**Optimization and Lego Car Racing Project**

**Phase II**

In Phase II of the project, you will be translating the insights gained from Phase I into a mathematical model that will guide the decision-making process in designing and building your Lego car. This model should integrate all the parameters and values that you have identified in Phase I to determine the most cost-effective combination of Lego parts to maximize the total distance travelled by the car within a $45 budget.

Here are the tasks you need to complete:

1. **Define the decision variables that will be used in your model. This should include but not be limited to the quantity of each Lego part.**

**Decision variables**

Let Xi be the number of parts required of ith part of Lego car.

|  |  |
| --- | --- |
| **X\_i** | **Part Names** |
| X\_1 | plate with bow |
| X\_2 | curved slope,2x3 |
| X\_3 | curved slope,1x3 |
| X\_4 | curved slope,2x2 |
| X\_5 | root tile |
| X\_6 | slope 2x3 |
| X\_7 | steering wheel |
| X\_8 | Small wheel + Slick tire + Bearing element |
| X\_9 | Big wheel + Treaded tire + Bearing element |
| X\_10 | Spoiler |
| X\_11 | Seat |
| X\_12 | Rudder |
| X\_13 | Left Wing |
| X\_14 | Right Wing |
| X\_15 | Motor |
| X\_16 | Flame |
| X\_17 | Wheel arch |
| X\_18 | Clamp |
| X\_19 | Claw |
| X\_20 | Roof tile with lattice |
| X\_21 | angled plate 1x2,1x4 |
| X\_22 | brick with screen |
| X\_23 | mini handle |
| X\_24 | stick with flange |
| X\_25 | radiator grille |
| X\_26 | plate with angle |
| X\_27 | round plate 1x1 |
| X\_28 | plate 1x1 with holder |
| X\_29 | plate 1x1 with holder |
| X\_30 | tile 1x2 |
| X\_31 | angular plate |
| X\_32 | plate 1x2 with clamp |
| X\_33 | plate 1x2 with 1Knob |
| X\_34 | plate 1x2 |
| X\_35 | Brick 1x2 |
| X\_36 | Plate 1x2 holder |
| X\_37 | Plate 1x2 holder |
| X\_38 | Plate 1x4 |
| X\_39 | Plate 2x2 |
| X\_40 | Corner Plate |
| X\_41 | Brick 2x2 |
| X\_42 | Plate 2x4 |
| X\_43 | Plate 2x6 |
| X\_44 | Plate 2x8 |
| X\_45 | Plate 2x10 |

1. **Identify the parameters in your model, including but not limited to the cost of each Lego part and the value of each part from Phase I.**

**Parameters**

* **List of Part\_names**
* **Cost (Ci): Cost of each ith part**
* **Value (Vi): Value of each ith part**
* **Quantity (Qi): Quantity of each ith part**

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
|  | **Part Names** | **Cost (Ci)** | **Value (Vi)** | **Quantity (Qi)** |
| X\_1 | plate with bow | 2 | 3 | 8 |
| X\_2 | curved slope,2x3 | 2 | 4 | 1 |
| X\_3 | curved slope,1x3 | 2 | 7 | 2 |
| X\_4 | curved slope,2x2 | 2 | 3 | 5 |
| X\_5 | root tile | 3 | 3 | 1 |
| X\_6 | slope 2x3 | 3 | 2 | 1 |
| X\_7 | steering wheel | 3 | 0 | 2 |
| X\_8 | 2 Small wheel + 2 Slick tire + 1 Bearing element | 11 | 10 | 2 |
| X\_9 | 2 Big wheels + 2 Treaded tire + 1 Bearing element | 15 | 9 | 2 |
| X\_10 | Spoiler | 3 | 0 | 1 |
| X\_11 | Seat | 3 | 1 | 2 |
| X\_12 | Rudder | 2 | 6 | 2 |
| X\_13 | Left Wing | 1 | 5 | 1 |
| X\_14 | Right Wing | 1 | 5 | 1 |
| X\_15 | Motor | 2 | 4 | 1 |
| X\_16 | Flame | 1 | 0 | 4 |
| X\_17 | Wheel arch | 1.5 | 4 | 1 |
| X\_18 | Clamp | 1 | 0 | 1 |
| X\_19 | Claw | 0.5 | 1 | 2 |
| X\_20 | Roof tile with lattice | 0.5 | 0 | 2 |
| X\_21 | angled plate 1x2,1x4 | 1 | 0 | 2 |
| X\_22 | brick with screen | 1 | 4 | 2 |
| X\_23 | mini handle | 0.5 | 0 | 1 |
| X\_24 | stick with flange | 0.5 | 0 | 1 |
| X\_25 | radiator grille | 0.5 | 3 | 5 |
| X\_26 | plate with angle | 0.5 | 0 | 4 |
| X\_27 | round plate 1x1 | 0.2 | 0 | 6 |
| X\_28 | plate 1x1 with holder | 0.2 | 0 | 2 |
| X\_29 | plate 1x1 with holder | 0.2 | 0 | 2 |
| X\_30 | tile 1x2 | 0.3 | 1 | 3 |
| X\_31 | angular plate | 0.3 | 3 | 2 |
| X\_32 | plate 1x2 with clamp | 0.3 | 0 | 2 |
| X\_33 | plate 1x2 with 1Knob | 0.2 | 0 | 1 |
| X\_34 | plate 1x2 | 0.2 | 1 | 4 |
| X\_35 | Brick 1x2 | 0.3 | 2 | 2 |
| X\_36 | Plate 1x2 holder | 0.2 | 0 | 2 |
| X\_37 | Plate 1x2 holder | 0.2 | 0 | 2 |
| X\_38 | Plate 1x4 | 1 | 2 | 3 |
| X\_39 | Plate 2x2 | 1 | 2 | 4 |
| X\_40 | Corner Plate | 1 | 2 | 6 |
| X\_41 | Brick 2x2 | 2 | 2 | 2 |
| X\_42 | Plate 2x4 | 3 | 2 | 5 |
| X\_43 | Plate 2x6 | 4 | 4 | 1 |
| X\_44 | Plate 2x8 | 6 | 5 | 2 |
| X\_45 | Plate 2x10 | 7 | 7 | 1 |

1. Develop **a mathematical model** incorporating the parameters and decision variables. The model should include an objective function that aims at maximizing the total distance travelled by the car under a budget constraint. Moreover, it should include a series of constraints that represent the factors which might limit the car's performance or the availability of parts. Explain your objective function and each constraint in detail. Ensure that you clearly state what each part of your model represents.

**Objective Function:**

The objective is to maximize total contribution of the parts which helps to maximize the total distance travelled by the car within a $45 budget. The total contribution of the parts is determined by the value of each part multiplied by its quantity, and the budget constraint ensures that the total cost does not exceed $45.

**Constraints:**

1. **Budget Constraint**: The total cost of the Lego parts should not exceed $45.
2. **Quantity Constraint**: The quantity of each part used should not exceed the quantity available in Lego car kit.

**for *i*=1,2,...,45**

1. **Steering\_wheel\_Constraint:** We should have steering wheel.

Where is the decision variable for Steering\_wheel

1. **Motor\_Constraint**: We should have motor and only one.

Where is the decision variable for Motor

1. **Seat\_Constraint**: We should have steat and only one.

Where is the decision variable for Seat

1. **Wheel\_tire\_bearing\_element\_limit Constraint :**

We considered the (Small wheel + Slick tire + Bearing element) as one part and (Big wheel + Treaded tire + Bearing element) as another part and assigned the value for those. Because these things cannot be used separately.

Where is (Small wheel + Slick tire + Bearing element) and is (Big wheel + Treaded tire + Bearing element).

1. **Plate Constraint:**

To arrange all the required parts like Steering wheel, Seat, Motor on plate ,we atleast need a 2x8 or 2x10 plate.

1. **Code your model based on your mathematical formulation using Cplex. Make sure to comment your code adequately so that the logic and steps of your model are clear.**

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1. **Run your model and interpret the solution. Note down the optimal quantity of each Lego part suggested by your model, the predicted maximum distance that your car can travel, and the cost of your car.**

|  |  |
| --- | --- |
| **Part Given by model** | **No of Parts required** |
| steering wheel | 1 |
| Small wheel + Slick tire + Bearing element | 2 |
| Seat | 1 |
| Left Wing | 1 |
| Right Wing | 1 |
| Motor | 1 |
| claw | 1 |
| brick with screen | 2 |
| radiator grille | 5 |
| angular plate | 2 |
| plate 1x2 | 4 |
| Brick 1x2 | 2 |
| Plate 2X8 | 1 |

**The predicted maximum contribution of car: 78.**

**The cost of your car: 45.**