TR-GY 7013: Urban Transport & Logistics Systems
Fall 2024, Prof. Joseph Chow
Assignment #1

This assignment part is worth **10 points**.

1) **(2 pts)** Read the following paper:

Prencipe, L. P., Colovic, A., Binetti, M., & Ottomanelli, M. (2024). Zero-emission vehicle adoption towards sustainable e-grocery last-mile delivery. *Research in Transportation Economics*, *104*, 101429.

   a) **What is the research contribution of this paper? i.e. what innovation does this paper add to the literature?**
   The paper brought out a Mathematical model which measure the performance of the eco-friendly cargo shipping vehicles. The model considers that factors like capacity, time windows for delivery, and partial recharging. The model compared E-cargo bilks, e-mopeds and E-vans as the last mile delivery method, and finally interpreted the advantage of the each.

   b) **Consider the system design problem they study (don't worry about the model). If we were to adopt their proposed system in NYC, what would be the benchmark system to compare against? What are the parameters you would need to collect data for in the benchmark system? Be sure to reference your sources in supporting your points.**

When applying the model from Prencipe et al.'s study on zero-emission vehicles to New York City, a key parameter to consider is the pricing of traffic congestion in Midtown and Downtown areas during high-traffic periods. This pricing mechanism will influence the selection of vehicles used for deliveries, as the cost of entering these zones during peak times will add to operational costs. Parameters to gather would include the cost per vehicle entry during congestion pricing hours, the volume of traffic entering these zones, delivery time windows, and vehicle emissions data. These factors will directly impact the efficiency of adopting zero-emission vehicles for last-mile deliveries, as the model considers constraints like time windows and energy consumption, which would be affected by congestion pricing（Homepage - Streetsblog New York City).

2) **(2 pts)** Larry Edison is the director of the Computer Center for Buckly College. He now needs to schedule the staffing of the center. It is open from 8AM until midnight. Larry has monitored the usage of the center at various times of the day and determined that the following number of computer consultants are required in Table 1. Two types of computer consultants can be hired: full-time and part-time. The full-time consultants work for 8 consecutive hours in any of the following shifts: morning (8AM-4PM), afternoon (noon-8PM) and evening (4PM-midnight). Full-time consultants are paid $40 per hour. Part-time consultants can be hired to work any of the four shifts listed in the table. Part-time consultants are paid $50 per hour. An additional requirement is that during every time period, there must be at least 2 full-time consultants on duty for every part-time consultant on duty. Larry would like to determine how many full-time and how many part-time workers should work each shift to meet the above requirements at the minimum possible cost. Formulate the LP (make sure to start by defining your decision variables! And it is ok to treat them as continuous variables) and solve using Excel or any other LP solver tool you prefer.

Table 1.

TIME OF DAY	MINIMUM NUMBER OF CONSULTANTS REQUIRED TO BE ON DUTY
8AM-noon	3
Noon-4PM	9
4PM-8PM	10
8PM-midnight	6

	X1	X2	X3	X4	X12	X23	X34				
	0	0	0	2	3	6	4				
C:	200	200	200	200	320	320	320		z		
St.									4560		
8-noon	1	0	0	0	1	0	0		3	>=	3
noon-4	0	1	0	0	1	1	0		9		9
4-8	0	0	1	0	0	1	1		10		10
8-midnight	0	0	0	1	0	0	1		6		6

3) (**3 pts**) Do BHM77 Ch 2 Q4.

4. Consider the linear program

$$\text{Maximize } z = x_1,$$

subject to:

$$\begin{aligned} -x_1 + x_2 &\leq 2, \\ x_1 + x_2 &\leq 8, \\ -x_1 + x_2 &\geq -4, \end{aligned}$$

$$x_1 \geq 0, \qquad x_2 \geq 0.$$

a) State the above in canonical form.
b) Solve by the simplex method.
c) Solve geometrically and also trace the simplex procedure steps graphically.
d) Suppose that the objective function is changed to $z = x_1 + cx_2$. Graphically determine the values of c for which the solution found in parts (b) and (c) remains optimal.
e) Graphically determine the shadow price corresponding to the third constraint.

a) Maximize z = x1
-x1+x2+x3 = 2
x1+x2+x4 = 8
-x1+x2-x5 = -4
x1, x2, x3, x4, x5>=0

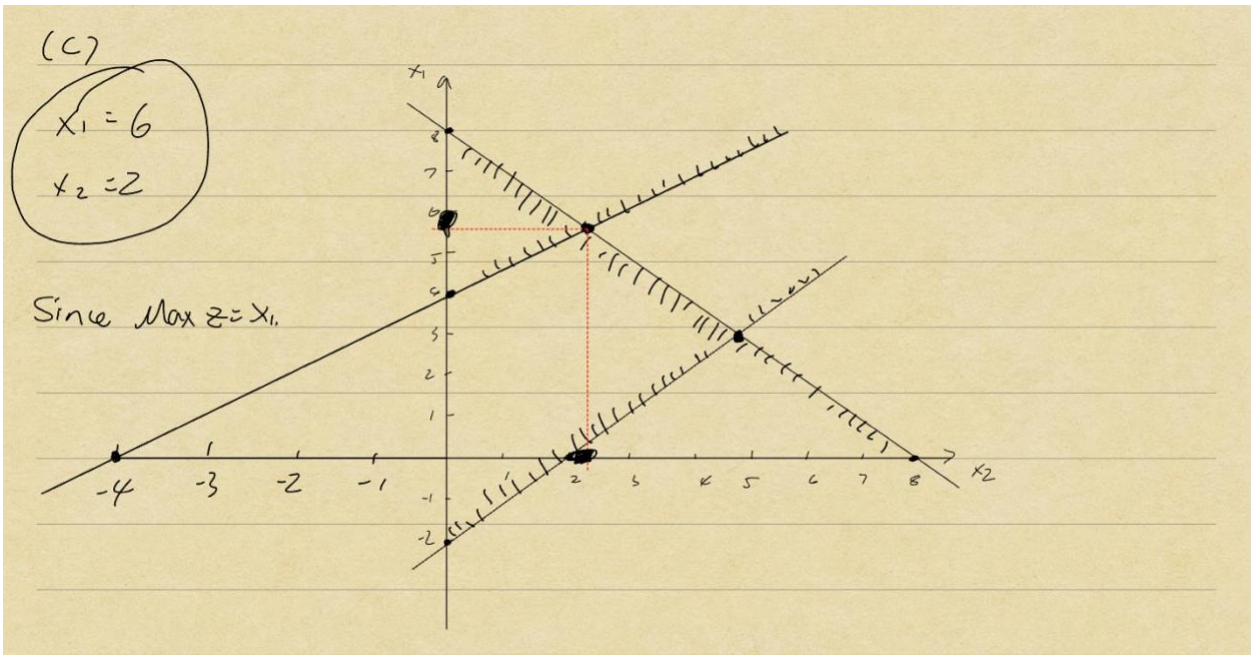
(b)

Basic variables	Current values	x_1	x_2	x_3	x_4	x_5	
x_3	2	−1	1	1	0	0	$2/-1 = -2$
x_4	8	1	1	0	1	0	$8/1 = 8$
x_5	−4	−1	1	0	0	−1	$-4/-1 = 4$
z	0	−1	0	0	0	0	

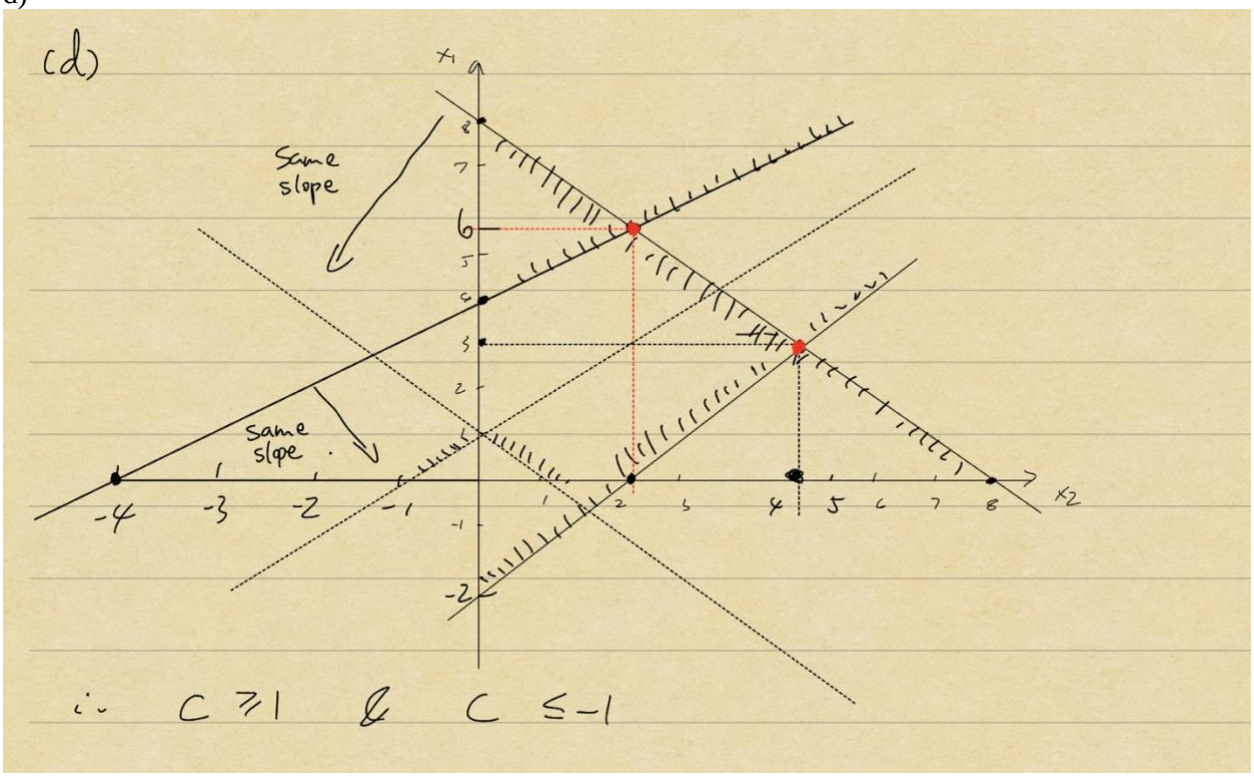
Basic variables	Current values	x_1	x_2	x_3	x_4	x_5	
x_3	6	0	0	1	0	1	
x_4	4	0	2	0	1	−1	$4/2 = 2$
x_1	4	1	−1	0	0	1	
z	4	0	−1	0	0	1	

Basic variables	Current values	x_1	x_2	x_3	x_4	x_5
x_3	6	0	0	1	0	1
x_2	2	0	1	0	$\frac{1}{2}$	$-\frac{1}{2}$
x_1	6	1	0	0	$\frac{1}{2}$	$\frac{1}{2}$
z	6	0	0	0	$\frac{1}{2}$	$\frac{1}{2}$

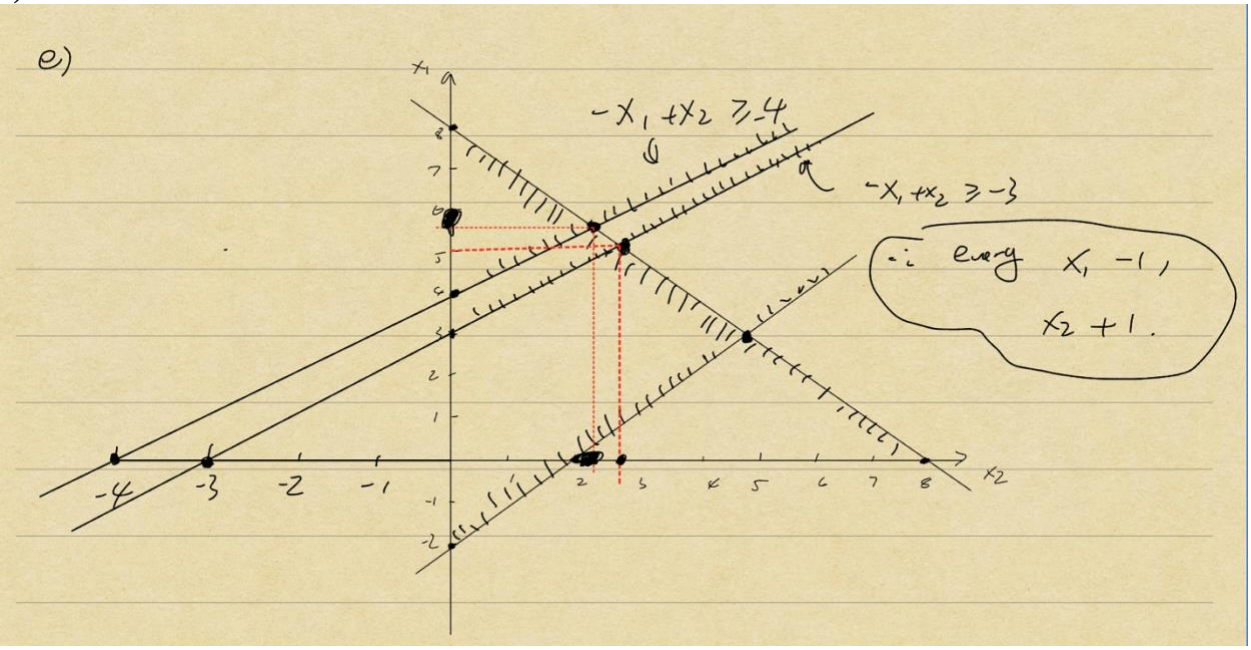
$\therefore \quad x_1 = 6 \;,\; x_2 = 2 \;,\; \text{Max } z = 6$


(c)
$x_1 = 6$
$x_2 = 2$
Since Max $z = x_1$.

d)


(d)
Same slope
Same slope
$\therefore \quad C \geq 1 \quad \& \quad C \leq -1$

e)



4) (**3 pts**) Do BHM77 Ch 3 Q3 (a) – (i).

3. Jean-Pierre Leveque has recently been named the Minister of International Trade for the new nation of New France. In connection with this position, he has decided that the welfare of the country (and his performance) could best be served by maximizing the net dollar value of the country's exports for the coming year. (The net dollar value of exports is defined as exports *less* the cost of all materials imported by the country.)

   The area that now constitutes New France has traditionally made three products for export: steel, heavy machinery, and trucks. For the coming year, Jean-Pierre feels that they could sell all that they could produce of these three items at existing world market prices of $900/unit for steel, $2500/unit for machinery, and $3000/unit for trucks.

   In order to produce one unit of steel with the country's existing technology, it takes 0.05 units of machinery, 0.08 units of trucks, two units of ore purchased on the world market for $100/unit, and other imported materials costing $100. In addition, it takes .5 man-years of labor to produce each unit of steel. The steel mills of New France have a maximum usable capacity of 300,000 units/year.

   To produce one unit of machinery requires .75 units of steel, 0.12 units of trucks, and 5 man-years of labor. In addition, $150 of materials must be imported for each unit of machinery produced. The practical capacity of the country's machinery plants is 50,000 units/year.

   In order to produce one unit of trucks, it takes one unit of steel, 0.10 units of machinery, three man-years of labor, and $500 worth of imported materials. Existing truck capacity is 550,000 units/year.

   The total manpower available for production of steel, machinery, and trucks is 1,200,000 men/year.

   To help Jean-Pierre in his planning, he had one of his staff formulate the model shown in Fig. E3.4 and solved in Fig. E3.5. Referring to these two exhibits, he has asked you to help him with the following questions:

   a) What is the optimal production and export mix for New France, based on Fig.E3.5? What would be the net dollar value of exports under this plan?
   b) What do the first three constraint equations (STEEL, MACHIN, and TRUCK) represent? Why are they equality constraints?
   c) The optimal solution suggests that New France produce 50,000 units of machinery. How are those units to be utilized during the year?
   d) What would happen to the value of net exports if the world market price of steel increased to $1225/unit and the country chose to export one unit of steel?

a) Export 8750 units of Machinery, 232500 units of truck, and produce 300000 unit of steel, 50000 units of Machinery and 262500 units truck will be the optimal mix for New France. Net dollar of exports will be 0.490625E+09 dollars.

b) **STEEL**:
To export 1 unit of steel, it will cost 1 unit of steel.
To export Machinery or Trucks, dose not cost steel.
To produce 1 unit of steel, 1 unit of steel will gain.
To produce 1 unit of Machinery, it will cost 0.75 unit of steel.
To produce 1 unit of truck, it will cost 1 unit of steel.
MACHIN:
To export 1 unit of steel, it will cost 0 unit of machinery.
To export 1 unit of Machinery, it will cost 1 unit of machinery.
To export 1 unit of truck, it will not cost any machinery.
To produce 1 unit of steel, it will cost 0.05 unit of machinery.
To produce 1 unit of machinery, 1 unit of machinery will gain.
To produce 1 unit of truck, it will cost 0.1 unit of machinery.
TRUCK:
To export 1 unit of steel, it will cost 0 unit of truck.
To export 1 unit of Machinery, it will cost 0 unit of truck.
To export 1 unit of truck, it will cost 1 unit of truck.
To produce 1 unit of steel, it will cost 0.08 unit of truck.

To produce 1 unit of machinery, it will cost 0.12 unit of truck.
To produce 1 unit of truck, 1 unit of truck will gain.

(c) Machinery:

$50000 - 8750 - 300000 \times 0.05 - 262500 \times 0.1 = 0$

∴ Export 8750 unit

- Use 15000 unit to produce steel,
- Use 26250 unit to produce truck.

(d) $0.05 \times 2500 + 0.08 \times 3000 + 200 + 100 = 665$

$900 - 665 = 235$

$1225 - 665 = 560$ $560 - 235 = 325$.

Net export will increase $325/unit of steel exported.

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TITLE: COMMERCIAL PRINTING
PROCEED, DISPLAY, OR REJECT? PROCEED

MAXIMIZE OR MINIMIZE? MAX

OPTIMAL SOLUTION FOUND.
     CONTRIB       10110.0

OUTPUT OPTION? EXTENDED

ALL ITEMS NOT LISTED IN SECTIONS 1 - 4 HAVE THE VALUE ZERO.

*1* DECISION VARIABLES
  1. CLASS-AR  12.5000
  2. CLASS-BR  20.0000
  4. CLASS-BO  2.50000
  5. CLASS-CO  10.0000

*2* SLACK(+) AND SURPLUS(-) IN CONSTRAINTS
  4. +PRESS     7.50000
  5. +BINDERY   7.50000
  6. -CLA-MIN   2.50000
  7. -CLB-MIN   12.5000

*3* SHADOW PRICES FOR CONSTRAINTS
  1. TYPE-REG   116.667
  2. TYPE-OVT   112.667
  3. CAMERA     66.6667
  8. CLC-MIN    -450.000

*4* REDUCED COSTS FOR DECISION VARIABLES
  3. CLASS-CR   .000000

*5* RANGES ON COEFFICIENTS OF OBJECTIVE CONTRIB
     VARIABLE   LOWER BOUND   CURRENT VALUE   UPPER BOUND
  1. CLASS-AR    .19073E-05      200.00         876.00
  2. CLASS-BR     300.00         300.00        UNBOUNDED
  3. CLASS-CR   UNBOUNDED        100.00         100.00
  4. CLASS-BO     66.667         292.00         292.00
  5. CLASS-CO     88.000         88.000         538.00

*6* RANGES ON VALUES OF RIGHT-HAND-SIDE CAPACITY
     CONSTRNT   LOWER BOUND   CURRENT VALUE   UPPER BOUND
  1.  TYPE-REG     15.000         40.000         43.000
  2.  TYPE-OVT     30.000         35.000         38.000
  3.  CAMERA       82.500         90.000         94.500
  4.  PRESS        192.50         200.00        UNBOUNDED
  5.  BINDERY      152.50         160.00        UNBOUNDED
  6.  CLA-MIN    UNBOUNDED        10.000         12.500
  7.  CLB-MIN    UNBOUNDED        10.000         22.500
  8.  CLC-MIN      9.1176         10.000         11.667

OUTPUT OPTION? NO
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Figure E3.3 Solution for commericial printing firm.

e) If New France wants to identify other products it can profitably produce and export, what characteristics should those products have?

f) There is a chance that Jean-Pierre may have $500, 000 to spend on expanding capacity. If this investment will buy 500 units of truck capacity, 1000 units of machine capacity, or 300 units of steel capacity, what would be the best investment?

g) If the world market price of the imported materials needed to produce one unit of trucks were to increase by $400, what would be the optimal export mix for New France, and what would be the dollar value of their net exports?

e)

Besides everything already mentioned on the above, I think the labor force should also be considered, but not only manpower.

f) Steel expansion:

$1585 \times 300 = \$475{,}500$

Machinery expansion:

$302 \times 1000 = \$302{,}000$

Truck expansion:

$0 \times 500 = 0.$

∴ expan capacity of Machinery will be the best investment.

g)

$$\text{Max } Z = 900X_1 + 2500X_2 + 300X_3 - 300X_4 - 150X_5 - (600+500)X_6$$

St.

$$-X_1 + X_4 - 0.75X_5 - X_6 = 0$$

$$-X_2 - 0.5X_4 + X_5 - X_6 = 0$$

$$-X_3 - 0.8X_4 - 1.2X_5 + X_6 = 0.$$

$$X_4 \leq 300000$$

$$X_5 \leq 50000$$

$$X_6 \leq 550000$$

$$05X_4 + 5X_5 + 3X_6 \leq 1200000$$

	X1	X2	X3	X4	x5	x6				
	0	8750	232500	300000	50000	262500				
C:	900	2500	3000	-300	-150	-900		z		
St.								403250000		
	-1	0	0	1	-0.75	-1		0	=	0
	0	-1	0	-0.5	1	-1		0	=	0
	0	0	-1	-0.8	-1.2	1		0	=	0
	0	0	0	1	0	0		0	<=	300000
	0	0	0	0	1	0		0	<=	50000
	0	0	0	0	0	1		0	<=	550000
	0	0	0	0.5	5	3		0	<=	1200000

Export 0 unit of steel
Export 8750 unit of Machinery
Export 232500 unit of trucks
Produce 300000 unit of steel
Produce 50000 unit of machinery
Produce 262500 unit of trucks

The new max export is 4.03e+09

Variables:

X_1 = Steel production for export (EXSTEE),
X_2 = Machinery production for export (EXMACH),
X_3 = Truck production for export (EXTRUC),
X_4 = Total steel production (TOSTEE),
X_5 = Total machinery production (TOMACH),
X_6 = Total truck production (TOTRUC).

Constraints:

Steel output	(STEEL)
Machinery ouput	(MACHIN)
Truck output	(TRUCK)
Steel capacity	(CAPSTE)
Machinery capacity	(CAPMAC)
Truck capacity	(CAPTRU)
Manpower available	(AVAMAN)

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TITLE: NEW FRANCE INTERNATIONAL TRADE
PROCEED, DISPLAY, OR REJECT? DISPLAY

OBJECTIVES:

             EXSTEE     EXMACH     EXTRUC     TOSTEE     TOMACH     TOTRUC
EXPORTS      900.0      2500.      3000.     -300.0     -150.0     -500.0

CONSTRAINTS:

             EXSTEE     EXMACH     EXTRUC     TOSTEE     TOMACH     TOTRUC
             RELATION   CAPACITY
STEEL       -1.000      .0000      .0000      1.000     -.7500     -1.000
               EQ       .0000
MACHIN       .0000     -1.000      .0000     -.5000E-01  1.000     -.1000
               EQ       .0000
TRUCK        .0000      .0000     -1.000     -.8000E-01 -.1200      1.000
               EQ       .0000
CAPSTE       .0000      .0000      .0000      1.000      .0000      .0000
               LE       .3000E+06
CAPMAC       .0000      .0000      .0000      .0000      1.000      .0000
               LE       .5000E+05
CAPTRU       .0000      .0000      .0000      .0000      .0000      1.000
               LE       .5500E+06
AVAMAN       .0000      .0000      .0000      .5000      5.000      3.000
               LE       .1200E+07
```

Figure E3.4 Formulation of optimal production and export for New France.

h) The Minister of Defense has recently come to Jean-Pierre and said that he would like to stockpile (inventory) an additional 10,000 units of steel during the coming year. How will this change the constraint equation STEEL, and what impact will it have on net dollar exports?

i) A government R&D group has recently come to Jean-Pierre with a new product, Product X, that can be produced for export with 1.5 man-years of labor and 0.3 units of machinery for each unit produced. What must Product X sell for on the world market to make it attractive for production?

j) How does this particular formulation deal with existing inventories at the start of the year and any desired inventories at the end of the year?

h)

new Constraint: $-X_1 + X_4 - 0.75X_5 - X_6 = 10000$

Change in Net export: $-2250 \times 10000 = \$-22500000$

```
TITLE: NEW FRANCE INTERNATIONAL TRADE
PROCEED, DISPLAY, OR REJECT? PROCEED

MAXIMIZE OR MINIMIZE? MAX

OPTIMAL SOLUTION FOUND.
     EXPORTS      0.490625E+09

OUTPUT OPTION? EXTENDED

ALL ITEMS NOT LISTED IN SECTIONS 1 - 4 HAVE THE VALUE ZERO.

*1* DECISION VARIABLES
  2. EXMACH     8750.00
  3. EXTRUC     232500.
  4. TOSTEE     300000.
  5. TOMACH     50000.0
  6. TOTRUC     262500.

*2* SLACK(+) AND SURPLUS(-) IN CONSTRAINTS
  6. +CAPTRU    287500.
  7. +AVAMAN    12500.0

*3* SHADOW PRICES FOR CONSTRAINTS
  1. STEEL     -2250.00
  2. MACHIN    -2500.00
  3. TRUCK     -3000.00
  4. CAPSTE     1585.00
  5. CAPMAC     302.500

*4* REDUCED COSTS FOR DECISION VARIABLES
  1. EXSTEE    -1350.00

*5* RANGES ON COEFFICIENTS OF OBJECTIVE EXPORTS
     VARIABLE  LOWER BOUND  CURRENT VALUE  UPPER BOUND
  1. EXSTEE    UNBOUNDED       900.00        2250.0
  2. EXMACH     2218.6         2500.0        13067.
  3. EXTRUC     1650.0         3000.0        3347.7
  4. TOSTEE    -1885.0        -300.00       UNBOUNDED
  5. TOMACH    -452.50        -150.00       UNBOUNDED
  6. TOTRUC    -1850.0        -500.00       -96.667

*6* RANGES ON VALUES OF RIGHT-HAND-SIDE CAPACITY
     CONSTRNT  LOWER BOUND  CURRENT VALUE  UPPER BOUND
  1. STEEL     -4166.7         .00000        .23250E+06
  2. MACHIN    UNBOUNDED       .00000        8750.0
  3. TRUCK     UNBOUNDED       .00000        .23250E+06
  4. CAPSTE     47283.         .30000E+06    .30357E+06
  5. CAPMAC     41860.         50000.        54545.
  6. CAPTRU     .26250E+06     .55000E+06    UNBOUNDED
  7. AVAMAN     .11875E+07     .12000E+07    UNBOUNDED

OUTPUT OPTION? NO
```

Figure E3.5 Solution of New France model.