MODELOS DE DECISIÓN

- NO RESTRINGIDOS

  MAX: f(X) o MIN: f(X)

  Ejemplo: $\text{MIN}: 3 \cdot x_1 + \frac{2}{x_1} + \ln x_2 + 4 \cdot x_1 \cdot x_2$

- RESTRINGIDOS
  (PROGRAMAS MATEMÁTICOS)

PROGRAMACIÓN MATEMÁTICA

MAX: $Z = f(x)$

Sujeto a:

$$\begin{cases} g_1(x) \leq b_1 \\ g_2(x) \leq b_2 \\ \cdots\cdots\cdots \\ g_m(x) \leq b_m \end{cases}$$

PROGRAMACIÓN LINEAL

Maximizar $\sum c_j \cdot x_j$

sujeto a un conjunto de restricciones $\sum a_{ij} \cdot x_j \leq b_i$

siendo $x_j \geq 0$

FUNCIÓN OBJETIVO

Maximizar $Z = \Sigma\, c_j \cdot x_j$

FUNCIONAL

Ejemplo: $Z = 6 \cdot x_1 + 8 \cdot x_2 + 3 \cdot x_3$

Coeficientes del funcional

FUNCIÓN OBJETIVO

Maximizar $Z = \sum c_j \cdot x_j$

FUNCIONAL

Ejemplo: $Z = 6 \cdot x_1 + 8 \cdot x_2 + 3 \cdot x_3$

Variables de decisión

RESTRICCIONES

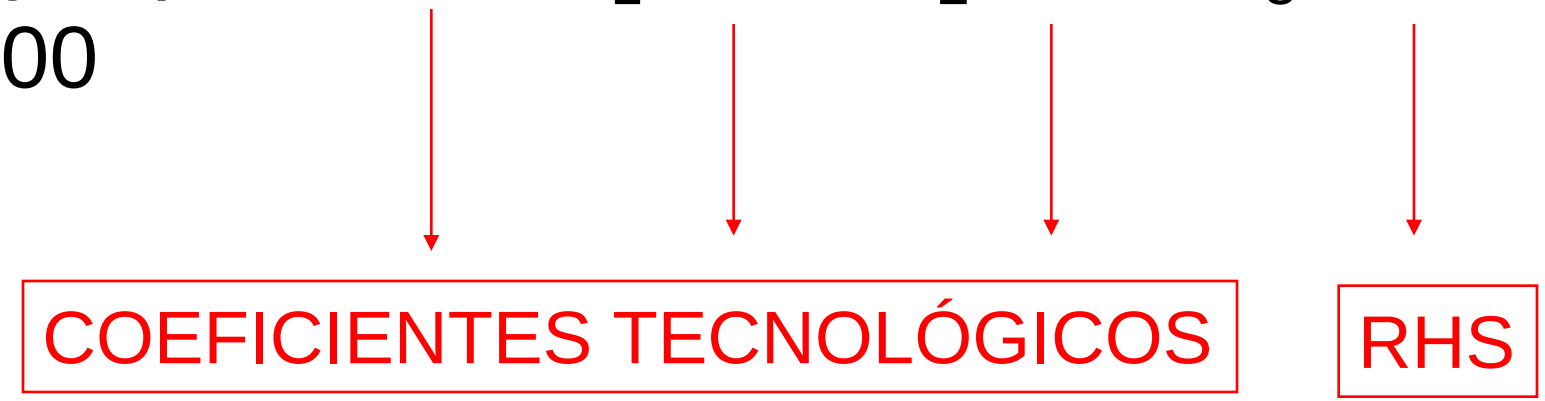
Conjunto de inecuaciones o ecuaciones

CONDICIONES DE VÍNCULO

$$\begin{cases} \sum a_{ij} \cdot x_j \leq b_i \\ \sum a_{ij} \cdot x_j \geq b_i \\ \sum a_{ij} \cdot x_j = b_i \end{cases}$$

CONDICIONES DE VÍNCULO

Ejemplo: $12 \odot x_1 + 9 \odot x_2 + 4 \odot x_3 \leq 500$



CONDICIONES DE LAS VARIABLES X_j

- NO NEGATIVIDAD
- CONTINUIDAD

CONDICIONES DE LOS TÉRMINOS INDEPENDIENTES (“RHS”)

b_i

- NO NEGATIVIDAD

  (en su forma estándar)

$6 \odot x_1 + 9 \odot x_2 \leq 4 \odot x_3$

INCORRECTO

$6 \odot x_1 + 9 \odot x_2 - 4 \odot x_3 \leq 0$

$$\frac{x_2}{4} + \frac{x_5}{6} \geq 10$$

INCORRECTO

$$0{,}25 \cdot x_2 + 0{,}1667 \cdot x_5 \geq 10$$

$$\sum a_{ij} \cdot x_j \leq b_i$$

$$\sum a_{ij} \cdot x_j \geq b_i$$

$$\sum a_{ij} \cdot x_j = b_i$$

INECUACIÓN ⟹ ECUACIÓN

$$12 \cdot x_1 + 9 \cdot x_2 + 4 \cdot x_3 \leq 500$$

VARIABLES “SLACKS”

$$12 \cdot x_1 + 9 \cdot x_2 + 4 \cdot x_3 \leq 500$$

$$12 \cdot x_1 + 9 \cdot x_2 + 4 \cdot x_3 + x_4 = 500$$

DE HOLGURA

INECUACIÓN ⟹ ECUACIÓN

$$2 \cdot x_1 + 2 \cdot x_2 + 3 \cdot x_3 \geq 100$$

VARIABLES “SLACKS”

$$2 \cdot x_1 + 2 \cdot x_2 + 3 \cdot x_3 \geq 100$$

$$2 \cdot x_1 + 2 \cdot x_2 + 3 \cdot x_3 - x_4 = 100$$

SUPERFLUA

FORMA NATURAL

MAX: $6 \cdot x_1 + 8 \cdot x_2 + 3 \cdot x_3$

Sujeto a:

$$\begin{cases} 12 \cdot x_1 + 9 \cdot x_2 + 4 \cdot x_3 \leq 500 \\ 3 \cdot x_1 + 15 \cdot x_2 + 6 \cdot x_3 \leq 700 \\ 2 \cdot x_1 + 2 \cdot x_2 + 3 \cdot x_3 \geq 100 \\ 7 \cdot x_1 + 4 \cdot x_2 + 3 \cdot x_3 = 200 \end{cases}$$

siendo: $x_j \geq 0$

FORMAS DE FORMULACIÓN DE UN MODELO DE PL

- **FORMA NATURAL**: Restricciones de “≤”, “≥” y “=”

- **FORMA CANÓNICA**
  - De MAX: Todas las restricciones de “≤”
  - De MIN: Todas las restricciones de “≥”

- **FORMA ESTÁNDAR**
  - Todas las restricciones de “=”

FORMA ESTÁNDAR

MAX: $6 \cdot x_1 + 8 \cdot x_2 + 3 \cdot x_3$

Sujeto a:

$$\begin{cases} 12 \cdot x_1 + 9 \cdot x_2 + 4 \cdot x_3 + x_4 = 500 \\ 3 \cdot x_1 + 15 \cdot x_2 + 6 \cdot x_3 + x_5 = 700 \\ 2 \cdot x_1 + 2 \cdot x_2 + 3 \cdot x_3 - x_6 = 100 \\ 7 \cdot x_1 + 4 \cdot x_2 + 3 \cdot x_3 = 200 \end{cases}$$

siendo: $x_j \geq 0$

FORMA CANÓNICA DE MAX

NATURAL

$$\text{MAX: } 6 \cdot x_1 + 8 \cdot x_2 + 3 \cdot x_3$$

$$12 \cdot x_1 + 9 \cdot x_2 + 4 \cdot x_3 \leq 500$$
$$3 \cdot x_1 + 15 \cdot x_2 + 6 \cdot x_3 \leq 700$$
$$2 \cdot x_1 + 2 \cdot x_2 + 3 \cdot x_3 \geq 100$$
$$7 \cdot x_1 + 4 \cdot x_2 + 3 \cdot x_3 = 200$$

$$x_j \geq 0$$

CANÓNICA

$$\text{MAX: } 6 \cdot x_1 + 8 \cdot x_2 + 3 \cdot x_3$$

$$12 \cdot x_1 + 9 \cdot x_2 + 4 \cdot x_3 \leq 500$$
$$3 \cdot x_1 + 15 \cdot x_2 + 6 \cdot x_3 \leq 700$$
$$-2 \cdot x_1 - 2 \cdot x_2 - 3 \cdot x_3 \leq -100$$
$$7 \cdot x_1 + 4 \cdot x_2 + 3 \cdot x_3 \leq 200$$
$$-7 \cdot x_1 - 4 \cdot x_2 - 3 \cdot x_3 \leq -200$$

$$x_j \geq 0$$

FORMA CANÓNICA DE MIN

NATURAL

$$\text{MAX: } 6 \cdot x_1 + 8 \cdot x_2 + 3 \cdot x_3$$

$$12 \cdot x_1 + 9 \cdot x_2 + 4 \cdot x_3 \leq 500$$
$$3 \cdot x_1 + 15 \cdot x_2 + 6 \cdot x_3 \leq 700$$
$$2 \cdot x_1 + 2 \cdot x_2 + 3 \cdot x_3 \geq 100$$
$$7 \cdot x_1 + 4 \cdot x_2 + 3 \cdot x_3 = 200$$

$$x_j \geq 0$$

CANÓNICA

$$\text{MIN: } -6 \cdot x_1 - 8 \cdot x_2 - 3 \cdot x_3$$

$$-12 \cdot x_1 - 9 \cdot x_2 - 4 \cdot x_3 \geq -500$$
$$-3 \cdot x_1 - 15 \cdot x_2 - 6 \cdot x_3 \geq -700$$
$$2 \cdot x_1 + 2 \cdot x_2 + 3 \cdot x_3 \geq 100$$
$$7 \cdot x_1 + 4 \cdot x_2 + 3 \cdot x_3 \geq 200$$
$$-7 \cdot x_1 - 4 \cdot x_2 - 3 \cdot x_3 \geq -200$$

$$x_j \geq 0$$

FORMA CANÓNICA

MAX: $c_1 x_1 + c_2 x_2 + c_3 x_3 + \ldots\ldots\ldots\ldots + c_k x_k$

Sujeto a:

$$\begin{cases} a_{11} x_1 + a_{12} x_2 + a_{13} x_3 + \ldots\ldots\ldots\ldots + a_{1k} x_k \leq b_1 \\ a_{21} x_1 + a_{22} x_2 + a_{23} x_3 + \ldots\ldots\ldots\ldots + a_{2k} x_k \leq b_2 \\ a_{31} x_1 + a_{32} x_2 + a_{33} x_3 + \ldots\ldots\ldots\ldots + a_{3k} x_k \leq b_3 \\ \ldots\ldots\ldots\ldots \\ a_{m1} x_1 + a_{m2} x_2 + a_{m3} x_3 + \ldots\ldots\ldots\ldots + a_{mk} x_k \leq b_m \end{cases}$$

siendo: $x_j \geq 0$

FORMA ESTÁNDAR

MAX: $c_1 x_1 + c_2 x_2 + c_3 x_3 + \ldots\ldots\ldots + c_k x_k$

Sujeto a

$$\begin{cases} a_{11} x_1 + a_{12} x_2 + a_{13} x_3 + \ldots\ldots\ldots + a_{1k} x_k + x_{k+1} = b_1 \\ a_{21} x_1 + a_{22} x_2 + a_{23} x_3 + \ldots\ldots\ldots + a_{2k} x_k + x_{k+2} = b_2 \\ a_{31} x_1 + a_{32} x_2 + a_{33} x_3 + \ldots\ldots\ldots + a_{3k} x_k + x_{k+3} = b_3 \\ \ldots\ldots\ldots\ldots\ldots\ldots \\ a_{m1} x_1 + a_{m2} x_2 + a_{m3} x_3 + \ldots\ldots\ldots + a_{mk} x_k + x_n = b_m \end{cases}$$

siendo $x_j \geq 0$

FORMA MATRICIAL EXPANDIDA

X1	**X2**	**X3**		**RHS**
6	8	3	⇨	MAX
12	9	4	≤	500
3	15	6	≤	700
2	2	3	≥	100
7	4	3	=	200

En un taller metalúrgico se fabrican dos tipos de piezas A y B, que deben seguir los siguientes procesos:

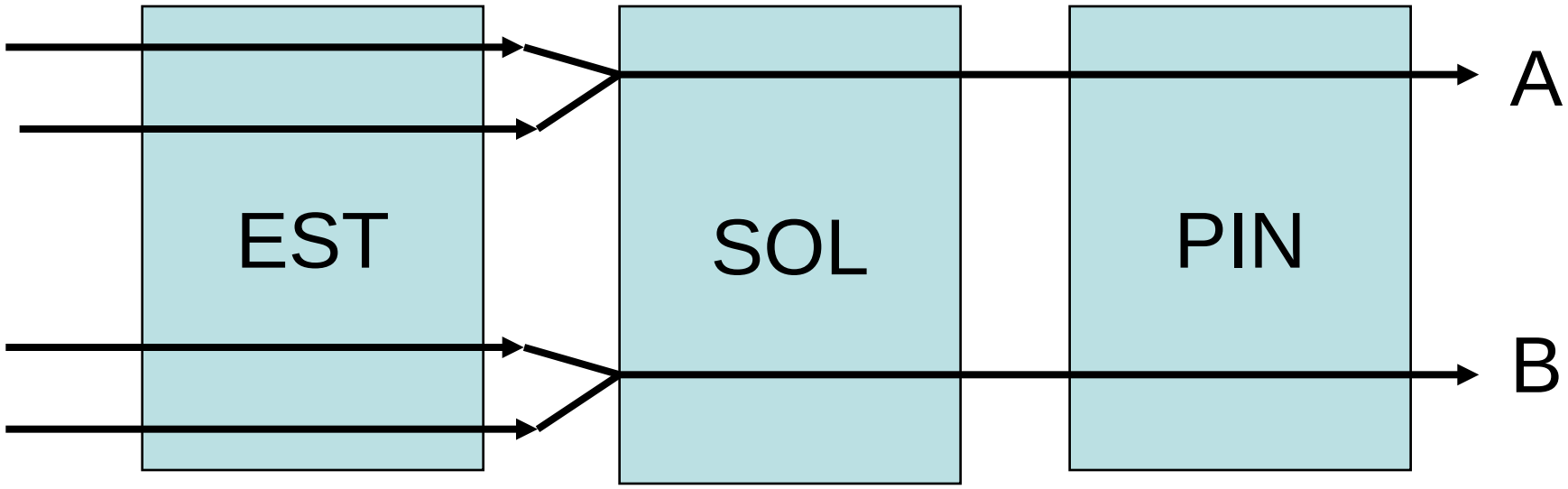
1. Estampado en hojas metálicas
2. Soldado
3. Pintado

La operación de estampado consiste en preparar partes idénticas que luego serán soldadas de a pares, formando la pieza A. El mismo proceso se realiza para la pieza B.

La utilidad unitaria es de $ 4 para la pieza A y $ 3 para la pieza B. Se desea establecer el programa semanal de producción que maximice la utilidad del taller con respecto a las piezas consideradas.

Los insumos de equipos son los siguientes, para la realización de cada una de las operaciones (expresados en segundos por pieza):

Operación	A	B	Tiempo disponible (seg./semana)
Estampado de c/parte	3	8	48.000
Soldado	12	6	42.000
Pintado	9	9	36.000


EST
SOL
PIN
A
B

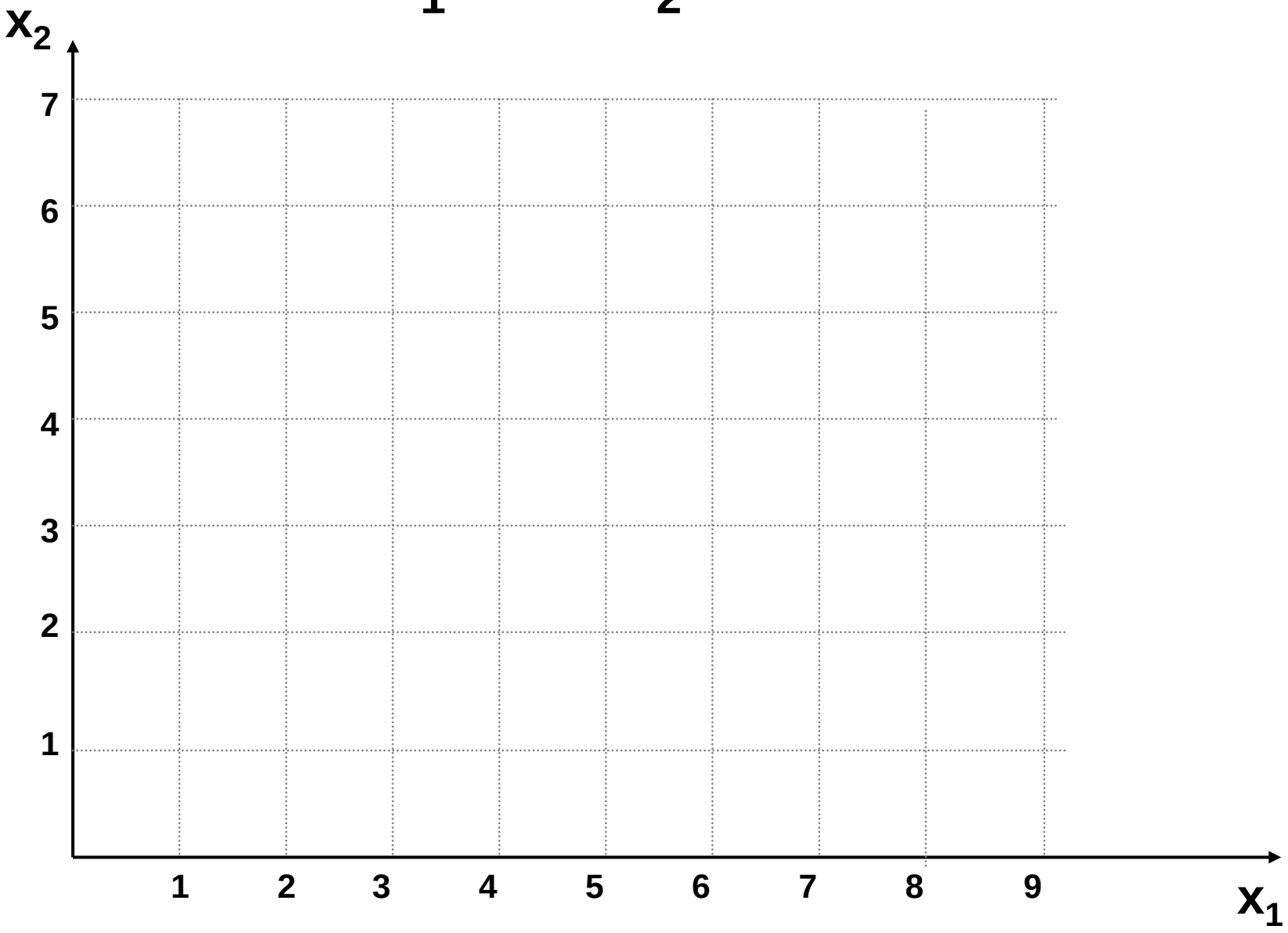
MAX: $Z = 4x_1 + 3x_2$

Sujeto a:

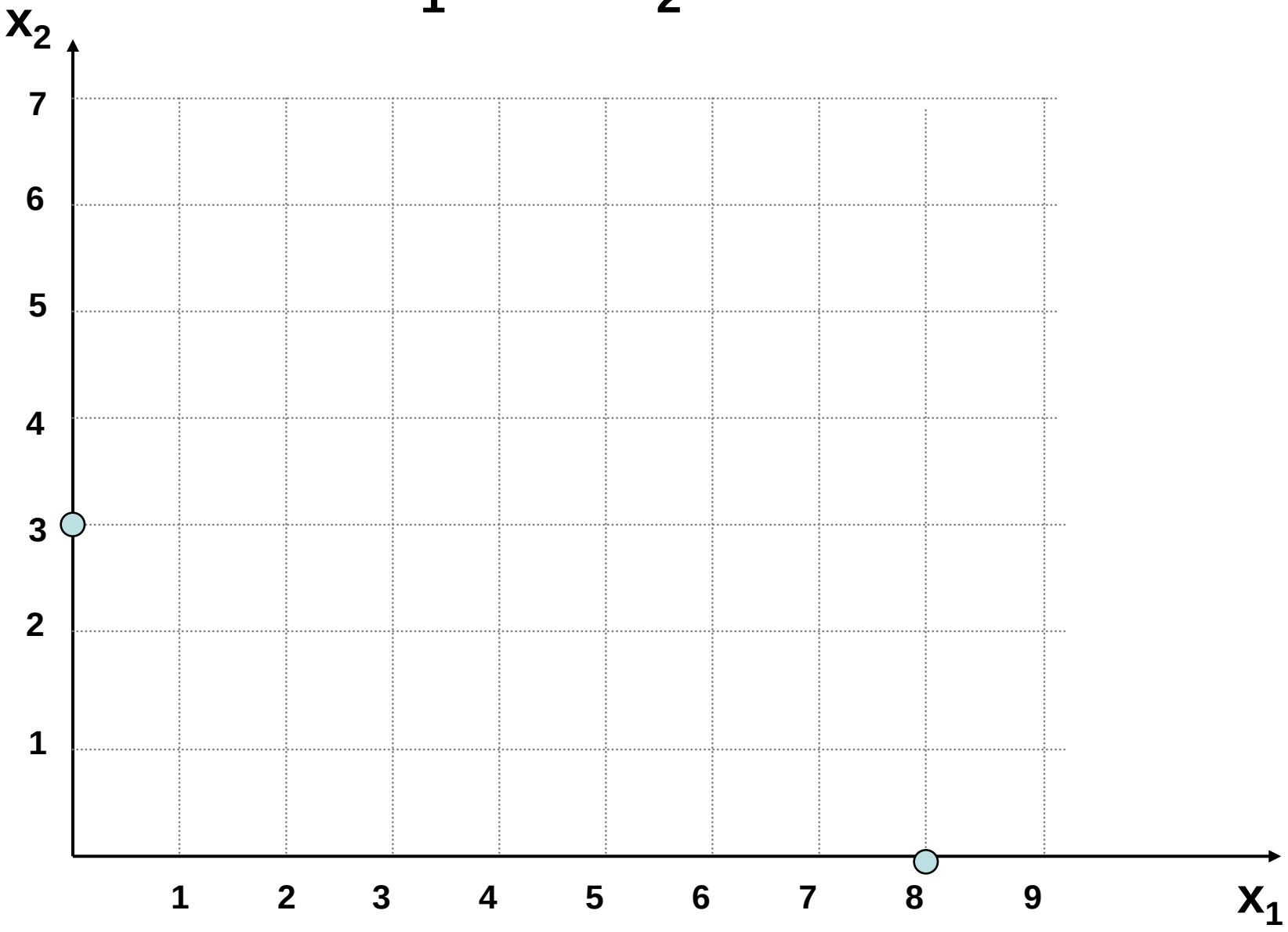
$$\begin{cases} 6x_1 + 16x_2 \leq 48000 \\ 12x_1 + 6x_2 \leq 42000 \\ 9x_1 + 9x_2 \leq 36000 \end{cases}$$

siendo: $x_1, x_2 \geq 0$ **y continuas**

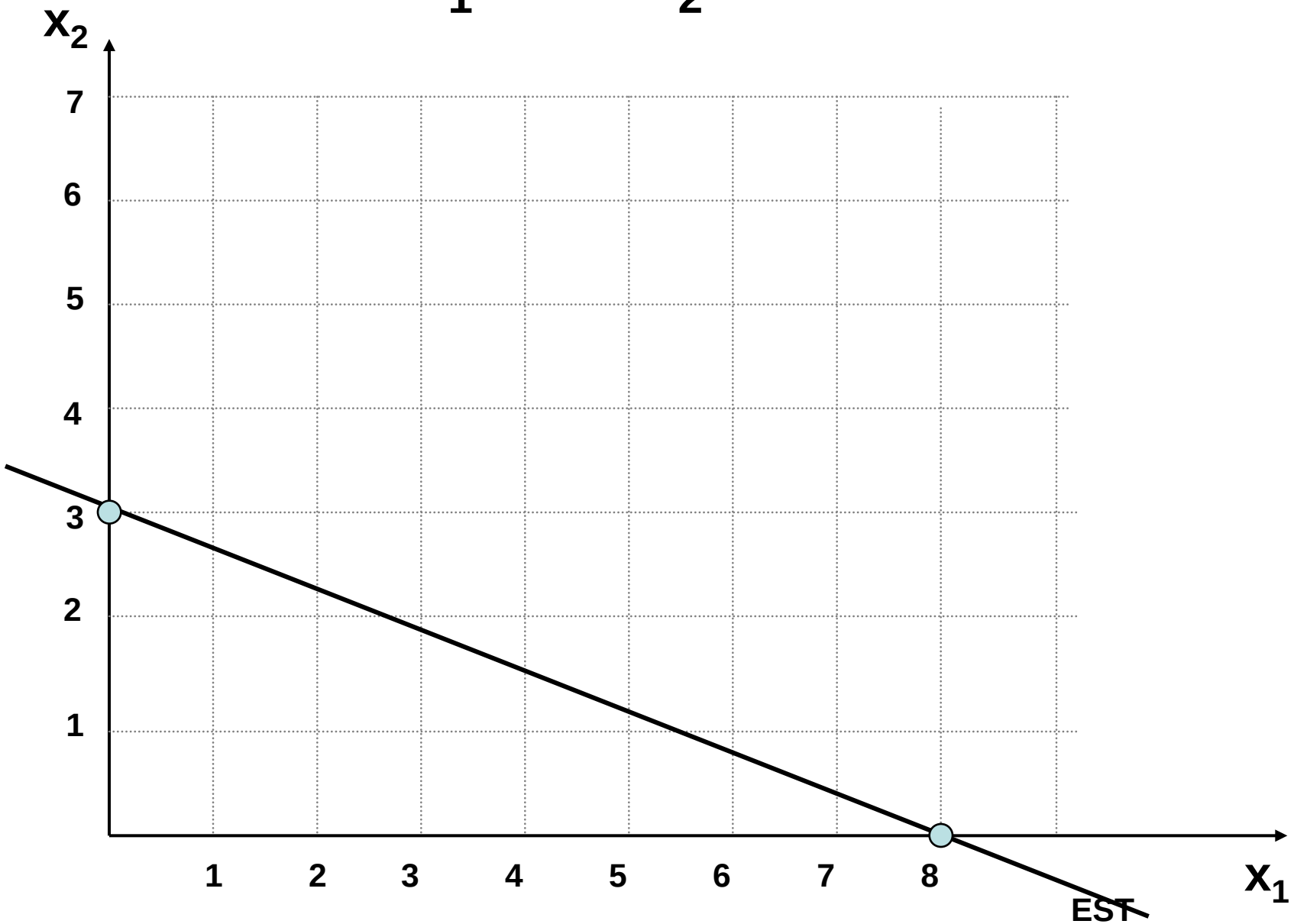
$$6\,x_1 + 16\,x_2 \leq 48000$$



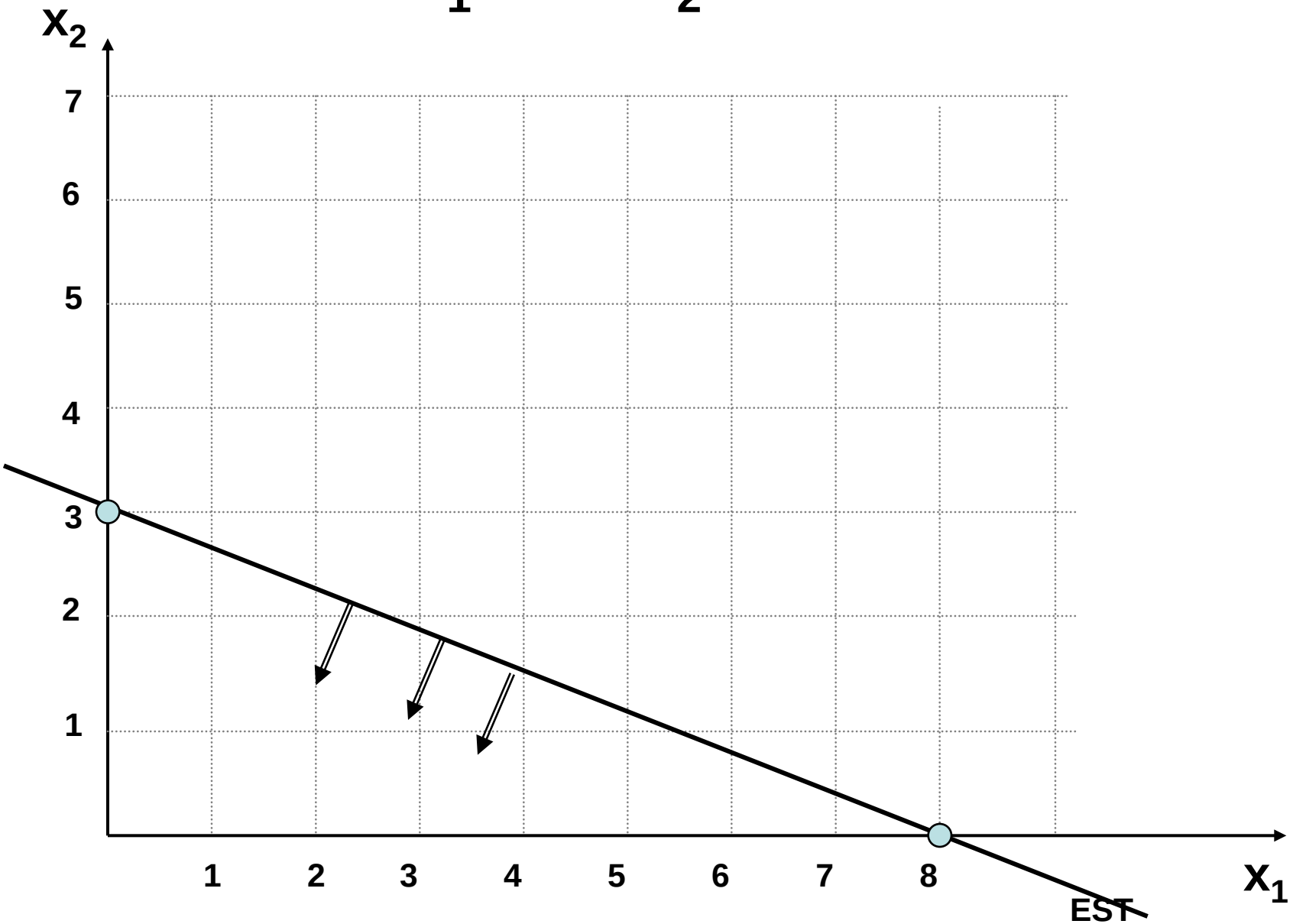
$$6\,x_1 + 16\,x_2 = 48000$$



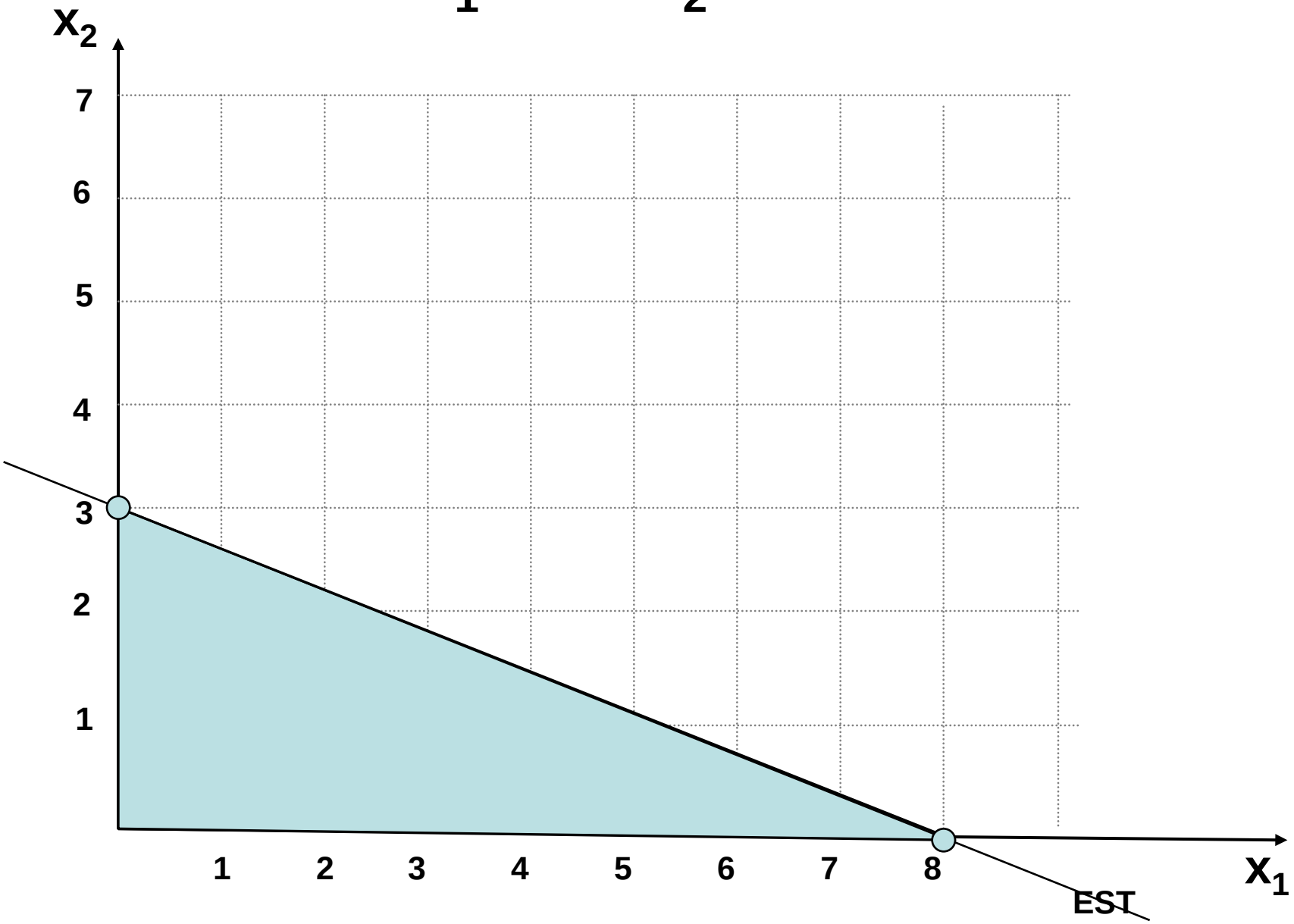
$$6\,x_1 + 16\,x_2 = 48000$$



$$6\,x_1 + 16\,x_2 \leq 48000$$

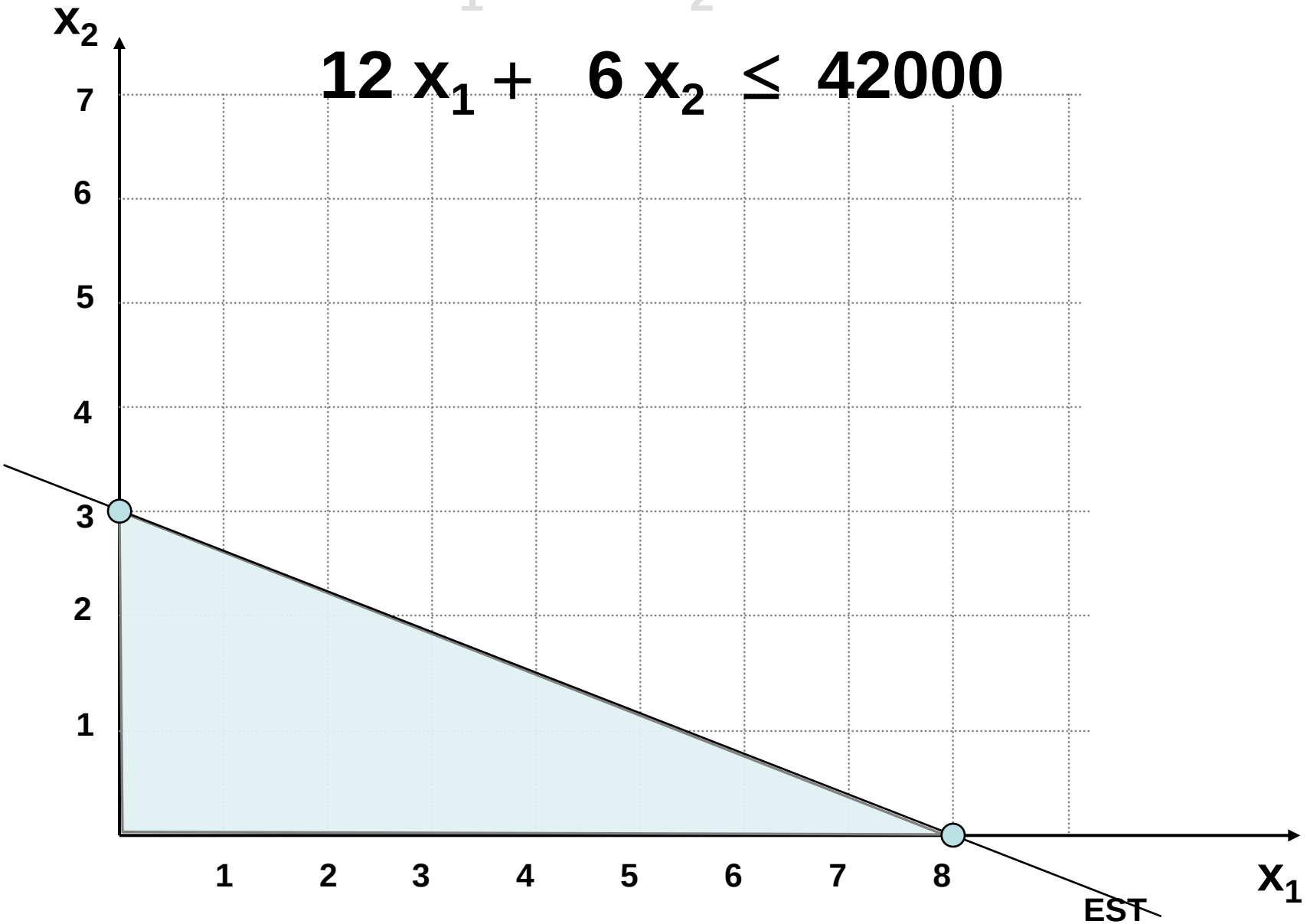


$$6\,x_1 + 16\,x_2 \leq 48000$$

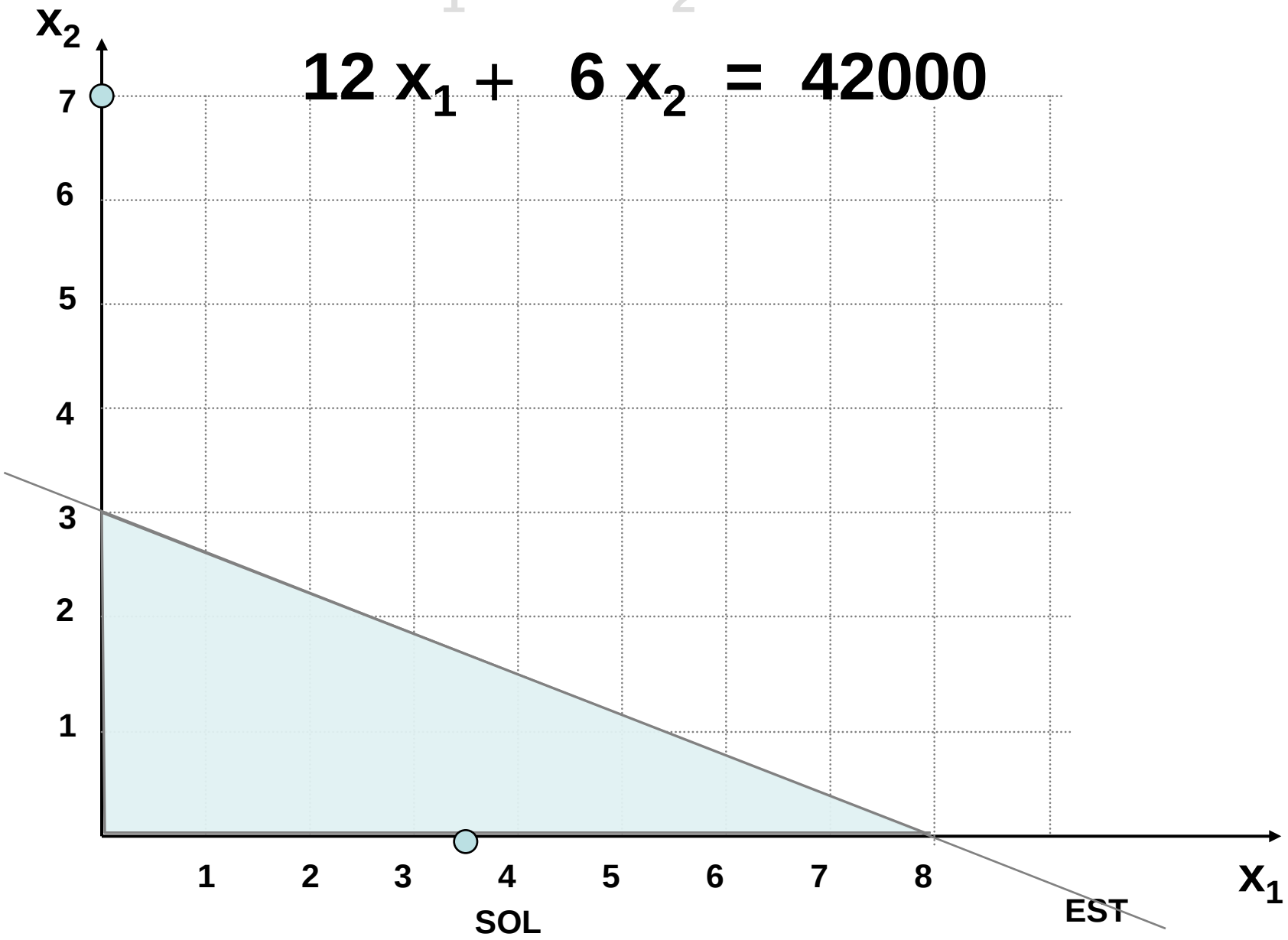


$6\,x_1 + 16\,x_2 \leq 48000$

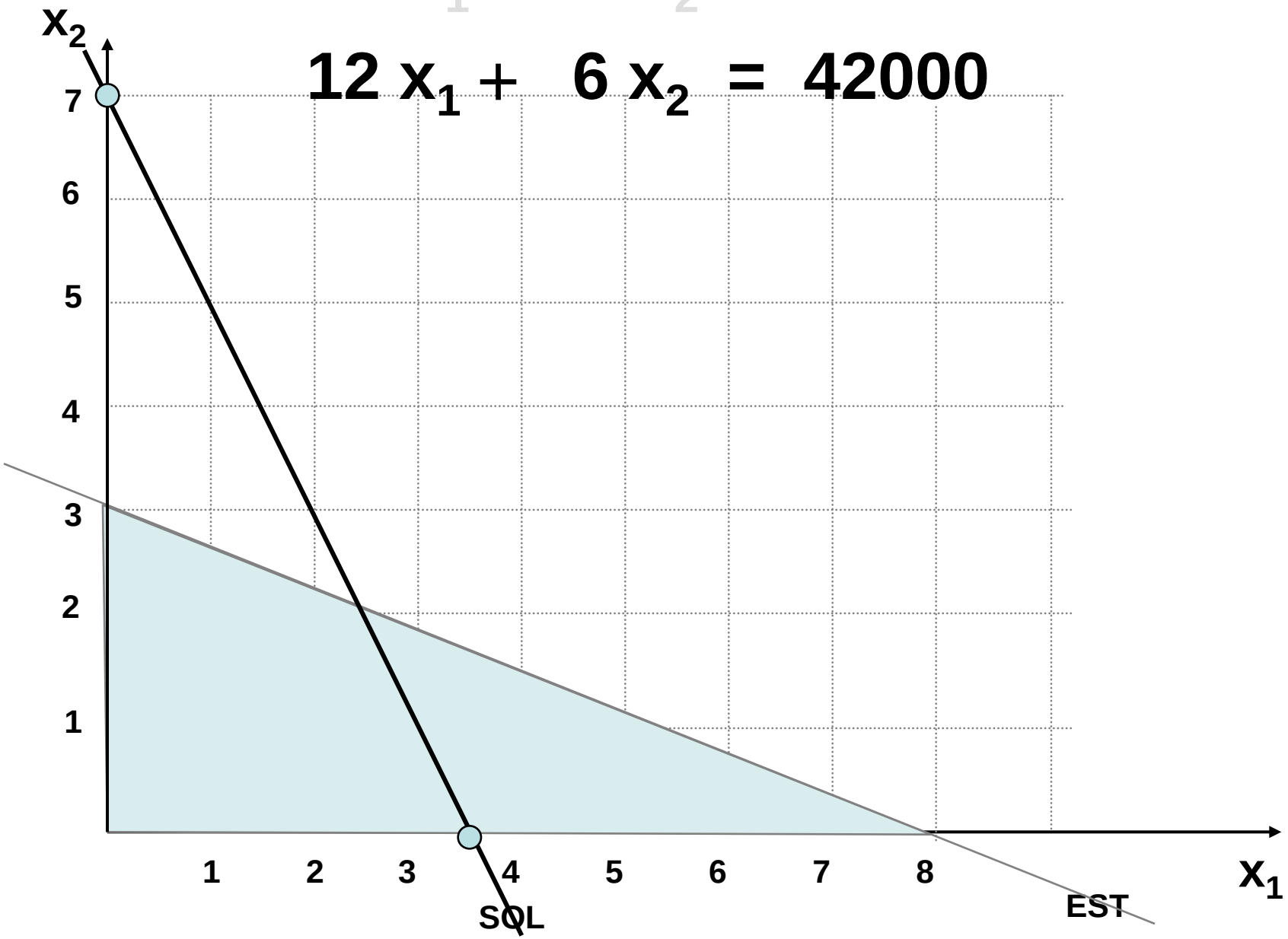
$12\,x_1 + 6\,x_2 \leq 42000$



$6\,x_1 + 16\,x_2 \leq 48000$

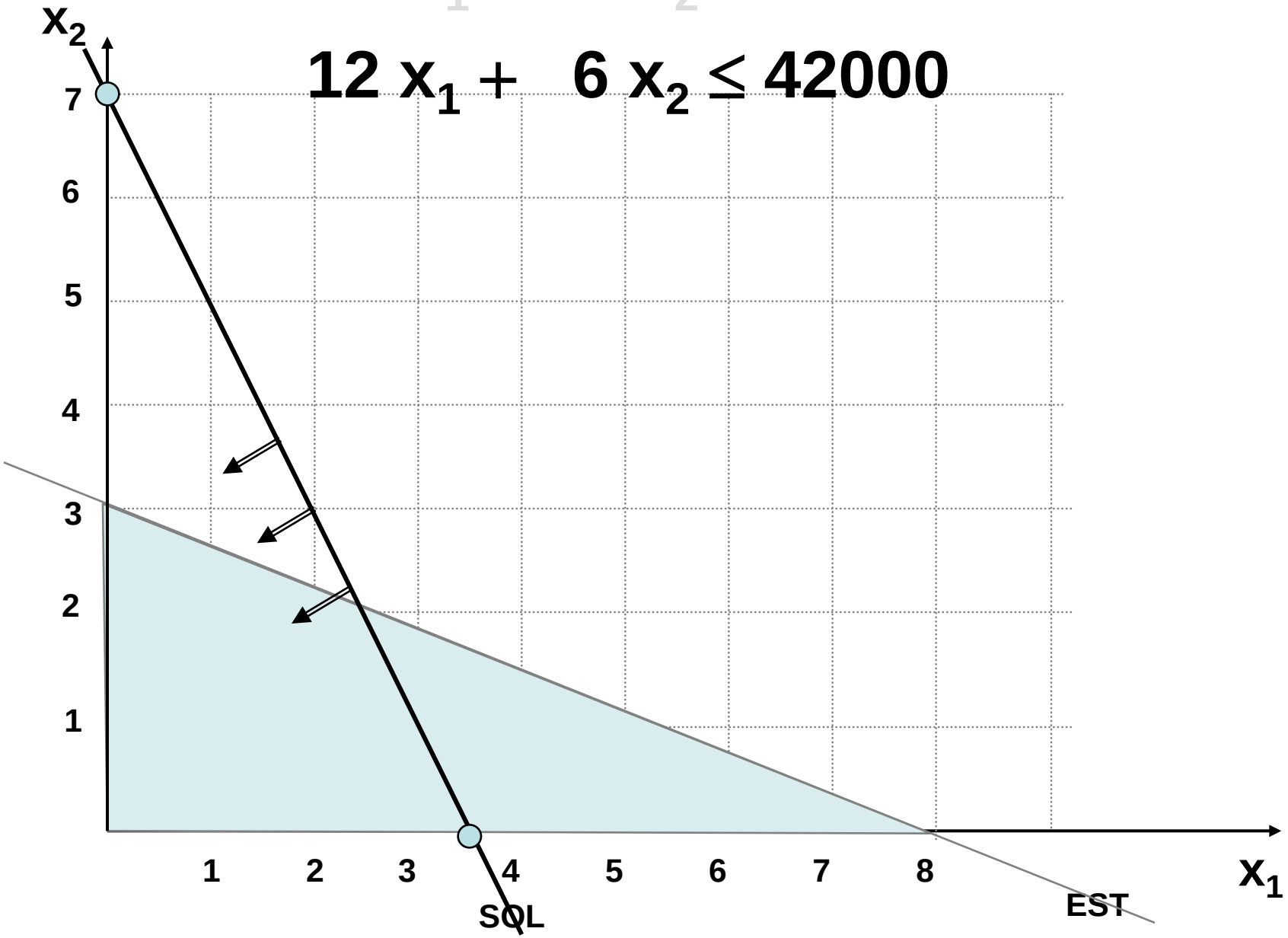


$6\,x_1 + 16\,x_2 \leq 48000$



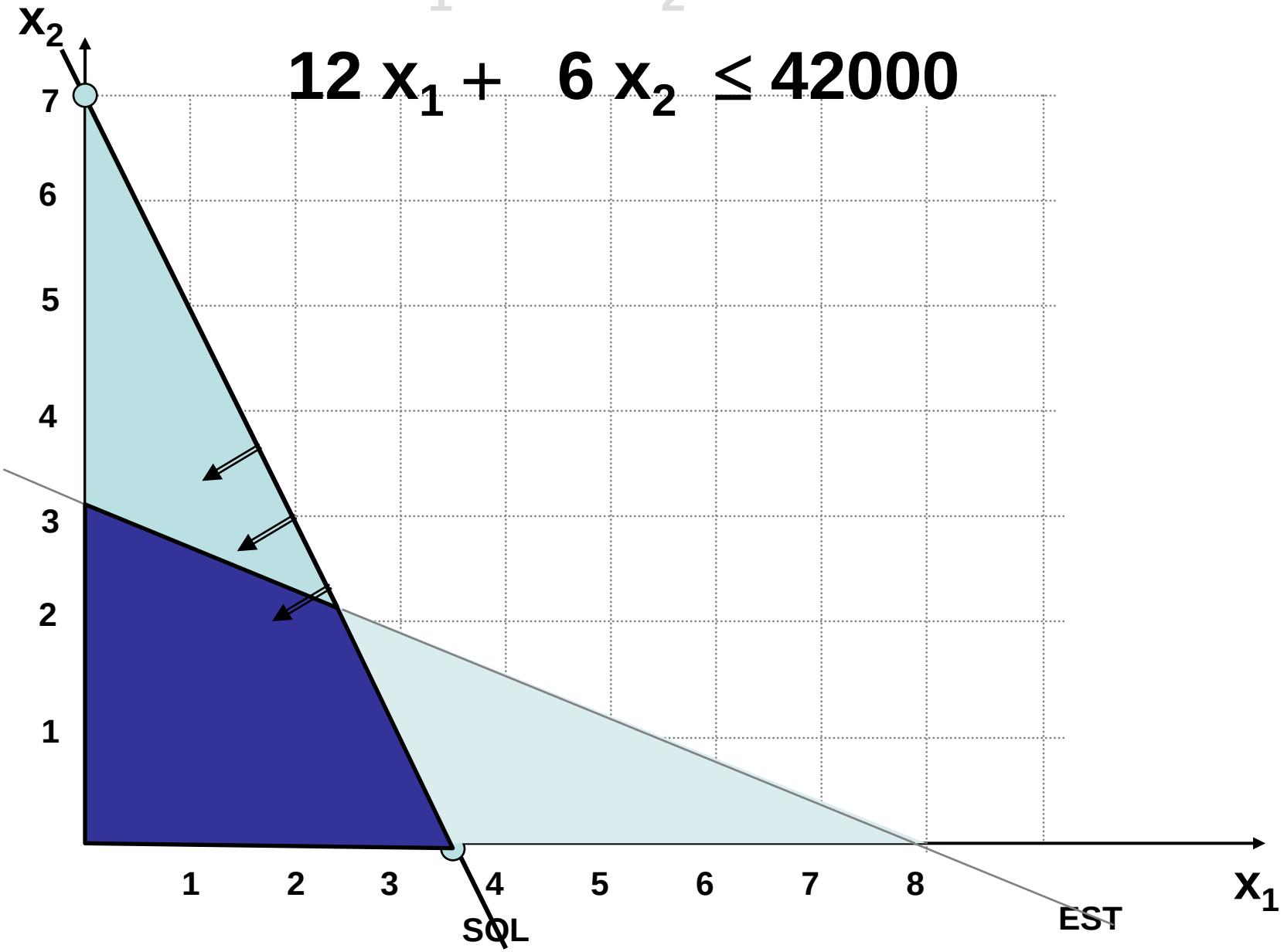
$6\,x_1 + 16\,x_2 \leq 48000$

$12\,x_1 + 6\,x_2 \leq 42000$



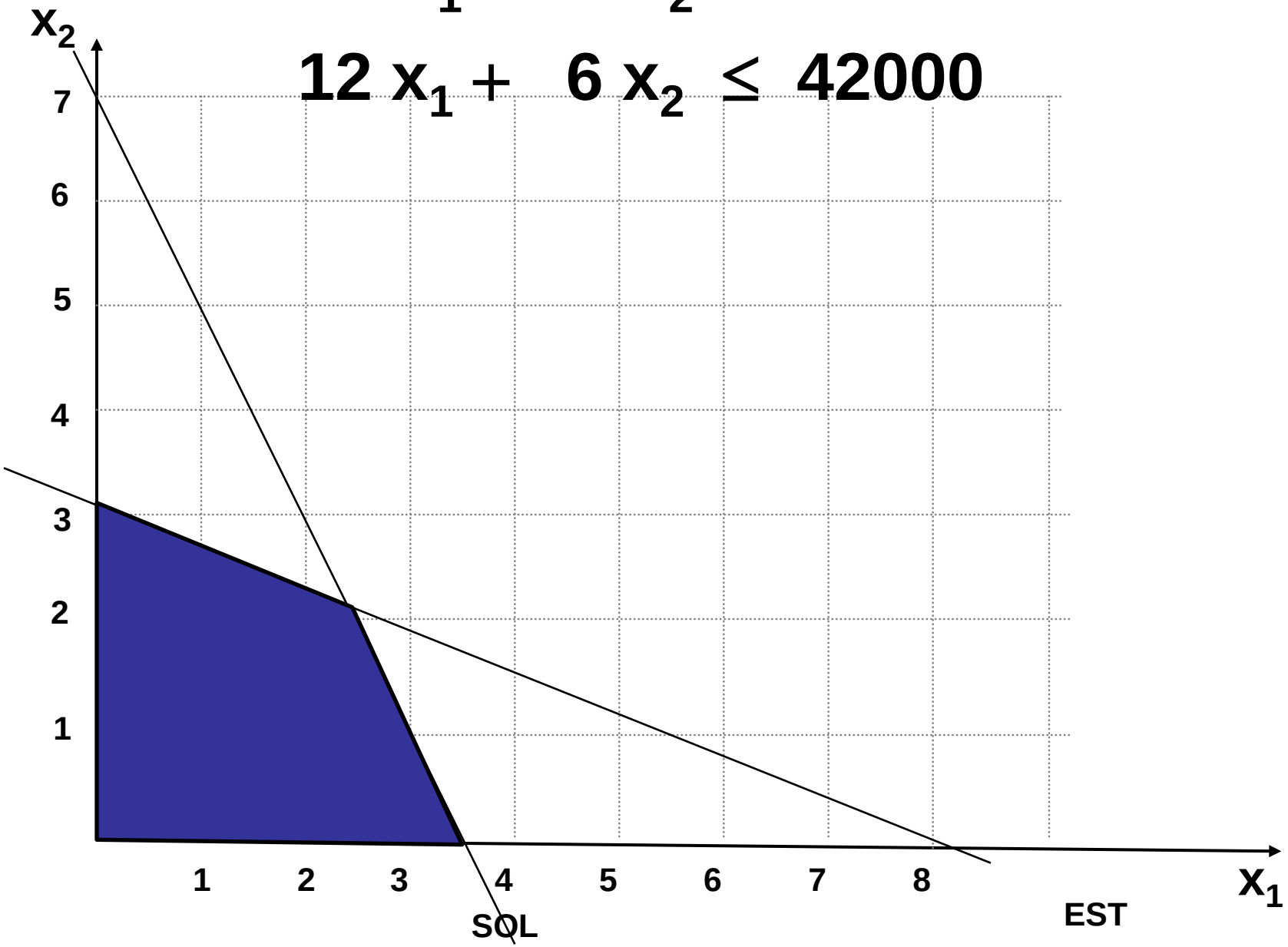
$6\,x_1 + 16\,x_2 \leq 48000$

$12\,x_1 + 6\,x_2 \leq 42000$



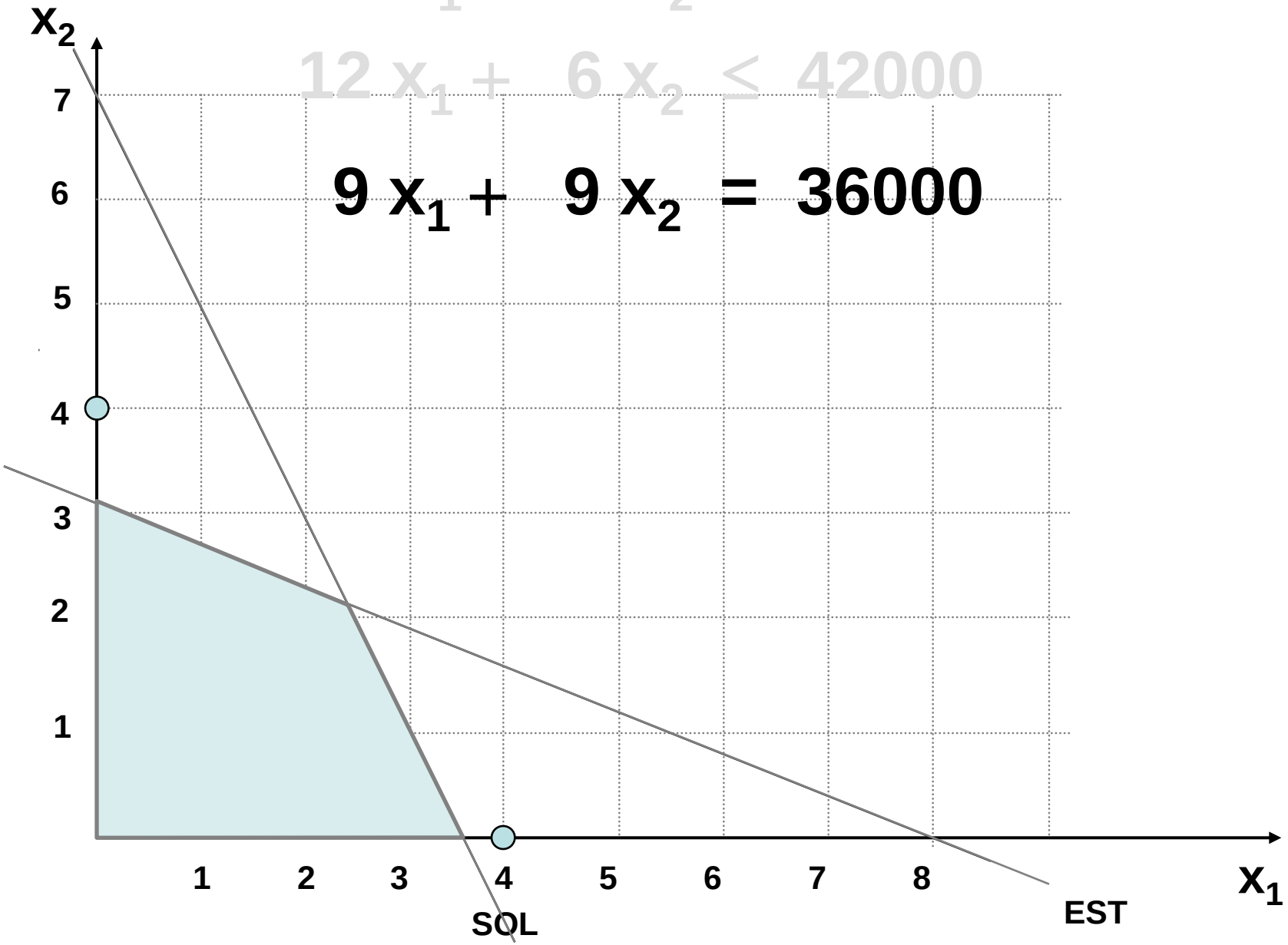
$$6\,x_1 + 16\,x_2 \leq 48000$$

$$12\,x_1 + 6\,x_2 \leq 42000$$



$6\,x_1 + 16\,x_2 \leq 48000$

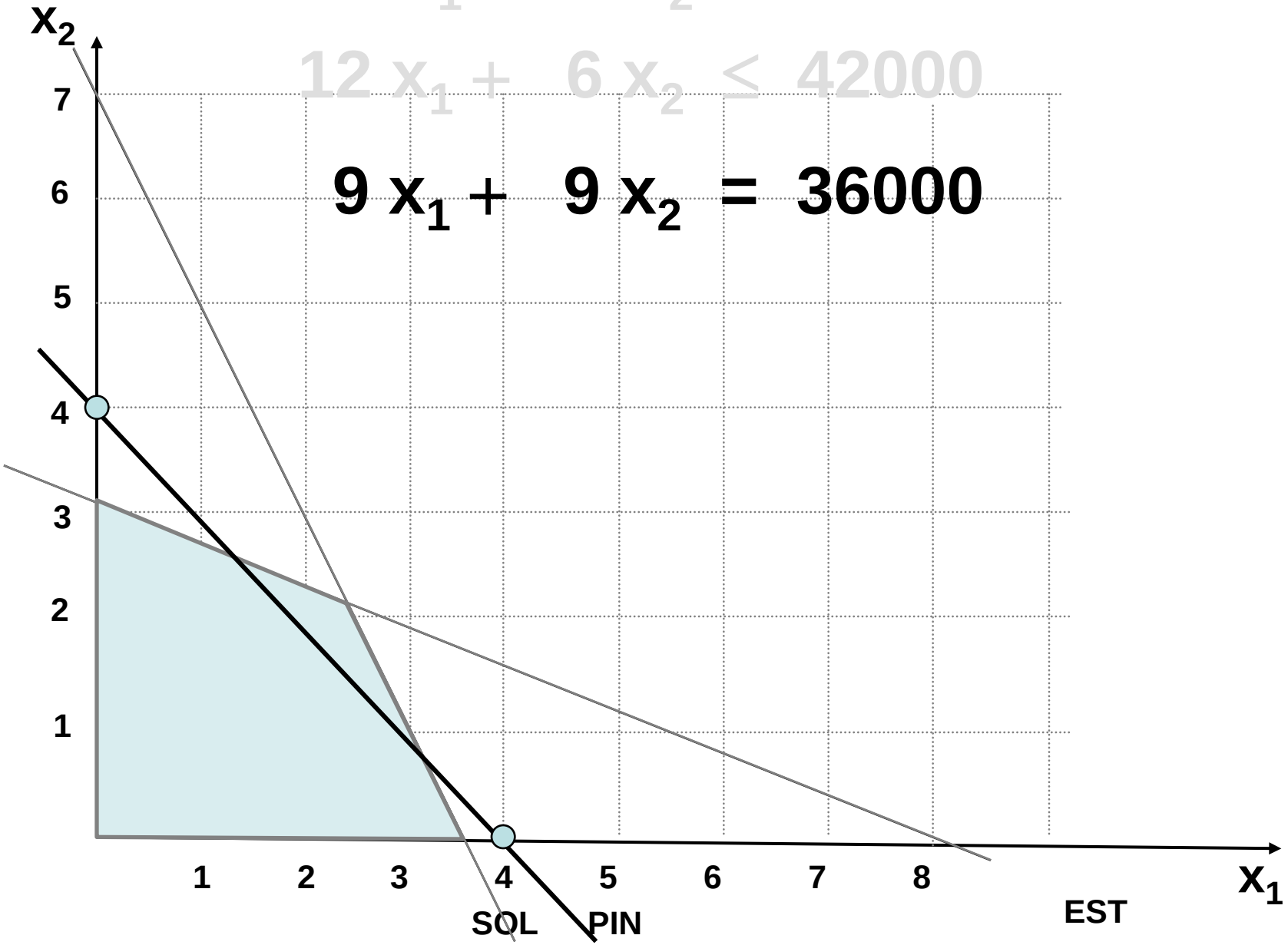
$12\,x_1 + 6\,x_2 \leq 42000$



$6\,x_1 + 16\,x_2 \leq 48000$

$12\,x_1 + 6\,x_2 \leq 42000$

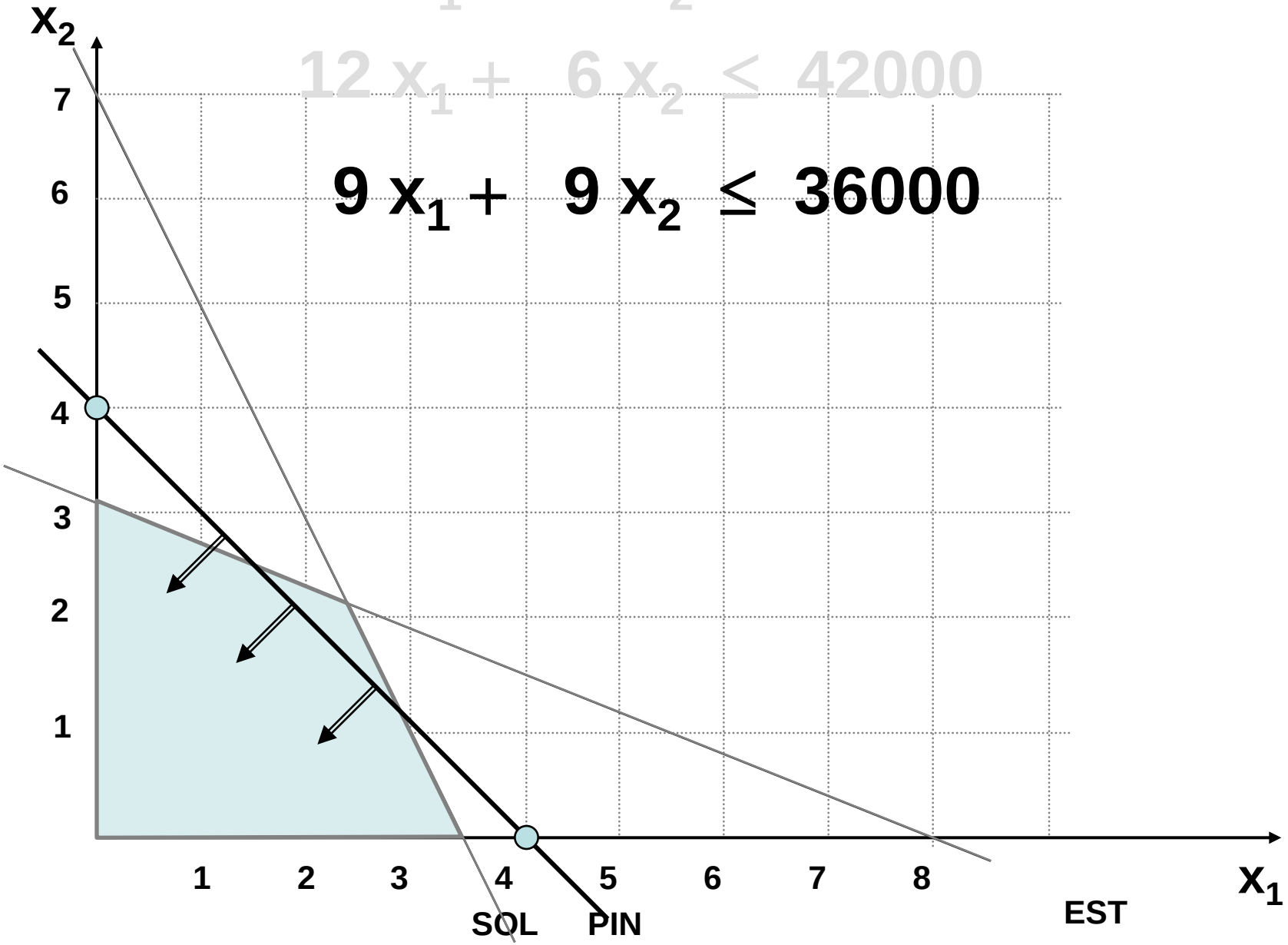
$9\,x_1 + 9\,x_2 = 36000$



$6\,x_1 + 16\,x_2 \leq 48000$

$12\,x_1 + 6\,x_2 \leq 42000$

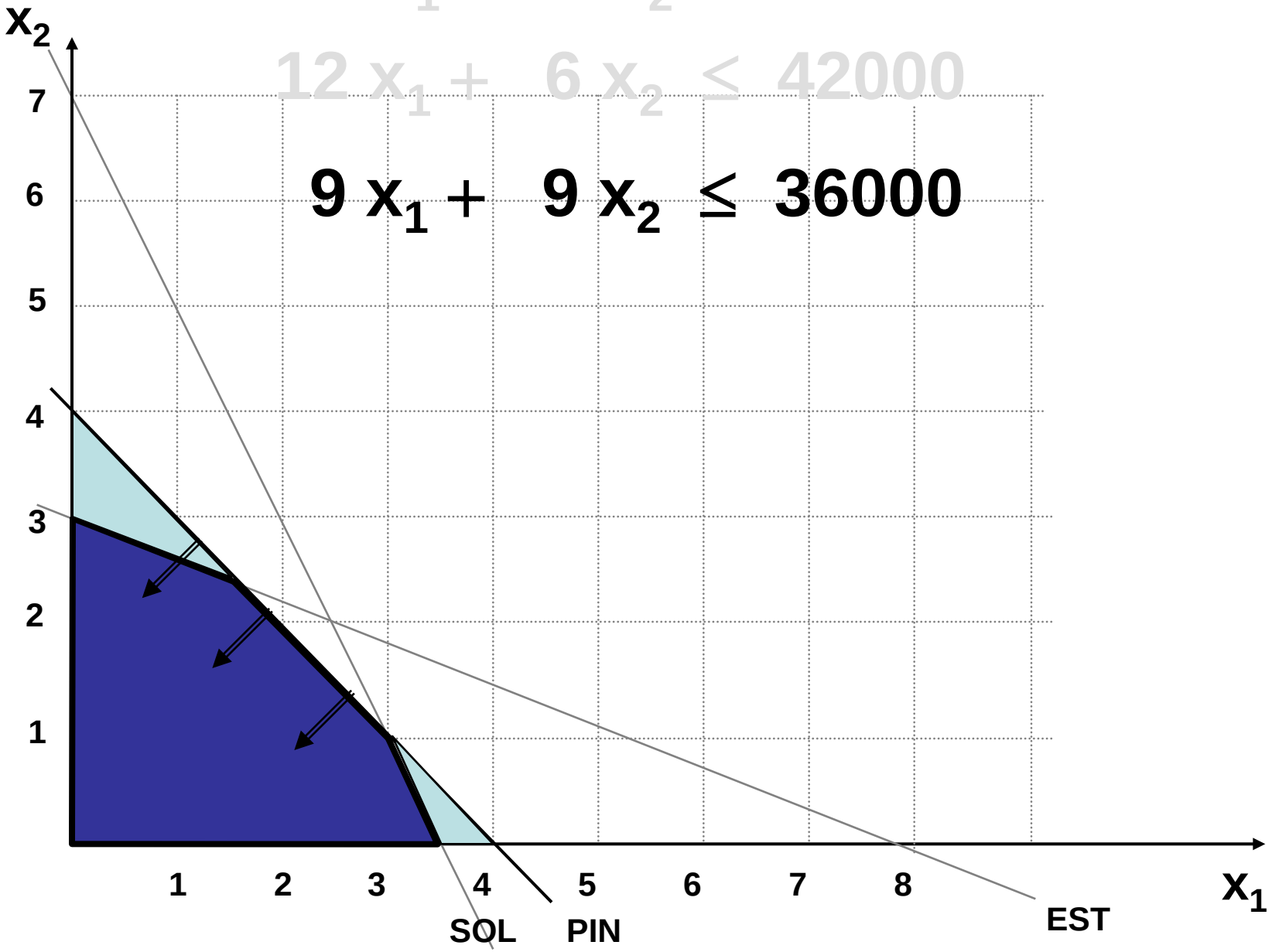
$9\,x_1 + 9\,x_2 \leq 36000$



$$6\,x_1 + 16\,x_2 \leq 48000$$

$$12\,x_1 + 6\,x_2 \leq 42000$$

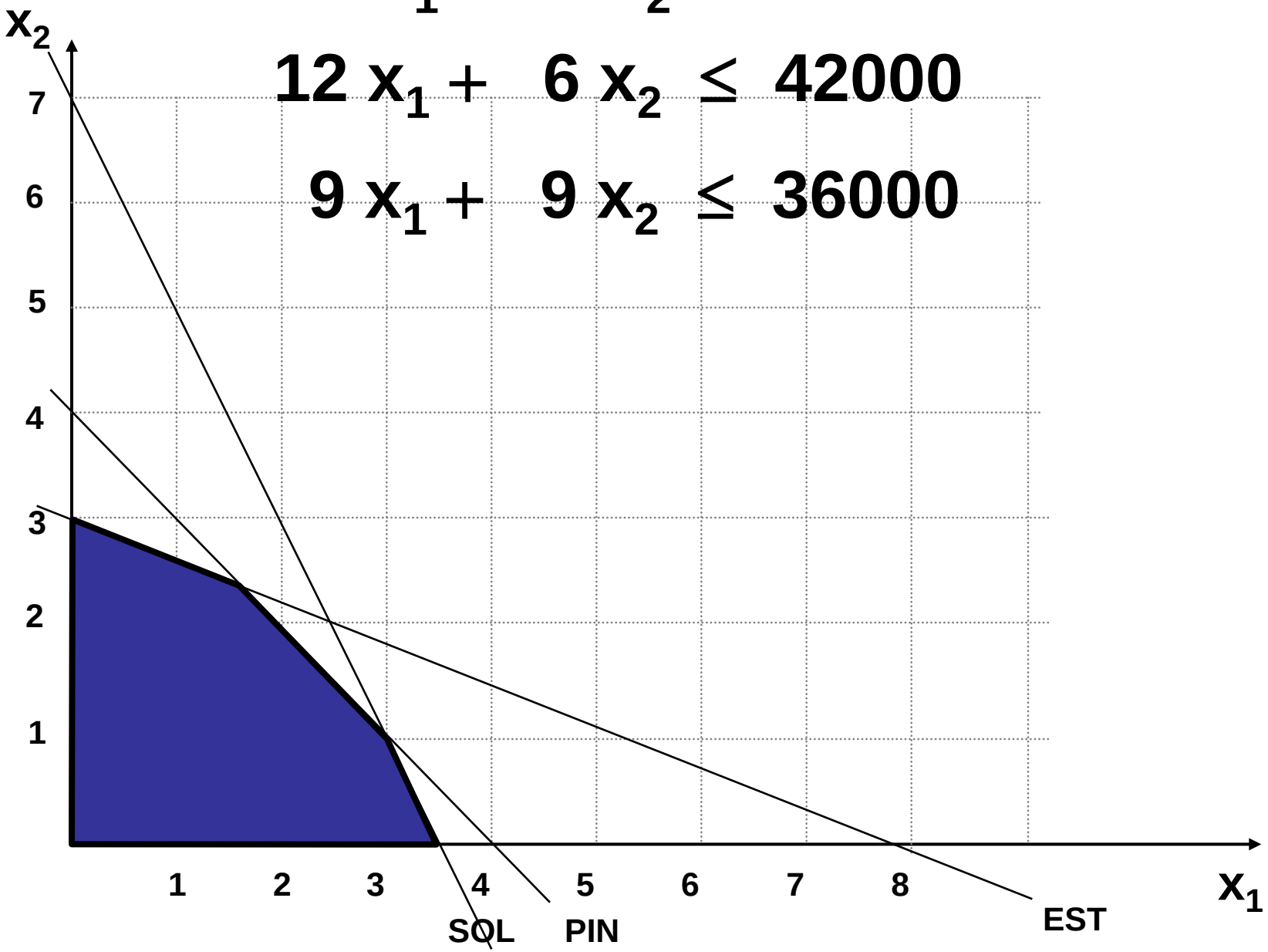
$$9\,x_1 + 9\,x_2 \leq 36000$$

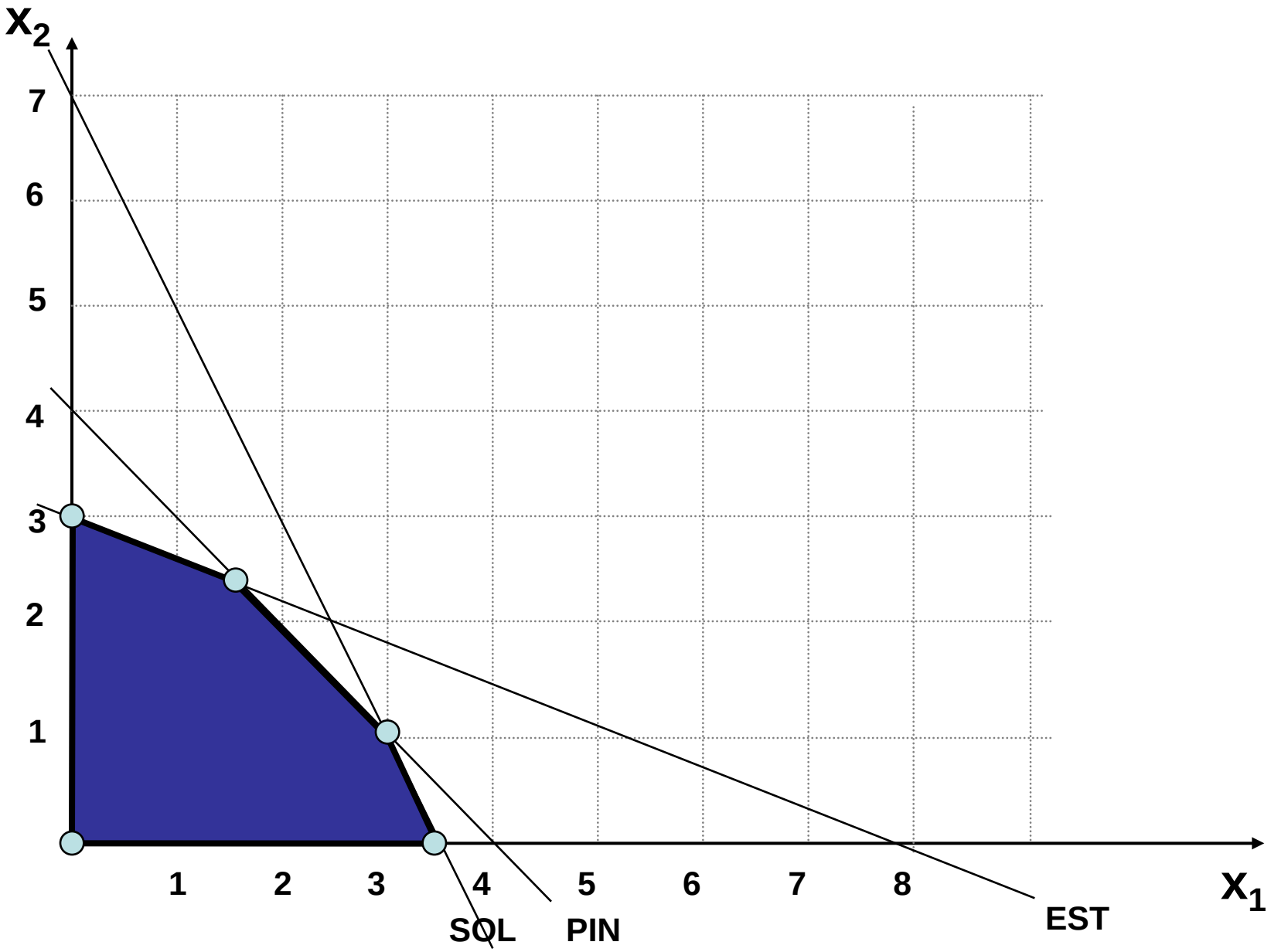


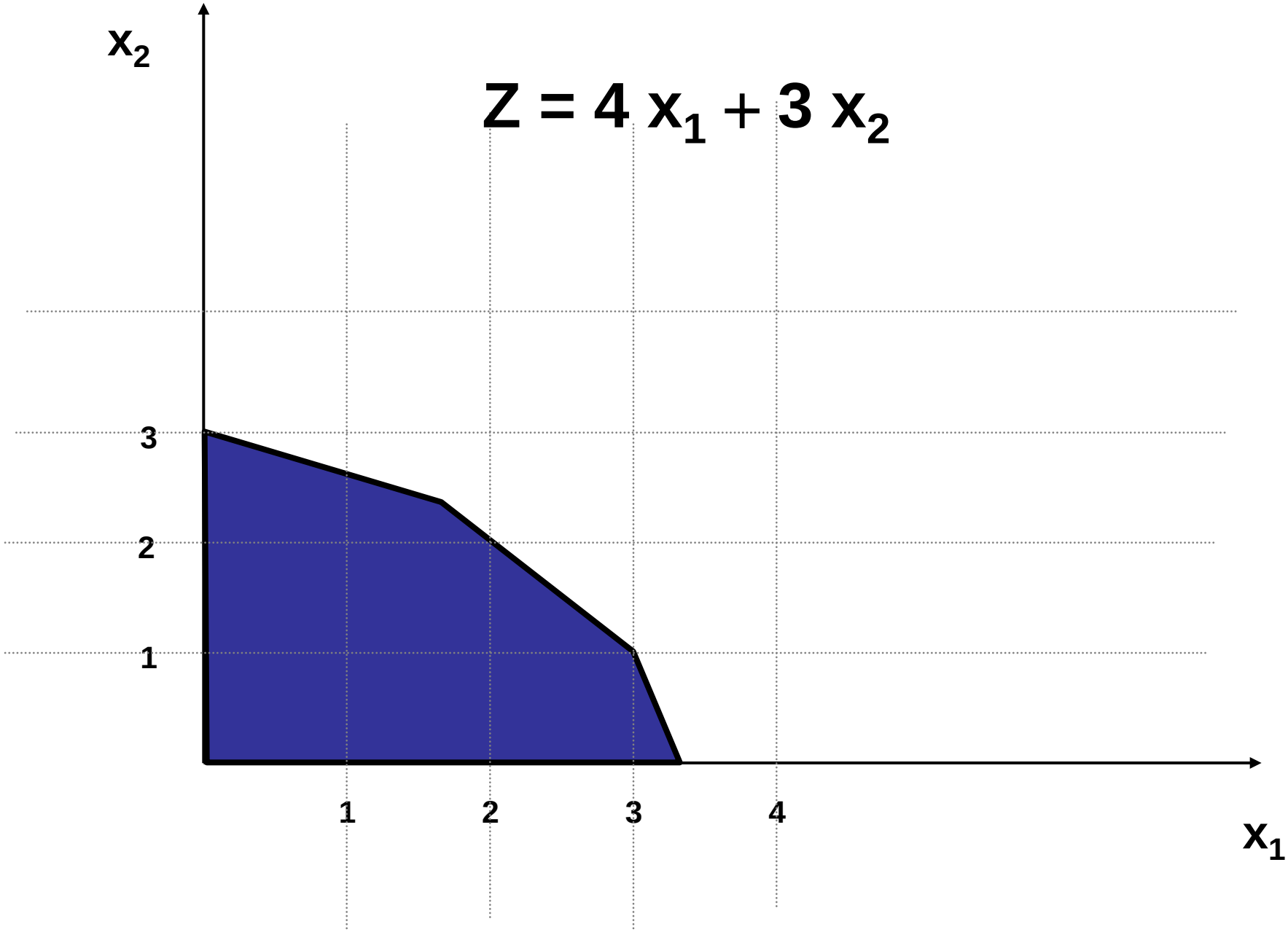
$$6\,x_1 + 16\,x_2 \leq 48000$$

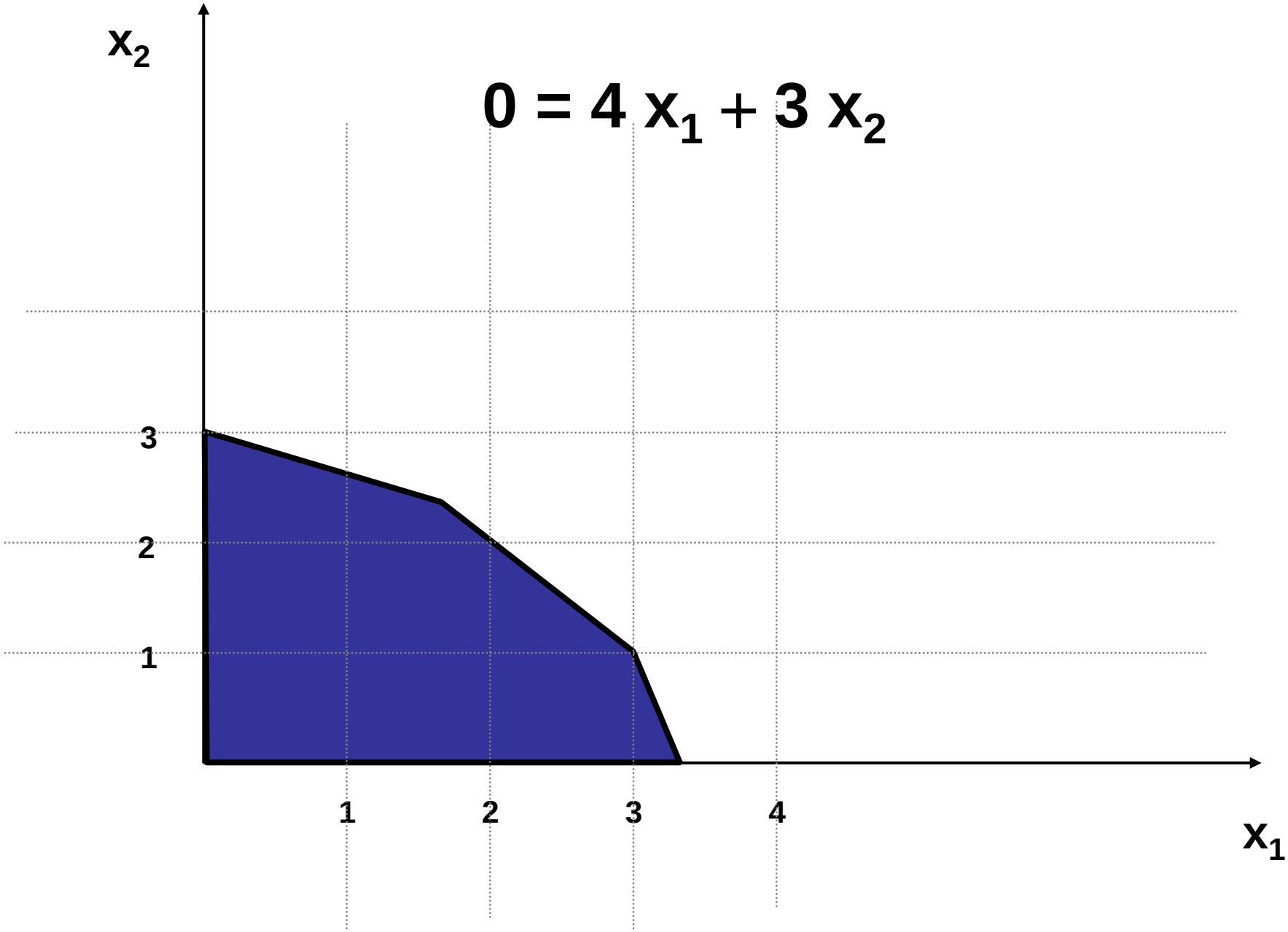
$$12\,x_1 + 6\,x_2 \leq 42000$$

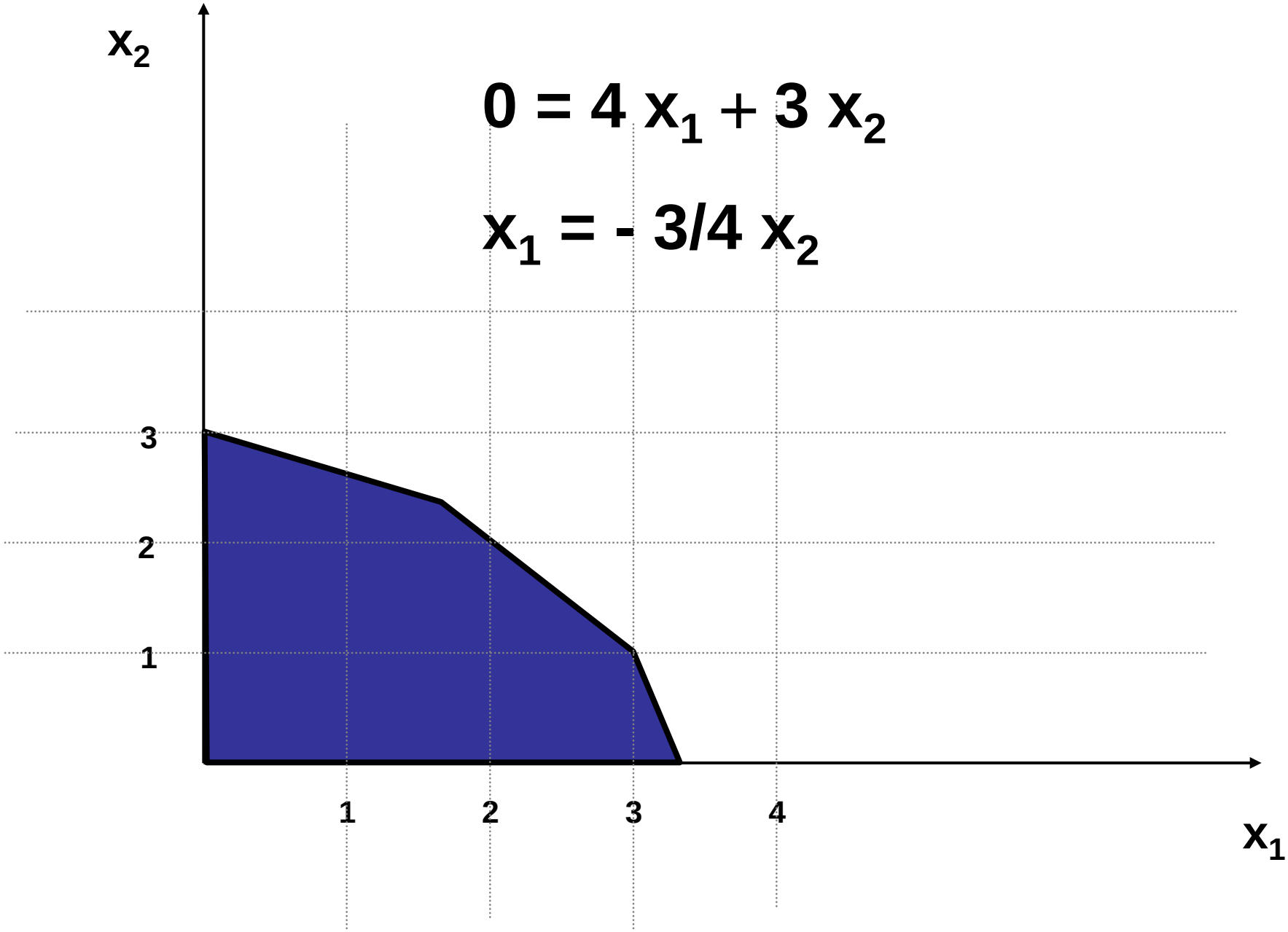
$$9\,x_1 + 9\,x_2 \leq 36000$$

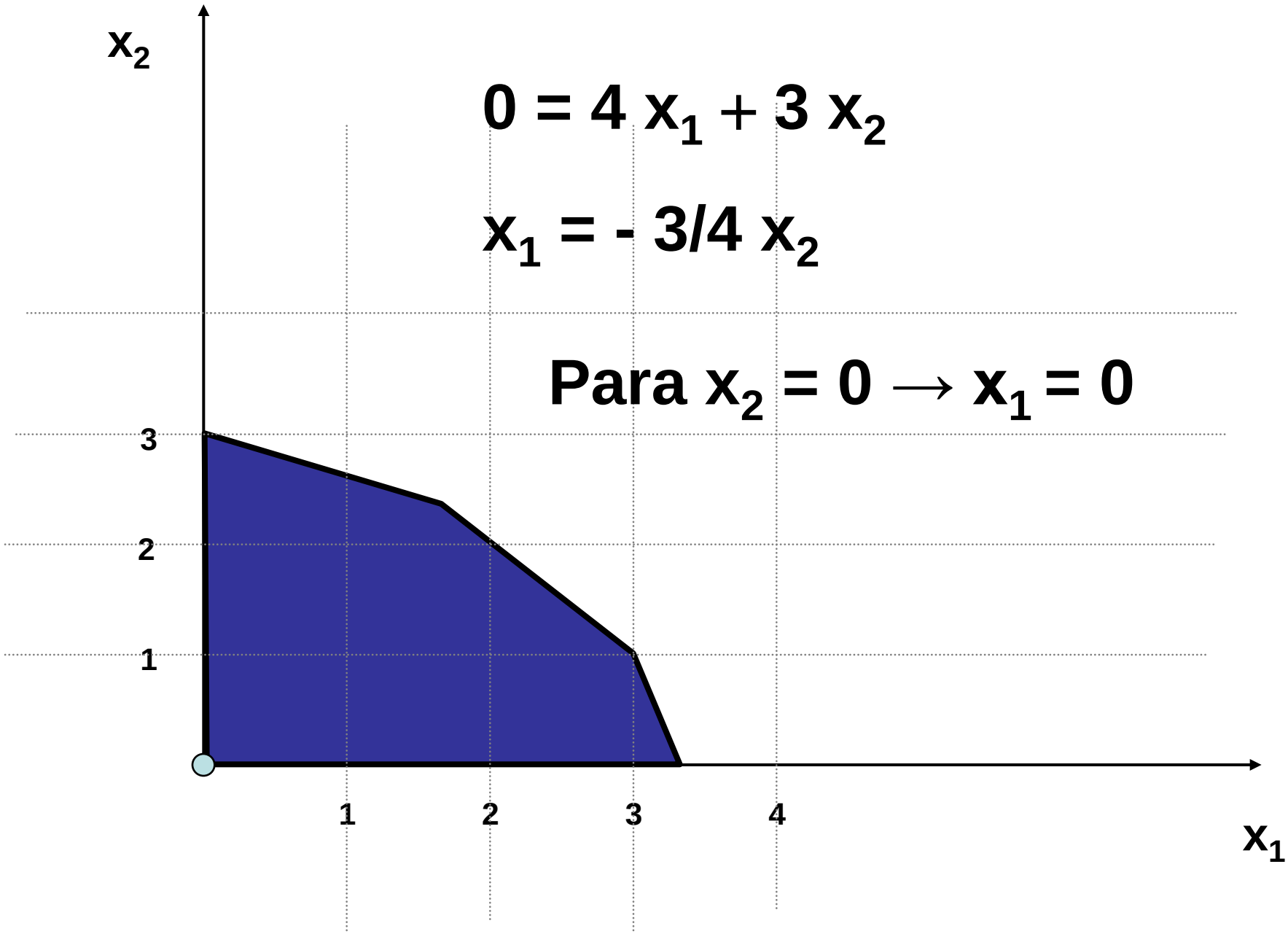


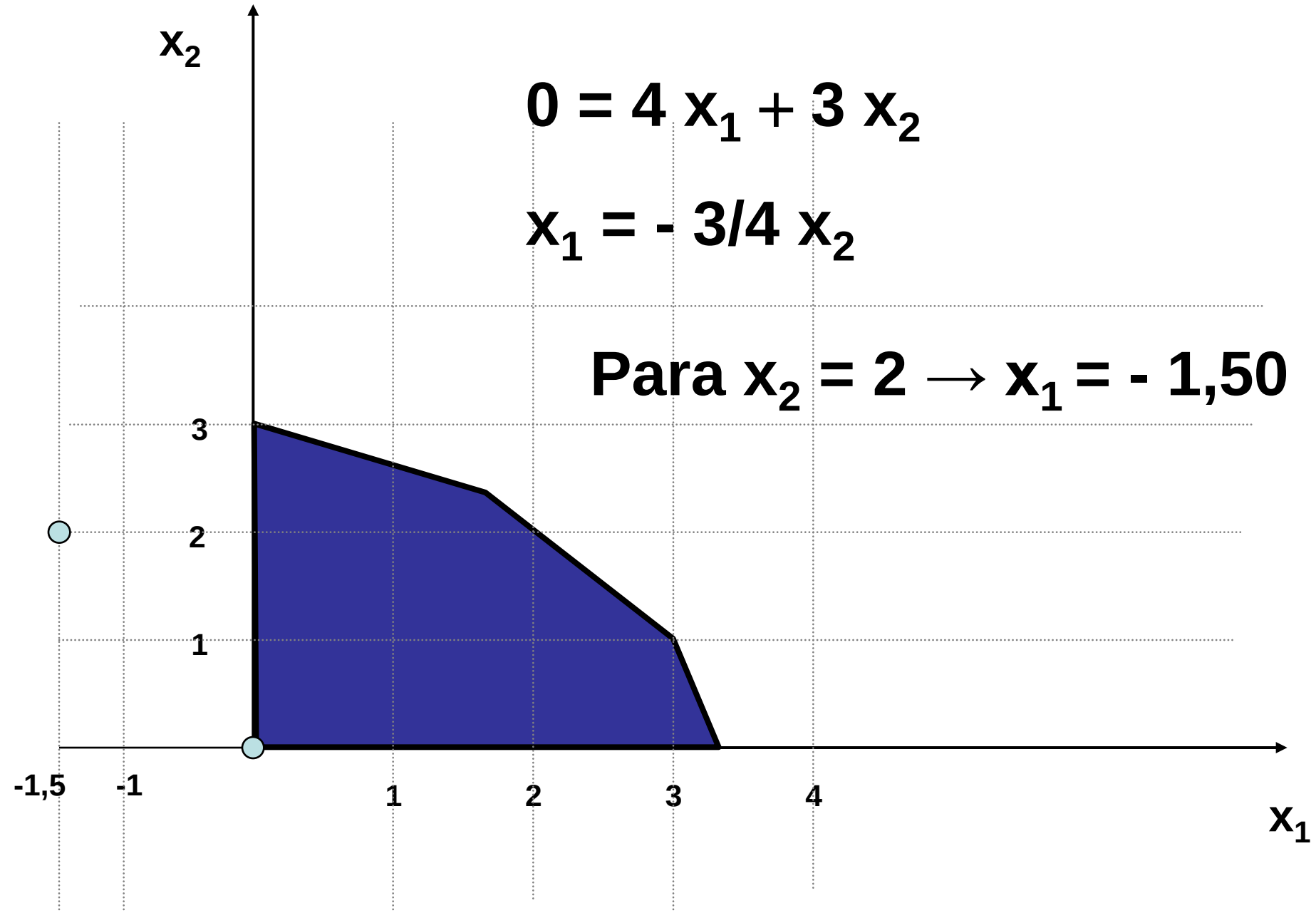

X2
7
6
5
4
3
2
1
1
2
3
4
5
6
7
8
X1
SOL
PIN
EST

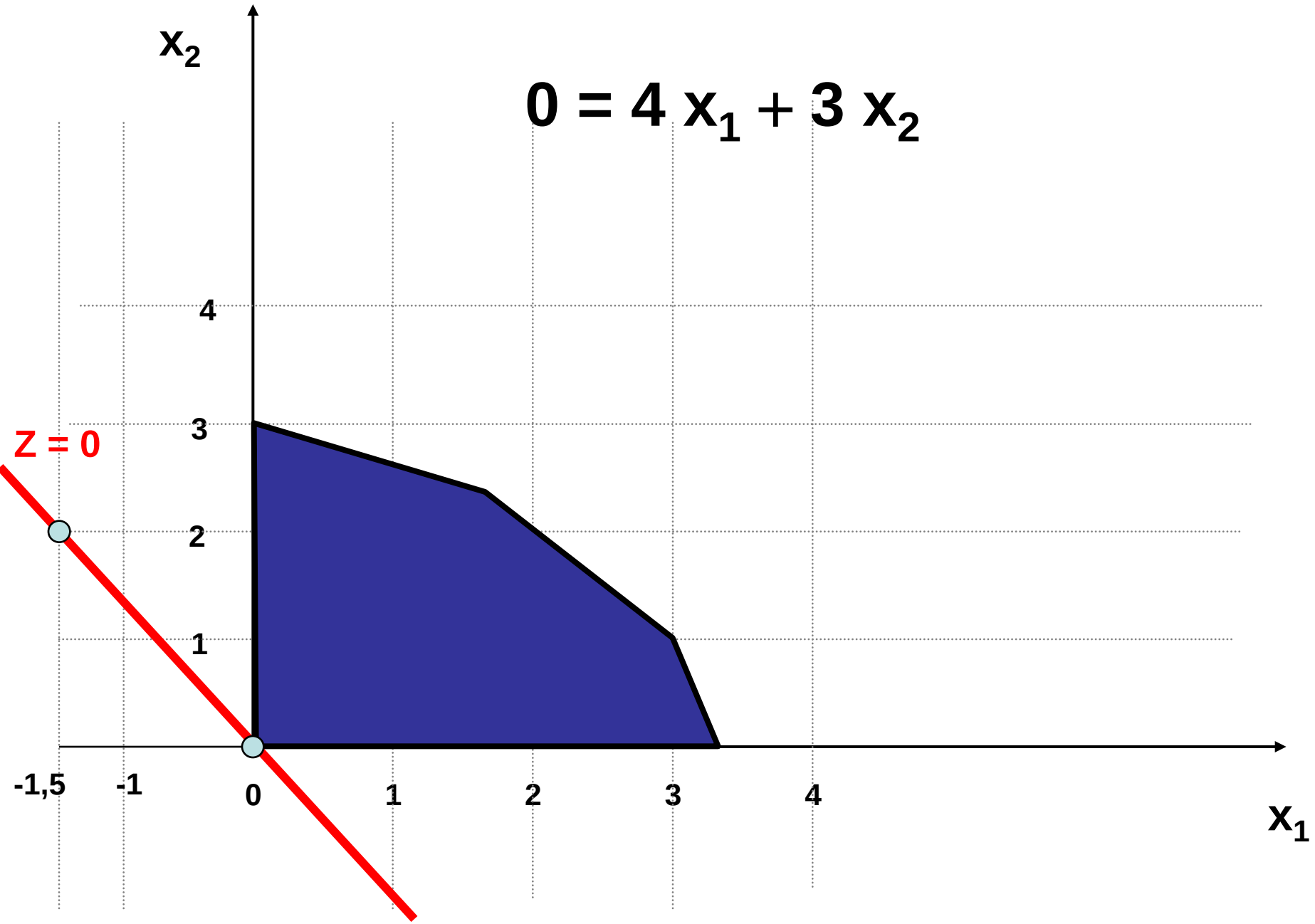

x_2
$Z = 4\,x_1 + 3\,x_2$
3
2
1
1
2
3
4
x_1

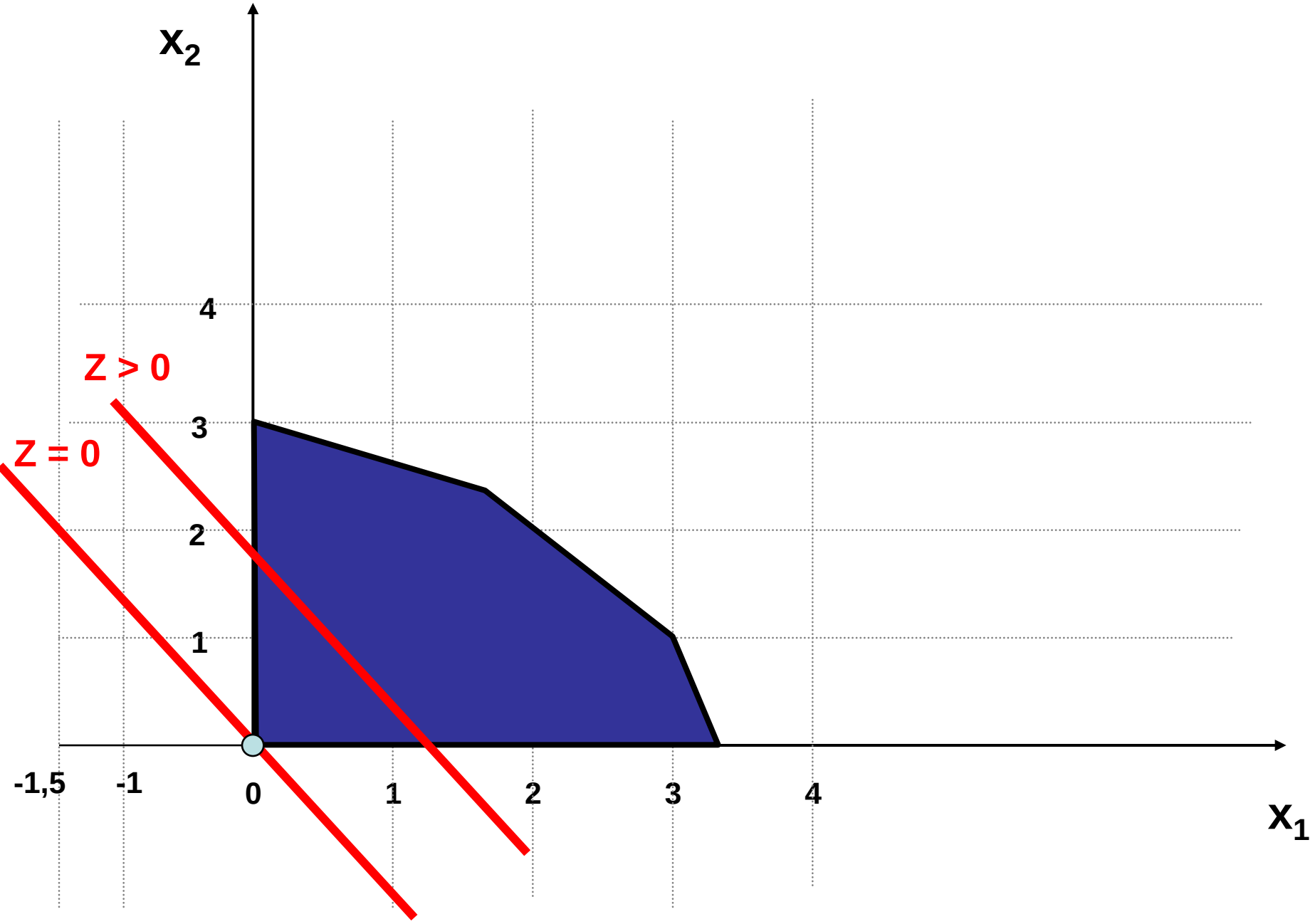

x_2
$0 = 4\,x_1 + 3\,x_2$
3
2
1
1
2
3
4
x_1

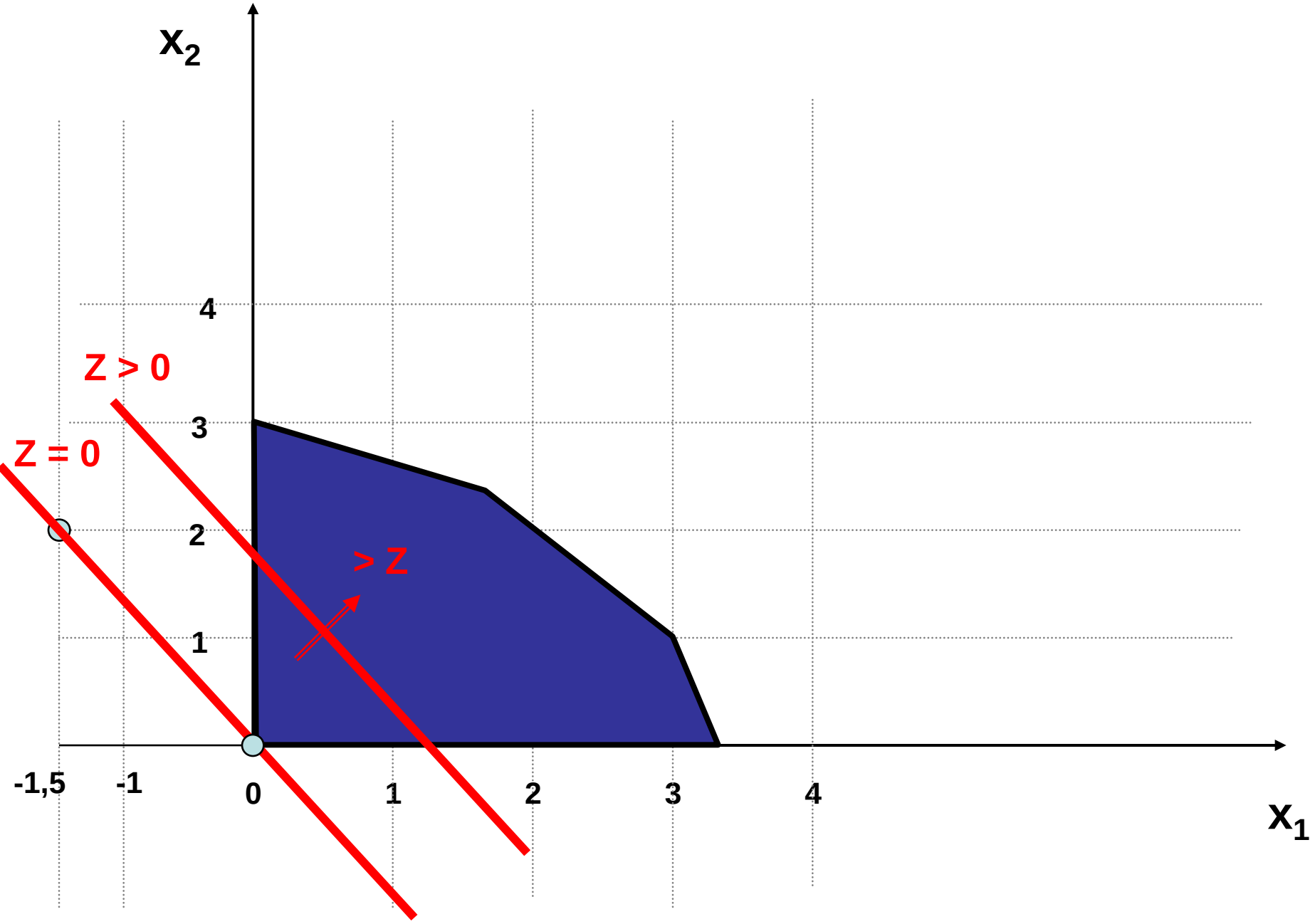

x_2
$0 = 4\,x_1 + 3\,x_2$
$x_1 = -\,3/4\,x_2$
3
2
1
1
2
3
4
x_1

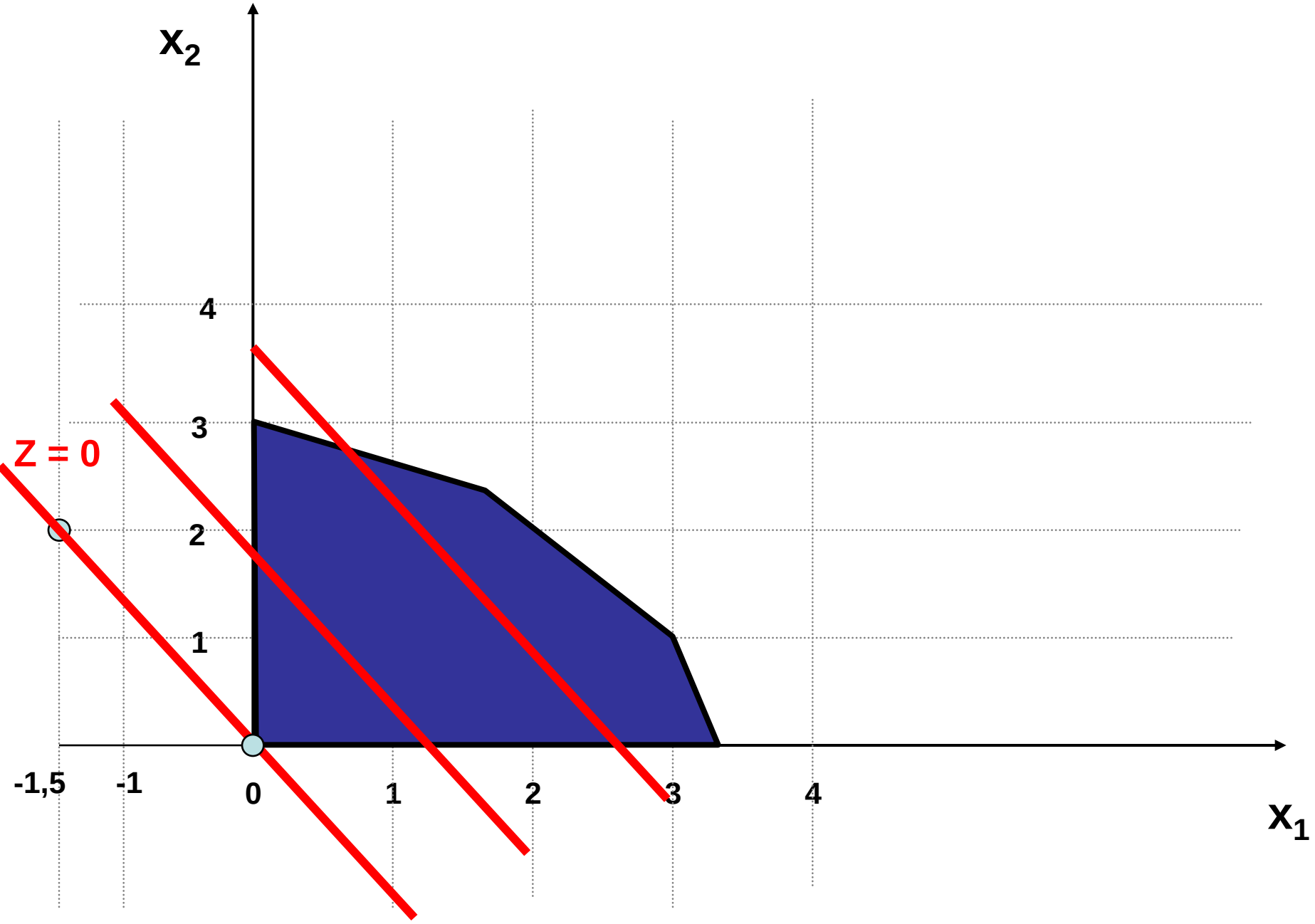

x_2
$0 = 4\,x_1 + 3\,x_2$
$x_1 = -\,3/4\,x_2$
Para $x_2 = 0 \rightarrow x_1 = 0$
3
2
1
1
2
3
4
x_1

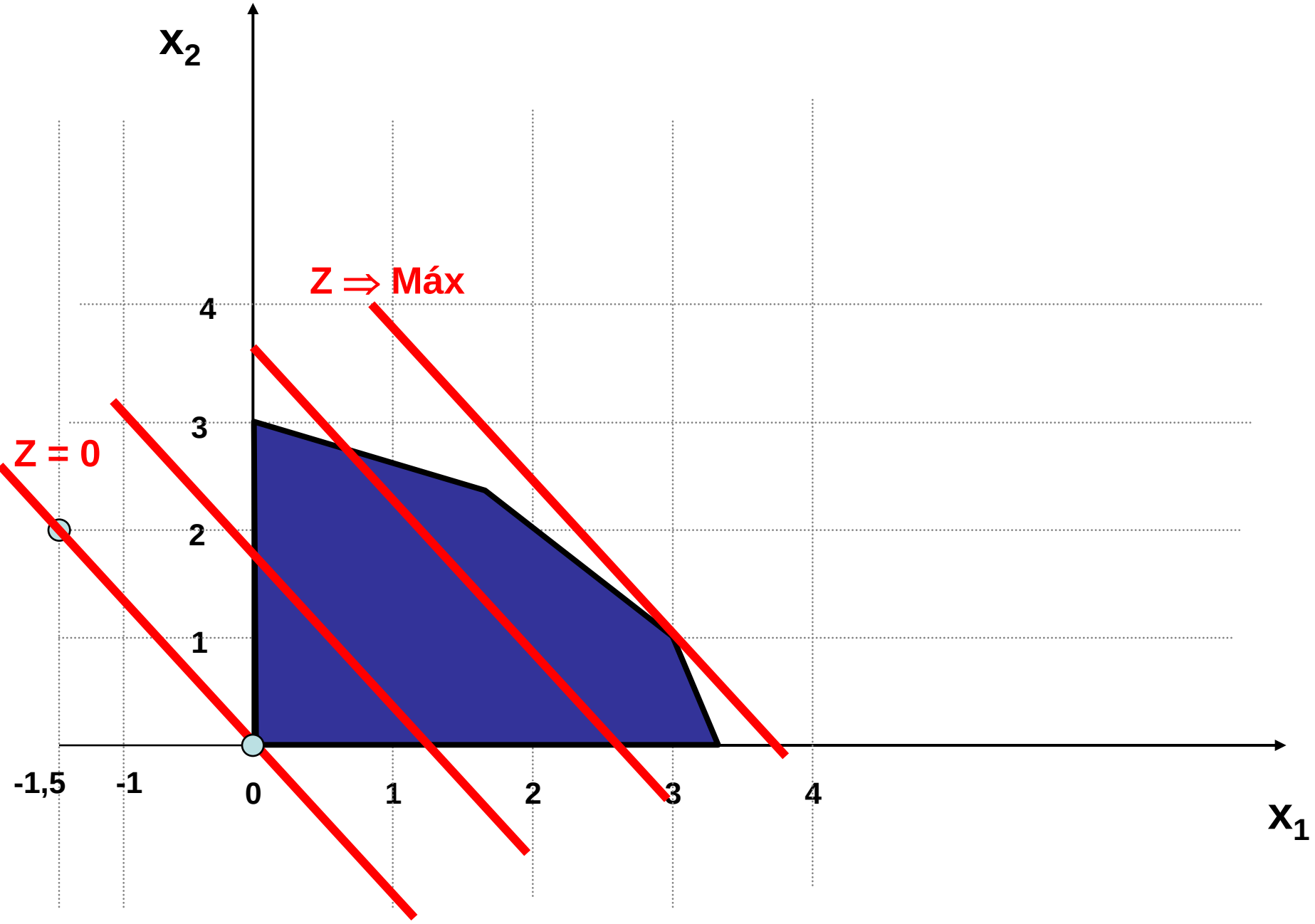

x_2
$0 = 4\,x_1 + 3\,x_2$
$x_1 = -\,3/4\,x_2$
Para $x_2 = 2 \rightarrow x_1 = -\,1{,}50$
3
2
1
-1,5
-1
1
2
3
4
x_1

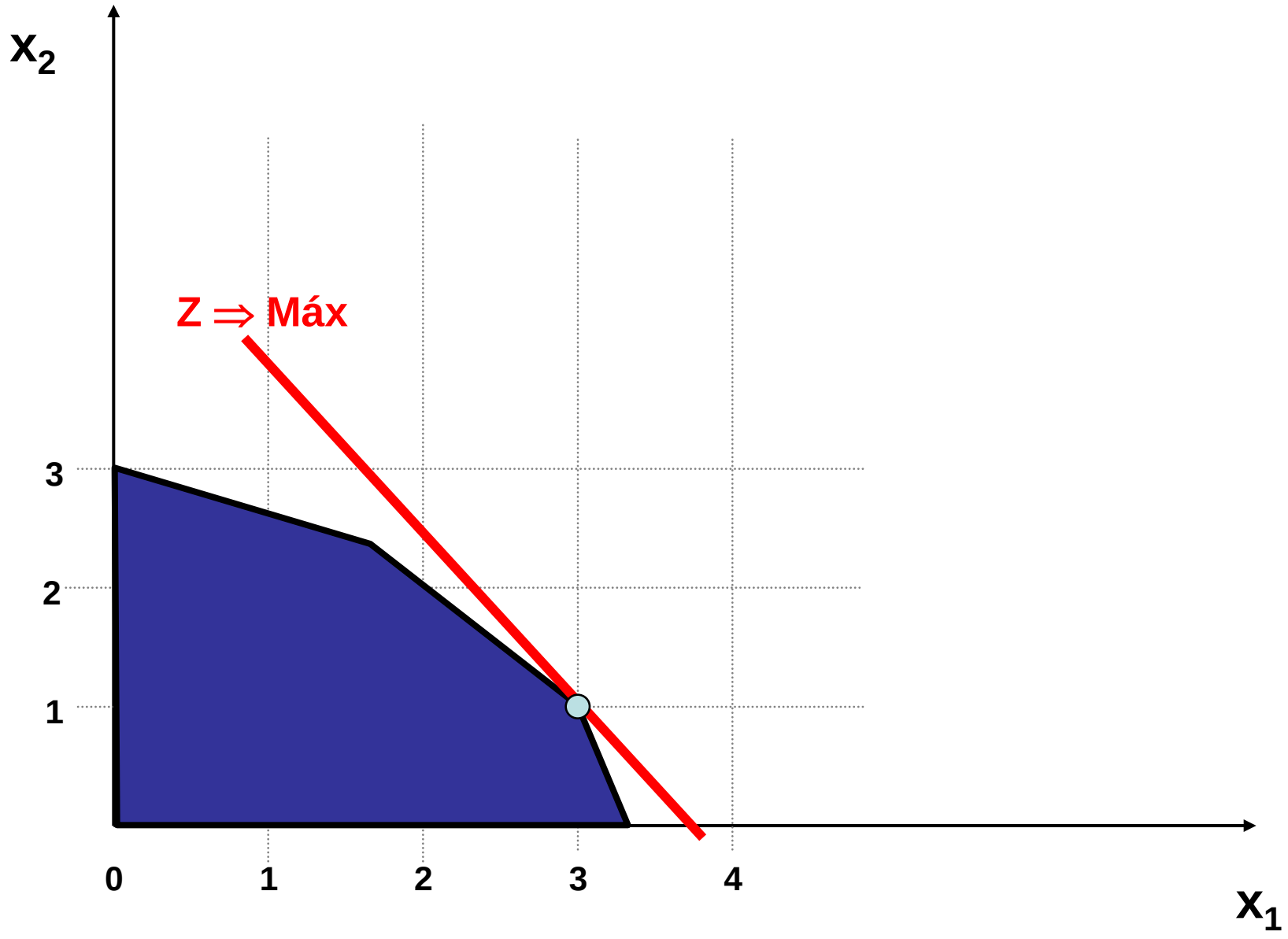

x_2
$0 = 4\,x_1 + 3\,x_2$
4
3
2
1
Z = 0
-1,5
-1
0
1
2
3
4
x_1

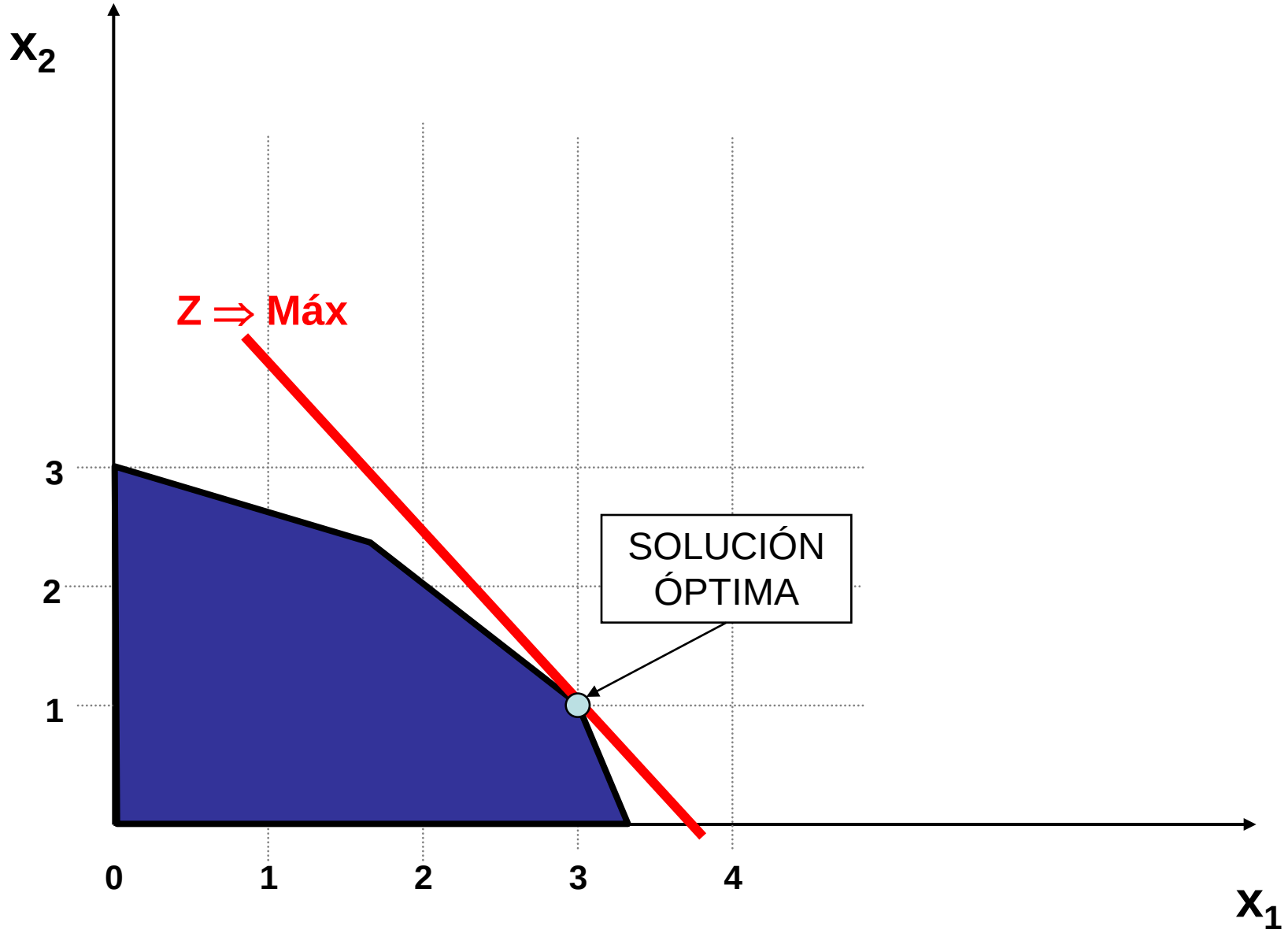

x_2
4
3
2
1
Z > 0
Z = 0
-1,5
-1
0
1
2
3
4
x_1

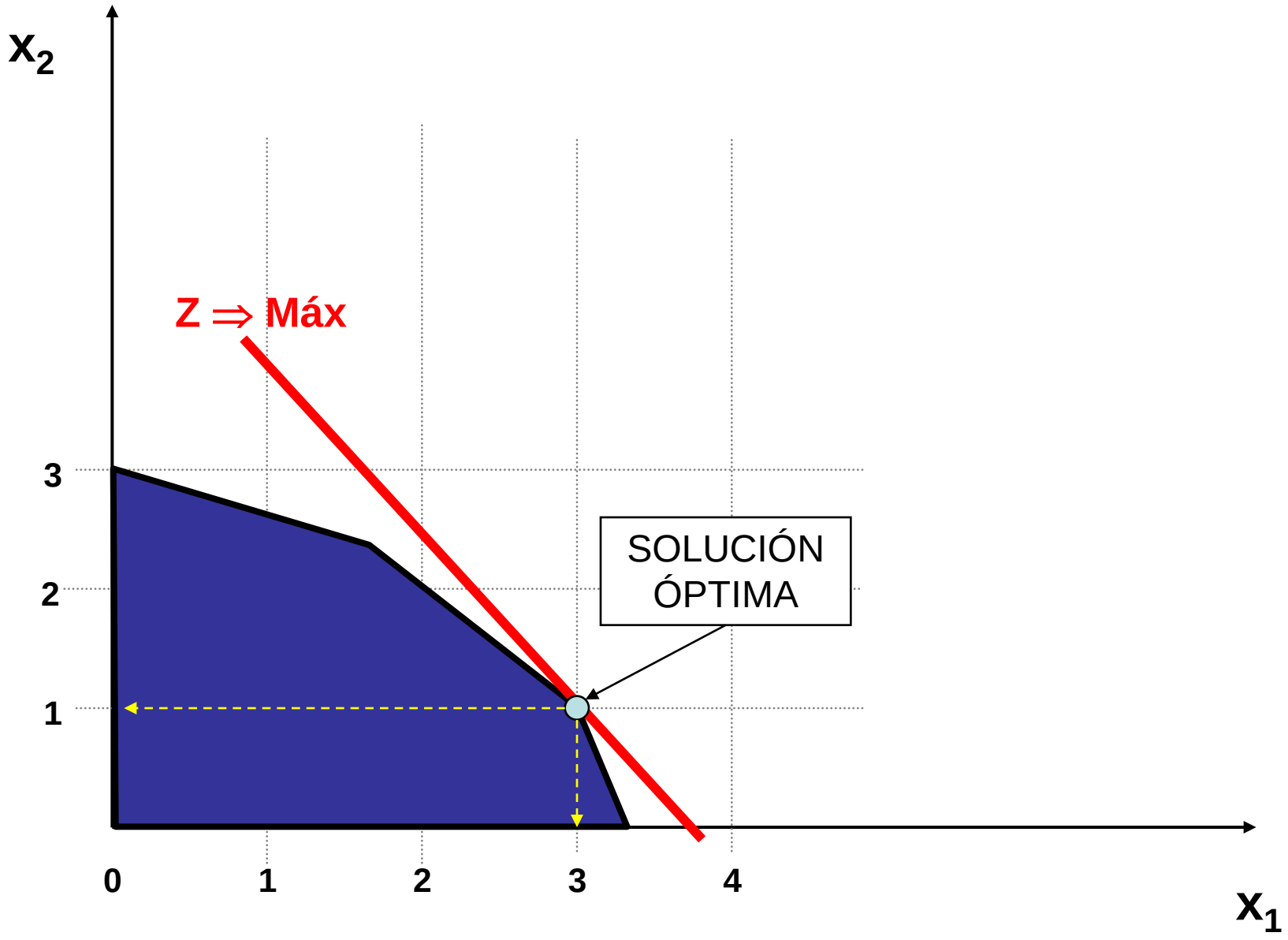

x_2
4
3
2
1
Z > 0
Z = 0
> Z
-1,5
-1
0
1
2
3
4
x_1

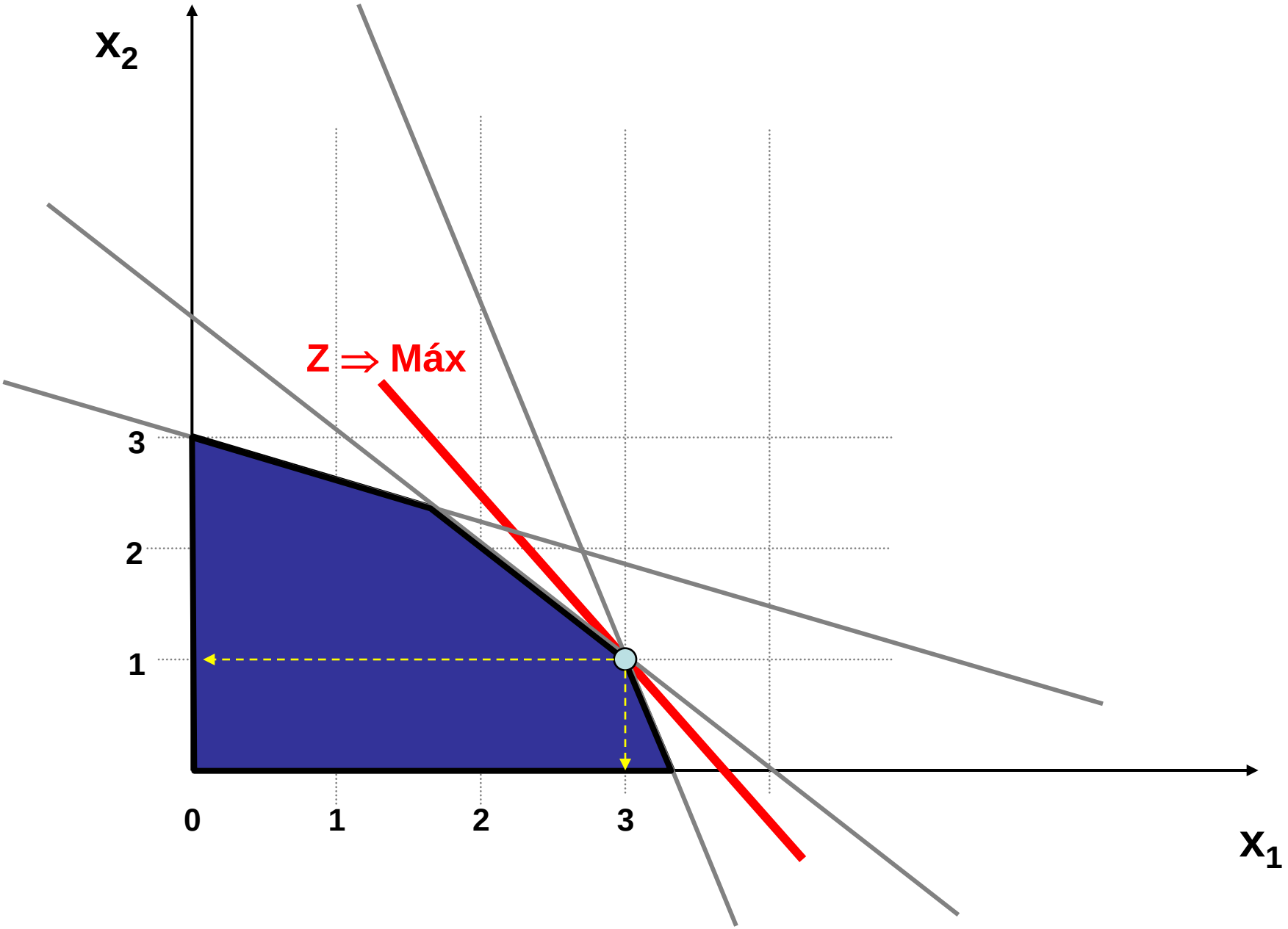

x_2
4
3
Z = 0
2
1
-1,5
-1
0
1
2
3
4
x_1

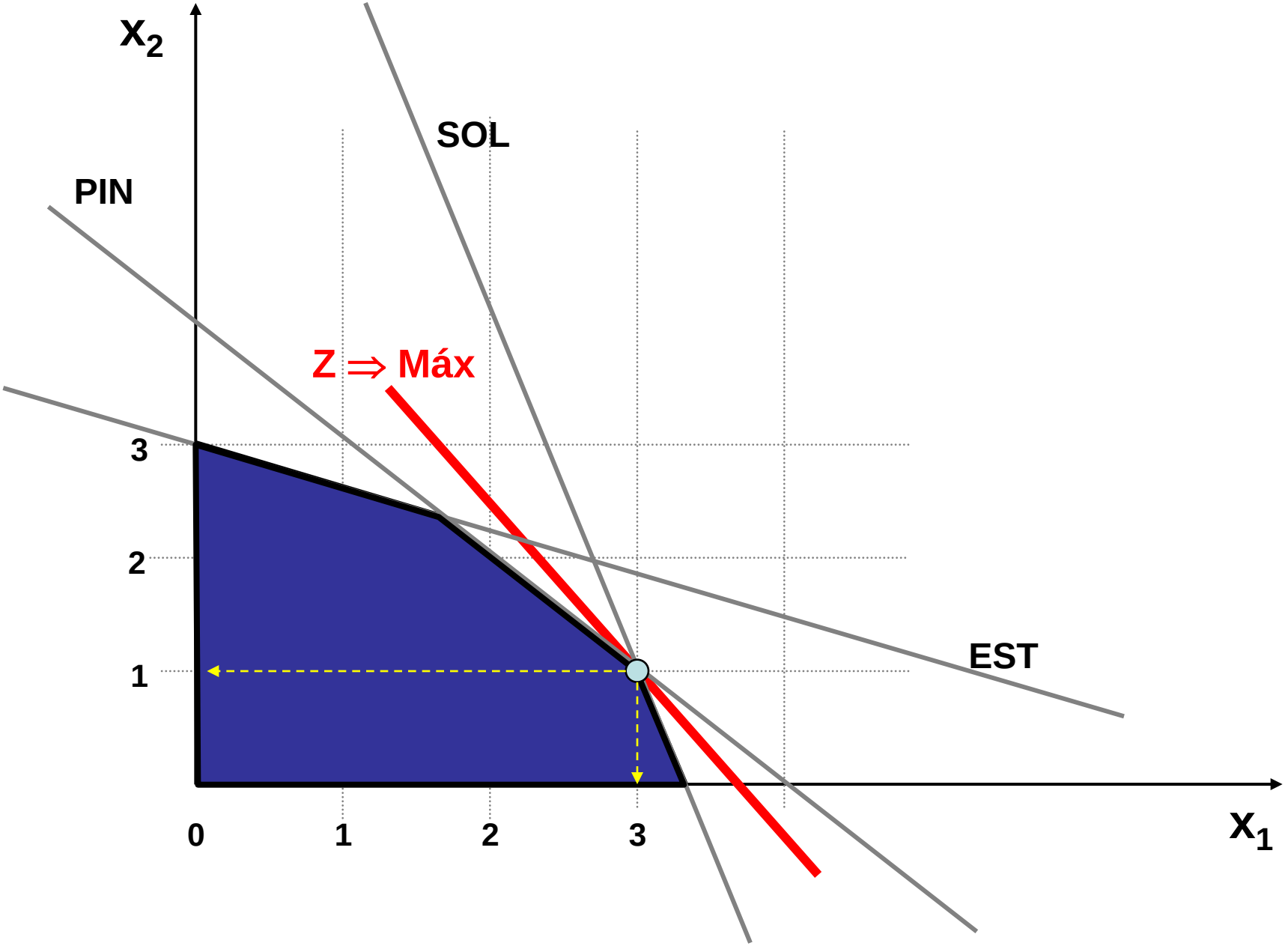

x_2
$Z \Rightarrow$ Máx
Z = 0
4
3
2
1
-1,5
-1
0
1
2
3
4
x_1

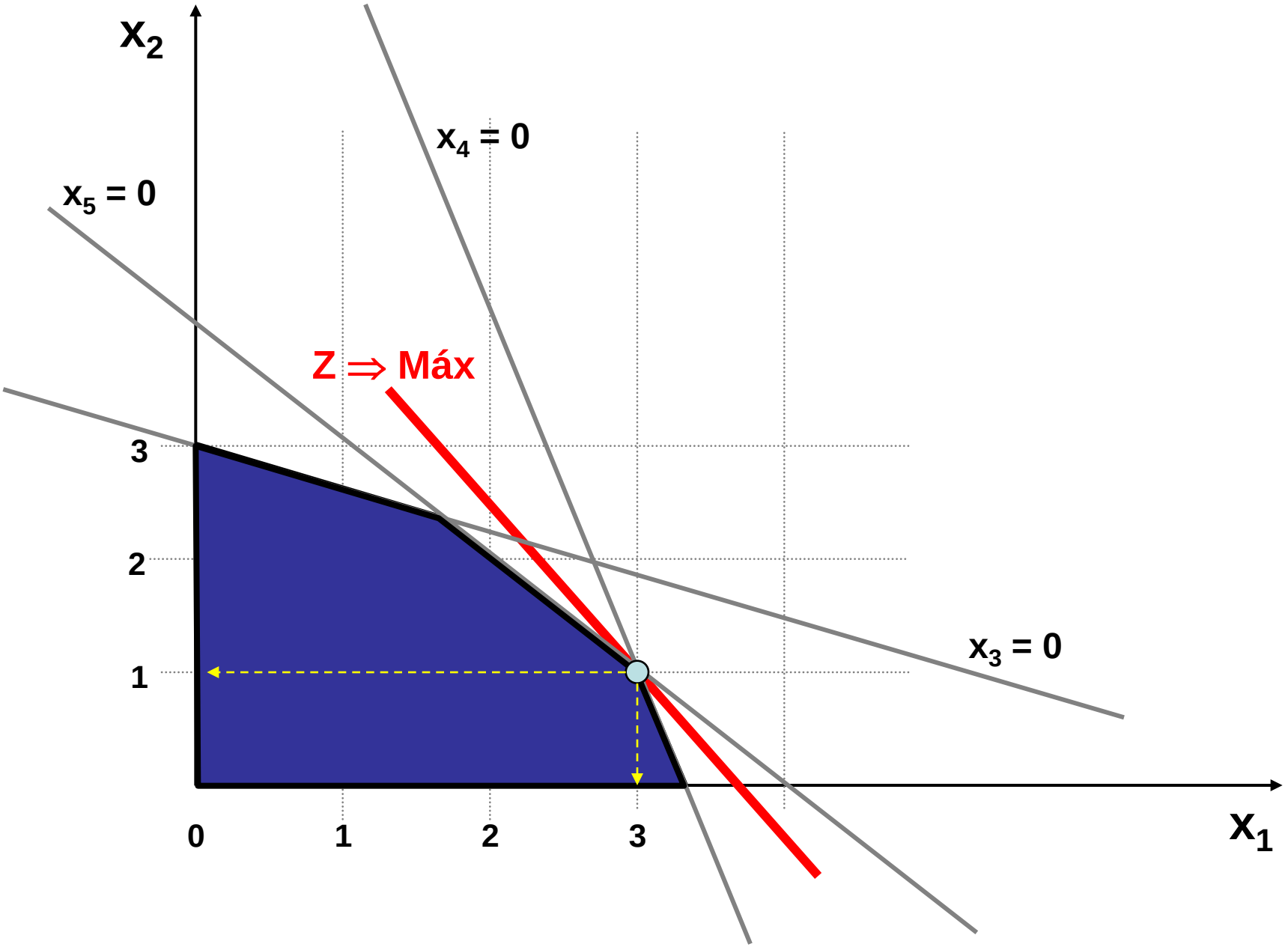

x_2
Z ⇒ Máx
3
2
1
0
1
2
3
4
x_1

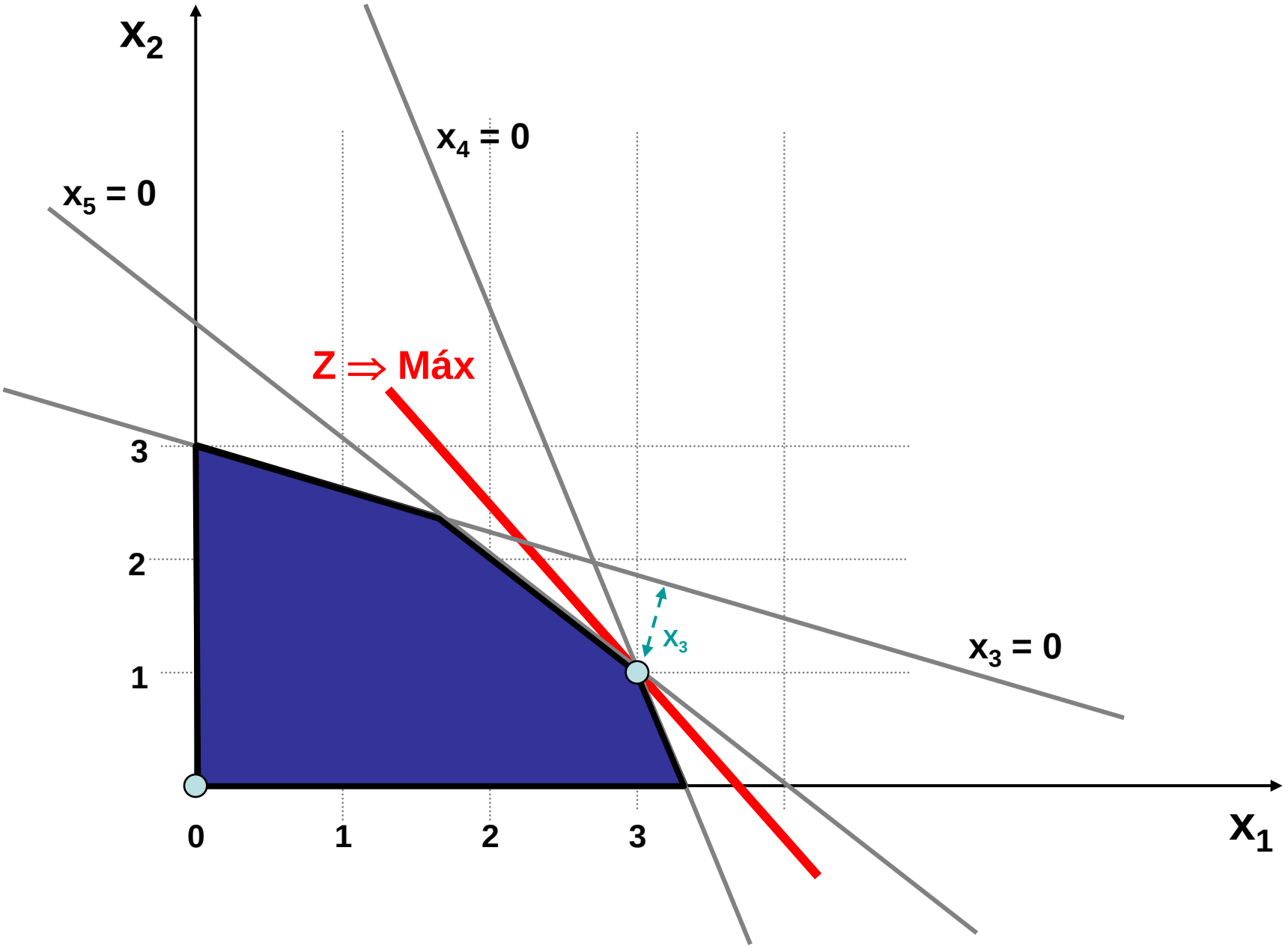

x_2
Z ⇒ Máx
3
2
1
SOLUCIÓN ÓPTIMA
0
1
2
3
4
x_1

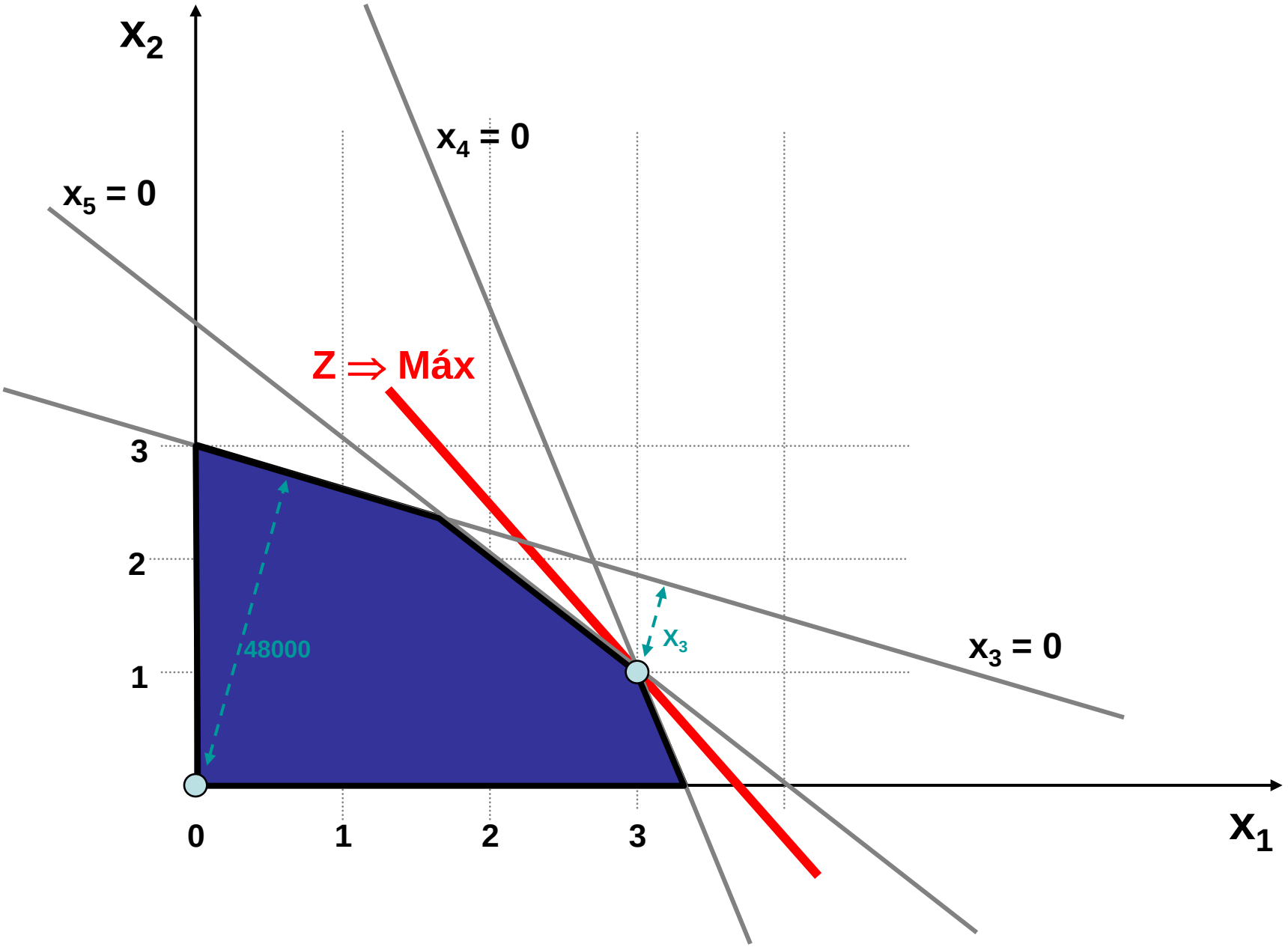

x_2
Z ⇒ Máx
3
2
1
SOLUCIÓN ÓPTIMA
0
1
2
3
4
x_1


x_2
$Z \Rightarrow$ Máx
3
2
1
0
1
2
3
x_1


X2
SOL
PIN
Z ⇒ Máx
3
2
1
EST
0
1
2
3
X1


x_2
$x_4 = 0$
$x_5 = 0$
$Z \Rightarrow$ Máx
3
2
1
$x_3 = 0$
0
1
2
3
x_1


x2
x4 = 0
x5 = 0
Z ⇒ Máx
3
2
1
x3
x3 = 0
0
1
2
3
x1


x2
x4 = 0
x5 = 0
Z ⇒ Máx
3
2
1
48000
x3
x3 = 0
0
1
2
3
x1

MAX: $Z = 4x_1 + 3x_2$

$$\begin{cases} 6x_1 + 16x_2 \leq 48000 \\ 12x_1 + 6x_2 \leq 42000 \\ 9x_1 + 9x_2 \leq 36000 \end{cases}$$

$$x_1, x_2 \geq 0$$

FORMA MATRICIAL EXTENDIDA

	X_1	X_2	SIGNO	RHS
Z)	4	3	➡	MAX
EST)	6	16	≤	48000
SOL)	12	6	≤	42000
PIN)	9	9	≤	36000
Var.	NN	NN		

MAX: $Z = 4x_1 + 3x_2$

$$\begin{cases} 6x_1 + 16x_2 + x_3 = 48000 \\ 12x_1 + 6x_2 + x_4 = 42000 \\ 9x_1 + 9x_2 + x_5 = 36000 \end{cases}$$

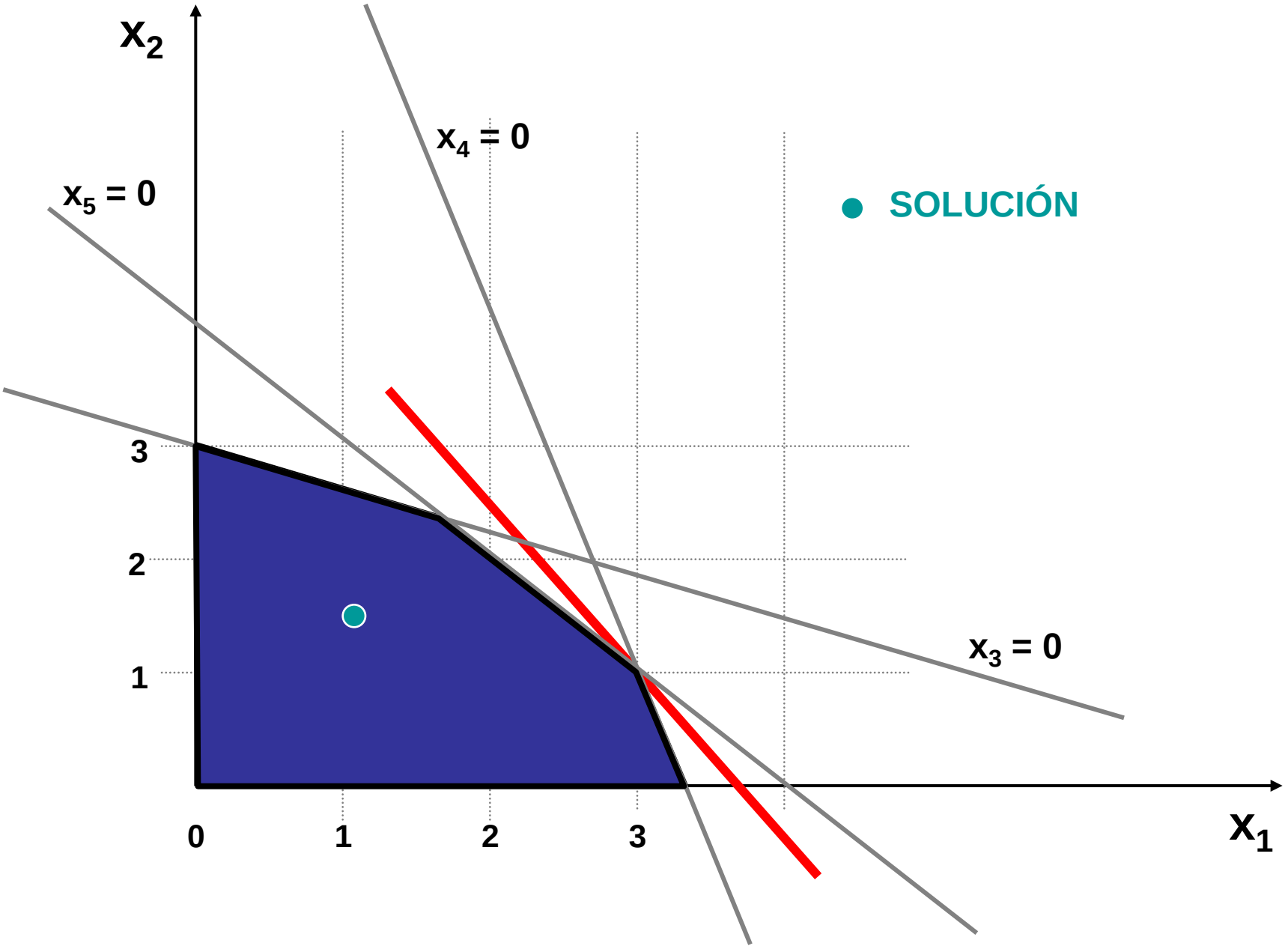
$x_1, x_2, x_3, x_4, x_5 \geq 0$

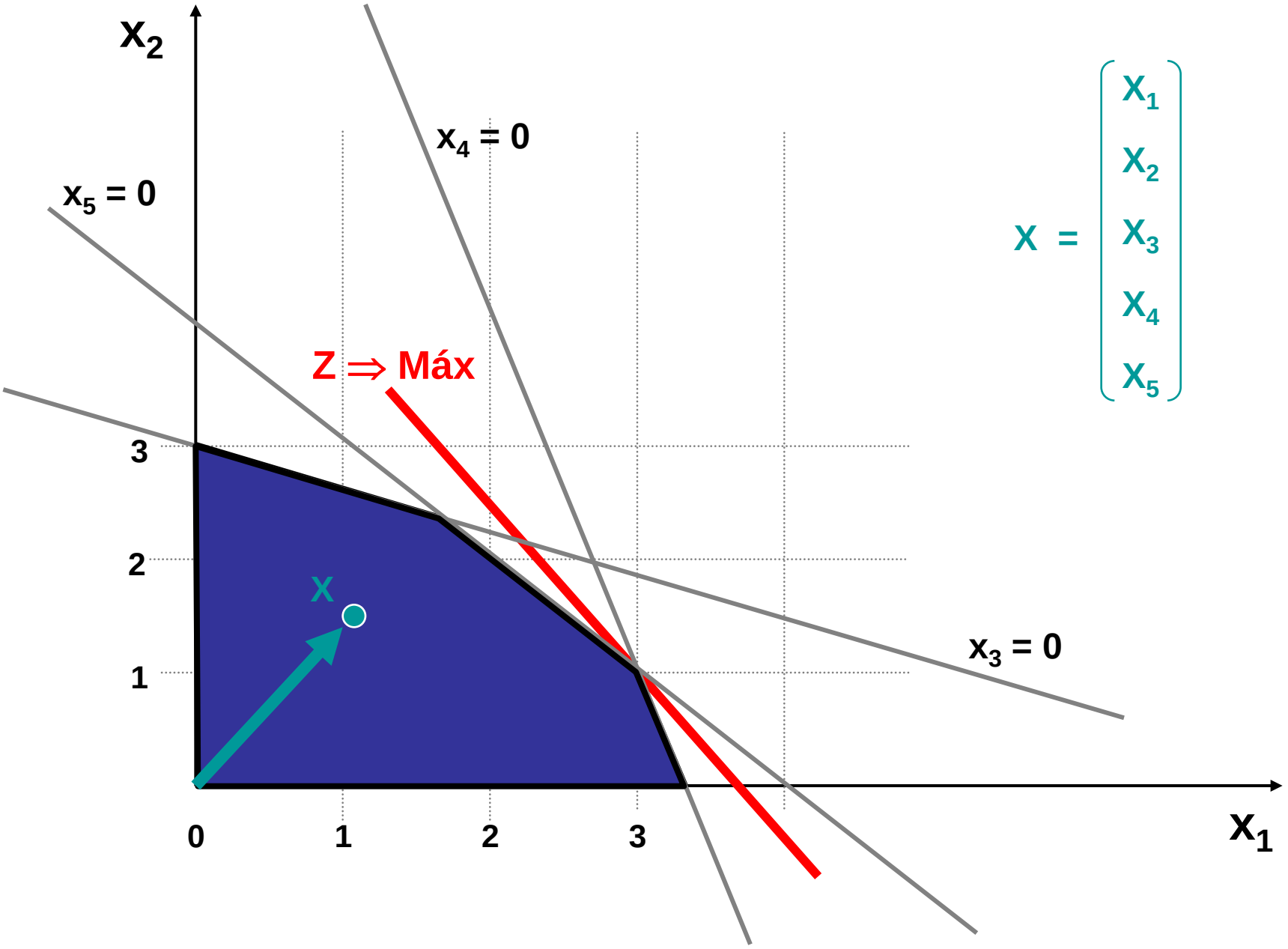
SISTEMA DE ECUACIONES LINEALES

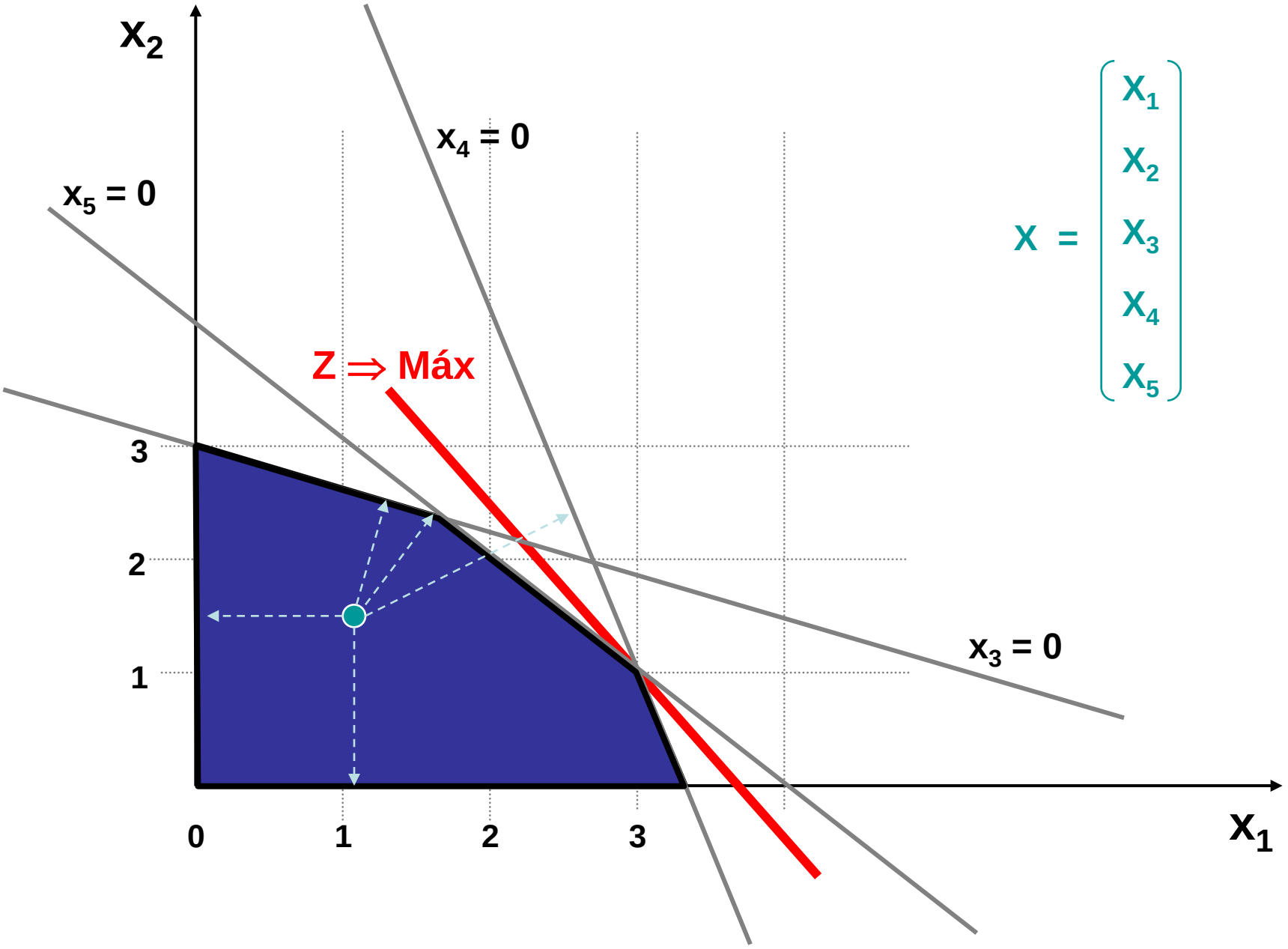
$$\begin{cases} 6x_1 + 16x_2 + x_3 = 48000 \\ 12x_1 + 6x_2 + x_4 = 42000 \\ 9x_1 + 9x_2 + x_5 = 36000 \end{cases}$$

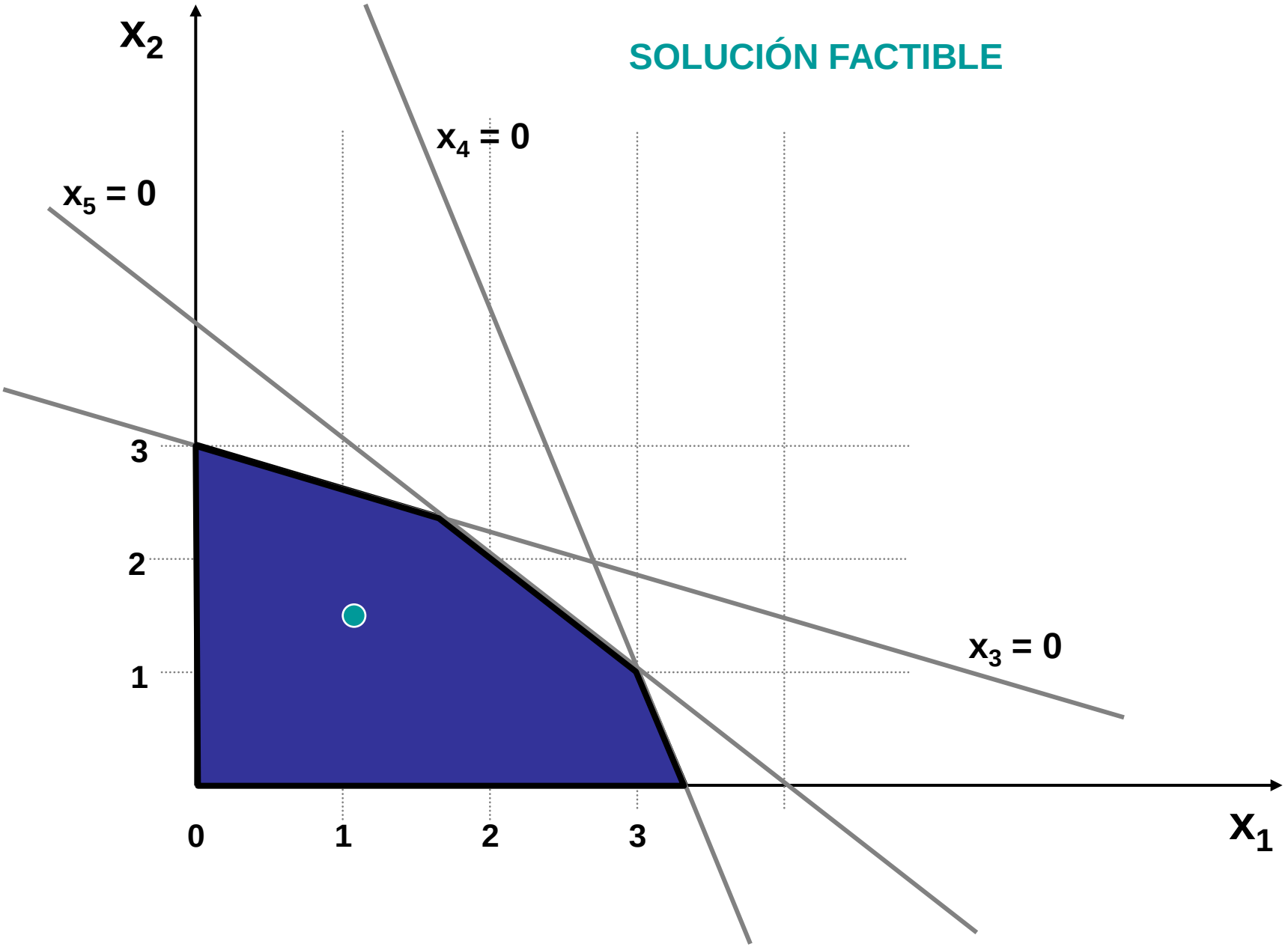
n = número de variables (5)

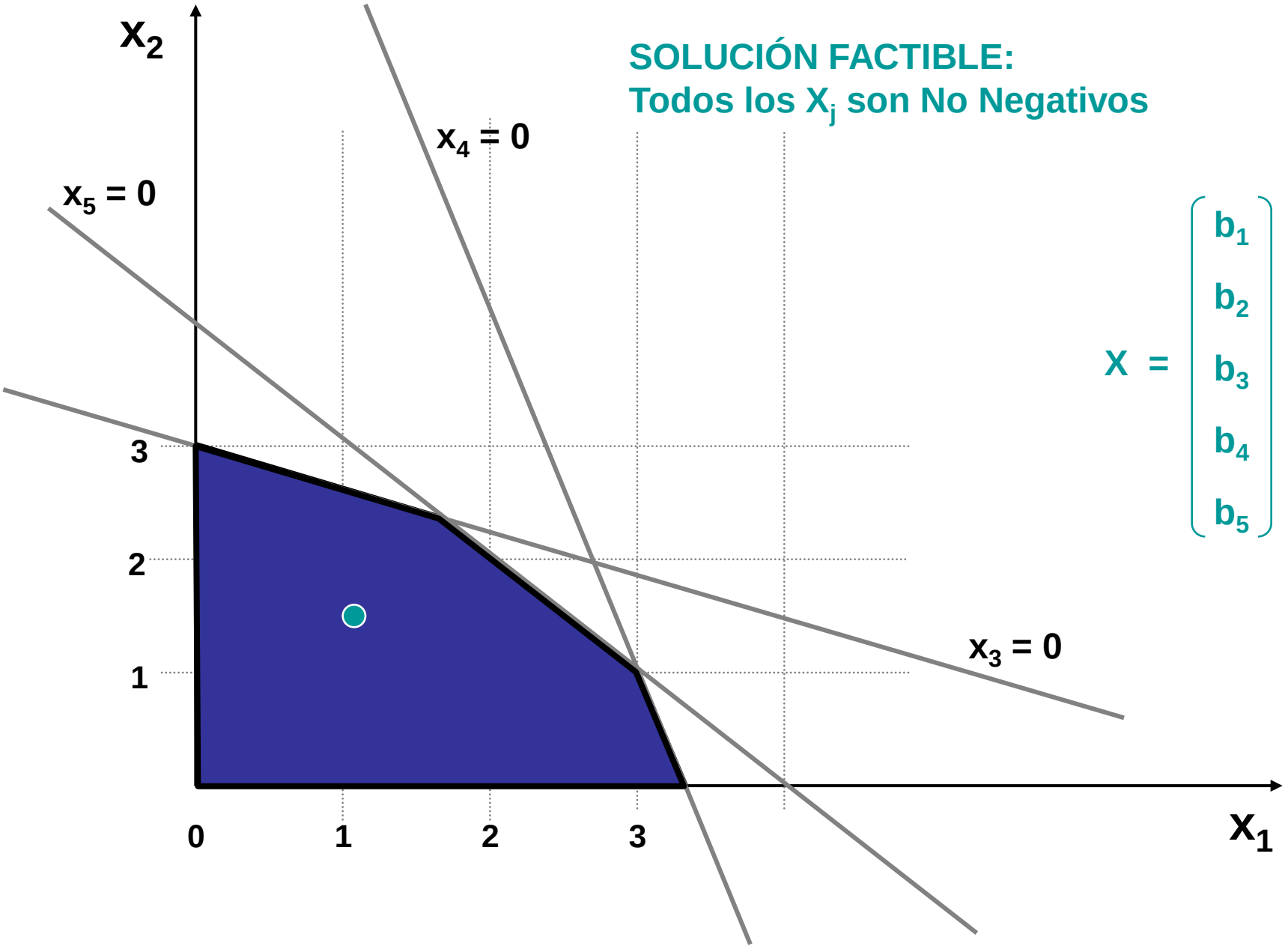
m = número de restricciones (3)

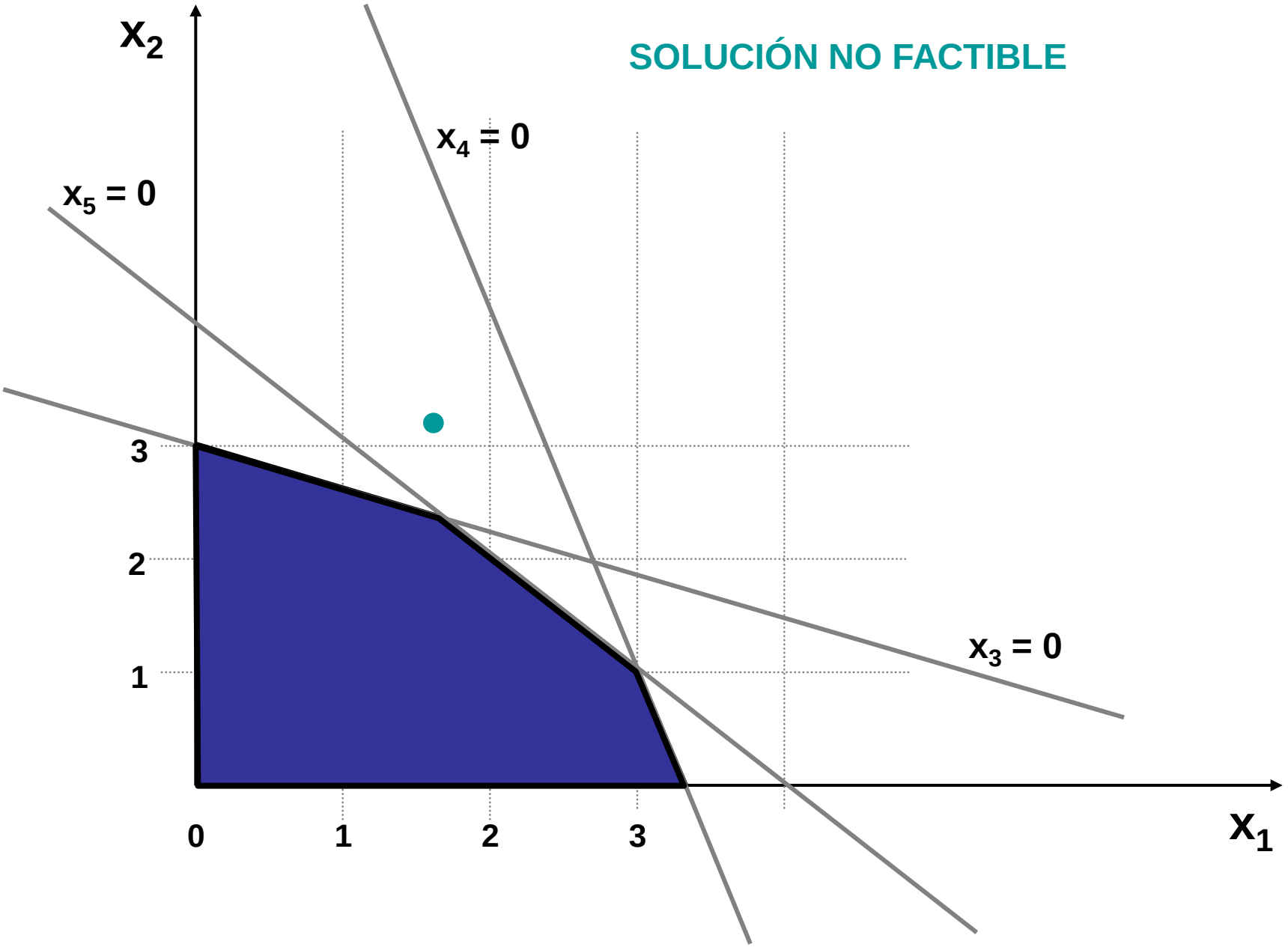

x_2
$x_4 = 0$
$x_5 = 0$
SOLUCIÓN
3
2
1
$x_3 = 0$
0
1
2
3
x_1

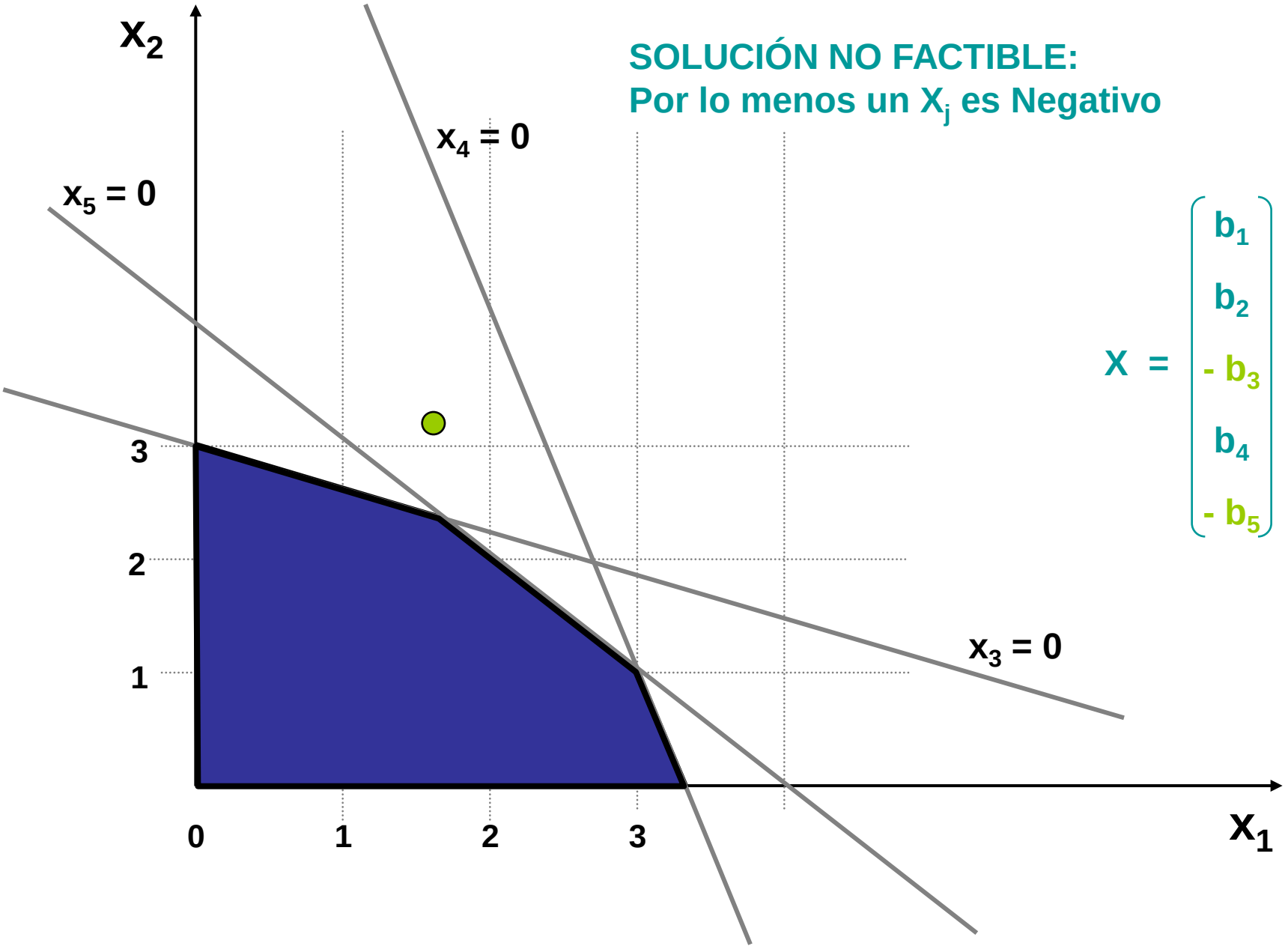

x_2
$x_4 = 0$
$x_5 = 0$
$Z \Rightarrow$ Máx
$X = \begin{pmatrix} X_1 \\ X_2 \\ X_3 \\ X_4 \\ X_5 \end{pmatrix}$
3
2
1
X
$x_3 = 0$
0
1
2
3
x_1

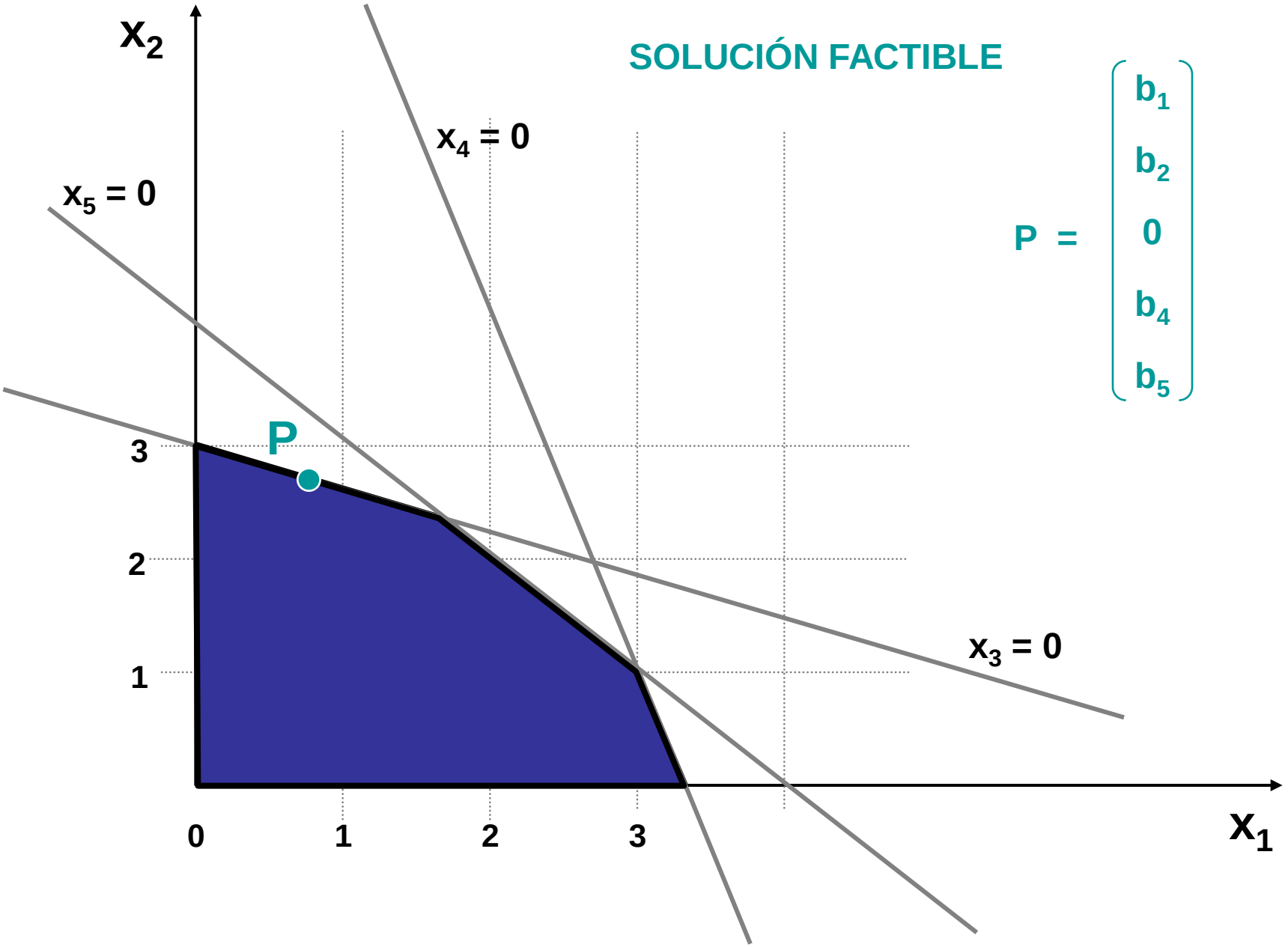

x2
x4 = 0
x5 = 0
Z ⇒ Máx
X = X1 X2 X3 X4 X5
3
2
1
0
1
2
3
x3 = 0
x1

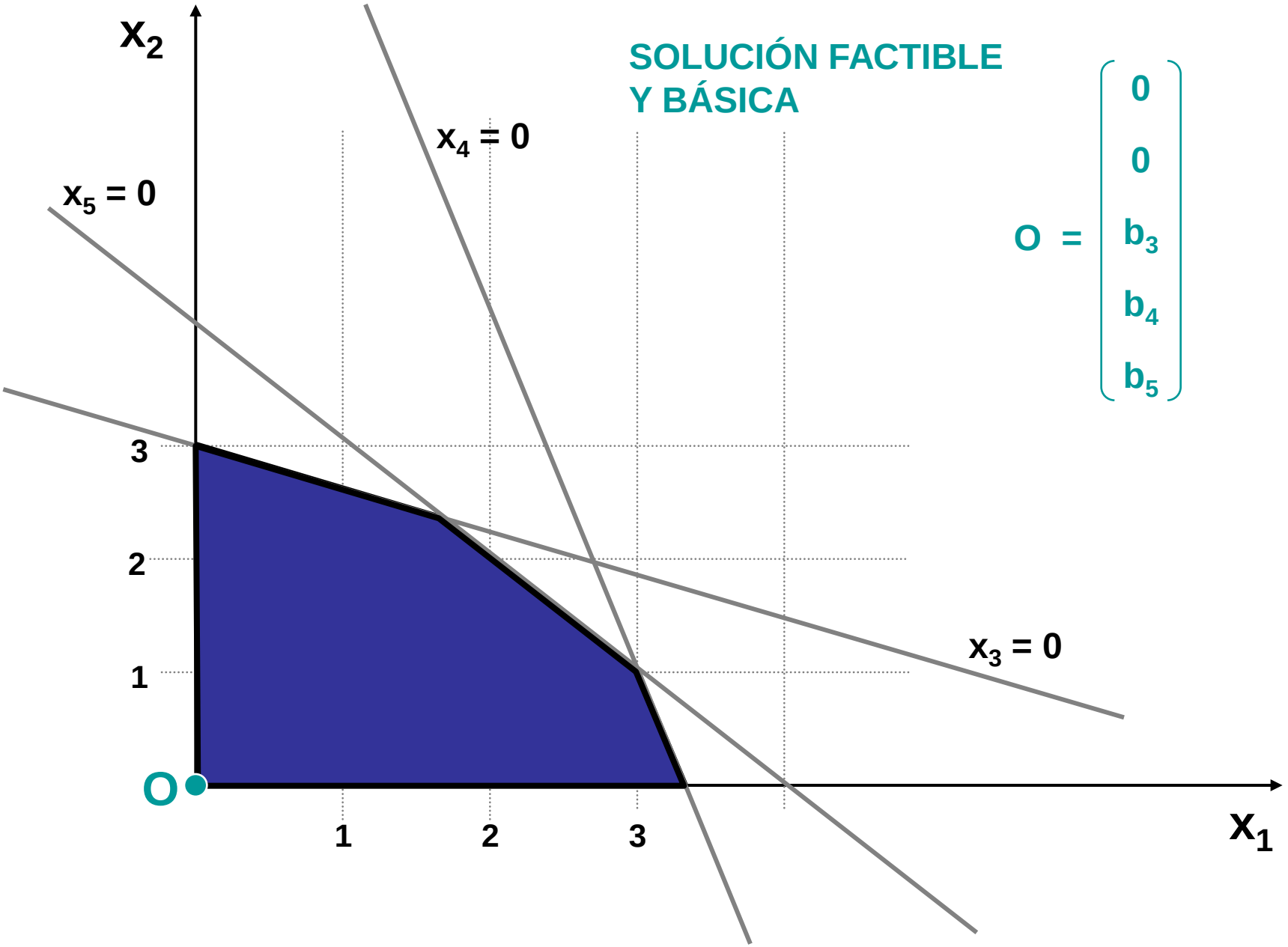

SOLUCIÓN FACTIBLE
x2
x4 = 0
x5 = 0
x3 = 0
3
2
1
0
1
2
3
x1

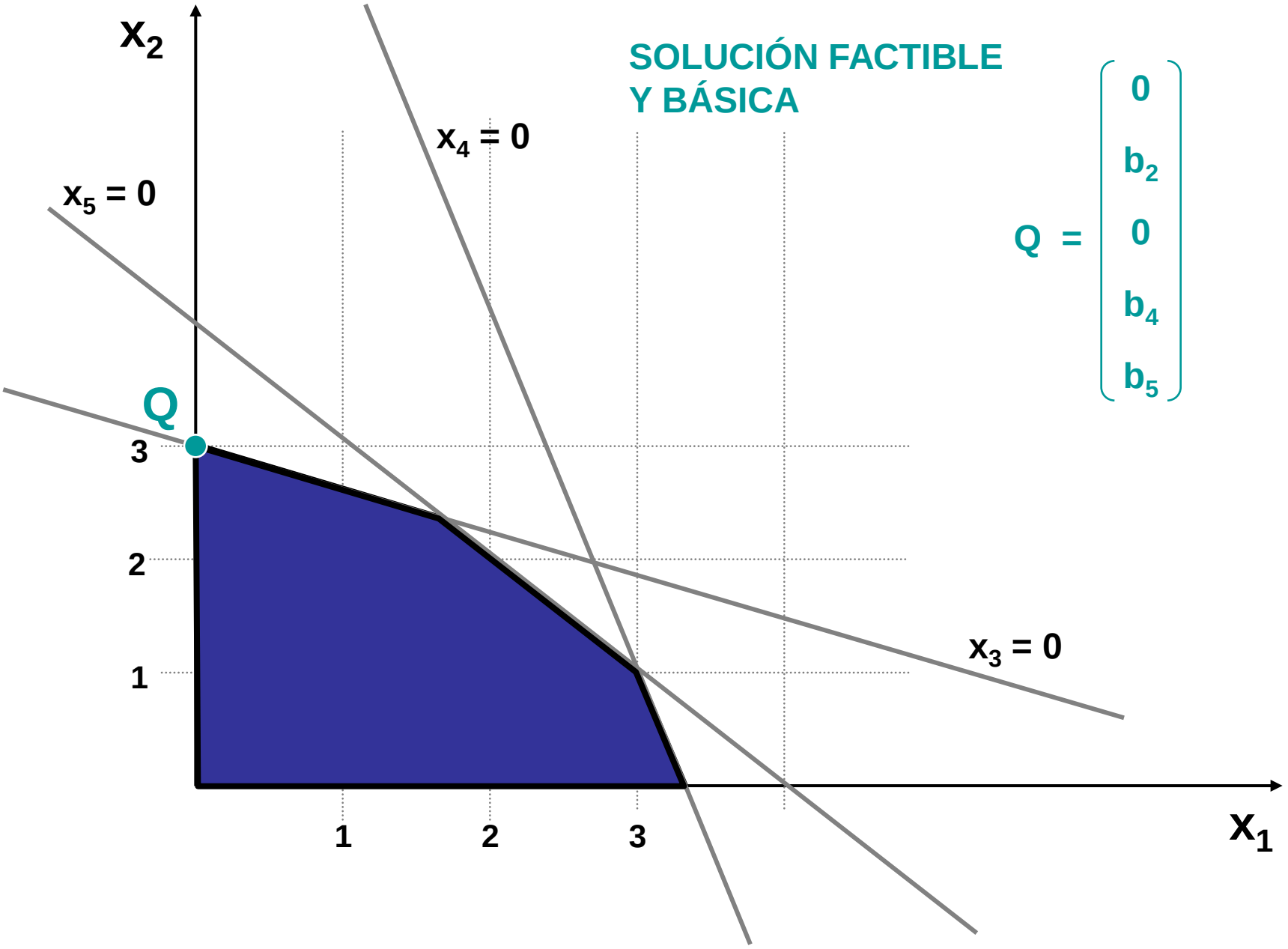

SOLUCIÓN FACTIBLE:
Todos los X_j son No Negativos
$X = \begin{pmatrix} b_1 \\ b_2 \\ b_3 \\ b_4 \\ b_5 \end{pmatrix}$
x_2
x_1
$x_4 = 0$
$x_5 = 0$
$x_3 = 0$
0
1
2
3
1
2
3

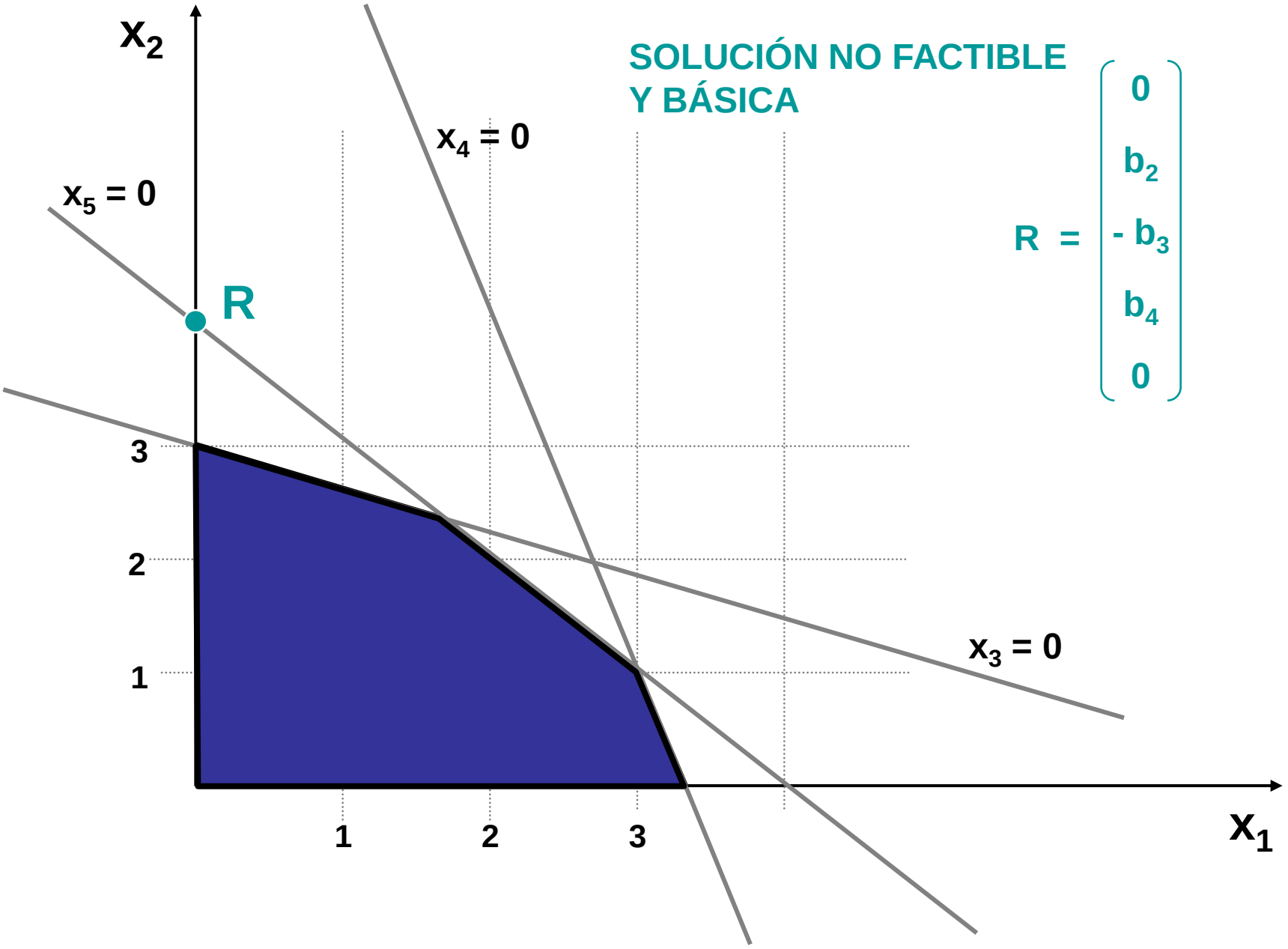

SOLUCIÓN NO FACTIBLE
x_2
$x_4 = 0$
$x_5 = 0$
$x_3 = 0$
3
2
1
0
1
2
3
x_1


SOLUCIÓN NO FACTIBLE:
Por lo menos un X_j es Negativo
X_2
$x_4 = 0$
$x_5 = 0$
$x_3 = 0$
3
2
1
0
1
2
3
X_1
$X = \begin{pmatrix} b_1 \\ b_2 \\ - b_3 \\ b_4 \\ - b_5 \end{pmatrix}$


SOLUCIÓN FACTIBLE
P = b1 b2 0 b4 b5
x2
x1
x4 = 0
x5 = 0
x3 = 0
P
0
1
2
3
1
2
3


SOLUCIÓN FACTIBLE
Y BÁSICA
O = 0 0 b3 b4 b5
x2
x1
x4 = 0
x5 = 0
x3 = 0
O
1
2
3
1
2
3

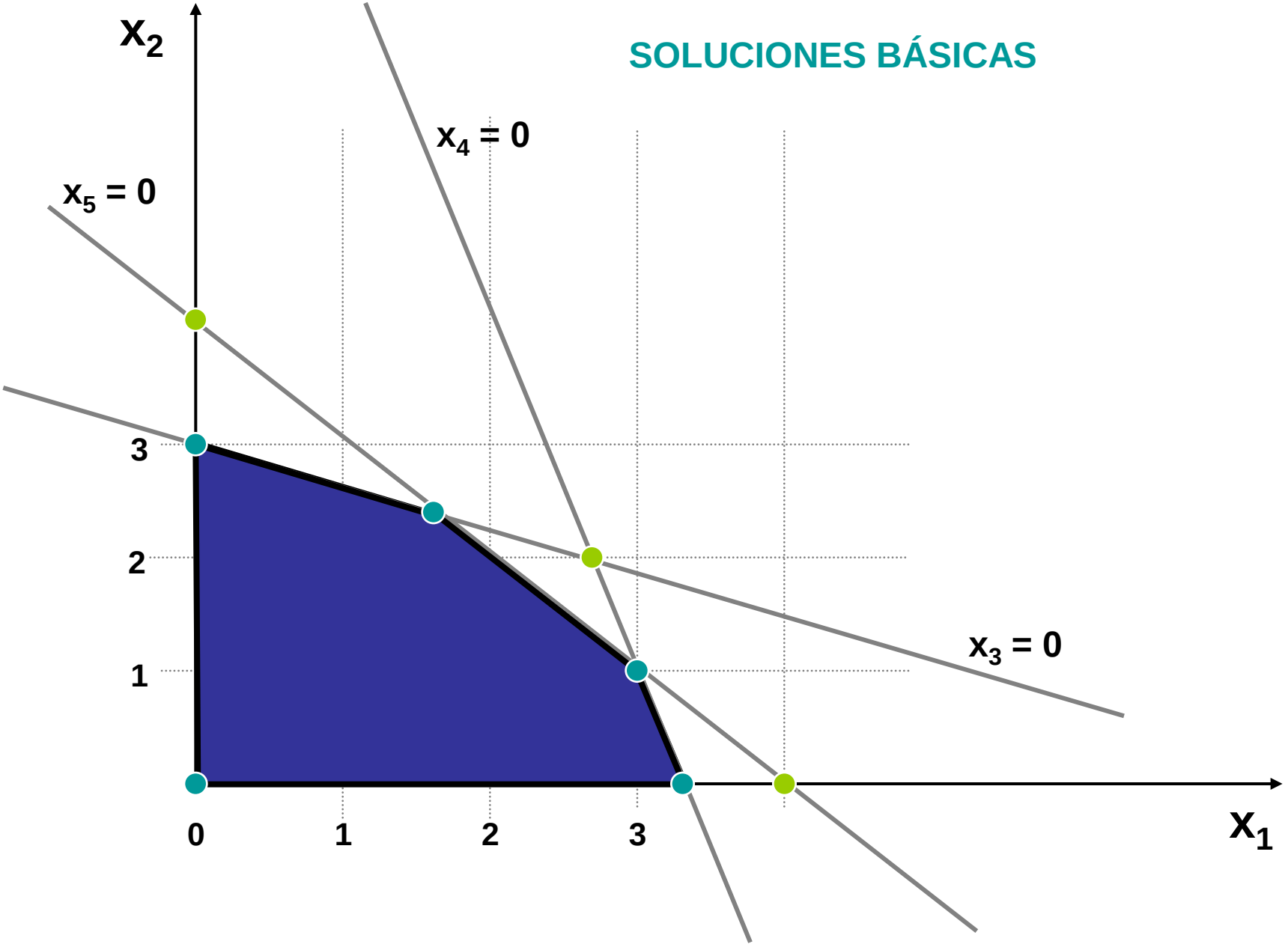

SOLUCIÓN FACTIBLE
Y BÁSICA
Q = 0 b2 0 b4 b5
x2
x1
x4 = 0
x5 = 0
x3 = 0
Q
1
2
3
1
2
3



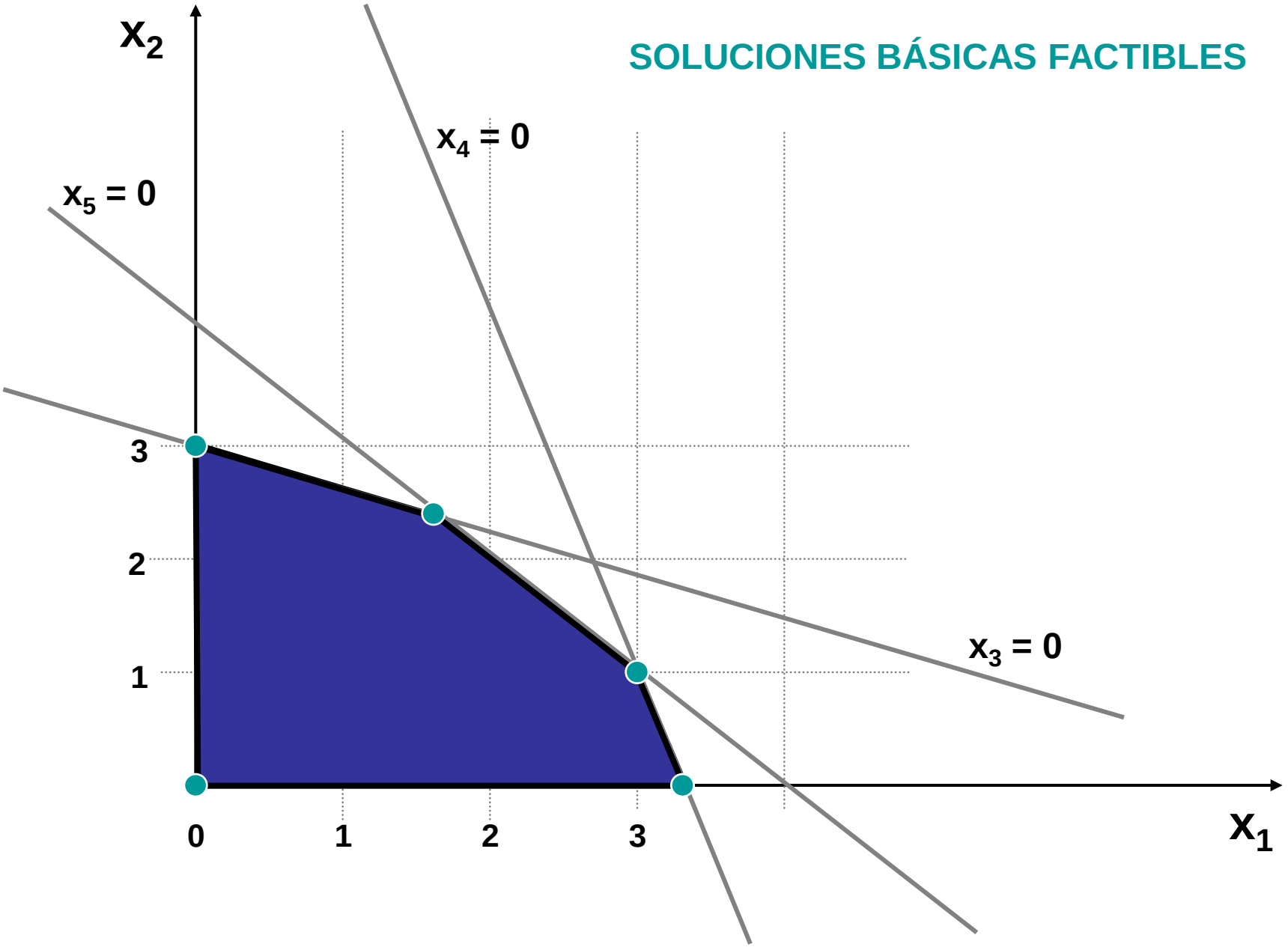
SOLUCIÓN NO FACTIBLE Y BÁSICA

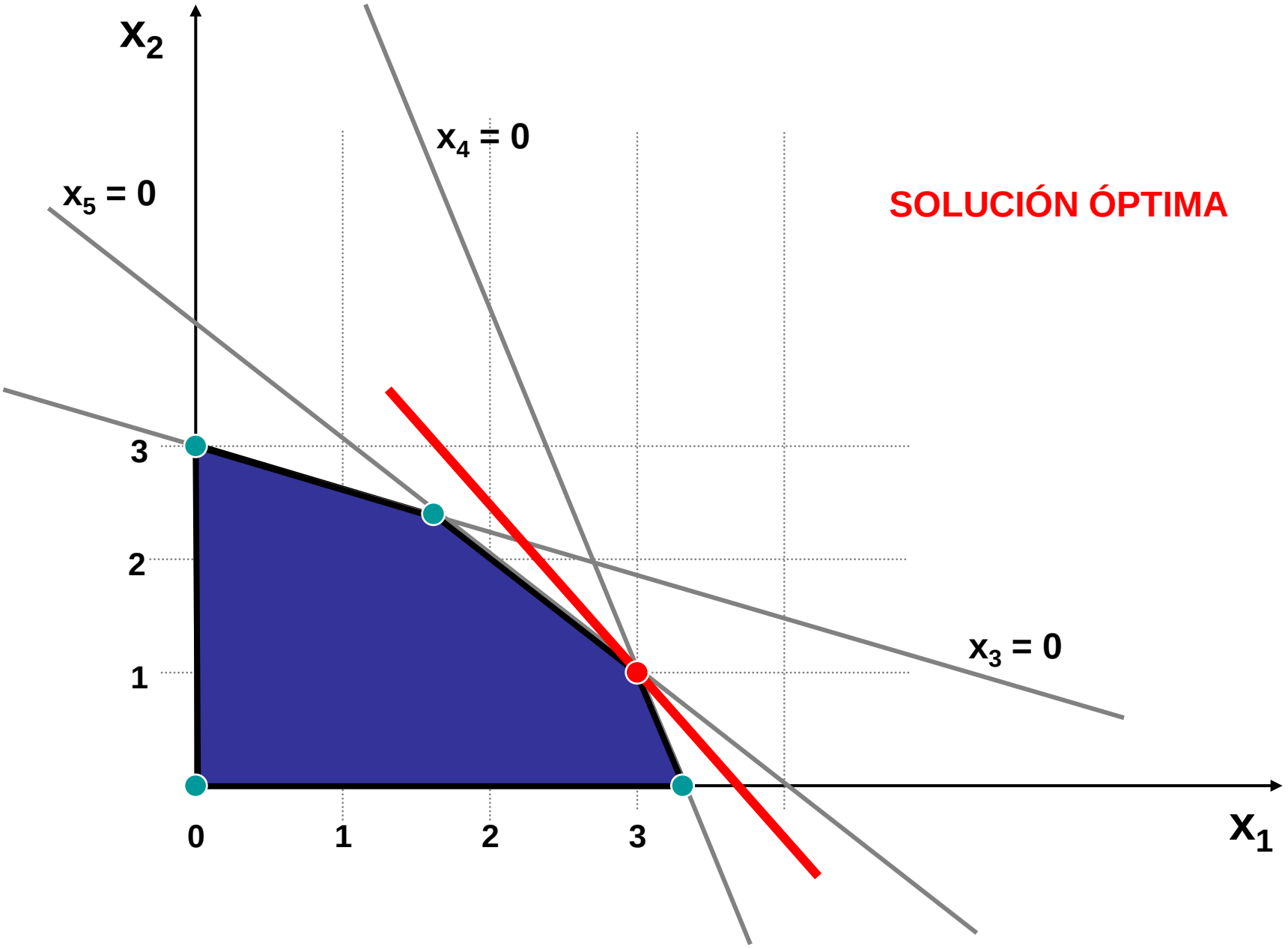
$$R = \begin{pmatrix} 0 \\ b_2 \\ -b_3 \\ b_4 \\ 0 \end{pmatrix}$$

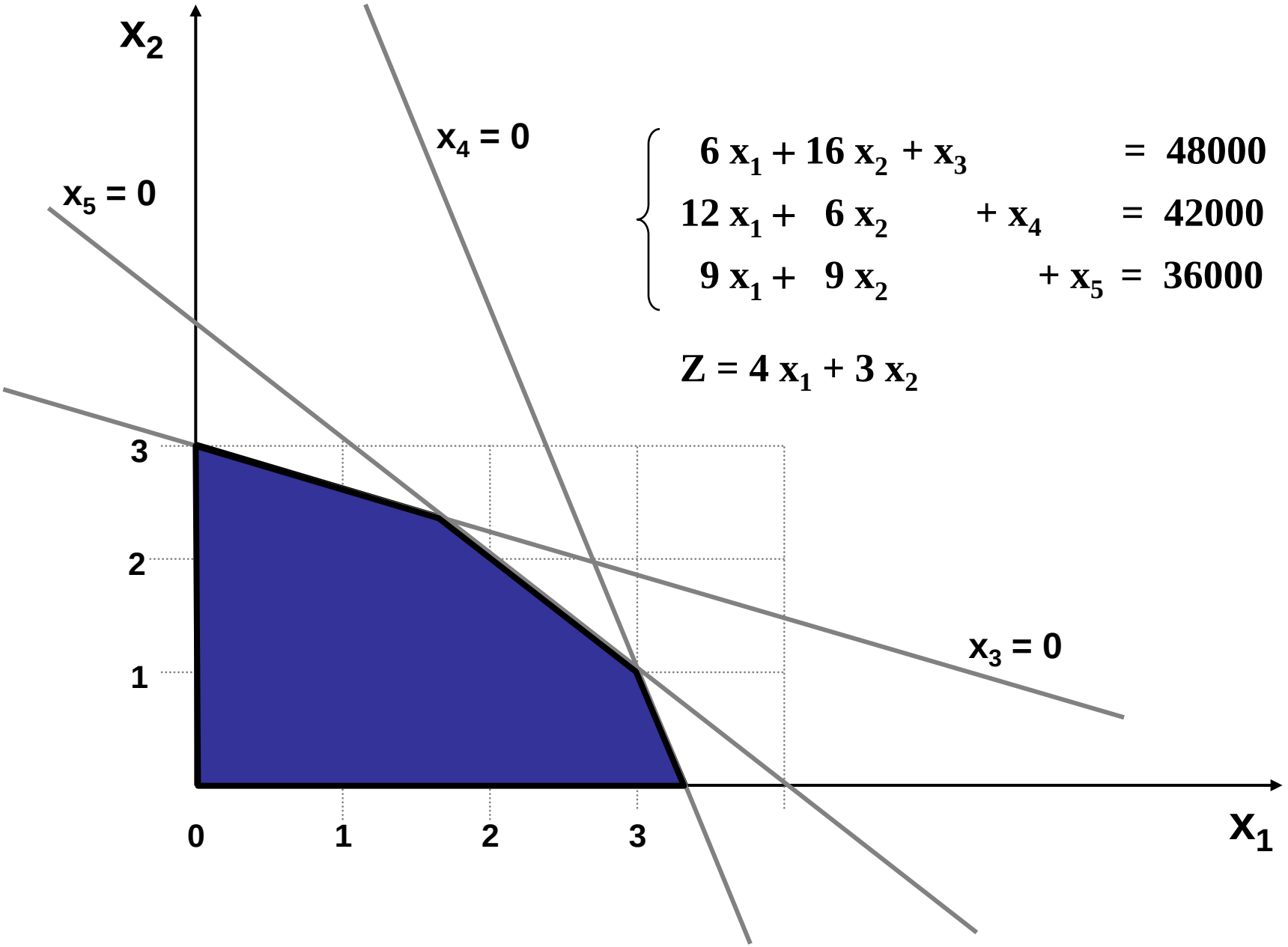
SOLUCIONES BÁSICAS



SOLUCIONES BÁSICAS FACTIBLES




x_2
$x_4 = 0$
$x_5 = 0$
SOLUCIÓN ÓPTIMA
3
2
1
$x_3 = 0$
0
1
2
3
x_1



$$\begin{cases} 6\,x_1 + 16\,x_2 + x_3 = 48000 \\ 12\,x_1 + 6\,x_2 + x_4 = 42000 \\ 9\,x_1 + 9\,x_2 + x_5 = 36000 \end{cases}$$

$$Z = 4\,x_1 + 3\,x_2$$

$$\begin{cases} 6x_1 + 16x_2 + x_3 = 48000 \\ 12x_1 + 6x_2 + x_4 = 42000 \\ 9x_1 + 9x_2 + x_5 = 36000 \end{cases}$$

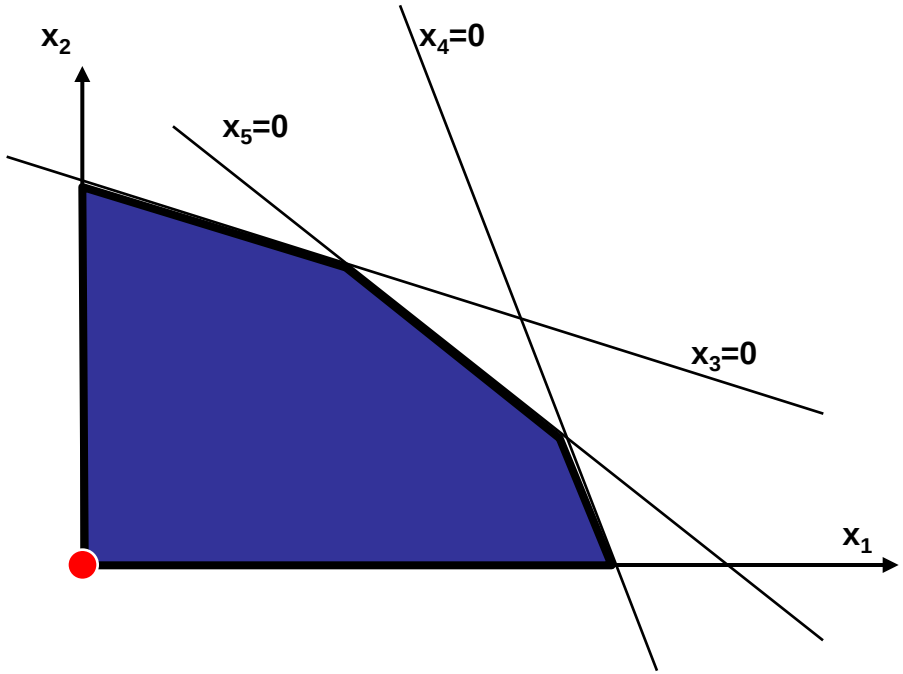
$$X = \begin{pmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \\ x_5 \end{pmatrix} \qquad Z = 4x_1 + 3x_2$$

$$\begin{cases} x_3 = 48000 \\ x_4 = 42000 \\ x_5 = 36000 \end{cases}$$

$$X = \begin{pmatrix} 0 \\ 0 \\ 48000 \\ 42000 \\ 36000 \end{pmatrix} \qquad Z = 0$$

$$\begin{cases} x_3 = 48000 \\ x_4 = 42000 \\ x_5 = 36000 \end{cases}$$

$$X = \begin{pmatrix} 0 \\ 0 \\ 48000 \\ 42000 \\ 36000 \end{pmatrix} \qquad Z = 0$$



$$\begin{cases} 6x_1 + 16x_2 + x_3 = 48000 \\ 12x_1 + 6x_2 + x_4 = 42000 \\ 9x_1 + 9x_2 + x_5 = 36000 \end{cases}$$

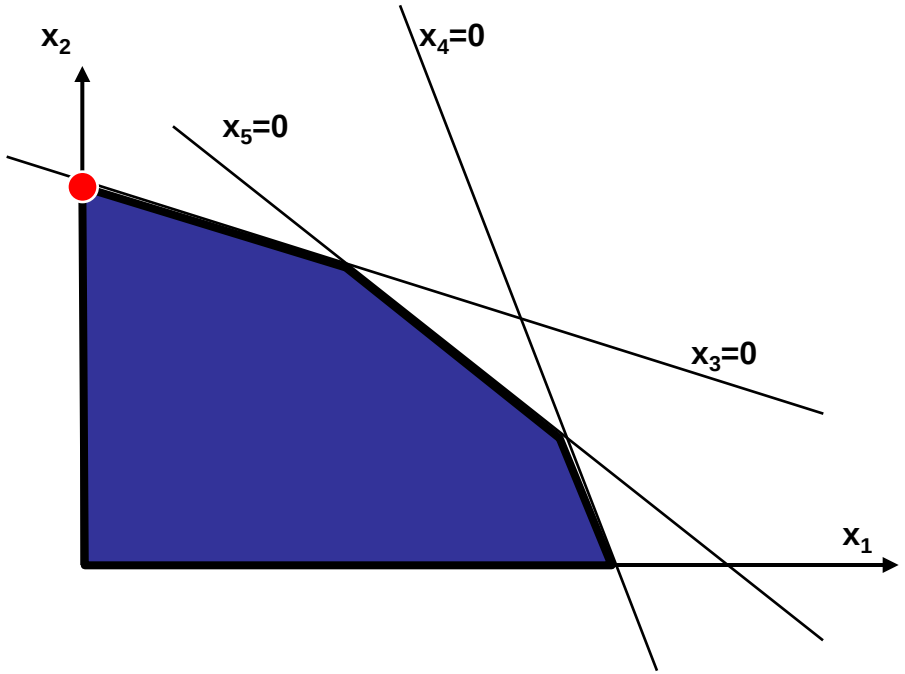
$$X = \begin{pmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \\ x_5 \end{pmatrix} \qquad Z = 4x_1 + 3x_2$$

$$\begin{cases} 16\,x_2 = 48000 \\ 6\,x_2 + x_4 = 42000 \\ 9\,x_2 + x_5 = 36000 \end{cases}$$

$$X = \begin{pmatrix} 0 \\ 3000 \\ 0 \\ 24000 \\ 9000 \end{pmatrix} \qquad Z = 9000$$

$$\begin{cases} 16\,x_2 = 48000 \\ 6\,x_2 + x_4 = 42000 \\ 9\,x_2 + x_5 = 36000 \end{cases}$$

$$X = \begin{pmatrix} 0 \\ 3000 \\ 0 \\ 24000 \\ 9000 \end{pmatrix} \qquad Z = 9000$$



$$\begin{cases} 6x_1 + 16x_2 + x_3 = 48000 \\ 12x_1 + 6x_2 + x_4 = 42000 \\ 9x_1 + 9x_2 + x_5 = 36000 \end{cases}$$

$$X = \begin{pmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \\ x_5 \end{pmatrix} \qquad Z = 4x_1 + 3x_2$$

$$\begin{cases} 6\,x_1 + x_3 = 48000 \\ 12\,x_1 + x_4 = 42000 \\ 9\,x_1 = 36000 \end{cases}$$

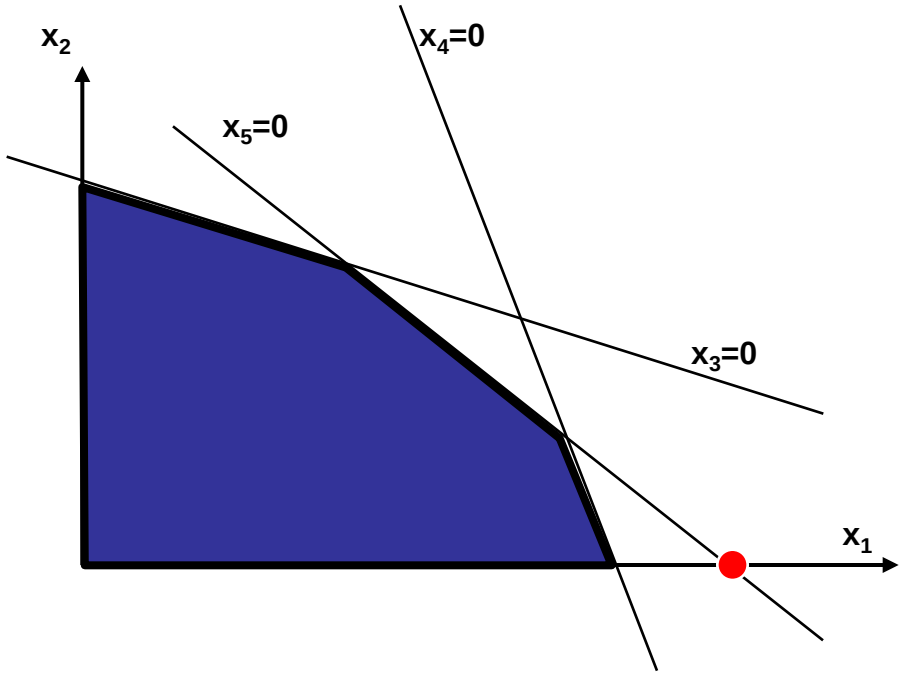
$$X = \begin{pmatrix} 4000 \\ 0 \\ 24000 \\ -6000 \\ 0 \end{pmatrix}$$

NO FACTIBLE

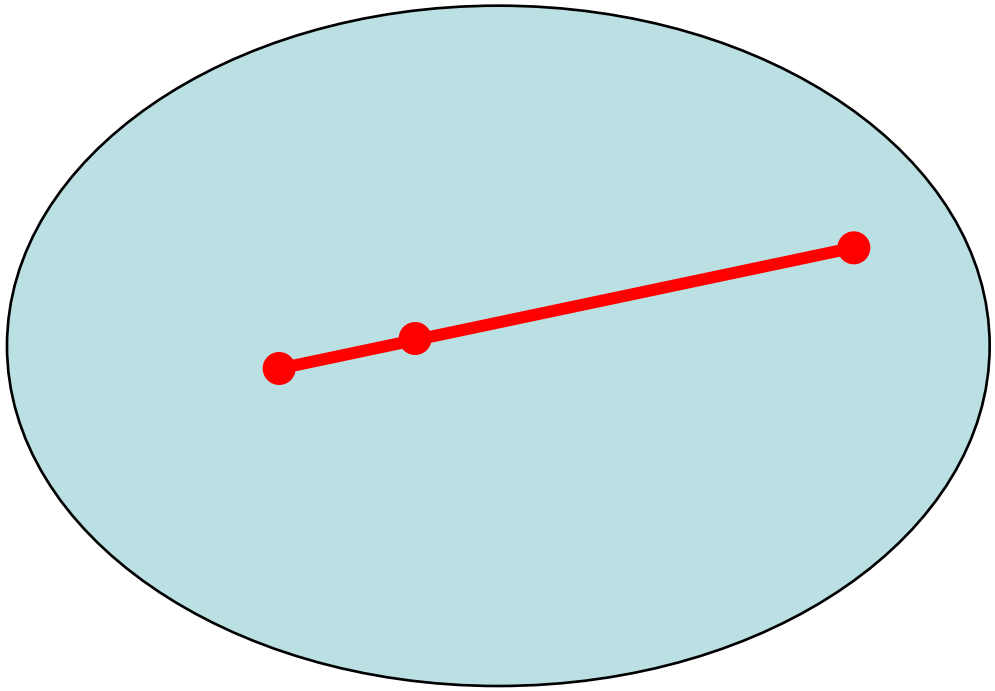
$$\begin{cases} 6\,x_1 + x_3 = 48000 \\ 12\,x_1 + x_4 = 42000 \\ 9\,x_1 = 36000 \end{cases}$$

$$X = \begin{pmatrix} 4000 \\ 0 \\ 24000 \\ -6000 \\ 0 \end{pmatrix}$$

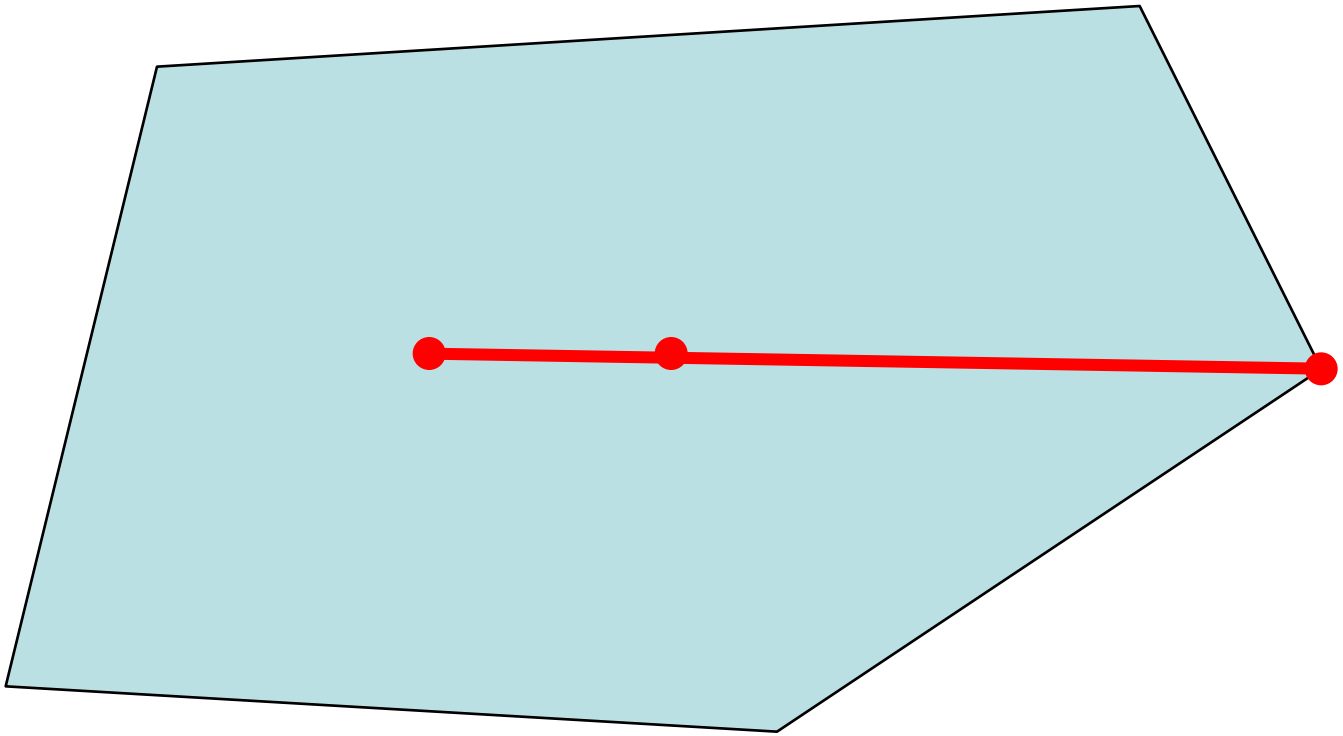
NO FACTIBLE



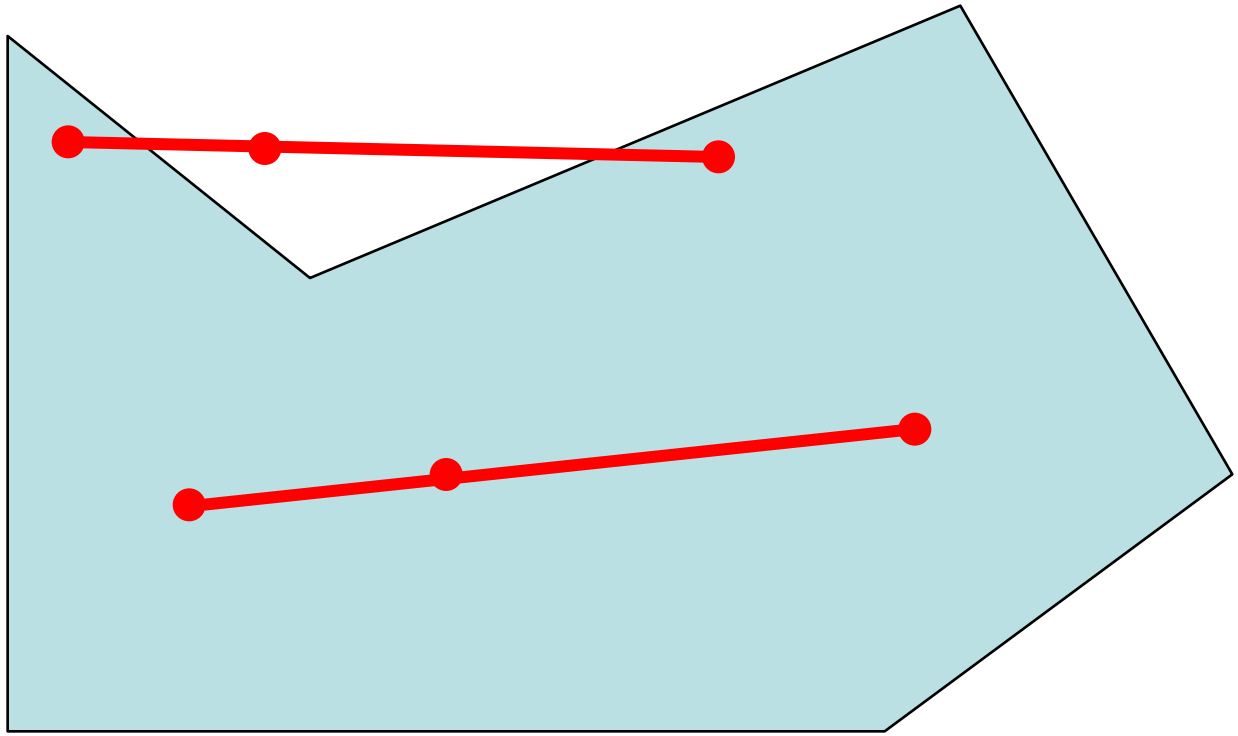
CONJUNTO CONVEXO



CONJUNTO CONVEXO



CONJUNTO NO CONVEXO



CONJUNTO NO CONVEXO