On the Effectiveness of Anti-Lock Braking Systems

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One of the most prevalent safety features in today’s automobiles is the anti-lock braking system (ABS). A vehicle that has a conventional braking system without ABS may lock one or more wheels under heavy braking. A locked wheel refers to one that has stopped rolling due to insufficient friction from the road to sustain its rolling motion as the wheel decelerates. Slippery surfaces like wet or icy roads exacerbate this tendency to lock up. Locked wheels are highly unsafe because a locked wheel increases the minimum braking distance required to bring the vehicle to a halt under most circumstances. In addition, a locked wheel makes the vehicle very difficult or even impossible to steer depending on which wheels have locked up.

The technology to prevent wheels from locking up is now commonly seen in automobiles. An ABS equipped vehicle has sensors on all four wheels that monitor the rate of rotation of the wheel. A computer receives data from the sensors and if it detects readings that suggest that a wheel has locked, it reduces the braking pressure on that wheel. With the reduced braking pressure, the wheel in question starts to roll again at which point, the computer increases braking pressure till the wheel starts to lock up again. At this stage, the computer reduces the braking pressure again. This cyclic process of locking and unlocking happens at a frequency so high that the wheel appears to be rolling without locking up throughout the braking period [1]. Tests have been conducted by independent bodies to confirm the theory that ABS equipped vehicles do achieve shorter stopping distances and retain steering control compared to identical vehicles with locked wheels [2]. Despite the seemingly infallible logic and evidence in favour of ABS, several statistical studies have cast doubt on the effectiveness of ABS in the real world. Many of these studies conclude from accident statistics that the probability of a vehicle meeting with an accident is not reduced by the presence of ABS. Furthermore, some studies show that certain types of accidents such as rollover crashes are more likely to occur if the vehicle is equipped with ABS [3,4].

This essay will thus examine the reasons behind the discrepancy between the statistics and the theory and will proceed to emphasize on the effectiveness of ABS as a safety feature. Due to the large scale of the problem, this study will only look at passenger cars in developed countries. This excludes transport vehicles such as vans, trucks, buses, etc. and also only considers accident statistics from developed countries. With ABS being equipped on a majority of cars today and required by law in some countries, it is important to have a conclusive answer on whether ABS works in the real world as it is intended to. This essay will show that the statistical studies that conclude that ABS does not boost automotive safety do not take into account several important factors that cause accidents. The interpretation of data in these statistical studies is flawed and the conclusion is therefore, incorrect. It will be concluded that ABS optimizes braking under almost all circumstances and helps save countless lives by helping drivers avoid what would otherwise be inevitable accidents.

The Physics of ABS

The force of friction acting between two surfaces can vary between zero and a maximum magnitude. A car’s deceleration is limited by this maximum magnitude of friction that can act on its wheels. A rolling wheel’s contact patch remains at rest relative to the road while the contact patch of a locked wheel is in relative motion with the road. The type of friction which acts on the rolling wheel is called static friction and the type of friction which acts on the locked wheel is called kinetic friction. It is well established that the maximum magnitude of static friction is greater than that of kinetic friction for a given pair of surfaces [5]. This allows the rolling wheel to have a greater deceleration compared to the locked wheel. Thus, ABS equipped cars will stop in shorter distances compared to identical vehicles without the system.
Steering control is the other major benefit of ABS because the steering system on a car only works if the wheels are rolling. If a car locks its wheels, then the direction in which the wheels are pointing is irrelevant; the inertia of the car will cause it to keep moving in the same direction as it was moving in before the wheels locked up. However, if the wheels are rolling, then the direction in which they are pointing determines the direction in which the car will move. If some wheels are locked while others roll, there may be partial steering control. In any case, ABS allows the driver to retain full steering control.

Thus, the technology behind ABS is well grounded in physics and, in theory, should result in lower minimum braking distances and prevent loss of steering control. These results were confirmed when vehicles were subjected to braking tests under controlled conditions on test tracks [2]. Having established how ABS works, the next section shall examine the statistical findings reported in many studies and their conclusions on ABS.

Statistical Findings on the Effectiveness of ABS

The overarching conclusion from most of the statistical studies was that ABS did not have a net benefit in terms of occupant safety [6]. In certain scenarios, ABS was proven to be beneficial while in other scenarios, ABS equipped cars were less safe than non-ABS cars according to the statistics. It was found that ABS equipped cars generally performed better on wet and slippery surfaces. Also, ABS equipped cars had a lower probability of being involved in multivehicle crashes as well as pedestrian and bicycle accidents. However, these gains were cancelled out by the increased risk of an ABS equipped vehicle being involved in certain other types of crashes such as rear end crashes and rollover crashes [3]. The net gain in terms of safety, after accounting for all types of accidents, was found to be either zero or statistically insignificant in these studies.

Methodology:
The methodology generally used in these studies was based on police reported crashes. Using the Vehicle Identification Number (VIN) of the crashed vehicle and cross referencing it with the manufacturer, it was determined whether or not the vehicle had ABS. Many models had ABS as an optional feature and the non-ABS versions of the models were used as a reference to understand how ABS changed crash statistics. Some studies used data from consecutive years during which ABS was introduced for the first time on a specific vehicle model [4]. It is worth noting that none of the studies evaluated had any method to find the number of crashes that were averted for due to ABS installation. Also, it is extremely difficult to recreate such studies now since almost all new cars being produced in first world countries come equipped with ABS. The next sections will elaborate on those types of accidents where ABS equipped cars fared poorly.

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Rear End Impacts:
One of the significant findings was that ABS increased the odds of the vehicle suffering a rear end impact under wet conditions. It was shown that the probability of crashing into the rear of another vehicle or running into a stopped vehicle was reduced by 32% for ABS equipped cars if the conditions were wet. However, the probability of an ABS equipped car being rear ended increased by 30% on wet roads [7]. These findings are consistent with what is expected. A vehicle with better brakes is naturally less likely to crash into vehicles ahead of it. It is also logical to expect a vehicle with better braking ability to face a higher chance of being rear ended, particularly if the following car has less effective brakes.

However, it would be incorrect to conclude from this data that the presence of ABS increases the likelihood of being rear ended. The data shows us that ABS equipped cars were less likely to run into the rear of the car ahead. Yet, they were more likely to be struck from behind. Both these statements can be true only if the ABS equipped cars were rear ended by non-ABS cars in a majority of cases. This is in agreement with the fact that these studies were performed at a time when most cars on the road did not have ABS.

Thus, it is logical to conclude that the cause of the rear end accident is more likely to be due to the absence of ABS in the following car rather than the presence of ABS in the leading car. When an ABS equipped vehicle decelerates hard, the car behind cannot slow down as quickly because it is not equipped with ABS and therefore runs into the back of the lead car. As ABS becomes increasingly popular, the probability that the following car is also equipped with ABS increases and this would make ABS equipped cars less likely to be rear ended. Thus, the statistics do not highlight problems with ABS; rather they highlight the pressing need for ABS to become a universal feature in automobiles.

Human Factors:
Another conclusion from studying crash statistics was that ABS equipped cars tended to be involved in more single vehicle crashes. A Swedish study found that ABS equipped vehicles were more likely to be involved in crashes where the vehicle has to cross into oncoming traffic to perform an overtaking manoeuvre [4]. One of the studies also found that ABS equipped vehicles were 10% more likely to be involved in a fatal single vehicle crash [8]. Finally, while ABS equipped vehicles were less likely to crash into the rear of another vehicle on wet roads, the results were reversed on dry roads. In fact, ABS equipped vehicles had a 23% higher chance of running into the rear end of the vehicle ahead on dry surfaces [7].

The results are surprising because there is no theoretical reason to believe that the presence of ABS would, in any way, increase the risk of single vehicle crashes. ABS malfunction is very rare and hence, not a factor in this statistic. In fact, the only convincing explanation is that ABS equipped vehicles are driven faster and more aggressively than their predecessors.
non-ABS counterparts. This difference in driving patterns can be explained by a phenomenon called risk compensation [4]. Risk compensation refers to the adjustment of human behaviour with the perceived change in risk levels. In the context of vehicles, a safer car makes a driver drive more dangerously because of the lower perceived risk of death or injury due to an accident. This phenomenon is a factor that has to be taken into account when evaluating ABS equipped vehicles against non-ABS vehicles. In a study on taxi drivers in Munich, it was found that the drivers of taxis that had ABS drove at higher average speeds and also were more aggressive on the road and, in general, open to taking more risks. The number of accidents that the taxis suffered was not lowered due to the presence of ABS. In other words, the benefits of ABS were negated by the psychological changes in the drivers’ minds [9].

As was the case with rear end crashes, this is a problem that arises due to the fact that ABS is not present in every car yet. As ABS becomes more widespread, the presence of ABS will no longer be a factor that registers with the driver’s psychology. That would effectively eliminate the phenomenon of risk compensation or at least reduce it significantly.

Rollover and Run off Road Crashes:
A significantly more alarming statistical finding was that the risk of being involved in a rollover crash and run off road crash increased significantly on ABS equipped vehicles. A report by the National Highway Transport Safety Authority in the United States found that non fatal run off road crashes increased by 19% and fatal run off road crashes were up 28% for ABS equipped vehicles over their non ABS counterparts. The study also found that fatal sideways impacts with fixed objects and rollovers were increased by 40% for ABS equipped cars [3]. These are typically crashes that suggest a total loss of directional control. While it is difficult to make conclusions on exactly why there is such a severe loss of directional control in ABS equipped vehicles, it is conceivable that the drivers of ABS equipped vehicles did not steer the vehicle correctly prior to the impact. In a non-ABS vehicle, attempting to steer the vehicle is likely to be futile when the wheels are locked. However, an ABS equipped car retains complete steering control. An abrupt steering input may unsettle the vehicle and cause rollovers/ run off road crashes. This is a serious flaw with the Anti-Lock Braking System as drivers cannot be expected to steer calmly in the face of an imminent accident.

In the previous sets of data, an incorrect interpretation of data led to the incorrect conclusion that ABS was flawed. However, the statistics on rollover crashes and run off road crashes indeed highlight a serious problem with ABS. The retention of steering control appears to be a double edged sword that works well at low speeds or in the hands of calm drivers but poses a serious threat to the occupants of the vehicle at higher speeds, particularly if the driver reacts with panic. The solution to abrupt steering movements is to introduce another system that helps the driver maintain directional control at all times. This system is known as the Electronic Stability Program (ESP). ESP works by monitoring the car’s steering position (which represents the car’s intended trajectory) and the actual trajectory of the car. If it detects a mismatch, it corrects it automatically. For instance, if a driver goes around a right hand turn at excessive speed, a normal car will understeer wide and run off the road. If the car is equipped with ESP, the system will detect the understeer and apply the right rear brake. This would cause the car to pivot about the right rear wheel which would bring it back onto the intended trajectory. Similarly, if it detects that the car is about to rollover, ESP will intervene and use each of the four brakes independently to correct the rollover tendency. ESP and ABS are independent systems but they can be installed on the same vehicle and can work together [11]. The presence of ESP reduces the chances of abrupt driver steering inputs from causing a run off road incident or a rollover crash.

Thus, even though ABS ensures that the car can be steered at all times, it does not take into account the abrupt steering inputs of drivers. It is therefore reasonable to conclude that ABS is insufficient in an emergency to compensate for driver error. The presence of ESP is likely to make loss of directional control under emergency braking less probable.

Conclusion
The overall benefit of ABS was claimed to be zero or insignificant by the studies evaluated here. As ABS is increasingly common and even a mandatory feature on all new cars in some countries, the human factors and rear end impact issues will be significantly reduced, if not eliminated altogether. Accounting for that, ABS equipped vehicles would now display a net statistical safety benefit over non-ABS equipped vehicles. It has also been shown that the presence of ESP would further increase the safety benefits of ABS. After accounting for these factors, we can expect to see statistical data that will mirror the theoretically expected safety gains due to ABS. Thus, it can now be concluded that ABS is an extremely effective automotive safety feature that saves many lives and makes cars significantly safer, both now and in the future.

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References

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