Active and Passive Safety Passenger Car Technologies: Potentials to Save Lives in India

Pradeep Puthan, Prateek Thalya, Nils Lubbe

I. INTRODUCTION

Mobility plays an important role in socio-economic growth of a country. The number of road vehicles has grown at a mean annual rate of 10.6% in India from 1951 to 2015 [1]. Although road transportation is a necessity, two of the most highlighted adverse effects are pollution and injuries [2]. An estimated 45–60 million passenger cars on Indian roads by 2025, compared to 28 million in 2015, call for attention [3-4]. The Ministry of Transport reported 137,527 road traffic fatalities for 2013, while the World Health Organization (WHO) estimated 207,551 fatalities [5-6].

India has committed to the Brasilia Declaration and pledged to reduce the number of road traffic fatalities and injuries by 50% by 2020 [7]. Results from the Global New Car Assessment Programme (NCAP) tests on Indian passenger cars show potential for improving road safety in India by introducing well-known vehicle safety technologies [8]. The aim of this paper is to quantify the potential benefits of passive and active safety technologies for passenger cars in preventing road traffic fatalities in India.

II. METHODS

This study used data from Road Accident Sampling System – India (RASSI), an in-depth database of Indian road accidents. RASSI collects accidents that occurred on public roads within selected areas (Coimbatore, Pune, Ahmedabad, Kolkata and Jaipur). There were total of 1,420 accidents (from 2014 to May 2017) considered for this study. The first step was to identify safety technologies that can be applied to the selected data to estimate whether the technology can prevent a specific accident or fatality from occurring and thus can save lives.

Technologies that act before and possibly prevent an accident were termed *active safety technologies*. Technologies that mitigate an accident and possibly prevent a fatality outcome in an accident were termed *passive safety technologies*. Only the first collision during the accident was considered for active safety technology benefit estimation while all collisions in an accident were considered for passive safety technologies. It was assumed that all passenger cars involved in the accidents were equipped with all technologies.

Safety benefit estimation

Simple rules were created for estimating the safety potential of each technology. Based on these rules, all accidents were evaluated and it was estimated whether a specific technology avoids or mitigates accidents and thus prevents fatalities in these accidents. To obtain a more robust assessment, the effects of each technology were estimated by an optimistic rule and a conservative rule.

An example of the benefit estimation for Autonomous Emergency Braking (AEB) technology follows: AEB automatically apply the brakes in a passenger car if the driver fails to respond in an imminent frontal accident scenario. To apply the rules, accidents were filtered for cases with at least one passenger car with frontal damage and one collision partner being any motorised vehicle having rear damage. This gave 79 accidents. Since AEB performance depends on the travelling speeds, the relative speed between the vehicle equipped with AEB and the vehicle ahead was calculated. If the travel speed was unknown, speed limit was used instead of travel speed. For the optimistic rule AEB was assumed to be effective up to a relative speed of 100km/h. For the conservative rule, AEB was considered effective only up to a relative speed of 80 km/h, and in fine weather. Accidents where AEB was effective were treated as avoided; accidents where AEB was not effective were treated as remaining. Accidents with any of the parameters with value unknown in the rule set were assumed as avoided in optimistic rule set and remaining in conservative rule set. With the optimistic rule set, AEB car-vehicle technology prevented

P. Puthan (mobile: - +91 9900951334, email: -pradeep.pisharam.puthan@autoliv.com) is Traffic Safety Research Engineer at Autoliv India Pvt. Ltd, Bangalore, India. P. Thalya is Traffic Safety Research Engineer and Dr, Nils Lubbe is Group Manager, Traffic Safety Research at Autoliv Development AB, Vårgarda.

72 accidents (5% of all accidents) and saved 60 lives (7% of all fatalities). With the conservative rule set, it prevented 60 accidents (4% of all accidents) and saved 48 lives (5% of all fatalities).

The safety potential of several technologies was calculated similarly with specific rulesets listed in the Appendix.

Calculation of road user group lives saved

Fatalities in India are divided into 17% occupants of 4-wheeled and light vehicles, 4% cyclists, 9% pedestrians, 34% riders of powered 2 or 3 wheelers, and 35% other road traffic fatalities [3]. The sample size and distribution of road users included in RASSI differ substantially from this national road user distribution. Passenger car fatalities are overrepresented in RASSI. The distribution of road users in RASSI contains 30% occupants of 4-wheeled and light vehicles, 1% cyclists, 17% pedestrians, 39% riders of powered 2 or 3 wheelers, and 12% other road traffic fatalities. Hence, the estimated benefits of technologies from RASSI were extrapolated to India's national road user distribution.

The extrapolation is explained by an example: Passive safety technologies with the optimistic rules saved 96% of the fatalities occurring among occupants of 4-wheeled and light vehicles in RASSI. This effectiveness, applied to occupants of 4-wheeled and light vehicles, which represent 17% of all road users, implies saving 16% of all reported fatalities in India. Similarly, by extrapolating the effectiveness from RASSI to India for all road user groups, summation of individual benefits gives overall effectiveness for India for the given technology group.

Grouping of technologies

Table I lists technologies that were grouped to simplify effectiveness estimates according to maturity. While estimating the safety benefit of different technologies, there is a high probability that the same accident could be prevented or mitigated, or the same life could be saved by multiple technologies. This phenomenon, double counting, can exaggerate the effectiveness of system combinations [9]. Double counting was avoided in this study by the deterministic rule set applied for each accident, so that an accident can be avoided only once, even though by several different technologies.

TABLE I
GROUPING OF TECHNOLOGIES

Group Name	List of technologies
Passive safety	Improved frontal structure (IFS), Child seat, Seat belt reminder (SBR), Frontal airbag (FAB) and Side airbags (SAB)
Standard ADAS	AEB for passenger cars, Electronic Stability Control (ESC), Intelligent Speed Adaptation (ISA), Lane Change Assist (LCA), Lane Keep Assist (LKA) , Rear AEB
Advanced ADAS	Standard ADAS, Evasive Steering Assist (ESA), Intersection Movement Assist (IMA), Night Vision (NV)

III. RESULTS

Table II lists the effectiveness of different technology groups for different road user groups from RASSI. The group-wise, extrapolated results (Figure 1) indicate that passive safety alone could save at least 14% of lives in India, which is marginally less than the effectiveness of standard ADAS technologies alone. Both together have an effectiveness of at least 19%, indicating that these technologies complement each other to some extent and neither can replace the other completely. Implementing advanced ADAS along with the passive safety technologies has some marginal increase in the maximum effectiveness. These results show that a fast implementation of active and passive technologies in passenger cars will have substantial influence in reducing road traffic fatalities.

TABLE II
EFFECTIVENESS OF GROUPED TECHNOLOGIES FOR DIFFERENT ROAD USER GROUPS IN RASSI

Road user group	Passive safety only		Standard ADAS+ Passive safety		Advanced ADAS + Passive safety	
	Conservative	Optimistic	Conservative	Optimistic	Conservative	Optimistic
Occupants of 4-wheeled and light vehicles	84%	96%	94%	99%	96%	100%
Pedestrians	0%	0%	13%	16%	20%	23%
Cyclist	0%	0%	15%	15%	15%	15%
Riders of powered 2 or 3 wheelers	0%	0%	5%	9%	9%	13%
Others	0%	0%	0%	0%	1%	1%

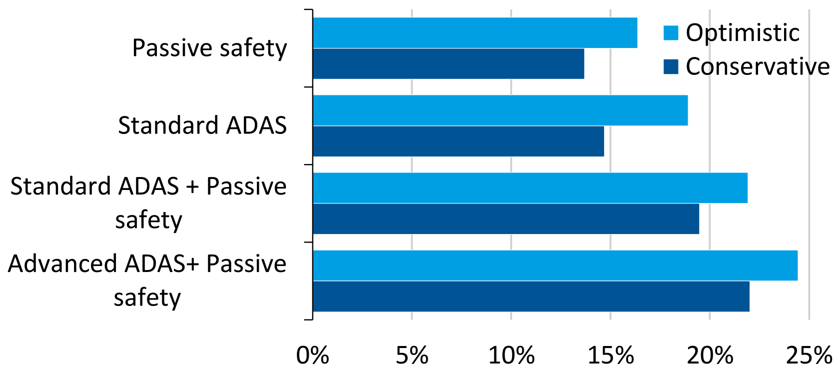

Fig. 1. Optimistic and conservative estimates for effectiveness of different technology groups in reducing fatalities in India.

The effectiveness of individual technologies in Figure 2 displays two effects: The first is the standalone effect of a particular technology if introduced – individual effectiveness; the second is the effect if all technologies were introduced except this technology – marginal effectiveness. The marginal effectiveness gives an indication if other technologies could prevent the fatality from occurring as well. This plays an important role when considering implementation priorities. The most effective technology when introduced first was seat belt reminders, but a large part of the effect could also be covered by other technologies, reducing the individual effectiveness of 25% to a marginal effectiveness of about 7% if implemented with all other technologies. ESC was estimated to have about 15% effectiveness, but there were other technologies which could potentially prevent those accidents, reducing marginal effectiveness close to 3%.

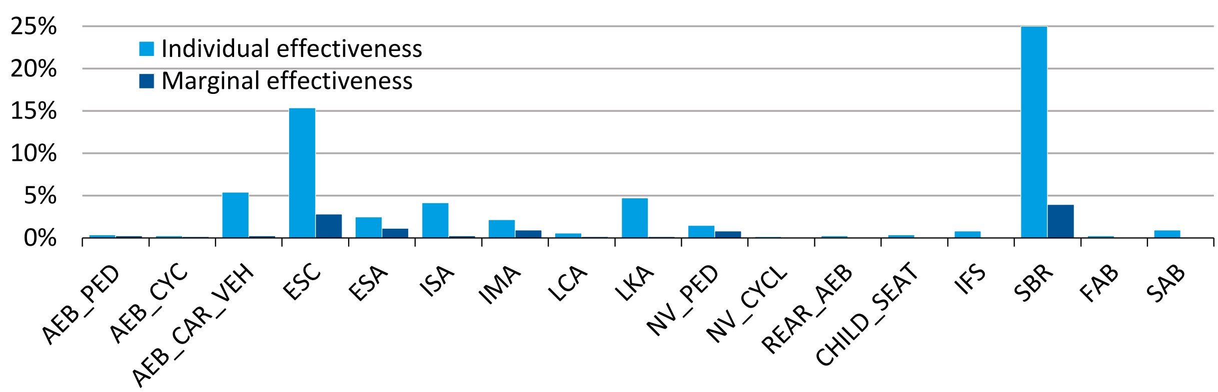

Fig. 2. Individual and marginal effectiveness of different technologies in reducing fatalities

IV. DISCUSSION

Robust estimation of potential of any safety technology requires reasonably accurate data sources. Even though in-depth accident databases give adequate information for safety benefit estimation, scaling it to national Indian data is challenging due to a mismatch in the number of reported road traffic fatalities by different national organisations. The data to understand market penetration of a safety technology in India is hardly available or at least not published. It was assumed that all vehicles were equipped with all safety technology, a limitation of this study. The estimation did not account for special cases such as manual overriding of the safety system and ignoring the warning of the safety technologies.

All the active safety technologies mentioned in the study are primarily developed and implemented in high income countries. Many active safety systems depend on infrastructure like proper lane marking, traffic signals, which is well developed in high income countries, but not to the same extent in India. There is also a big difference in share of road users when comparing India to high income countries [4]. All these factors can have a substantial effect on performance of active safety technology performance in real-life traffic. It is therefore a limitation to assume that all the active safety technologies have the same performance in India as in high income countries. More studies on the effectiveness of safety technologies in low and middle income countries are urgently needed.

Effectiveness results from this study highlight the importance of introducing passive and active safety technologies together to maximise the reduction of road traffic fatalities. However, focusing on passenger car safety technologies alone may not be sufficient to achieve India's commitment to the Brasilia Declaration. Advanced ADAS technology along with passive safety technologies has a potential to prevent about 20% of today's fatalities. One should therefore not only consider passenger car safety technologies, but also other vehicle technologies. Another opportunity to reduce fatalities would be improving infrastructure and enforcing the traffic rules such as usage of seatbelts and helmets.

V. REFERENCES

[1] Ministry of Road Transport and Highways, (2015) Government of India, *"Basic Road Statistics of India 2012 13"*, New Delhi, India.

[2] Solanki, H. K., *et al.*,2016. Road Transport in Urban India: Its Implications on Health. Indian Journal of Community Medicine, **41**(1), p.16–22.

[3] The Energy and Resource institute, "Proliferation of Cars in Indian Cities: Let Us Not Ape the West", July 2004, http://www.teriin.org/policybrief/index.php?a=13 [28 September 2017]

[4] Ministry of Road transport and Highways,(2017) Government of India, "Annual report 2016-17", New Delhi, India

[5]Ministry of Road transport and Highways, (2015) Government of India, "Road accidents in India 2014", New Delhi, India

[6] World Health Organization, (2016), WHO, "Global Status Report on Road Safety 2015", Geneva, Switzerland

[7] Ministry of Road transport and Highway, (2017) Government of India, "Road Accidents in India 2016", New Delhi, India

[8] GLOBAL NCAP, http://www.globalncap.org/ [26 September 2017]

[9] Strandroth, J. (2015) Chalmers University of Technology, *Identifying the Potential of Combined Road Safety Interventions - A Method to Evaluate Future Effects of Integrated Road and Vehicle Safety Technologies*, Goteborg

VI. APPENDIX

Technology	Applicability	Optimistic rule	Conservative rule
Autonomous Emergency Braking (AEB) – Car- Any vehicle (AEB_CAR_VEH)	Passenger car front to-Vehicles (Cyclists excluded) rear end collisions	Relative Speed <100km/h, GADEV1 (General Area of Damage) = Front	Relative speed <80km/h, GADEV1 (General Area of Damage) = Front, WEATHER = Clear
AEB – Car - Pedestrian (AEB_PED)	Passenger car front to Pedestrian	V0_1st (Initial velocity/SPLIMIT (Speed limit) <60 km/h GADEV1 (General Area of Damage) = Front, VOBSTRUCT (Vision obstruction) = None	V0_1st (Initial velocity/SPLIMIT (Speed limit) <60 km/h GADEV1 (General Area of Damage) = Front, VOBSTRUCT (Vision obstruction) = None, WEATHER=Clear
AEB – Car – Cyclist (AEB_CYC)	Passenger car front to Cyclist	V0_1st (Initial velocity/SPLIMIT (Speed limit) <60, GADEV1 (General Area of Damage) = Front, VOBSTRUCT (Vision obstruction) = None	V0_1st (Initial velocity/SPLIMIT (Speed limit) <60, GADEV1 (General Area of Damage) = Front, VOBSTRUCT (Vision obstruction) = None, WEATHER = Clear
Electronic Stability Control (ESC)	Passenger cars without ESC	PRESTAB (Pre-impact stability) = Skidding longitudinally/laterally	PRESTAB (Pre-impact stability) = Skidding longitudinally/laterally
Evasive Steering Assist (ESA)	Passenger cars with frontal accident	GADEV1 (General Area of Damage) = Front, AVOIDMAN (Avoidance manoeuvre) = Turning left/right with/without breaking/ accelerating	GADEV1 (General Area of Damage) = Front, AVOIDMAN (Avoidance manoeuvre) = Turning left/right with/without breaking/ accelerating, V0_1st (Initial velocity)/SPLIMIT (Speed limit) > 50 km/h & < 100 km/h
Intelligent Speed Adaptation (ISA)	Passenger cars	CRITPRE (Critical pre-crash event) = Vehicle loss control due to over speeding for the conditions	CRITPRE (Critical pre-crash event) = Vehicle loss control due to over speeding for the conditions, WEATHER = Clear
Intersection Movement Assist (IMA)	Passenger cars	CRITPRE (Critical pre-crash event) = Ego vehicle turning left/right or passing through intersection or Other vehicle turning left/right or passing through intersection	CRITPRE (Critical pre-crash event) = Ego vehicle turning left/right or passing through intersection or Other vehicle turning left/right or passing through intersection, WEATHER = Clear
Lane Change Assist (LCA)	Passenger cars	V0_1st (Initial velocity)/SPLIMIT (Speed limit) > 40 km/h and < 120 km/h, PREVEH (Pre-event movement) = Changing lanes	V0_1st (Initial velocity)/SPLIMIT (Speed limit) > 40 km/h and < 120 km/h, PREVEH (Pre-event movement) = Changing lanes, Presence of lanes unknown - excluded, WEATHER = Clear
Lane Keep Assist (LKA)	Passenger cars	CRITPRE (Critical pre-crash event) = Off the edge of the road on right/left side, or Over the lane right/left side, V0_1st (Initial velocity)/SPLIMIT (Speed limit) <60 km/h	CRITPRE (Critical pre-crash event) = Off the edge of the road on right/left side, V0_1st (Initial velocity)/SPLIMIT (Speed limit) <60 km/h Presence of lanes unknown - excluded, WEATHER = Clear

Technology	Applicability	Optimistic rule	Conservative rule
Night Vision (NV) (a) NV_PED (b) NV_CYC	Passenger car front impacting Pedestrian/Animal/Cyclist accidents	LGTCOND (Light condition) = Dark /Dark-lighted	LGTCOND (Light condition) = Dark /Dark-lighted,
Rear Automatic breaking (REAR AEB)	Passenger car rear impacting Pedestrian	GADEV1 (General Area of Damage) = Rear	GADEV1 (General Area of Damage) = Rear, WEATHER = Clear
Improved frontal structure (IFS)	Passenger car to Passenger car / Passenger car to HV / Passenger car to (Concrete barrier/ impact attenuator/other barrier/wall/building/ frontal accidents /Other fixed objects/ unknown fixed objects)	GADEV1 (General Area of Damage) = Front, VC_1ST (Collision speed 1st collision) = 64km/h, OVERLAP_1ST (Overlap 1st collision) >20% , HISP (Highest Injury severity - person) = Fatal	GADEV1 (General Area of Damage) = Front, VC_1ST (Collision speed 1st collision) = 56km/h, OVERLAP_1ST (Overlap 1st collision) >20% and <60%, HISP (Highest Injury severity - person) = Fatal
(a) Airbags –Frontal (FAB) (b) Airbags –Side (SAB)	Passenger cars	(a) Frontal Airbag – SEATPOS (Seating position) = 11/13, BAGAVAIL (Frontal Airbag availability) = Not equipped/Disconnected/Unknown EXTENT (Deformation extent) <3 (b) Side Airbag – SEATPOS = 11/13/21/23 , BAGAVOTH (Other Airbag availability) = Not equipped/Disconnected/Unknown, HISP (Highest Injury severity - person) = Fatal	(a) Frontal Airbag – SEATPOS (Seating position) = 11/13, BAGAVAIL (Frontal Airbag availability) = Not equipped/available EXTENT (Deformation extent) <3 (b) Side Airbag – SEATPOS = 11/13/21/23 , BAGAVOTH (Other Airbag availability) = Not equipped/available, HISP (Highest Injury severity - person) = Fatal
Child seat	Passenger cars	AGE (Age of occupant) >=4 and <=12, CHTYP (Type of child safety seat used by the occupant) = None, HISP (Highest Injury severity - person) = Fatal	AGE (Age of occupant) >=4 and <=12, CHTYP (Type of child safety seat used by the occupant) = None, HISP (Highest Injury severity - person) = Fatal
Seatbelt reminder (SBR)	Passenger cars	MANUSE (None used or not available or belt removed/destroyed or Inoperative, HISP (Highest Injury severity - person) = Fatal	MANUSE (None used or not available or belt removed/destroyed or Inoperative or Unknown, HISP (Highest Injury severity - person) = Fatal