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Smart Automotive Side Mirror

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Abstract - *The side mirrors are fixed on the outside of motor vehicle for the driver to see areas behind and the sides of the vehicle. There are two types of mirrors, side-view mirrors, and rear-view mirrors. But still, there are some areas of the road which cannot be seen by the driver even with the assistance of these mirrors. These unseen areas are called 'Blind Spots'. Every driver is at risk of facing an accident simply because of the existence of these blind spots.*

At present, there are many solutions proposed by the vehicle manufacturers to make these blind spots visible or to inform the state of these blind spots to the driver. These solutions could be broadly divided into Active monitoring systems and Passive monitoring systems. From literature, it was evident that these systems have not completely solved the issues related to blind spots, but partially. These solutions have proposed an artificial sense to the driver, and driver must pay additional attention, thus it distracts the driver's concentration and creates undue problems. Therefore, a better solution is needed.

This study has designed a smart side mirror, which automatically identifies the necessity and adjusts itself in order to visualize the blind spots to the driver. The solution is evaluated by a model in which the results justify the performance of the proposed system. The average response time is 2-3 seconds which is acceptable. The solution could be easily adapted to the existing power mirrors with simple modifications. Since almost all the vehicles with auto mirrors (except few luxury ones consists of in-built blind spot detection facility) in Sri Lanka could potentially adopt this system and minimize the blind spot risk. The vehicle manufactures could incorporate this option to their future vehicles which will be beneficial not only to the manufacturers, but also to the vehicle owners/drivers for safe driving.

Key Words*: *Side Mirror, Blind Spots, Product Design and Development.

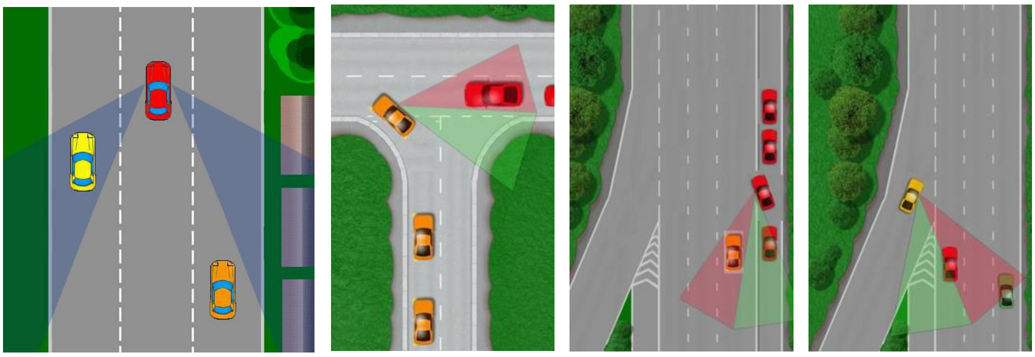
Nomenclature

Subscripts
FOV- Field of view.
BoQ- Bill of Quantities

1 INTRODUCTION

Side mirrors are found on the exterior of motor vehicles for the purposes of assisting the driver to observe the rear areas and the sides of the vehicle. In fact, a vehicle cannot safely drive without side mirrors (1A Auto, 2017). Side mirrors, also known as the wing mirrors, fender mirrors, door mirrors or outside rear-view mirrors, are mounted at the A-pillar on the front doors. They are equipped with either manual or remote (power mirrors) vertical and horizontal adjusters, to provide adequate coverage to the drivers of differing heights and seating postures. The remote adjusters may operate mechanically by means of bowden cables or electrically by means of geared motors.

A blind spot is an area around the sides of the vehicle that cannot be directly observed by the driver even with the assistance of side mirrors and rear-view mirror. Every driver is at risk of accident, simply because of these blind spots (Mathew et.al., 2018). The shaded areas in Fig.1(a) shows blind spots of both sides when the vehicle drives straight. Blind spots are usually occurring when entering to the main road from a by-road and leaving or backing out of a driveway lane or parking spots. Fig.1(b), Fig.1(c), and Fig.1(d) illustrates the blind spots when making a left-hand turn across two lanes of oncoming traffic, changing lane on the wide road and entering to highway lines, respectively.



(*a*) (*b*) (*c*) (*d*)

Fig. 1. Blind spots to the drivers (blind spots are shaded in red in *b*, *c*, *d*)

Blind spots of vehicles are more than an annoyance since they have cause serious accidents. The drivers must pay additional effort to check the blind spots. Blind spots can lead to, backing into objects or individuals, changing lanes interfering another vehicle, pushing another vehicle off the road into oncoming traffic, etc., and accidents caused by blind spots can lead to two or multi-vehicle accidents that result in property damage, minor to serious injuries, and fatalities (Shawky, 2019). Blind spots on larger cars are particularly dangerous to children. Every year, adults back into kids playing in their driveways, causing preventable serious injuries and deaths (Krist Law Firm P.C., 2018). Statistics from the National Highway Traffic Safety Administration show that nearly 840,000 blind spot accidents occur each year in the United States resulting in 300 fatalities, due to not properly checking the blind spots before changing lanes (Gordon & Partners, 2013). With the existence of new technological features, blind spots are still a worldwide problem. It is difficult to find written evidences of accidents occurred directly due to blind spots in Sri Lanka, which could be mainly due to the unavailability of a proper analysis or categorization of the accidence. However, there are ample evidences of considerable number of automotive accidents due to blind spots from other countries (Shawky, 2019; Krist Law Firm P.C., 2018; Gordon & Partners, 2013).

At present, many solutions have been introduced to make blind spots visible to the driver by using Active and Passive monitoring systems (Fernandez et al., 2013). These efforts have not provided a complete solution by addressing all the issues related to blind spots (Souders et al, 2016). These solutions demand much effort from the driver to visualize the blind spots which makes them ineffective, and some solutions distract the driver's concentration which eventually induce undue issues. Further, these solutions made an artificial sense for drivers, it demands additional attention of the drivers to refer those

(Souders et al, 2016). For a vehicle with blind spot monitoring options, mainly in luxury cars with options, the clients must pay extra, which many feels the cost is not compensates the benefit. In Sri Lanka it is hard to find a vehicle with those options, since the blind spots are not been evident as a cause of accident. But even though the accidents have not been categorized, blind spots could be one of the main causes for road accidents. Therefore, there should be a better solution to minimize the blind spots without any disruption to drivers and which are beneficial if the solution could also be adopted to existing mirror systems with minor modifications.

Hence it is a problem, requiring a right solution which eliminates the drawbacks of existing mirror systems, specially it enables driver to visualise blind spot with minimum effort and without distractions. Under this study a smart side mirror was developed. The existence of blind spots, characteristics of side mirrors, and existing solutions were analysed, and features of the end-product were recognized according to the views/needs of drivers (people who drives vehicles). Technical features of a vehicle related to real-time mirror angle adjustments were identified. The proposed system was evaluated by a model and further developments were proposed. If such a system is designed and developed to work with existing power mirrors with little modifications, the product will be greatly appreciated by many vehicle owners/drivers and it has high utility value for the customers

Throughout the study, the Product Design and Development techniques (Ulrich et al, 2012; Otto & Wood, 2009) were followed. The current Product Design and Development practices provide techniques which enable concept generation and select best solution leading to the development of the end product to a segmented market.

2 LITERATURE REVIEW

Nowadays, almost all auto manufacturers approach the problem of blind-spot detection. There are two main categories of blind-spot monitoring technologies, namely active and passive monitoring systems (Saboune, 2011).

Active Blind Spot Monitoring Systems: A blind spot monitoring system uses electronic detection devices mounted on the sides of the vehical (often in the vicinity of the side mirrors or near the rear bumpers) that sends out either electronic electromagnetic waves (usually in the radar wavelengths) or takes computer-processed images with a digital camera. When one of these detectors notices another vehicle getting too closer, it indicates to the driver, by flashing a light in the driver's peripheral vision or by making audible sounds (beep sound) or both together, depending on how likely it looks that the driver steers the car into other vehicle (HowStuffWorks, 2018). The most advanced active monitoring systems steer the vehical back to the safety zone (Wu, 2012). Depending on the maker, the system of blind spot monitoring named differently; Ford, Lincoln, and Volvo call it as Blind Spot Information System (BLIS), Audi calls it Side Assist (SA), General Motors as Side Blind Zone Alert (SBZA), and Infiniti's name it as Blind Spot Warning (BSW) (ExtremeTech, 2017; Tigadi et al, 2015, Hassan & Ariffin, 2013). The main target of these systems is to monitor blind spots and inform the driver when entering into adjacent lanes.

Passive Blind Spot Monitoring Systems: This system consists of mirrors with less advanced monitoring features. Presently, lots of mirror attachments are used to see blinds spots, such as Fisheye mirrors, Aspheric mirrors and Panoramic rear-view mirrors, to reduce the size of a blind spot (UWM, 2016). Many car manufacturers will offer the alternative special convex mirror at the corner of a current external rearview mirror, which allows the driver to see the areas beyond the coverage of the normal side mirrors (HowStuffWorks, 2018). The passive blind spot monitoring systems also target to track and minimize the blind spots as much as possible.

Steering ratio and field of view are two important automotive kinematic features which have given special attention in designing the smart side mirror.

Steering Ratio: Steering ratio (ratio of the number of degrees the steering wheel turned vs. the number of degrees the front wheels turn) is an inherent design consideration, which gives the mechanical advantage to the driver in turning. If the steering wheel turned by 20° and corresponding front turn of front wheels is 1°, that gives a steering ratio of 20:1. For most modern cars, the steering ratio is in between 12:1 and 20:1. This, coupled with the maximum angle of deflection of the wheels gives the lock-to-lock turns for the steering wheel. For example, if a car has a steering ratio of 18:1 and the front wheels have a turn by 25°, then the steering wheel should turn by (25°x18) 450°. That is only to one side, so the entire steering goes from -25° to +25° giving a lock-to-lock angle of steering wheel of 900°, or 2.5 turns (Kong, 2015).

Field of View: FOV is the observable area to the driver through eyes or via an optical device as shown in Fig.2, while mean angles of FOV which driver could see are given in Table 1 (Reed et al, 2000).
In the context of optical devices and sensors, FOV describes the angle through which the devices can pick up electromagnetic radiation (Reed et al, 2000).
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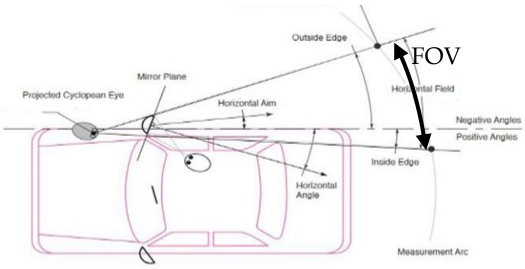


Fig. 2. Field of View (FOV) of a vehicle optical device

Table 1 Angles of view

Mirror		**Angle**
Left	Outside	-21.1^{0}
	Inside	2.2^{0}
Right	Outside	-13.2^{0}
	Inside	0.2^{0}

3 METHODOLOGY

Product Design and Development approach: The Product Design and Development approach were studied (Ulrich et al, 2012; Otto & Wood, 2009) and process illustrated in

Fig. 3 was followed in this study. A product design, and development process is the sequence of steps/activities which adhered to initiate/conceive, design and commercialize a product. In this study, the commercialization part is omitted, but a cost analysis has been carried out.

Mission Statement: The output of the planning phase is the project mission statement, which specifies the target market for the product, business goals, key assumptions, and constraints.

Identifying Customer Needs (and Technical Aspects): The goal of this activity is to understand customers' needs and to effectively communicate to the product design and development team. The output of this step is a set of carefully constructed customer need statements, organized in a hierarchical list, with importance weightings for many or all the needs.

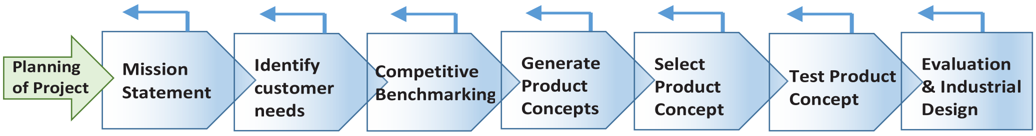


Fig. 3. Product Design and Development process followed throughout this study

Competitive Benchmarking: In this phase it compares competitors' systems with assumed solutions for the problem.

Concept Generation: The goal of concept generation is to thoroughly explore the space of product concepts that may address the customer needs. It covers Identification of limitations for solutions considering actual situations, decomposition of the complex problem into simple sub problems and listing solutions for each sub problem to generate the concept of product design. The result of this activity is several conceptual solutions.

Concept Selection: Concept selection is the activity in which various product concepts are analyzed and sequentially eliminated to identify the most promising concept(s). The process usually requires several iterations and may initiate additional concept generation and refinement.

Prototyping and Testing: Selected concept is tested by developing a model based on the selected design concept and tested to check whether it fulfills the design limitations, the aim and the objectives.

Evaluation and Industrial Design: It was the final stage of the product design process that lists out the future works by evaluating the results from 'Prototype and testing' stage and concludes about the product as industrial design.

4 RESULTS AND DISCUSSION

2.1 Mission Statement

The mission statement shown in Table 2 was finalized after thoroughly investigation under the project planning stage.

2.2 Gathering Customer Needs

A questionnaire was administered, and planned discussions were conducted to gather customer needs.

Questionnaire Administration: The questionnaire was designed and administered to gather user/customer information specifically drivers, and professionals who drive regularly. A Google Forum was established and s shared. Administration of the questionnaire through Google Forum is cost effective and easy to share with persons through mails and social media, and it is convenient to analyze and compile data. Incidence faced due to blind spots and the awareness regarding the blind spots among drivers were identified. Analyzed statistically the responses to make some decisions and conclusions. Customer needs were identified, ranked, and recognized the primary needs which directly affect the development activities.

Table 2 Mission statement of Smart Side Mirror project

Mission Statement: Smart Side Mirror Project	
Production Description	• Car side view mirror which able to change the field of view angle dynamically in real time.
Benefit Proposition	• Avoid blind spots by modifying existing side mirror.
Key Business Goals	• Product which has the potential to compete in the market and with a cost-effective design.
Primary Market	• Car owners/drivers.
Secondary Markets	• Car manufactures.
Assumptions	• Car has inbuilt power mirror. • Known steering ratio. • Inputs can be read from sensors.
Stakeholders	• Owners /drivers • Car manufactures • Spare part dealers/repairing persons

Analysis of Survey Data: Conclusions were made from the data gathered from 72 respondents. The data were tabulated, and SPSS was used to analyse and sort out the customer needs and their priority levels.

Limitations and Conclusions Based on the Survey: According to analyzed data, the solution (the end-product) should be developed within the following boundaries/limitations:

- The most important scenarios which the product should focus on are ***1.*** Entering the main road from a by-road and **2.** Entering to highway lanes**.**
- Use electrically operated side mirrors (power mirrors) with design features to automatically adjust the mirror to visualize the blind spots.
- Design for the light vehicles specifically for cars (sedan/hatchback), but it could be used with other vehicles such as Vans, SUVs, etc.

Further, it is understood that 32% of respondents have mirror attachments (passive systems), but still they are facing difficulties due to blind spots when, entering to the main road form a by-road (77.1%), entering to highway lines (55.7%), leaving or backing out of a driveway or parking spot (44.3%) and changing the track while driving on the wide straight road (41.4%). Therefore, it was obvious that the usage of mirror attachments is not a good solution for those blind spots issues, especially at entering the main road form a by-road and entering highway lines (55.7%). The mirror attachments have a slight positive effect when leaving or backing out of a driveway or parking spot and changing the track.
Almost all the respondents, 95.8%, including those who used mirror attachments have insisted having a system to avoid blind spots and 91.6% are preferred smart side mirrors to make blind spots visible.

2.3 Identify Customer Needs

The data gathered by questionnaires and discussions were effective. The customer needs/requirements were rated using a 1–5 scale and prioritized (refer Table 3). These were considered according to priority level.

Table 3 Assessment of Customer needs

No.	Need	Relative importance
1	Light vehicle drivers need to avoid accidents due to blind spots.	4
2	Drivers need to see and verify side rear view of main road when entering to main road from a by road & entering highway line.	5
3	Drivers need to see and verify side rear of multilane highway road view when switching the track on a multilane highway.	3
4	Drivers like to have visualized system to see blind areas rather than using active blind spot detection systems.	5
5	Drivers feel better to view side rear view through the side mirror rather than using a camera display.	4
6	Side mirror able to dynamically change the angle quickly.	5
7	Side mirror able to back to initial state in a normal road drive.	4
8	The system is cost effective and easy to install.	3
9	Capable to use with existing power mirrors.	2

The technical needs/specifications are identified and rated by 1–5 scale as in Table 4 to address rated customer needs in Table 3.

Table 4 Technical needs

No.	Need	Relative importance
1	The time taken to move mirror from initial position to maximum angle.	5
2	Take steering angle.	5
3	Signal light condition (on / off).	5
4	Vehicle speed.	4
5	Configuration of initial mirror angle.	4
6	Vehicle length (length between front wheel to rear wheel)	2
7	Existing side mirror maximum moving angle.	5
8	Product price.	3
9	Existing mechanism of power mirror.	4

2.4 Competitive Benchmarking

The proposed system was rated based on the weight of importance for systems on customer needs by comparing existing systems. The results are, active detection 30, passive detection 60, proposed system 103, as illustrated in Table 5. It could be confirmed that the proposed solution is comparatively more reliable.

Table 5 Competitive benchmarking with weights of importance: *Key (.)- Not perceived satisfaction of the need, (..) - Less perceived satisfaction of the need, (…) - Well enough perceived satisfaction of the need, (….) - Good perceived satisfaction of the need, (…..) - Greater perceived satisfaction of the need.*

No.	Need	Imp.	Active detection	Passive detection	Proposed system
1	Light vehicle drivers need to avoid accidents due to blind spots.	4	….	…	….
2	Drivers need to see and verify side rear view of main road when entering to main road from a by road & entering highway line.	5	.	.	….
3	Drivers need to see and verify side rear of multilane highway road view when switching the track on a multilane highway.	3	…	…	…..
4	Drivers like to have visualized system to see blind areas rather than using active blind spot detection systems.	5	.	…	….
5	Drivers feel better to view side rear view through the side mirror rather than using a camera display.	4	.	..	….
6	Side mirror able to dynamically change the angle quickly.	5	.	.	…
7	Side mirror able to back to initial state in a normal road drive.	4	….	….	….
8	The system is cost effective and easy to install.	3	.	…..	….
9	Capable to use with existing power mirrors.	2	.	…..	….
	Weight of importance for systems on customer needs		**30**	**60**	**103**

2.5 Concept Generation

The design concept generation was done as per the process illustrated in Fig. 4. Only the important segments of the concept generation are described under this section.

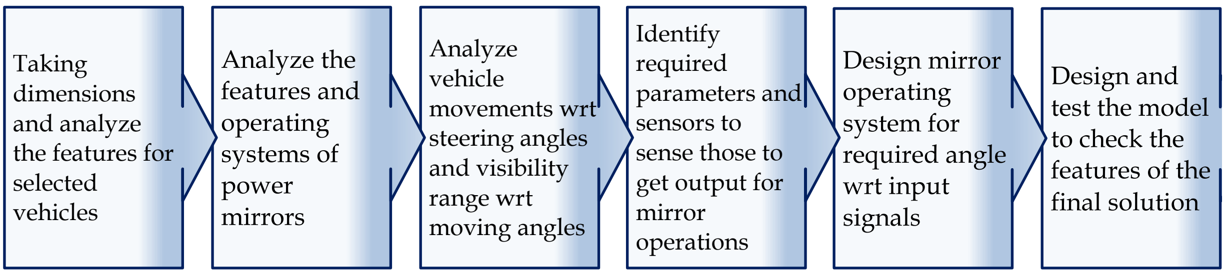


Fig. 4. Concept generation process

4.5.1. Testing for Concept's limitations

Three experiments were conducted to analyse the correlation between, **1.** Vehicle speed and turning time, **2.** Movement of steering wheel turning angle, and **3.** FOV and operating angles of the mirror.

Experiment 01 Time to take a turn and respective vehicle speed: The average time vehicle took to make a turn from by-road to the main-road were recorded (by stopwatch) and corresponding vehicle speed (from dashboard indicator) were observed and averaged form 10 trials. The mean value of time to take a turn was 5.5 *seconds* and the mean speed was 7.6 km/h.

Experiment 02 Taking real time steering angle: The wheel turning angle was geometrically measured with respect to the movement of the steering wheel. On average, the turned angle of the front wheel for 360^0 turns of the steering wheel is 20^0, therefore the steering ratio is 18:1.
Experiment 03 Taking real time FOV of side mirror at its minimum and maximum operating angles: **T**he minimum and maximum angles of FOV were considered as the minimum and maximum turning angles of the mirror. The minimum angle was 9^0 and the maximum angle was 35^0.

4.5.2. Limitations

The total functions could be decomposed into main three folds, inputs, processing input data (system with functions), and adjust mirror angle accordingly (output) as illustrated in Fig 5. Inputs of the system are steering angle, vehicle speed, and signal light on/off.

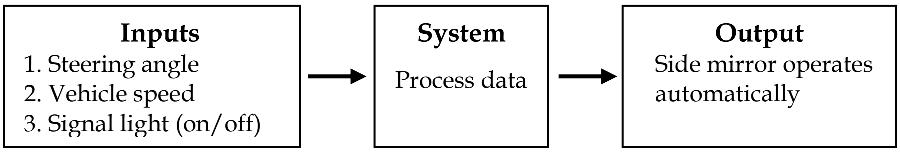


Fig. 5. Representation of main folds of the development process.

Real time experiments were conducted, and real-time data were collected to find input limitations.
Steering angle and corresponding angles: The observations show that the maximum amount of steering angle to take a turn when entering to the main road and changing drive track of wide road is about 30°. Simultaneously with car tuning between 10° and 30° (if steering ratio 18:1 maximum steering wheel turning angle is between 180^0 and 540^0), the angle of side mirror changes its angle from initial value to maximum angle and when the steering wheel returns side mirror returns to the initial position simultaneously.
Vehicle speed: Since the average speed of entering to the main road is 7.6km/h, the range of speed is considered as 0 -15km/h. The change of the side mirror should accommodate this speed.
Turning indication by signal lights (on/off) is mandatory: when entering to the main road or change drive track, it is assumed that the driver turns on the signal lights. In the proposed system, the signal indication “ON”, is mandatory to operate the system.

4.5.3. Concept Selection

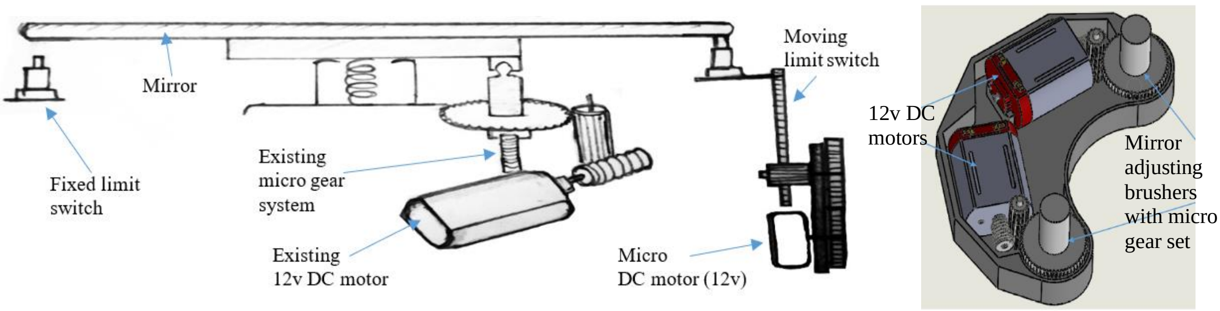
The concept combination table, given in Table 6. The main problems were identified and decomposed to sub-problems.

Table 6 Concept combination table of sub-problems

Get vehicle speed	Get steering angle	Detect signal light condition	Change angle of mirror glass	Drive position changing system

Read from OBD	Read from OBD	Read from signal light connection	Use existing power mirror system	Servo Motor
Use accelerometer sensor	Use a Gyroscope	Get signal light on/off condition from ECU	Separate modified attachment to existing power mirror	Stepper Motor
Read Wheel Rotation Speed	Use Encoder		Replace mirror operating system	Normal DC Motor
Get Signals from ECU System				

The solutions were then proposed based on firm facts. Finally, the most effective and reliable solution (concept) was selected. Selections were done based on parameters such as ease of handling, ease of use, readability, accuracy, durability and ease of application. The selected combination of concepts to develop the final solution/end-product are shaded and connected by dotted lines in Table 6. The basic sketch representing the final concept along with the internal arrangement is shown in Fig.6.



(a) (b)

Fig. 6. Sketch represent the final concept, (a) sketch of the component arrangement, (b) 3-D view of the inside arrangement

2.6 Concept Design

After identifying the inputs, functions/sub-functions of the system (and implementation hardware and software, such as input sensors, controllers, actuators and feedback components, connectors, switches) and interaction each of them is illustrated in Fig.7, which gives an overall idea of how the final concept works.

By sensing the vehicle speed, steering angle, and the signal light on/off as inputs, the system identified the area needed to be covered or visualized, i.e. the angle of FOV. All three input requirements should be satisfied to operate the mirror. Then the DC motor (adjust the mirror angle) was actuated as per the controller program. The controller operates on two modes, the Auto mode, and Manual mode. Manual mode is to adjust the mirror to the home position as per the driver and the smart mirror function operates only in Auto mode. There were two limit switches, one is to accommodate the maximum rotation of the mirror and the other one is to accommodate the home position of the mirror. These limit switches transmit feedbacks to the controller. The system flow charts/algorithms of the final concept and the sub-system to adjusting home position are illustrated in Fig.8 and Fig.9 respectively. An existing power mirrors (with its operating mechanism) could be used with the proposed new operating system with minor modifications. The space inside is adequate to accommodate additional components.

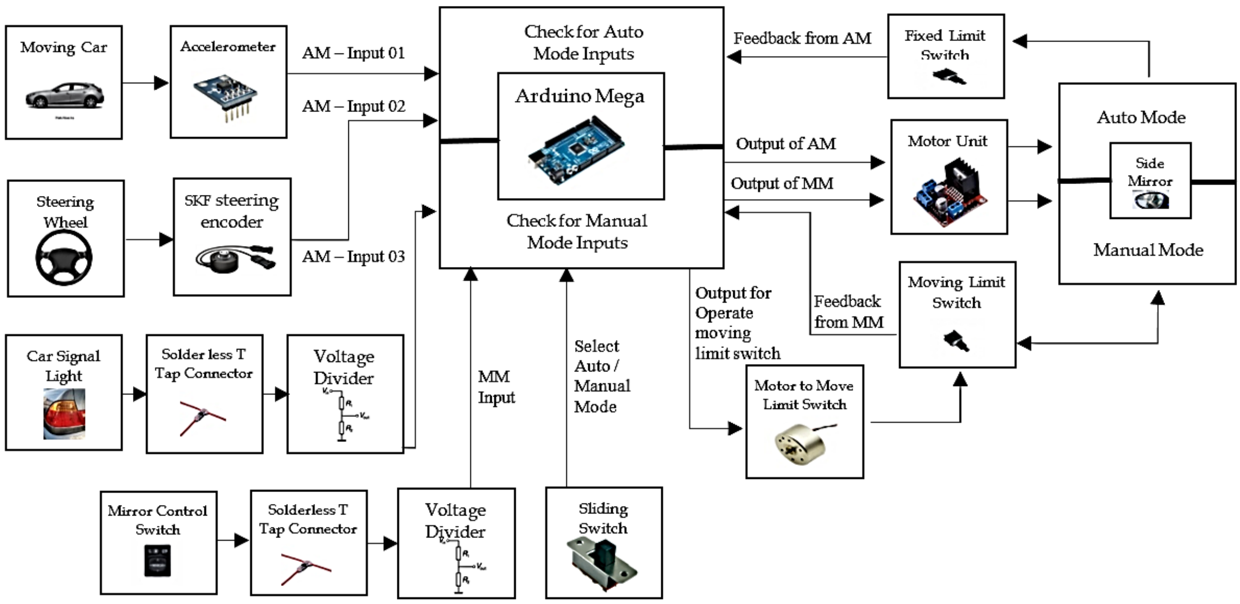
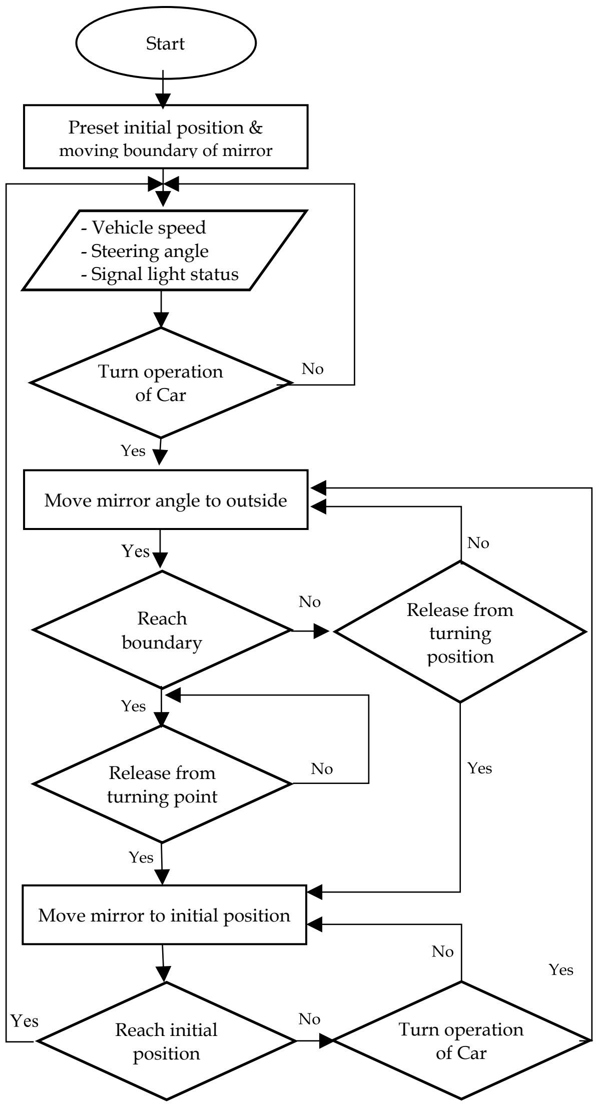


Fig.7. Schematic diagram of design



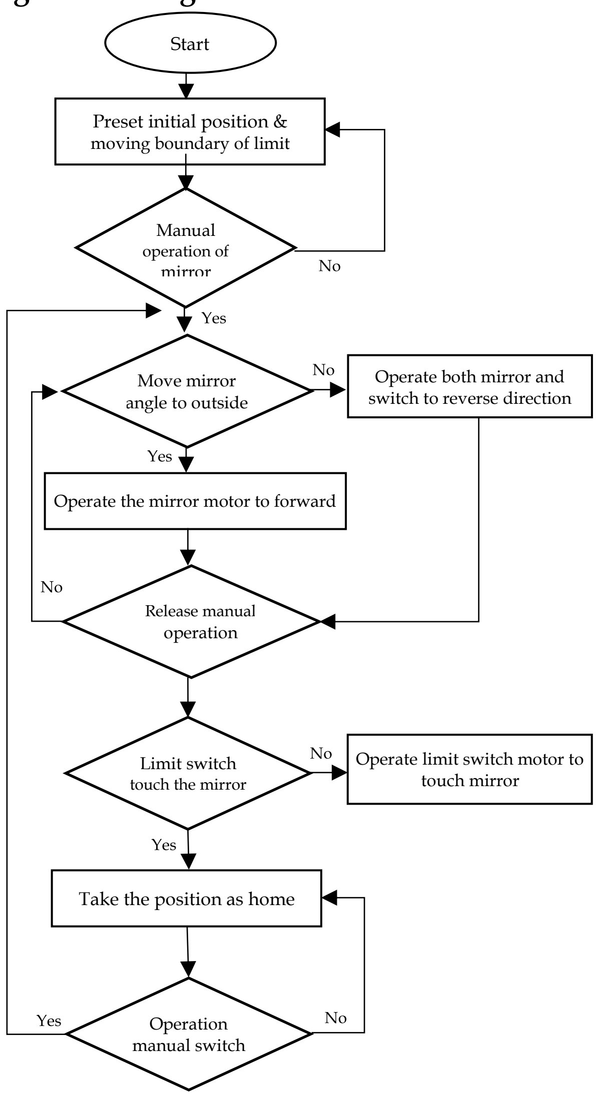


Fig.8. System flow Fig.9. Sub-System

2.7 Concept Testing and Development of the Model

The model was developed based on the concept table given in Table 7, which extracted from the final concept combination (refer Table 6).

Table 7 Combination of sub-problems to develop the model

Get Vehicle Speed	Get Steering Angle	Detect Signal Light Condition	Change Angle of Mirror Glass	Select Auto & Manual Mode	Drive Position Changing System
Use inter-locking switch to make condition	Use Encoder to sense and feed angle variation as input	Use inter-locking switch to feed on/off condition as input	Separate modified attachment to existing power mirror with micro limit switches	Use Toggle switch to change the mode	Use DC Motors (FK-130RH)

Fig.10 illustrates the operating sequesnce of the model. The working conditions and limits are identical to the final conceptual design. But some of the hardware components such as, the accelerometer and signal light on/off sensor were not included to the model, inserted the respective indication signals were provided by an interlocking switch. Also, due to practical difficulties (since the testing was not done with a vehicle it is impractical to use real vehicle conditions as inputs of model demonstration) a rotary encoder was used in place of steering encoder. The model's working principle, processing methods, and actuator operations, as well as response time, will be exactly as identical with the final concept (end-product).

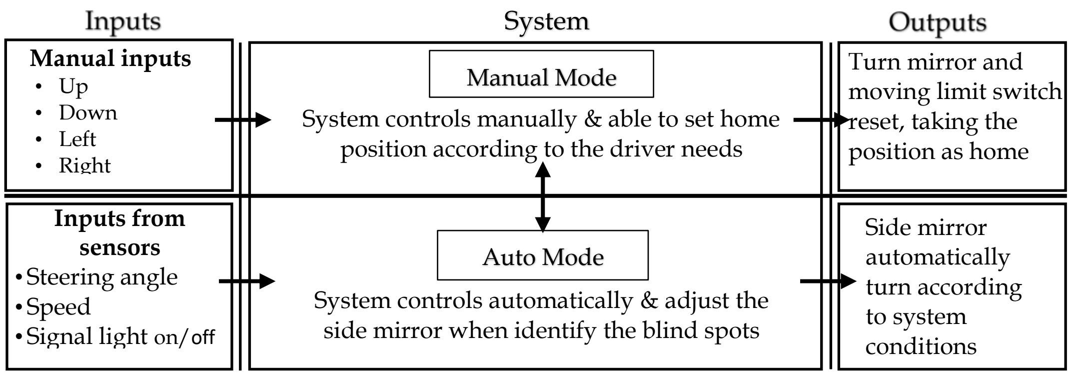


Fig. 10. Working process of auto and manual modes

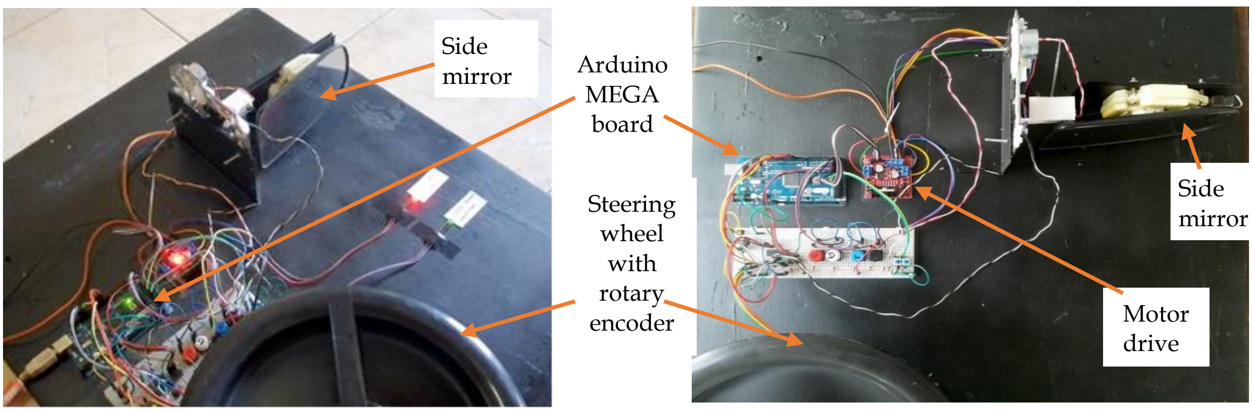


Fig.11. Test model setup

The arrangement of the test model along with the components are shown in Fig. 11, and the results are tabulatrd in Table 8. Referring Table 8, the experimental results show that the system accurately works in both manual and auto modes by complying with all the conditions as defined. In manual mode, the movements of the mirror could be obtained as the requirement of the driver irrespective of the signal light, vehicle speed, and steering angle status, which is the requirement. In auto mode (refer the shaded row) all the three conditions, the signal light (on), vehicle speed ($<15 km/h$) and steering angle ($180< \alpha<540$) should be satisfied to automatically adjust the angle of the side mirror (outwards as required). At this stage, the mirror cannot turn manually. The choice of selecting auto or manual mode is totally decided by the driver as per his convenience.

Real-time 'response-time' is critical in this design. The response time to rotate mirror (from starting position to the end position) is 2-3 *seconds* (average) which is less than 5.5 *seconds.* The response time to rotate the mirror back to the initial position is also 2-3 *seconds* (average), which is acceptable.

Table 8 Results from experiments conducted by the test model (√ - on, X - off)

Manual mode	Auto mode	Signal light on/off	Speed <15km/h	Steering angle 180<α<540	Can operate derection manually Yes(Y)/No(N)				Mirror turning			
					In	Out	Up	Down	In	Out	Up	Down
√	X	√	√	√	Y	Y	Y	Y	√	√	√	√
√	X	√	√	X	Y	Y	Y	Y	√	√	√	√
√	X	√	X	√	Y	Y	Y	Y	√	√	√	√
√	X	√	X	X	Y	Y	Y	Y	√	√	√	√
√	X	X	√	√	Y	Y	Y	Y	√	√	√	√
√	X	X	√	X	Y	Y	Y	Y	√	√	√	√
√	X	X	X	√	Y	Y	Y	Y	√	√	√	√
√	X	X	X	X	Y	Y	Y	Y	√	√	√	√
X	√	√	√	√	**N**	**N**	**N**	**N**	-	√	**X**	**X**
X	√	√	√	X	N	N	N	N	-	X	X	X
X	√	√	X	√	N	N	N	N	-	X	X	X
X	√	√	X	X	N	N	N	N	-	X	X	X
X	√	X	√	√	N	N	N	N	-	X	X	X
X	√	X	√	X	N	N	N	N	-	X	X	X
X	√	X	X	√	N	N	N	N	-	X	X	X
X	√	X	X	X	N	N	N	N	-	X	X	X

2.8 Cost Analysis

The BoQ and costing for the developmet of a prototype based on the final conceptual design is given in Table 9. The total cost is Rs. 38,691.00 which is much less compared to an additional amount a buyer has to pay for a vehical with a blind spot detecting option. Assuming a profit margin of Rs. 10,000.00 (10% of the selling price) the product coud be marketable for a price around Rs. 50,000.00. However a comprehensive financial analysis needed to be performed.

Table 9 BoQ and Cost of design

Component	Quntity (Nos.	Unit price (Rs.)	Total price (Rs.)
Micro DC motor	1	250.00	250.00
Motor Driver Module (L293D)	1	350.00	350.00
SKF Steering encoder (sensor)	1	20,000.00	20,000.00
Arduino Mega Board	1	7,800.00	7,800.00
Wires (Jumper)	40	4.00	160.00
Wires (Circuit connectors)/(m)	1	85.00	85.00
Limit switch (micro)	2	450.00	900.00
Resistores (10K)	10	4.00	40.00
Resistores (4.7K)	2	4.00	8.00
Resistores (6.8K)	2	4.00	8.00
Solderless T tap connector	1	250.00	250.00
Accelerometor	1	650.00	650.00
3D printed mini scale rack & Wheel se	1	3500.00	3500.00
Vero Board 1344-Points	1	150.00	150.00
Toggle switch	1	40.00	40.00
Total overhead cost			2,000.00
Assembly (Installation) cost			2,500.00
Total Cost			**38,691.00**

5 CONCLUSIONS

The design effort of Smart Side Mirror was conducted by adhering to the Product Design and Development methodologies. The aim and objectives of the study were achieved. The final concept is developed based on the critical needs and problems faced by vehicle drivers regarding the existence of blind spots. The final concept was tested by a model simulating real-time test procedure. There are differences in the model with respect to the developed concept (end products) but the operating principles were identical and test results justify the performance of the final concept. The most important parameter is the response time of the system, in which the average response time of the prototype was 2-3 *seconds* which is less than the practical average time when taking a turn, therefore the response time is acceptable. The cost analysis indicates that the amount that a car owner must be spent is worth compared to the risk involved with respect to Blind Spots. The results justify that the final concept is acceptable to produce as an industrial marketable product.

It was understood that the response time of the mirror could be further reduced by designing and replacing the existing cogwheel system of the mirror attachment. Furthermore, the accuracy and reliability could be enhanced by further verifying/cross-checking the operating input signals to the mirror, by using image processing devices such as a camera.

The prototype development takes more time and due to the time constraints, it is beyond the preview of this study, but it is recommended to conduct a prototype test with the real vehicle and to get confirmed the results of this study.

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