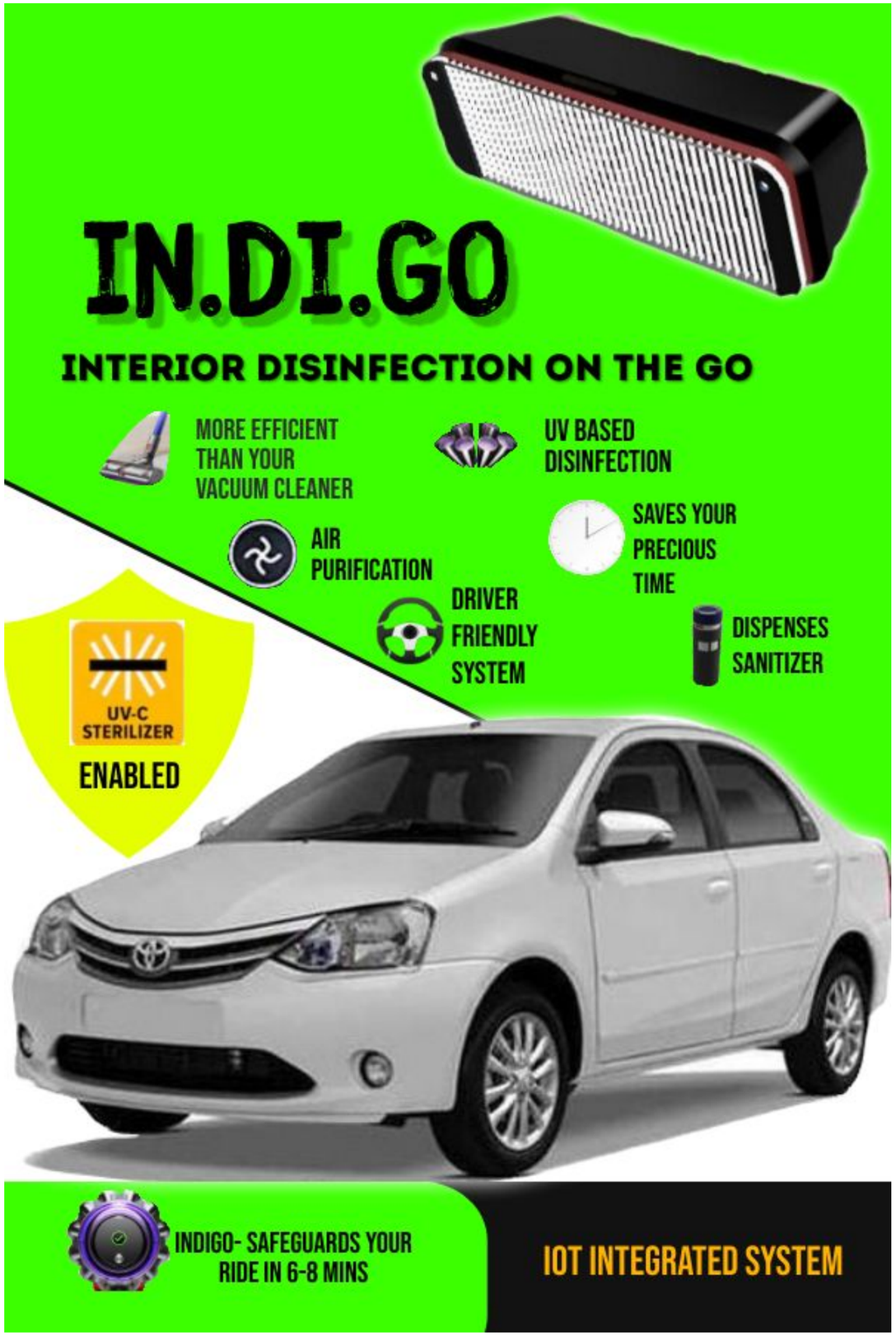

IN.DI.GO
INTERIOR DISINFECTION ON THE GO
MORE EFFICIENT THAN YOUR VACUUM CLEANER
UV BASED DISINFECTION
AIR PURIFICATION
SAVES YOUR PRECIOUS TIME
DRIVER FRIENDLY SYSTEM
DISPENSES SANITIZER
UV-C STERILIZER ENABLED
INDIGO- SAFEGUARDS YOUR RIDE IN 6-8 MINS
IOT INTEGRATED SYSTEM

Problem

Disinfecting the Interiors of a car using UV-C rays of "222 nm" integrated with GPS module and IoT cloud system

Covid-19 accentuated the importance given to hygiene and sanitation, which led to established Cab service providers like 'ola' and 'uber' become more stringent with the safety norms involving disinfection, this is proving to be painstaking and cumbersome for the cab drivers

Process

An interconnected interior system consisting of 3 subsystems connected via IoT cloud platforms.

- A pair of subsystems affixed to the roof handles on both sides of the car using detachable adhesive pads (**Bio-inspired** from **Snails**) emit **Safe UV-C rays** of wavelength 222 nm with diffraction grating
- The 2nd subsystem affixed to the dashboard consists of an air purifier and a UV-C emitter which disinfects the shotgun seat.
- The 3rd subsystem is a vacuum pump which has four tubes like tentacles (**Bio-Inspired** from **Octopus**) which transfers the dust to a bag attached under the driver's seat (**Bio-inspired** from the **rumen of a cow**).
- The starting and cessation of the entire system is controlled by GPS.

Proposal

This project addresses the urgent need of an *Urban Ecosystem* to disinfect the interior of cabs (*New Norm*)

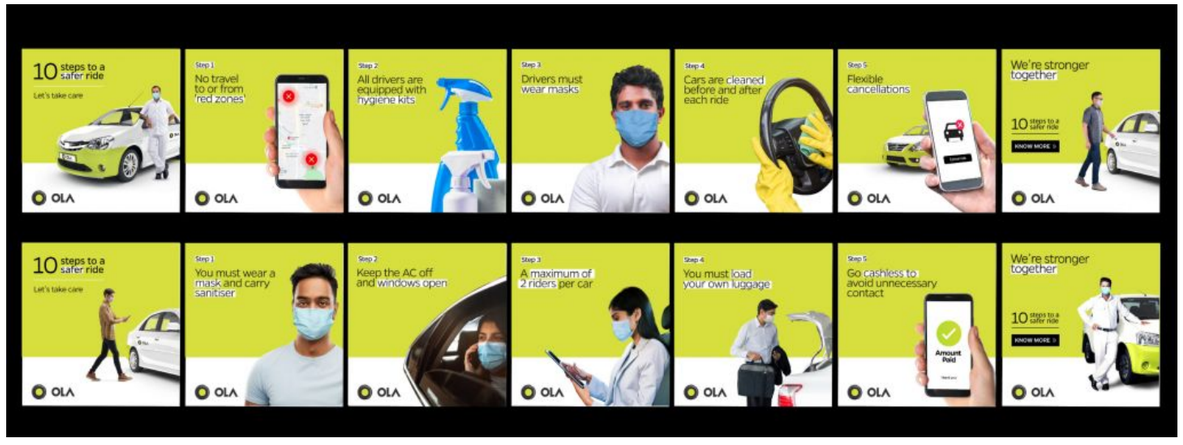
- This product targets the car dimensions of a sedan which is the most prevalent model in over 250 countries.
- The current UV-C lamp technology uses a wavelength in the range of 254nm and is composed of high energy particles. Exposure to such harmful rays can prove to be fatal, hence we have substituted the existing UV range with a range of 222nm.
- There is a provision to add accessories which clean masks and dispense sanitizer

Proposal- Current methods

What are the Guidelines and safety precautions currently being employed by the cab services across India?

Drivers of the Ola platform have undergone dedicated training modules and received guidance, which prepared them to follow mandated safety precautions. These include a detailed understanding of how to carry out

- deep sanitization of cars using disinfectant liquids
- wipe down high-touch surfaces, which is carried out before every ride
- practice recommended personal hygiene and maintain hygiene equipment in cars



For Driver-partners:

1. No travel in red zones
2. Selfie-authentication of drivers
3. Equipped with hygiene kits
4. Cars to be cleaned regularly: Common surfaces like the handle, inner handle and seat to be cleaned before every ride.
5. Flexible cancellations
6. Cashless payments

For Customers:

1.
2. Wearing a mask is compulsory
3. AC to be switched off: To avoid re-circulation of air
4. 2 passengers per car
5. Load and unload luggage themselves

Briefly:

- Uber and Ola have made it mandatory for their driver executives to wear masks. Ola has asked its partners to authenticate the same before the start of every ride by sharing a selfie through their partner app.
- For riders, the platforms have advised cashless payments which will ensure minimum contact. Flexible cancellation policy has also been introduced by both companies under which the customer or driver-partner can cancel the ride if they feel the other party is not following the rules or not wearing a mask.
- Ola has further requested its riders to load and unload their luggage themselves to help maintain social distancing and said that it will provide its driver-partners with masks, sanitizers, and disinfectants.
- Ola has mandated all vehicles on the platform to follow hygiene and safety standards that will include the cars being cleaned and sanitized before every ride. Fumigation of the vehicle will also be done every 48 hours. a protective screen between the driver-partner and passengers have been installed
- Regular temperature checks of drivers are closely monitored. If a driver fails to adhere to these, he is sent an app reminder and is given a 24-hour window to complete the processes, failing which he is off-roaded.

Flaws :

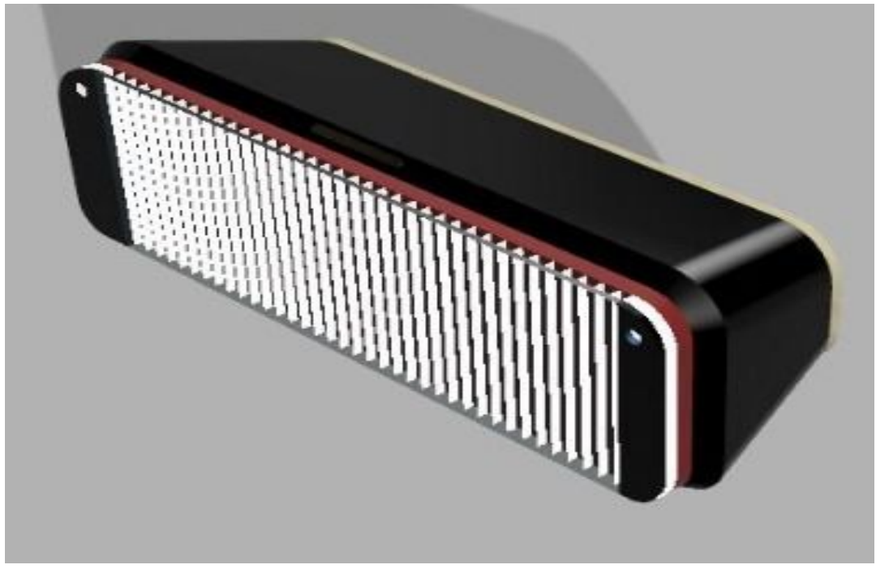
- A major psychological aspect plays into account in the current scenario, number of reports of drivers being paid less by the established services have surfaced in the recent times, in such a scenario, one can easily question the dedication with which the sanitization of the seats is being done
- Though mandatory fumigation after every 48 hours sounds like a good idea, 48 hours is a rather large time interval as the vectors can easily transmit the disease and disrupt the whole service when a case is reported
- Cleaning the foot mats has always been an issue, they have to be entirely removed and dusted, the only alternative is to go to a carwash and get professional help, which may not seem to be lucrative from a business standpoint
- Unclean interiors play into the minds of the potential customers, that is, the passengers, this may lead to cancellation of rides without any repercussions because of the introduction of the ' Flexible cancellations' system
- Cleaning the Common surfaces like the handle, inner handle and seat before every ride is gruesome on the driver, to say the least, after toiling 5-6 hours a day and dealing with customers with different mindsets and behaviours, the last thing they would need is a physically taxing task

Proposed Method of Cleaning 'n' Disinfection

Uv based disinfection:

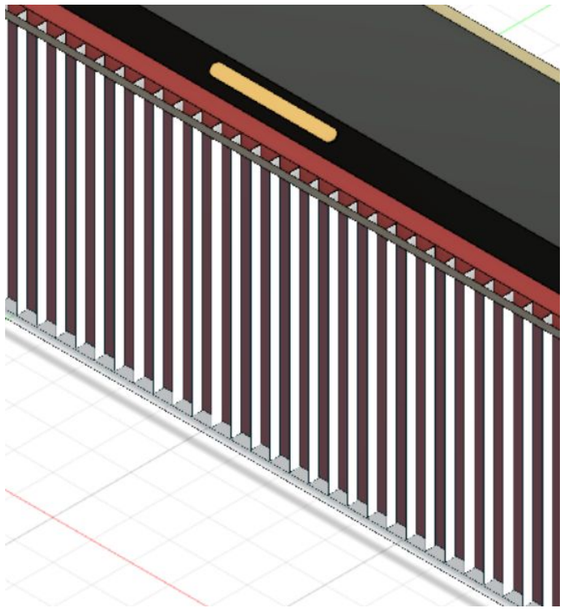
Coming up with a solution for the new normal requires a novel idea and execution. Cleaning and disinfection of the back seats are of utmost importance since customers using the cab services are reluctant to use cabs which have not been disinfected.

UV-C rays are extremely effective in removing the COVID-19 virus from surfaces and have found extensive uses in hospitals and public places. Exposure to UV-C for even 10 secs may lead to drastic consequences however that does not mean that we have to reject it and restrain ourselves from using such a potent technology.



Here we have identified that the traditional 254 nm can be replaced by 222nm far UV-C rays. These lamps will be placed strategically close to the roof handles on both sides of the back of the car.

The use of 254 nm UV-C rays would require the driver to step out of the car for **6-10 min** till the disinfection occurs which would not be helpful. By using the far UV-C rays we have come with a solution that does not affect the driver and removes the need for him to step out of the car.



There are a few drawbacks though, like the fact that we would not be able to control the area over which the UV-C rays fall over and long exposure to Far UV-C rays is also harmful. To tackle this we have included diffraction gratings with aperture comparable to the wavelength of the far UV-C rays. By including the diffraction gratings in the lamps we can reduce the spread of the Far UV-C rays and control the intensity of spread preventing the rays from spilling out of the designated area.

The designated area has been identified to be the seating area, back of the front seats and handles present to open the door. By placing 2 UV lamps on either side of the back of the car we will be able to cover maximum area increasing the intensity of the UV rays on the above-mentioned places disinfecting the seats to the maximum extent.

UV rays originating from the SUN are UV-A rays and have a different wavelength of close to 400nm as compared to the Far UV-c rays having a wavelength of 222nm. The problem of destructive interference is minimal due to this difference in wavelength.

The UV-C rays of the 2 lamps are of 2 different sources having different phase angles and frequency though they emit rays having an equal wavelength. Due to this wave difference, small destructive interferences may arise but this will occur only on the overlapping regions and not completely. This overlapping region will be made to the minimal by taking into consideration the aperture size of the gratings, the spread area of the UV-C lamp used and dimensions of the sedan back of the cab car being serviced.

The UV-C disinfection will be done once the passenger exits the car on reaching the final destination and before the driver accepts the OTP from the next customer. This process of disinfection will be done automatically with the UV-C system integrated into the GPS.

This disinfection process will take 6-8 minutes and it will be the driver's responsibility to be careful when the system starts working to not allow customers into the car during that period. "Opt-In" services can be introduced where customers could be asked to wait for an extra few minutes if the cleaning process is yet to be completed before the next ride.

Air Purifier:

A typical sedan consists of a shotgun seat and a couch at the back typically suitable for a family of 4. The shotgun seat is often preferred by working professionals who tend to give directions or like to converse with the driver on their way to work.

Taking into consideration we have identified that a device placed near the AC vents would be sufficient to dispense the car freshener. However, once the customer has departed, the scent will be replaced by releasing positively charged molecules that neutralise the negatively charged COVID-19 molecules if any present in the air within the car.

This helps to increase the ambience of the car but at the same time ensures that the interiors are disinfected efficiently

An IoT cloud-integrated app that is connected to the Cab service app's GPS module will confirm before the above activity occurs.

Furthermore, a second device will be placed in the area provided before the hand brake. This can be added as an additional sanitizer dispenser for the cleanliness of the driver. This device will be included with a Far UV-C lamp that will be restricted to the shotgun seat area alone.

Vacuum pump:

In the current scenario, the needs of a customer are slowly shifting towards safety and quality of travel, it would not be an exaggeration to say that a passenger would be willing to pay a premium to get the best quality of service, keeping that in mind, it would be a blunder if the cab driver ignores the quality and the cleanliness of the interiors of the car.
Especially with the introduction of flexible cancellations, the rider would be able to cancel the booking without facing any penalty if the interiors and the quality of service expected by the customer are not up to the mark. Cancellation not only reduces the overall revenue, but it also affects the driver psychologically.

An important aspect of cleanliness is the neatness of the floor mats, as it is the area which is highly prone to contract dirt. To tackle this we are using:

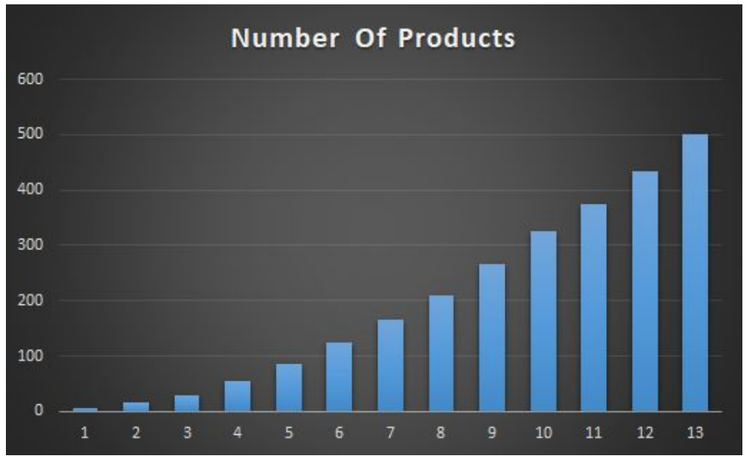
- A vacuum pump which has four tubes like tentacles (**Bio-Inspired** from **Octopus**) will be fastened to the space between the seats (behind the handbrake)
- There would be a single vacuum fan motor which drives the entire system
- The tubes transfer the dust to a bag attached under the driver's seat (**Bio-inspired** from the **rumen of a cow**).
- This vacuum system will revolutionize how the floor mats are cleaned inside a car, as the conventional way of cleaning them involves the laborious process of removing them entirely and dusting them, such a process would be useful for rubber/vinyl based mats but would prove to be largely ineffective for floor mats which have a fibrous/matted/rough exterior.
- These types of mats are generally given a wash and then are left out to dry, which may not be a practical way of cleaning given the fact that they take a lot of time, this method of regular cleaning not only helps to keep the car dust-free but also ensures that the longevity of the floor mats increases.

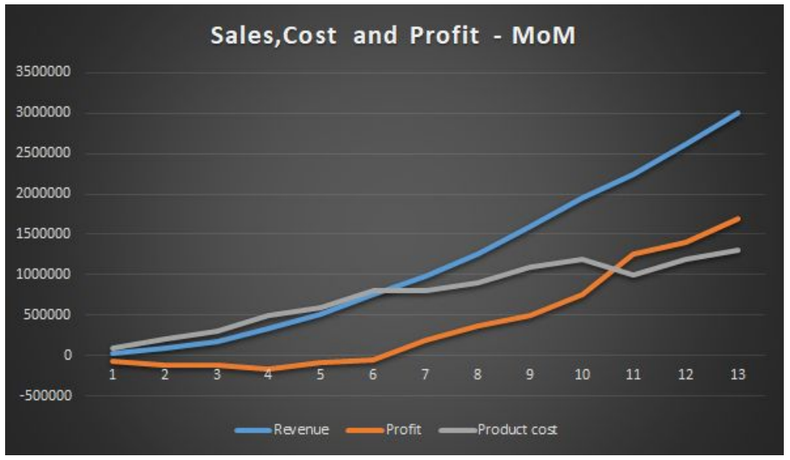
Functioning:

As soon as the driver reaches the drop-off point and the payment is made, the GPS sends a signal to the vacuum, this, in turn, would start the vacuum motor, the system would run for 2 mins to ensure that minimal amount of dirt remains on the mat. After the driver is done with the day's work, the bag can be detached and the contents can be emptied into a dustbin

Business Proposal:

InDiGO is an innovative integrated cleaning system that will be leased out to cab drivers depending on demand at a nominal rate of **RS 1500/ week** and **RS 6000/ month.**
With product cost estimated at around **RS 20,000,** we predict the following revenue growth taking into consideration the current selling price of quality substitute products.
Initial Investment of **25 lakhs** we plan on producing **125** products for an amount of 10 lakhs with 5 lakhs used for warehouse rent, manufacturing machinery and advertisement.





Analysing the above graph we estimate 500 products to be sold at the end 1 year and 3 months. The number of cab services in India alone is 80 lakh cabs with TamilNadu alone contributing to 4.04 lakh cabs. At this rate we would be able to provide around 5000 cabs at the end of 2nd year and 20000 products at the end of 3rd year. We predict a break- even analysis at the end of the 6th year and estimate providing service to over 2 lakh cabs at the end of 5 years.

FUTURE EXPANSION:

- Due to the Pandemic, people are afraid to opt for carpooling because of the pandemic, this has reduced the number of customers per ride and has led to an increase in carbon emissions. By providing this disinfecting service we can revive this pre covid revolutionary service, thereby providing a safe and clean service for all.
- The energy sources can be made renewable such as extracting energy from the rotating axles, solar power irradiated on the car, hydrogen packs can be used to provide the energy for the vacuum pump and UV-radiation lamps.
- It can be linked to the IR temperature recorder if the temperature of a passenger sitting on any seat records higher than recommended or preset, this apparatus will not function and a notification will be sent to driver/operators helpdesk for necessary directions.
- Camera sensors can be used to detect if customers are wearing masks. Using computer vision, the position of the masks on the face can be recognized and any displacement from the ideal position can be notified to the customer.
- In the future, we would like to expand the service to Trucks, SUVs and other services.

Strengths

- Lack of direct competitors, threat of substitutes is low.
- Lack of time efficient methods to carry out the same process
- Increased Sanitation increases the number of customers using cab services similar to Pre-Covid
- Car-pooling and usage of AC systems which are restricted now can be resumed in full scale.
- Usage of 222 nm wavelength UV-C has scientifically been validated by researchers.

Weaknesses

- The lack of end user based market
- Customers and drivers following existing regulations on masks can not be tracked and followed up.
- Since UV-C 222 nm is a new research find, there is no practical proof on whether it will be effective in its cleaning other than the research validations.

Opportunities

- Tie ups with existing heavyweights in the cab service industry will help us reach the BEP more easily
- There is scope for improvement/changes in the existing design to cater to the needs of the end customers
- Utilising carwash for disinfecting after every 48 hours would not be lucrative from a business perspective as the number of cars which are needed to be maintained is on a higher scale, therefore it creates a market for a cheaper alternative

Threats

- Negative notions about the use of uv rays for disinfecting
- The current cab- disinfectant system (inefficient one) is very much stable.
- Due to the current pandemic, there may be rise in new entrants in car-disinfectant market.

Supporting Material:

Is UV sterilization effective for viruses and bacteria?

Studies have shown that UV-C at 254 nm is effective against all foodborne pathogens, natural microbiota, moulds, and yeasts. Because microorganisms come with different sizes and shapes that affect their UV absorption, the required time for killing each species varies.

How long does it take to disinfect an object?

- A UV lamp held within 1 inch above a petri dish grown with E. coli will take 1-2 min to show complete sterilization.
- For sterilizing surgical instruments in a medium UV box, it might take 5-10 min.
- For sterilizing an 8-foot biosafety cabinet in a lab, a common recommendation is 30 min.

Is it safe to use a UVC lamp for disinfection purposes?

Pros for UV Sterilization	Cons for UV Sterilization
It is convenient to use and no chemicals are needed. Therefore you won't leave any chemical residue behind.	UVC is dangerous to humans. That's why UV sterilization is usually done using UVC lamps with protective shields. Remember to avoid direct exposure to UVC, especially skin and eyes. Some UVC lamps generate ozone which can be irritating to the airway.
It can kill all kinds of microorganisms including drug-resistant bacteria.	UV only works only in its light path and can be blocked by objects. Make sure what you want to be sterilized is directly in line with the UV light. You can minimize this issue by using multiple UV bulbs to generate UV irradiation from different angles. UVC can degrade certain materials, such as plastic, polymers, and dyed textile.

UV radiation is divided into 3 main groups:

- UVA rays have the least energy among UV rays. These rays can cause skin cells to age and can cause some indirect damage to cells' DNA. UVA (315-400 nm)
- UVB rays have slightly more energy than UVA rays. They can damage the DNA in skin cells directly, and are the main rays that cause sunburns. They are also thought to cause most skin cancers. UVB (280-315 nm)
- UVC rays have more energy than other types of UV rays. Fortunately, because of this, they react with ozone high in our atmosphere and don't reach the ground, so they are not normally a risk factor for skin cancer. UVC (100-280 nm)

What are the different types of lamps that can produce UVC radiation?

- **Low-pressure mercury lamp:** this lamp has its main (>90%) emission at 254 nm.
- **Excimer lamp or Far-UVC lamp:** Type of lamp, called an "excimer lamp", with a peak emission of around 222 nm.
- **Pulsed xenon lamps:** These lamps, which emit a short pulse of broad-spectrum (including UV, visible and infrared) light have been filtered to emit mainly UVC radiation and are sometimes employed in hospital settings to treat environmental surfaces in operating rooms or other spaces.
- **Light-emitting diodes (LEDs):** Light-emitting diodes (LEDs) that produce UV radiation are also becoming more commonly available. Typically, LEDs emit a very narrow wavelength band of radiation. Currently, available UV LEDs have peak wavelengths at 214 nm, 265 nm, and 273 nm, among others.

We are using Far-UVC lamps in our system

So how is UV-C of range 222nm better than UV-C of range 254 nm?

- A wavelength of 222 nm UVC cannot penetrate the outer, non-living layer of the human eye and skin so it won't cause harm to the living cells beneath.
- Since 254 nm UVC harms exposed human tissues, it can only be used to sanitize empty rooms. But 222 nm UVC can be a promising disinfection system for occupied public spaces including hospitals where nosocomial infections are a possibility.
- Studies involving 222 nm UVC, also known as Far-UVC, have so far only looked at its potency in eradicating seasonal coronaviruses that are structurally similar to the SARS-CoV-2 but not on the COVID-19-causing virus itself.
- An in vitro experiment by HU researchers showed that 99.7% of the SARS-CoV-2 viral culture was killed after a 30-second exposure to 222 nm UVC irradiation at 0.1 mW/cm2. The study is published in the *American Journal of Infection Control.*

How are we planning to deliver UV-Rays onto the seats without harming the driver? - Technical Advantage

A NEW METHOD - Diffraction of UV using Fraunhofer method

Fraunhofer Diffraction:

The width of the slit is W. The pattern has a maximum intensity at θ = 0, and a series of peaks of decreasing intensity. Most of the diffracted light falls between the first minima. The angle, α, subtended by these two minima is given by:

$$\alpha \approx \frac{2\lambda}{W}$$

Thus, the smaller the aperture, the larger the angle α subtended by the diffraction bands. The size of the central band at a distance z is given by

$$d_f = \frac{2\lambda z}{W}$$

The difference in phase between the two waves is determined by the difference in the distance travelled by the two waves.

. The path difference between two waves travelling at an angle θ is given by

$$d \sin\theta \approx d\theta.$$

When the two waves are in phase, the summed amplitude, and therefore the summed intensity is maximal, and when they are in anti-phase, then the two waves cancel, and the summed intensity is zero. This effect is known as interference.

The interference fringe maxima occur at angles

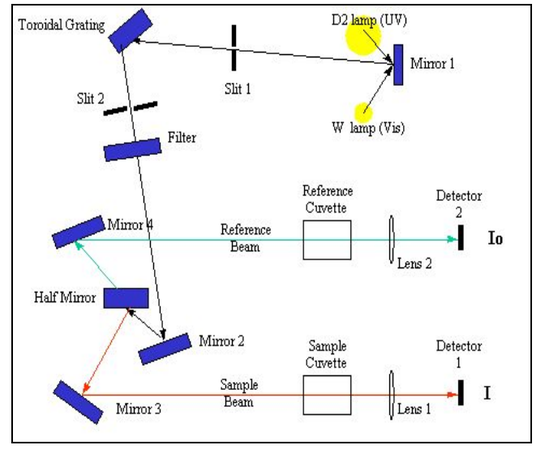
$$d\theta_n = n\lambda, \quad n = 0, 1, 2, \ldots,$$

where λ is the wavelength of the light. The angular spacing of the fringes is given by

$$\theta_\mathrm{f} \approx \lambda/d.$$

When the distance between the slits and the viewing plane is z, the spacing of the fringes is equal to $z\theta$ and is the same as above:

$$w = z\lambda/d.$$



Diffraction Grating:

A diffraction grating consists of a series of small parallel groves. These groves cause interference, which makes the grating split the light into different wavelengths.
It is rotated to the wavelengths selected and diffracts the light into several beams. The direction that light is diffracted depends on the angle and wavelength of the incident beam, and the grating's groove (or line) frequency or the number of grooves on the grating per millimetre.

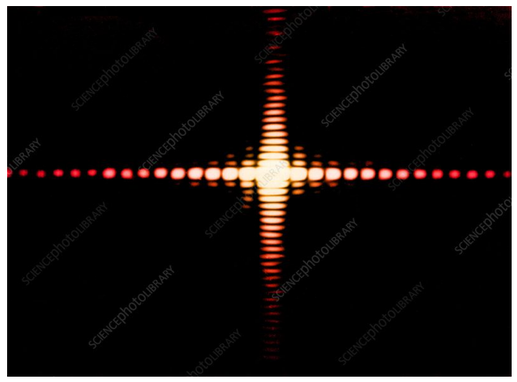
A grating whose elements are separated by S diffracts a normally incident beam of light into a set of beams, at angles θ_n given by:

$$\sin\theta_n = n\lambda/S, n = 0, \pm1, \pm2.....$$

This is known as the grating equation. The finer the grating spacing, the greater the angular separation of the diffracted beams. If the light is incident at an angle θ_0, the grating equation is:

$$\sin\theta_n = \frac{n\lambda}{S} + \sin\theta_0, n = 0, \pm1, \pm2....$$

The image below shows a laser beam diffracted by a grating into *n* = 0 and ±1 beams. The angles of the first-order beams are about 20°; if we assume the wavelength of the **UVC beam is 222 nm**, we can infer that the grating spacing is about **65 µm**.



Diffraction grating is employed to carry out this process to ensure that the UV-C rays do not escape from the rear cabin.
In optics, a diffraction grating is an optical component with a periodic structure that splits and diffracts light into several beams travelling in different directions.
The relationship between the grating spacing and the angles of the incident and diffracted beams of light is known as the grating equation.

The condition for maximum intensity is the same as that for the double-slit or multiple slits, but with a large number of slits, the intensity maximum is very sharp and narrow, providing the high resolution. The peak intensities are also much higher for the grating.

Which segment of the cab industry is our main target?

-Sedan

Usually, when one uses the word "sedan" they're talking about a mid-size or full-size vehicle. Compact and smaller cars also come in sedan form (four doors with trunk) but the word "sedan" is just describing its form factor.
Sedans are described as having "three-box" bodies: the front box is home to the engine; the middlebox is larger and houses the passengers; and the third box, located in the rear, is the trunk.
Sedans have the following average dimensions: car lengths vary from 3995-5027mm, height ranges from 1116-1475mm and width ranges from 1735-1992mm.

Vacuum pumps

Clean-Air Design

A vacuum cleaner design in which the airflow which picks up the dirt is cleaned by the filtering system before it passes through the fan or fans of the suction motor. This design eliminates fan breakage problems which can be caused when objects are picked up by a dirty-air system. It consists of two parallel disks with curved fins mounted between them. The one disk has a very small hole at its hub for mounting it on the motor shaft while the other has a hole about one and one-half inches in diameter in the centre where the air enters it. Typical dimensions are six inches in diameter with one-fourth or three-eighths inch wide fins. It spins at a very high speed, creating a strong suction but is more limited in the amount of air-flow it can handle efficiently. Since the air is cleaned by most of the filtration system before it goes through the fan, the risk of failure of the fan is greatly reduced.

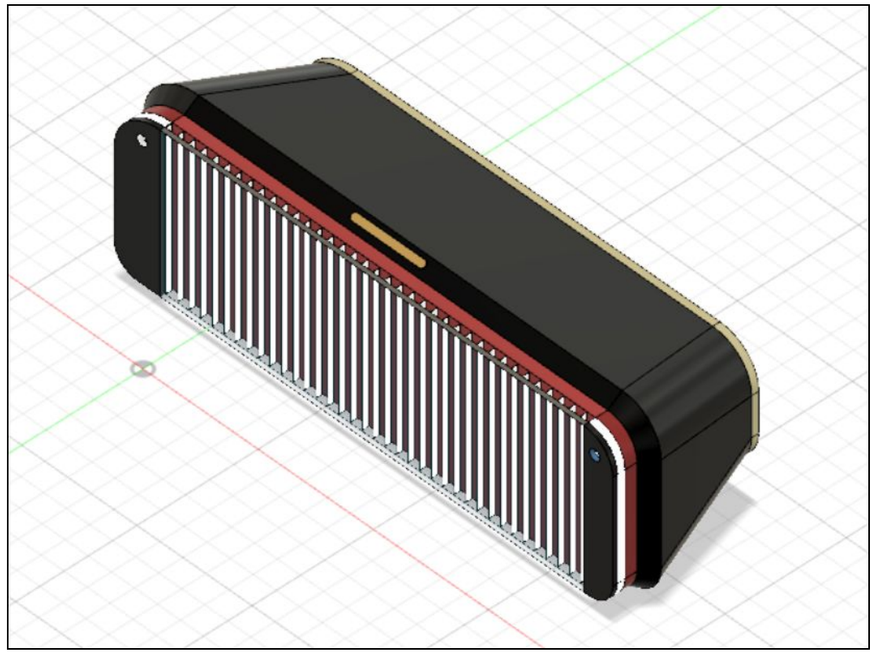
Bag

The vacuum cleaner's bag acts as the process's storage container and air filter. The bag is made with a cloth with microscopic holes large enough such that air particles can pass through but dust and dirt cannot.

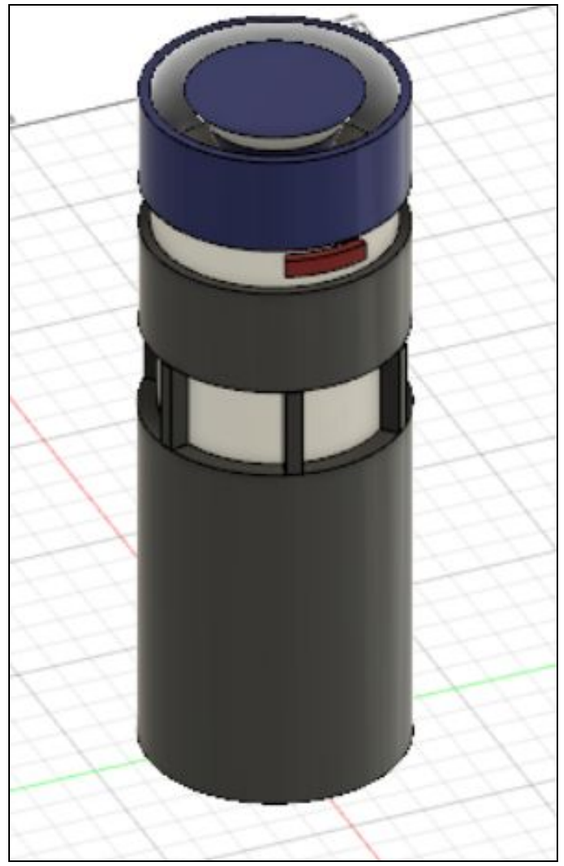
The intake port :

The inlet's opening size is fairly small relative to the rest of the piping in the vacuum cleaner. This design takes advantage of a physical law called the conservation of mass. Since air does not accumulate in the vacuum, all air that enters the vacuum cleaner must leave the vacuum cleaner. This implies that the amount of air travelling through the vacuum must be the same at any point in the vacuum. Therefore, as piping becomes smaller, the stream's velocity must increase. The vacuum cleaner's inlet has a small opening to increase the initial airstream velocity, which helps the vacuum pick up dust and dirt stuck to the floor.

3D CAD MODELS FOR THE ABOVE DISCUSSED SUBSYSTEMS IN A ENLARGED VIEW



This is **UV-222 nm** emitting source that is to be attached to the roof handles in the car.
As **Fraunhofer diffraction** concept is used, there are **multiple grates** after the Uv source to diffract the **Far UV-C** light.



The figure to the right depicts the air purifier cum UV light source so that the shotgun is disinfected every time. An Air purifier is provided so that the airflow out of the AC Vent is purified every time it circulates throughout the car.
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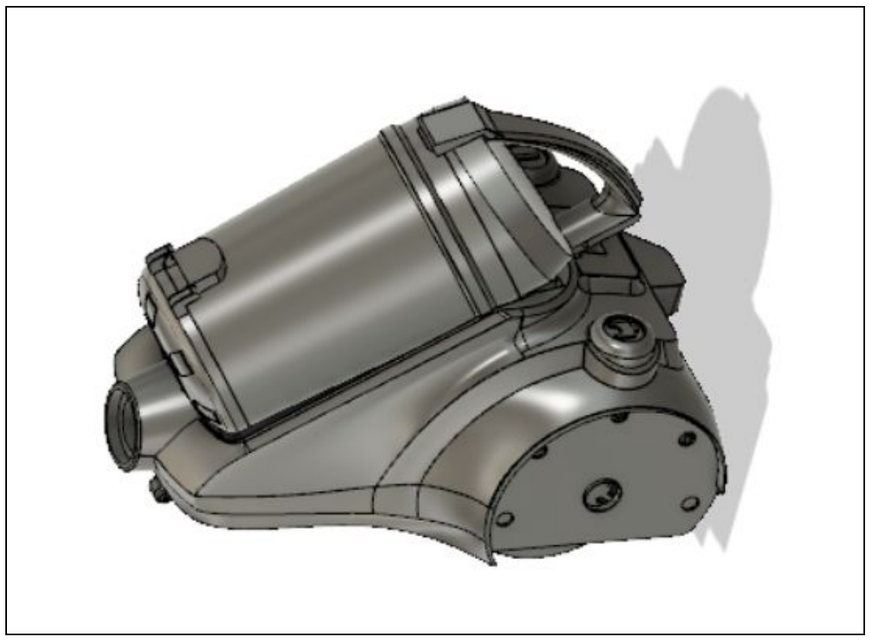

The figure to the left is the vacuum pump we plan on using in the system.

Team Members: Indian Institute of Information Technology Design and Manufacturing Kancheepuram, 3rd Year B.Tech Mechanical

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