Model Manual

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Problem

The University of Arkansas Ranch Horse Team wants to get as many points as possible next season while keeping travel costs low. The team of six has five shows that they need to travel to: SHTX Bryan, SHTX World, Bridles and Brains, NRCHA, and NIRSHA. The team cannot exceed a budget of $30,000 per season and they are restricted on how many members can go to a show and who can compete for points. University regulations state that each team member must attend at least two shows, but they do not have to be point-riders.

Data Collection

Our data was collected from a variety of sources. Most data came directly from the University of Arkansas Ranch Horse Team. This data included which shows the team planned to attend, where those shows were located, how many nights would be spent at each show, point rider requirements, team members, team member average scores, and season budget. The rest of the data came from the following sources:

Vehicle Rental Fees: Took the average rental fee from online sources using Microsoft CoPilot

Hotel Room Fees: Took the cheapest hotel single room rate of any 4 star or better hotel within 10 miles of show location Hotels.com

Entry and Stall Fees: Taken from show websites and handbooks

SHTX Shows: SHTX Shows link

Bridles and Brains: Bridles and Brains Show link

NRCHA: NRCHA Show Link

NIRSHA: NIRSHA Show link

Gas Price Per Gallon: Estimated average for Arkansas and Texas (Gas Price link)

Distance to show: Taken from Google Maps

SHTX Bryan: Google Maps Link to SHTX Bryan

SHTX World: Google Maps Link to SHTX World

Bridles and Brains &NRCHA: Google Maps Link to Bridles and Brains & NRCHA,

NIRSHA: Google Maps Link to NIRSHA

Notes: Vehicle miles per gallon, hotel rates, and gas price per gallon will be kept constant for simplicity

Commented [JS1]: Should we put our constants here? Like the numbers

Commented [MB2R1]: Should we put our numbers for all of our parameters??

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MPG for truck = 12

MPG for traverse = 27

Hotel at show 1 = 240

Hotel at show 2 = 147

Hotel at show 3 = 215

Hotel at show 4 = 215

Hotel at show 5 = 94

Gas price per gallon = 3

Indices

i = Each show

j = Each team member

Parameters

ro = Rent fee for each truck

rn = Rent fee for each traverse

h[i] = Cost of one hotel room for one night at each show

p[i] = Number of nights in the hotel for each show

q[i] = Entry fee per person for each show

t[i] = Stalling fee per horse for each show

g = Gas price per gallon

l[i] = Max number of people per show

a[i] = Distance driven to each show

k[i] = Number of riders that can earn points at each show

c = Season budget

do = MPG for a truck

dn = MPG for a traverse

x[i, j] = Total points member j scored at show i last season

e[j] = Gender of each rider

*The values of these parameters can be found in the Python file.

Decision Variables

b[j,i] = Binary variable indicating if team member j's score was counted in show i

s[j,i] = Binary variable indicating if team member j competed in show i

o[i] = Number of trucks needed for show i

n[i] = Number of traverses needed for show i

f[i] = Number of females participating in show i

m[i] = Number of males participating in show i

y[i] = Number of female hotel rooms to purchase for show i

w[i] = Number of male hotel rooms to purchase for show i

z[i] = Total number of hotel rooms to purchase for show i

Model

Objective Function

$$\text{Maximize} \sum_{j=1}^{6} \sum_{i=1}^{5} x_{ij} \cdot b_{ij}$$

Maximizes the total team score across all shows. Sums the total points member j scored at every show i (x[i, j]) multiplied by 1 if their points were counted for that show and 0 if their points are not counted (b[j, i]).

Constraints

1. Every team member must attend at least 2 shows:

$$\sum_{i=1}^{5} s_{ij} \geq 2 \ \forall j = 1,\ 2,\ \ldots,\ 6 \quad \text{(Minimum show attendance for each team member)}$$

2. For each show, the sum of females and males attending must be less than the limit:

$$f_i + m_i \leq l_i \quad \forall i = 1,2,\ldots,5 \quad \text{(maximum show limit)}$$

3. Maximum of four women in a hotel room:

$$yi \geq fi4 \ \forall i = 1,2,\ldots,5(number\ of\ women's\ hotel\ rooms)$$

4. Maximum of four men in a hotel room:

$$y_i \ \geq \ \frac{m_i}{4} \ \forall i = 1,\ 2,\ \ldots,\ 5 \quad \text{(number of men's hotel rooms)}$$

5. Number of females attending each show:

$$f_i \ = \ \sum_{j=1}^{6} s_{ij} \cdot e_j \ \ \forall i = 1,\ 2,\ \ldots,\ 5 \quad \text{(number of female riders)}$$

6. Number of males attending each show:

$$m_i \ = \ \sum_{j=1}^{6} s_{ij} \cdot \left(1 - e_j\right) \ \forall i = 1,\ 2,\ \ldots,\ 5 \quad \text{(number of male riders)}$$

7. For each show, the total number of hotel rooms is the sum of men’s and women’s rooms plus one for the coach:

$$z_i = w_i + y_i + 1 \quad \forall i = 1,2,\ldots,5 \quad \text{(total hotel rooms)}$$

8. Each truck can carry up to five horses. The number of horses attending the event is the same as the number of riders attending the event:

$$\sum_{j=1}^{6} s_{ij} \le 5o_i \,\forall i = 1,\ 2,\ \dots,\ 5 \quad \text{(number of trucks to rent for the number of horses)}$$

9. Each truck can carry 2 people, and each traverse can carry 4 people:

$$\sum_{j=1}^{6} s_{ij} \le 2o_i + 4n_i \quad \forall i = 1,\ 2,\ \dots,\ 5 \quad \text{(number of vehicles to rent for the number of people}$$

10. For each show, there are k number of point riders who contribute to the team score:

$$\sum_{j=1}^{6} b_{ij} = k_i \quad \forall i = 1,2,\dots,5 \quad \text{(choose top k scores for each event)}$$

11. The number of scores counted must be less than the number of participants in the show:

$$b_{ij} \le s_{ij} \quad \forall i = 1,2,\dots,5 \quad \forall j = 1,2,\dots,6 \quad \text{(A score can only be counted if a team member participates)}$$

12. Total Cost of the Season$\sum_{i=1}^{5}(h_i \cdot z_i) + \sum_{i=1}^{5}\big(q_i(f_i + m_i)\big) + \sum_{i=1}^{5}\big(t_i(f_i + m_i)\big) + \sum_{i=1}^{5}\Big(\big(ro + (a_i/do)\big)o_i + \big(rn + (a_i/dn)\big)n_i\Big) \le c$ (Total cost for season)

$$\sum_{i=1}^{5}(h_i \cdot z_i \cdot p_i) + \sum_{i=1}^{5} q_i(f_i + m_i) + \sum_{i=1}^{5} t_i(f_i + m_i) + \sum_{i=1}^{5}\left[\left(ro + \frac{a_i}{do}\right)o_i + \left(rn + \frac{a_i}{dn}\right)n_i\right] \le c$$

The total cost for the season cannot exceed the budget c. This includes hotel costs, entry fees, stalling fees, and transportation costs like vehicle rental plus gas. This constraint adds up all expenses across the season including: hotel accommodations($\sum_{i=1}^{5}(h_i \cdot z_i \cdot p_i)$), entry fees ($\sum_{i=1}^{5} q_i(f_i + m_i)$), stalling fees ($\sum_{i=1}^{5} t_i(f_i + m_i)$), and transportation costs which include both the base rental fee plus gas expenses for trucks and traverses ($\sum_{i=1}^{5}\left[\left(ro + \frac{a_i}{do}\right)o_i + \left(rn + \frac{a_i}{dn}\right)n_i\right.$)

Solution

The model comes to a feasible solution.

Optimized Team Schedule

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Total Team Score: 5163 points

Total Cost: $16026.03 of $30,000 budget

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Show: SHTX Bryan

Total Attendees: 5 of 6 max

Vehicles: 1 truck, 1 traverse

Hotel Rooms: 3 total (2 female, 0 male, 1 coach)

Show Cost: $2242.97

Team Member Name	Point Status	Score
Jordan	Point Rider	289
Justine	Point Rider	281
Kate	Point Rider	291
Carson	Non-Point Rider	N/A
Morgan	Point Rider	281
Total Score		1142

Show: SHTX World

Total Attendees: 5 of 6 max

Vehicles: 1 truck, 1 traverse

Hotel Rooms: 3 total (1 female, 1 male, 1 coach)

Show Cost: $1970.11

Team Member Name	Point Status	Score
Jordan	Point Rider	289
Justine	Point Rider	281
Kate	Point Rider	291
Alex	Non-Point Rider	N/A
Morgan	Point Rider	281
Total Score		1142

Show: NRCHA

Total Attendees: 3 of 3 max

Vehicles: 2 trucks, 0 traverses

Hotel Rooms: 2 total (1 female, 0 male, 1 coach)

Show Cost: $2140.50

Team Member Name	Point Status	Score
Jordan	Point Rider	145
Justine	Point Rider	137
Kate	Point Rider	145
Total Score		425

Show: Bridles and Brains

Total Attendees: 4 of 4 max

Vehicles: 1 truck, 1 traverse

Hotel Rooms: 2 total (1 female, 0 male, 1 coach)

Show Cost: $1535.36

Team Member Name	Point Status	Score
Jordan	Point Rider	331
Justine	Point Rider	338
Kate	Point Rider	325
Carson	Point Rider	316
Total Score		1310

Show: NIRSHA

Total Attendees: 5 of 6 max

Vehicles: 1 trucks, 1 traverses

Hotel Rooms: 3 total (1 female, 1 male, 1 coach)

Show Cost: $2077.08

Team Member Name	Point Status	Score
Jordan	Point Rider	289
Justine	Point Rider	281
Kate	Point Rider	291
Alex	Non-Point Rider	N/A
Morgan	Point Rider	281
Total Score		1142

Team Member Participation Summary:

Name	Shows Attended	Shows as Point Rider	Total Points
Jordan	SHTX Bryan, SHTX World, NRCHA, Bridles and Brains, NIRSHA	SHTX Bryan, SHTX World, NRCHA, Bridles and Brains, NIRSHA	1343
Justine	SHTX Bryan, SHTX World, NRCHA, Bridles and Brains, NIRSHA	SHTX Bryan, SHTX World, NRCHA, Bridles and Brains, NIRSHA	1318
Kate	SHTX Bryan, SHTX World, NRCHA, Bridles and Brains, NIRSHA	SHTX Bryan, SHTX World, NRCHA, Bridles and Brains, NIRSHA	1343
Alex	SHTX World, NIRSHA	N/A	0
Carson	SHTX Bryan, Bridles and Brains	Bridles and Brains	316
Morgan	SHTX Bryan, SHTX World, NIRSHA	SHTX Bryan, SHTX World, NIRSHA	843

Characteristics

This is an integer linear programming (ILP) model because all constraints and the objective function are linear. It is integer because the model has only integer variables. GLPK is appropriate for this type of problem due to its ability to handle both linear constraints and integer variables. The model has a feasible solution. All feasible solutions fall under a feasible region that only consists of discrete points, making the model non-convex. This model successfully finds a feasible solution that satisfies all constraints while maximizing total points. The solution above uses only $16,026.03 of the $30,000 budget, suggesting that the budget constraint is not binding and that team performance is instead limited by other constraints such as attendance limits and availability.

Challenges

The biggest challenge is both having a clear and meaningful goal as well as making the result relevant due to the changing and uncertain nature of much of our data. For example, i is impossible to know the number of points required to win an individual show or even to optimize a season because an actual rider's performance in a show cannot be fully certain. There is a certain amount of luck and circumstance involved. All we can do is use previous data to predict how a rider will score in a future show. The model is also currently optimizing total points across the whole season instead of focusing on winning each individual show. However, if the total number of points from the season is maximized, it not only allows for a high performing season but also the best chance of winning as many shows as possible.

Another challenge is being able to accurately make solutions. Many variables were kept constant when in reality those variables (like gas price) are always fluctuating. Choosing to keep these variables constant allowed for more time making functional constraints which is debatably more important than getting realistic variables. For example, getting an accurate gas price would mean predicting the gas price at each gas station traveled to, for each trip. Other than the difficulty of making predictions, but the time to sum each gas station for each trip is an unnecessary amount of work for the goal of the project.

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Citations:

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