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CONCEPTUALISATION

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Smart bicycle helmet

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Contents

Introduction

The team was asked to develop a device that attaches on a helmet and makes it into a smart helmet. This report is in the continuation of the previous report which contained need statement, market constraints, device functions and customer requirements. So now in this report the team will propose some design ideas for the functions of the device. based on those ideas team will develop multiple concepts of the devices. Then the team will short list those concepts which not feasible or not well performing in comparison to others. after that the team will evaluate those short-listed concepts based on the customer requirements and determine the best concept for the device and team will work on the concept for prototype.

Conceptualisation

In this section the team started with a morphological chart in which the team has proposed few concepts based on the customer requirements.
To start with this the team has first got all the functions that the device needs to perform from the functions table of the previous report. The list of functions is mentioned below

- Turn input
- Brake sensing(detection)
- Mood input
- Sunlight sensing
- Power source
- Output light
- connectivity
- Mounting attachment

After this the team had proposed some feasible solutions for each function. Here team had used some existing solutions, but team has also come up with a few of the innovative solutions. As shown in the table 1 below.

Morphological chart

Table 1: Morphological chart

Function	Solution 1	Solution 2	Solution 3	Solution 4	Solution 5
Turn inputs(detection)	Automatic indication (history)*	user controlled (voice, remote, mobile)	navigation control	tilt control(sensor)	
brake inputs(detection)	switch (near brake)	wire sensor (look for movement in the brake cable)	accelerometer	IR sensor	
mood inputs	dial switch	user controlled (voice, remote, mobile)	Battery level	weather forecast	
sunlight sensor	UV sensor	Colour sensor (using here as light but can have more features)	Weather forecast	Light sensor (LDR)	
power source	Cable charging	Solar harvesting	Wind energy harvesting	power bank	combination of multiple
output lights	RGB LED (custom board)	RGB led matrix	Neo pixel RGB Led matrix	led strips	
connectivity	Bluetooth	Internet (Wi-Fi or GSM)	NFC	Zigbee	
mounting attachments	Velcro	2-way tape	Sliding attachments set	magnets	

* Based on the journey history it uses AI and indicate the turns (only useful for daily riders for same route after few journeys.)

From the above table all the solutions highlighted are the innovative solutions.

- Automatic indication: in this solution for turn detection the is going to work on the machine learning as it analyses the journeys of the rider and will turn the lights on and off based on that.
- Tilt control: inside the device there will be a tilt sensor that if the rider bends the neck the light will go on and when he repeats the light will go off.
- Accelerometer: in this solution the device will have an accelerometer inside that sense the acceleration and if deceleration is sensed brake light goes on.
- Weather forecast in this the device will get the weather information from the external device and would use that information for further operations.
- Wind energy harvesting: in this the device will have a fan attached that can be used as a power source as the rider rides the bike the fan will rotate by wind energy and that fan will move the dynamo attached which will convert the wind energy to electrical, and thus power the device.
- LED strips: this are the normal LEDs strips used in ambient lights. But here they are arranged in a different manner to give desired outputs

Considering the existing as well as innovative solutions proposed by the team for listed functions, there are multiple ways for designing the product. Some of them are selected to meet the requirement in a practical manner. In turn, building up the concept. But here the team has proposed

good 15 concepts that can be discussed and studied further. These 15 concepts are based on environmental effect, innovative, feasibility and cost.
They are all mentioned in the table 2 below in the concept table.

Concept table

Table 2: Concept table:

functions	Concept1	Concept 2	Concept 3	Concept 4	Concept 5
Turn inputs(detection)	Tilt sensor	Combination of tilt sensor &automatic indication	Navigation control	Tilt sensor	Navigation control
brake inputs(detection)	accelerometer	switch	Wire sensor	accelerometer	IR sensor
mood inputs	Dial switch	User controlled	Battery level	Weather forecast	Dial switch
sunlight sensor	Light sensor	Weather forecast	Colour sensor	Light sensor	Weather forecast
power source	Combination of wind and cable charger	Solar harvesting	Cable charger	Wind energy harvesting	Solar harvesting
output lights	RGB led matrix	RGB LEDs	Led strips	RGB LEDs	Neopixel RGB
connectivity	Bluetooth	GSM	GSM	Bluetooth	Zigbee
mounting attachments	2-way tape	Velcro	magnet	Sliding attachments	magnets
functions	Concept 6	Concept 7	Concept 8	Concept 9	Concept 10
Turn inputs(detection)	Navigation control	External remote	Voice controlled	Navigation control	Tilt sensor
brake inputs(detection)	switch	accelerometer	switch	Wire sensor	accelerometer
mood inputs	Battery level	Dial switch	Weather forecast	Battery level	User control
sunlight sensor	Weather forecast	Colour sensor	Colour sensor	Colour sensor	Weather forecast
power source	Sunlight harvesting	Cable charging	Wind energy harvesting	Cable charging	Sunlight harvesting
output lights	RGB led matrix	Neo pixel RGB	Led strips	RGB led matrix	RGB LED
connectivity	Bluetooth	Zigbee	GSM	Zigbee	NFC
mounting attachments	Velcro	2-way tape	magnet	2-way tape	Velcro
functions	Concept 11	Concept 12	Concept 13	Concept 14	Concept 15
Turn inputs(detection)	Automatic indication	Navigation control	Tilt sensor	Combination Tilt sensor & user control	Navigation control
brake inputs(detection)	Wire sensor	switch	IR sensor	accelerometer	IR sensor
mood inputs	Weather forecast	Battery level	Weather forecast	User control	Dial switch
sunlight sensor	Colour sensor	Weather forecast	Light sensor	Colour sensor	Weather forecast

power source	Cable charging	Wind energy harvesting	Cable charging	Cable charging	Combination (wind and cable)
output lights	Led strips	Neo pixel RGB	RGB led matrix	RGB LED	Neo pixel RGB
connectivity	Zigbee	NCF	Bluetooth	GSM	Bluetooth
mounting attachments	magnet	2-way tape	Velcro	Sliding attachments	Sliding attachments

Multiple concepts when made to synchronously function with each other, create various constraints which affect the feasibility of the product. Thence, it becomes necessary to choose the best of them which would work smoothly without affecting the design in any adverse manner. Those which are delisted by the team are mentioned below alongside the reasons for pulling them out: -

- The drawback of the concept 2 is that in some weather conditions the solar energy can not have enough power to run the device and GSM will consume a lot of power.
- The loophole in the concept 4 and 15 is that requires a lot of designing and research for sliding attachments, wind energy harvesting system and weather-controlled mood lighting which will eventually lead to rise in budget and time.
- The weakness of the concept 3 ,5 and 9 is that it uses ZigBee, but it cannot communicate with the smartphone as for the navigation control to get the indication for the turns.
- The concept 6,12, will be too much dependent on the external device which will be consuming lot of data and battery coz they are using navigation and weather which is planned to be input from external device.
- The concept 8 will become a bit bulky in design as it will have voice control system along with GMS and wind energy harvesting systems which will not be comfortable for the users on long rides.
- The concept 14 is over dependent on user for turn and mood selection which will lead to destruction to rider, and which can eventually lead to accident.

Feasible Concepts

So, the team selected the best 6 out of them to get the maximum features whilst also maintaining the qualities of the product. These mentioned in the table below: -

Table 3: final 6 concepts

functions	Concept 1	Concept 3	Concept 7	Concept 10	Concept 11	Concept 13
Turn inputs (detection)	Tilt sensor	Navigation control	External remote	Tilt sensor	Automatic indication	Tilt sensor
brake inputs (detection)	accelerometer	Wire sensor	Accelerometer	accelerometer	switch	IR sensor
mood inputs	Dial switch	Battery level	Dial switch	User input	Weather forecast	Weather forecast
sunlight sensor	Light sensor	Colour sensor	Colour sensor	Weather forecast	UV sensor	Light sensor
power source	Combination of wind and cable charger	Cable charger	Cable charging	Sunlight harvesting	Wind harvesting	Cable charging
output lights	RGB led matrix	Led strips	Neo pixel RGB	RGB LED	Led strips	RGB led matrix
connectivity	Bluetooth	GSM	Zigbee	NFC	Zigbee	Bluetooth

mounting attachment	2-way tape	magnet	2-way tape	Velcro	magnet	Velcro

Evaluation table

Design criteria

Now in this section the team will evaluate the 6 shortlisted concepts on the criteria based on the customer requirements, so those design criteria are explained below

- Mounting capabilities: these criteria will cover the how is the device attached to helmet, how firmly it is attached to helmet.
- Power management: the criteria will cover how battery is charged, how is the battery used, how can the battery life optimised, how is the battery life managed.
- User interface: these criteria will cover all the specifications which are directly in use with the user for example communication, User dependence (user inputs and outputs) and cheek how easy is the product will be for the user to adopt.
- Outputs light: here the team will cheek for how good the lights perform in energy consumptions and the functions.
- Sensing: this criterion will look for how is the sensing of turns, brake, sunlight, and mood working.

Now form the importance table (in the previous report) the team will group the customer requirement under each criteria. And found the priority based on the importance. From the priority the team gave the weighting factor. The sum of the weighting needs to be 1.

Weighting factor calculation:

Table 4: Weighting for each criteria

Design criteria	Customer requirement (from importance table)	Average of importance	priority	Weighting factor
Helmet Capability	Easy to attach (10), firm attachment (10).	10+10/2=10	high	0.22
Power management	Long battery life (9), Easy to charge (10), energy efficient (9).	9+10+9/3=9.3	normal	0.18
User interface	Connectivity (10), Light weight (10), compact size (10).	10+10+10/3=10	high	0.22
Output lights	Turn indicators (10), brake lights (10), mood lights (5), bright lights (10)	10+10+10+5/4=8.75	low	0.16
sensing	Night detection (10), brake detection (10), Turn detection (10).	10+10+10+10+/4=10	high	0.22

From the above table it clearly says that the helmet capability, user interface and sensing criteria has most priority. Power management has average priority. Output lights have the least priority. Based on this criteria team has evaluated final 6 concepts. Then the evaluated score was multiplied by the weighting factor (W.F) to give the relative factor (R.F). and the sum of relative factor will help determine the best concept among those 6.

Evaluation table:

Table 5: Evaluation table

Design criteria	Helmet capability	Power management	User interface	Output lights	sensing	Sum of W. F

Weighting factor	0.22		0.18		0.22		0.16		0.22		1
concepts	score	R.F.	score	R.F.	score	R.F.	score	R.F.	score	R.F.	Sum of R. F
concept1	10	2.2	8	1.44	10	2.2	10	1.6	10	2.2	9.64
concept3	7	1.54	4	0.72	8	1.76	8	1.28	8	1.76	7.06
concept7	10	2.2	5	0.9	7	1.54	7	1.12	8	1.76	7.52
Concept 10	8	1.76	6	1.08	7	1.54	8	1.28	7	1.54	7.2
Concept11	7	1.54	10	1.8	9	1.98	7	1.12	7	1.54	7.98
concept13	8	1.76	5	0.9	9	1.98	10	1.6	9	1.98	8.22

Based on the reasons stated in below tables, the scores were provided in the evaluation table for each of the concepts under each criteria.

Helmet capability(w.f.=0.22)

concepts	Score	Relative score	reason
Concept1	10	2.2	2-way tape is cheaper compared to others and strong enough for holding the device
Concept3	7	1.54	Not all the helmets have capabilities for magnetic connection
Concept7	10	2.2	2-way tape is cheaper compared to others and strong enough for holding the device
Concept10	8	1.76	Velcro would not be as strong as 2-way tape and difficult to attach as compared to others.
Concept 11	7	1.54	Not all the helmets have capabilities for magnetic connection
Concept 13	8	1.76	Velcro would not be as strong as 2-way tape and difficult to attach as compared to others.

Power management(w.f.=0.18)

concepts	Score	Relative score	reason
Concept1	8	1.44	being dependent on wind energy, it will have long battery life and will also be energy efficient and having cable charging function will help rider if required.
Concept3	4	0.72	This concept only has cable charging as only source of power, it will be easy to develop and requires less space but requires to be charge frequently as compared to other it also has higher power consumption for GSM.
Concept7	5	0.9	This concept only has cable charging as only source of power, it will be easy to develop and requires less space but requires to be charge frequently.
Concept10	6	1.08	This concept is dependent on the solar energy, it only works in the places with good sunlight and proves to inefficient for night use also.
Concept 11	10	1.8	being dependent on wind energy, it will have long battery life and will also be energy efficient and self-reliable.
Concept 13	5	0.9	This concept only has cable charging as only source of power, it will be easy to develop and requires less space but still requires to be charge frequently.

User interface(w.f.=0.22)

concepts	Score	Relative score	reason
Concept1	10	2.2	Bluetooth has better connectivity compared to others for device function, and the concept is easy to adopt for used as sensing will not district rider a lot.
Concept3	8	1.76	GSM will possess best connectivity but also contains more user dependent inputs
Concept7	7	1.54	Zigbee only support line of sight communication.
Concept10	7	1.54	NFC would be limiting over transfer of data, and dependent on user for mood input.
Concept 11	9	1.98	Zigbee only support line of sight communication, and easy for rider to use and adopt.
Concept 13	9	1.98	Bluetooth has better connectivity compared to others for device function, and the concept is easy to adopt for used as sensing will not district rider a lot. But it is dependent on the connection for mood input.

Output lights(w.f.=0.16)

concepts	Score	Relative score	reason
Concept1	10	1.6	RGB led matrix is easy to control and program and reasonable.
Concept3	8	1.28	Led strips are easy to use and less costly, but power need to manage as operating voltage is 12V
Concept7	7	1.12	Neopixel are easy to program but requires a custom printable circuit board (PCB) and costly.
Concept10	8	1.28	RGB LEDs will be cheapest among all but need to design soldering.
Concept 11	7	1.12	Neopixel are easy to program but requires a custom printable circuit board (PCB) and costly.
Concept 13	10	1.6	RGB led matrix is easy to control and program and reasonable.

Sensing(w.f.=0.22)

concepts	Score	Relative score	reason
Concept1	10	2.2	Turn input: tilt sensor is compact and easy to program and use. Brake input: accelerometer is consuming more power but does not need external wiring. Mood input: dial switch is easy to install and not dependent on external device. Sunlight sensor: light sensor is cheap, easy to use and compact.
Concept3	8	1.76	Turn input: Navigation will not work if rider knows the way or loss the connectivity. Brake input: Wire sensor is well efficient but need wiring outside device. Mood input: battery level it does not need any extra hardware. Sunlight sensor: Colour sensor has many extra feature can be added.

Concept7	8	1.76	Turn input: External remote will destruct the rider and extra device to carry. Brake input: accelerometer is consuming more power but does not need external wiring. Mood input: dial switch is easy to install and not dependent on external device. Sunlight sensor: Colour sensor has many extra feature can be added.
Concept10	7	1.54	Turn input: tilt sensor is compact and easy to program. Brake input: accelerometer is consuming more power but does not need external wiring. Mood input: user input is dependent on the range of NFC (connectivity). Sunlight sensor: weather input is dependent on the range of NFC (connectivity). And, easy to program
Concept 11	7	1.54	Turn input: Automatic turn need lot of data to setup; switch will need require an extra external wire to communicate. Brake input: switch need to have external wiring and not accurate compared to others. Mood input: weather input is dependent on the range of Zigbee(connectivity). Can be much innovative. (Customizable colours for customer) Sunlight sensor: UV sensor accurate and costly the compared to others.
Concept 13	9	1.98	Turn input: tilt sensor is compact and easy to program. Brake input: IR sensor (brake sensing) not reliable as other Mood input: weather input easy to use and completely automatic. Can be much innovative. (Customizable colours for customer) Sunlight sensor: light sensor is cheap, easy to use and compact.

From the evaluation table it can be stated that the concept 1 will fulfil the customer demand in the best possible manner. And this was supported by the reasons provided, Alongside the relative scores provide to them.

Conclusion

Team had structured the users' requirements as well as market scenario in the previous report which gave team an idea about the kind of device to be created. As there was an attachable device to be created for helmets that possessed modern world's technological features, team also needed a practical solution with specifications achieved through proper planning.

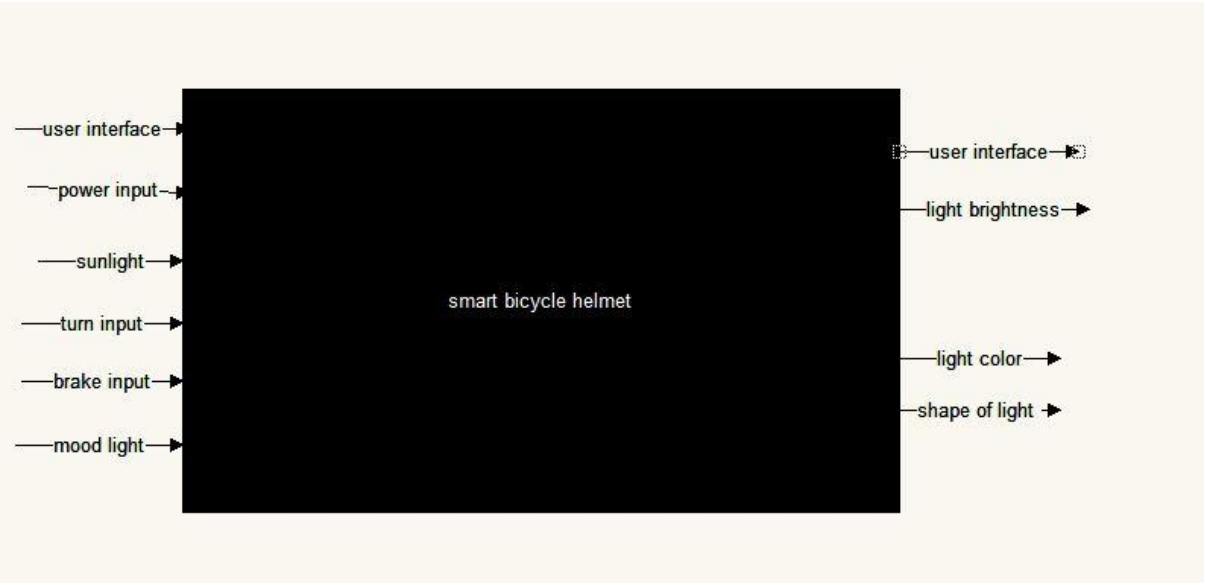
From this report the team had proposed multiple solutions for all the functions of the device with customer demands in mind. Further, those solutions were used to develop concepts for the device which were then evaluated based on the customer requirements. And as the result the best concept to use in further steps would be having combination of tilt sensor, accelerometer, dial switch, light sensor, RGB led matrix, and Bluetooth. It could be powered with wind energy and cable charger.

Also have 2-way tape to mount on helmet. And team suggest that the further prototype must be built on the concept 1.

Appendix

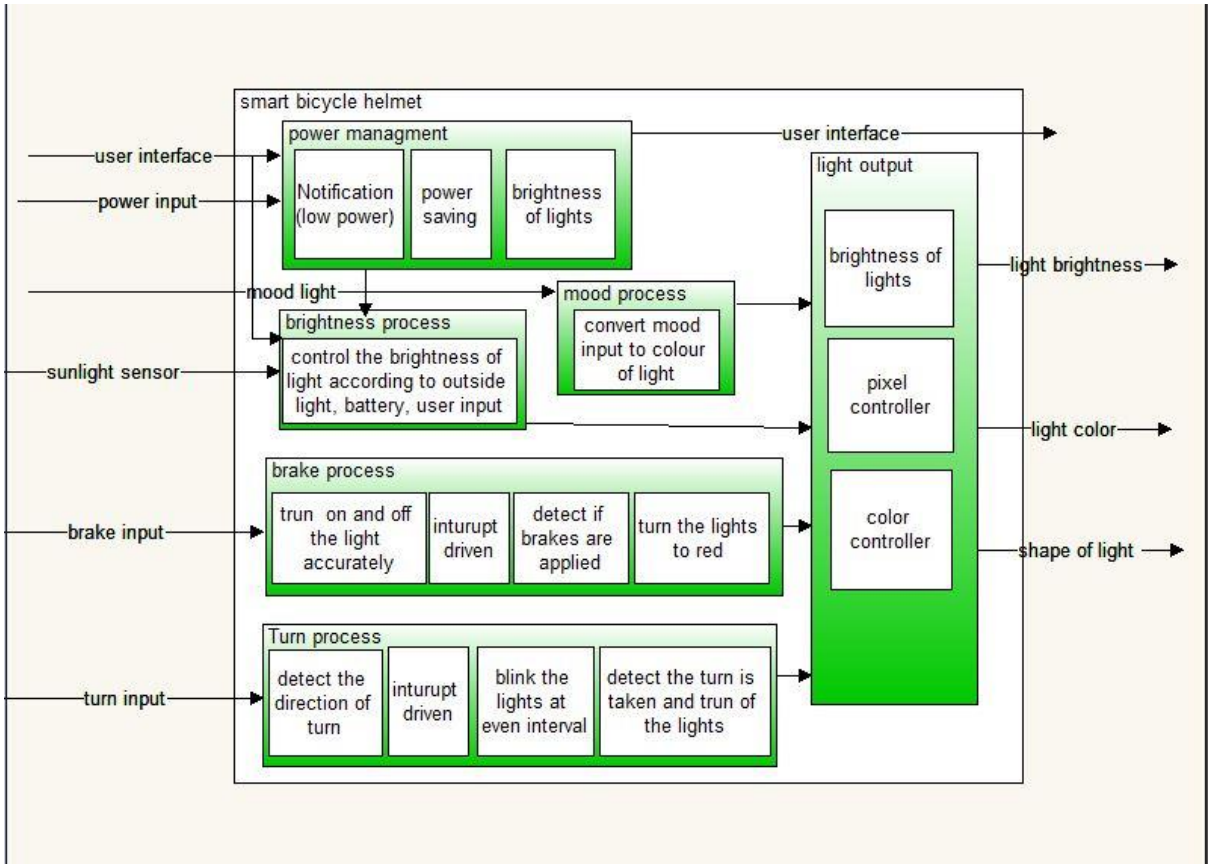
Function design

Black box



White box

In this report the white box has been updated as per the requirements, and team have added few functions that has helped in building concepts and removed few seem less important.



Customer requirement

The wish table was modified according to the requirements of this report as a few requirements were removed as they are not discussed till now.

Table 6: Wish table

Serial number	Customer requirements	Wish/demand	Importance
1	Compact size	demand	10
2	Light weight	demand	10
3	Bright Lights	demand	10
4	Firm attachment	demand	10
5	Easy to attach	demand	10
6	Long battery life	wish	9
7	connectivity	demand	10
8	Turn indicator	demand	10
9	Brake light	demand	10
10	Mood lights	wish	5
11	Night detection	demand	10
12	Low Maintenance and good product life	wish	7
13	Brake detection	demand	10
14	Turn detection	demand	10
15	Easy to charge	wish	10
16	Energy efficient	demand	9

Function diagram

Specifications table

Table 7: Specification table

Customer requirements	specifications
size	<100×70×30mm
weight	<1 kilogram
Lights	Multicolour and <1000mAh
battery	>2000mAh
connectivity	2–5-meter range
Turn indicator	Blinking every 1 sec
Mood lights	Multi colour lights (RGB values)
Light sensor	2-100%
Maintenance	none
Brake detection	Look for decrease in speed
Turn detection	15° or more
Easy to charge	20W charger
Cost	<£100
Light brightness control	30-100%
connectivity	Cellular 5G, Bluetooth 5.0, Wi-Fi 6.0
Water resistance	All electronics
Number of parts	<30
Product life	>50
Electronics enclosed	>90%
Number of mood lights	>2
Number of product colour	>6
Connection to helmet	Adhesive, 2-way tape, Velcro, custom parts
Energy efficiency	>80%
material	Waterproof, reflective at back
Operating voltage	~5V
Light brightness	>5000 mcd