BADM525 New Product Development

VEHICLE INSPECTION BOT

(INSPECTOR)

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1. Identify the Need/Problem

What is a problem? The theoretical definition of a problem is *'a matter or situation regarded as unwelcome or harmful and needing to be dealt with and overcome.*' A problem can be found by various means like emerging societal trends, inquiry etc. and the problem under discussion here has been observed during personal experience.

Multiple visits to hotels, malls, parking places, office premises and the human intervention of the security personnel with the vehicles entering the premises was the main reason behind the observation. Their inefficiency to check the vehicles thoroughly and their somewhat careless attitude was the major problem identified. This resulted in holistic thinking about the consequences that could follow and thus a major problem was identified.

The problem got strengthened by reading multiple articles and news about the car bombings that has left the world a significantly unsafe place to live. The number of attacks and the casualties they caused across the globe provided a major platform to think about the problem and what can be done about it.

The problem at hand is the security system at the entrance points of hotels, malls, public parking lots, offices, government buildings etc. which is a combination of human beings and a few tools that are being used to detect the threat. The number of people at a given point in time at these places can be in thousands. A bomb planted on a vehicle and the vehicle parked inside or near these buildings can cause in the multitude of casualties. The only thing that caused this problem was that the suspicious object or the bomb planted on a vehicle that was missed at the security checkpoint located at the entrance to these buildings or there was no security at the entrance at all. There is a need to implement a solution that could reduce the existing problem of human error and could do a better job at examining the vehicles.

2. Problem Validation

For the past few years, most of the jobs that were being performed by human beings have been replaced by machines. Taking an example of a branch of a bank, all the manual register entries, records, etc is now being done using computers and has increased the overall efficiency of the jobs. No manual calculation errors exist anymore and this keeps the customers happier. The world today has seen the advent of robots that are Machine Learning and Artificial Intelligence based and are catching up with human intelligence, sometimes even better. Sophia is one of the robots that has been developed by Hanson Robotics, Hong Kong. It has also been granted a citizenship by Saudi Arabia.

The advent of robots and machines can still be applied to a few untouched sectors and humans can gain from it. One of those fields is security. Although there are security cameras through which the presence of unwanted objects or people can be monitored and alarms that get triggered if there is any unauthorized access, there are places which are still being manually guarded. One such place is parking lots or places where there is a movement of vehicles and the vehicles are being parked for a longer duration of time.

The need of the hour is to inspect the current solutions guarding these places. The current observation suggests that the places where there are entry and exit of vehicles and/or the vehicles keep parked for hours such as parking lots in hotels, malls, public places, offices, government buildings, etc. are guarded by human beings. The role of the security guards is that they inspect all the vehicles entering the parking lots for any kind of suspicious objects like bombs, the vehicle-borne improvised explosive device (VBIED), explosives etc. that can cause damage to the building.

The drawback of the currently used methods to guard the entry/exit points is that it is being done manually and there are always chances of human error. Furthermore, the current method only inspects the exterior of the vehicle and if there is any suspicious object inside the car, there are high chances that it will be missed. Another possible drawback of the current solution is that the human lives are at risk right at the checkpoint itself in case of any unwanted activities such as blasts. Also, humans are corruptible and if there is any malicious activity planned, there is a high likelihood that the security guards might have been bribed to let a vehicle carrying explosives in the parking.

3. Idea Generation

The current solution that is a human guarding a building, has a main flaw that it is hard to check the vehicles effectively and efficiently by human efforts and simple instruments, therefore, a machine or robot that can sense typical materials in the bombs or huge metals which is not part of the car structure would be a better solution to this problem. Moreover, combining Artificial Intelligence with the machine would not only replace the function of the instruments but also have the learning ability of human beings.

The idea of developing a solution to replace a human with a machine that can do its job more effectively and efficiently came by observation. There was a lot of effort that was put into secondary research to identify the features that are feasible and cost efficient to be adjusted in the machine. A number of brainstorming sessions led to the conclusion that if the product has to replace the human it should have the capacity of a machine along with continuous learning capacity of a human. The tasks that were performed by the human security guards included noting the vehicle registration, checking the vehicle interiors (engine, trunk, glove box, etc.) and scanning the exteriors. The humans use their eyes and intelligence to scan the vehicle and make decisions

about any object on the vehicle being objectionable. Similarly, the machine could use cameras to read the number plates and store the data of the vehicles entering the building in a database. The machine should utilize cameras that can move like the human eye or better to visualize the exteriors of the vehicle and as the machine cannot open the doors itself (can do if the machine is a human bot - Sophia by Hanson Robotics, Honk Kong), it should have powerful optical sensors to scan the interiors of the car. Another aspect of the human is that it can see the face of the person driving the vehicle and also move around the vehicle. Once there is no suspicious object in the vehicle, the human security guard opens the entrance for the vehicle to proceed. Similarly, the machine should be mobile. Thus, wheels were added to the machine so that it has the capacity to move around the vehicle and can even go under the vehicle for further inspection, if needed. The camera of the machine should also capture the image of the person and keep it as a record in its database. Once the vehicle is cleared of any suspicious object, another pair of sensors between the machine and the entrance door should communicate to make way for the vehicle to enter the building premises.

While working on day to day basis, the human security guard learns from his experience and also improves efficiency to reduce the time required to check a vehicle. The idea of Machine Learning and Artificial Intelligence struck and by utilizing ML and AI, the human learning capacity can be incorporated in to the product. As the machine did not need any manual intervention to be operated but could be programmed do the job on its own, it was more a robot than a machine.

4. Product concept(s)

There are always various solutions to a problem. It is on the user to choose the one that fits its need the best. But, for an innovator, it is the best possible solution that can be delivered on a value

per dollar basis. To solve the existing problem in a better way, there are multiple solutions that could be adopted. Some of the solutions are discussed below:

4.1. Ceiling mounted camera and sensor based system

The ceiling mounted device will be placed on the ceiling or above head in the pathway for vehicles and the other part of the receiving will be x-ray receiving plate attached to the ground below the vehicle. The vehicles will be required to stop at the entrance. The device mounted on a frame will have a horizontal motion for maximum coverage (Exhibit 2a). The device will use the camera to capture the registration plate of the vehicle, the image of the driver and the x-ray sensor will scan the vehicle for any suspicious objects and the image will be formed on the x-ray plate on the ground. It will need a security personnel to view the x-ray scans and then based on the scans, the human security guards can open the entrance gate or trigger the alarm. The security personnel will be responsible to alarm the security and the police about any suspicious object found in the vehicle. The product is cost-effective and can easily replace the existing process of vehicle inspection, recording the registration plate number. The product still requires minimal human intervention which can be corrupted. Also, some extra infrastructure is required to install the product.

4.2. Sensor based vehicle detection system

This type of system requires two parallel walls on which the sensor can be mounted It makes use of X-ray technology to scan the vehicle (Exhibit 2b). On one wall, the source of the x-rays will be mounted and on the other wall will be the receptor screen to capture the image. As the vehicle passes between the walls the x-rays will capture the image on the other wall which will be transmitted to a computer screen monitored by a security

personnel.. The security personnel will view the x-ray scans and then based on the scans, the human security guards can open the entrance gate or trigger the alarm. The security personnel will be responsible to alarm the security and the police about any suspicious object found in the vehicle. The product fulfils only the need of vehicle scanning but does not capture the registration plate or the drivers face. The product comes with some added costs of infrastructure and needs human intervention.

4.3. Vehicle Inspection Bot

The vehicle inspection bot is movable robot that comprises of a 360° rotating camera, proximity sensor, motion detector and a plasmon sensor. The device starts to function automatically as soon as a vehicle enters the premises using the motion detectors. The vehicle is made to stop at the automated entrance door. The bot will move towards the vehicle and scan the number plate of the vehicle and the face of the driver using the camera. This data will be stored in the database for future reference. The bot will move under the vehicle and capture images of the same to detect any suspicious object. Further, it will move around the vehicle to detect any explosive substance using the plasmon sensor. Once the inspection has been done, the bot will compare the data gathered with the existing database to find any suspicious objects like a bomb or a gun in the vehicle. If there are no undesirable objects found on the car, the bot will transmit the signal to the entrance gate to let the vehicle pass through. In case there is any suspicious object found on the vehicle, the bot will apply electronic brakes of the vehicle so that the vehicle cannot move. It will further trigger an alarm for the local security and also for the police, thus helping the culprit get caught. The product should range between $120,000 to $170,000.

5. Evaluate alternatives

5.1. Product Description

The product here is a robot which is used for inspection of the vehicles entering a premises of a building like a hotel, mall, government building, etc. The product is consists of a motion sensor to detect any vehicle coming through the entrance, a proximity sensor to maintain safe distance from the vehicle, a 360° rotating camera to record the registration plate, the driver's picture, to check the exteriors of the vehicle for any objectionable object on the vehicle, a Plasmon sensor chip to detect the presence of explosives inside the vehicle using optical oscillation technology, a transmitter to send signals to the entrance gate to open or to remain closed whose receiver is at the gate, a wi-fi receiver to connect to the internet (private network) for transmission of videos and images to the database, another transmitter to send the signal to alarm the local security and the local police force. The product also has the capacity to remotely apply brakes electronic to the car if any suspicious object is found. All the sensors, transmitters and camera are mounted on a motherboard which is further connected to a rechargeable battery (The product offers 2 batteries, so that 1 battery can be recharged while the other is being used). The electronic circuits and batteries are placed on the body of the robot that adjusts its height based on the height of the vehicle. The product is mobile and consists of 4 DC motors to facilitate its movement. It has belt like structure (Exhibit 1), like a tank, in place of tyres, to overcome small obstacles in its way. The product has the capacity to move underneath the cars at the entrance of the building premises and can inspect the vehicle. For the vehicles that have very low ground clearance, the product will be dependent on the Plasmon sensor to inspect the vehicle.

5.2. Advantages of the Product

The product has a number of advantages over the current solution and the alternatives. Some of the advantages over the current solution are discussed below:

5.2.1. Increased Security

The sensors of the product makes its accuracy much higher and consistent than the human security personnel. Above that, it is incorruptible. The machine learning and artificial coupled with the robot make it smarter day by day. The product also has the capacity to stop the vehicle remotely in case any suspicious object is found. It will remotely alert the security personnel of the premises and local law enforcement authority about the vehicle.

5.2.2. Portability

The product is similar to the existing practice of human security guards that can move around the vehicle under inspection and can also go from one place to another in case there is a change in the entry point of the building premises. But the added feature here is that the bot is small enough to move under the vehicle and capture a more holistic view of the vehicle from underneath its surface, thus increasing its overall effectiveness. Also, the product comes with a feature of adjusting its height based on the vehicle.

5.2.3. Data retention

The data, registration plate, driver's photographs and the exterior of the vehicles as images are all capture in the online central database. This helps in data retention of the

vehicles entering the premises for a much longer time without destruction and also help the product learn from modelling and data analysis of the data collected.

5.2.4. Continuous learning

The product is based on machine learning and artificial intelligence. This means that the product is not only learning from its experience but also from the data collected by similar products throughout the world.

**The comparison of the product and the alternatives is discussed in Exhibit 9.

5.3. Drawbacks

There is no product which is ideal. There are trade-offs that need to be made to provide one benefit over the other. Some of the disadvantages of the products are discussed below:

5.3.1. Cyber security of the vehicle inspection bot

As the product is connected through a wireless network to transmit the data and images captured during inspection of the vehicles, there is a probability of the product to get hacked and the data be stolen. Also, the hackers can try to change the software of the product thus making it incapable of performing its functions.

5.3.2. Vulnerable to damage

As the product is a small sized device it is susceptible to be damaged by a vehicle. The vehicle can run over the bot and can damage the sensors, camera or even the bot itself.

5.4. Future Benefits

The product is capable of incorporating a vehicle freeze system by switching off the engine of the vehicle remotely if any suspicious object is found. Currently the technology is under development. Also, the product can utilize the bomb-diffusion technology which is currently limited to manually controlled robots.

6. Validation of Product Concept

In recent years, it has been noted that security threats are increasing around the world. Every year hundreds of people lose their loved ones in tragic incidents, putting human lives in a vulnerable situation. There are so many horrible stories where people lost their lives due to a simple mistake of someone else, resulting in complete devastation for their families. A little negligence can put so many lives in danger and therefore, requires a much more sophisticated solution to this problem. Despite taking several measures to improve security through scanners, sensors and CCTV cameras, there is still a huge gap that must be filled to make commercial properties more secure and above all, to prevent loss of human life.

Although, it has been identified through evaluation of different alternatives that none of the solutions can ensure 100% security, however, the need is to introduce a product which can add more efficiency into the security system and also bring down the losses to a bare minimum. The 3 alternatives discussed, have their own pros and cons. For instance, ceiling device is effective in capturing images of the registration plate and the driver, but it won't be able to do a thorough scan of the car. On the other hand, the parallel walls device system can scan the car through x-rays but capturing images of registration plate and driver are out of its scope. Furthermore, both these alternatives are fixed at a certain place, hence, restricting any flexibility required for a complete detection of threats. Also, the x-ray technology may not be a very effective mode of scanning the

cars to a satisfactory level as it won't be able to detect any complex or highly sophisticated modern explosives used by terrorists.

Lastly, in both ceiling and parallel wall devices, security personnel are the ones who scrutinize the images and take the final decision whether to open the gates or not. In many instances, it has been observed that tragedies occurred due to negligence of the security personnel where they failed to do a proper scan. It usually happens in the peak hours when the workload is high, and they become lenient with the checking process. Moreover, long duty hours can make them tired and thus, there are chances of slacking, which can be very harmful.

Humans are corruptible and cannot be relied fully. Supporting the terrorism plan has also been observed in several instances, where the security personnel intentionally allowed the terrorists to pass a security gate or check post. In scenarios, where the security personnel become a party to such heinous crimes, it is nearly impossible to prevent the damage. Therefore, a product is required that can eliminate these concerns.

The technical feasibility of the product puts forward a big question about its success. Here, the product (a type of security bot) is using the available technologies to be incorporated on a single device to perform multiple tasks. There is no new technology that needs to be developed to make the product work. The basic robots are available, the sensors and the transmitters are available with tried and tested technologies and can be mounted on the basic robot for desired function. The product also leaves an opportunity to attach a mechanism to diffuse bombs and also freeze the car by turning off the engine of the car in future.

There was a $1.34 billion market for security robots in 2015 across the globe which is expected to grow at a CAGR of 8.5% to $2.37 billion by 2022. The US consists of the major 41%

share in this market. The major customers of this product is the defence sector, but there is a small market that is growing in the corporate sector as well. Microsoft has deployed security surveillance bots in its headquarters. Also, there are a number of competitors in the US market, which signifies opportunities and an existing market for security robots and the product itself..

From the above discussion, it can be concluded that mobile robot is the most appropriate concept to enhance security of commercial properties, such as hotels, shopping malls, parking lots, sensitive government buildings and, but not limited to office spaces. The mobile robot comes with features that have the capability to minimize risks that go unchecked with the current security measures taken by the owners of commercial properties.

Artificial intelligence (AI) is the key feature of this product. With proper utilization of AI, the robot will be learning on the job not only from its experience but also from the similar bots worldwide that will be sharing the data through a central server. Equipped with advanced sensors and scanning capabilities, enables it to detect the most dangerous threats. The 360 degree camera will further enhance its capabilities by capturing advanced images. The plasmon sensor will help identify the minutest traces of any explosives present. In addition, the mobility of the robot will enable it to move into areas of the car where other systems cannot reach. Furthermore, a robot will not get lenient in carrying out its job or slack due to long duty hours like in the case of human security personnel and will be incorruptible.

There are a few drawbacks of the product that can be overcome. The first drawback is that the product can be hacked as it is connected to the internet. It is advised to connect the product to a private network which is built for its own use and there is no user interference on the network. The other issue of it being small and can be crushed can be overcome by the proximity sensors

installed on the product. As soon as a vehicle moves towards the product, it can move itself into a safe spot, thus cannot be crushed.

7. Product Design

The physical form of the products is a basic robot (XXcm x XXcm) with a height of XXcm. The height of the products is adjustable so as to inspect vehicles of different heights. The mechanism of the adjustable height is like a pallet and is adjusted automatically based on the height of the vehicle. The body of the product has a motherboard on which different peripherals are mounted. The main sensors to inspect a vehicle entering the building premises include, a 360° rotating camera, three signal transmitters, a plasmon sensor, proximity sensor and motion detector. For the movement of the robot, 4 DC motors will be used at each of the wheels supporting the chain track belt. The functions of the motors and the peripherals will be supported by rechargeable lithium-ion battery.

The functioning of the robot is fully automated and no manual intervention is required. The robot will sense the arrival of any vehicle using the motion detector. As soon as the vehicle stops at the entrance door which is closed, the robot will move towards the vehicle and maintain a safe distance using the proximity sensors. The robot will first use the camera to capture the registration plate and the driver's picture. Then the camera will be used to scan the vehicle form outside. All these images will be stored directly to an online database. The plasmon sensor will be used to scan the vehicle from inside for any explosives. In case there is no suspicious object found on the vehicle, one of the transmitter will send a signal to the gate to open and let the vehicle pass through. In case there is any suspicious object (a bomb or a weapon) found on the vehicle, the robot would use the second and the third transmitter to alarm the security personnel and the local police

respectively and to apply remote brakes using electronic circuits respectively. This will allow the vehicle to stay there and will not be able to move until the security arrives.

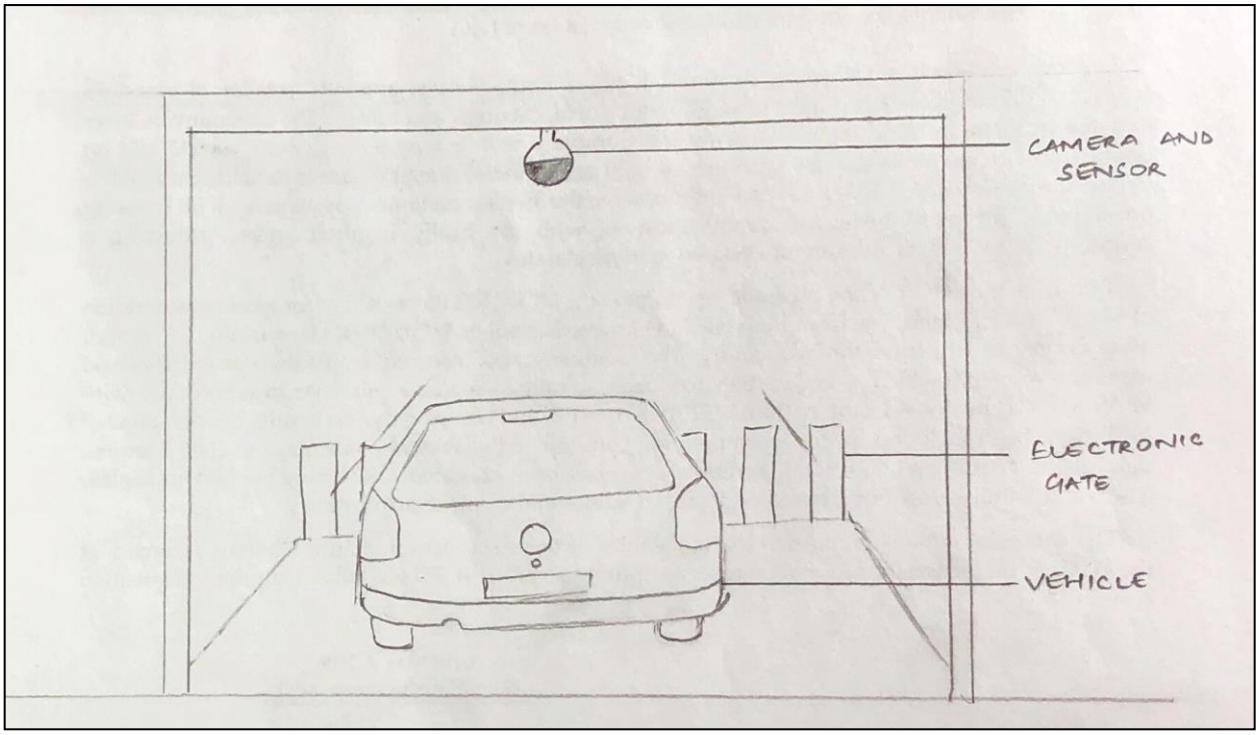
The cost of the product is expected to be around $150,000 including all the components and the assembly cost. The detailed costs of each of the components is discussed in Exhibit 10.

8. Exhibits

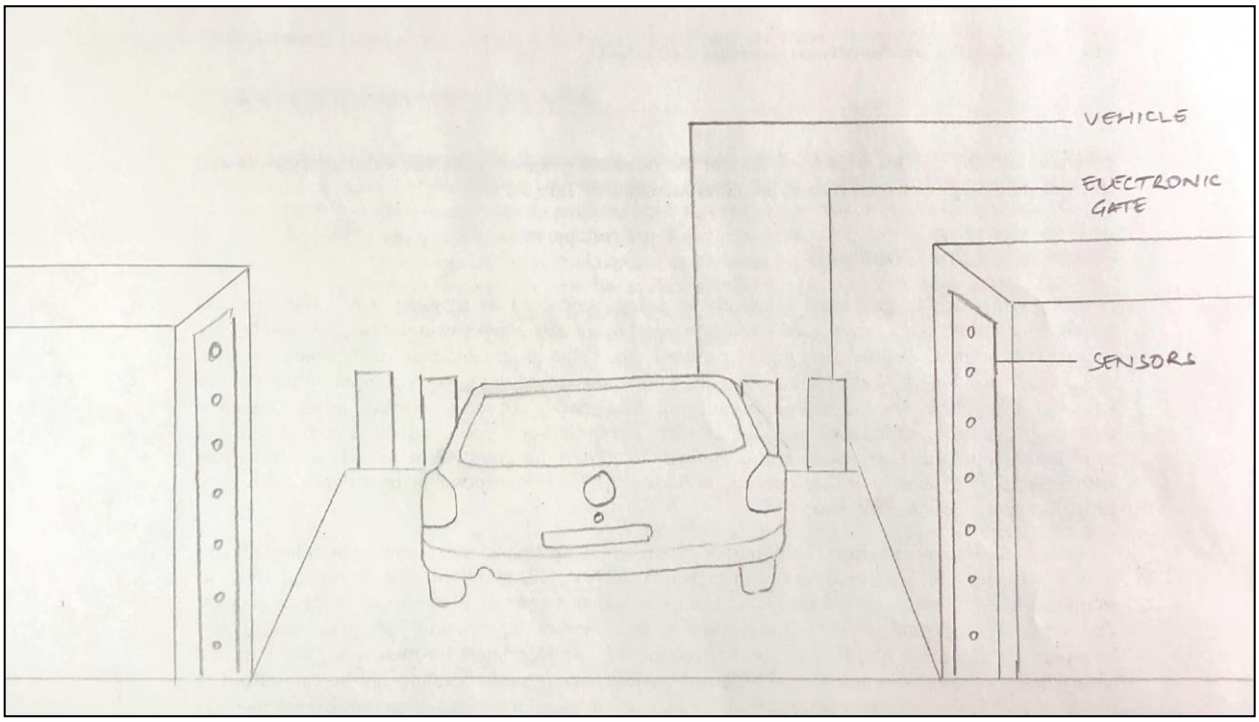
8.1. Exhibit 1 – Product Design

8.2. Exhibit 2 – Design of Alternatives

2a.



2b.



8.3. Exhibit 3 – Classification of the product

1) **Type –**
    i) Unmanned Underwater Vehicle (UUV)
    ii) Unmanned Aerial Vehicle (UAV)
    iii) Unmanned Ground Vehicle (UGV)

2) **Application –**
    i) Patrolling and Surveillance
    ii) Rescue Operations
    iii) Firefighting
    iv) Explosive Detection
    v) Others

3) **Component –**
    i) Camera System
    ii) Propulsion System
    iii) Frame
    iv) Guidance, Navigation and Control System
    v) Other Payload

NOTE – The bold text in each of the Classification suggests the category in which the product falls.

8.4. Exhibit 4 – Major Competitors

Eminent names profiled in in the security robots' market:

1. Elbit Systems Ltd. (Israel)
2. L3 Technologies, Inc. (U.S.)
3. DJI (China)
4. Northrop Grumman Corporation (U.S.)
5. QinetiQ Group plc (U.K)
6. Knightscope, Inc. (U.S.)
7. AeroVironment, Inc. (U.S.)
8. Leonardo S.p.A (Italy)
9. ReconRobotics, Inc. (U.S.)
10. Lockheed Martin Corporation (U.S.)

8.5. Exhibit 5 – Customer Analysis

The target customer base is corporates. The product is suited for use in hotels, malls, corporate offices, public parking, government buildings. In future, the target customers can be housing societies. Companies like Microsoft are already using robot security guards for surveillance.

8.6. Exhibit 6 – SWOT Analysis

Strengths

- Increased effectiveness
- Increased efficiency
- Cost effective
- Incorruptible

Weakness

- Can be hacked as web-based
- High time to market

Opportunities

- Increase in defence spending by the developing economies
- Rising trend of autonomous operations

Threats

- Existing competitors
- Lesser priced models that may develop
- New start-ups in security robot industry

8.7. Exhibit 7 – Achievable Market

Market Analysis for Security Robots		
	2022	**2025**
Worldwide market for security robots (expected)	237,000,000	3,800,000,000
US Market (41%)	971,700,000	1,558,000,000
Expected Market share in US (0.2% in 2022 and 0.5% in 2025)	1,943,400	7,790,000
Cost per robot (Calculated)	150,000	150,000
Number of units sold (Based on above assumptions)	13	52

8.8. Exhibit 8 – Cost Analysis for security personnel

Cost Analysis for security personnel	
Average wages for 1 security personnel ($/hr)	11
Wages for 24 hours for 1 security personnel	264
Wages for 1 security personnel for a year	96,360
Wages for 2 security personnel for a year	192,720
Wages for 2 security personnel for a year	289,080

8.9. Exhibit 9 – Comparison of alternatives

Comparison of alternatives			
Factors of comparison	**Ceiling mounted sensor**	**Wall mounted sensors**	**Vehicle Inspection Bot**
Cost	Medium	Low	High
Infrastructure changes required	Yes	Yes	No
Manual intervention required	Yes	Yes	No
Continuous learning ability	No	No	Yes
Registration plate captured	Yes	No	Yes
Driver captured	Yes	No	Yes
Portable	No	No	Yes

8.10. Exhibit 10 – Cost of the robot

Cost of the robot	
Parts	**Cost**
Basic robot structure (Avg.) in $	75,000
Battery in $ (X2)	30,000
Camera in $	1,000
Plasmon Sensor in $	1,000
Software in $	1,000
Chain Track Belt in $ (X2)	1,000
DC motors in $ (X4)	320
Transmitter 1 (Gate) in $	250
Transmitter 2 (Alarm) in $	250
Transmitter 3 (Brakes) in $	250
Proximity Sensor in $	150
Motherboard/PCB board in $	50
Motion Detector in $	25
Wifi-receiver in $	20

9. References

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