## Miller-Tucker-Zemlin (1960)

min  $\sum \sum c_{ij}x_{ij}$ 

 $\sum x_{ij} = 1$ 

 $1 < u_i < n - 1$ 

 $i=0, i\neq i$ 

 $u_0 = 0$ 

with constraints around origin

Desrochers-Laporte (1991)

$$\sum_{i=0, i \neq j}^{n-1} x_{ij} = 1 \qquad j = 0, \dots, n-1$$

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min  $\sum \sum c_{ij}x_{ij}$ 

$$j = 0, \dots, n-1$$

$$< n-2$$
  $1 < i \neq j < n-1$ 

$$\sum_{j=0, \ j \neq i}^{n-1} x_{ij} = 1$$

$$=0,\ldots,n-1$$

$$u_i - u_j + (n-1) x_{ij} \le n - 2$$

$$1 \le i \ne j \le n$$

$$x_{ij} \in \{0, 1\}$$

$$0 \le i \ne j \le n$$

$$j=0, j\neq i$$
 
$$u_i-u_j-1$$

 $i = 0, \dots, n-1$ 

$$0 \le i \ne j \le n$$

i = 0, ..., n-1

 $2 - x_{0i} + (n-3) x_{i0} \leq u_i$ 

 $u_i \leq n-2+x_{i0}-(n-3)x_{0i}$ 

$$=0,\ldots,n-1$$

$$0 \le i \neq j \le n - i = 1, \dots, n - 1$$

$$u_i - u_j + (n-1) x_{ij} + (n-3) x_{ji} \le n-2$$

$$0 \le i \ne j \le n - 1$$

$$(n-1) x_{ij} + (n-3) x_{ji}$$

$$x_{ii} \leq$$

$$\begin{cases} n-2 \\ \leq i \neq j \leq n \end{cases}$$

 $0 < i \neq j < n-1$ 

i = 1, ..., n-1

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$$(x_{ji} \leq$$

$$< n - 1$$

$$u_i - u_j + (n-1)$$
:

 $x_{ii} \in \{0,1\}$ 

 $u_0 = 0$ 

$$1 \le i \ne j \le n - 1$$

$$3) x_{ji} \leq$$

$$i < n - 1$$

$$1) x_{ij} + (n-3) x_{ji}$$

$$n = 2$$

$$) x_{ji} \leq n-2$$