

Instructions for the ECN201 Project on Least-Cost Nutritionally-Adequate Diets

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1 Overview

For this project, each student should (a) determine her or his nutritional needs, (b) compute quantities of foods required to satisfy the nutritional needs at minimum cost, and (c) write and submit a report on the nutritional needs and minimum-cost diet. The project, as indicated in the syllabus, counts for 20% of the course grade. Details on each part of the project are provided below.

2 Determining nutritional needs

Information on the nutritional needs specific to an individual's physical characteristics and activities is provided by the United States Department of Agriculture (USDA). To obtain this information, point a web-browser to <http://fnic.nal.usda.gov/fnic/interactiveDRI/>. At that site, fill in your sex, age, height, weight, and activity level. If female, select your status relative to pregnancy or lactation. Check the boxes for daily calorie needs, carbohydrate, total fiber, protein, fat, calcium, copper, iron, magnesium, manganese, phosphorus, potassium, selenium, sodium, zinc, and all vitamins *except* biotin and carotenoids. (Altogether, boxes for 28 nutrients should be checked.) For example, a 35-year-old, 140 lb, 5'8" female who has been lactating over seven months and now devotes 30 minutes a day to moderate exercise would complete the USDA form as shown in Figure 1. Clicking "Submit" at the bottom of her completed form produces the results shown in Figure 2.

After clicking the "Submit" button on your completed USDA form, record the recommended intakes and tolerable upper limit (UL) intakes on nutrients in food. (You may ignore upper limits on nutrients from synthetic sources such as vitamin and mineral tablets.)

3 Computing a least-cost nutritionally-adequate diet

Given your nutritional needs and foods' prices and nutritional compositions, the problem of calculating a least-cost nutritionally-adequate diet can be solved by coding it in LP format and executing it with freely available linear-programming software as explained in the following subsections.

3.1 Coding

A nearly complete computer program in LP format is provided by a file in the class Sakai site (2159-ECN2010001: Prin of Econ: Microeconomics). To download this file, go to the class Sakai site, open the folder titled "Resources" and then the sub-folder titled "Linear programming tools and applications." Using the left-mouse button, click on "DietTemplateF15.lp" and save it. This file includes the needed information about food prices and nutritional composition. The only information you need to supply relates to your nutritional requirements, as described in section 2. Using a

Sex: ☐ Male ☒ Female Lactating - Over 7 months ▼

Age: ☒ yrs. ☐ or for infants, months.

Meas. Units: US (feet/inches/pounds) ▼

Height: feet inches

Weight: lbs.

Activity: Low Active ▼ [What's This?](#)

For detailed nutrient descriptions and terminology, see the [Interactive DRI Glossary](#).

Calculate

- ☐ Body Mass Index ☒ Daily Calorie Needs

Macronutrients

Check/Uncheck All Macronutrients ☐

- | | | |
|--|---|--|
| <input checked="" type="checkbox"/> Carbohydrate | <input type="checkbox"/> Saturated Fatty Acids | <input type="checkbox"/> Linoleic Acid |
| <input checked="" type="checkbox"/> Total Fiber | <input type="checkbox"/> <i>Trans</i> Fatty Acids | <input type="checkbox"/> Dietary Cholesterol |
| <input checked="" type="checkbox"/> Protein | <input type="checkbox"/> α -Linolenic Acid | <input type="checkbox"/> Total Water |
| <input checked="" type="checkbox"/> Fat | | |

Vitamins

Check/Uncheck All Vitamins ☐

- | | | | |
|--|---|--|--|
| <input checked="" type="checkbox"/> Vitamin A | <input checked="" type="checkbox"/> Vitamin E | <input checked="" type="checkbox"/> Riboflavin | <input checked="" type="checkbox"/> Pantothenic Acid |
| <input checked="" type="checkbox"/> Vitamin C | <input checked="" type="checkbox"/> Vitamin K | <input checked="" type="checkbox"/> Folate | <input type="checkbox"/> Biotin |
| <input checked="" type="checkbox"/> Vitamin D | <input checked="" type="checkbox"/> Thiamin | <input checked="" type="checkbox"/> Niacin | <input type="checkbox"/> Carotenoids |
| <input checked="" type="checkbox"/> Vitamin B ₆ | <input checked="" type="checkbox"/> Vitamin B ₁₂ | <input checked="" type="checkbox"/> Choline | |

Minerals (Elements)

Check/Uncheck All Minerals ☐

- | | | | |
|---|---|--|--|
| <input type="checkbox"/> Arsenic | <input type="checkbox"/> Fluoride | <input type="checkbox"/> Molybdenum | <input type="checkbox"/> Silicon |
| <input type="checkbox"/> Boron | <input type="checkbox"/> Iodine | <input type="checkbox"/> Nickel | <input type="checkbox"/> Sulfate |
| <input checked="" type="checkbox"/> Calcium | <input checked="" type="checkbox"/> Iron | <input checked="" type="checkbox"/> Phosphorus | <input checked="" type="checkbox"/> Sodium |
| <input type="checkbox"/> Chromium | <input checked="" type="checkbox"/> Magnesium | <input checked="" type="checkbox"/> Potassium | <input type="checkbox"/> Vanadium |
| <input checked="" type="checkbox"/> Copper | <input checked="" type="checkbox"/> Manganese | <input checked="" type="checkbox"/> Selenium | <input checked="" type="checkbox"/> Zinc |
| <input type="checkbox"/> Chloride | | | |

Submit

Reset

Figure 1: USDA Interactive RDI form as completed by a 35-year-old, 140 lb, 5'8" female who has been lactating over seven months.

You Entered:			
Female	Age: 35 yrs	Height: 5 ft. 8 in.	Weight: 140 lbs.
Low Active		Lactating - Over 7 months	
Results:			
Estimated Daily Caloric Needs: 2586 kcal/day			

• **About BMI**

Macronutrients

Each reference value refers to *average daily nutrient intake*; day-to-day nutrient intakes may vary.

Macronutrient	Recommended Intake per day
Carbohydrate	291 - 420 grams ¹
Total Fiber	29 grams
Protein	83 grams
Fat	57 - 101 grams ²

Click on numbered footnote for more information.

Vitamins

Each reference value refers to *average daily nutrient intake*; day-to-day nutrient intakes may vary.

Vitamin	Recommended Intake per day	Tolerable UL Intake per day
Vitamin A	1,300 mcg	3,000 mcg ³
Vitamin C	120 mg	2,000 mg
Vitamin D	15 mcg	100 mcg
Vitamin E	19 mg	1,000 mg ⁴
Vitamin K	90 mcg	ND
Thiamin	1.4 mg	ND
Riboflavin	1.6 mg	ND
Niacin	17 mg	35 mg ⁵
Vitamin B ₆	2 mg	100 mg
Folate	500 mcg	1,000 mcg ⁶
Vitamin B ₁₂	2.8 mcg	ND
Pantothenic Acid	7 mg	ND
Choline	550 mg	3,500 mg

Click individual vitamin for fact sheet.

Click on numbered footnote for more information.

Minerals (Elements)

Each reference value refers to *average daily nutrient intake*; day-to-day nutrient intakes may vary.

Mineral	Recommended Intake per day	Tolerable UL Intake per day
Essential		
Calcium	1,000 mg	2,500 mg
Copper	1,300 mcg	10,000 mcg
Iron	9 mg	45 mg
Magnesium	320 mg	350 mg ⁷
Manganese	2.6 mg	11 mg
Phosphorus	700 mg	4,000 mg
Potassium	5.1 g	ND
Selenium	70 mcg	400 mcg
Sodium	1.5 g	2.3 g
Zinc	12 mg	40 mg

Click individual mineral for fact sheet.

Click on numbered footnote for more information.

Figure 2: USDA nutritional requirements for a 35-year-old, 140 lb, 5'8" female who has been lactating over seven months.

programmer's editor, insert your nutritional needs between the inequality signs and semicolons on the right side of the nutritional constraints. For example, the energy constraint for the 35-year-old female would be $42x_1 + 143x_2 + 884x_4 + 119x_5 + 52x_6 + 32x_7 + 49x_8 + 70x_9 + 135x_{10} + 129x_{11} + 337x_{12} + 336x_{13} + 387x_{14} + 361x_{15} + 362x_{16} + 340x_{17} \geq 2586$; because, as shown in Figure 2, she needs 2586 kcal per day.

Suitable editors include Emacs, Nano, Notepad, and the editor bundled with lp_solve IDE (Windows edition). (Do *not* try to use Word or Wordpad to edit DietTemplateF15.lp; they tend to insert invisible formatting characters that can prevent the file from executing properly.) Lp_solve is installed on most of the machines the Carothers Library's computer lab, room LL4. All of the relevant software (except for Notepad, which comes installed with Windows) can be freely downloaded: Emacs from <http://www.gnu.org/software/emacs/>, Nano from <http://www.nano-editor.org/>, and lp_solve from https://groups.yahoo.com/neo/groups/lp_solve/info or <http://www3.cs.stonybrook.edu/~algorithm/implement/lpsolve/implement.shtml>.

If you are lactose-intolerant, impose $x_1 = 0$ by deleting the comment characters (`/* */`) surrounding that equation at the bottom of the input file. (If *severely* lactose-intolerant, you may also want to impose $x_2 = 0$ in the same manner.) If you are gluten-intolerant, impose $x_{19} = 0$ and $x_{20} = 0$ by deleting the comment characters surrounding those equations. Your nutritional needs should be entered without commas—e.g., as 1250 rather than 1,250. Counting both lower and upper bounds, you will insert a total of 45 nutritional requirements. Save the edited file as `fn.lp`, where `fn` is a file name of your choosing, such as your own name.

3.2 Executing your code

Your LP formatted code can be executed by either (a) uploading it to the NEOS (Network-Enabled Optimization System) server or (b) using lp_solve on a local computer. To use the former method, point your browser to <http://www.neos-server.org/neos/solvers/lp:bpmpd/LP.html> and scroll down to the line immediately below “BPMPD data (LP format file),” clicking on the “Choose File” button there. Upload your input file `fn.lp`. Scroll to the bottom of the page to enter your email address and click on “Submit to NEOS.”

For the latter method, you may use either the computers in the library lab LL4 or any computer on which you have installed lp_solve.

Command-line driven versions of lp_solve for Linux, Mac OS X, and Windows are easy to use. Under those operating systems, opening a terminal, going to the directory (folder) where `fn.lp` resides, and typing “`lp_solve fn.lp`” will display the cost of the diet and the quantities of foods selected. To get more detailed results we can use the command “`lp_solve -S4 fn.lp`.” To send the output to a file `fn.out`, we would type “`lp_solve -S4 fn.lp > fn.out`” where `fn.out` is a name of your choosing.

As an alternative to the command-line driven versions, you could use the menu-driven LPSolve IDE (Integrated Development Interface) for Windows, which is documented in <http://lpsolve.sourceforge.net/5.5/IDE.htm>. To access it in the library lab, sit down at one of the Windows machines, click on “start” in the lower left corner of the screen and search for LPSolve IDE. Once the program is running, use its menu to open your `fn.lp` file. From the menu on the top of the LPSolve screen, select “Action” and then “Solve.” After the program is solved, you should see near the top of the LPSolve screen a “Result” tab giving access to three other tabs: Objective, Constraints, and Sensitivity. All three tabs display the cost of the diet. Besides that, the Objective tab shows the quantities of twenty foods, expressed in hectograms per day; the Constraints tab displays the amounts of the nutrients supplied by the diet; and the Sensitivity tab provides “from” and “till” numbers indicating the price ranges over which the reported food quantities of foods are optimal. Clicking on “File,” and “Export Result” will allow you to write the objective and sensitivity output to files on a removable usb drive. You can later merge these output files into a single item with a name such as `fn.out`, where `fn` is a file name of your choice.

3.3 Interpreting your output

NEOS server output and lp_solve output are identical in meaning but different in format, as can be seen by comparing and contrasting the two outputs for the 35-year-old woman discussed above. The most important part of the lp_solve output is shown for this individual in Figure 3. The interpretation of this output is obvious: The diet costs about \$2.57 a day and includes 1.45358 hg of food 1 (milk), 0 hg of food 2 (yogurt), 0.778267 hg of food 3 (eggs), etc.

```
Value of objective function: 2.56589

Actual values of the variables:
x1          1.45358
x2           0
x3         0.778267
x4         0.0221194
x5         0.761964
x6         0.842431
x7           0
x8           0
x9           0
x10         0.874337
x11          0
x12          0
x13         0.853954
x14          0
x15         1.67034
x16         1.40111
x17         0.401554
x18          0
x19         1.79549
x20          0
```

Figure 3: Output from lp_solve on a Linux terminal

For same individual, the key section of the NEOS server output is shown in Figure 4. The numbers in this output are shown in scientific notation. For example, the cost of the diet appears as 0.256588581710E+01, which is equivalent to 2.56588581710, meaning that the diet costs about \$2.57 a day. Similarly, the quantity of food 1 is shown as 0.14535824272E+01, which can be interpreted as 1.4535824272 hg of milk. The quantity of food 2 is shown as 0.10300395801E-09, meaning 0.00000000010300395801, which can be interpreted as zero plus rounding error. In the column labeled “STATUS,” the word “basic” appears to the right of quantities that are really positive and a blank appears to the right of quantities that are just rounding error. In the “REDUCED COST” column, the numbers are zero (plus rounding error) for foods that are basic (included in the diet) and positive for foods excluded from the diet. Each of these numbers indicates the price reduction that would justify including the corresponding food in the diet. For example, the number is zero (plus rounding error) for milk because no price reduction is required to justify consuming it. In contrast, the 0.38214378265E+00 that appears in the row for food 2 (yogurt) indicates that a price reduction of \$0.38 per hg would be required to make this food part of the woman’s least-cost nutritionally-adequate diet.¹

¹The equivalent of reduced costs can be found in the full output from lp_solve, labeled as “dual values” for the foods.

```

OPTIMAL SOLUTION FOUND
OBJECTIVE : r_0          VALUE :  0.256588581710E+01 min

Iterations   :           8   Time       :           0.00 Sec
Corrections  :          16   Average    :           2.00
TOTAL SOLUTION TIME   =           0.00 Sec

-----C-O-L-U-M-N-S---R-E-P-O-R-T-----
NAME          VALUE          STATUS      REDUCED COST
-----
x1            0.14535824272E+01  BASIC      0.23580534590E-10
x2            0.10300395801E-09                0.38329125645E+00
x3            0.77826653776E+00  BASIC      0.49901838802E-10
x4            0.22119449338E-01  BASIC      0.13935089705E-07
x5            0.76196434322E+00  BASIC      0.51553293578E-10
x6            0.84243093259E+00  BASIC      0.49095334415E-10
x7            0.34121347200E-09                0.11554412678E+00
x8            0.93092908831E-09                0.42901433791E-01
x9            0.11721470485E-09                0.33419984431E+00
x10           0.87433738610E+00  BASIC      0.44325636524E-10
x11           0.61698603475E-09                0.63895691065E-01
x12           0.42276562105E-09                0.10166568685E+00
x13           0.85395386953E+00  BASIC      0.46750518791E-10
x14           0.62253940620E-10                0.63692561940E+00
x15           0.16703410230E+01  BASIC      0.23992406599E-10
x16           0.14011102353E+01  BASIC      0.26784316894E-10
x17           0.40155359313E+00  BASIC      0.94025349442E-10
x18           0.23559982425E-09                0.16681847080E+00
x19           0.17954902655E+01  BASIC      0.22973252015E-10
x20           0.48326258216E-09                0.84824097146E-01

```

Figure 4: Output from the NEOS server

4 Reporting your findings

Your report should consist of three items:

1. Your `lp_solve` input file `fn.lp`, where `fn` is a file name of your choice.
2. Your output file `fn.out` generated by executing the commands in `fn.lp`, where `fn` is again the file name of your choice.
3. Your written interpretation of the output file. This should start with (a) a table showing your 45 nutritional requirements—e.g., energy kcal LB 2540, as stipulated in your input file, (b) the cost per day of your least-cost nutritionally-adequate diet, as shown in your output file, and (c) a table showing how many hectograms of each of the twenty foods are included in your least-cost nutritionally-adequate diet, as also shown in your output file. The interpretation should conclude with your thoughts regarding (d) what features of the diet, if any, you find attractive, (e) any difficulties you would expect to encounter while trying to follow the diet, and (f) any foods (besides the twenty currently considered) that you believe may be cheap and nutritious enough to be worth including among the eligible foods in future versions of the input code. Your writing must be original—i.e., devoid of plagiarism as defined in the University Manual sections 8.27.10–14, available at <http://web.uri.edu/manual/chapter-8/chapter-8-2/>.

Using your input file `fn.lp`, I shall try to replicate your output file `fn.out`. The replication effort could fail if the input file contains hidden formatting codes such as inserted by Word or WordPad. If your input file does not allow me to replicate your output file, your grade for the project will be adversely affected. Hence you should be careful to submit a `fn.lp` file that is in plain text format, such as created by Emacs, Nano, Notepad, or the editor bundled with `lp_solve` in the LPSolve IDE for Windows.

The three elements of the report should be submitted to me, no later than December 1, via the Assignments tab on the Sakai site for our course. If you submit a first draft by November 17, I shall respond with comments by November 24 and allow you to submit a final version of the paper by December 1.