Theory and Methods of Optimization

Embedded Robotics

Computer assignments

LP1. Murderville has specified the minimum requirements for the number of patrolmen on duty during each 4-hour period as seen in the table below:

Time of day	Number of patrolmen
Midnight–4A.M.	36
4A.M.–8A.M	18
8A.M.–Noon	12
Noon–4P.M.	10
4P.M.–8P.M	20
8P.M.–Midnight	32

Each policeman works for consecutive 8 hours during the day, and his assignment is repeated on each day (in particular, he may be assigned to a shift starting on one day and ending on the next one). Moreover, at least 30% of policemen working at any time must be officers with at least 4-year experience in the force. The total number of such officers available is 23. The number of less experienced officers can be considered unlimited. Find the assignment of experienced and unexperienced officers to each of the 8-hour shifts which minimizes the total number of policemen used and satisfies all the requirements imposed by the town. Solve the problem using a linear programming model.

LP2. The Education Council in a town in the mid-west of the United States tries to plan the assignment of students from 3 neighbourhoods to the 2 public schools in town. The assignment is supposed to minimize the total cost of school busing subject to the constraints related to the number of students each school can accomodate as well as requirements of the racial balance policy. The data realated to the problem is given in the table below (costs are given in dollars per person):

Neighbourhood	No. of black students	No. of white students	Cost of bus to school 1	Cost of bus to school 2
A	1100	0	0	13
B	720	960	15	10
C	510	760	17	5

The capacity of school 1 is 2500 students, while the capacity of school 2 is 2200 students. The racial balance policy requires that there are no more than 70% students of each race in each school.

Formulate and solve the integer programming model that will find the optimal assignment of students to schools satisfying all the constraints.

LP3. Suppose five daily newspapers are published in a certain country, each paper covering some of the twelve regions of the country as shown in the following table:

Newspaper	Regions covered	Cost of advertisment	Expected benefit
1	$1, 2, 4, 9$	\$3000	\$12000
2	$2, 3, 6, 8, 10, 12$	\$7000	\$14000
3	$4, 5, 7, 10$	\$4000	\$10000
4	$2, 3, 8, 10, 11$	\$5000	\$19000
5	$4, 5, 6, 9, 11, 12$	\$8000	\$20000

The marketing manager wants to find an advertisment maximizing the expected total profit such that

(a) The advertisment covers the whole country.

(b) The sum of total costs of advertisment will not exceed 20000 and will be at most one third of the expected profit from the advertisment.

Formulate the manager's problem as an integer linear program and solve it.

LP4. Suppose a restaurant working 7 days a week wants to hire waiters. Based on past experience, the number of waiters needed on each day of the week can be given as follows:

Day	Mon	Tue	Wed	Thu	Fri	Sat	Sun
Demand	11	9	15	13	17	19	22

There are three types of waiters: full-time waiters work for 5 consecutive days and then rest for the next two; part-time waiters work for 3 consecutive days and then rest for the next 4 days, week-end waiters work only on saturday and sunday. Each worker repeats his weekly working pattern indefinitely. Full-time waiters are paid \$14 per day of work, part-time waiters are paid \$16 per day of work, while week-end waiters are paid \$12 per day of work. Provide the waiters' work-plan for the week minimizing the cost for the restaurant. The plan must satisfy all the demand constraints. Do it using an integer programming model.

LP5. A supermarket working 7 days a week wants to hire employees. The number of people needed on each day of the week are known to be:

Day	Mon	Tue	Wed	Thu	Fri	Sat	Sun
Demand	23	19	24	17	25	39	30

There are two types of candidates for this work: full-time employees work for 5 consecutive days and then rest for the next two, they can start their shift on any day of the week and are paid \$16 per day of work; part-time employees work only on weekends (that is – either on friday and saturday or on saturday and sunday) and are paid \$13 per day of work. Each worker repeats his weekly working pattern indefinitely. Provide the supermarket's work-plan for the week minimizing the cost of labour. The plan must cover all the demand on every day of the week. Do it using an integer programming model.

LP6. (Based on [MK80]) The American Safety Council has allocated \$250000 to efforts to prevent automobile accidents. Two assumed measures of effectiveness of such efforts are the reduction in fatalities and in property damage. The projects suggested and relevant expected reductions per \$1000 invested are given in the table below:

Project	Exp. fatality reduction	Exp. prop. dam. reduction
Education in schools	18	\$10
Education for perpetrators	12	\$35
Promotion of seat-belt usage	20	\$0
Promotion of not using mobiles while driving	18	\$70
Additional financing of traffic police	24	\$15
Research in improved vehicle design	3	\$16

The main goal of these projects is the reduction of fatalities, hence, the council seeks for the allocation of funds which maximizes the expected reduction of fatalities, subject to the following constraints:

(a) The expected reduction in property damage should be at least \$5000.

(b) At least half of the funds are invested in educational or scientific programs.

Write an appropriate linear program allowing to find the optimal allocation of funds.

LP7. (Based on [MK80]) The Department of Agriculture is encouraging better crop planning. In order to acheive that it rents some land to the farmers from three provinces A, B and C under the condition that the amounts of different crops planted are such that the total revenue is maximized. These amounts should differ according to natural conditions in each of the regions as presented in the table below

Region	For rent [acres]	Water availability [gallons]	Percentage of 1st class grounds
A	8400	9500000	60
B	9700	20000000	70
C	4500	750000	45

Crops data is as follows:

Crop	Water consumption [gallons/acre]	Is 1st class soil necessary	Profit [\$/acre]
Millet	1200	No	150
Cane	3000	No	470
Cotton	2100	Yes	390
Patatoes	1500	No	260

What should be planted in what proportion in each region if the goal is to maximize the profit subject to the following constraints:

(a) On at least 7500 acres (in all regions together) patatoes should de planted.

(b) The crops must satisfy all the constraints due to their water consumption and the class of soil necessary for their cultivation.

Write and solve the linear program allowing you to find the optimal plan for the Agriculture Department.

LP8. Knoxville burns 5000 tons of trash every day in 4 incinerators. The data concerning them is given in the table below:

Incinerator	Daily capacity [t]	Emission of SO_2 per ton	Emission of particulate per ton
1	900	250	22
2	1700	230	20
3	1400	130	30
4	1000	220	25

The state Environmental Quality Commision has determined the limits on emissons of SO_2 and particulate, which are 500000 for SO_2 and 60000 for particulate. The town has to determine, how much garbage can be burnt in each incinerator so that the norms are satisfied (the rest must be transported to land fill in the neighbouring state, which is a much more expensive way to get rid of it). Create the linear program allowing you to find it out.

LP9. The increase of the cost of coal has forced the Knoxville Municipal Power Company to seek some savings in their energy production plan. The company has to produce $8000MWh$ of energy every day subject to the state norms of emissions of particulate and SO_2. The cost of producing $1MWh$ of energy in \$ and the levels of emissions of particulate and SO_2 in μg per $1MWh$ of energy are as follows:

Coal	Production cost	Emision of particulate	Emission of SO_2
Colombian	42	3.5	80
Indonesian	18	12	270

The daily norm for the emission of particulate is $60000\mu g$, while that for the amission of SO_2 is $300000\mu g$.

There's also a possibility of installation of filters on the chimneys of the plant. In that case the cost of producing $1MWh$ of energy increases by \$20 (for each type of coal), but the emission of particulate decreases by 90%, while that of SO_2, by 80%. Some amount of energy can also be bought at the market price of \$57 per $1MWh$. Write an integer program allowing you to find out, how much Colombian and how much Indonesian coal should be used for production, as well as whether the filters should be installed or not and whether some fraction of energy should be bought at the market. Your goal is the minimization of the total cost.

LP10. The head of the building department is planning the inspections for the upcoming week. He has 3 inspectors at his disposal: plumbing inspector (28h per week for inspections), electrical inspector (30h for inspections) and building inspector (34h for inspections). The times necessary for inspecting different types of buildings are given in the table below:

Inspector	Gas station	Restaurant	Garage	Residential building
plumbing insp.	4	2	1	2
electrical insp.	2	5	4	2
building insp.	3	3	2	3

For some buildings all three inspections can be done. In that case the probability of finding a defect is 12%, but the inspection takes as much time as the work of the longest-woking inspector needs. If only one inspector is sent, the probability of finding a defect decreases to 2.5%. Write and solve the linear program allowing to find the optimal inspection plan for the upcoming week (i.e. how many buildings of what type should be inspected by which inspector and how many of them should be inspected by all inspectors). Your goal is to maximize the expected number of defects found by the inspectors.

LP11. (Based on [Ec79]) The banquet manager for the Aristocrat Hotel must select a soup, a salad, and an entree for a forthcoming banquet. The total cost of items selected must not exceed \$4.25 per serving. In addition, the manager would like to maximize the total popularity rating of the items selected.

Item	Cost per serving	Popularity rating	Remarks
Soups:			
A	\$0.35	15	Not compatible with salad C
B	\$0.90	40	
Salads:			
C	\$0.50	25	
D	\$0.75	40	Not compatible with entree F
E	\$0.60	30	
F	\$1.20	50	
Entrees:			
G	\$2.10	20	
H	\$3.40	70	
I	\$2.50	50	

Formulate an integer programming model for optimizing the banquet menu taking also remarks given in the table above as additional constraints. Solve it.

LP12. (Based on [LP05]) The Cleveland Sprinkler Company buys PVC pipes, which come in 120cm lengths, and cuts them into the 30cm, 42cm, and 56cm lengths it requires for its projects. The following table gives the number of pieces of each required for each of the three lengths. Any cut of less than 30cm is considered waste and is discarded. The same can be said about the additional pipes that exceed the demand. The company would like to purchase enough pipe to satisfy its requirements while minimizing its total losses.

	30cm	42cm	56cm
Required	1300	750	1530

How many 120cm pipes should be purchased to satisfy all the demands and how should they be cut. Formulate and solve an integer program allowing to find the solution.
Hint: The 120cm pipes can be cut into several variations (e.g., four 30cm lengths, two 30cm lengths, and one 42cm length with 18cm of waste; one 30cm length and two 42cm lengths with 6cm of waste; etc). The decision variables are the number of pipes cut into each of these configurations.

LP13. A sawmill produces standard boards which are 22 inches wide. Some clients order narrower boards (of the same length) though. The orders for today consist of 120 7-inch boards, 135 5-inch and 72 3-inch ones. Smaller boards are cut off from the standard ones: e.g. the firm may decide to cut a standard board into 2 7-inch boards, one 5-inch and one 3-inch one. It could also decide to cut it into 3 7-inch boards, but in that case a 1-inch strip is a waste. The firm wants to satisfy the demand in such a way that there is no waste produced. In this case it prefers to produce additional 7-, 5- or 3-inch boards and store them so that they can be used on another day. The storage however induces storage cost proportional to the total sum of lengths of boards stored. Create the integer program allowing to find the way to cut the boards using least storage space and solve it.
Hint: Find all the possible ways to cut a 22-inch board into 7-, 5- and 3-inch ones without waste. The variables should be the numbers of 22-inch boards cut using each way.

LP14. (Based on [Ec79]) National Transit operates buses between major cities and carries commercial packages on a space-available basis. A departing bus has room for up to 650 cubic feet of packages. Also, the packages that are included cannot exceed a total weight of 750 pounds. Finally, it has to be taken into account that half of the space is reserved for the priority packages and cannot be taken by non-priority ones. Packages awaiting shipment are described in the table:

Package	Priority	Volume (ft^2)	Weight (pounds)
1	Yes	40	60
2	Yes	35	120
3	No	130	210
4	Yes	140	200
5	No	70	100
6	No	100	150
7	No	25	60
8	No	200	170
9	Yes	90	150
10	No	75	40

Formulate and solve an integer programming model for selecting packages to be included in the shipment. The goal of National Transit is to maximize the total number of packages shipped provided all the constraints are satisfied.

LP15. (Based on [Ec79]) Kronkhauser, Golden, and Smith, a public accounting firm, has received a request to audit the estate of a prominent individual who is being considered for appointment to a sensitive governmental position. The managing partner would like to assemble an auditing team that has maximum total auditing experience. At the same time, he does not want misunderstandings within the team, so he wants to have exactly two senior staff members on the team (as team's headperson and his deputy). The auditing team will travel by a private business jet that has a passenger-load capacity of 1000 pounds. Staff accountants who are available for assignment to the audit team are shown below:

Name	Weight in pounds	Years of experience	Senior staff member
Linda Nelson	95	2.0	no
Susan Mayo	120	6.5	yes
Karen Dubronsky	135	7.0	yes
George Oswald	140	5.0	no
Andrew Goldman	171	1.5	no
William Masterton	180	12	yes
Roland Smithee	185	5.5	no
Donald Crowder	190	2.5	no
Ronald Kramer	220	7.0	no
Josh Zushinsky	250	14	yes

Formulate and solve an integer program allowing to find the auditing team satisfying all the constraints.

LP16. A trading company must assign three sales managers to three sales offices. Its objective is to find the assignments that maximize the total yearly sales of all three offices. Naturally, only one person can be assigned to each sales office. The expected yearly sales (in millions of dollars) if each individual is assigned to each office are as follows:

	Atlanta	Boston	Chicago
Tardy	21	25	17
Vincent	14	17	15
Schuldiner	21	19	13

The relocation expense budget for all three moves is \$200000. The costs (in thousands of dollars) of relocating each individual to each location are as follows:

	Atlanta	Boston	Chicago
Tardy	65	50	30
Vincent	90	65	85
Schuldiner	100	20	80

Formulate and solve an integer programming model allowing you to decide which individual should be assigned to which office.

LP17. The head of Civil Defense in a town endangered by earthquakes wants to create the plan of assigning the casualties of a possible earthquake to four hospitals in town. The simulations suggests that almost all the casualties will come from three neighbourhoods: the historical neighbourhood A (up to 250 people), the inner city B (up to 450), and the city center (C; up to 90). The times of transporting people to each hospital (in minutes) and their estimated capacities (in number of beds) are given below:

Hospital	Beds available	Time from A	Time from B	Time from C
State Hospital	400	25	23	20
Saint Lucy	120	12	16	8
Saint Paul	250	20	26	16
Children's Hospital	210	30	35	21

Write a linear program allowing you to find the assignment of casulaties to the hospitals, assuming that your goal is to minimize the expected number of minutes necessary to transport all the casualties to the hospitals.

LP18. A presidential candidate is down to the last five days of the campaign and the race is close. Only $300,000 remains in the campaign budget. Four key states appear likely to swing the election one way or the other. In each state there are three campaign possibilities: it can be visited, a TV ad series can be purchased or no measures may be undertaken. The candidate's staff has made up the following estimates:

State	Action	Percentage of votes gained	Days required	Cost
J	Visit	8	4	200000
J	Ad campaign	3	0	100000
K	Visit	5	3	150000
K	Ad campaign	1	0	90000
L	Visit	3	1	40000
L	Ad campaign	4	0	15000
O	Visit	5	2	100000
O	Ad campaign	3	0	55000

In no case will both the ad series and a visit be scheduled in the same state. Formulate and solve an integer program allowing you to tell:

(a) Which states should be visited.

(b) In which states the ad series should be purchased.

(c) How much will the entire campaign cost.

The goal you should maximize is the average percentage of votes gained in the three states.

LP19. (Based on [NPTEL14]) Consider eight jobs (J1 to J8) and three non-identical parallel machines. The processing times are 23, 8, 15, 7, 5, 19, 16 and 8 on M1, 20, 9, 11, 13, 9, 12, 10 and 9 on M2 16, 14, 8, 5, 11, 15, 17 and 13 on M3. Each job has to be allotted to only one machine. Formulate and solve an integer program allowing to find the allocation that minimizes makespan.

LP20. Consider the situation where there are eight projects but only three people bid for them. Person B does not bid for project 2. Find the assignment of people to projects that maximizes the total number of projects completed subject to the constraints that the total cost does not exceed $100000 and that each person is assigned to at least two and at most four projects. The costs in $1000 for each assignment are given in the table below:

	Person A	Person B	Person C
Project 1	12	15	8
Project 2	16	x	7
Project 3	14	15	21
Project 4	13	14	9
Project 5	17	13	11
Project 6	22	24	16
Project 7	13	12	10
Project 8	9	6	12

Do it, using integer programming formulation of the problem.

LP21. (Based on [LP05]) Coolbike Industries manufactures boys' and girls' bicycles in both 20-inch and 26-inch models. Each week it must produce at least 350 girl models and 350 boys models. The following table gives the unit profit and the number of minutes required for production and assembly for each model:

Bicycle	Unit profit	Production minutes	Assembly minutes
20 – inch girls	\$32	28	20
20 – inch boys	\$28	25	16
26 – inch girls	\$54	19	30
26 – inch boys	\$48	26	25

The work is performed by two separate groups of workers: production team and assembly team, each of which works two (eight-hour) shifts per day, five days per week. The workers for both teams and both shifts are taken from the same pool of 20 people assigned to one of the teams for the whole week. Determine Coolbike's optimal (that is, maximizing profit) assignment of people into teams and optimal schedule for the week. What profit will it realize for the week? Solve the problem using a linear programming model.

LP22. (Based on [LP05]) Jones, Jimenez, and Sihota (JJS) is expanding its tax service business into the San Antonio area. The company wishes to be able to service at least 260 personal and 80 corporate accounts per week.

JJS plans to hire three levels of employees: CPAs, experienced accountants without a CPA, and junior accountants. The following table gives the weekly salary level as well as the projection of the expected number of accounts that can be serviced weekly by each level of employee.

Employee	No. of pers. accounts	No. of corp. accounts	Salary
CPAs	6	3	\$1500
Experienced accountants	6	2	\$900
Junior accountants	3	1	\$500

JJS estimates that the number of candidates for work with a CPA will not exceed 10. Determine the number of employees from each experience level the firm should hire for its San Antonio office to minimize its total weekly payroll. Do it using an integer programming model.

LP23. (Based on [MK80]) The company providing cleaning services for the hospitals has found out that the demand for its services is quite seasonal. The number of hours of service needed in each month is given in the table below:

Month	Hours
January	1800
February	2500
March	1500
April	900
May	700
June	1000
July	700
August	600
September	1300
October	1600
November	1800
December	2300

Each person is hired at the begenning of a month for a 3- or 6-month contract. Each person needs to pass the training in the first month, which decreases the number of hours for which he/she is available to 80. In any other month he/she can work for 196 hours. The monthly payment of any worker is \$1700. Write an integer program allowing you to find the optimal plan of hireing people for 3- and 6-month contracts. Your goal should be the minimization of cost subject to covering all the demand.

LP24. (Based on [LP05]) The We-Haul Company is about to lease 5000 new trucks for its California operations. The specifications of each truck under consideration are as follows:

Truck	Country	Capacity	Capital outlay	Monthly lease
Ford	U.S.A.	1 ton	\$2000	\$400
Chevrolet	U.S.A.	1 ton	\$1000	\$700
Dodge	U.S.A.	0.8 ton	\$3500	\$300
Mack	U.S.A.	5 tons	\$9000	\$1000
Nissan	Japan	0.5 ton	\$1000	\$200
Toyota	Japan	0.9 ton	\$0	\$550

We-Haul has decided that, for public relations reasons, given the current "Buy American" atmosphere, it will lease at least 60% of the trucks from American manufacturers. Each truck requires an initial capital outlay as well as monthly lease payments. We-Haul feels that it can support a total monthly lease payment of at most \$3000000 and total capital outlay of at most \$1500000. Its fleet requirements mandate at least a 8000-ton total capacity for the 5000 trucks leased. Formulate and solve an integer program allowing you to determine the number of each truck We-Haul should lease to maximize its total capacity.

LP25. Consider a company making a single product. The demand for the next four days is 90, 200, 150 and 140 units. The company employs at most 15 people and each person works for 8 hours daily. Each person can make one unit of the product per hour. The employees can work for 2 extra hour per day overtime. The company uses different systems to pay for regular and overtime work. The regular work is paid \$400 per day of work, regardless of the amount of product made by the person (i.e. regardless of whether they have worked for the entire day or stayed idle for several hours. Cost of over time production is \$70 per product. The company has to meet the daily demand but can produce more and store them for further use at \$10 per unit per day. The company can get the product made outside and buy it at \$125 per unit. Find the number of peaople to be employed and the least cost production plan for those people.

LP26. (Based on [LP05]) Frank has just inherited \$100000. Frank is quite risk-averse, hence, the consulting company suggests the following potential investments that can offer good returns with small risk:

Investment	Exp. return	Jones's rating	Liquidity anlysis	Risk factor
Savings account	5.0%	A	Immediate	0
Certificate of deposit	7.3%	A	5-year	5
Atlantic Lighting	9.8%	B+	Immediate	25
Arcansas REIT	12.8%	C	Immediate	40
Nocal Mining bond	11.2%	B+	1-year	15
Minicomp Systems	8.6%	B	Immediate	50
Antony Hotels	9.5%	B+	1-year	35

Given that Frank is risk-averse, the final recommendation should minimize the weighted average risk factor while meeting the additional goals:

- The weighted expected return should be at least 9%.
- No more than 40% of the inheritance in investments rated below B+ (that is, B or C).
- At least 30% of the inheritance in immediately liquid investments.
- No more than \$40000 invested in savings account or certificate of deposit.

Find the portfolio recommended for Frank using a linear programming model.

LP27. The prison canteen has to provide food for the prison's 370 inmates. The meals it provides must consist of foods A, B, C and D in proportions which assure that they meet some state-imposed requirements related to their nutritional properties. The table below gives the amounts of nutritional elements that one unit of each food contains as well as the minimum requirements in each category that a meal for each person should satisfy:

	per unit of A	per unit of B	per unit of C	per unit of D	required per person
units of carbohydrates	3	1	2	1	8
units of vitamines	4	2	6	3	23
units of proteins	1	2	5	7	12

Unit cost of food A is \$20, unit cost of food B is \$30 and they are available on the market in any amount. Product C is available at cost of \$45. Its availability is limited to 400 units. Finally, food D is available at \$40, but its availability is limited to 800 units

Find out using a linear programming model, how much of each type of food should be bought in order to minimize the cost while satisfying all the availability and nutritional constraints.

LP28. (Based on [LP05]) Tritech Mortgage specializes in making first, second, and even third trust deed loans on residential properties and first trust deeds on commercial properties. Any funds not invested in mortgages are invested in an interestbearing savings account. The following table gives the rate of return and the company's risk level for each possible type of loan:

Loan type	Rate of return	Risk rating
First trust deeds	7.25%	3
Second trust deeds	12.25%	6
Third trust deeds	15.75%	9
Commercial trust deeds	13.5%	5
Savings account	4.15%	0

Tritech wishes to invest $38000000 in available funding so that:

- Yearly return is maximized.
- At least $5000000 is to be available in a savings account for emergencies.
- At least 50% of the money invested in trust deeds should be in first or second trust deeds.
- The average risk rating should not exceed 5.

What distribution of funding do you recommend? What is the rate of return on this distribution of funds? Answer these questions using a properly constructed linear programming model.

LP29. (Based on [LP05]) Atlantic Standard Homes has aquired two lots in a new community in the Florida Keys: the first one is 10 acres, while the second is 15 acres. There are four models it can build on each lot, and Atlantic Standard must satisfy four requirements: at least 40 are to be one story; at least 50 are to have three or more bedrooms; all the houses built on the first lot are supposed to be one story; and there are to be at least 10 of each model. Atlantic Standard estimates the following gross profits:

Model	Lot size (acres)	Stories	Bedrooms	Profit
Tropic	0.20	1	2	$40000
Sea Breaze	0.27	1	3	$46000
Orleans	0.25	2	3	$60000
Grand Key	0.38	1	4	$80000

Formulate the problem as an integer linear programming model and solve for Atlantic Standards optimal production of homes in this community.

LP30. (Based on [NPTEL14]) Consider an airline that has demand for baggage handlers in a domestic airport. The hourly requirements for 24 hours starting from midnight are 7, 5, 3, 1, 2, 6, 7, 9, 10, 13, 16, 19, 15, 10, 10, 13, 18, 20, 23, 22, 15, 9, 8 and 7 respectively. There are 6 shifts for handlers: the first shift starts at midnight. The next shifts start at 4AM, 8AM, 12, 4PM and 8PM. Each shift works for 8 consecutive hours. The demand is the same for all days. Using an integer programming model find the minimum number of handlers required that meets the demand. Suppose the starting time of the first shift can be moved to some other hour (with all other shifts starting 4, 8, 12 16 and 20 hours after it). Will it make sense for the airline to change it, if the union accepts this change only if the payment of the baggage handlers increases by 10% in that case?

LP31. (Based on [NPTEL14]) Consider a caterer who has to provide food for several dinners happening in the next 8 days. The demand for cloth napkins that are used in the dinners is 89, 130, 109, 100, 70, 150, 206 and 151. New napkin costs $8. Napkins can be put to laundry and washed napkins can be used on subsequent days. Two types of laundry are available. The fast laundry that charges $2.9 per unit and will deliver for use on the second day and the slow laundry that costs $1.3 per unit and can deliver for use on the third day. Find the least cost purchase and use plan for the caterer using linear programming (the optimal solution should be integer without adding integrity constraint).

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