LEGO PROJECT

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Project objectives

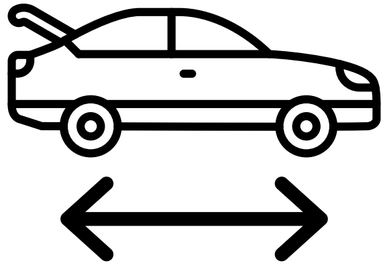
Maximize the distance traveled by a LEGO car down a 30-degree slope.

Goals

- Use Designed Experiments (DOE) to identify optimal configurations.
- Balance cost and performance for the best design.
- Win the Grand Prix for ultimate bragging rights!

Factors and Levels

1



Wheelbase Length

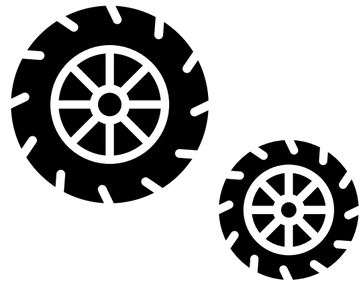
Long & Short

2

Wheelbase Width

Narrow & Broad

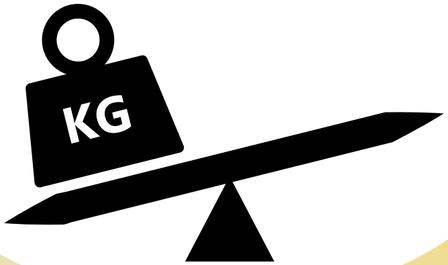
3



Tire Size

Big & Small

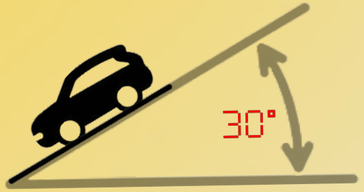
4



Weight Distribution

Front & Back

Experimental Setup



Ramp Construction:
Built with consistent height, angle, and length to ensure uniform conditions.

Release Mechanism:
A stopper was used for controlled and consistent car release from the top of the ramp.

Measurement Process:
Horizontal distance was measured using a traditional tape measure for accuracy.

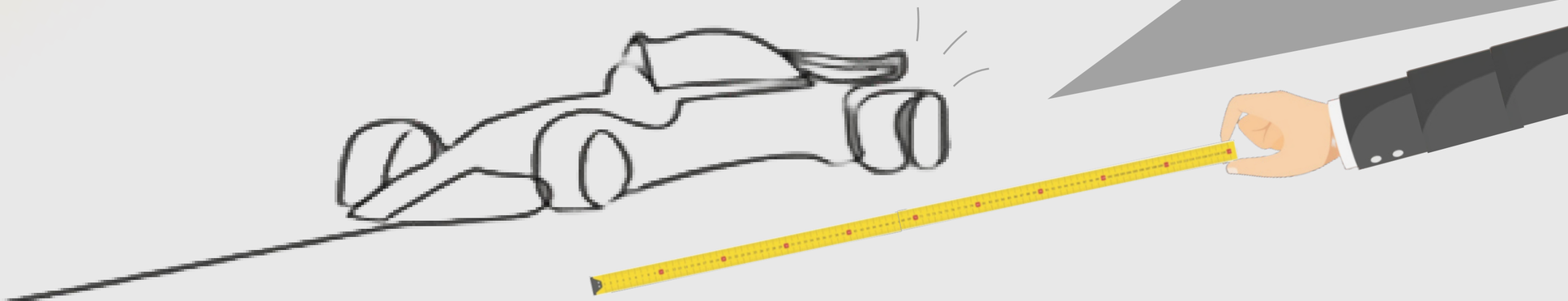
Units:
Distances were recorded in centimeters.

Response Variable

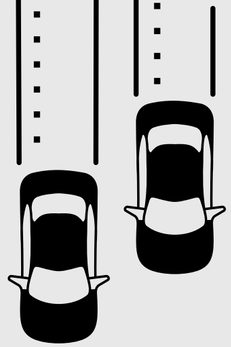
Horizontal distance traveled by the car after leaving the ramp.

Why Horizontal Distance?

- The car design's efficiency is directly related. It's easily measured and offers clear, quantifiable comparisons.



How did we perform the experiment?



Experimental Design

- We applied a half factorial DOE to efficiently assess the factors' impact, exploring their interactions without exhaustive testing.
- We conducted ANOVA (Analysis of Variance) to determine which factors significantly affect the speed of the LEGO cars.

Blocking Noise Parameters

- To reduce outside effects, we tested under consistent conditions - same surface and slope.
- Maintained consistent measurements for reduced variability.

Experiment Execution

- Factor Selection:We had four factors to see how each one influenced the car’s performance.
- Slope Setup: We created a consistent testing environment by using a slope set at a 30-degree angle.
- Car Construction: Multiple LEGO cars were built, each with different configurations based on your chosen factors.
- Speed Testing: We let the cars go down the slope and measured their speed. We used a stopper to release the car and ensured it stayed in the lane.

WHY HALF FACTORIAL?

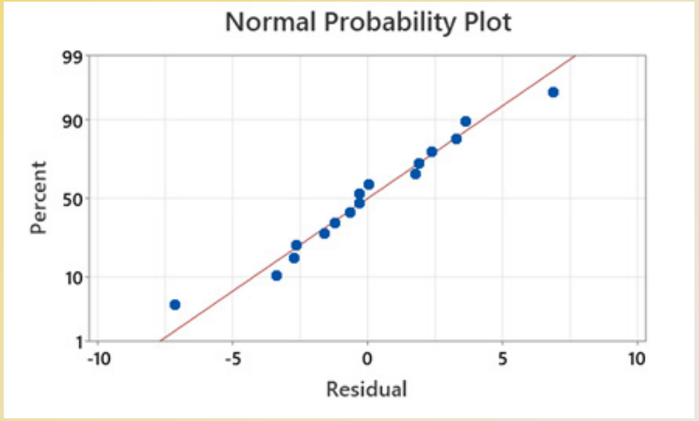
Key Insights: Focuses on main effects and key interactions to identify impactful factors.

Simplified Analysis: Excludes negligible higher-order interactions for clarity.

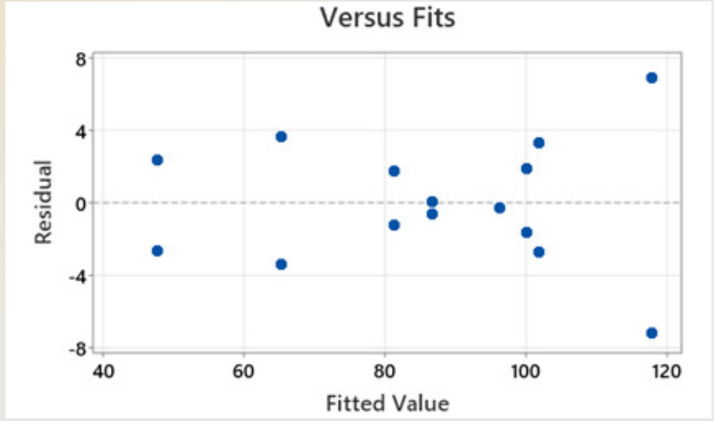
Quick Iteration: Enables faster testing and refinement before race day.

Resource Efficient: Reduces experimental runs, saving time and materials.

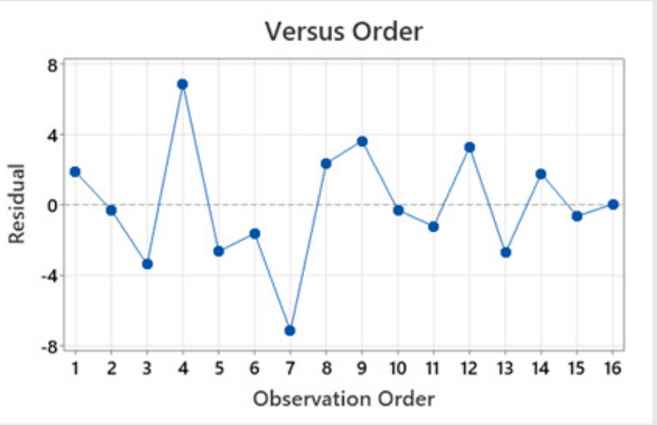
Residual Analysis



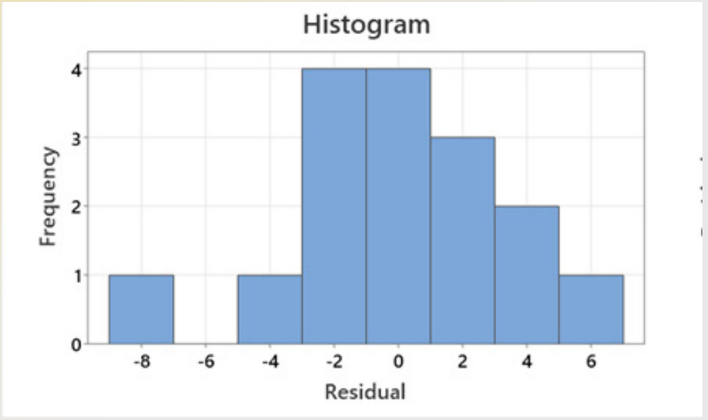
Residuals are approximately normally distributed, confirming the assumption of normality.



Residuals are scattered randomly, showing no patterns or heteroscedasticity, which indicates a good model fit.



No trend or bias was observed, confirming the independence of residuals.



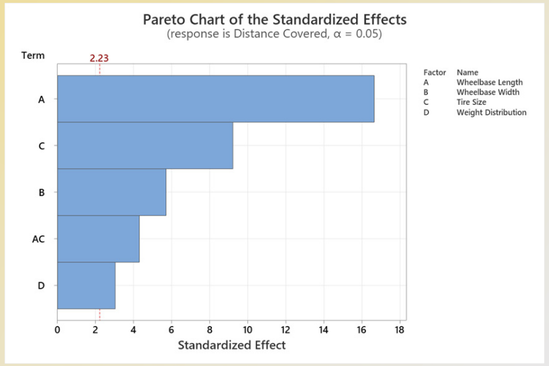
Residuals are symmetric, supporting the normality assumption.

The Model is in NID

The residual plots validate that the model assumptions (normality, independence, and constant variance) are satisfied.
This confirms the adequacy of the model for analyzing the impact of design factors on distance covered.

Experimental Insights

Main Effects Plot: Illustrates Wheelbase Length (A) as a strong influencer of distance.
Interaction Plot: Emphasizes A's significant role, especially when combined with Big Tires (C).



Pareto Chart: Wheelbase Length (A) has the largest standardized effect, clearly dominating other factors. Interactions (AC) also play a role, reinforcing the importance of combined factors.
Normal Plot: Confirms significance of A (Wheelbase Length), C (Tire Size), and their interaction (AC).

While other factors like Tire Size (C) and Weight Distribution (D) contribute, Wheelbase Length (A) has the strongest and most consistent impact, making it the primary driver of performance. Optimizing this factor should be your first priority when designing the car.

Model Adequacy

Analysis of Variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	5	6953.48	1390.70	84.45	0.000
Linear	4	6648.97	1662.24	100.94	0.000
Wheelbase Length	1	4563.00	4563.00	277.08	0.000
Wheelbase Width	1	535.92	535.92	32.54	0.000
Tire Size	1	1398.76	1398.76	84.94	0.000
Weight Distribution	1	151.29	151.29	9.19	0.013
2-Way Interactions	1	304.50	304.50	18.49	0.002
Wheelbase Length*Tire Size	1	304.50	304.50	18.49	0.002
Error	10	164.68	16.47		
Lack-of-Fit	2	0.81	0.41	0.02	0.980
Pure Error	8	163.87	20.48		
Total	15	7118.16			

Coded Coefficients

Term	Effect	Coef	SE Coef	T-Value	P-Value	VIF
Constant		87.10	1.01	85.85	0.000	
Wheelbase Length	33.77	16.89	1.01	16.65	0.000	1.00
Wheelbase Width	11.57	5.79	1.01	5.70	0.000	1.00
Tire Size	18.70	9.35	1.01	9.22	0.000	1.00
Weight Distribution	6.15	3.07	1.01	3.03	0.013	1.00
Wheelbase Length*Tire Size	-8.73	-4.36	1.01	-4.30	0.002	1.00

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
4.05811	97.69%	96.53%	94.08%

Fits and Diagnostics for Unusual Observations

Obs	Distance Covered	Fit	Resid	Std Resid
4	124.70	117.84	6.86	2.14 R
7	110.70	117.84	-7.14	-2.22 R

With a P value below 0.05, Wheelbase Length is the most significant factor, followed by Tire Size. The interaction of these two also affects performance.

By removing unimportant factors, the model improved by 3.29% in predicting. The decrease in S means the updated model fits the data better. Observations 4 and 7 with standardized residuals 2.14 and -2.22, but they are within manageable limits.

Financial Analysis

We selected the top-performing designs based on distance covered in the experiments.For these configurations, we calculated their total cost using the provided Bill of Materials (BOM).

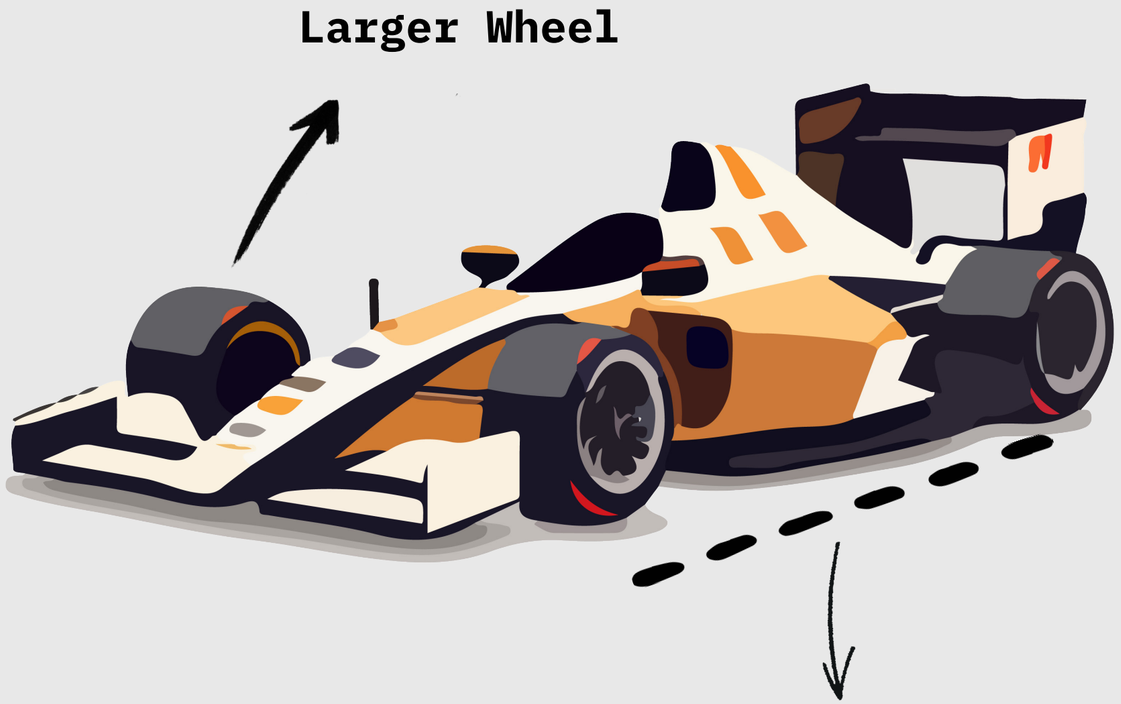
Wheelbase Length	Wheelbase Width	Tire Size	Weight Distribution	Distance Covered	Cost	Cost effectiveness
Long	Narrow	Big	Front	102	16300	0.006257669
Long	Broad	Big	Back	124.7	18400	0.006777174
Long	Broad	Big	Back	110.7	18400	0.006016304
Long	Broad	Small	Front	105	13600	0.007720588
Long	Broad	Small	Front	99	13600	0.007279412

For each top-performing design, we calculated:
- Total Distance Covered.
- Total Cost.
- Cost-Effectiveness Ratio (Distance per Dollar).

This helped determine which designs offered the best value for money versus maximum performance.

Conclusion

Key Factors Identified:
Longer wheelbase and larger Wheel size significantly boosted performance, validated by the Main Effects and Interaction plots. Rear weight distribution also improved distance covered, albeit less prominently.



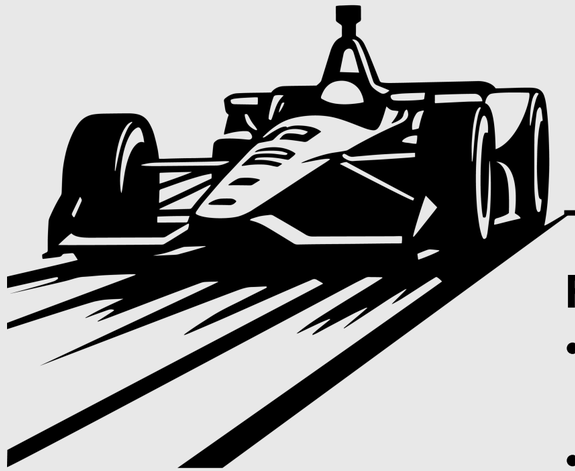
Recommendations

Cost-effective

To save money, go for Long + Broad + Small Tires + Front Weight ($13,600 for 105 cm).

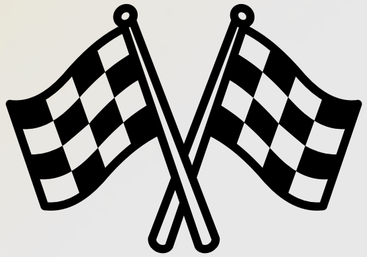
Better performance

To get top performance, go for Long + Broad + Big Tires + Back Weight ($18,400 for 124.7 cm).



Future Consideration:

- Consider mid-sized tires or lighter materials to boost performance at a lower cost.
- Look into alternative wheelbase or tire materials for reduced weight and maintained durability.



THANK YOU