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Spatial Variability Of Terrorist Vehicle Bomb Safety Risks

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Improvised Explosive Devices (IEDs) have been a weapon of choice for terrorist attacks in Europe, North America and other western countries. Most IED attacks have involved (i) a Person-Borne Improvised Explosive Device or (ii) a Vehicle Borne IED (VBIED). Recent IED attacks include the attack on nightclubs in Bali (2002), Australian embassy in Jakarta (2004), Oslo government buildings (2011), Brussels airport and train station (2016), and Manchester Arena (2017). Added to this is the failed VBIED (car bomb) attack on Times Square and countless VBIED attacks on civilians and military personnel in Iraq, Afghanistan, Pakistan and elsewhere. People are highly vulnerable to VBIED attacks. VBIEDs comprise a large quantity of explosives, and produce primary fragments such as wheels, engine block, parts of door panels and other shrapnel that pose a serious safety hazard to people exposed in a street or other place of public assembly.

A VBIED explosive field trial was conducted for three identical medium-sized cars. A unique aspect of the field trial was the repeatability of tests. Explosive charge shape and location were identical for each vehicle, minimising test set-up variability. To record the directionality of blast pressures, eight incident pressure gauges will be set-up to record pressure-time histories for 45° azimuth intervals. Witness panels will record fragment velocity and density which can be used to help validate future stochastic models. Figure 1 shows the VBIED detonation, and fragments hitting a witness panel at velocities up to 800 m/s. This paper describes the spatial variability (directionality) of incident pressure and impulse, and compares these to results from the ConWep model often used for predicting blast loads from IEDs. Knowledge of the spatial distribution of blast loads is important for protective design, particularly for barriers and structures in the near-field and close to the source of the explosion, and also for casualty prediction. The paper also estimates the safety hazard risks from fragmentation.

Fig. 1. Detonation of a VBIED (image courtesy of RUREX Pty. Ltd.), and fragments impacting a witness panel.

An IED may cause direct damage to the human body primarily to the ears and lungs and the body (i.e. impacting hard surfaces), due to the impacts of the pressure front of the blast wave itself. The probability of fatality from airblast is estimated as a function of peak pressure (*P*) and total impulse (*I*). If the threat scenario is a terrorist VBIED comprised of 500 kg of ANFO, then Figure 2 shows the airblast fatality risks for a person located 12 m from the vehicle. A conventional risk assessment (ConWep) would predict a near 100% fatality risk in every direction around the VBIED. However, this is conservative. If the airblast directional factors obtained from the VBIED explosive field trial are used to better characterise P and I, then Figure 2 shows that fatality risks reduce significantly by at least 61%, and by as much as 99.9% for the rear of the vehicle (180°).

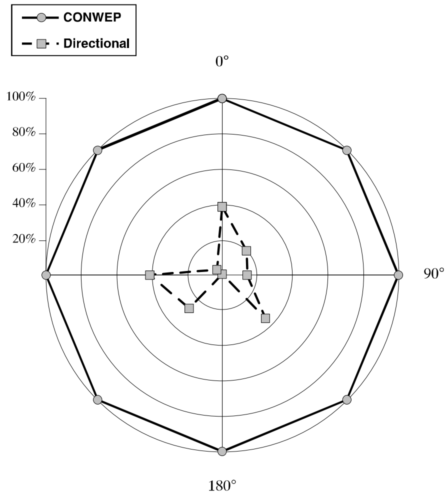

Fig. 2. Airblast fatality risks for 500 kg VBIED at 12 m.

Trajectory angle and fragment density may be treated as a bivariate distribution for vertical (θ_x) and horizontal (azimuth) (θ_y) trajectory angles; see e.g. (Sielicki et al. 2021). As the data for the VBIED trial is still being analysed, assume that the trajectory angle θ_x is uniformly distributed between 0^{o} and 45^{o}. Moreover, the number of fragments in each direction at a distance exceeds 25 m (see Table 1) is assumed uniformly distributed over the 5 m width. For an average standing person the exposed critical body area A_P is 0.50 m^2. At a short distance of 25 m fragments will travel in approximately a straight line. It follows that the average number of fragments (N_R) impacting a standing person 25 m from the VBIED can be calculated, as is shown in Table 1. As expected, the higher the number of fragments generated for each direction the higher is N_R. The probability of being hit (P_{hit}) by at least one fragment is 43% higher for a person standing behind the VBIED than it is for someone standing directly in front.

If the fragments with the highest recorded velocity (800 m/s) are a mere 2 g in mass then kinetic energy (KE) is 640 J. A larger fragment of 20 g but slower one at 200 m/s still retains a high KE of 400 J, and in both circumstances would be fatal if struck. When probabilistic knowledge on fragment mass and velocity are inferred, then fatality risks can be estimated; see e.g. (Qin and Stewart 2021).

Table 1. Fragment count in a 5 m strip and probability of a person being hit at 25 m from VBIED.

	0°	45°	90°	135°	180°	225°	270°	315°
Fragments	195	123	153	189	454	291	548	391
N_R	0.99	0.63	0.78	0.96	2.31	1.48	2.79	1.99
P_{hit}	63.0%	46.6%	54.1%	61.8%	90.1%	77.3%	93.9%	86.3%

References

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