DEVELOPMENT AND IMPLEMENTATION OF ADAPTIVE CRUISE CONTROL IN BANGLADESH ROAD TRANSPORTATION SYSTEMS

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ABSTRACT

Adaptive cruise control (ACC) is one of the latest vehicle digitalization inventions in the world. It is an enhancement of conventional cruise control (CCC) which automatically adjusts the speed of ACC-equipped vehicles. There is no scientific evidence of the implementation of ACC vehicles in Bangladesh. Therefore, it is necessary to summarize the implementation and research achievements of the ACC systems over the world. The development of ACC systems has been reported in a published paper namely The Daily Star showing advanced driving assistant techniques in Bangladesh. ACC provides comfort to drivers especially, for long driving. Nonetheless, studies have found some drawbacks of the ACC system in banking roads, turning points on roads, and making drivers less conscious. The system also has some challenges in terms of slow-moving vehicles and control over lane positions. However, the experimental and simulation results showed that ACC works perfectly by stopping a vehicle about 6m from the succeeding vehicle. This paper also investigated the related development and research achievements of ACC systems in Bangladesh. The survey on Bangladeshi drivers ended with disappointing results. Most of the drivers in Bangladesh do not prefer ACC as a road safety feature because of its sensing limitations.

Keywords: *Conventional cruise control (CCC), Adaptive cruise control (ACC), Traffic flow stability of ACC, ACC Challenges.*

1. INTRODUCTION

Road safety in Bangladesh has become a concerning issue. The Business Standard report on 4 February 2023 revealed that 585 people were killed in road accidents in the first month of 2023 (The Business Standard Report, 2023). More than 4 thousand people die due to road accidents in Bangladesh every year (Syed Zain Al-Mahmood, 2019). Road accidental death rate is also increasing day by day. Globally, Road accidents will be the seventh leading cause of death by 2030 (Ahmed SK, Mohammed MG, et al., 2023). Financial loss due to road accidents in Bangladesh is also high. The World Health Organization (WHO) report previewed that Bangladesh losses £1.2 billion or BDT 139.88 billion annually due to road accidents. Developed countries have taken necessary steps to minimize road accidents. A lot of technologies have also been developed to reduce road accidents. Adaptive Cruise Control (ACC) is one of the latest technological inventions to reduce road accidents. ACC is a technological feature used in vehicles to automatically adjust the speed of a subject vehicle to match the speed of the car in front of the subject vehicle.

Adaptive Cruise Control (ACC) is the second-generation invention of road safety features. At the beginning of ACC systems, it was only implemented on luxury vehicles. Today, the automakers are now implementing the ACC systems from mid-range vehicles to luxury class. Bangladesh first imported ACC-equipped vehicles in 2015 (Rahbar Al Haq, 2022). Five brands of automobile cars have introduced a lot of ACC-implemented models in Bangladesh (bdnews24 report, 2023).

ACC exclusively prevents rear-end collisions. It automatically accelerates or decelerates a vehicle to maintain a selected time gap, resulting in a drastic reduction in traffic congestion (Arne Kesting, Martin Treiber, et al., 2008). Empirical studies on the properties of ACC systems showed that the response time range for controllers is between 1.7 and 2.5 seconds (M. Goodrich and E. Boer, 2000). In terms of Bangladesh's road traffic scenario, there is no scientific research on the implementation of ACC. This advanced system is completely new to the automakers in Bangladesh. Thus, “will ACC work perfectly on Bangladesh road traffic condition?” is the key question. This paper aims to find out the drawbacks and probabilities of ACC implementation in Bangladesh. Firstly, this paper finds out the background of ACC. Later, it discussed the systematic features of ACC. Based on the experimental analysis, and feedback of Bangladeshi drivers and automakers, this paper decides whether ACC will work perfectly in Bangladesh road traffic condition or not.

2. BACKGROUND OF ACC

Developed countries first initiated advanced technological research on vehicle modules after the massive death rate due to road accidents. From 2015 to 2019, the United States witnessed an average of 36,791 crash deaths (Merissa A. Yellman, Erin K. Sauber, 2019). Consequently, technological research on vehicles started in the United States in the 20th century. Cruise control was invented in 1948 in Pennsylvania. However, there were a lot of problems with the initial technological achievements of cruise control. The features of cruise control were unable to be adopted in high-traffic situations. Later, in 1990, William Chundrlik and Pamela Labuhn invented Adaptive Cruise Control (ACC) as a possible solution for Cruise Control in high-traffic situations. In the next year, General Motors first patented Adaptive Cruise Control (ACC). In Japan, the advanced features of ACC were introduced by Mitsubishi. Later, advanced technological upgradation was developed by Mitsubishi in Japan. Thus, the automaker brand Mitsubishi is the inventor of today’s ACC. Since the early 2000s, Ford, Mercedes, BMW, Volkswagen, Cadillac, Infinity, Toyota, Hyundai, and Audi have created their versions of ACC in their vehicles.

3. SYSTEMETIC REVIEW OF ACC

Adaptive Cruise Control is the advancement of conventional cruise control. In a conventional cruise control, a Cruise switch is used to maintain a selected constant speed. ACC is designed to maintain a

safe following distance and stay within the speed limit. Figure 1 shows the cruise control and adaptive cruise control apparatus in vehicle.

Figure 1: ACC switch on vehicle

The main part of ACC system is its Electronic Control Units (ECU). The ECU used in ACC is called the ACC control module. The ACC control module is consits of a range of sensor and ACC controller. Table 1 shows the sensors that are used in ACC system.

Table 1: Sensors used in ACC systems

Sensor Name	**Functions in ACC Systems**
LRR (Long Range Radar) sensor	Provides exact measurement of distance and relative speed of objects in front
Light Detection and Ranging sensor	Allows the vehicle to break when it detects the car is approaching another vehicle ahead. When the traffic is clean, it allows the car to accelerate
Thermal Radiation Sensor	Monitor the temperature of solids, gases, or liquids
Steering Angle Sensor	Measures the steering wheel position angle and rate of turn
Yaw Rate Sensor	It determines whether the car is developing a tendency to spin around the vertical axis
Lateral Acceleration Sensor	It adjusts the vehicle speed to the surrounding traffic
Navigation Sensor	Detects vehicles and obstacles surrounding the source vehicle
Velocity Sensor	It adjusts the speed and maintains the set distance from the car

The Human Machine Interface (HMI) is built to make the ACC systems user-friendly. The HMI consists of displays, operating switches, pedals, and warning devices. All of the parts used in ACC systems are connected to CAN (Control Area Network) Bus or LIN (Local Interconnect Network) LIN Bus. The working principle of ACC system is categorized into four parts, which are (i) Signal Collecting (SC) (ii) Signal Processing (SP) (iii) Signal Actuating (SA) (iv) Signal Displaying (SD) (Marsden, G., Mcdonald, et al., 2022). Figure 2 shows the systematic structure of adaptive cruise control. From the figure, ACC works through collision mitigation control and cruise control. Using sensor apparatus in Table 1, ACC detects its front line vehicle and sense the vehicular state. After sensing the condition of its frontline vehicle, ACC takes decision to move slow or fast.

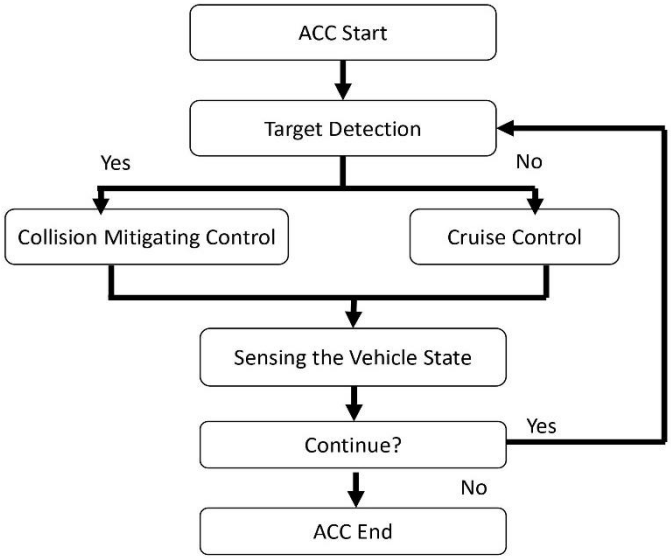

Figure 2: System structure of ACC

4. EXPERIMENTAL AND NUMERICAL ANALYSIS OF ACC

Several experiments and simulations have been conducted on ACC by Kia Motors. Automobile industries have also checked the practical driving performance of ACC vehicles. Two vehicle kinetics simulation programs called SIMULINK and CARSIM were applied to ACC systems. In the simulation, a preceding vehicle was configured at 35 and 40 KPH. The starting vehicle distance between the preceding vehicle and the succeeding vehicle was configured by 70 m. This distance is the maximum measurement distance of the laser scanner.

While running the simulation, the succeeding vehicle was driven with a uniform velocity according to the input velocities and decelerated as the vehicle distance to the preceding vehicle reached the safety distance. The simulation was run to verify that the succeeding vehicle represents driving while maintaining a safe distance from the preceding vehicle. In the end, the succeeding vehicle was stopped at about 9m from the preceding vehicle. Using a practical vehicle, the experiment on the ACC system was conducted on a straight asphalt road in Dong-myeon, Yangsan City, Gyungsangnamdo. The experiment showed similar driving characteristics to the simulation.

In the experiment, the succeeding vehicle showed uniform driving according to input velocities. The succeeding vehicle also maintained a safe distance from the preceding vehicle. The experiment verified that the test vehicle stopped at about 6 m (Man Hyung Lee, Hyung Gyu Park, et al., 2012).

5. SAFETY MEASURES OF ACC

ACC emphasizes safety by increasing driving comfort rather than increasing road capacity. ACC implies a headway policy to determine the following distance. This technology finds the proper spacing by human factor issues (M. Goodrich and E. Boer, 2000). ACC is trained by real-driver data which is more natural. In the Monte Carlo simulations, ACC showed less probability of collisions (2.76%) between ACC-equipped vehicles and the leading vehicle (A. Touran, M. Brackstone, et al., 1999).

ACC vehicles with automatic braking systems reduced the probability of collision by 85% to 90% compared to those vehicles without ACC (Takubo, 1995). The latest survey report from the Highway Loss Data Institute (HLDI) previewed that ACC-equipped vehicles resulted in less property damage and body injury (HLDI report, 2017). Table 2 reveals the safety measures of ACC-equipped vehicles.

Table 2: Reduction on Accidental Parameters by ACC systems according to HLDI report

Accidental Parameter	**Reduction (%)**
Collision	6
Property Damage	27
Bodily Injured	37

6. BANGLADESH PERSPECTIVE OF ACC

6.1 Current Scenario of Bangladesh Road Traffic

Bangladesh has mixed road traffic. The country has an average of 25318 traffic fatalities per year (Samsur Rahman, 2022). Due to the excessive population, the number of motor vehicles in Bangladesh road has increased. In 2022, the number of registered motor vehicles was 578151. As of March 2023, Car import shipments in Bangladesh stood up at 69 thousand. The principal contributing factors to road accidents in Bangladesh are adverse roadway roadside environment, default land use and road network, and poor detailed design of junctions and road sections (Sohel Mahmud, S. M., Ahmed, et al., 2014).

6.2 Implementation of ACC in Bangladesh

Bangladesh has imported a lot of vehicles where Adaptive Cruise Control (ACC) has been enabled. The first Adaptive Cruise Control vehicle was imported to Bangladesh in 2015 (Rahbar Al Haq, 2022). Table 3 previews the brand names of ACC-implemented vehicles in Bangladesh.

Table 3: Brand names of ACC-implemented vehicles in Bangladesh

Kia forte GT 2020	**Subaru Forester AWD**
2020 Ford Fusion	2020 Toyota Camry
2020 Toyota Prius	2020 Mazda6
2020 Honda Accord	2020 Honda HR-V
2020 Hyundai Sonata	2020 Subaru Crosstrek
2020 Toyota Corolla Hybrid	2020 Honda Insight
2020 Subaru Legacy	2020 Mazda CX-30
2020 Mazda3	2020 Toyota C-HR
2020 Honda Civic	2020 Mazda CX-3
2020 Nissan Sentra	2020 Subaru Impreza
2020 Toyota Corolla	2020 Honda Fit
2020 Nissan Versa	

6.3 Drivers' Concern Regarding ACC

In Bangladesh, the number of drivers who believe in the positive impacts and safety features of ACC is not impressive. In most cases, they disagree on the potential benefits of ACC (A. Huq, S. Iqra, Z. Ikram, 2022).

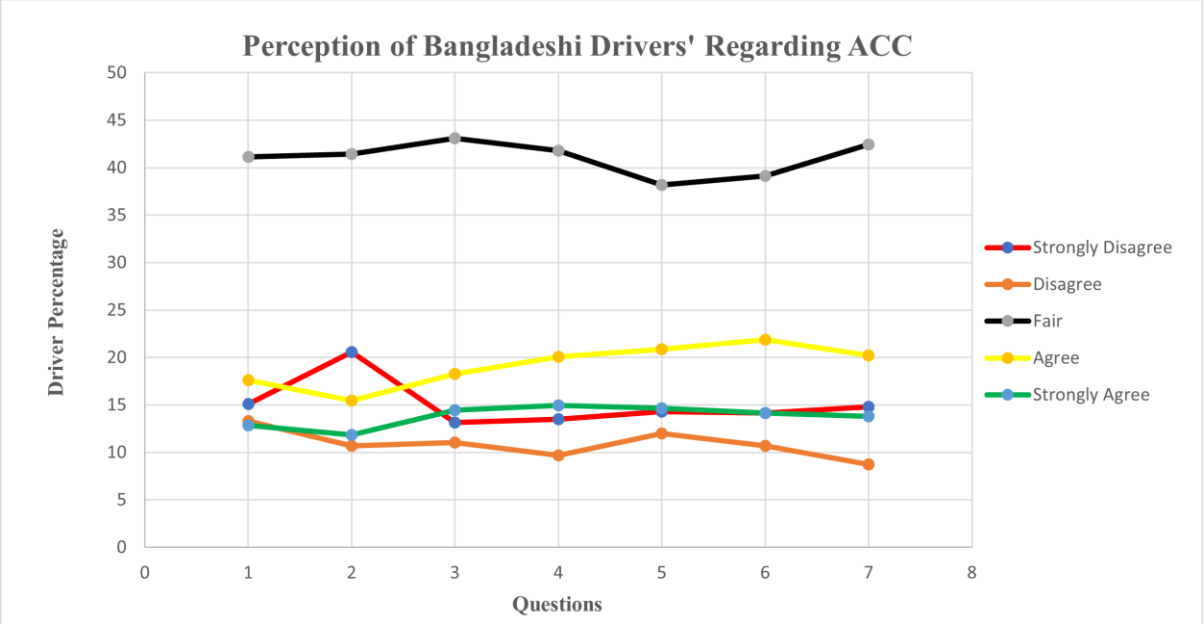

Figure 3: Perception of Bangladeshi drivers regarding ACC

Questions under the survey:

1. ACC helps when overtaking on a slippery road
2. ACC helps in driving on a wet road
3. ACC helps while speeding while climbing a steep road
4. ACC helps in the sudden hard break
5. ACC helps while speeding on a flat road
6. ACC helps to maneuver at regular speed
7. There is a lower risk of skidding with a car equipped with ACC than a car without ACC
8. There is a better chance to correct a slide with a car equipped with ACC than a car without ACC
9. A car with ACC can accelerate faster than a car without it
10. A car with ACC can be driven faster on slippery road than a car without it
11. A car with ACC can be steered and braked simultaneously better than a car without it.

Figure 3 reveals questionnaire survey results conducted on the perception of Bangladeshi drivers' on ACC. From the questionnaire survey, 17.43% of Bangladeshi drivers strongly disagree with the ACC benefits while overtaking on a slippery road. On the contrary, 12.01% believe that ACC helps when overtaking on a slippery road. In terms of wet roads, 11.35% of Bangladeshi drivers believe that it helps in driving on a wet road while the percentage is high at strongly disagree on this question. Driver's concern on ACC in terms of the sudden hard brake is disappointing. From the survey results, most the Bangladeshi drivers do not prefer ACC in terms of traffic safety manners.

6.4 Obstacles to Apply ACC in Bangladesh

Adaptive Cruise Control performs poorly during heavy rain, fog, or snow. The weather conditions in Bangladesh are uncertain. Thus, applying ACC frequently on Bangladesh roads is risky. Adaptive Cruise Control delays the break time. For a heavy traffic congested country like Bangladesh, the time delays in breaking ACC systems are very alarming. The important drawback of Adaptive Cruise Control is its ineffective sensing towards slow-moving vehicles (Ford's Article, 2023). Adaptive Cruise Control may not detect slow-moving or stationary vehicles below 6 mph (10 km/h). In Bangladesh, the braking tendency of drivers is uncertain. Besides, drivers rest their vehicles at the roadside frequently. Thus, ACC sensors may not detect these conditions of vehicles every time and everywhere. Adaptive Cruise Control implemented vehicles spent more time in the left lane than subjects driving without ACC. In Bangladesh, all drivers follow the right-hand driving style. In the long run, ACC systems can cause problems for the right-hand driving styles.

7. CONCLUSION

Adaptive Cruise Control is considered to be an extension of Cruise Control systems. ACC is implemented to remove or reduce the longitudinal driving work on the highway by automatically keeping a user-set headway or speed between the ACC-equipped vehicle and the preceding vehicle in the same lane. From the simulation and practical point of view, ACC systems have some limitations. It performs poorly in terms of slow-moving vehicles. Thus, more advanced research is needed for ACC to properly implement it in Bangladesh's road traffic system.

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