Smoke Alarm Response Time:

Examining the Relationship Between Working Smoke Alarms, Fire Service Response Times and Fire Outcomes

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Executive Summary

This report examines 868 residential fire incidents that were responded to by Surrey Fire Services between March 2008 and April 2018, inclusive, and reported to the British Columbia (BC) Office of the Fire Commissioner (OFC). At a high-level, this research was intended to examine the relationship between a working fire safety system, fire service response time, and fire outcomes.

The analysis focused on residential structure fires that either occurred with a working smoke alarm or without a smoke alarm. Data was screened to focus on the influence of response times for the first wave of a total effective attack force. Fire damage and building loss were examined as a function of response time (first unit on-scene and last unit on-scene from the initial attack force), smoke alarm presence, and the time of day at which the fire occurred.

The risk of fires spreading beyond the room of origin, where a smoke alarm was not present increased by 17% for each one minute increase in the time required for the fire service to assemble a total effective attack force.

The influence of response time was countered by the presence of working smoke alarms, which reduced the likelihood of fires extending beyond the room of origin (by 71%) regardless of response time.

Fires that occur during the day were at least 60% less likely to extend beyond the room of origin and were less likely to sustain large amounts of building loss.

The analysis provides additional support to the belief that the influence of smoke alarms is to increase the likelihood of building residents controlling the fire before the fire department arrives. This emphasises the importance of having a working smoke alarm in all residential properties. Furthermore, this supports targeted smoke alarm education and installation efforts that use risk to identify areas within cities that are most likely to have non-functioning or missing alarms.

The Purpose of this Research

This report examines 868 residential[1] fire incidents that were responded to by Surrey Fire Services between March 2008 and April 2018, inclusive, and reported to the British Columbia (BC) Office of the Fire Commissioner (OFC). These fires were screened to include only events where the post-fire inspection determined a smoke alarm was either present and functioning or not present. The purpose of this research was to examine the relationship between the response times, smoke alarm presence, time of day of fires, and fire outcomes (with respect to damage to properties and fire-related casualties) by fires responded to by Surrey Fire Services. At a high-level, this research was intended to examine the relationship between a working fire safety system, fire service response time, and fire outcomes. These findings are discussed with respect to the potential to enhance residential building fire safety in a targeted manner.

Methodology

This analysis builds on the approach taken by the New Zealand Fire Service [1]. All of the available calls for service during this time period were matched with data from the BC OFC and then sorted to identify residential structure fires that met the following criteria:

- Records related to non-firefighting apparatus[2] were excluded;
- To manage for fires where something unusual had influenced the recorded response time, first unit on-scene times greater than 20 minute were excluded and last unit on-scene times greater than 20 minute were excluded;
- Duplicate records were excluded;
- Single-unit responses were excluded because an active structure fire would require at least a total effective attack force;
- Subsequent waves of units dispatched later into an event were excluded to focus on the impact of the initial attack force;
- Only records relating to residential structure fires (OFC PC3100, 3400, and 3500, see footnote 1) were retained; and
- Only fires with working smoke alarms (OFC SD1000, 2000, 3000, 4000, or 5000) or without any smoke alarms (OFC SD9900) were retained.

This process retained a total of 868 fire incidents: 479 fires where the smoke alarm was recorded as present and functioning; and 389 fires where the smoke alarm was recorded as not present. To explore the link between fire spread and response time, response times were grouped into

[1] Defined here as buildings classified as "Residential - row, garden, town housing, condominium", "Residential - single detached", or "Residential - duplex, 3-plex, 4-plex" in the BC fire reporting manual.

[2] Surrey Chief 5-1, Surrey Chief 5-3, Surrey Chief 5-4, Surrey Chief 5-5, Surrey Chief 5-6, Surrey Chief 5-7, Surrey Chief 5-8, Surrey Chief 5-9, Surrey Chief 5-10, Surrey Duty Chief, Surrey Battalion 1, Surrey Inspector 6-0, Surrey Inspector 6-1, Surrey Inspector 6-2, Surrey Inspector 6-3, Surrey Inspector 6-4, Surrey Inspector 6-5, Surrey Inspector 6-6, Surrey Inspector 6-7, Surrey Inspector 6-8, SREHAB, Computer Support, Surrey Mobile Command, Surrey Clothing.

1 minute intervals. For example, a time that was greater than or equal to 6 minutes and less than 7 minutes was grouped into the 6 minute interval. A binary variable was used to examine the extent of fire spread, with fires either classified as contained to the room of origin or having extended beyond the room of origin (this extent of fire spread has been demonstrated in previous research [e.g., 2, 3] to be correlated with significant increases in fire damage and risk to life). A binary variable was also used to examine the significance of the timing of the fire, with fires either classified as occurring during the 'day' (having commenced between 07:00 and 22:59) or 'night' (commencing between 23:00 and 06:59). This data forms the basis for the remainder of the analysis discussed in this report.

First Units on Scene: Relationship Between Time, Smoke Alarms and Fire Damage

The first on-scene response time was estimated using the arrival time of the first unit dispatched in the first wave of apparatus sent to the fire incident. The relationship between the first unit on-scene response time, smoke alarm functionality, timing of the fire, and extent of fire spread was examined. Figure 1 demonstrates a strong positive relationship between total response time and probability of the fire extending beyond the room of origin for fires that occurred in the presence of a working smoke alarm (accounting for 65% of the variance in this outcome). The y-intercept of this slope suggests a hypothetical fire with a 0-minute response time for the first unit on-scene and a working smoke alarm would extend beyond the room of origin 17% of the time. This figure also shows that for fires where a smoke alarm was activated the first unit arrived on-scene in less than 7 minutes 85% of the time (green bars sum to 100% within the figure).

FIGURE 1: PERCENT OF FIRES WITH SMOKE ALARMS EXTENDING BEYOND THE ROOM OF ORIGIN (95% CONFIDENCE INTERVALS) AND PERCENT OF ALL FIRES WITH SMOKE ALARMS (*N* = 479) BY GROUPED FIRST UNIT ON-SCENE RESPONSE TIME (MINUTE)

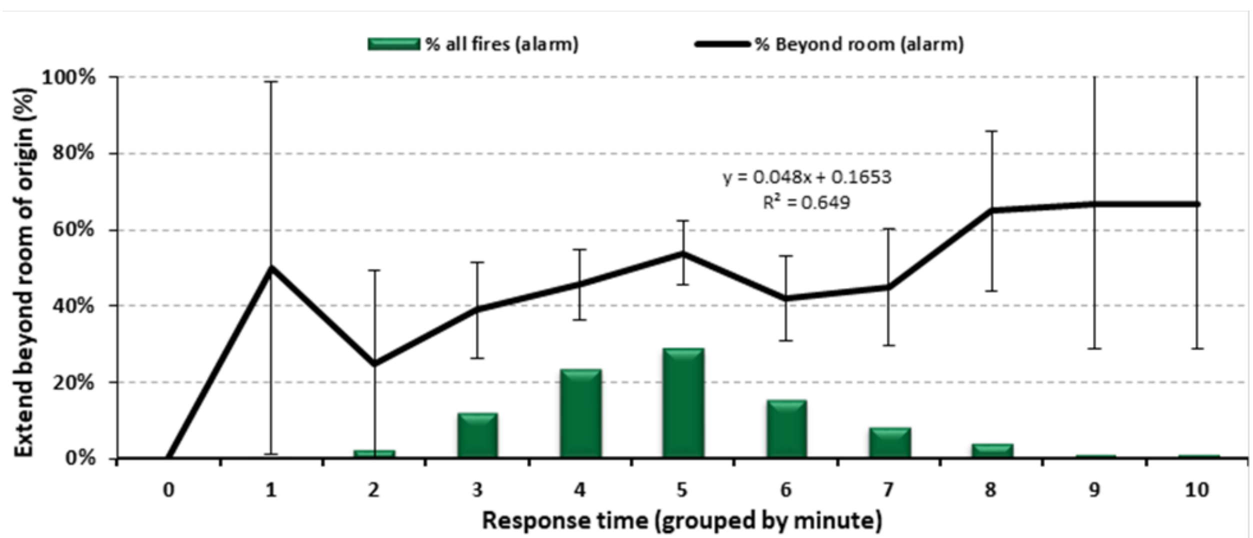
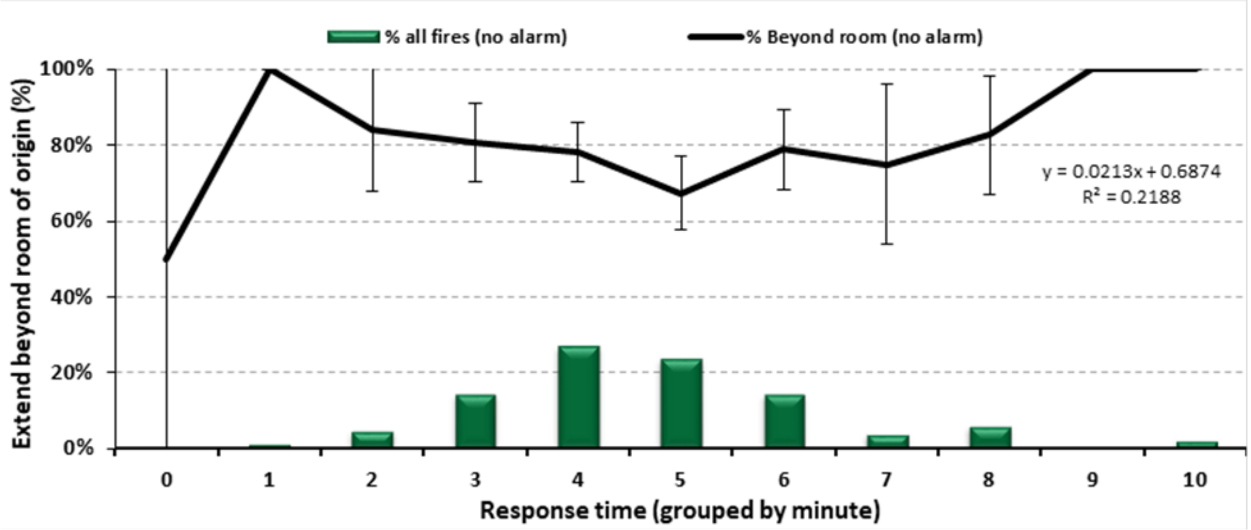


Figure 2 demonstrates there is a weak positive relationship between total response time and probability of the fire extending beyond the room of origin for fires that occurred without a smoke alarm (accounting for 22% of the variance in this outcome). The y-intercept of this slope suggests a hypothetical fire with a 0-minute response time for the first unit on-scene and without a smoke alarm would extend beyond the room of origin 69% of the time. This figure also shows that for fires where a smoke alarm was activated the first unit arrived on-scene in less than 7 minute 87% of the time (green bars sum to 100% within the figure).

FIGURE 2: PERCENT OF FIRES WITHOUT SMOKE ALARMS EXTENDING BEYOND THE ROOM OF ORIGIN (95% CONFIDENCE INTERVALS) AND PERCENT OF ALL FIRES WITHOUT SMOKE ALARMS (*N* = 389) BY GROUPED FIRST UNIT ON-SCENE RESPONSE TIME (MINUTE)



To examine the relationship between these two patterns, a binary logistic regression model was run. Smoke alarm presence (dichotomous variable: present vs. not present), first unit on-scene response time (continuous variable: 0 minute to 10 minute), and time of fire (dichotomous variable: day vs. night) were used to predict the probability a fire would extend beyond the room of origin (binary variable). This model returned a significant overall fit, and demonstrated significant influence of smoke alarm status and time of fire. The presence of a working smoke alarm significantly reduced the likelihood of fires spreading beyond the room of origin by 71% across the board (avg. 47% of fires with working smoke alarms extended this far, compared to avg. 77% of fires with no smoke alarms). If a fire occurred during the day the likelihood it would spread beyond the room of origin reduced by 64% (avg. 53% of day fires extended this far, compared to avg. 79% of night fires). There was no significant effect of first on-scene response time on the extent of fire spread.

The same variables were also modelled using a linear regression model to examine their relationship with building loss (dependent variable). The values for building loss were heavily positively skewed (towards $0), which meant it was acceptable to conduct a logarithmic transformation for the purposes of the regression model. This model also returned a significant overall fit but a very low percentage of variance was explained (R^2 = 0.01). No significant influence of response time or smoke alarm status was found, but there was a significant relationship between time of fire and building loss such that fires that occurred during the day resulted in a 47% reduction in building loss.

Last Units on Scene: Relationship Between Time, Smoke Alarms and Fire Damage

The total effective attack force response time was estimated using the arrival time of the final unit dispatched in the first wave (to make up the total effective attack force). The relationship between the last unit on-scene response time, smoke alarm status, timing of the fire, and extent of fire spread was examined. Figure 3 demonstrates a strong positive relationship between total response time and the probability of the fire extending beyond the room of origin with a working smoke alarm (accounting for 90% of the variance in this outcome). The y-intercept of this slope suggests a hypothetical fire with a 0-minute response time for the total effective attack force and a working smoke alarm would only extend beyond the room of origin 14% of the time. This figure also shows that for fires where a smoke alarm was activated the last unit arrived on-scene in less than 13 minute 85% of the time (green bars sum to 100% within the figure).

FIGURE 3: PERCENT OF FIRES WITH SMOKE ALARMS EXTENDING BEYOND THE ROOM OF ORIGIN (95% CONFIDENCE INTERVALS) AND PERCENT OF ALL FIRES WITH SMOKE ALARMS (*N* = 479) BY GROUPED LAST UNIT ON-SCENE RESPONSE TIME (MINUTE)

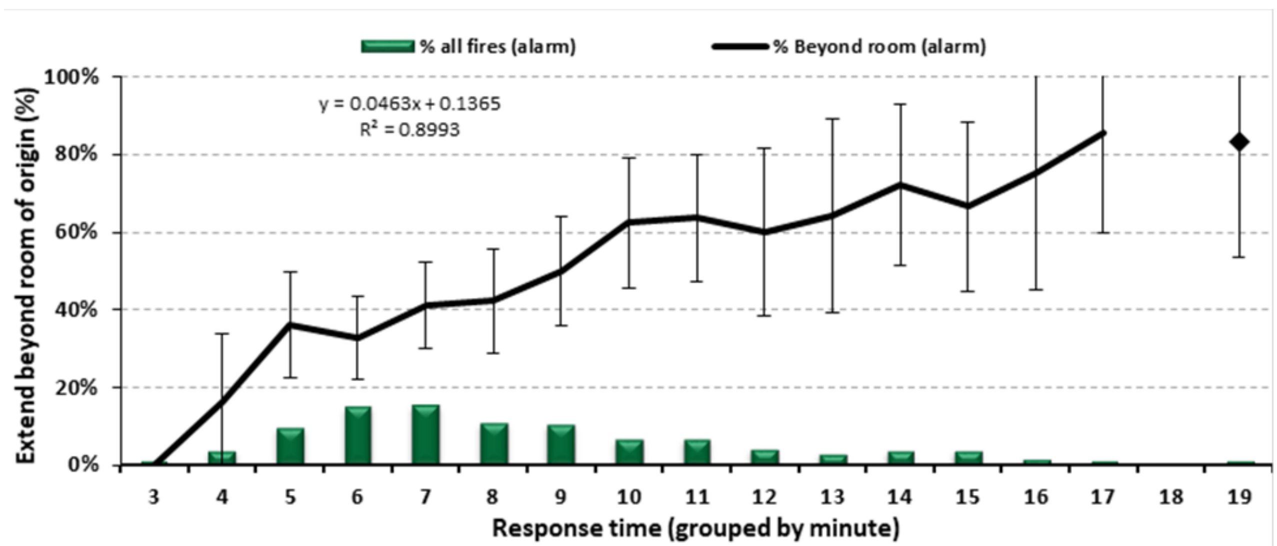
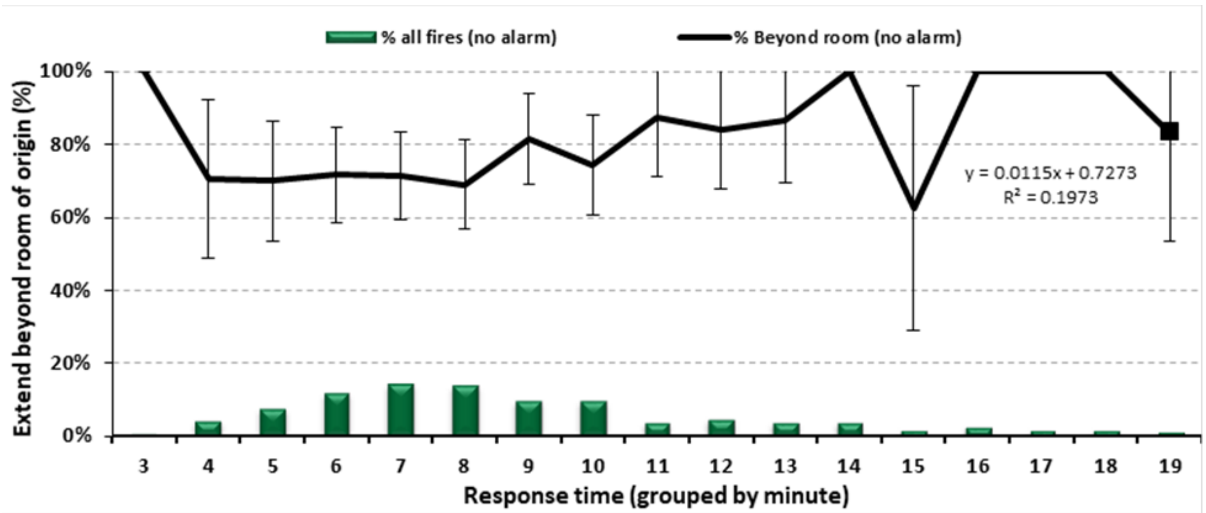


Figure 4 demonstrates there is a weak positive relationship between total response time and probability of the fire extending beyond the room of origin without a working smoke alarm (accounting for 20% of the variance in this outcome). The y-intercept of this slope suggests a hypothetical fire with a 0-minute response time for the total effective attack force and without a smoke alarm would extend beyond the room of origin 73% of the time. This figure also shows that for fires where no smoke alarm was present the last unit arrived on-scene in less than 13 minute 82% of the time (green bars sum to 100% within the figure).

FIGURE 4: PERCENT OF FIRES WITHOUT SMOKE ALARMS EXTENDING BEYOND THE ROOM OF ORIGIN (95% CONFIDENCE INTERVALS) AND PERCENT OF ALL FIRES WITHOUT SMOKE ALARMS (*N* = 389) BY GROUPED LAST UNIT ON-SCENE RESPONSE TIME (MINUTE)



As with the first on-scene responses, to examine the relationship between these two patterns, a binary logistic regression model was run. Smoke alarm presence (dichotomous variable: present vs. not present), response time (continuous variable: 3 minute to 19 minute), and time of fire (dichotomous variable: day vs. night) was used to predict probability a fire would extend beyond the room of origin (binary variable). This model returned a significant overall fit, and demonstrated significant influence of response time, smoke alarm status, and time of fire. Total response time was positively related to fire spread, with each 1 minute increase raising the odds of the fire extending beyond the room of origin by roughly 17%. The presence of a working smoke alarm significantly reduced the likelihood of fires spreading beyond the room of origin by 72% across the board. Fires that occurred during the day reduced the likelihood of the fire spreading beyond the room of origin by 61%.

Once again, the same variables were also modelled using a linear regression model to examine their relationship with building loss (dependent variable). The values for building loss were heavily positively skewed (towards $0), which meant it was acceptable to conduct a logarithmic transformation for the purposes of the regression model. This model also returned a significant overall fit but a low percentage of variance was explained ($R^2 = 0.05$). A significant influence of response time and time of fire were found. Total response time was positively related to building loss, with each 1 minute increasing building loss by roughly 18%. Fires that occurred during the day reduced the building loss by 41%. The presence of a working smoke alarm did not significantly reduce the building loss that was incurred.

Aggregating the Findings Related to Response Time

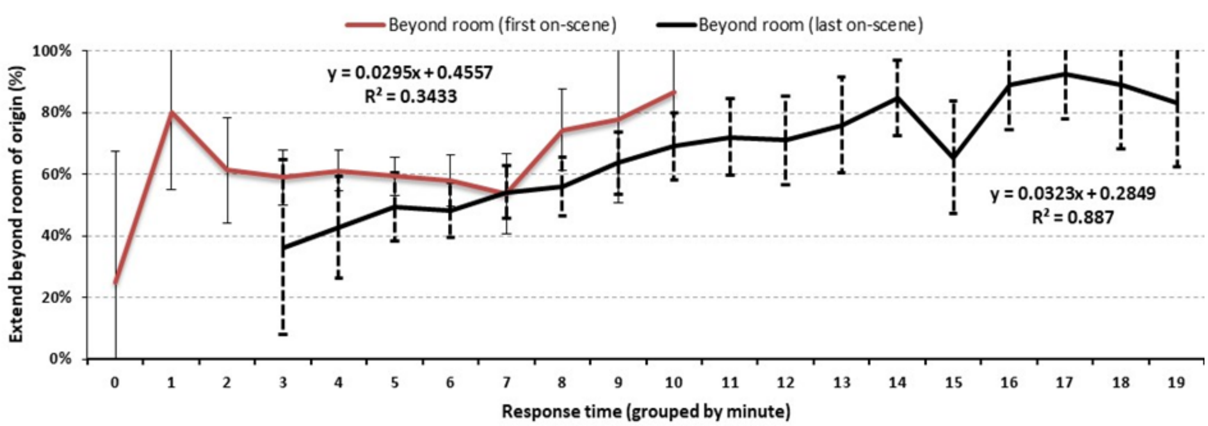
As can be seen from Table 1, the two approaches to modelling fire outcomes as a function of when the apparatus arrived returned different results for the significance of response time. In the first instance, the range of times within which the first unit arrived on-scene did not result in an increased likelihood of the fire extending beyond the room of origin. However, in comparison, as the arrival time increased for the total effective attack force dispatched in the first wave, the likelihood of the fire extending beyond the room of origin was significantly increased.

TABLE 1: SUMMARY OF THE MAIN EFFECTS OF THE REGRESSION MODELS ACROSS FIRST AND LAST UNIT ON-SCENE RESPONSE TIMES

	First unit on-scene		Last unit on-scene	
Independent variables	Prob(extend beyond room)	Ln(Loss)	Prob(extend beyond room)	Ln(Loss)
1 minute increases in response time	–	–	↑ (17%)	↑ (18%)
Functioning smoke alarm	↓ (71%)	–	↓ (72%)	–
Fire during the day	↓ (64%)	↓ (47%)	↓ (61%)	↓ (41%)

To help explain this difference, the two trends are presented simultaneously in Figure 5. The red line (first on-scene response times and fire spread) is overall much flatter than the black line (last on-scene and fire spread), and the corresponding R^2 values for each model demonstrate the much clearer relationship between increased time and fire spread for the total effective attack force formation.

FIGURE 5: PERCENT OF FIRES EXTENDING BEYOND THE ROOM OF ORIGIN (95% CONFIDENCE INTERVALS) AS A FUNCTION OF GROUPED FIRST-IN RESPONSE TIME (RED LINE) AND TOTAL EFFECTIVE ATTACK FORCE RESPONSE TIME (BLACK LINE)



Why are Alarm Fires Contained to the Room of Origin More Often?

To understand more about the differences observed here, some additional analyses were undertaken to examine why alarm fires were contained to the room of origin more often regardless of response time. Building on prior research it is reasonable to assume this outcome occurs because building occupants intervene to attack the fire before the fire department arrives. Proxies that would be consistent with this would show (a) elevated levels of injuries when smoke alarms activated with injuries sustained while fighting fires, and (b) less fire department intervention required to control fires when alarms were present.

The result of an independent sample *t*-test supported this first hypothesis, with a significant difference[3] in injuries sustained as a function of alarms sounding (estimated rate of 150 injuries per 1,000 fires) relative to when no alarm was present (estimated rate of 70 injuries per 1,000 fires).

To test the second hypothesis, a binary variable was created relating to fire department intervention in controlling the fire. This binary variable was examined for frequency in relation to alarm activation using a Chi-square test (Table 1). Analysis revealed significant differences consistent with the expectation that alarm activation reduced fire department involvement in controlling fires.[4] Overall, the fire department was required to control fires 74.5% of the time. When a smoke alarm was activated ($n = 479$ fires) the fire department controlled 61.4% of these fires. In comparison, when no smoke alarm was installed ($n = 389$ fires), the fire department controlled 90.8% of the fires.

TABLE 2: CROSS-TABULATION OF FIRE DEPARTMENT INVOLVEMENT IN CONTAINING THE FIRE AND SMOKE ALARM ACTIVATION (TOTAL 868 FIRES)

	Fire department involvement	
Smoke alarm	**Not involved (n = 221)**	**Extinguished fire (n = 647)**
Alarm activated (n = 479)	185	294
No alarm (n = 389)	36	353

[3] $t(866) = 2.55, p < .02$

[4] X^2 (df = 1) = 97.55, $p < .0001$

Conclusions

The following main points are worth restating with respect to the potential to enhance residential building fire safety in a targeted manner:

Although it was not clear based on the arrival time of the first unit on-scene, the risk of fires spreading beyond the room of origin increased by 17% for each one minute increase in the time required for the fire service to assemble a total effective attack force.

Fires that occur during the day are also at least 60% less likely to extend beyond the room of origin and appear less likely to sustain large amounts of building loss.

The influence of response time is countered by the presence of working smoke alarms, which reduce the likelihood of fires extending beyond the room of origin (by 71%) regardless of response time. The analysis provides additional support to the belief that the influence of smoke alarms is to increase the likelihood of building residents controlling the fire before the fire department arrives [2, 3]. This emphasises the importance of having a working smoke alarm in all residential properties. Furthermore, this supports targeted smoke alarm education and installation efforts [e.g., 4, 5] that use risk to identify areas within cities that are most likely to have non-functioning or missing alarms.

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