Warman Design Project

Team 42

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Design Summary (redo this)

The Warman design project for 2020 requires an automated system to deposit balls into a series of tubes located around a course. The system also needs to avoid an obstacle located in the middle of the course. Furthermore, it must return to the beginning once it has deposited all the balls and this must be done in under 120 seconds.

Product Design Specification (PDS)

Functional Requirements:

- System must be able to carry 10 Wilson Tour Competition Tennis Balls which have a diameter of 6.75cm.
- The system must also be able to deposit these 10 balls into 4 different vessels, which vary in height from 80mm to 300mm.
- 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.

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.

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.

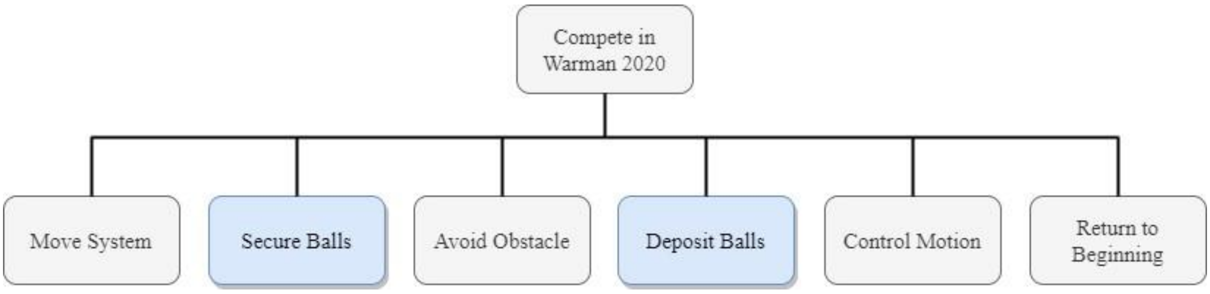


Figure 1 - Product Decomposition

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.

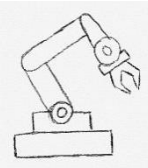
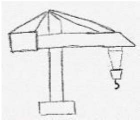
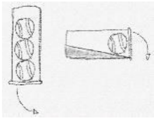
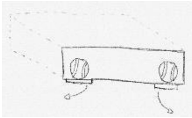
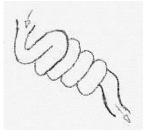
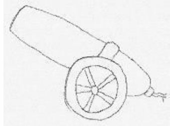
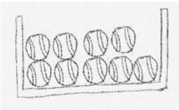
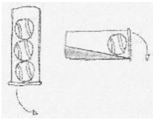
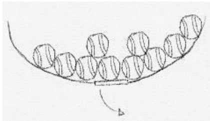
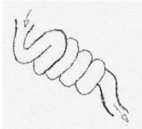
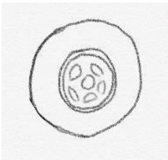
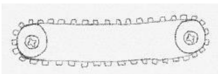
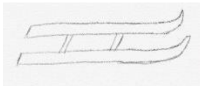
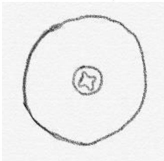
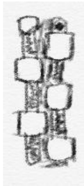
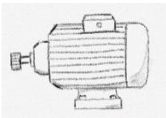
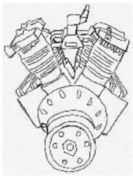
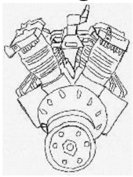
2.) Securing balls
- A basket or hopper of balls.
- Vertical or horizontal tubes each containing the amount of balls needed to deposit in each vessel, also has an openable lid.
- Dispenser of some kind.
- Tubes turning to store balls, could also be adjusted into a depositing mechanism.

3.) 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.

4.) Providing power
- Electric motors
- Engines, diesel or petrol
- Gears or purely mechanical system
- Solar power
- Wind

5.) Transmitting power
- Hydraulics
- Chains or gears
- Belts
- Electrical via wires from battery

Morphological Analysis

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

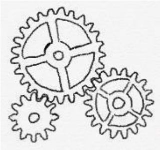
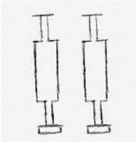
Transmitting Power	 Gears	 Hydraulics	N/A	N/A	N/A	N/A

Table 1 - Morphological Analysis

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

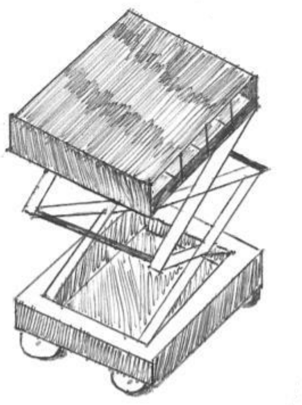


Figure 2 - Concept 1

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 2

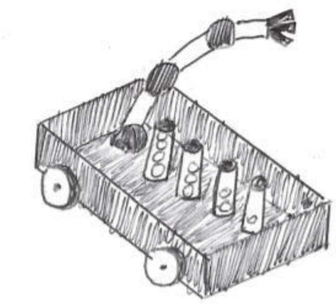


Figure 3 - Concept 2

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.

Concept 3

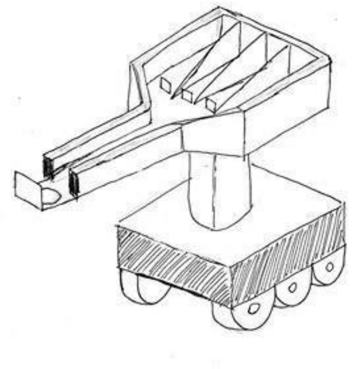


Figure 4 - Concept 3

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

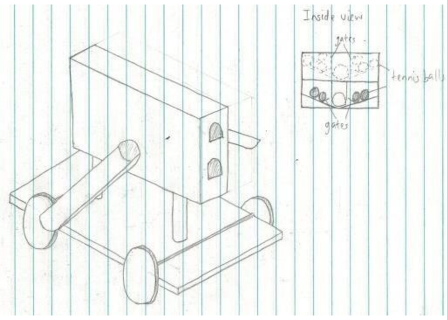


Figure 5 - Concept 4

Concept 5

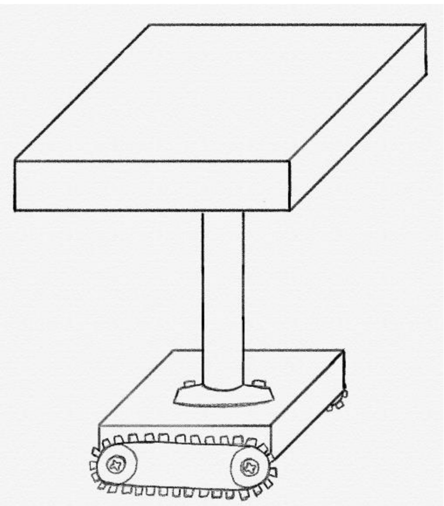


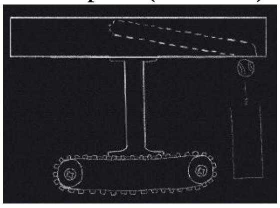
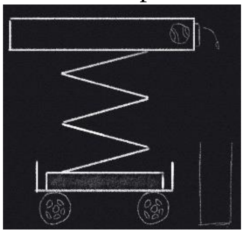
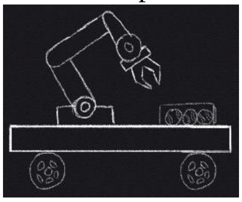
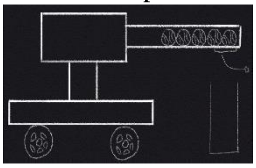
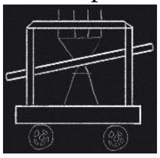
Figure 6 - Concept 5

The robot has a depositing container on top which drops the payloads into the drop-zones once the robot has aligned itself. The pillar in the middle isn't vertically adjustable, so there is a risk the payload might bounce out of the drop-zone. The primary way of manoeuvring the robot is via tracks. This design seemed optimal to get over the angled obstacle, however there might be a tilt of an angle more than desired.

The inspiration for the depositing container came from the game 100 Balls. The chassis and the tracks idea came from military tanks and how easy it is for them to get over obstacles (as shown in movies).

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

Table 2 - Pugh's Matrix 1

Concept Designs Continued

After working on our first Pugh's Matrix as a group, each member went home and worked on our first concept designs to improve what had been discussed. Each member came up with updated designs which are shown below. Concept Design 2 didn't get an upgrade, as it didn't pass out first Pugh's Matrix.

Concept 1

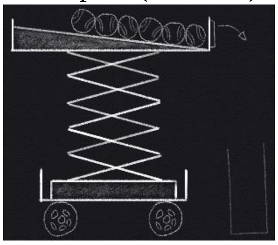
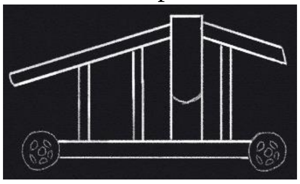
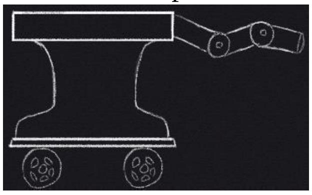
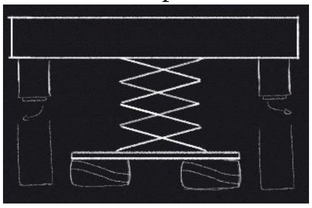
Concept 2

Concept 3

Concept 4

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

Table 3 - Pugh's Matrix 2

Final Design Sketch

Calculations

-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

CAD

- First CAD design.
- Second CAD design

Final Design

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

-Describe how it will operate around the track

-Explain how it will work

Teamwork Reflection

What did you learn from the design process?

What worked for us and what didn't?

What can we do next time?

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