population movements, etc. It might be assumed that the benefits of using semi-professionals would increase if the call frequency increases, at least when it reaches a point where the professional emergency services are busy when new calls arrive.

The mission alerts sent out during the experiment can easily be grouped into event types for which there exist time values (from Jaldell, 2004). However, the real benefit from a semi-professional response might vary from one emergency to another. For instance, if a semi-professional arrives early to a traffic accident and is able to ensure free airways for someone, this may save a life. At another traffic accident, it is possible that a semi-professional cannot contribute with anything of value. The calculations done here are based on an average efficiency, which is reasonable since also the time values are averages. In reality, the variation in the contribution from the semi-professionals will affect the result. Speculating, it is likely that the benefit in a majority of the cases will be small, while it will considerably exceed the calculated average benefit in specific cases where the semi-professional contribution has a crucial impact (e.g. extinguishing a fire before it starts to spread, or initializing CPR on a person who would otherwise have died).

The time from receiving the alert until start of travel towards the emergency site, has a major impact on the potential benefit. Just like the benefit with the response, the preparation time will vary with each individual and event. Sometimes, the semi-professionals will arrive after the professional emergency services, while in other cases, they might arrive much quicker than any calculated average. As the semi-professionals have the largest chance of making a valuable contribution in the initial phase of an incident, it can be argued that the calculated monetary benefit should increase if variations in preparation times, and travel times for that matter, were taken into account.

In fact, the preparation time is probably the part of the response chain with most potential for improvement. Given that the semi-professionals receive the alert simultaneously with the professional resources, and that they have access to a car, it is not trivial to reduce the response time by making the alert management or the travel phases more efficient. It should however be possible to develop methods for reducing the preparation time, e.g. through routines for where vehicles are parked and for how equipment is handled, so that there never is anything missing.

Even if the results are based on a case study for a Swedish municipality, they should be reasonably applicable for other geographical areas as well, at least as long as the general emergency response system is set up similarly. As discussed above, the expected first response time reductions will vary with the number of new resources, and their geographical dispersion. The availability of the resources will most likely vary depending on their regular profession, and the routines in place for allowing them to deviate from their normal duties. These parameters can be estimated in the same manner as described in this paper, using an alert experiment. Given that a dispatch system, and a corresponding smartphone application exists, this is not very resource or time consuming, and it may be a good way of introducing the initiative to the new first responders. The method should thus be useful for evaluating similar semi-professional initiatives in other municipalities involving other professions. It may also be possible to utilize it for evaluating volunteer first response initiatives, but a major difference lies in the uncertainness of the resources. For a semi-professional response initiative, it is easier in advance to estimate the number of new resources, and possibly even their likely location. For a volunteer initiative, this becomes more difficult, and it may be necessary to use stochastic methods like in Khamelsky and Schwartz (2017).

In relation to a larger public sector innovation and cross-sector collaboration context, the method is most relevant for contexts where the response time is crucial. An example could be if certain semi-professionals can act when elderly people living in their homes activate their home safety alarms e.g. when they have fallen, or by mistake. This might shorten the response times, or have other benefits such as relieving home care personnel with a long distance from the person’s home. Of course, this will require that they e.g. have basic medical training and access (keys) to the elderly person’s home. Another potential application domain is prevention, where for instance security guards may take over certain tasks from the fire services, e.g. home visits informing on fire protection, or creating social relations in excluded areas, e.g in schools and leisure centers. However, for the method developed here to work in that context, the effect measures have to be adapted, e.g. to capture if there is a decrease of incidents in these areas.

5 Conclusions

In this study we have investigated and evaluated the potential benefits of utilizing fire service day personnel as semi-professional first responders to daily emergencies, and also developed a method which can be used before launching such an initiative. The case study shows that fire service day personnel are well suited for the task, and would be able to make a positive contribution to a range of incident types, in particular medical emergencies. There is a large potential monetary benefit in utilizing semi-professionals, but it is rapidly decreasing with the preparation time for the new resources. Thus, it is vital to establish routines and support for ensuring that no time is lost from the reception of the mission alert until travel towards the emergency site has started.

It may be noted that the marginal benefit of the semi-professional resources most likely is decreasing with the number of added resources. Every added resource will have less possibility to contribute, given the increased competition. However, the marginal cost should also be decreasing, at least to the point that the equipment necessary for a single semi-professional constitutes the major part of the marginal cost. Thus, there exist an optimal number of semi-professional resources, were the marginal benefits equal the marginal cost, which might be a topic for future research.

Given that a preliminary evaluation, like the one presented here, has shown that an initiative most likely is beneficial, a more thorough evaluation can start, as an integral part of a real implementation. This means recruiting, training, equipping and dispatching first responders to real emergencies, while continuing to collect data on their availability, response times and actions. A good example is the sms-lifesavers project (Ringh et al. 2011, 2015), where data from many years of volunteer responses to cardiac arrest cases has been collected, and can be used to evaluate the benefits. Of course, it becomes more complex with multiple event types, requiring different types of interventions. Then, optimal task assignment, like in Falasca and Zobel (2012), can be useful, and contribute to an even more effective emergency response. For future work, it would also be of interest to look into similar application areas like semi-professionals assisting elderly people living in their homes or carrying out work aimed to prevent incidents from occurring, and how the developed method might be adapted to these domains.

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References

Agranoff, R., McGuire, M. (2010) 'Collaborative Public Management: New Strategies for Local Governments', Georgetown University Press, Washington, US.

Alford, J. L., O'Flynn, J. (2012), 'Rethinking Public Service Delivery: Managing with External Providers', Palgrave Macmillan, Basingstoke, Hampshire.

Babiak, K., Thibault, L. (2009) 'Challenges in multiple cross-sector partnerships', Nonprofit and Voluntary Sector Quarterly, Vol. 38, No. 1, pp. 117–143.

Baker, J., McKnew, M., Gulledge, T.R., Ringuest, J.L. (1984) 'An application of multiattribute utility theory to the planning of emergency medical services', Socio-Economic Planning Sciences, Vol. 18, No. 4, pp. 273-280.

Barsky, L., Baumann, J., Torres, M., Aguirre, B. (2007). 'Managing volunteers: FEMA's urban search and rescue programme and interactions with unaffiliated responders in disaster response', Disasters, Vol. 31, No. 4, pp. 495–507.

Brinkerhoff, J. M. (2002) 'Government–nonprofit partnership: a defining framework', Public Administration and Development, Vol. 22, No.1, pp. 19–30.

Bryson, J. (2004) 'What to do when stakeholders matter. Stakeholder identification and analysis techniques,' Public Management Review, Vol. 6, No 1, pp. 21–53.

Caputo, M. L., Muschietti, S., Burkart, R., Benvenuti, C., Conte, G., Regoli, F., Mauri, R., Klersy, C., Moccetti, T., Auricchio, A. (2017) 'Lay persons alerted by mobile application system initiate earlier cardio-pulmonary resuscitation: A comparison with SMS-based system notification', Resuscitation, Vol. 114, pp. 73-78.

Degel, D., Wiesche, L., Rachuba, S., Werners, B. (2014) 'Reorganizing an existing volunteer fire station network in Germany', Socio-Economic Planning Sciences, Vol. 48, No. 2, pp. 149-157.

Falasca, M., Zobel, C., (2012) 'An optimization model for volunteer assignments in humanitarian organizations', Socio-Economic Planning Sciences, Vol. 46, No. 4, pp. 250-260.

Gazley, B., Brudney, J. L. (2007) 'The purpose (and perils) of government-nonprofit partnership', Nonprofit and Voluntary Sector Quarterly, Vol. 36, No. 3, pp. 389–415.

Greve, C., Hodge, G. (Eds.), (2005) The Challenge of Public–private Partnerships: Learning from International Experience, Edward Elgar, Cheltenham, UK; Northampton, MA.

Groeneveld P. W., Owens, D. K. (2005) 'Cost-effectiveness of training unselected laypersons in cardiopulmonary resuscitation and defibrillation', American Journal of Medicine, Vol. 118, No. 1, pp. 58-67.

Haddow, G., Bullock, J., Coppola, D. P. (2013) 'Introduction to emergency management', Butterworth-Heinemann, Waltham, MA.

Huxham, C., Vangen, S. (2000) 'Ambiguity, complexity and dynamics in the membership of collaboration', Human Relations, Vol. 53, No. 6, pp. 771–806.

Jaeger, P. T., Shneiderman, B., Fleischmann, K. R., Preece, J., Qu, Y. and Fei Wu, P. (2007) 'Community response grids: E-government, social networks, and effective emergency management', Telecommunications Policy, Vol. 31, No. 10–11, pp. 592–604.

Jaldell, H. (2004) 'Tidsfaktorns betydelse vid räddningsinsatser – en uppdatering av en samhällsekonomisk studie', FoU Rapport, Räddningsverket.

Khalemsky, M., Schwartz, D. G. (2017) 'Emergency Response Community Effectiveness: A simulation modeler for comparing Emergency Medical Services with smartphone-based Samaritan response', Decision Support Systems, Vol. 102, pp. 57-68.

Morgan, R., Herrington, L. (2014) 'The effect of tackling on shoulder joint positioning sense in semi-professional rugby players', Physical Therapy in Sport, Vol. 15, No. 3, pp. 176-180.

O'Leary, R., and Bingham, L. B. (2009) 'The Collaborative Public Manager: New Ideas for the Twenty-first Century'. Georgetown University Press, US.

Pilemalm, S., Stenberg, R., Granberg, T. A. (2013) 'Emergency Response in Rural Areas', International Journal of Information Systems for Crisis Response and Management, Vol. 5, No. 2, pp. 19–31.

Ramsell, E., Pilemalm, S., Andersson Granberg, T. (2017) 'Using volunteers for emergency response in rural areas – Network collaboration factors and IT support in the case of Enhanced Neighbours' in ISCRAM 2017: Proceedings of the 14th International Conference on Information Systems for Crisis Response and Management, Albi, France, pp. 985-995.

Ringh, M., Fredman, D., Nordberg, P., Stark, T., and Hollenberg, J. (2011) 'Mobile phone technology identifies and recruits trained citizens to perform CPR on out-of-hospital cardiac arrest victims prior to ambulance arrival', Resuscitation, Vol. 82, No. 12, pp. 1514-1518.

Ringh, M., Rosenqvist, M., Hollenberg, J., Jonsson, M., Fredman, D., Nordberg, P., Jarnbert-Pettersson, H., Hasselqvist-Ax, I., Riva, G., and Svensson, L. (2015) 'Mobile-phone dispatch of laypersons for CPR in out-of-hospital cardiac arrest', New England Journal of Medicine, Vol. 372, No. 24, pp. 2316-2325.

Smith, K. L., Peeters, A., McNeil, J. J. (2001) 'Results from the first 12 months of a fire first-responder program in Australia', Resuscitation. Vol., 49, No. 2, pp. 143-150.

Sund, B., Svensson, L., Rosenqvist, M., Hollenberg, J. (2012) 'Favourable cost-benefit in an early defibrillation programme using dual dispatch of ambulance and fire services in out-of-hospital cardiac arrest', European Journal of Health Economics, Vol. 13, No. 6, pp. 811-818.

Sund, B., Jaldell, H. (2018) 'Security officers responding to residential fire alarms: Estimating the effect on survival and property damage', Fire Safety Journal, Vol. 97, pp. 1-11.

Venema, A. M., Groothoff, J. W., Bierens, J. J. L. M. (2010) 'The role of bystanders during rescue and resuscitation of drowning victims', Resuscitation, Vol. 81, No. 4, pp. 434–439.

Vigoda, E. (2003) 'Managing collaboration in public administration: the Promise of alliance among governance, citizens, and businesses'. Westport, CT: Praeger.

Waugh, W., Streib, G. (2006) 'Collaboration and leadership for effective emergency management', Public Administration Review, Vol. 66, pp. 131–140.

Weinholt, Å. Andersson Granberg, T. (2015) 'New collaborations in daily emergency response - applying cost-benefit analysis to new first response initiatives in the Swedish fire and rescue service', International Journal of Emergency Services, Vol. 4, No. 2, pp. 177-193.

Weisfeldt, M. L., Sitlani, C. M., Ornato, J. P., Rea, T., Aufderheide, T. P., Davis, D., Dreyer, J., Hess, E. P. (2010) 'Survival after application of automatic external defibrillators before arrival of the emergency medical system: Evaluation in the resuscitation outcomes consortium population of 21 million', Journal of the American College of Cardiology, Vol. 55, No.16, pp. 1713–1720.

Young, D. R. (2000) 'Alternative models of government-nonprofit sector relations: theoretical and international perspectives', Nonprofit and Voluntary Sector Quarterly, Vol. 29, No. 1, pp. 149–172.

Yousefi Mojir, K. and Pilemalm, S. (2016) 'Actor-Centered Emergency Response Systems: A framework for needs analysis and information systems development', International Journal of Emergency Management, Vol. 12, No. 4, pp. 403-434.

Yousefi Mojir, K., Pilemalm, S., Andersson Granberg, T. (2019) 'Semi-professionals: emergency response as an additional task in current occupations', International Journal of Emergency Services, Vol. 8, No. 2, pp. 86-107.