1. **IMPLEMENTATION**
   1. **OBSTACLE NEGOTIATING STRATEGIES**
      1. Types of Obstacles

Before developing obstacle negotiation, the types of obstacles which the robot may encounter should be determined. Since the robot is designed to use in urban terrain, obstacles that are commonly found in urban environment are chosen. Six different types of obstacles are chosen, they are step, ramp, and staircase (see Figure (4.1))

[2D LINE DIAG OF OBSTACLES - IMAGE]

* + 1. Obstacle Negotiation

The main concept of ONS is that the configuration of all the five arms (Front, Rear and Nose) should be such that they should negotiate with the shape of the terrain (formed by the obstacles and the ground) as closely as possible. This can prevent drastic motion of robot as well as enable smooth maneuver on the terrain. Whenever there are obstacles in front of the robot that may block its way, the Nose Arm first comes in contact with it – as it protrudes a bit when compared to Front Arms – followed by the Front Arms and thus the negotiation is done which is shown in the figure.

[2D LINE DIAG OF STEP BY STEP NEGOTIATION - IMAGE]

* + 1. Proposed performance specifications

From the assessment of specifications of different wheeled All-Terrain Vehicles and the calculation of dimensions of common obstacles like steps and obstacles, required specifications to be achieved by the robot are proposed and tabulated.

Table 3.1: Performance Specifications of the Proposed Robot

|  |  |
| --- | --- |
| **Obstacle Clearance** | **Specifications** |
| Slope | Max 45° |
| Staircase | Max 45° |
| Step Height | Max 180mm |

* 1. **DEVELOPMENT OF IAR 1 AND IAR 2**

Achieving a perfect design which could fulfill all the considered objectives was not an easy task. It took weeks of research, consideration of dimensions from several references, mind boggling evaluation, numerous sketches, several drafts of 1:1 scaled 2D sketches, redesigned 3D models and fabrication of three different prototypes. Many mistakes were corrected and many more design additions were made throughout the development.

* + 1. Performance Comparison of IAR 1 and IAR 2

IAR 1 can be considered as a fundamental design. Its body contained two different compartments. One compartment is dedicated for vehicle circuits and the other is dedicated for payload. It is made spacious to incorporate payload ranging from 2kg to 5kg, if it occupied a volume of around 75mm3 for 1kg (100mm3 is an average volume occupied by materials from safety kits to food and tools). Which creates a total payload volume of 150mm3. The rest of the volume is occupied my battery pack and motor circuits.

[3D ISO VIEW OF THE BODY SHOWING COMPARTMENTS - IMAGE]

As shown in Figure, the ground clearance of IAR 1 was insufficient and the base of vehicle body hindered the obstacle negotiating capability of IAR 1 as the base trapped while climbing the stair case and lack of suspension made the robot tumble a lot while traversing on a rough terrain. Greater payload capacity made the robot unable to lift itself up and is also a cause for hindering stair climbing capability. It was very troublesome to replace the battery as it located under the payload space and the payload had to be removed whenever the battery is in need for change.

Based on the lessons learned and experiences gained from IAR 1, several major revisions together with other minor changes were incorporated to bring out IAR 2. One main change is the addition of weight shifting mechanism and suspensions. This brought a major change in performance of the vehicle.

As shown in the figure, the obstacle negotiation has changed but the fundamental strategy remained the same. Here, as the nose presses against the obstacle it suspends inside the vehicle’s body with the help of a spring. The payload along with the battery, which act as the weight to be shifted, are attached to the rod inside the vehicle’s body. Thus, a lift is generated which makes climbing easy.

Tumbling of the IAR 1 provoked to add suspensions. So, after reviewing some reference designs a decision to add springs at the end of the arms, in between arms and vehicle’s body is made. The arms are redesigned as shown in the figure. Several design considerations such as the distance of the spring from the pivot, the angle of the arm from the pivot and its length etc. played a key role in arm design.

[3D ISO VIEW OF THE BODY SHOWING MECHANISM - IMAGE]

Though addition of weight shifting increased the climbing height, a major flaw is detected with the design. Uncontrolled automatic retraction of the nose arm made the weight to shift when there is no obstacle to keep the nose pressed to inside. This lead to the slipping of the whole vehicle Figure. Addition of weight shifting and making the payload as the weight to be shifted made the payload space and amount decrease. It is observed that assembly of the components is also a bit complex which opposes our motto of keeping the design simple.

[2D ANIMATED IMAGE SHOWING TUMBLING]

Table 3.2: Performance Comparison of IAR 1 and IAR 2

|  |  |  |
| --- | --- | --- |
| **Comparison Factor** | **IAR 1** | **IAR 2** |
| Weight of Robot |  |  |
| Space Occupied |  |  |
| Payload Capacity  Max. Volume  Max. Weight |  |  |
| Speed Traversed |  |  |
| Max. Height of Obstacle climbed |  |  |

* 1. **FINAL DESIGN AND PROTOTYPE – IAR 3**

Valuable experiences were gained and important lessons were learned from the two earlier prototype developments. The third and final prototype had considered most of the problems observed in the earlier prototype developments. There were major design revisions as compared to IAR 1 and IAR 2 which are made to preserve the robot’s simplicity as opposed to IAR 2 where it became complex. It is made sure that assembly of the parts is easily done and not confusing to an average user by trimming down unwanted areas and imparting familiar mechanisms. Every actuation of the vehicle is given control to the user to avoid distractions. Even the weight shifting can be controlled by the user.

* + 1. Design of Vehicle Body

Though the dimensions of the body remained the same, the internals have undergone a drastic change. The bottom part hosts the weight shifting mechanism which contains a rack driven by a pinion attached to a 12V motor with 10 rpm. This rack is attached to the weight housing which houses battery & payload. This housing is rested on LM6 slider bearings which slide over a 6mm dia. Shaft of length 200mm. Thus, if the motor is driven, it drives the rack (which is fixed to the housing) which slides over the shafts, providing smooth shifting. This gives the user complete control over the weight shifting as opposed to that or IAR 2. The connecting wires are freely moved inside the body along with the payload housing, but are fixed at the walls of the body.

The external walls of the body are attached with springs which act as suspension and arms which are pivoted with the same walls.

[3D ISO VIEW OF THE BODY SHOWING LINES OF SHAFT, MOTOR, SPRING POSITIONS - IMAGE]

Table 4.1: List of Components in IAR 3 Vehicle Body

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Components** | **Dimensions** | **Specifications** | **Unit Weight (kg)** | **Quantity** | **Total Weight (kg)** |
| Motors |  | 12V at 10 rpm |  | 1 |  |
| Pinion |  |  |  | 1 |  |
| Rack |  |  |  | 1 |  |
| Bearings | 6mm internal dia. | LM6 sliders |  | 2 |  |
| Shafts | 6mm dia. x 200mm length |  |  | 2 |  |
| Battery |  |  |  |  |  |
| Payload |  |  |  |  |  |

* + 1. Design of Vehicle Arms

Links which mount wheels and are connected to the body are termed as Arms. There are a total of five Arms, two Front arms, two Rear arms and one Nose arm. After several revaluations, arms are designed to host, motors, wheels and support springs. The length of these arms are adjusted according to the angle they make when they are pivoted to the vehicle body, in rest position.

Table 4.2: List of Components in IAR 3 Vehicle Arms

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Components** | **Dimensions** | **Specifications** | **Unit Weight (kg)** | **Quantity** | **Total Weight (kg)** |
| Motors |  | 12V at 45 rpm |  | 5 |  |
| Springs | 10mm dia. x 40mm length | SS |  | 5 |  |
| Pivot shafts | 6mm dia. x 35mm length |  | Negligible | 4 |  |
| Wheels | 70mm dia. x 40mm width |  |  | 5 |  |

* + 1. Performance of the Vehicle

Performance evaluation for third prototype has been done and it has been found out that this model – IAR 3 – has been closer to our objectives than any other previous prototypes IAR 1 and IAR 2. The values are tabulated below.

Table 4.3: Performance Evaluation of IAR 3

|  |  |
| --- | --- |
| **Comparison Factor** | **IAR 1** |
| Weight of Robot |  |
| Space Occupied |  |
| Payload Capacity  Max. Volume  Max. Weight |  |
| Speed Traversed |  |
| Max. Height of Obstacle climbed |  |