Modeling and Simulation Projects' Topics
Basic Modeling and Simulations
(CSH3H2)

2018

Rules and Regulations

In Basic Modeling and Simulation course (CSH3H2), the modeling project is worth **40**% of a student final mark. The project can be completed *individually* or *in a group* of four students or less. The number of groups in a class of N students is $\lceil N/4 \rceil$. For instance, if a class contains 35 students, then there are $\lceil 35/4 \rceil = 9$ groups in such class. The group formation is left to the student, however, the instructor of each class will give the list of students who are selected to become the ***group leaders***. The selection criteria for the group leaders are based on the result of the previous quizzes (quiz 1 – 4) as well as midterm exam. This regulation of class partitioning is conducted for ensuring that excellent students do not congregate in the same group. In addition, by mingling excellent students with the mediocre ones, students will learn to cooperate in a heterogenous condition. Furthermore, the modeling projects are expected to be completed on time.

In this final project, a group is expected to solve a modeling problem using the combination of mathematical reasoning, algorithmic thinking, and computer programming, that have been previously studied in elementary courses, such as: Calculus, Basic Programming and Algorithms, Data Structures, Discrete Mathematics, Matrices and Vector Spaces, Probability and Statistics, and Design and Analysis of Algorithms. The students are not compelled to solve the modeling problem with a specific non-deterministic approach as explained in Basic Modeling and Simulation course, because this compulsion can restrain students creativity in problem solving.

This document contains a list of problems for the modeling project of the year 2018. Some of these problems have been featured either on modeling contest or programming competition. Some modeling problems are selected from the *Mathematical Contest in Modeling* (MCM [MCM]), while others are interesting algorithmic-related problems excerpted from the *International Collegiate Programming Contest* (ACM-ICPC [ICPC]). Both of these competitions are considered as prestigious contests for undergraduate students. In reality, the problems must be solved in less than a week[1]. However, in Basic Modeling and Simulation course students have more than two weeks to complete their modeling project. Students are allowed to use internet (e.g.: Stack Overflow, YouTube, personal blog, etc.), to ask fellow students, and to cooperate with other students from other institutions[2]. Aside from the previous MCM and ACM-ICPC problems, the instructors also proposed several interesting ad-hoc modeling problems that can be solved individually or in a group of two. This additional problems are created to ensure that a team leader that has no member can still complete the modeling project on time without burdening his/her academic life with this two credits course.

Notice that some problems have been proposed and used for the previous year Basic Modeling and Simulation course. If you choose such problem, you may use the previous project report of your seniors as references. However, you must cite the project and acknowledge their

[1]Three days for the MCM and five hours for the ACM-ICPC.

[2]Students may discusss the problem with the following people: Rakina Zata Amni, Muhammad Ayaz Dzulfikar, Zamil Majdy, Albert Darmawan, Rafael Herman Yosef, or Willson Wijaya.

works in your report; otherwise your project report will be considered as plagiarism. Notice that the outcome of this modeling project is a written report containing the modeling approach and the solution of a particular problem. There are several milestones for the completion of this project, i.e.:

1. **Preliminary/initial presentation**: a presentation regarding the problem description, assumption, and proposed methods for finding the solution. This presentation is worth $\mathbf{20-25}\%$ of the grade for the modeling project. The presenter can be anyone but the group leader[3].

2. **Progress presentation**: a presentation regarding more detailed approach of the problem solving where students can demonstrate their proposed algorithms, mathematical models, or computer programs for solving the problem. This presentation is worth $\mathbf{20-25}\%$ of the grade for the modeling project.

3. **Final report**: a written report regarding the description of the problem and its complete solution. This report is worth $\mathbf{50-60}\%$ of the grade for the modeling project.

There is no final presentation for the modeling project. The final report will be assessed solely based on the problem solving approach as well as its scientific writing. Some high-quality examples of the written reports from the previous year courses will be uploaded to IDEA. All groups are expected to use them as examples for the report. Although all of the proposed problems in this documents is written in English, the students of the regular classes can write their reports in Bahasa Indonesia[4]. However, the students of the international class must write their reports in English; otherwise the report will not be graded. All students within the same group will obtain identical grade for this modeling project. The group leader must ensure that each of the group members has proportional contribution to the project. Nevertheless, a group leader may exclude any of his/her team member in the following circumstances:

1. The group member did not attend the midterm exam (and he/she had missed the makeup exam as well)[5].

2. The attendance rate of the group member is below $\mathbf{75}\%$. Students should be aware that the modeling project replace the conventional written exam in this course[6].

3. The group member has little or none contribution to the final project.

The final project grade will only be given to the students whose names are written in the final project report. In addition, a group leader has the right to select his/her team members. All

[3] Unless if a group consists only of one person.

[4] There are no additional points for students of regular classes who write their report in English.

[5] We consider such student to be missing and thus we assume that he/she will not be participating for the rest of the course.

[6] However, the instructors leave the final decision of this exclusion to the group leader.

students must be registered to precisely one group. A non team leader student who has not been registered in a group must contact his/her class instructor immediately.

The final project reports will be graded by a team of lecturers. To avoid any type of plagiarism, the instructors are planning to grade all final projects with identical topics uniformly (i.e., reports of the same topics are graded by the same person). For the topic selection, different groups in the same class cannot choose the same topics. The topic is selected by the group leader or any representative of the group. Suppose there are N groups in a class, the instructor will first sort the group leaders by his/her academic performance in the midterm/quizzes. The group whose leader has the highest academic performance is assigned the number 1 (thus we refer the group to group 1) while the group whose leader has the lowest academic performance is assigned the number N (hence we refer the group to group N). Group N will have the privilege to choose the first topic, group $N-1$ will have the privilege to select the second topic, and so on until the group 1 that chooses for the remaining topics available. There are more than 20 topics overall. The submission deadline of this modeling project is identical for all classes and will be informed in IDEA. The written report must be submitted in .pdf format prior to the deadline.

The rules and regulations of this modeling project are summarized as follows:

1. The modeling project can be completed individually[7] or in a group of four students or less.
2. All groups in the same class must choose different problems.
3. Students are allowed to use internet, to ask fellow students, and to cooperate with other students from other institutions.
4. Inter class discussion is allowed.
5. Students may use previous modeling project reports as reference.
6. For a class of N students, there are $\lceil N/4 \rceil$ different groups.
7. Class instructor will determine the group leaders of each group.
8. Groups are numbered based on the academic performance of the group leaders for the midterm exam/quiz.
9. Group 1 refers to the group whose leader has the highest academic performance, whereas group N refers to the group whose leader has the lowest academic performance.
10. Students may modify the description of the problem, however the modification should be discussed with and approved by the class instructor.
11. Several modeling topics are solely intended for a group of one or two students. However, the groups of one or two members might choose other problems as well.

[7] In the case where the student is also a group leader.

12. Any revision of this modeling project will be informed in IDEA.

Contents

1 Measuring the Evolution and Influence in Society's Information Networks

(*2016 ICM, Problem D, proposed by D. Suandi*)

Information is spread quickly in today's tech-connected communications network; sometimes it is due to the inherent value of the information itself, and other times it is due to the information finding its way to influential or central network nodes that accelerate its spread through social media. While content has varied—in the 1800s, news was more about local events (e.g., weddings, storms, deaths) rather than viral videos of cats or social lives of entertainers—the prevailing premise is that this cultural characteristic to share information (both serious and trivial) has always been there.

However, the flow of information has never been as easy or wide-ranging as it is today, allowing news of various levels of importance to spread quickly across the globe in our tech connected world. By taking a historical perspective of flow of information relative to inherent value of information, the Institute of Communication Media (ICM) seeks to understand the evolution of the methodology, purpose, and functionality of society's networks. Specifically, your team, as part of ICM's Information Analytics Division, has been assigned to analyze the relationship between speed/flow of information versus inherent value of information based on consideration of five periods:

- in the 1870s, when newspapers were delivered by trains and stories were passed by telegraph;
- in the 1920s, when radios became a more common household item;
- in the 1970s, when televisions were in most homes;
- in the 1990s, when households began connecting to the early internet;
- in the 2010s, when we can carry a connection to the world on our phones.

Your supervisor reminds you to be sure to report the assumptions you make and the data you use to build your models. Your specific tasks are:

1. Develop one or more model(s) that allow(s) you to explore the flow of information and filter or find what qualifies as news.
2. Validate your model's reliability by using data from the past and the prediction capability of your model to predict the information communication situation for today and compare that with today's reality.
3. Use your model to predict the communication networks' relationships and capacities around the year 2050.

4. Use the theories and concepts of information influence on networks to model how public interest and opinion can be changed through information networks in today's connected world.

5. Determine how information value, people's initial opinion and bias, form of the message or its source, and the topology or strength of the information network in a region, country, or worldwide could be used to spread information and influence public opinion.

1.1 Possible Data Sources

As you develop your model and prepare to test it, you will need to assemble a collection of data. Below are just some examples of the types of data you may find useful in this project. Depending on your exact model, some types of data may be very important and others may be entirely irrelevant. In addition to the sample sources provided below, you might want to consider a few important world events throughout history—if some recent big news events, such as the rumors of country-turned-pop singer Taylor Swift's possible engagement had instead happened in 1860, what percentage of the population would know about it and how quickly; likewise, if an important person was assassinated today, how would that news spread? How might that compare to the news of US President Abraham Lincoln's assassination?

1.2 Sample Circulation Data and Media Availability

See `https://www.comap.com/undergraduate/contests/mcm/contests/2016/problems/`.

1.3 Historical Perspective of News and Media

See `https://www.comap.com/undergraduate/contests/mcm/contests/2016/problems/`.

2 Optimizing the Passenger Throughput at an Airport Security Checkpoint

(*2017 ICM, Problem D, proposed by D. Suandi*)

Following the terrorist attacks in the US on September 11, 2001, airport security has been significantly enhanced throughout the world. Airports have security checkpoints, where passengers and their baggage are screened for explosives and other dangerous items. The goals of these security measures are to prevent passengers from hijacking or destroying aircraft and to keep all passengers safe during their travel. However, airlines have a vested interest in maintaining a positive flying experience for passengers by minimizing the time they spend waiting in line at a security checkpoint and waiting for their flight. Therefore, there is a tension between desires to maximize security while minimizing inconvenience to passengers.

During 2016, the U.S. Transportation Security Agency (TSA) came under sharp criticism for extremely long lines, in particular at Chicago's O'Hare international airport. Following this public attention, the TSA invested in several modifications to their checkpoint equipment and procedures and increased staffing in the more highly congested airports. While these modifications were somewhat successful in reducing waiting times, it is unclear how much cost the TSA incurred to implement the new measures and increase staffing. In addition to the issues at O'Hare, there have also been incidents of unexplained and unpredicted long lines at other airports, including airports that normally have short wait times. This high variance in checkpoint lines can be extremely costly to passengers as they decide between arriving unnecessarily early or potentially missing their scheduled flight. Numerous news articles describe some of the issues associated with airport security checkpoints.

Your Internal Control Management (ICM) team has been contracted by the TSA to review airport security checkpoints and staffing to identify potential bottlenecks that disrupt passenger throughput. They are especially interested in creative solutions that both increase checkpoint throughput and reduce variance in wait time, all while maintaining the same standards of safety and security.

The current process for a US airport security checkpoint is displayed in Fig 1. This checkpoint can be divided into four zones:

1. **Zone A**: Passengers randomly arrive at the checkpoint and wait in a queue until a security officer can inspect their identification and boarding documents.

2. **Zone B**:

   (a) The passengers then move to a subsequent queue for an open screening line; depending on the anticipated activity level at the airport, more or less lines may be open.

   (b) Once the passengers reach the front of this queue, they prepare all of their belongings for X-ray screening. Passengers must remove shoes, belts, jackets, metal objects, electronics, and containers with liquids, placing them in a bin to be X-rayed separately; laptops and some medical equipment also need to be removed from their bags and placed in a separate bin.

(c) All of their belongings, including the bins containing the aforementioned items, are moved by conveyor belt through an X-ray machine, where some items are flagged for additional search or screening by a security officer (Zone D).

(d) Meanwhile the passengers process through either a millimeter wave scanner or metal detector.

(e) Passengers that fail this step receive a pat-down inspection by a security officer (Zone D).

3. **Zone C:** The passengers then proceed to the conveyor belt on the other side of the X-ray scanner to collect their belongings and depart the checkpoint area.

4. **Zone D**: The passengers who failed the regular check receives additional screening from TSA agents.

Approximately 45% of passengers enroll in a program called Pre-Check for trusted travelers. These passengers pay $\$85$ to receive a background check and enjoy a separate screening process for five years. There is often one Pre-Check lane open for every three regular lanes, despite the fact that more passengers use the Pre-Check process. Pre-Check passengers and their bags go through the same screening process with a few modifications designed to expedite screening. Pre-Check passengers must still remove metal and electronic items for scanning as well as any liquids, but are not required to remove shoes, belts, or light jackets; they also do not need to remove their computers from their bags.

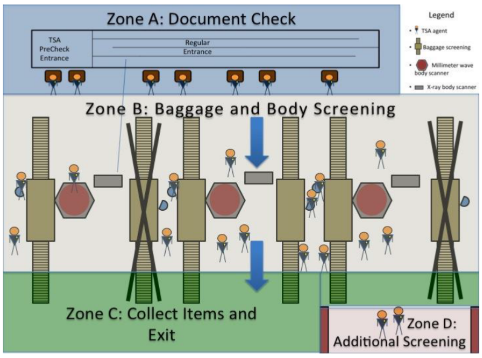

Figure 1: Illustration of the TSA Security Screening Process.

Data has been collected about how passengers proceed through each step of the security screening process (see `2017_ICM_Problem_D_Data.xlsx`). Your specific tasks are:

1. Develop one or more model(s) that allow(s) you to explore the flow of passengers through a security check point and identify bottlenecks. Clearly identify where problem areas exist in the current process.

2. Develop two or more potential modifications to the current process to improve passenger throughput and reduce variance in wait time. Model these changes to demonstrate how your modifications impact the process.

3. It is well known that different parts of the world have their own cultural norms that shape the local rules of social interaction. Consider how these cultural norms might impact your model. For example, Americans are known for deeply respecting and prioritizing the personal space of others, and there is a social stigma against "cutting" in front of others. Meanwhile, the Swiss are known for their emphasis on collective efficiency, and the Chinese are known for prioritizing individual efficiency. Consider how cultural differences may impact the way in which passenger's process through checkpoints as a sensitivity analysis. The cultural differences you apply to your sensitivity analysis can be based on real cultural differences, or you can simulate different traveler styles that are not associated with any particular culture (e.g., a slower traveler). How can the security system accommodate these differences in a manner that expedites passenger throughput and reduces variance?

4. Propose policy and procedural recommendations for the security managers based on your model. These policies may be globally applicable, or may be tailored for specific cultures and/or traveler types.

In addition to developing and implementing your model(s) to address this problem, your team should validate your model(s), assess strengths and weaknesses, and propose ideas for improvement (future work). Useful references can be seen at `https://www.comap.com/undergraduate/contests/mcm/contests/2017/problems/`.

3 How Does Climate Change Influence Regional Instability?

(*2018 ICM, Problem E, proposed by D. Suandi*)

The effects of Climate Change, to include increased droughts, shrinking glaciers, changing animal and plant ranges, and sea level rise, are already being realized and vary from region to region. The Intergovernmental Panel on Climate Change suggests that the net damage costs of climate change are likely to be significant. Many of these effects will alter the way humans live, and may have the potential to cause the weakening and breakdown of social and governmental structures. Consequently, destabilized governments could result in fragile states.

A fragile state is one where the state government is not able to, or chooses not to, provide the basic essentials to its people. For the purpose of this problem "state" refers to a sovereign state or country. Being a fragile state increases the vulnerability of a country's population to the impact of such climate shocks as natural disasters, decreasing arable land, unpredictable weather, and increasing temperatures. Non-sustainable environmental practices, migration, and resource shortages, which are common in developing states, may further aggravate states with weak governance (Schwartz and Randall, 2003; Theisen, Gleditsch, and Buhaug, 2013). Arguably, drought in both Syria and Yemen further exacerbated already fragile states. Environmental stress alone does not necessarily trigger violent conflict, but evidence suggests that it enables violent conflict when it combines with weak governance and social fragmentation. This confluence can enhance a spiral of violence, typically along latent ethnic and political divisions (Krakowka, Heimel, and Galgano 2012).

Your tasks are the following:

1. **Task 1**: Develop a model that determines a country's fragility and simultaneously measures the impact of climate change. Your model should identify when a state is fragile, vulnerable, or stable. It should also identify how climate change increases fragility through direct means or indirectly as it influences other factors and indicators.

2. **Task 2**: Select one of the top 10 most fragile states as determined by the Fragile State Index (`http://fundforpeace.org/fsi/data/`) and determine how climate change may have increased fragility of that country. Use your model to show in what way(s) the state may be less fragile without these effects.

3. **Task 3**: Use your model on another state not in the top 10 list to measure its fragility, and see in what way and when climate change may push it to become more fragile. Identify any definitive indicators. How do you define a tipping point and predict when a country may reach it?

4. **Task 4**: Use your model to show which state driven interventions could mitigate the risk of climate change and prevent a country from becoming a fragile state. Explain the effect of human intervention and predict the total cost of intervention for this country.

5. **Task 5**: Will your model work on smaller "states" (such as cities) or larger "states" (such as continents)? If not, how would you modify your model?

3.1 Useful References

1. Krakowka, A.R., Heimel, N., and Galgano, F. "Modeling Environmenal Security in Sub-Sharan Africa – ProQuest." The Geographical Bulletin, 2012, 53 (1): 21-38.

2. Schwartz, P. and Randall, D. "An Abrupt Climate Change Scenario and Its Implications for United States National Security", October 2003.

3. Theisen, O.M., Gleditsch, N.P., and Buhaug, H. "Is climate change a driver of armed conflict?" Climate Change, April 2013, V117 (3), 613-625.

4 Camping along The Big Long River

(*2012 MCM, Problem B, proposed by D. Nuraiman dan M. Arzaki*)

Visitors to the Big Long River (225 miles) can enjoy scenic views and exciting white water rapids. The river is inaccessible to hikers, so the only way to enjoy it is to take a river trip that requires several days of camping. River trips all start at First Launch and exit the river at Final Exit, 225 miles downstream. Passengers take either oar-powered rubber rafts, which travel on average 4 m.p.h. or motorized boats, which travel on average 8 m.p.h. The trips range from 6 to 18 nights of camping on the river, start to finish. The government agency responsible for managing this river wants every trip to enjoy a wilderness experience, with minimal contact with other groups of boats on the river.

Currently, X trips travel down the Big Long River each year during a six month period (the rest of the year it is too cold for river trips). There are Y camp sites on the Big Long River, distributed fairly uniformly throughout the river corridor. Given the rise in popularity of river rafting, the park managers have been asked to allow more trips to travel down the river. They want to determine how they might schedule an optimal mix of trips, of varying duration (measured in nights on the river) and propulsion (motor or oar) that will utilize the campsites in the best way possible.

In other words, how many more boat trips could be added to the Big Long River's rafting season? The river managers have hired you to advise them on ways in which to develop the best schedule and on ways in which to determine the carrying capacity of the river, remembering that no two sets of campers can occupy the same site at the same time.

5 Searching for a Lost Plane

(*2015 MCM, Problem B, proposed by D. Nuraiman*)

Recall the lost Malaysian flight MH370. Build a generic mathematical model that could assist "searchers" in planning a useful search for a lost plane feared to have crashed in open water such as the Atlantic, Pacific, Indian, Southern, or Arctic Ocean while flying from Point A to Point B.

Assume that there are no signals from the downed plane. Your model should recognize that there are many different types of planes for which we might be searching and that there are many different types of search planes, often using different electronics or sensors.

6 Emergency Medical Response

(*2013 HiMCM, Problem A, proposed by I. N. Wahyuni*)

The Emergency Service Coordinator (ESC) for a county is interested in locating the county's three ambulances to best maximize the number of residents that can be reached within 8 minutes of an emergency call. The county is divided into six zones and the average time required to travel from one zone to the next under semi-perfect conditions is summarized in the following Table 6.1.

	Average Travel Times					
Zones	**1**	**2**	**3**	**4**	**5**	**6**
1	1	8	12	14	10	16
2	8	1	6	18	16	16
3	12	18	1.5	12	6	4
4	16	14	4	1	16	12
5	18	16	10	4	2	2
6	16	18	14	12	2	2

Table 6.1: Average travel times (in minutes) from zone i to zone j in semi-perfect conditions.

The population in zones 1, 2, 3, 4, 5 and 6 are given in Table 6.2 below:

Zones	**Population**
1	$50,000$
2	$80,000$
3	$30,000$
4	$55,000$
5	$35,000$
6	$20,000$
Total	$270,000$

Table 6.2: Population in each zone.

Goals of your model:

1. Determine the locations for the three ambulances which would maximize the number of people who can be reached within 8 minutes of a 911 call. Can we cover everyone? If not, then how many people are left without coverage?

2. We now have only two ambulances since one has been set aside for an emergency call; where should we put them to maximize the number of people who can be reached within the 8 minutes window? Can we cover everyone? If not, then how many people are left without coverage?

3. Two ambulances are now no longer available; where should the remaining ambulance be posted? Can we cover everyone? If not, then how many people are left without coverage?

4. If a catastrophic event occurs in one location with many people from all zones involved, could the ESC cover the situation? How do counties or cities design for those rare but catastrophic events?

7 Bank Service Problem

(*2013 HiMCM, Problem B, proposed by I. N. Wahyuni*)

(Only for a group of one or two students.)

The bank manager is trying to improve customer satisfaction by offering better service. Management wants the average customer to wait less than 2 minutes for service and the average length of the queue (length of the waiting line) to be 2 persons or fewer. The bank estimates it serves about 150 customers per day. The existing arrival and service times are given in the Table 7.1 and Table 7.2 below.

Time between arrival (minutes)	Probability
0	0.10
1	0.15
2	0.10
3	0.35
4	0.25
5	0.05

Table 7.1: Time between arrival of two consecutive customers.

Service time (minutes)	Probability
1	0.25
2	0.20
3	0.40
4	0.15

Table 7.2: Service time of a customer.

Your task is as follows:

1. Build a mathematical model of the system.
2. Run at least 10 simulations to obtain the average waiting time and the average queue length for the customer service. Provide confidence intervals of the average waiting time and the average queue length using 90%, 95%, and 99% confidence levels.
3. Determine whether the current customer service is satisfactory according to the manager guidelines. If not, determine, through modeling, the minimal changes for servers required to accomplish the manager's goal.

8 Forest Service

(*2001 HiMCM, Problem B, proposed by I. N. Wahyuni*)

Your team has been approached by the Forest Service to help allocate resources to fight wildfires. In particular, the Forest Service is concerned about wildfires in a wilderness area consisting of small trees and brush in a park shaped like a square with dimensions 80 km on a side. Several years ago, the Forest Service constructed a network of north-south and east-west firebreaks that form a rectangular grid across the interior of the entire wilderness area. The firebreaks were built at 5 km intervals.

Wildfires are most likely to occur during the dry season, which extends from July through September in this particular region. During this season, there is a prevailing westerly wind throughout the day. There are frequent lightning bursts that cause wildfires.

The Forest Service wants to deploy four fire-fighting units to control fires during the next dry season. Each unit consists of ten firefighters, one pickup truck, one dump truck, one water truck ($50,000$ liters), and one bulldozer (with truck and trailer). The unit has chain saws, hand tools, and other fire-fighting equipment. The people can be quickly moved by helicopter within the wilderness area, but all the equipment must be driven via the existing firebreaks. One helicopter is on standby at all times throughout the dry season.

Your task is to determine the best distribution of fire-fighting units within the wilderness area. The Forest Service is able to set up base camps for those units at sites anywhere within the area. In addition, you are asked to prepare a damage assessment forecast. This forecast will be used to estimate the amount of wilderness likely to be burned by fire as well as acting as a mechanism for helping the Service determine when additional fire-fighting units need to be brought in from elsewhere.

9 Supermarket Checkout Counter

(*Problem from the textbook: Simulation Modeling and Analysis, proposed by K. Yulianti*)

A supermarket has two checkout stations, regular and express, with a single checker per station, see Fig. 2.

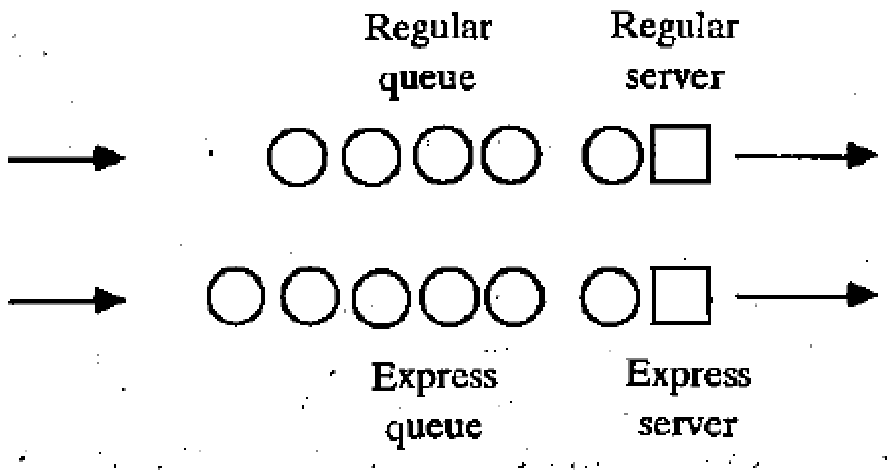

Figure 2: Checkout counters at a supermarket.

Regular customers have exponential inter-arrival times with mean 2.1 minutes and have exponential service times with mean 2.0 minutes. Express customers have exponential inter-arrival times with mean 1.1 minutes and exponential service times with mean 0.9 minute. The arrival processes of the two types of customers are independent of each other.

A regular customer arriving to find at least one checker idle begins service immediately, choosing the regular checker if both are idle; regular customers arriving to find both checkers busy join the end of the regular queue. Similarly, an express customer arriving to find an idle checker goes right into service, choosing the express checker if both are idle; express customers arriving to find both checkers busy join the end of the express queue, even if it is longer than the regular queue.

When either checker finishes serving a customer, he takes the next customer from his queue, if any, and if his queue is empty but the other one is not, he takes the first customer from the other queue. If both queues are empty the checker becomes idle.

Note that the mean service time of a customer is determined by the customer type, and not by whether the checker is the regular or the express one. Initially, the system is empty and idle and the simulation is to run for exactly 8 hours.

Your task is to compute the average delay in each queue, the time average number in each queue, and the utilization of each checker. What recommendations would you have for further study or improvement of this system?

10 Bus Tour

(*2012 ACM-ICPC World Final, Problem C, proposed by K. Yulianti and P. Turnip*)

Imagine you are a tourist in Warsaw and have booked a bus tour to see some amazing attraction just outside of town. The bus first drives around town for a while (a *long* while, since Warsaw is a big city) picking up people at their respective hotels. It then proceeds to the amazing attraction, and after a few hours goes back into the city, again driving to each hotel, this time to drop people off.

For some reason, whenever you do this, your hotel is always the first to be visited for pickup, and the last to be visited for drop-off, meaning that you have to suffer through two not-so-amazing sightseeing tours of all the local hotels. This is clearly not what you want to do (unless for some reason you are really into hotels), so let's fix it. We will develop some software to enable the sightseeing company to route its bus tours more fairly—though it may sometimes mean longer total distance for everyone, but fair is fair, right?

For this problem, there is a starting location (the sightseeing company headquarters), h hotels that need to be visited for pickups and drop-offs, and a destination location (the amazing attraction). We need to find a route that goes from the headquarters, through all the hotels, to the attraction, then back through all the hotels again (possibly in a different order), and finally back to the headquarters. In order to guarantee that none of the tourists (and, in particular, *you*) are forced to suffer through two full tours of the hotels, we require that every hotel that is visited among the first $\lfloor h/2 \rfloor$ hotels on the way to the attraction is also visited among the first $\lfloor h/2 \rfloor$ hotels on the way back. Subject to these restrictions, we would like to make the complete bus tour as short as possible. Note that these restrictions may force the bus to drive past a hotel without stopping there (this is not considered visiting) and then visit it later, as illustrated in the first sample input.

10.1 Input

The first line of each test case consists of two integers n and m satisfying $3 \leq n \leq 20$ and $2 \leq m$, where n is the number of locations (hotels, headquarters, attraction) and m is the number of pairs of locations between which the bus can travel.

The n different locations are numbered from 0 to $n-1$, where 0 is the headquarters, 1 through $n-2$ are the hotels, and $n-1$ is the attraction. Assume that there is at most one direct connection between any pair of locations and it is possible to travel from any location to any other location (but not necessarily directly).

Following the first line are m lines, each containing three integers u, v, and t such that $0 \leq u, v \leq n-1$, $u \neq v$, $1 \leq t \leq 3600$, indicating that the bus can go directly between locations u and v in t seconds (in either direction).

10.2 Output

For each test case, display the case number and the time in seconds of the shortest possible tour.

Sample Input	Output for Sample Input
5 4 0 1 10 1 2 20 2 3 30 3 4 40 4 6 0 1 1 0 2 1 0 3 1 1 2 1 1 3 1 2 3 1	Case 1: 300 Case 2: 6

11 Repeater Coordination

(*2011 MCM, Problem B, proposed by M. Arzaki*)

The VHF radio spectrum involves line-of-sight transmission and reception. This limitation can be overcome by "repeaters," which pick up weak signals, amplify them, and retransmit them on a different frequency. Thus, using a repeater, low-power users (such as mobile stations) can communicate with one another in situations where direct user-to-user contact would not be possible.

However, repeaters can interfere with one another unless they are far enough apart or transmit on sufficiently separated frequencies. In addition to geographical separation, the "continuous tone-coded squelch system" (CTCSS), sometimes nicknamed "private line" (PL), technology can be used to mitigate interference problems. This system associates to each repeater a separate subaudible tone that is transmitted by all users who wish to communicate through that repeater. The repeater responds only to received signals with its specific PL tone. With this system, two nearby repeaters can share the same frequency pair (for receive and transmit); so more repeaters (and hence more users) can be accommodated in a particular area.

For a circular flat area of radius 40 miles radius, determine the minimum number of repeaters necessary to accommodate $1,000$ simultaneous users. Assume that the spectrum available is 145 to 148 MHz, the transmitter frequency in a repeater is either 600 kHz above or 600 kHz below the receiver frequency, and there are 54 different PL tones available.

How does your solution change if there are $10,000$ users? Discuss the case where there might be defects in line-of-sight propagation caused by mountainous areas.

12 Fare and Balanced

(*2009 ACM-ICPC World Final, proposed by M. Arzaki*)

Handling traffic congestion is a difficult challenge for young urban planners. Millions of drivers, each with different goals and each making independent choices, combine to form a complex system with sometimes predictable, sometimes chaotic behavior. As a devoted civil servant, you have been tasked with optimizing rush-hour traffic over collections of roads.

All the roads lie between a residential area and a downtown business district. In the morning, each person living in the residential area drives a route to the business district. The morning commuter traffic on any particular road travels in only one direction, and no route has cycles (morning drivers do not backtrack).

Each road takes a certain time to drive, so some routes are faster than others. Drivers are much more likely to choose the faster routes, leading to congestion on those roads. In order to balance the traffic as much as possible, you are to add tolls to some roads so that the perceived "cost" of every route ends up the same. However, to avoid annoying drivers too much, you must not levy a toll on any driver twice, no matter which route he or she takes.

Figure 3 shows a collection of five roads that form routes from the residential area (at intersection 1) to the downtown business district (at intersection 4). The driving cost of each road is written in large blue font. The dotted arrows show the three possible routes from 1 to 4. Initially the costs of the routes are 10, 8 and 12. After adding a toll of cost 2 to the road connecting 1 and 4 and a toll of cost 4 to the road connecting 3 and 4, the cost of each route becomes 12.

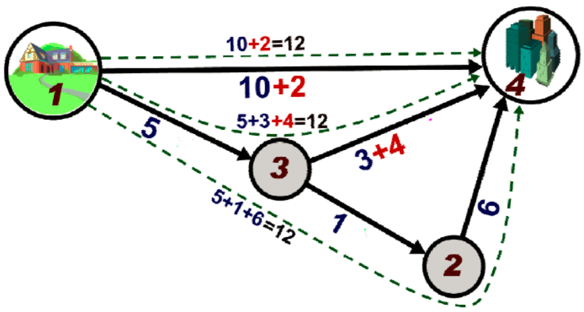

Figure 3: Roads connecting residential area at intersection 1 to business district at intersection 4.

You must determine which roads should have tolls and how much each toll should be so that every route from start to finish has the same cost (driving time cost + possible toll) and no route contains more than one toll road. Additionally, the tolls should be chosen so as to minimize the final cost. In some settings, it might be impossible to impose tolls that satisfy the above conditions.

12.1 Input

Input consists of several test cases. A test case starts with a line containing an integer N ($2 \leq N \leq 50000$), which is the number of road intersections, and R ($1 \leq R \leq 50000$), which is the number of roads. Each of the next R lines contains three integers x_i, y_i, and c_i ($1 \leq xi, yi \leq N$, $1 \leq c_i \leq 1000$), indicating that morning traffic takes road i from intersection x_i to intersection y_i with a base driving time cost of c_i. Intersection 1 is the starting residential area, and intersection N is the goal business district. Roads are numbered from 1 to R in the given input order. Every intersection is part of a route from 1 to N, and there are no cycles. The last test case is followed by a line containing two zeros.

12.2 Output

For each test case, print one line containing the case number (starting with 1), the number of roads to toll (T), and the final cost of every route. On the next T lines, print the road number i and the positive cost of the toll to apply to that road. If there are multiple minimal cost solutions, any will do. If there are none, print `No solution`. Follow the format of the sample output.

Sample Input	Output for Sample Input
4 5 1 3 5 3 2 1 2 4 6 1 4 10 3 4 3 3 4 1 2 1 1 2 2 2 3 1 2 3 2 0 0	Case 1: 2 12 4 2 5 4 Case 2: No solution

13 Surely You Congest

(*2013 ACM-ICPC World Final , Problem C, proposed by M. Arzaki*)

You are in charge of designing an advanced centralized traffic management system for smart cars. The goal is to use global information to instruct morning commuters, who must drive downtown from the suburbs, how best to get to the city center while avoiding traffic jam.

Unfortunately, since commuters know the city and are selfish, you cannot simply tell them to travel routes that take longer than normal (otherwise they will just ignore your directions). You can only convince them to change to different routes that are equally fast.

The city's network of roads consists of intersections that are connected by bidirectional roads of various travel times. Each commuter starts at some intersection, which may vary from commuter to commuter. All commuters end their journeys at the same place, which is downtown at intersection 1. If two commuters attempt to start travelling along the same road in the same direction at the same time, there will be congestion; you must avoid this. However, it is fine if two commuters pass through the same intersection simultaneously or if they take the same road starting at different times.

Determine the maximum number of commuters who can drive downtown without congestion, subject to all commuters starting their journeys at exactly the same time and without any of them taking a suboptimal route.

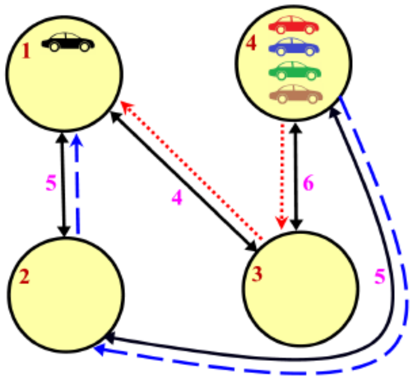

Figure 4: Ilustation of maximum number of commuters who can reach downtown without congestion.

In Fig. 4, cars are shown in their original locations. One car is already downtown. Of the cars at intersection 4, one can go along the dotted route through intersection 3, and another along the dashed route through intersection 2. But the remaining two cars cannot reach downtown while avoiding congestion. So a maximum of 3 cars can reach downtown with no congestion.

13.1 Input

The input consists of a single test case. The first line contains three integers n, m, and c, where n ($1 \leq n \leq 25000$) is the number of intersections, m ($0 \leq m \leq 50000$) is the number of roads, and c ($0 \leq c \leq 1000$) is the number of commuters. Each of the next m lines contains three integers x_i, y_i, and t_i describing one road, where x_i and y_i ($1 \leq x_i, y_i, n$) are the distinct intersections the road connects, and t_i ($1 \leq t_i \leq 10000$) is the time it takes to travel along that road in either direction. You may assume that downtown is reachable from every intersection. The last line contains c integers listing the starting intersections of the commuters.

13.2 Output

Display the maximum number of commuters who can reach downtown without congestion.

Sample Input 1	Sample Output 1
3 3 2 1 2 42 2 3 1 2 3 1 2 3	2

Sample Input 2	Sample Output 2
4 4 5 1 2 5 1 3 4 4 2 5 4 3 6 4 4 4 4 1	3

14 Harvest Season

(*2015 ACM-ICPC Jakarta Regional Contest, Problem H, proposed by M. Arzaki*)

Windarik owns a large apple farm, and there are M ripe apples ready to be picked in his farm. Windarik's farm can be represented in a Cartesian plane where each apple is located at (x_i, y_i) coordinate. To help him in harvesting, Windarik has bought N apple-picker machines, which can be used to automatically pick any specified apples (programmed). Each machine can also be moved.

To pick an apple at (x_a, y_a), a machine at position (x_b, y_b) requires an energy of:

$$(|x_a - ya| + |y_a - y_b|) \cdot B \text{ (for some positive constant } B)$$

and to move a machine from position (x_c, y_c) to position (x_d, y_d), it requires an energy of:

$$(|x_c - x_d| + |y_c - y_d|) \cdot A \text{ (for some positive constant } A).$$

Unfortunately, due some technical difficulties, each machine can only be placed and moved along x-axis Initially, each machine is located at $(x_i, 0)$.

Each machine can be programmed to pick a certain number of apples. However, it comes with a fatal drawback. Once the machine is started, it cannot be stopped (or moved) until it finished picking all the programmed apples, and once it stopped, it cannot be used for another six months, which means it will miss the entire harvest season.

Windarik needs to minimize the total required energy to harvest all the apples, after all, more energy means higher cost, and it is bad for business. Help Windarik to determine the minimum total energy required to harvest all the apples.

For example, let there be two apple-picker machines at $(2, 0)$ and $(7, 0)$, and four apples at $(3, 4)$, $(5, 2)$, $(6, 3)$, and $(6, 7)$ as depicted in Figure 1 of Fig. 5. Let A be 1 and B be 100, then the minimum total energy can be obtained by moving machine at $(2, 0)$ to $(3, 0)$ and machine at $(7, 0)$ to $(6, 0)$ as shown in Figure 2 of Figure , the harvest can be done as follows:

- move a machine from $(2, 0)$ to $(3, 0)$, the cost is $(|2 - 3| + |0 - 0|) \cdot 1 = 1$;
- move a machine from $(7, 0)$ to $(6, 0)$, the cost is $(|7 - 6| + |0 - 0|) \cdot 1 = 1$;
- apple at $(3, 4)$ picked by machine at $(3, 0)$, the cost is $(|3 - 3| + |4 - 0|) \cdot 100 = 400$;
- apple at $(5, 2)$ picked by machine at $(6, 0)$, the cost is $(|5 - 6| + |2 - 0|) \cdot 100 = 300$;
- apple at $(6, 3)$ picked by machine at $(6, 0)$, the cost is $(|6 - 6| + |3 - 0|) \cdot 100 = 300$;
- apple at $(6, 7)$ picked by machine at $(6, 0)$, the cost is $(|6 - 6| + |7 - 0|) \cdot 100 = 700$.

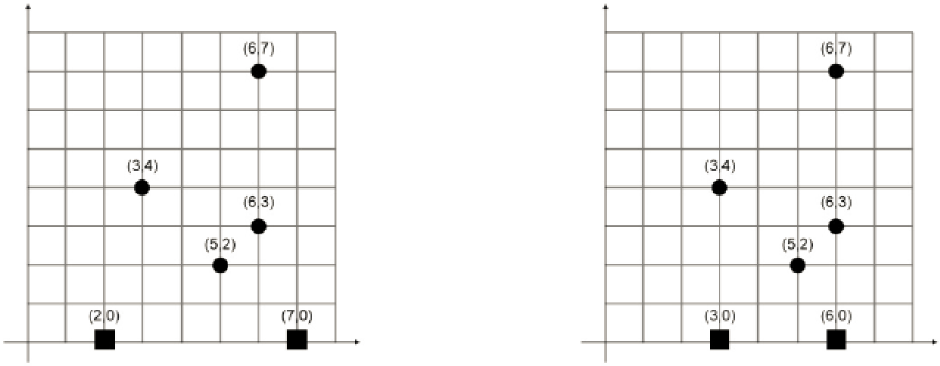

Figure 1. Figure 2.

Figure 5: Figure 1 and Figure 2 for Harvest Season Problem.

14.1 Input

The first line of input contains an integer T ($T \leq 100$) denoting the number of cases. Each case begins with four integers: N ($1 \leq N \leq 100$), M ($1 \leq M \leq 500$), A ($1 \leq A \leq 10^6$), and B ($1 \leq B \leq 10^6$) in a line, denoting the number of machines, the number of apples, the constant multiplier for moving a machine, and the constant multiplier for picking an apple, respectively. The following line contains N integers x_i ($0 \leq x_i \leq 106$) separated by single space, representing the initial x-position of each machine. The next M lines each contain two integers x_j and y_j ($0 \leq x_j, y_j \leq 10^6$) representing the position of an apple.

14.2 Output

For each case, output "Case #X: Y" (without quotes) in a line where X is the case number (starts from 1), and Y is the minimum total energy required to harvest all the apples.

Sample Input	**Output for Sample Input**
4 2 4 1 100 2 7 3 4 5 2 6 3 6 7 2 4 100 1 2 7 3 4 5 2 6 3 6 7 3 3 2 2 1 4 10 4 5 8 2 9 6 4 1 15 30 2 15 10 40 12 3	Case #1: 1702 Case #2: 21 Case #3: 30 Case #4: 120

Explanation for 2nd sample cases

The position of all apples and machines are equivalent to those in 1st sample case; however, in this case, the constant multiplier for moving a machine is 100, while the constant multiplier for picking an apple is 1. In this case, it is much better not to move the machines and pick all the apples from machine which require the least energy.

15 Predicting The FIFA World Cup 2018 Winner

(*Ad-hoc problem proposed by M. Arzaki*)

The 21st FIFA World Cup is scheduled to take place in Russia from 14 June to 15 July 2018. The final tournament will involve 32 national teams, including Russia as the host of the competition. In this problem, your task is to create simulations to determine the winner of the 21st FIFA World Cup. In order to do so, firstly you need to gather the data regarding the statistics of the previous matches' results of each pair of teams.

For example, suppose we want to run the simulation to determine the match winner between Portugal and Spain in group B. From `https://www.11v11.com/`, we know that there had been 36 matches between Portugal and Spain: 6 matches won by Portugal, 18 matches won by Spain, and 12 matches ended in a draw. Therefore, the probability for Portugal to win the game is $6/36 = 0.167$, the probability for Spain to win the game is $12/36 = 0.333$, and the probability that the match will end in a draw is $18/36 = 0.500$. From this fact, we can construct a discrete random variate for determining the match result if we have a particular random number.

The simulation needs to be conducted several times to improve the accuracy of the prediction. You also have to be careful for the knock-out round, as there will be extra time or even a penalty shootout to determine the winner of the game. Note that in the knock-out round, there will always be a winner in a game.

16 Predicting The 2018 Indonesian Super League Winner

(*Ad-hoc problem proposed by M. Arzaki*)

The second season of the Indonesian Super League, also known as Liga 1 is scheduled to take place from 24 February to 24 October 2018. The league consists of 18 teams and each team will face one another in a round-robin format. This means each team will face another team in a home and away fixtures. Therefore, each team will play 34 matches and there will be 306 matches overall.

In order to predict the winner of the Liga 1, firstly you need to gather the data regarding the statistics of the previous matches' results of each pair of the participating teams. This data can be obtained from several websites, such as `https://www.soccerpunter.com/`. However, you should be careful since the information in this website does not distinguish the condition for home and away fixtures (thus, you need to find a more reliable source). As all of Indonesian football fans aware, the home team is very likely to perform better when they play in front of their own supporters. Nevertheless, the simulation will be a lot easier (yet a little bit unrealistic) if we do not consider the home and away fixture as two different games. For instance, in the last five years, the notorious Persib-Persija games were 62.5% ended in a draw, 25% won by Persib, and 12.5% won by Persija.

Please be aware that the simulation needs to be run several times to improve the reliability of the prediction.

17 Rainy Days During Ramadan in Bandung

(*Ad-hoc problem proposed by M. Arzaki*)

(Only for a group of one or two students.)

Ramadan (also romanized as Ramadhan), is the ninth month of the Islamic calendar, and it is observed by Muslims all over the world as the month of fasting. In 2018, the first day of Ramadan is expected between May 14–16. Islamic calendar is purely lunar (which is based on the monthly cycle of the Moon's phases), hence the length of Ramadan cannot exceed 30 days. Thus, in 2018, Ramadan will fall between 14 May – 14 June.

Indonesia is a country located on the equator and thus its climate is almost entirely tropical. The country has two seasons, the dry season which normally happens between June to October and the rainy season which usually occurs between November to May. As a result, the Ramadan of 2018 falls in the intersection of the rainy and dry season. During Ramadan, the weather may affect many aspects, such as the type of foods and drinks consumed for breaking the fast (*iftar*), the traffics condition for the evening commute, and the number of people participating at the congregational prayers (*tarawih*).

In this modeling project, your task is to predict the rainy days during Ramadan of 2018. The prediction is limited to the City of Bandung. The probability of the rainy days can be obtained from reliable website (e.g., `https://www.bmkg.go.id`). However, we are only interested about the chance of raining happens on evening. Conduct at least 10 simulations and provide a resume of their results.

18 Traffic Jam at Buah Batu Junction

(*Ad-hoc problem proposed by M. Arzaki*)

The intersection between Buah Batu street and Soekarno-Hatta avenue in Bandung is one of the busiest road intersections in Bandung. Located at south of Bandung, this intersection becomes a primary access for those who goes in and out of Bandung Regency (*Kabupaten Bandung*) as well as Buah Batu toll gate. Therefore, traffic jam becomes an inevitable occurrence that happens during the morning and evening commute.

There are many people who leaves in the city of Bandung and works at Bandung Regency, or vice versa. These people traverse Buah Batu Junction every weekdays. Hence, the traffic condition of this intersection is something pertinent in their daily life. People want to know the average traffic condition of this junction, so they can think for other alternative routes or modes of transport (if there is any).

In this project, your task is to build a simulation to determine the average waiting time of each car traversing Buah Batu Junction from every direction. We are interested to determine the queueing time of the car during the morning or evening commute (or possibly both). Notice that Buah Batu Junction is an example of a four-armed intersection. For each arm, there are two sets of traffic lights. The first set controls the traffic for the straight direction, and the other one manages the vehicle movements for the turn-right direction. The vehicles are assumed to follow the *turn-left ahead* scheme, which means that any vehicle from one arm can turn left directly without following the traffic light signs to its immediate arm in a clockwise direction.

Since there are eight sets of traffic lights overall, we have eight different queues of vehicles at Buah Batu Junction. Your task is to build a simulation for these queues and analyze some of their characteristics. This task can be break down as follows:

1. Collect the data about the average inter-arrival time of vehicles on each of the four arms of the intersection. You may assume that the inter-arrival times are exponentially distributed with some particular parameters. You can obtain these parameters from direct observation.

2. Collect the data about the average service time of vehicles on each of the four arms of the intersection. The service times are the duration of the green lights in each sets of the traffic lights. Normally, the intervals of the green lights are fixed.

3. Build a simulation for the queues and analyze several aspects, i.e.: the average queueing time for a vehicle, the average idle time of the traffic lights, and the average queue length of the vehicles on every arms.

Please write the assumption of the model clearly.

19 Smoke Alarms

(*2007 HiMCM, Problem A, proposed by N. N. Nissa*)

Fire is one of the leading causes of accidental deaths. It is important for everyone to take every preventative measure and precaution possible to be ready to deal with a fire emergency. More than half of all fatal fires occur between 10 p.m. and 6 a.m. when everyone in the home is usually asleep. Smoke alarms are necessary to alert you to fires when you sleep. Will smoke alarms allow enough time to evacuate safely?

Build a mathematical model to determine the number and locations of smoke alarms to provide the maximum time for evacuation. Also include a model to determine the number and location of at-home fire extinguishers to have available. Build a mathematical model for evacuation of a family from both one and two story homes.

The floor plan for the one story home is illustrated in Fig. 6.

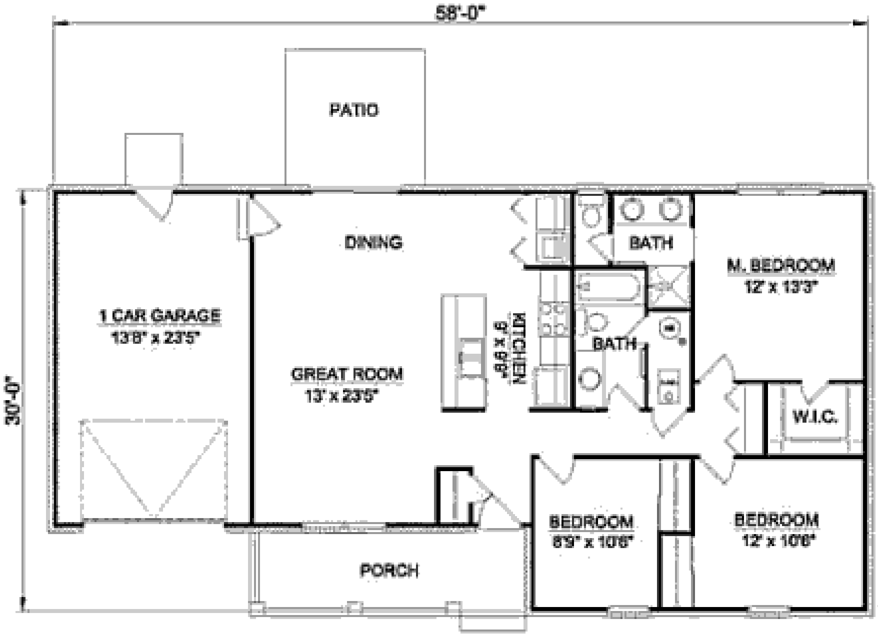

Figure 6: Floor plan of the one story home.

The floor plan for the two story home is illustrated in Fig. 7 (for the downstairs) and Fig. 8 (for the upstairs).

Figure 7: Downstairs floor plan of the two story home.

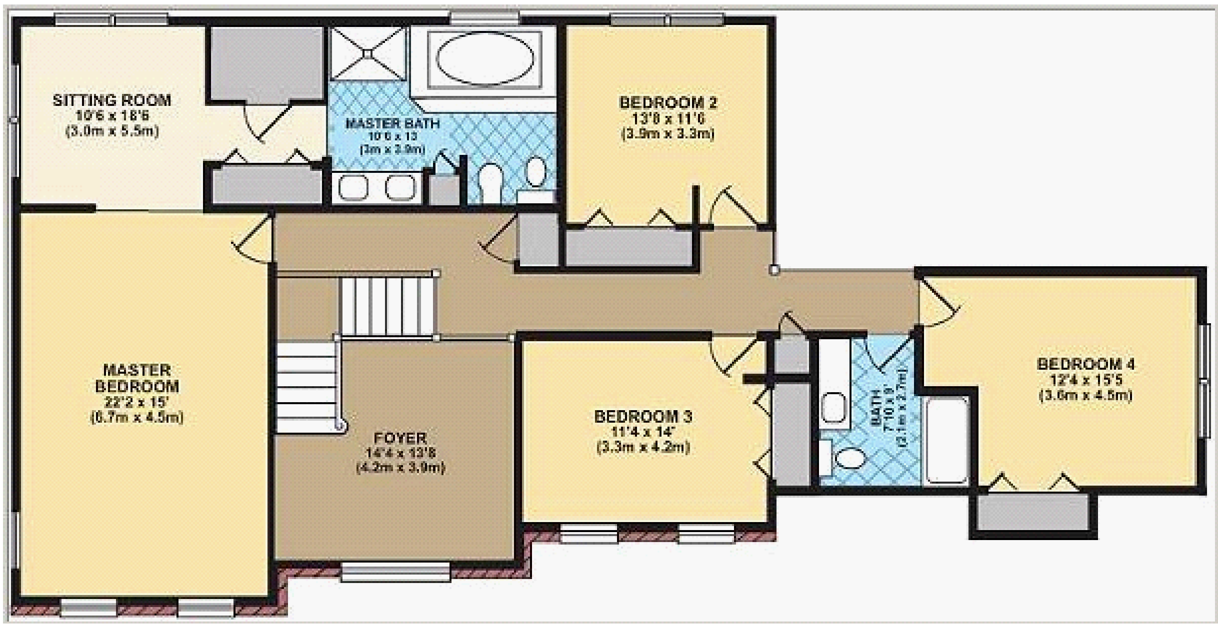

Figure 8: Upstairs floor plan of the two story home.

20 Car Rentals

(*2007 HiMCM, Problem B, proposed by N. N. Nissa*)

Some people rent a car when they are going on a long trip. They are convinced they save money. Even if they do not save money, they feel that the knowledge that "if the car breaks down on the trip, the problem is the rental company's" makes the rental worth it. Analyze this situation and determine under what conditions renting a car is a more appropriate option. Determine mileage limits on one's own car and a break-even value of "ease of mind" for the driver and his family.

21 City Crime and Safety

(*2015 HiMCM, Problem B, proposed by N. N. Nissa*)

What can we make of the massive amount of crime statistics collected in major cities? Beyond just reporting numbers, how can we use these data to determine the safeness of a city?

Assume that you and your modeling team live in My City, a large international hub of commerce, technology, finance and travel, with a current population of 2.8 million people impacted by a metropolitan area of an additional approximately 6 million people.

The data set provided (`My_City_Crime_Data.xlsx`) shows two weeks from police reports in My City and includes crimes listed by case number, date of occurrence, primary and secondary crime descriptions, crime location, whether an arrest was made, whether or not this was domestic crime, and the beat number of the police route.

Analyze the data using mathematical modeling. Create a safety rating for My City. Use your safety rating to specify a measure of how safe My City is.

22 A Faster QuickPass System

(*2004 MCM, Problem B, proposed by P. Turnip and M. Arzaki*)

"QuickPass" systems are increasingly appearing to reduce people's time waiting in line, whether it is at tollbooths, amusement parks, or elsewhere. Consider the design of a QuickPass system for an amusement park. The amusement park has experimented by offering QuickPasses for several popular rides as a test. The idea is that for certain popular rides you can go to a kiosk near that ride and insert your daily park entrance ticket, and out will come a slip that states that you can return to that ride at a specific time later. For example, you insert your daily park entrance ticket at 1:15 P.M., and the QuickPass states that you can come back between 3:30 and 4:30 P.M. when you can use your slip to enter a second, and presumably much shorter, line that will get you to the ride faster. To prevent people from obtaining QuickPasses for several rides at once, the QuickPass machines allow you to have only one active QuickPass at a time.

You have been hired as one of several competing consultants to improve the operation of QuickPass. Customers have been complaining about some anomalies in the test system. For example, customers observed that in one instance QuickPasses were being offered for a return time as long as 4 hours later. A short time later on the same ride, the QuickPasses were given for times only an hour or so later. In some instances, the lines for people with QuickPasses are nearly as long and slow as the regular lines.

The problem then is to propose and test schemes for issuing QuickPasses in order to increase people's enjoyment of the amusement park. Part of the problem is to determine what criteria to use in evaluating alternative schemes. Include in your report a non-technical summary for amusement park executives who must choose between alternatives from competing consultants.

23 How Many Students Will Graduate on Time?

(*Ad-hoc problem proposed by R. T. Lazwardi*)

Every undergraduate student of informartics engineering at Telkom University has their own academic ability. Many freshmen and sophomores are bedazzled with the courses that require combination of hardwork, cognitive reasoning, and technical knowledge. Some students can easily follow the course without significant obstacle, having a GPA of at least 3.50, or even participating in programming contest. However, some other students barely understand basic materials, reluctantly complete their assignments, and half-heartedly prepare for exams. Thus, many students are not able finish their study on time or even forced to leave the program without any degree.

In this problem, your objective is to predict the ratio (or proportion) of students that will graduate on time in the year 2019.

1. Given the data about the students enrolled in undergraduate program of informatics engineering at Telkom University in 2013, determine factors that cause students graduated on time (in the year 2017).

2. Build a model to predict the number of students (or the proportion of students) that graduate on time for those enrolled in 2015.

24 Money for Nothing

(*2017 ACM-ICPC World Final, Problem D, proposed by R. T. Lazwardi*)

In this problem you will be solving one of the most profound challenges of humans across the world since the beginning of time—how to make lots of money.

You are a middleman in the widget market. Your job is to buy widgets from widget producer companies and sell them to widget consumer companies. Each widget consumer company has an open request for one widget per day, until some end date, and a price at which it is willing to buy the widgets. On the other hand, each widget producer company has a start date at which it can start delivering widgets and a price at which it will deliver each widget.

Due to fair competition laws, you can sign a contract with only one producer company and only one consumer company. You will buy widgets from the producer company, one per day, starting on the day it can start delivering, and ending on the date specified by the consumer company. On each of those days you earn the difference between the producer's selling price and the consumer's buying price.

Your goal is to choose the consumer company and the producer company that will maximize your profits.

24.1 Input

The first line of input contains two integers m and n ($1 \leq m, n \leq 500\,000$) denoting the number of producer and consumer companies in the market, respectively. It is followed by m lines, the i-th of which contains two integers p_i and d_i ($1 \leq p_i, d_i \leq 10^9$), the price (in dollars) at which the i-th producer sells one widget and the day on which the first widget will be available from this company. Then follows n lines, the j-th of which contains two integers q_j and e_j ($1 \leq q_j, e_j \leq 10^9$), the price (in dollars) at which the j-th consumer is willing to buy widgets and the day immediately after the day on which the last widget has to be delivered to this company.

24.2 Output

Display the maximum total number of dollars you can earn. If there is no way to sign contracts that gives you any profit, display 0.

Sample Input 1	Sample Output 1
2 2 1 3 2 1 3 5 7 2	5

Sample Input 2	Sample Output 2
1 2 10 10 9 11 11 9	0

Reference

[MCM] https://www.comap.com/undergraduate/contests/mcm/previous-contests.php

[ICPC] https://icpc.baylor.edu/worldfinals/problems