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**Comparing driving behaviour between 4WD and sedan vehicles:
Preliminary results**

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Abstract

Vehicle rollover is the most common characteristic of 4WD (4-Wheel-Drive) crashes. Among all fatal crashes in Australia, a significantly higher proportion of 4WD vehicles were involved in rollovers compared with passenger cars (35 per cent and 13 per cent respectively) (ATSB, 2001). 4WDs are particularly over-represented in rollover crashes in both high- and low-speed zones (ATSB, 1999). While 4WD vehicles have (on average) different physical characteristics to passenger cars, it is also asserted that driver behaviour plays a role in the differential crash patterns of these vehicles. To our knowledge, no systematic empirical research has been undertaken to examine behavioural factors that contribute to 4WD crashes. This paper presents the preliminary results of a larger pilot project on the investigation of the behaviour of 4WD vehicle drivers in terms of driver attitudes, self-reported behaviour, and actual driving performance on the road as measured with state-of-the-art Intelligent Transport Systems (ITS).

The project involved experienced drivers (N=16) who drove a 4WD and a sedan on a selected route (24 km) for 30 minutes in Brisbane suburban areas. Both vehicles were fitted with technology which passively measured driver performance characteristics such as following distance, direction of gaze, acceleration and deceleration, lateral forces and vehicle speed. This paper focuses on the comparison of vehicle dynamics between 4WD and sedan driving.

Introduction

Four-wheel-drive (4WD) vehicles offer a romantic vision of outdoor adventures, toughness and safety. The appeal of 4WDs has extended to urban dwellers. Many 4WDs never go “off-road” but their owners enjoy the high seating position and feeling of safety that these vehicles provide for urban driving. The market for 4WDs is growing at double the rate of car sales in general. The number of light truck (vans, utilities, 4WD) has grown over 106% from 1991 to 2001. In 2004, Australians purchased 85,545 new 4WDs which was an increase of 13.8% on purchases in 2002.

The image of 4WDs being safer appears to be unfounded. Previous research indicates that 4WDs are prone to roll over, killing and injuring occupants at an alarming rate, and they are dangerous to other road users, inflicting catastrophic damage to cars that they hit and posing a lethal threat to pedestrians (Bradsher, 2002). 4WDs are also alleged to pose a threat for the environment and to intimidate other road users such as cyclists and pedestrians (Baker, 2003).

In Australia, the incidence of fatal 4WD crashes increased by 85% between 1990 and 1998. This increase is largely attributed to the growing number of kilometres travelled by 4WDs (ATSB, 2001). Most 4WD kilometres travelled are on bitumen as opposed to off-road and most of the crashes occur on normal roads. These vehicles were

associated with a 2.5-times increased risk of fatality (Holland et al., 2000). According to the aggressivity metric, large cars (large kerb mass, wheelbase and bumper height) cause less death to their occupants than small cars in crashes involving more than one car. However, in a head on collision between a 4WD and a conventional passenger car, the passenger car occupants were 12.8 times more likely to be killed (ATSB,1999). 4WD vehicles also appear to be overrepresented in injuries. In 2000, 4WDs were involved in 42% of all injuries, although they accounted for just 30.4% of registered vehicles in NSW. Driveway incidents involving toddlers and 4WD's are also an increasing concern due to the poor visibility to the rear from these types of vehicles.

As discussed in the sections below, this increased involvement in crashes is variously attributed to the characteristics of the 4WD vehicle (especially in rollover crashes), the characteristics of the driver, and an interaction between the vehicle and driver.

Vehicle factors contributing to 4WD crashes:

The type of vehicle plays a significant role into the incidence of rollovers. 4WDs typically have a higher ground clearance than sedans and have higher centres of gravity, and thus are more likely to roll over if involved in a single vehicle crash. In all fatal crashes, a significantly higher proportion of 4WD vehicles rolled over compared with passenger cars (35 per cent and 13 per cent respectively) (ATSB, 2002). This takes place in both high- and low-speed zones (ATSB, 1999), in many cases subsequent to the vehicle running off the road

The U.S. Department of Transportation's National Highway Traffic Safety Administration (NHTSA) have demonstrated a link between rollover risk and an at-rest laboratory measurement known as the Static Stability Factor (SSF) (NHTSA, 2004). A vehicle's SSF is $T/2H$, where T is the "track width" of the vehicle and H is the "height of the centre of gravity" of the vehicle. The track width is the distance between the centres of the right and left tyres along the axle. A higher SSF value equates to a more stable, less top-heavy vehicle. Sedans have a SSF between 1.30 and 1.50 whilst 4WDs (known as SUVs in the US) have SSF between 1 and 1.30 on average. Figure 1 (taken from SafeCar, 2006) shows the results of analysis of vehicle crash testing, which also indicates that 4WDs (SUVs) are more likely to roll over compared to cars (sedan).

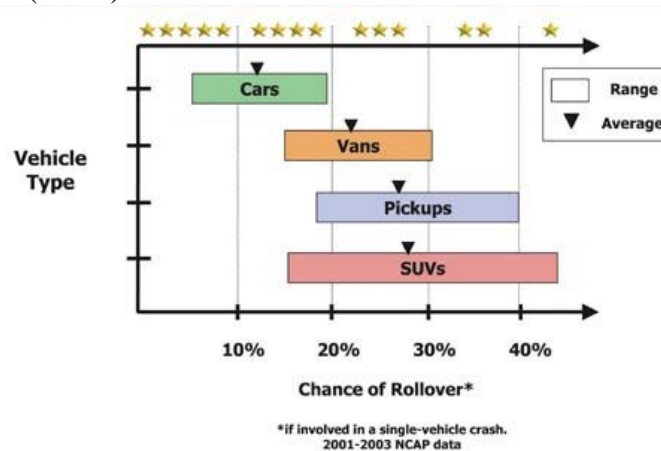


Figure 1: NHTSA rollover ratings (SafeCar, 2006)

Driver factors and 4WD crashes:

There is some evidence that drivers of 4WDs differ from other drivers in several respects. A recent study has shown that drivers of 4WDs are more likely than drivers of other cars to not comply with the law by using handheld mobile phone and not to wear seatbelts (Walker et al. ,06). A study on demographic and attitudinal characteristics of 4WD owners also showed that they are less concerned than most about the impact of their decisions on other members of the community (Hamilton and Barbato, 2005).

However, it is unclear whether these differences are attributable to the fact that 4WD drivers are a different group, or to the interaction between the characteristics of the vehicle and the driver, such that different behaviour is elicited in a 4WD. There is some indirect evidence that this can occur. Horswill and McKenna (1999) showed that in a simulated environment, a driver will choose a faster speed when the level of internal car noise is reduced. They argued that this effect was likely to be due to driver's auditory estimates of speed. Wasilewsko and Evans (1985) argued that drivers of heavy vehicles drive faster and follow the vehicle in front more closely. Sports cars have also been linked to greater risk taking (Horswill, Coster, 2002). Safety features of vehicles have also been found to have influences on behaviour. For example, drivers of vehicles equipped with ABS drive significantly closer to the car in front (Sagberg et al. 1997).

The research reported here is a part of a larger program which examines the impact of vehicle characteristics on driving style, controlling for driver choice of vehicle type by having the each participant drive both a sedan and a 4WD. The aim is to determine the extent to which the characteristics of the vehicle itself contribute to driving behaviour, and hence to develop recommendations about issues such as the need for special training for people driving 4WDs.

Methods

Participants:

The results reported here are the preliminary results of a pilot study. At the time of preparation, only 16 participants (4 female and 10 male) had completed the study. All participants were licensed and experienced drivers who regularly drove both 4WD vehicles and sedans. They were recruited using advertisements in a local newspaper. The average age of drivers was 43 years (range: 25-71 years old). The average length of driving experience was 21 years.

Procedure:

Upon arrival, participants were briefed about the experiment which consisted of approximately 2x30 minute sessions (1 session each vehicle) of driving in real traffic conditions, each preceded by 15 minutes required to tune the eye tracker (see Apparatus, below). Participants also spent 20 minutes completing a questionnaire. All participants were asked to drive a 4WD and a sedan provided by our research partner (QFleet, which manages the Queensland Government vehicle fleet). The two sessions of driving were separated by a 20 minute break and were conducted in similar traffic conditions using a counterbalanced design, i.e. half drove the sedan first and half drove the 4WD first. Each participant was accompanied by a research assistant who

was assigned to both their trips. The research assistant operated all in-vehicle technology and gave clear but minimal instructions on route directions from the back seat.

A route featuring different types of road conditions was chosen (the pink route in Figure 2), including roundabouts, traffic lights, stop signs, highway, city and suburban streets, and different speed zones. The choice of different speed zones was made because of the possibility that a difference in speed behaviour might occur only on high speed roads (for example). The inclusion of traffic lights and stop signs allowed observation of different stop/start patterns for each vehicle type. The experiments were conducted in daylight and outside peak hour traffic conditions. The route was partitioned into 3 sections as labelled in Figure 2:

1. A-B section: highway, speed zones between 80 and 110 kph;
2. B-C section: mixture of highway, suburban roads including an arterial link to the highway, zebra crossings, traffic lights and stop signs, speed zones ranging between 30 and 110 kph; and
3. C-D-A section: suburban dual carriageway, speed zone 60 kph.

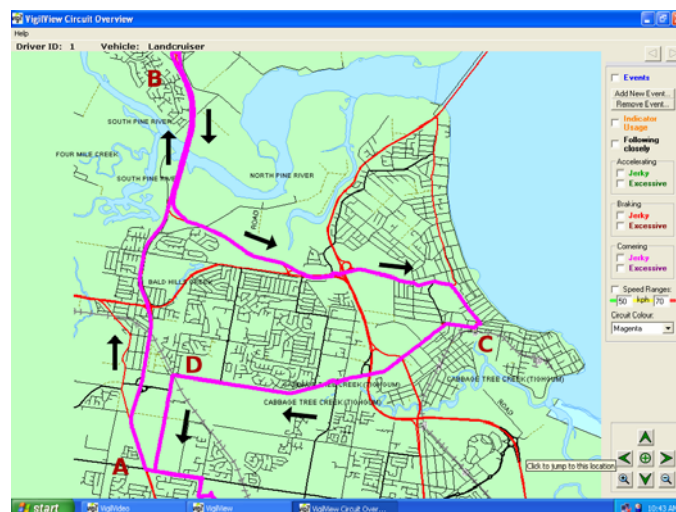


Figure 2: Test route (Vigil)

At the completion of the experiment, each driver was asked to complete a questionnaire comprised of standard items from existing driver behaviour questionnaires used regularly by CARRS-Q, as well as additional items focusing on issues relating to the differences between driving 4WDs and sedan cars. The information solicited covered self-reported driver behaviour, behaviour differences when driving different vehicle types, vehicle preference, and person-related variables such as attitudes, sensation-seeking and aggression. This aspect of the research is not discussed in this paper.

Apparatus:

The drivers' actions, environmental conditions and vehicle dynamics were captured with ITS technology, using two in-vehicle devices:

1. A Vigil Vanguard multimedia datalogger, incorporating four video cameras. The cameras were positioned to observe the driver's face and body, and the

road scene ahead and behind the vehicle (see Figure 3). Events were recorded manually by the research assistant if something unusual happened.

2. A faceLab eye tracker (from Seeing Machines) that measures and records direction of eye gaze by monitoring head and pupil movements.

Both devices are non-intrusive, enabling passive measurement of following distance, direction of gaze, acceleration and deceleration, lateral/longitudinal forces, the internal and external driving environment and vehicle speed. Very large amounts of data are collected, with each participant generating about 250Mb of data.

Two vehicles representing the most popular sedan and 4WD in the Australian fleet were selected. The vehicles have similar power and torque and equivalent interior comfort:

- 4WD Toyota Landcruiser 100 GXL V8 Petrol, Automatic 4.7 litres, ABS, weight 3,260kg, power 170kW @4800rpm, torque 410Nm @ 3400 rpm, ground clearance 210mm, SSF 0.97 (based on 1997 model L80); and
- Sedan Holden Commodore Acclaim V6 Petrol, Automatic , 3.6 litres, ABS, weight 1,570 kg, power 172kw @6000rpm, torque 320Nm @ 2800rpm, ground clearance 114mm, SSF 1.5.



Figure 3: Vigil Vanguard rear, front and driver's video footage

Results:

This section presents analysis of the data from the Vigil Vanguard device. The data analysis on eye movements is not presented due to space limitations. Four drivers were excluded from the analysis as some of the devices were not properly calibrated therefore the collected data featured too many errors.

Speed on highway.

Figure 4 shows the speed of one participant's vehicle along the selected route. Red represents speed in the 4WD, and blue the speed in the sedan. It can be seen that there

is an overall similarity in the pattern of speeds, however speeds in the two vehicles diverge at several points.

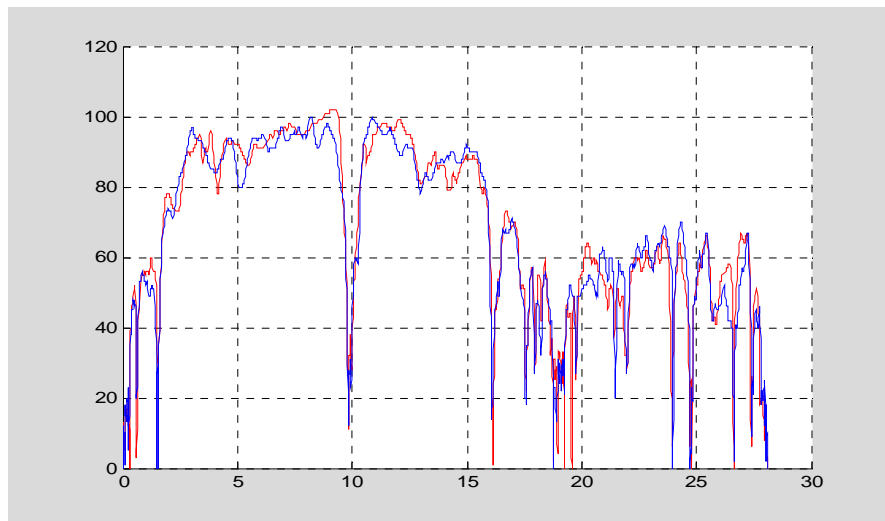


Figure 4: 4WD(red) and sedan (blue) speed on test route for one participant

At this stage only a limited number of analyses have been completed. Figure 5 shows the difference between the average speed over the whole route for the 4WD vs the sedan, for each participant. It can be seen that nine drove the 4WD faster than the sedan. Their average speed difference was 2.82km/h (standard deviation 1.40km/h). The three other three participants who drove slower in the 4WD by an average difference of -2km/h (standard deviation 1.65km/h). Negative value means that the participant drove faster on the sedan.

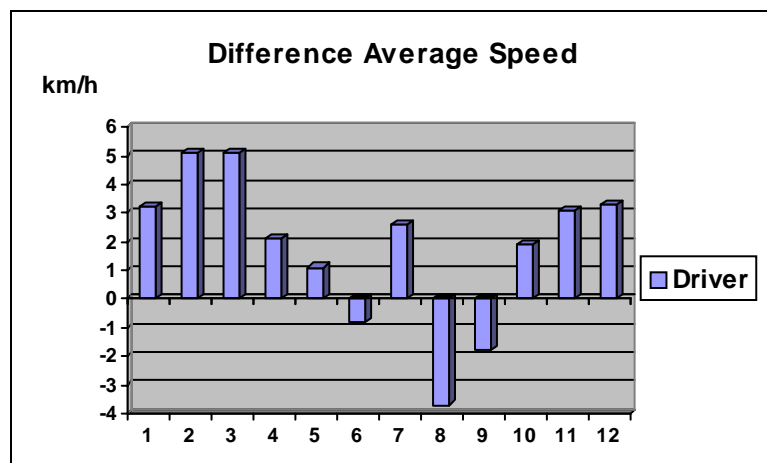


Figure 5: Difference in Average speed between 4WD and sedan on highway

It is intended to analyse speed data in more detail, according to road section, when more data have been collected. At this stage a more focused analysis has been done only for the highway section (from A to B), examining the proportion of the route on which the 4WD was driven faster (cases where the speeds were equal were not considered, and in fact accounted for only 1% of the distance in any case). Figure 6

shows that 9 drivers out of 12 drove the 4WD faster on at least half the highway section.

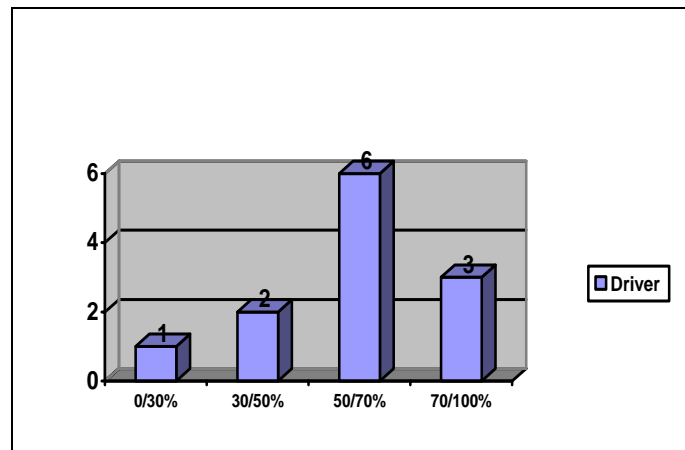


Figure 6: Percentage of distance on the highway section where 4WDs' speeds were higher

Table 1 gives more details on speed difference shown in Figure 6. It shows the average speed difference and standard deviation for each category. Negative value means that the participant drove faster on the sedan.

% Highway Where 4WD Faster	Average Speed Difference (kph)	Standard Deviation
0/30%	-4.03	0
30/50%	-0.99	0.99
50/70%	2.47	1.32
70/100%	3.50	1.27

Table 1 Average speed difference speed on highway by proportion of highway on which the 4WD was faster

Of particular interest was the beginning of the highway section, where all drivers commenced from a stationary position. The above analysis was repeated for the first 300m of the highway, giving the results in Figure 7.

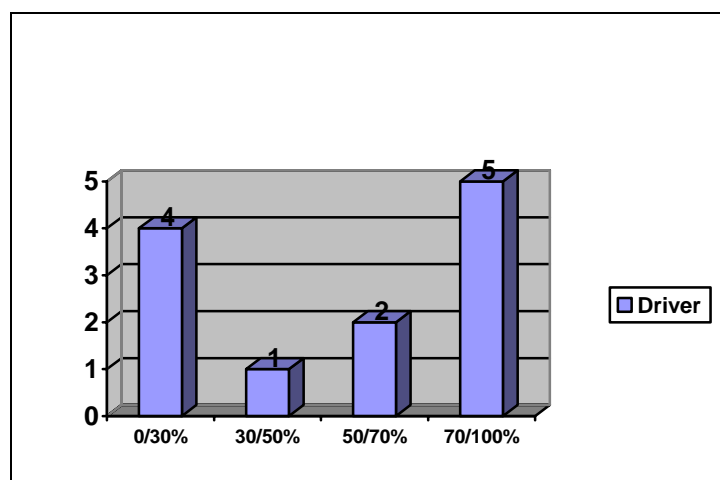


Figure 7: Percentage of distance on first 300m of highway section where 4WDs' speed are higher

This shows a more even distribution, with seven drivers being faster in the 4WD for at least half the length, and five drivers being faster in the 4WD for less than half the length. This suggests that more detailed analyses by road section are likely to show interaction effects rather than an overall consistency in behaviour, bearing in mind that the sample size is at present quite small.

Driver behaviour at stop sign on 90 degree turn

Data were also analysed for longitudinal and lateral deceleration and acceleration behaviour at a point in the route requiring a 90 degree turn at a stop sign. Figure 7 presents an example from one driver's data. The Head axis represents the vehicle's directions obtained from an electronic compass. The bottom of the two graphs represents the point D in Figure 2 where each car made the 90 degree turn.

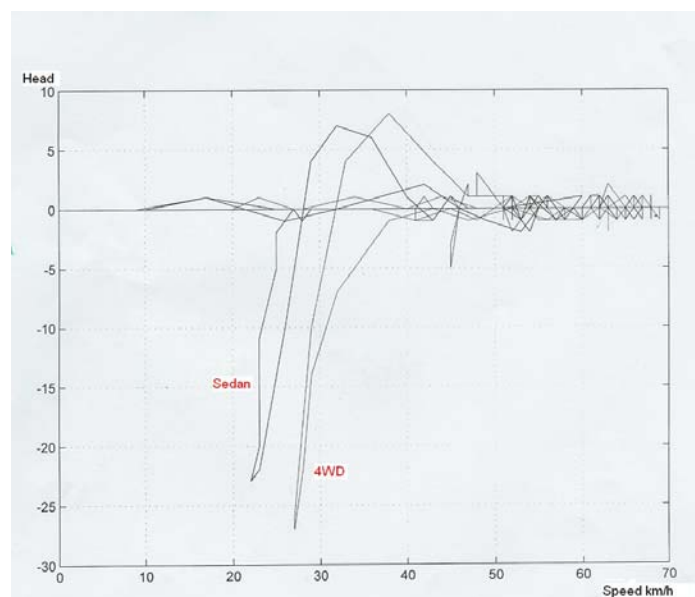


Figure 7: Acceleration on 90 degree curve

The preliminary results showed that eight drivers out of 12 drove the 4WD faster over this part of the route compared to the sedan (roughly 3 km/h more). Before stopping, all drivers began to decelerate the 4WD later than the sedan. From a stopping position, all drivers accelerate the 4WD faster than the sedan.

Discussion:

These preliminary findings show a relationship between vehicle type and driver behaviour. The average speed of the 4WDs was slightly higher over all the trip for the majority of the drivers. On the highway section, more drivers travelled faster in the 4WD on average, and most drivers travelled faster in the 4WD on more than half the section. Given the greater size and weight of the 4WD, the additional speed of the vehicle would multiply its road safety risk.

Looking at the first 300m of the highway section (where drivers started from a stationary position) showed a more even distribution. This implies that, in addition to the interaction between the driver and the type of vehicle, the characteristics of the road section may also interact to produce varying speed by driver and vehicle type.

Around the 90 degree, turn with the stop sign, most drivers again drove the 4WD faster. They decelerated later in the 4WD than in the sedan, in spite of the greater initial speed, which is of safety concern as the braking distance required to stop in a 4WD is substantially longer than for a sedan due to vehicle's weight. There are also implications for tyre wear and potentially for brake wear, as other explanations for the results include heavier pressure on the brake pedal or greater reliance on the use of the brakes to slow the vehicle. From a stopping position, all drivers accelerated faster in the 4WD than in the sedan. As for their deceleration behaviour, this has both safety implications linked to speed, and implications for fuel consumption and tyre wear.

A possible explanation for their greater deceleration and acceleration at the 90 degree turn relates to effect of driver height on speed perception. Rudin-Brown (2004) manipulated vehicle height in a simulator task to examine whether sitting higher (as in an SUV) led to a different choice of speed, in the absence of a speedometer. She found that drivers drove faster in higher vehicles. If the participants in the study reported here were driving at a speed they felt comfortable with, they would exhibit both the greater deceleration and acceleration observed, since from their point of view they would be stopping from, and returning to, the same speed in both the 4WD and sedan, and over the same distance. It should be noted, however, that they tended to decelerate later in the 4WD, not at the same time as the sedan, so this issue needs more investigation. For example, it is possible that the greater view afforded by the higher 4WD seating position means that the drivers feel less need to be wary of unexpected vehicles or pedestrians when approaching an intersection.

There are a number of limitations in the methodology used for this study mainly due to practical limitations. As mentioned earlier, this study is a pilot study and we plan to address its limitations in the next stages. One limitation was the sample size. Another limitation was the vehicle type; we limit the experiment to one vehicle of each type. The geographic region in which the study was conducted is another limitation. Efforts were made to feature all type of driving situations but we did not include rural driving which are subject to significant number of 4WD crashes.

Conclusion

The preliminary results presented in this paper focused on comparison of the driving behaviour in a 4WD and a sedan each driven by 12 drivers. The results showed a tendency for drivers to travel faster in the 4WD, and to decelerate and accelerate more rapidly at a 90 degree turn. These results have safety implications, as the size of 4WDs already makes them more aggressive in a crash, while greater speed increases their risk of a crash, even for modest increases in average speeds (Nilsson, 1982). As yet these results are indicative only, due to the small sample size and the limited analyses conducted on the available data. However a larger sample and more thorough analysis will improve knowledge relating to driver performance and the attitude/behaviour of 4WD drivers. It is anticipated that this will provide further insight and guidance to inform the development and implementation of strategies designed to reduce the frequency and severity of 4WD crashes.

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