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Activities and social interactions during disaster evacuation

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ABSTRACT

Over the past decades there has been an increase in the frequency and intensity of disasters. The unpredictability of the circumstances around disasters means that proposed evacuation and transportation plans should be adaptable to the changing situation. Though the act of evacuating and the decision leading to it have been studied extensively, social aspects of the situation as well as other intermediate stops received less attention.

This paper presents an investigation of data collected after a WUI fire that took place in Haifa, Israel, on November 24th, 2016. The results show individuals make multiple intermediate stops, before either evacuating or returning back home. A key goal within these stops is to visit home, which is a task undertaken the majority of households. A related phenomenon is that of waiting. The data shows that in many cases individuals report waiting at intermediate stops to learn more about the state of the event before taking further actions. With respect to their interactions, the results show that households tend to gather together during the event. This observation quantifies similar claims made in previous researches. These intra-household interactions are a main purpose of travel during such events. Within those, child pick-up stands out as a prominent activity. Child pick-up patterns suggest the involvement of a complex decision-making process which includes a wider social circle beyond household members. Thus, it is argued that the prediction of traffic during disasters would have to be based upon a full understanding of individuals' social along with intra-household spheres.

1. Introduction

Over the past decades there has been an increase in the intensity, as well as the frequency, of both natural and man-made disasters [1]. These events have dramatic implications in terms of loss of human lives, well-being and economic costs [2,3]. In Israel, similarly to other Mediterranean countries, a rise in the frequency of forest fires and a subsequent expansion of the affected area is observed [4].

The characteristics of disasters vary widely in cause, in the warning time given, the duration of events and the spatial and temporal extent of the impacted area [5,6]. When planning the response for any type of disaster, efficient management of the transportation system is vital in order to allow for an effective evacuation of the affected population and the mobilization of equipment and relief and response personnel [6,7]. This need is presented and recognized by the transportation planning community [6,8,9]. Understanding the demand for travel during disasters, particularly when evacuations take place, is critical for efficient management of the event [10]. These demand patterns may change drastically during an event, to the point of making the usual demand matrices irrelevant.

The act of evacuating and the decision leading to it have been studied extensively [11–14]. Other elements of the evacuation process were also examined, especially as a by-product of the evacuation decision. The timing and duration of the evacuation process was estimated in a few studies about both pre-notice and no-notice evacuations [15–18].

Evacuations create situations that require decision-making in new and changing environments, affecting a large portion of the population. They are characterized by lack or partial information and high levels of uncertainty. Review papers that examine the body of research regarding disasters emphasize the need for studies dealing with the impact of social interactions on the evacuation process [1,19]. Limited data availability and the complexity of the required modeling, even under normal conditions, limit the empirical study of social interactions and joint decision-making during disasters. Dobler et al. [8] argue that household members tend to gather in the same location before or during an evacuation, as mentioned by others as well [20–22]. Auld et al. [9] and Liu et al. [23] analyzed stated preferences (SP) data to find that stops would be made in order to gather as a family. They found that one's proximity, access to a car, gender and employment status have an effect on the decision of who picks up household children. Others [10,24–27] used

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this logic to simulate the evacuation process, or model the gathering of household members. Urata and Hato [28] conducted interviewed after the 2011 Great East Japan Earthquake. They asked about respondents' personal evacuation experience and found that evacuation is, to a large extent, a social activity which involves an elaborate family and social network. They later used the data to create a network model for rural communities during a mudslide disaster. Hara & Kuwahara [29] analyzed traffic patterns during the same earthquake. They found that a significant number of people returned home before evacuating. Sadri et al. [30] developed and estimated a choice model for the decision to evacuate during Hurricane Sandy. They found that individuals' decisions whether to evacuate is significantly affected by their social network and the decisions made within it.

The purpose of this paper is to broaden the knowledge regarding activities and social interaction which take place during a no-notice evacuation and their effect on travel patterns during such events. Towards this goal, data collected after a fire that took place in the city of Haifa, Israel, on November 24th, 2016, was used. The contributions made in this paper include analysis of the intermediate stops that individuals make before evacuating (or returning home) and the activities that take place at these stops. The results provide empirical quantitative evidence to the tendency of households to gather before evacuating, which has previously been stated only qualitatively in the literature. Furthermore, a discrete choice model for the identity of the persons picking up children was developed using this data. The few earlier studies of intermediate stops and child pick up were based on stated preferences data, rather than reports of actual actions. Finally, the results suggest a substantial waiting behavior before making decisions whether to evacuate. To the best of our knowledge this behavior has not been described in the literature. The remainder of this paper is organized as follows: the following section describes the wildfire event that took place in Haifa in November 2016 and the data collected by a survey conducted a few months after the fire. Section 3 discusses travel patterns during the event. It presents an analysis of the activities engaged in at intermediate stops, followed by an investigation of evidence on joint travel, in particular that related to child pick-up. Finally, a conclusion section summarizes the findings and points out limitation of the current study and future research directions.

2. Case study – Haifa 2016 fire

On Thursday, November 24th, 2016, at 10:05 a.m., the emergency services were first alerted about a fire raging in an open area in the city of Haifa, Israel [31]. By the time the fire was extinguished the next day, 175 buildings housing 1784 apartments were damaged. The fire had hit a densely populated area (with approximately 4000 inhabitants per square kilometer) in a mostly residential part of the city [32]. Fig. 1 depicts the city of Haifa and the area affected by the fire. As an illustration of the city's scale, travel time on road 23 from the train station near MATAM on the west side to the one near the intersection with road 75 is normally about 15 min. During that day, around 60,000 residents were instructed by the authorities to evacuate their homes [34]. This was not strictly enforced, leaving the final evacuation decision in the hands of the residents themselves. The fire was the most severe among a series of fires which raged across Israel during that week [34].

Fires in Mount Carmel forests, adjacent to the city of Haifa, occur every few years. The 2010 fire caused the death of 44 prison guards during the evacuation of the Damon Prison [4]. These fires usually affect mostly the natural reserve and cause limited evacuation of the adjacent neighborhoods or nearby rural villages. The Haifa 2016 fire was unique in that it raged across the wildland-urban interface (WUI) parts of the city, causing mass evacuation. At the time of its eruption, on a weekday morning, most children were at school and adults were either at work or occupied elsewhere. These facts render the incident an example case study for a daytime no-warning disaster evacuation.

Soon after the outbreak of the fire, the Haifa Municipality called in

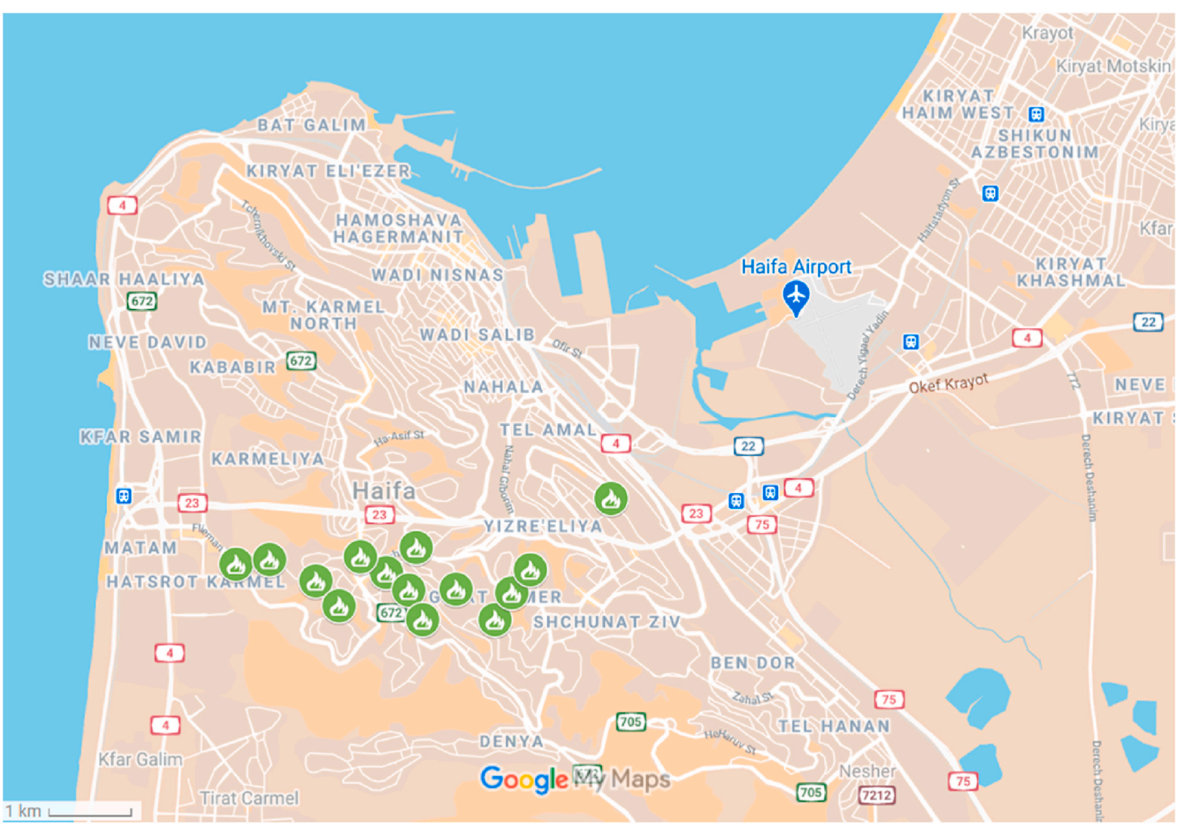

Fig. 1. Map of Haifa wild fires [33].

several private buses in an attempt to help the civilian evacuation. Most of these buses, arriving from outside of the city of Haifa, were ultimately not employed in the evacuation process, due to traffic conditions [34].

2.1. Survey instrument

A survey was conducted following the fire evet, between March and July 2017. The survey was distributed using snowball sampling primarily through social media (Facebook) and convenience sampling among Technion students and staff. Monetary incentives were not offered to respondents. The questionnaire was written after six open interviews were conducted with residences of the area that had indicated that people quite vividly remember the day's events. The questionnaire was designed to collect information about the activities of respondents and their entire household's activities during the day of the event. Respondents, answering for the entire household, were screened to those older than 18 who have at least one household member (either themselves or another) that was in the area ordered to evacuate on that day.

The questionnaire was constructed of several sections: First, respondents were asked to list the members in their household and their age. Listed household members also included those who were not in the affected area during that day. Next, respondents were asked where and when they first learned of the fire and to detail each trip and stop they had made until the following day, or until they no longer returned to the affected area. Details regarding trips included:

1. Its approximate duration (up to ½ hour, ½ hour to an hour, and so on).
2. Transportation mode (car driver, car passenger, public transportation, walking or other).
3. Individuals that accompanied them (household members, non-household relatives and other non-household individuals).

Details about stops included:

1. Type (respondent's home, homes of other people, workplace, school, a public place, etc.).
2. Location (in the affected area, within Haifa city but not in the affected area, near Haifa or farther away from Haifa).
3. Duration of stay at the stop (up to ½ hour, ½ hour to an hour, and so on up until the next day).
4. Activities engaged in at the stop (picking up/being picked up, protecting property, giving assistance, rescuing pets, etc.).

Next, respondents were asked to consult with their household members in order to provide details about the trips and stops these members had made during that day, answering questions similar to the ones described above.

In the final section of the questionnaire, respondents were asked several socio-demographic questions regarding their households, the ages and gender of its members, the location of the house and workplace, educational level and income.

2.2. Sample characteristics

708 respondents started the questionnaire. Out of those, 229 either immediately quit or were screened out (when the respondents themselves were under 18 years old or when none of the household members were within the affected area during the event). After an initial data verification, data from 522 individuals that were in the area that day from 267 households was available. Partial responses were available from additional 110 individuals from 52 household. Another 220 individuals in these households were not in the affected area during that day. Travel data for these individuals was not collected. They were excluded from the analyses. Furthermore, in the current research, only observations from individuals who reside inside the affected area and were in the area during that day was used. The final sample consists of 469 individuals from 209 households.

3. Travel and activity patterns during the fire event

The analysis of the Haifa 2016 Fire data focuses on the activities that household members undertook during the evacuation process. The results show that evacuation was not immediate. Individuals made intermediate stops to complete various tasks before leaving the affected area. Among these tasks, one of the most basic was to bring the household together as a unit and stick together as one. This tendency is mentioned in the disaster literature as early as Moore's [20] work. However, the process of gathering the household members proves to be more complex than previously assumed in evacuation modeling. The results presented hereinafter suggest that other, less discussed, tasks and activities also occur during the evacuation.

With the focus on interactions within the household, the analysis distinguishes between households with different compositions and the individuals within them: adults in multi-person household with and without children, children in multi-person households, and adults in single-person households (singletons). Singletons are the least represented group in the sample, making it harder to draw conclusions regarding their behavior during the event. Nevertheless, understanding the specific preferences and needs of different socio-demographic groups (more of which could be categorized) is vital to improving the mitigation efforts during disasters. It should be noted that the vast majority (92%) of trip legs reported were made using private vehicles. Thus, analysis related to travel modes and their effect on other behaviors was not relevant.

3.1. Intermediate stops and activities

If individuals would have evacuated as soon as possible, it would be expected that they would report making no stops from the moment they have heard of the event until they left the affected area. Table 1 shows the distribution of the total number of intermediate stops that adults (over 18 years old) made before evacuating from the area affected by the fire or returning to the place where they stayed overnight within that area if they did not evacuate (their homes in most cases). The intermediate stops count does not include their initial location when the event occurred and their final location. On average, individuals made 1.29 intermediate stops. Thus, they more than doubled the number of trips they would have made had they evacuated directly. Adults that evacuated made more stops than those who did not. Among the groups, adults in households with children made the most stops (1.49) and singletons made the least stops (0.78), which again suggests that household-related tasks affect these travel patterns. Thus, it is useful to understand the activities that take place in these intermediate stops.

It is well established that trips are derived from activities that people engage in at their destinations [35]. Table 2 presents the proportions of intermediate stops for which adults reported that they engaged in various activities. The respondents could choose not to provide information about the activities. Activities were not reported for 83% of children's stops compared to 1.7% of adults' stops. This may be because an adult completed the survey. In addition, children may be considered passive during such an event. Hence, children are omitted from the activity analysis. Respondents could report multiple activities for each stop. Thus, the sums of proportions of activities at stops that were reported in Table 2 may exceed one.

For adults in households with children, the most frequently reported activity was 'Picking-up someone or being picked-up', followed by 'Waiting to see what is going on/passing the time'. The same two activities were also the most frequent for adults in households with no children, but in reverse order: While the frequency of reported picking-up activities was lower, waiting reports were higher. In both multi-

Table 1
Proportions of individuals that made numbers of intermediate stops, between the initial and final location that day, by adult groups. Numbers in [#] represent the number of adult individuals in the relevant samples.

Total number of intermediate stops made	Adults w/children		Adults w/o children		Singletons		All adults [291]
	Evacuated [122]	Stayed put [24]	Evacuated [85]	Stayed put [37]	Evacuated [15]	Stayed put [8]	
Did not travel	–	0.13	–	0.05	–	0.25	0.02
Travel directly	0.16	0.25	0.34	0.27	0.53	0.13	0.25
1	0.37	0.33	0.39	0.38	0.4	0.38	0.37
2	0.31	0.21	0.09	0.22	0.07	0.13	0.21
3+	0.16	0.08	0.17	0.08	0	0.13	0.14
Average	1.59	1	1.15	1.11	0.53	1.25	1.29

Table 2
Proportions of stops where activities were reported by adult groups. More than one or no activity could be reported for each stop. Numbers in [#] represent the numbers of stops with reported activities in the relevant samples.

Activity	Adults w/children		Adults w/o children		Singletons		All adults' stops with activity reports [465]
	Evacuated [248]	Stayed put [24]	Evacuated [127]	Stayed put [39]	Evacuated [17]	Stayed put [10]	
Pick up	0.56	0.54	0.26	0.21	0.53	0	0.44
Wait	0.25	0.38	0.42	0.62	0.18	0.70	0.34
Pick up belongings	0.20	0.17	0.19	0.05	0.18	0.10	0.18
Take care of pets	0.10	0	0.07	0.03	0.12	0.30	0.08
Drop off	0.05	0.04	0.06	0.10	0.06	0	0.05
Protect property	0.02	0.17	0.06	0.03	0.18	0	0.05
Help others	0.04	0	0.01	0	0.06	0	0.02
Other	0.11	0.13	0.13	0.05	0.18	0.20	0.12

person household types, there were only small differences between adults that evacuated and those that did not in picking-up occurrences rates. Much higher rates of waiting activities were reported for those that did not evacuate. The high frequency of picking-up activities indicates the importance of social interactions in the evacuation process, especially in the context of children. Waiting activities may be related to the high level of uncertainty, incomplete information and confusion that characterized the fire event. This phenomenon is further investigated later. Beyond these two activities, 'picking up belongings' was the next most frequently reported by all adults, and to a greater extent among those who evacuated. The fact that individuals who stayed put went home to pick up belongings suggests that the decision whether to evacuate may have come after making some initial preparatory steps towards the evacuation allowing time for deliberations. Singletons that evacuated reported high rates of pick-up, while those that did not evacuate reported high rates of waiting. However, their sample sizes are too small to support meaningful conclusions.

Table 3 shows the proportions of stop types reported by adults in the sample. The most frequent stops were the respondents' home (25%) and homes of others (28%). 77% of households had at least one member at home during the event: either at the beginning of the event (46% of households), and/or stopping there during the event (44% of households). This suggests that stopping at home is a household task of its own and an internally motivated goal during such events. The analysis of activities carried out at various stops adds to this conclusion. It is also worth noting in this context that there were times during the event that people were not allowed into specific neighborhoods. This led to congestion at neighborhood entrances where people waited for access to their homes. As expected, schools were significant stopping points for adults in households with children. Other locations, such as public places (e.g., malls, train stations) and the roadside were also frequent.

Table 4 presents the locations where different activities took place, focusing on the most common activities of waiting and picking up. Individuals that evacuated waited mostly in public places (e.g., train stations, shopping malls), individuals that did not evacuated waited mostly at other people's home. To a lesser extent, waiting also occurred at individuals' homes. For adults in households with children, picking up from school was dominant. For all other adults, pick-up took place at other people's homes, as well as at roadsides and other locations, in addition to the small proportion of childless individuals who picked-up from school. These data demonstrate people's significant tendency to come together as the evacuation process unfolded. Other activities including picking-up belongings, protecting property or pets and helping others, occurred mostly at home or at the roadside – and these activities may be seen as either mitigating activities aimed at fighting the fire's outcomes, or as preparatory actions before evacuating.

As noted above, waiting, alongside with picking up others, were the most frequently reported activities. To the best of our knowledge, waiting patterns have not been previously studied. They are further examined by comparing the locations and durations of waiting to those of other reported activities, in Table 5 Table 6, respectively.

Waiting occurred mostly within the area of the fire (39% of waiting

Table 3
Proportions of stop types reported by adult groups. Numbers in [#] represent the numbers of stops in the relevant samples.

Stop location	Adults w/children		Adults w/o children		Singletons		Stops by all adults [659]
	Evacuated [316]	Stayed put [45]	Evacuated [183]	Stayed put [76]	Evacuated [23]	Stayed put [16]	
Home	0.18	0.51	0.20	0.51	0.17	0.44	0.25
Others' home	0.30	0.11	0.29	0.24	0.39	0.31	0.28
School	0.22	0.18	0.03	0.03	0	0.06	0.13
Public place	0.09	0.04	0.12	0.08	0.13	0.06	0.10
Roadside	0.10	0.07	0.19	0.07	0.22	0.13	0.12
Other	0.10	0.09	0.18	0.08	0.09	0	0.12

Table 4
Proportions of stop types for various activities by adult groups. Numbers in [#] represent the number of stops with the indicated activity in the relevant samples.

Stop location	Adults w/children		Adults w/o children		Singletons		Stops by all adults
	Evacuated	Stayed put	Evacuated	Stayed put	Evacuated	Stayed put	
Wait							
	[62]	[9]	[53]	[24]	[3]	[7]	[158]
Home	0.27	0.11	0.19	0.08	0	0.14	0.20
Others' home	0.31	0.44	0.19	0.54	0	0.57	0.32
School	0.02	0	0	0	0	0	0.01
Public place	0.23	0	0.26	0.21	0.67	0.14	0.23
Roadside	0.06	0.11	0.13	0	0	0.14	0.08
Other	0.11	0.33	0.23	0.17	0.33	0	0.17
Pick up							
	[140]	[13]	[33]	[8]	[9]	[0]	[203]
Home	0.13	0	0.18	0.25	0.11	–	0.13
Others' home	0.16	0.23	0.03	0	0.11	–	0.13
School	0.45	0.62	0.06	0.25	0	–	0.37
Public place	0.11	0.08	0.18	0.13	0.22	–	0.12
Roadside	0.08	0	0.36	0.25	0.56	–	0.15
Other	0.08	0.08	0.18	0.13	0	–	0.09
All other activities							
	[67]	[4]	[42]	[8]	[6]	[3]	[130]
Home	0.43	0.25	0.45	0.125	0.50	0	0.41
Others' home	0.04	0	0.07	0.50	0.33	0.33	0.10
School	0.04	0	0	0	0	0.33	0.03
Public place	0.07	0.25	0.07	0	0	0	0.07
Roadside	0.27	0.50	0.33	0.375	0.17	0.33	0.29
Other	0.13	0	0.07	0	0	0	0.10

Table 5
Proportions of locations relative to the affected area where waiting and other activities took place by adult groups. Numbers in [#] represent the number of stops with the indicated activity in the relevant samples.

zone	Adults w/children		Adults w/o children		Singletons		All adults
	Evacuated [248]	Stayed put [24]	Evacuated [127]	Stayed put [39]	Evacuated [17]	Stayed put [10]	
Wait							
	[62]	[9]	[53]	[24]	[3]	[7]	[158]
Affected area	0.42	0.56	0.42	0.21	0	0.43	0.39
In Haifa	0.44	0.11	0.40	0.67	0.67	0.14	0.43
Near Haifa	0.08	0	0.13	0.13	0.33	0.29	0.11
Further way	0.06	0.33	0.06	0	0	0.14	0.07
All other activities							
	[186]	[15]	[74]	[15]	[14]	[3]	[307]
Affected area	0.71	0.80	0.7	0.53	0.57	0.33	0.69
In Haifa	0.22	0.13	0.16	0.2	0.29	0.67	0.21
Near Haifa	0.03	0.07	0.08	0.27	0.14	0	0.06
Further away	0.04	0	0.05	0	0	0	0.04

Table 6
Proportions of durations of waiting and other activities by adult groups. Numbers in [#] represent the number of stops with the indicated activity in the relevant samples.

Duration	Adults w/children		Adults w/o children		Singletons		All adults
	Evacuated [248]	Stayed put [24]	Evacuated [127]	Stayed put [39]	Evacuated [17]	Stayed put [10]	
Waiting							
	[62]	[9]	[53]	[24]	[3]	[7]	[158]
Up to ½ hour	0.11	0.11	0.08	0.08	0	0.29	0.10
½ hour to 2 h	0.29	0.11	0.26	0.17	0.33	0.14	0.25
More than 2 h	0.59	0.78	0.66	0.75	0.67	0.57	0.65
All other activities							
	[186]	[15]	[74]	[15]	[14]	[3]	[307]
Up to ½ hour	0.69	0.73	0.58	0.67	0.5	0.67	0.66
½ hour to 2 h	0.22	0.13	0.27	0.33	0.36	0.33	0.24
More than 2 h	0.09	0.13	0.15	0	0.14	0	0.10

stops) or in other areas within the city of Haifa (43%). Other activities, which are associated with various tasks to be performed before evacuating or returning home, increasingly take place within the affected area (69% and 21%, respectively). The different nature of waiting compared to other tasks that involve completing a task, is also reflected in their durations. Waiting durations were much longer than those of other activities. Only 10% of respondents reported staying for less than 30 min at stops where they waited, while 65% reported staying over 2 h in these stops. The durations for other activities are a mirror image of those: 66% reported staying less than 30 min and 10% reported staying more than 2

h. Thus, most of the delay before taking the final action to evacuate or to return home was due to waiting periods rather than delays in completing other activities. These results suggest the need to consider waiting as a relevant strategy for individuals during no-notice wildfire evacuations. Furthermore, the evidence for significant waiting periods at other peoples' homes is another indication to the role of social ties in the evacuation process, going beyond those within the household itself. Thus, waiting may have mental mitigating qualities of its own, and have more functions beyond just delaying decision making. However, the current data does not allow for a deeper understanding of the motivations and nature of this kind of behaviors.

3.2. Joint travel and child pick-up

The most direct indication of the interactions among individuals is the number of joint trips made on the day of the fire. Joint trips, which are those taken by at least two individuals together, are shown in Table 7 for the various trip legs that individuals took on the day. Note that the sample sizes decrease with increasing leg trips, as some of the individuals do not make additional trip legs. The share of joint trips was high throughout the event: 97% for children and 61% for adults. Furthermore, 32% of all trip legs included individuals that are not members of the household. They share of joint travel also increased as individuals moved between stops. The average group size that an individual was part of in a car trip to the first stop made on that day was 1.45. It increased to 2.39 on the second trip and to 2.57 on subsequent trips. The shares of joint trips increased substantially from the first to the second trip leg, especially for adults in households with children. Thus, in many cases the first trip is to a location where people picked-up or were picked-up by others. Singletons exhibited lower shares of joint travel, but these still account for almost half of the trips and increase in subsequent ones. These findings illustrate the strength of the motivation to gather and travel together during the evacuation event. No significate differences were found between individuals who eventually evacuated and those who stayed put.

Children's trips were almost exclusively joint, meaning that in most cases they were picked-up and then continued to travel with others. When the Haifa 2016 fire began, at about 10 a.m., most children (85%) were reported to have been in school. Shortly after, when the evacuation instructions were given, children had to leave schools in the affected area. An official report regarding the event [34] depicted the evacuation of school children by their parents as one of the major causes of traffic that interfered with the authorities' efforts to handle the event. Table 8 presents the fraction of children that were accompanied by various individuals when they left their schools, grouped by their relations to the children. Multiple companions could have been reported, and so the sum of fractions of all companions exceeds one. A hierarchical set of rules was used to determine who, among the individuals traveling with the child from school, would be considered the responsible person picking them up. The responsible person was determined to be, in order, the driver - if pick up was by car, an adult member of the household that the child was taken to their home present in the group, age and closeness of the relations to the child.

Only a small fraction of the children (5%) left their school alone. Most children were picked up from school by members of their own households: adults (50%) or older children (3%). 7% of the children picked up others or left school alone. However, 40% of the children were initially picked up by individuals that are not members of their household, either relatives (20%) or other individuals (20%).

Table 8
Fraction of children [162] that reported traveling from school by travel companions.

Companion	Participants in the trip	Who is responsible
By self	0.04	0.04
Adult/s in the household	0.53	0.50
Other child/children in the household	0.53	0.03
Relatives not from the household	0.24	0.20
Others, not relatives	0.37	0.20

These findings show that child pick-up in evacuation situations is more complex than assumed in previous research. To better understand child pick-up behavior, a multinomial logit (MNL) discrete choice model was developed for the identity of the main person picking-up the child from school. The alternatives in the model are that the child was picked-up by any of the adults and older children in the household, as well as relatives that are non-household members or other non-household individuals. Finally, the child could have left school alone (or with smaller children). It is assumed that this option was available only to children 6 years or older. Thus, for specific observations in the data, the number of alternatives in the model depends on the household composition (number of adults and older siblings). The utilities of the alternatives are given by:

$$U_{in} = \beta' X_{in} + \varepsilon_{in} \tag{1}$$

U_{in} is the utility of alternative i to individual n. X_{in} and β are a vector of explanatory variables and the corresponding parameters respectively. ε_{in} is an i. i.d. Random error term, which is assumed to follow a Gumbel distribution. The child pick-up choice probabilities are given by:

$$p(Y_{in}|X_n) = \frac{\exp(\beta' X_{in})}{\sum_j \exp(\beta' X_{jn})} \tag{2}$$

The model parameters were estimated using the maximum likelihood estimator. Table 9 presents the model estimation results. The factors that predict the identity of the person picking the child up from school are grouped in three categories: characteristics of the children, specifically their age; of the household they are part of; and of the persons picking them up. Alternative-specific constants are not included in the model, as they would be perfectly correlated with the child age group variables for the non-household member and the alone alternatives. The results show that child pick-up was not done only by household members, which has been often assumed in previous studies [10,23,25]. The probability that a child would be picked up by a member of their household was higher when that person was an adult rather than an older child. It also depended on their availability for the task: picking up probabilities increased for household members that were within the city and at home at the time that the fire started, and had a car available to them at that time. The probability that individuals that are non-household members would have picked up young children was lower and increased with the child's age. It was also higher if the

Table 7
Fraction of individuals making joint trips by group and order of the trip leg. Numbers in [#] represent the number of individuals in the relevant samples.

Trip leg	Adults w/children		Adults w/o children		Singletons		All adults	Children	
	Evacuated	Stayed put	Evacuated	Stayed put	Evacuated	Stayed put		Evacuated	Stayed put
1st	0.31 [122]	0.24 [21]	0.56 [85]	0.46 [35]	0.33 [15]	0.50 [6]	0.40 [284]	0.97 [158]	0.90 [20]
2nd	0.79 [103]	0.47 [15]	0.70 [56]	0.76 [25]	0.57 [7]	0.40 [5]	0.72 [211]	1.00 [89]	0.67 [12]
3rd+	0.86 [91]	0.89 [9]	0.83 [42]	0.69 [16]	1.00 [1]	0.40 [5]	0.82 [164]	1.00 [53]	1.00 [8]
All	0.62 [316]	0.44 [45]	0.67 [183]	0.83 [76]	0.43 [23]	0.44 [16]	0.61 [659]	0.98 [300]	0.85 [40]

Table 9
Estimation results for the child pick-up model.

Parameter		Estimates (standard errors)		
		Household member	Non-household member	Alone
Child age	5 or under	–	2.43 (0.65)**	–
	6–12	–	3.47 (0.65)**	2.13 (0.87)**
	13–18	–	4.12 (0.82)**	5.18 (0.88)**
Household characteristics	No car ownership	–	1.9 (1.23)	–
	High risk	–	–	−1.47 (0.86)*
Household individual	Age 13-18	1.35 (0.91)	–	–
	Age 19 and up	2.01 (0.60)**	–	–
	Location: in city	1.08 (0.39)**	–	–
	Location: at home	0.93 (0.35)**	–	–
	Car available	0.66 (0.35)*	–	–
No. Of parameters: 17		No. Of observations: 162		
Null log-likelihood: 282.177		Final log-likelihood: 222.09		
Adjusted rho-square: 0.153				

* p-value <0.10 **p-value<0.05.

household did not own a car – also in comparison to evacuating alone. The probability of evacuating alone was higher for older children compared to younger ones and was lower in comparison to any other alternative, if the home was in an area where the fire risk was high. The importance of car ownership and availability was consistent with the dominance of its use as the travel mode during the evacuation. In contrast to the findings of Liu et al. [23]; gender was not found to have any influence on the identity of the person picking up the children.

To illustrate the model results, predicted probabilities of child pick up were calculated for four pick-up scenarios. The scenarios are presented in Table 10. They are defined by the composition of the household, the age group of the child being picked-up, the locations of household members and whether they had a car available to them when the fire began, and the fire risk level at the home location. The predicted pick-up probabilities are shown in Table 11. The results emphasize the substantial probabilities of pick-up by individuals outside the household. They also indicate the differences between households with one or two adults. Having one adult in the household increases the probability of engaging individuals outside the household for pick-up. The higher probabilities of traveling alone for older children and the importance of the initial location in the city and at home are also evident.

4. Discussion and conclusion

This paper uses quantitative RP data from the Haifa 2016 fire to explore the travel behaviors of individuals during a no-notice disaster evacuation. While most of the relevant literature focuses on the decision whether to evacuate, this research focuses on intermediate stops in the evacuation process, the gathering of household members and the task of child pick-up within these.

A basic assumption that commonly underlies evacuation models is that individuals who evacuate do so immediately with minimal additional trips. The Haifa fire data contradicts this assumption. Most individuals make at least one, and in some cases several intermediate stops prior to the evacuation. This is also true for individuals that decide not to evacuate. A main activity at these stops is to pick-up and meet with others. This is consistent with, mostly qualitative, previous claims that household members tend to gather for the evacuation. Pick-up activities mostly take place at schools and in public locations, such as train stations and shopping malls, or at the roadside. However, another stop pattern is also evident in the data: Individuals report waiting at intermediate stops prior to the eventual evacuation. To the best of our knowledge, this behavior has not been previously reported in the literature. Waiting occurs mostly at public places, at homes or the homes of others, and takes significantly longer than other activities. This suggests a pattern of household members gathering and delaying the decision to evacuate under the uncertainty of the situation. This behavior may be affected by the nature of the event, which in this case did not encompass the entire city or even whole neighborhoods but had very local yet unpredictable and immediate effects.

Some activities are conducted at the household level. Most notably, stopping at home, which in most households was done by at least one of the members. This might be true even for households that none of their members were within the impacted area at the beginning of the event. These activities thus bring in additional traffic to the affected area, which may lead to traffic congestion at its entry points. This may be especially disruptive to the event management and mobility of emergency forces. This behavior counters common assumptions made in no-notice disaster evacuation management that mostly focus on traffic heading away from the affected area.

As noted above, similarly to previous studies, the tendency to gather and travel together is evident in the data. This was found to be true regardless of the household's composition or final evacuation decision. The rates of joint trips increased sharply for the second and onward trip legs, compared to the first one. A non-trivial number of such observed joint travel involved also individuals outside the household. This was evident, for example, in trips taken by singletons and trips to pick up children. Hence, understanding and evaluation of a broader social sphere is needed. The clearest outcome with respect to gathering behavior regards child pick-up, as practically all children travelled with others from the first trip leg that they make. This behavior may have been especially emphasized in the Haifa fire event, which started when children were at school. However, school pick-up is apparently more complex than described in previous studies, which assumed that the task is undertaken only by adults in the household. A significant fraction of the children included in the data left school accompanied by individuals from outside of their own households. Modeling results showed that ease or quick access to the child's location is a central consideration in who will pick them up. This is captured by variables of the proximity of the adults to the child and their access to cars. When these conditions are not met, the likelihood that an individual outside the household would pick the child up increases substantially.

Table 10
Definition of child-pick up test case scenarios.

Household characteristics		Scenario 1	Scenario 2	Scenario 3	Scenario 4
Child age		6–12	6–12	13–18	0–6
Fire risk level		Low	High	Low	Low
Household adult 1	Location	Home	City	Home	City
	With car	No	Yes	No	Yes
Household adult 2	Location	Outside	–	City	–
	With car	Yes	–	Yes	–
Sibling	Age	13–18	–	–	13–18
	Location	City	–	–	Home

Table 11
Predicted pick-up probabilities for the test case scenarios.

Individual picking up	Scenario 1	Scenario 2	Scenario 3	Scenario 4
Household adult 1	0.36	0.39	0.24	0.62
Household adult 2	0.09	–	0.09	–
Sibling	0.07	–	–	0.06
Non-household relative/other	0.42	0.60	0.28	0.32
Alone	0.05	0.02	0.39	–

In conclusion, the findings suggest that the prediction of travel patterns during evacuations requires understanding and modeling of intermediate stops and activities and the role of social interactions within the household as well as in the broader social context. The relevant literature is limited and often narrowly focused on the decision whether to evacuate.

The analyses reported and the data they rely on have their limitations. The data collection was conducted using a questionnaire that was administered after the event took place. Limitations of the data collection instrument and of relying on individuals' recollection abilities dictated imprecise data on the timing of travel and the locations of stops. Thus, the spatial and temporal analyses are coarse. While data on all household members was collected, details about individuals outside the household that they interacted with is minimal and coarse. Reports on some of the behaviors, such as waiting as an activity, stopping at home or at the roadside, are mediated by the subjective perceptions of respondents and the researchers. Disaster events are unexpected and differ from one another. Thus, it is not clear to what extent the results may be generalized. Studies in this area are currently fragmented, rely on data sets with different and partial information that are collected ad-hoc in various events. To facilitate more systematic study of human behavior during these events, it is advised that a uniform multi-lingual, culturally and geographically adaptable survey will be developed and distributed after disaster evacuations.

Finally, it is noted that this study, similarly to others regarding interpersonal interactions, focus on multi-person households. The behavior of single-person households remains relatively unexplored. Nonetheless, their interactions, involving harder to affiliate others, are still evident in this study, showing joint trips with others in almost half of their trips. Further study is needed to predict the needs and behaviors of this growing sector of the population[36–45].

Declaration of competing interest

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