### Overall Test and Results

After all the submodule tests are conducted and desired results are obtained, we conducted some series of tests to determine overall performance of the system as a whole. These tests are suited to measure the compatibility, synchronization and physical aspects of the module.

To observe all effects and errors we conducted these tests with complete demo setup. Teleoperator is located with a distance slightly more than 30-meter indoor with the robot. Robot is located at demo ground, METU EEE Block E top floor. Moreover, all these tests are conducted 3 times with 3 different teleoperator to minimize the effect of the experience level of operator.

First test was path following test. This test is designed to measure maneuverability of the robot and user friendliness of controller mechanism. To perform this test, a test path is drawn to the ground using red tape. Path contains both straight lines and sharp angle turns. From the teleoperator it is expected to complete the path with minimum time without going off-track. For success of this test we expect to complete the test under 3:30 minutes without going off-track. After 3 test runs all operators succeed to follow the path with 2 minute 26 second average time. Also, all the times are under 3:30 minutes. The use of the robot was simple and response time and speed was satisfactory in this test.

Second test was defense test. This test is designed to measure responsivity of the robot and its ability to defend its goal. To perform this test, half field is built and from 75cm distance ball are shoot to the goal. Total 10 shoot with various speed is sent to the goal for each teleoperator. For the success of this test at least 5 of the balls need to be saved. In the tests 5.33 of the balls are saved by the robot and 2 of 3 teleoperator performed above success criteria. Despite being above the success criteria, these results showed us that for defense, experience level of teleoperator is crucial.

Third test was offense test. This test is designed to measure ball handling ability of the robot and precision of the shoots. To perform this test, complete field is built and at random time intervals a ball is randomly placed into the operator’s half field. Total 10 balls are placed for each teleoperator. For the success of this test at least 7 of the balls should be sent to opponent’s half field and at least 3 of them go into the opponent’s goal. Also, if the ball stays at players half field more than 20 seconds, or player crosses the half field a penalty point is given to the player. In the tests, mean of the successfully sent shoots to opponent’s half field is 8.66. Average 4 of the sent shoots were gone into opponents’ goal. In this test only two player has a one penalty point. The over the top location of the camera gives teleoperator to determine approximate location of the robot with wide angle view. This configuration also makes finding and controlling the ball simpler. Because of that we can say that independent from the experience level of teleoperator, attack ability of this module is simple and effective.

# Budget

The financial expenses on the development process of this module can be examined in two parts, cost of module and additional costs. The cost of module shows the cost of building another module with current parts. On the other hand, additional costs shows the cost of the development process of this module from scratch. This expenditure is non-recurring and totally dependent of the learning process of the team.

## Cost Breakdown

The total expenditure for building the robot is provided in Table 6.1. cost breakdown table.

Table 6.1: Cost breakdown table

|  |  |  |  |
| --- | --- | --- | --- |
| **Materials** | **Quantity** | **Price per each** | **Total Price** |
| **Motors** |  |  |  |
| DC Motors | 2 | $10 | $20 |
| Gearbox | 2 | $5 | $10 |
| Encoders | 2 | $5 | $10 |
| L298N Motor Driver | 2 | $1.5 | $3 |
| **Development Boards** |  |  |  |
| Clone Arduino Uno | 1 | $4 | $4 |
| Clone Arduino Mega | 1 | $10 | $10 |
| **Shooting** |  |  |  |
| Push-Pull Solenoid | 1 | $4 | $4 |
| **Communication** |  |  |  |
| FPV Drone Kit | 1 | $35 | $35 |
| NRF24L01+PA+LNA SMA | 2 | $4 | $8 |
| **Telecontroller** |  |  |  |
| Joystick | 1 | $0.50 | $0.50 |
| LCD screen | 1 | $30 | $30 |
| **Power** |  |  |  |
| 1000 mAH Li-Po Battery | 1 | $14 | $14 |
| 1350 mAH Li-Po Battery | 1 | $18 | $18 |
| Buck Converter | 3 | $1 | $3 |
| **Structural** |  |  |  |
| Plexiglass Chassis | 1 | $6 | $6 |
| Standard Wheels | 2 | $2 | $4 |
| Ball Wheel | 3 | $1 | $3 |
| Cables & Connectors | N/A | N/A | $6 |
| 3D Printed Parts | N/A | N/A | $2 |
| Structural connections | N/A | N/A | $3 |
| **Demo Setup** |  |  |  |
| Dummy Robot | 1 | $2 | $2 |
| Balls | 2 | $0.25 | $0.5 |
| Play Field Walls | 3 | $1 | $3 |
|  |  |  |  |
| **Total:** |  |  | **$196** |

## Additional costs

Additional costs cover the expenses made on the development process of the module. Contains but not limited with cost of necessary tools, software, not used parts due to design changes, engineering cost, etc. These costs are non-recurring costs and after the first product these costs will not repeat.

Table 6.2: Additional costs

|  |  |  |  |
| --- | --- | --- | --- |
| **Materials** | **Quantity** | **Price per each** | **Total Price** |
| **Electronics** |  |  |  |
| Raspberry Pi 3(Unused) | 1 | $35 | $35 |
| Raspi Camera (Unused) | 1 | $30 | $30 |
| Radio (Unused) | 1 | $5 | $5 |
| Extra step-up converters | 2 | $1 | $2 |
| Resistors and Capacitors | N/A | N/A | $3 |
| **Tools** |  |  |  |
| Solder Iron and Utilities | N/A | $4 | $4 |
| Various Tapes | N/A | N/A | $3 |
| Multimeter | 1 | $10 | $10 |
| Scissors and Cutters | N/A | N/A | $5 |
| Tools | N/A | N/A | $20 |
| **Engineering** |  |  |  |
| Non-Recurring Engineering Cost | 200 hr | $0.25 | $50 |
| **Total Additional Costs:** |  |  | **$167** |
| **Total Expenses:** |  |  | **$363** |