

Practice Problems – Module 11 – Version A

1) **CHALCO CARTON COMPANY (CCC)** - The Chalco Carton Company produces egg cartons (among other items) at three eastern Nebraska locations (Gretna, Louisville, and, of course, Chalco). The company has just received contract to provide a onetime shipment of egg cartons to ‘mom and pop’ grocery stores in Ashland, Greenwood, Waverly and Eagle. The contract will pay CCC a fixed amount for the satisfaction of the demand specified in the contract for the egg cartons at the grocery stores.

A quick analysis of shipping costs using historical records and basic CCC accounting principles leads to the following table which shows the per carton cost of transporting a crate of cartons from the production locations to the grocery stores.

	Ashland	Greenwood	Waverly	Eagle
Gretna	10	7	8	15
Louisville	16	13	9	14
Chalco	12	11	12	16

Gretna has 75 crates of cartons in stock, Louisville, 80 crates, and Chalco, 55 crates. The contract states that CCC needs to ship Ashland 50 creates, Greenwood 60 crates, Waverly 70 crates and Eagle, 65 crates.

- a) Find the least cost way to ship crates while TRYING to meet demand.
- b) How did CCC screw up in agreeing to this contract? Which location(s) gets ‘shorted’?

2) **RED CLAD LOONS I** - December 7, 2015 ... A day of infamy ... after many years of futility, the Nebraska Cornhuskers, by virtue of an upset of the Notre Dame Fighting Irish during a freak ice storm in the Big 14 Championship football game held at Soldier Field in Chicago, were selected to play in the BCS Championship game, held in what used to be called the Rose Bowl.

Nebraska fans, notorious for their rabidity in traveling to Bowl Games, quickly began to clamor for chartered flights to the LA area.

Travel and Transport (T&T), a local travel agency, quickly scooped up the rights for 7600 airline seats from various flight chartering companies. It was estimated that this would be about 1/3 of the total demand for chartered flights from the Nebraska area.

Anyway, T&T has some flexibility in deciding which airports to use for their chartered flights, as well as the airports to use in California to drop off the red-attired fanatics.

Their first decision was to identify that they will send their 7600 customers from 4 airports; from Denver (close to Western Nebraska), Lincoln, Omaha and Kansas City (fairly close to both Omaha and Lincoln). They estimate that they will partition their

customer base into 750 people flying from Denver, 2000 people from Lincoln, 4500 people from Omaha, and 350 people from Kansas City.

T&T secured the rights to transport no more than 1500 people to the Burbank airport, no more than 3000 to John Wayne Airport (SNA) in Orange County, and can send as many as they wish to LAX. Burbank and SNA limits are meant as upper bounds.

In doing some aggregate planning (not down to the airplane level), due to some legal reasons, plane sizes, etc., Lincoln and Omaha are constrained on the maximum amount that they can send to any one airport in LA. Lincoln can send at most 900 people to any one individual airport, while Omaha has a similar restriction, but a larger ceiling– it can send at most 2000 people to any one individual airport. So these restrictions do not keep T&T from meeting customer demand, they will only cause additional constraints to the best way to transport Nebraska fans to California.

T&T wishes to minimize their cost in determining their plan to get 7600 Red Clad Loons to the Left Coast. (translated: 7600 Nebraskans to LA). Per person cost is assessed as follows:

Omaha to Burbank:	165	Omaha to LAX:	225	Omaha to John Wayne:	285
Lincoln to Burbank:	175	Lincoln to LAX:	250	Lincoln to John Wayne:	300
Denver to Burbank:	225	Denver to LAX:	255	Denver to John Wayne:	200
KC to Burbank:	150	KC to LAX:	235	KC to John Wayne:	275

Identify what their high-level plans should be for transporting the 7600 Red Clad Loons.

3) **Havis Rent-a-Wreck** (yes, another car problem – this is simply an old in-class exercise sequence – should be a good refresher – I’m not fixated on cars!).

Part A: Cars are needed in Stillwater, Tulsa and OKC for an upcoming event in Central and Eastern Oklahoma. 22 cars are needed in Tulsa, 15 cars in OKC and 9 in Stillwater. 46 cars have been located that can be driven from locations in Dallas (10 cars), College Station (20 cars) and Lubbock (16 cars).

Find the least distance way to get the cars from the Texas locations to the OK locations using the following distance information. Objective is to minimize total distance traveled of all vehicles.

	OKC	Tulsa	Stillwater
Dallas	209	256	268
C. Station	378	443	437
Lubbock	384	483	444

Part B (related to Part A): Change the problem to where the end location for the spare cars presently at the three Texas locations is St. Louis and Memphis. The cars must pass through one of the inspection stations in OKC, Tulsa or Stillwater prior to going to their final destination (St. Louis or Memphis). St. Louis needs 31 cars, while Memphis needs only 15. The distance from the OK inspection locations to the final locations is given in the table below.

i) With no restrictions on the number of vehicles that can go through a single inspection location, find the least cost (distance) way to ship vehicles from Texas, to OK, to their final destinations. Assume relevant data from above (distances, cars available, etc.) is still valid. Distance data for the second part of the supply chain is shown below.

	OKC	Tulsa	Stillwater
Memphis	474	400	471
St. Louis	511	395	463

ii) Consider how to implement a restriction on the number of cars that pass through a single inspection location – use a maximum of 20 units. Create a new model that implements that restriction.

Part C (unrelated to Part A except for data): A supervisor is needed at the OK locations during this event. There is one person available from each of the Texas locations to serve as supervisors in OK. Find the least cost (distance) way to send a supervisor from a Texas location to an OK location.

4) **RED CLAD LOONS II** - December 7, 2015 ... After a tough year and missing out on the Big 14 Championship game with a close defeat late in the season to the resurgent Notre Dame Fighting Irish, a 7-5 Nebraska Cornhuskers team accepts a bowl game invitation to the newly created Al Davis Memorial Bowl in Anaheim, CA. (Need to stretch the imagination here).

Nebraska fans, notorious for their rabidity in traveling to Bowl Games even when they are a lesser tier game, quickly began to clamor for chartered flights to the LA area.

Rural Transport Inc. (RTI), a local travel agency, has put together a package including game tickets whereby Nebraska fans from rural parts of Nebraska drive to three hub cities (Grand Island, Columbus, and Nebraska City), then are bused to airports in Lincoln, Omaha and Kansas City before catching flights to one of three California Airports (Burbank, LAX and John Wayne (SNA) Airports respectively) to get to the game.

RTI anticipates needing to bus 400 people from Grand Island, 500 people from Columbus, and 600 people from Nebraska City.

The Burbank airport can handle up to 300 of these fans, LAX up to 650 fans and SNA up to 550, respectively.

The goal is to minimize the cost (at high-level aggregate planning) in getting the Red Clad Loons (i.e., Nebraska fans) from the rural parts of Nebraska to the big city for the game.

There are two components of the cost – busing costs and airline costs. Airline costs are per person cost and assessed as follows:

Omaha to Burbank:	165	Omaha to LAX:	225	Omaha to John Wayne:	285
Lincoln to Burbank:	175	Lincoln to LAX:	250	Lincoln to John Wayne:	300
KC to Burbank:	150	KC to LAX:	235	KC to John Wayne:	275

Busing cost is \$1 per mile bused per person. Distance between the Nebraska hub cities and the airports in Nebraska and Missouri:

	Omaha	Lincoln	KC
GI	148	103	274
Columbus	83	78	256
Nebr City	45	52	128

a) Create a linear programming model that specifies the least cost way to get the 1500 Red Clad Loons to California for RTI.

b) Create a linear programming model that specifies the least cost way to get the 1500 Red Clad Loons to California for RTI considering that the airports in the Midwest (Omaha, Lincoln and KC) can each handle at most 600 travelers.

5) **Railroad Car Rumba** - The Rock Island Railroad (RIRA) has 100 empty railcars at its Sioux City rail yards and 150 rail cars at its North Platte location available for retro-fitting for a new project. Ultimately, RIRA must get 75 retro-fitted cars to Chicago, 85 retro-fitted cars to Peoria, and 55 retro-fitted cars to St Louis.

To retro-fit the cars, two different stages of maintenance must be performed on the rail cars. Stage 1 retro-fitting occurs either at Lincoln, Omaha or Des Moines. Stage 2 retro-fitting occurs at Davenport, IA or Kansas City. Cars must pass first through Stage 1, then Stage 2, before arriving at the final destination.

We are not interested in retro-fitting costs at the 5 different maintenance locations. Our goal is to find the least distance way to transform the railcars and get them (in their retro-fitted format) to Chicago, Peoria and St. Louis.

Stage 1 and Stage 2 locations have capacities for retro-fitting. They are listed below.

Location	Capacity	Stage
Lincoln	115	1
Omaha	90	1
Des Moines	50	1
Davenport, IA	95	2
Kansas City	135	2

Relevant distances are shown below. Using an appropriate linear programming model, find the optimal way of satisfying the rail car transformation problem for RIRA. Explicitly explain why your solution says in terms of cars transportation.

	Lincoln	Omaha	Des Moines	Chicago	Peoria	StLouis
Sioux City	188	162	209			
N Platte	214	248	372			
Davenport	320	281	156	152	76	203
Kcity	163	167	177	529	285	234

6) **Who is this FISHALOW you speak of?** - The WALLEYES are about to play the PIKES, another team in the '4 on 4' basketball league. Each team is allowed to carry five players on their roster; however, the PIKES only have 4 available due to injury. The two teams have played many times during the year. Based on past performances, the following table indicates how many points the PIKES player will score if guarded by the particular WALLEYE player (e.g., if Wilson guards Madsen, Madsen will score 25 points).

				PIKES			
WALLEYES		Madsen	Gordon	Pritza	Goodman		
Wilson		25	16	22	19		
Apker		4	10	5	34		
Fletcher		14	12	20	24		
Drvol		10	13	16	26		
Stone		20	18	10	22		

a) Based on the above data, determine the proper assignment of WALLEYES to PIKES that will minimize the amount of points scored by the PIKES. Who sits out?

b) Just before the game, Apker gets sick and cannot play. Using the four healthy WALLEYE, determine the worst possible assignment that could occur from the WALLEYE perspective (i.e., the matching that would lead to the highest amount of points scored by the PIKES).

### 7) The China Syndrome's Holiday Staffing

Jane Turner has to schedule people to work at the Ventana Nuclear Power Plant during 5 work days in November, December and New Year's when they have a skeleton crew (no pun intended) . These are the least 5 desirable work days of the year – Thanksgiving, Friday after Thanksgiving, December 24<sup>th</sup>, December 31<sup>st</sup>, and January 1<sup>st</sup>.

Abbreviations: TH, TF, XE, NYE, NYD – for the five days in the order listed above.

Jane needs to have 3 people work on Thanksgiving, 4 people on the Friday after, 2 people on December 24<sup>th</sup> (XE), 3 people on New Year's Eve, and 5 people on January 1<sup>st</sup>.

There are ten staffers (names noted as A thru J), no one can work more than 2 of the days.

The staffers were given 20 points to allocate among the 5 days – expressing their preferences on which days they wanted to be off: The higher values, the more desirable it is for the staff person to not have to work that day. Below is the preference table.

	TH	THF	XME	NYE	NY
A	8	2	5	3	2
B	10	4	2	2	2
C	2	6	6	1	5
D	1	2	3	4	10
E	4	5	5	4	2
F	2	2	10	2	4
G	1	1	4	10	4
H	3	3	3	3	8
I	2	10	2	4	2
J	6	5	2	3	4

Using an appropriate LP model, find the optimal way to staff the Ventana plant over the holiday season.

### 8) Sally League Umpire Crew Scheduling

The South Atlantic League is a minor league baseball league at the A-level. It is divided into a Northern and Southern division as shown below.

South Atlantic League - Wikipedia, the free encyclopedia - Internet Explorer provided by Dell

W: http://en.wikipedia.org/wiki/South\_Atlantic\_League

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Main article: [South Atlantic League rosters](#)

The league is divided into a **Northern Division** and a **Southern Division**.

Division	Team	MLB Affiliation	City	Stadium	Capacity
Northern	<a href="#">Delmarva Shorebirds</a>	Baltimore Orioles	Salisbury, Maryland	Arthur W. Perdue Stadium	5,200
	<a href="#">Greensboro Grasshoppers</a>	Florida Marlins	Greensboro, North Carolina	NewBridge Bank Park	7,499
	<a href="#">Hagerstown Suns</a>	Washington Nationals	Hagerstown, Maryland	Municipal Stadium	4,600
	<a href="#">Hickory Crawdads</a>	Texas Rangers	Hickory, North Carolina	L. P. Frans Stadium	5,092
	<a href="#">Kannapolis Intimidators</a>	Chicago White Sox	Kannapolis, North Carolina	Fieldcrest Cannon Stadium	4,700
	<a href="#">Lakewood BlueClaws</a>	Philadelphia Phillies	Lakewood, New Jersey	FirstEnergy Park	6,588
	<a href="#">West Virginia Power</a>	Pittsburgh Pirates	Charleston, West Virginia	Appalachian Power Park	6,200
Southern	<a href="#">Asheville Tourists</a>	Colorado Rockies	Asheville, North Carolina	McCormick Field	4,000
	<a href="#">Augusta GreenJackets</a>	San Francisco Giants	Augusta, Georgia	Lake Olmstead Stadium	4,400
	<a href="#">Charleston RiverDogs</a>	New York Yankees	Charleston, South Carolina	Joseph P. Riley, Jr. Park	6,000
	<a href="#">Greenville Drive</a>	Boston Red Sox	Greenville, South Carolina	Fluor Field at the West End	6,000
	<a href="#">Lexington Legends</a>	Houston Astros	Lexington, Kentucky	Whitaker Bank Ballpark	6,994
	<a href="#">Rome Braves</a>	Atlanta Braves	Rome, Georgia	State Mutual Stadium	5,105
	<a href="#">Savannah Sand Gnats</a>	New York Mets	Savannah, Georgia	Grayson Stadium	5,000

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Scheduling umpires is a classic application of Integer Programming (see Mike Trick's website). We're going to simulate on a much smaller level using the 14 teams of the Sally League (old nickname for the Southern Atlantic League – or SAL) so we don't need the next Module.

Consider the hypothetical schedule for July 6, 2012 and July 8, 2012. The games on July 6<sup>th</sup> represent the end of a (typical) 4 game series, while the games starting on July 8<sup>th</sup> represent the start of a (typical) 3 game mid-week series. July 7, 2012 – there are no games – a 'travel day'.

Games played on July 6<sup>th</sup> – (Umpire crew designation also shown).

CREW 1 - [Charleston RiverDogs](#) at [Rome Braves](#)  
 CREW 2 - [Greensboro Grasshoppers](#) at [West Virginia Power](#)  
 CREW 3 - [Lakewood BlueClaws](#) at [Delmarva Shorebirds](#)  
 CREW 4 - [Hickory Crawdads](#) at [Greenville Drive](#)  
 CREW 5 - [Savannah Sand Gnats](#) at [Augusta GreenJackets](#)  
 CREW 6 - [Lexington Legends](#) at [Hagerstown Suns](#)  
 CREW 7 - [Asheville Tourists](#) at [Kannapolis Intimidators](#)

Series( games) starting on July 8<sup>th</sup>.

July 8, 2012	<a href="#">Lexington Legends</a> at <a href="#">Hickory Crawdads</a>	7:00 p.m.
July 8, 2012	<a href="#">Greenville Drive</a> at <a href="#">Rome Braves</a>	7:00 p.m.
July 8, 2012	<a href="#">Augusta GreenJackets</a> at <a href="#">Asheville Tourists</a>	7:05 p.m.
July 8, 2012	<a href="#">Delmarva Shorebirds</a> at <a href="#">Charleston RiverDogs</a>	7:05 p.m.
July 8, 2012	<a href="#">West Virginia Power</a> at <a href="#">Hagerstown Suns</a>	7:05 p.m.
July 8, 2012	<a href="#">Kannapolis Intimidators</a> at <a href="#">Lakewood BlueClaws</a>	7:05 p.m.
July 8, 2012	<a href="#">Greensboro Grasshoppers</a> at <a href="#">Savannah Sand Gnats</a>	7:05 p.m.

One could develop a sophisticated, generic model that could be used for scheduling umpire travel at any point in the schedule. For this example though, we're just interested in a simple model that will determine how the umpire crews should travel to the series starting July 8<sup>th</sup>. The objective is to minimize combined miles traveled by the crews (the crews stay together). Unless you really want to as a personal challenge, don't make the model harder or more elaborate than necessary. This is a good modeler/model partnership situation.

Besides minimizing overall distance traveled, and the fact that each of the 7 crews must be assigned to exactly 1 series (and each series assigned a crew!), a crew can only be assigned to a series for teams they did NOT serve as a crew for in the July 6<sup>th</sup> games. So, for example, CREW 1 cannot be assigned to a July 8<sup>th</sup> series that has the Rome Braves or the Charleston River Dogs participating.

As a 'part b' of the problem, how does the optimal assignment of crews change if you add a constraint that says a crew cannot travel more than 325 miles to their next series? Compare and contrast the solution (i.e., use some words and tables or something). Below is the relevant mileage information for the July 6<sup>th</sup> to July 8<sup>th</sup> transition.

**PUNCHLINE: DETERMINE WHICH CREWS ARE ASSIGNED TO WHICH JULY 8<sup>TH</sup> BASEBALL SERIES!**

	Rome GA	Hickory NC	Asheville NC	Charleston SC	Hagerstown MD	Lakewood NJ	Savannah GA
Rome GA	0	296	221	361	636	851	318
Charleston WV	476	251	292	471	293	514	515
Salisbury MD	778	463	537	570	124	192	613
Greenville SC	202	115	63	213	499	690	257
Augusta GA	216	215	182	143	568	745	135
Hagerstown MD	636	394	452	599	0	234	643
Kannapolis NC	322	63	137	234	380	570	277

**9) RMC Corporation** – The RMC Chemical Company makes two products, fuel additive (FA) and solvent base (SB) at three different locations in Nebraska – Omaha, Lincoln and Grand Island. After production, RMC ships the chemicals to its three warehouses in Kansas City, Wichita and Oklahoma City, where customers drive up to the warehouse and take their tons of chemicals. Contracts have been previously signed and each customer is billed according to the terms of these contracts.

Production costs of the two products vary at each plant, as shown below (in thousands of \$\$ per ton). Also, maximum production levels for the upcoming period are also shown.



Location	Fuel Additive	Fuel Additive	Solvent Base	Solvent Base
Plants	Cost per ton	Production	Cost per ton	Production
Omaha	\$5	250	\$4	200
Lincoln	\$6	150	\$5	200
Grand island	\$4	100	\$5	150

Estimated average revenue per ton (also in 000's) for each of the three warehouses is shown below for each product, as is the contractual demand for the next period for each product.

Location	Fuel Additive	Fuel Additive	Solvent Base	Solvent Base
Warehouses	Revenue/ton	Demand	Revenue/ton	Demand
Kansas City	\$12	180	\$16	200
Wichita	\$15	225	\$12	125
Oklahoma City	\$16	95	\$14	225

Note that if RMC cannot meet contractual demand, they are assessed a lost sales charge of \$3 (000) per ton of unmet demand.

The only other family of constraints deals with the tonnage of chemicals that can be shipped from each plant due to truck size and other factors. Omaha can at most send a combined 150 tons of chemicals (this is adding FA and SB) to any one plant – thus, it could send 75 tons of FA and 75 tons of SB to KC, or it could send 0 tons of FA and 150 tons of SB to KC, etc. Similar restrictions for Lincoln (combined max of 120 tons to any one warehouse) and Grand Island (combined max of 90 tons to any one warehouse) should also be applied. The table below provides the per ton cost (in 000's) of shipping chemical products (either type) from the plants to the warehouse.

	Kansas City	Wichita	Oklahoma City
Omaha	\$5	\$7	\$11
Lincoln	\$5	\$7	\$9
Grand island	\$7	\$6	\$10

Create an LP model that determines the best distribution plan for the next period. Maximize profit by considering revenue and the costs of production, distribution and lost sales. Assume all costs are 'relevant'. Highlight why you did or did not get lost sales in your model.

## **10) UNION ATLANTIC RAILROAD – “AFTER THE FLOODIN”**

Using the Summer of 2011 as an example scenario - The floods of the Upper Midwest (the Missouri River, the situations in North Dakota, etc.) have wreaked havoc on railroad transportation.

After some additional track has been reopened with waters finally receding, a small segment of the Union Atlantic Railroad has a need to get two types of empty boxcars (Type I and Type II) that are presently in yards in Grand Island, NE and Des Moines, IA to rail yards in Minneapolis, MN and Fargo, N.D. as quickly as possible. Of course, subject to constraints that will not totally disrupt future railroad shipments.

Box car Type 1 – there is presently an inventory of 200 cars in Grand Island, and 160 cars in Des Moines. Minneapolis has requested 120 cars, Fargo 180.

Box car Type 2 – there is presently 50 cars at GI and 240 in Des Moines. Minneapolis has a need for 175 , Fargo 40.

Demand for the boxcars at Minneapolis and Fargo **MUST BE MET EXACTLY**.

Because of the time the cars have sat unoccupied, all boxcars must travel through inspection stations prior to arriving at their final destinations. The three inspection stations are located in Omaha NE, Kansas City, Mo. and Sioux Falls, SD.

Each inspection station, for the time frame relevant to this scenario, can handle at most 180 total box cars, and no more than 120 of any one kind of box car.

Additionally, in anticipation of future empty box car needs, at least 40 box cars (combined) must be kept at both Grand Island and Des Moines, and this includes a minimum of 15 of each specific type of boxcar at each location. So, not all cars available at Grand Island or Des Moines can be used.

Find the optimal way of transporting the unused boxcar inventory through the inspections stations to the rail yards that need them for their operations. Minimize overall distance traveled by the boxcars. The distance table is provided below. Clearly (in words) identify the optimal transportation of each type of box car.

	OMA	KC	SF
GI	147	287	251
DM	136	194	284
MPLS	378	436	236
FARGO	424	601	245

GI = Grand Island, DM = Des Moines, OMA = Omaha, KC = Kansas City, SF = Sioux Falls, MPLS = Minneapolis, FARGO = Fargo

Table 1 is distance from inventory yards to inspection station.

Table 2 is distance from inspection stations to desired location railroad yards.

“So I’ll send you the cars, after the floodin’ ... with the tracks that just opened yesterday.  
” (with apologies to Engelbert Humperdinck, and probably the reader who may have no clue who Mr. Humperdinck may be!)

### **11) ARAC-nophobia!**

American Rent-A-Car (ARAC) has 8 outlets in a metropolitan area. The outlets are referred to by their addresses: Yawkee Way (YW), Elysian Park Ave (EPA), Broad Street (BS), Bert Murphy Ave (BMA), West Addison St. (WAS), Hall of Fame Ave (HoFA), Lombardi Ave. (LOM) and Arrowhead Dr. (ADR). It ‘stocks’ cars in two broad categories, Compact and Mid-Size.

Each day, American operates under a policy where the number of available cars are redistributed to the outlets overnight to meet percentage ‘targets’ for the start of business that next day. The following table shows the percentage targets for each outlet and for each car-type.

Outlet	YW	EPA	BS	BMA	WAS	HoFA	LOM	ADR
Compact	20	10	20	5	10	20	5	10
Mid-Size	16	12	10	14	10	16	10	12

At the end of the present business day, there are 100 compact cars and 50 Mid-Size cars available. The following table provides the location of the cars by outlet and by type.

Outlet	YW	EPA	BS	BMA	WAS	HoFA	LOM	ADR
Compact	4	14	5	17	22	7	10	21
Mid-Size	10	0	5	3	9	11	7	5

Additionally, ARAC has a ‘car rotation’ policy stemming from an incident involving drug trafficking involving rental vehicles in the late 1990’s. This policy states that no more than a total of 6 cars (of any type combined) can be transported between a pair of outlets. Thus, trying to send 4 compact cars from YW to BS, and 3 Mid-size cars from BS to YW would violate this policy (it would be a total of 7 cars between YW and BS).

Your task is to find the least cost way to meet the rental car targets for the next day. The cost table is provided below and in spreadsheet form (in kilometers). Assume symmetric costs.

	EPA	BS	BMA	WAS	HoFA	LOM	ADR
YW	4.3	3.5	3.2	3.1	2.5	5	4.7
EPA		5.2	4.5	7.2	6.1	5.9	6.5
BS			7.1	5.3	5.5	5.2	4.6
BMA				6.1	5.4	6.3	7.5
WAS					6.5	7	5.8
HoFA						5.4	4.7
LOM							6.2
ADR							