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## ***Optimization Cases***

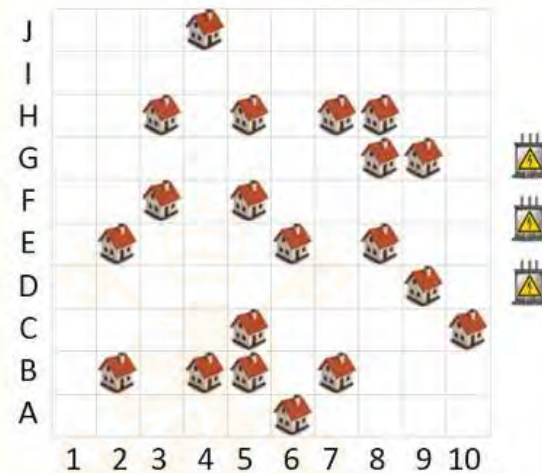
Prof. Andres Ramos

<https://www.iit.comillas.edu/aramos/>

[Andres.Ramos@comillas.edu](mailto:Andres.Ramos@comillas.edu)

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# Electrifying



A new city is being built which will include 20 distinct neighborhoods as shown by the house icons in the map. As part of the planning process, electricity needs to be connected to each of the neighborhoods.

The city has been allocated funds to put in 3 electrical substations to service the electrical needs of the neighborhoods. The substations are represented by the 3 electrical box icons to the right of the map. Because laying electrical line to each neighborhood is expensive, the placement of the substations on the map requires careful consideration.

A neighborhood will be serviced by the nearest electrical substation. A neighborhood may only be connected to one substation. The substations may be placed in any cell (including the same cell as an existing neighborhood). The cost of electrical wiring is \$1M per km. Distances are measured using a direct line between cells, which are each 1km apart. For example, the distance between cell A1 and B2 is 1.41km.

**Question:** What is the minimum cost required to connect all neighborhoods to electricity?

[http://puzzlor.com/2014-12\\_Electrifying.html](http://puzzlor.com/2014-12_Electrifying.html)

# Supply & Demand



Moving resources efficiently from supplier to consumer is a challenging problem that can be solved using O.R. techniques. Figure 1 shows a map of blue factories that supply food to orange towns. The numbers below the factories and towns indicate how much food (in kg) each supplies and demands, respectively. Any factory can supply any amount of food to one or several towns. A new factory is being built that can supply 1,000 kg of food but the location of the factory has not yet been determined. The distance between adjacent cells on the map is 1 km. The cost to transport 1 kg of food 1 km is \$10. The new factory cannot occupy a cell that already contains an existing factory or town.

**Question:** If the new factory is optimally located, what is the total transportation cost to satisfy the demand of all towns?

[http://puzzlor.com/2009-02\\_SupplyDemand.html](http://puzzlor.com/2009-02_SupplyDemand.html)

# Choose Your Crew



Name	Fishing	Sailing	Skills		Salary
			Navigation		
Amy	3	5	1		\$46,000
Bill	1	2	5		\$43,000
Carl	3	4	2		\$47,000
Dan	4	3	1		\$36,000
Eva	4	2	2		\$43,000
Fred	1	3	4		\$55,000
Greg	3	1	5		\$68,000
Henry	5	4	2		\$64,000
Ida	3	3	3		\$60,000

Table 1

Successfully navigating the waters during sea voyages is a challenging task. A captain's most important decision is selecting the right crew for the voyage. A mix of different skill sets are required to sail the ship efficiently, navigate to the destination, and fish for food along the way.

Table 1 shows a list of crew members that are available for you to hire for the voyage. Each crew member demands a salary for the voyage and has different skill levels of Fishing, Sailing, and Navigation.

In order for your journey to be successful, you must have a cumulative skill of 15 or more in each of the three skill categories from all of your chosen crew members. You may choose as many crew members as you like.

**Question:** What is the minimum achievable cost for the voyage?

<http://puzzlor.com/2011-04 ChooseYourCrew.html>

# Combination Locks



Many people store their valuables in home safes because they protect against burglaries and fires. They are a good place for storing insurance documents, car titles, cash, and many other valuables.

Figure 1 shows six dials that are on the front of your home safe. In order to open the safe, you must set each of the dials to one number. When the correct numbers are selected on each dial, the safe will open. Unfortunately you have forgotten the combination. All you can remember is that the numbers on all of the dials summed to 419.

**Question:** What numbers should you select in order to unlock the safe?

[http://puzzlor.com/2012-08\\_CombinationLocks.html](http://puzzlor.com/2012-08_CombinationLocks.html)

# Self Driving Cars

WEpod un autobús autónomo para desplazar hasta 6 personas



Self-driving cars are cars that can drive themselves without a human behind the wheel. This technology should be available in the not-too-distant future. New algorithms will need to be developed to help route these cars to get their passengers to their desired destinations efficiently.

Figure 1 shows 10 people in need of transportation. Their current location (the pickup point) is indicated by the person icon and their desired destination (the dropoff location) is indicated by the building icon. The purple arrow indicates the path from the pickup location to the dropoff location. Your job is to order the passengers so that they are picked up in an order that minimizes the total distance travelled by the self-driving car.

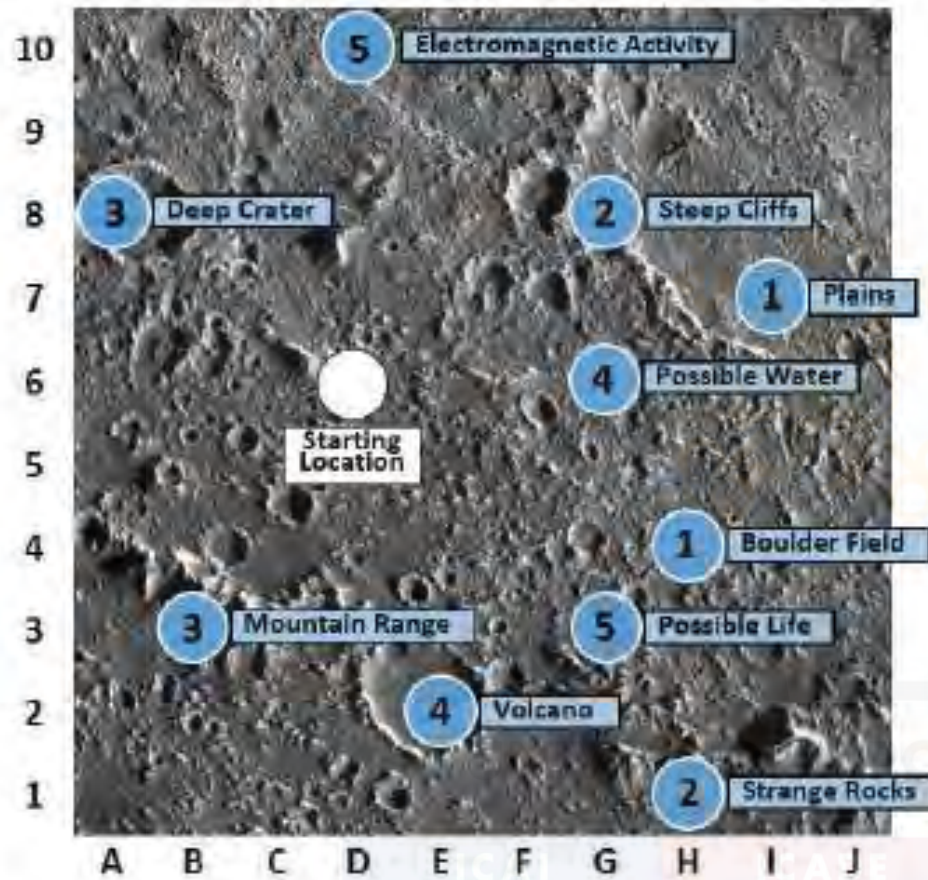
The car can start at any pickup point. You may only carry one person at a time. The car does not need to return to its starting point after the last person is dropped off. There is only one self-driving car available for use. Use Pythagorean theorem to calculate the distance between cells. For example, the distance between the person nearest the lower left corner and her dropoff point is 3.162 km.

**Question:** What is the minimum distance the car must travel in order to transport all of the passengers from their pickup points to their dropoff points?

<https://www.tudelft.nl/en/2016/tu-delft/wepod-autonomous-vehicles-operate-as-temporary-bus-service>

[http://puzzlor.com/2013-06\\_SelfDrivingCars.html](http://puzzlor.com/2013-06_SelfDrivingCars.html)

# Moon Rover



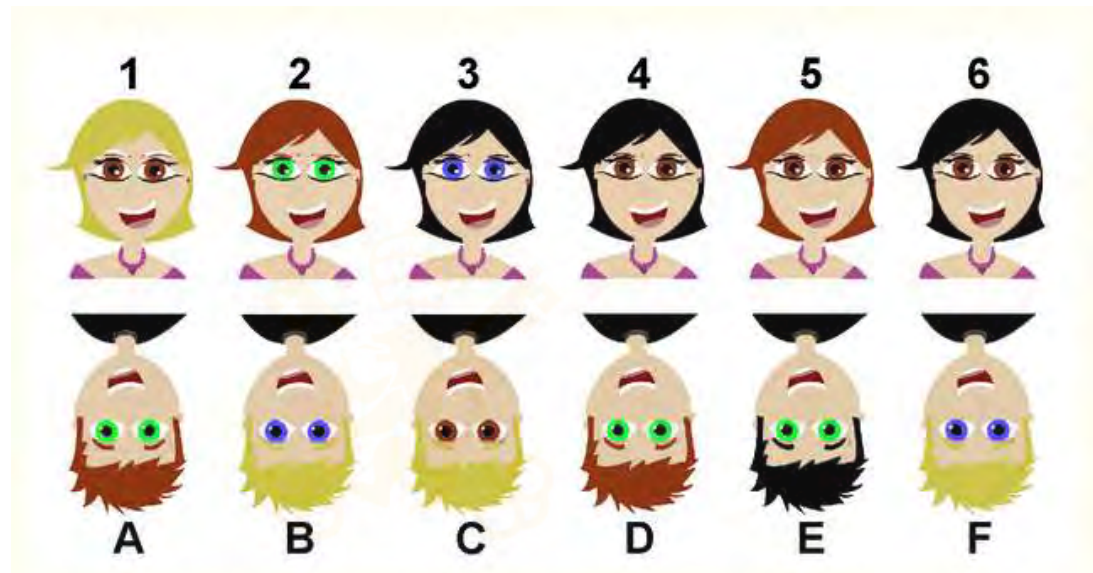
A new moon on a nearby planet has recently been discovered, and a rover has been sent to the surface to explore. Many interesting features on the new moon have been identified, but the rover has a limited travel distance ability so not all sites can be visited.

In order to prioritize the scientific value of a site, “science points” have been assigned to each of the sites of interest (as indicated by the numbers inside the circles). The rover starts at location D6. Due to the battery limitations of the rover, it can only travel a maximum distance of 25 kilometers. Use a direct line between sites to calculate travel distance (for example, the distance between G3 and H4 is 1.41km).

**Question:** What is the maximum number of “science points” you can achieve before the rover’s batteries run out?

[http://puzzlor.com/2015-08\\_MoonRover.html](http://puzzlor.com/2015-08_MoonRover.html)

# Matchmaker



The Matchmaker was an honored profession in past cultures, serving the valuable purpose of pairing off men and women in hopes of a long and successful relationship. The Matchmaker would carefully consider the characteristics of each partner to determine which pairs would be compatible.

Figure 1 shows six men and six women each with varying hair color and eye color. A man or woman will only accept a partner that has at least one of these traits in common. For example, Man A and Woman 5 would make a matching pair because they have at least one trait in common (same hair color). However Man A and Woman 1 would not make a matching pair because they do not have any traits in common.

**Question:** What pairings of men and women allow for everyone to have a partner with at least one trait in common? (There are several correct answers.)

[http://puzzlor.com/2011-06\\_Matchmaker.html](http://puzzlor.com/2011-06_Matchmaker.html)



# Dance Scheduling



Dance-pair	Student	Teacher	Skill
1	Daniel	Mr. Brown	2
2	Camila	Mr. Davis	4
3	Brianna	Ms. Evans	2
4	Eve	Ms. Clark	3
5	Ava	Ms. Anderson	1
6	Camila	Ms. Clark	5
7	Ava	Mr. Davis	3
8	Eve	Ms. Evans	1
9	Camila	Ms. Anderson	4
10	Brianna	Mr. Davis	3

The objectives, when scheduling a showcase, are to minimize the number of heats (in order to minimize the overall duration of the showcase), group similarly skilled dance-pairs in the same heat, and minimize the number of heats that have only one dance-pair.

Table 1 shows the dance-pairs that must be scheduled for the showcase. For example, dance-pair 1 shows student Daniel will dance with teacher Mr. Brown. Their Skill level is an indicator of how well this dance-pair performs together. Each dance-pair must be assigned to one heat. You may schedule as many heats as you like in order to fulfill this requirement but you cannot schedule students or teachers twice to the same heat. For example, you cannot assign dance-pairs 6 and 9 to heat 1 because it would require Camila to dance with both Ms. Clark and Ms. Anderson at the same time.

## Scoring:

The quality of the showcase is based on a points system. A dance-pair arrangement requiring 3 total heats is worth 110 points, 4 heats are worth 100 points, 5 heats are worth 90, 6 heats are worth 80, 7 heats are worth 70, etc. For every heat with a standard deviation over 1 there is a 25 point penalty. For every heat with only one dance-pair there is a 10 point penalty.

or friends lik

**Question: What is the optimal way to assign the dance-pairs to heats in order to maximize the quality of the showcase?**

A popular dance studio in New York City holds ballroom dancing showcases twice a year to provide its students with an environment for socializing, practice, and improvement. A showcase consists of several heats in which multiple dance-pairs dance at the same time. Because multiple objectives are desired to maximize the quality of the showcase, scheduling the dance-pairs becomes a complex problem that requires OR techniques to solve.

[http://puzzlor.com/2009-04\\_DanceScheduling.html](http://puzzlor.com/2009-04_DanceScheduling.html)

# Restaurant Scheduling

After faithfully serving the O.R. profession for 50 years, you decide to retire and open a restaurant. Among the hundreds of details with opening a restaurant, you need to hire and schedule employees. Based on the foot traffic of other restaurants in the area, you expect that you will need the following number of employees each day:

## Employees Schedule

Day of week	Employees Needed
Monday	4
Tuesday	5
Wednesday	5
Thursday	10
Friday	12
Saturday	12
Sunday	2

Your employees will work four consecutive days and then have three days off. They will be paid \$100 for each day they work. In your rush to get the restaurant started, you haphazardly hire 17 employees. Five will start on Monday, five will start on Thursday and seven will start on Friday. This schedule satisfies the above work requirements, but you have no idea how optimal this is.

**Questions:** How much money would you save each week from your current schedule if you optimized your workforce?

[http://puzzlor.com/2008-04\\_RestaurantScheduling.html](http://puzzlor.com/2008-04_RestaurantScheduling.html)

# Racecar Design

Sample car configuration	Engine	Tires	Transmission	Brakes	Race finish speed (minutes)
1	Awes Engine	Aero Tires	Accelo Trans	Control Brakes	12
2	Charm Engine	Boldo Tires	Accelo Trans	Control Brakes	17
3	Charm Engine	Aero Tires	Beast Trans	Bolt Brakes	14
4	Baller Engine	Boldo Tires	Accelo Trans	Control Brakes	13
5	Awes Engine	Boldo Tires	Beast Trans	Aero Brakes	15
6	Awes Engine	Clingo Tires	Beast Trans	Control Brakes	11
7	Baller Engine	Clingo Tires	Cert Trans	Aero Brakes	16
8	Baller Engine	Boldo Tires	Accelo Trans	Bolt Brakes	19
9	Charm Engine	Aero Tires	Cert Trans	Aero Brakes	18
10	Charm Engine	Clingo Tires	Cert Trans	Bolt Brakes	20

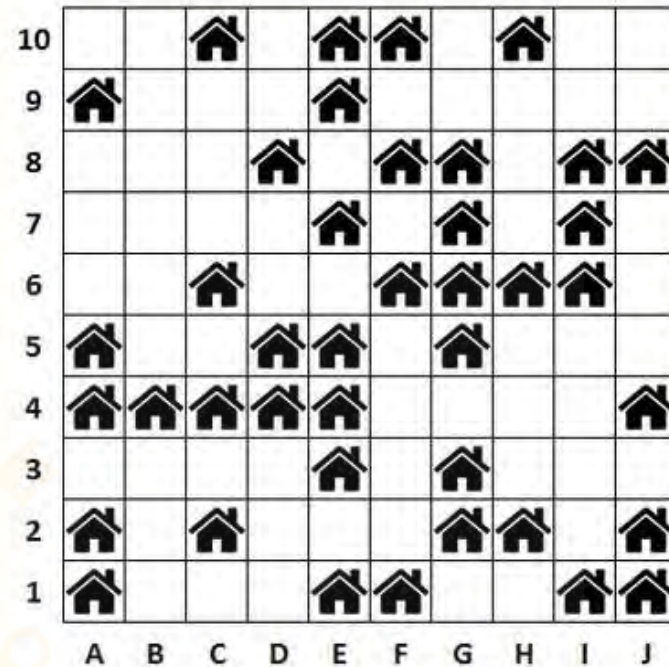
As the lead design engineer on a car racing team, you've been hired to build a car that can complete a racecourse in the fastest time. To get a feel for how each component performs, you've built several sample car configurations with varying engines, tires, transmissions, and brakes and then tested them on the race-track. Each combination of parts has yielded different speed results, as shown in Table 1.

There are three types of each component that you can choose from. You must pick exactly one component from each category: engine, tires, transmission and brakes.

**Question:** What combination of engine, tires, transmission and brakes will give you the fastest car?

[http://www.puzzlor.com/2015-10\\_RacecarDesign.html](http://www.puzzlor.com/2015-10_RacecarDesign.html)

# Cell Towers



As the head of analytics for a cell phone company, you have been asked to optimize the location of cell towers in a new area where your company wants to provide service. The new area is made up of several neighborhoods. Each neighborhood is represented by a black house icon in the accompanying image.

A cell tower can be placed on any square (including squares with or without a neighborhood). Once placed, a cell tower provides service to 9 squares (the 8 adjacent squares surrounding it and the 1 it sits on). For example, if you placed a cell tower in B2, it would provide service to A1, B1, C1, A2, B2, C2, A3, B3, and C3.

The company recognizes that it may not be worthwhile to cover all neighborhoods, so it has instructed you that it needs to cover only 70% of the neighborhoods in the new area. Each cell tower is expensive to construct and maintain so it is in your best interest to only use the minimum number of cell towers.

[http://puzzlor.com/2016-04\\_CellTowers.html](http://puzzlor.com/2016-04_CellTowers.html)

**Question:** What is the minimum number of cell towers needed to provide service to at least 70% of the neighborhoods?



Prof. Andres Ramos

<https://www.iit.comillas.edu/aramos/>

[Andres.Ramos@comillas.edu](mailto:Andres.Ramos@comillas.edu)

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