**Warman Design Project**

**Team 42**

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**Design Summary**

The Warman design project FLAMEOUT requires an automated system to deposit a total of 10 tennis balls into vessels located around a course. The system also needs to avoid an obstacle located near the centre of the course and return to the beginning once it has finished. It must do this in under 120 seconds.

**Product Design Specification (PDS)**

Functional Requirements:

* System must be able to carry 10 Wilson Tour Competition Tennis Balls and deposit them into 4 vessels.
* System must be autonomous, cannot have any physical contact with any team members or use any wireless systems to alter its path.
* The system must navigate around or over obstacles on the track, which include a PVC rod and the 4 vessels.
* The vessels vary in height; therefore, it must deposit certain amounts of balls into each vessel.

Other Requirements:

* System cannot exceed a mass of 6kg.
* Initial total cubic volume of 500mm x 500mm x 500m.
* System must leave the start/end zone, navigate through the 2.4m x 1.2m track, complete the deposit functions and return to the start/end zone in under 120 seconds.
* The system cannot have any untethered flying systems, and at any given time a part of the system must be in contact with the track.
* Considering the spirit of the competition, the system must be built using off the shelf parts (excluding LEGO), meaning an established system cannot be bought, although parts may be modified.
* Must be started by a single action by a team member without imparting energy (such as pushing).
* System cannot leave parts behind on the track apart from the payloads.
* Each tennis ball has a diameter of 6.75cm.

Design Objectives:

* Minimise the time it takes to complete the requirements set out by the Warman Design Competition.
* Maximise the safety precautions such as by conducting risk assessments and testing, to minimise risks to spectators and potential users.
* Minimise the cost of production, to reduce the associated number of parts and difficulty of assembly.
* Minimise the steps of manufacturing so assembling the system is easier.

**Problem Decomposition**

The blue squares represent critical subproblems.

A screenshot of a cell phone

Description automatically generated

**Brainstorming and Research**

1. Depositing balls

* A crane mechanism to deposit balls individually or a robot arm to grab balls.
* A pipe/tube to lock onto the top of a vessel and deposit balls with great accuracy.
* Projectile via cannon or spring.
* A ramp for balls to slide down and fall in.
* A flying mechanism or drone to deposit balls.

1. Securing balls

* A basket or hopper of balls.
* Vertical or horizontal tubes each containing the amount of balls needed to deposit in each vessel, also has an openable lid.
* Dispenser of some kind.
* Tubes turning to store balls, could also be adjusted into a depositing mechanism.

1. Moving the system

* Wheels, front vs back wheel drive. Also, have different kinds of wheels: mecanum wheels, omni wheels or tires.
* Tracks like on a tank.
* Scissor Mechanisms and Hydraulics to adjust height
* If system stationary then for support: pillars, hydraulics, pillars, blocks, metal stands.

1. Providing power

* Electric motors
* Engines, diesel or petrol
* Gears or purely mechanical system
* Solar power
* Wind

1. Transmitting power

* Hydraulics
* Chains or gears
* Belts
* Electrical via wires from battery

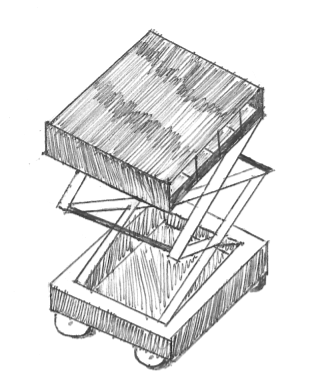
Inspiration and research were conducted via previous Warman projects (on YouTube) and part component sites such as RS electronics. These helped us have a clear vision of what a Warman robot would look like and how we would go about building one.

**Morphological Matrix**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Subproblem | Sub-problem Alternatives | | | | | |
| Depositing | Robotic Arm | Crane | Cylindrical  Container | Box Container | Spiral Tube | Projectile canon |
| Storage | Hopper | Cylindrical container | Dispenser | Spiral Tubes | N/A | N/A |
| Providing Support | Wheels | Tracks | Skis | Balloon Tyres | Mecanum  Wheels | Omni-  directional wheels |
| Power | Electric Motor | Petrol Engine | Diesel Engine | N/A | N/A | N/A |
| Transmitting Power | Gears | Hydraulics | N/A | N/A | N/A | N/A |

**Concept Designs**

From the morphological matrix each team member came up with at least one concept design which was explained to the rest of the group.

Concept 1

Scissor mechanism lifts the top plate up and down so that one of the four gates on the left side of the sketch aligns with the top of the vessel.

Behind each gate is the amount of balls required to go into each vessel on a ramp. Therefore, when the gate is removed the balls will roll down and drop into the vessel.

Concept design 1 has improved by removing the roof of the top plate and therefore reducing mass. The balls at the top have been formatted so that the loads are more evenly spread.

However, in principal the operation of the improved design works the same as the previous. By adjusting the height of the scissor mechanism and opening gates for each vessel.

Concept 2

A close up of a device

Description automatically generated

The robot arm grabs a cylinder corresponding to a specific vessel. It then tilts the cylinder or rotates it upside down to deposit the balls into the vessel.

The containers are designed so when turned upside down or tilted they will fall open and let the balls out.

A drawing of a person

Description automatically generatedConcept 3

The robot arm is designed to quickly deposit payloads into vessels. It does this by shooting the balls along the arm track and down the hole via a spring.

The container is divided into four spaces to separately store the payloads. The small gate inside the container will fold down when the robot reaches its target.

Concept 4

A picture containing drawing

Description automatically generated

# Pugh’s Matrix 1

Each concept design was then evaluated via a Pugh’s matrix where concept A was taken as the baseline.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Categories | Concept A (Baseline) | Concept B | Concept C | Concept D | Concept E |
| Stability | Not great because it only has 1 pillar to stand on. Could add more.  N/A | Scissor mechanism not very stable. Could make it a double scissor mechanism.  -VE | The arm of the robot could change the Centre of Mass, otherwise quite stable.  +VE | Centre of Mass would change due to extending arm. Only 1 pillar joining chassis and mechanism, thus unstable.  -VE | Quite stable due to the position of the wheels.  +VE |
| Accuracy | Fixed height, therefore, not great because payloads could bounce out of the drop-zones.  N/A | Quite accurate due to a varying height.  +VE | Very accurate, considering the code for the arm is done correctly.  +VE | Accurate due to the extending arm.  +VE | If the wheels align themselves properly, it could be accurate.  EQUAL |
| Speed | Tracks would be slower, and they will take time in aligning with the drop-zones.  N/A | Scissor mechanism could take time winding and unwinding, and gates could take time opening.  EQUAL | Relatively quick, deposits fast, however it will take time to put the tubes back.  -VE | 5 motors so would be quick.  +VE | Would need to slow down when going over the obstacle.  EQUAL |
| Buildability | Depositing Container hard to build.  N/A | Depositing container hard to build, as well as scissor mechanism.  -VE | Difficult to code the robotic arm and make it precise.  -VE | Lots of mechanical parts, so had to build.  -VE | Design could be heavy, so materials cost and difficult to get the top part right.  +VE |
| Cost | Expensive due to multiple complex parts.  N/A | Quite costly due to the depositing container, as well as the scissor mechanism.  +VE | Could be very expensive due to the robotic arm.  -VE | Expensive due to the depositing container and multiple motors.  -VE | Fairly reasonable  as there isn’t many complex mechanisms.  +VE |
| Overall | N/A | 0 | -1 | -1 | 3 |

# Pugh’s Matrix 2

We decided it would be easier if we iterated back a step and drew up improved concept designs based on the feedback we gave in the first Pugh’s Matrix. Afterwards we performed another Pugh’s matrix to help us come up with an optimal final design.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Categories | Concept A (Baseline) | Concept B | Concept C | Concept D |
| Stability | Fairly Stable, due to double scissor mechanism.  Potentially unstable whilst depositing. Could enlarge wheels.  N/A | Fairly stable, could enlarge wheels for more stability.  -VE | The mass of the robotic arm while depositing could alter the Centre of Mass of the system, otherwise stable.  -VE | Very Stable due to wide wheels.  +VE |
| Accuracy | Fairly accurate, if it aligns itself with the drop-zones.  N/A | Could be inaccurate for drop-zones ‘A’ and ‘B’, due to the inability to change height.  -VE | As long as the code for the robotic arm is done correct, it will be accurate.  +VE | Fairly accurate, due to varying height.  +VE |
| Speed | Scissor mechanism could take time to wind and unwind, otherwise quick.  N/A | Quite fast due to low mass and multiple motors.  +VE | Robotic arm may take time aligning itself with the drop-zones, otherwise fast.  -VE | Rollers with aligned tread means it doesn’t have to jump over the obstacle.  +VE |
| Buildability | Easy to build apart from the scissor mechanism.  N/A | Not many complex systems so should be easily buildable.  +VE | The robotic arm would be hard to code  -VE | Difficult to build due to multiple complex systems i.e Rollers with  aligned tread, scissor mechanism and depositing box.  -VE |
| Cost | Scissor mechanism, motors and microcontroller may increase the price but within reasonable range. N/A | The middle segment could be costly to build, maybe 3D print.  EQUAL | Costly due to the Robotic arm and the large support wheels.  -VE | Lots of complex mechanisms means a high cost.  -VE |
| Overall | N/A | 0 | -3 | 1 |

**Final Design**

From the Pugh’s matrix we established the following final design.

Our robot will have to begin at a specific location in the start zone due to how the rollers drive over the obstacle. Once started, the obstacle will go straight ahead, over the obstacle and go to A at 0.24m/s. While it is travelling it will raise the scissor mechanism by X mm. It will then spend approximately 5s depositing 1 tennis ball. The robot will then move to B and deposit balls, then at C. Afterwards the robot will adjust itself so it can then go over the obstacle again. Once over it will deposit the remaining 4 balls at D and then finish.

The method we chose to go over the obstacle is all in the wheel design. The wheels have deep grooves in them which allows the 25x25 mm obstacle pass right through if the rotation of the wheel is adjusted right.

In terms of depositing balls, the robot has a main scissor mechanism which adjusts the height of a top plate that stores the 10 tennis balls. We elected to go to vessels A to D as we didn’t want to go to max height at full load. This top plate has 4 gates containing railings for the balls to slide down once the gates are open. Each of these slides represents the balls needed to go in each vessel and are formatted so that the change in centre of mass is minimal when depositing.

-Verify the design: within 6kgs and 500x500x500, stable at lowest and highest position, can go over the obstacle, estimated cost and what parts we might use, battery and motor, and what our score could be

**Teamwork Reflection**

What did you learn from the design process?

As a group we learnt how to effectively solve a non-routine design. Batteries, gears, analysis of design, how to come up with multiple designs, how to effectively eliminate concept designs and evaluate pros and cons of each design, time effectiveness.

What worked for us and what didn’t?

-Didn’t communicate effectively and didn’t use the time well

-Left calculations to late

-Working individually usually didn’t work well, more efficient when working as a group

-CAD worked well

-Coming up with concept designs and solutions to subproblems

What can we do next time?

We needed to follow the design process more closely. We strayed away from it occasionally which left gaps in our design which we had to fill in later. We didn’t follow our problem decomposition very well and did not evaluate the subproblems very effectively. A better approach would have been to use all the subproblems in our morphological matrix as we didn’t include ‘avoiding the obstacle’ in our rapid firing brainstorm session. This may have allowed for better concept designs and even a more potent final design. In terms of calculations, we never really started any until quite late mainly due to uncertainty in how to approach these. Next time, I would highly recommend us to do these earlier on.

**What we need to get done:**

-Calculations

-Teamwork reflection exercise (fastest way is to answer the above questions individually and combine answers)

-Fill out the rest of the morphological matrix and Pugh’s matrix

-CAD drawings and renderings

-Final design explanation in report