

Test VRPTW

July 6, 2023

1 TWVRP: Problema de enrutamiento de vehículos con ventanas temporales.

Antes que nada, se crea dentro de cualquier directorio un entorno virtual python con `mkvirtualenv JoseAndres -p python3`. El kernel JoseAndres va sin ningun paquete que debeos ir cargando con `pip`. Tambien se puede hacer en anaconda pero yo no lo utilizo.

1. Se instalan los packages necesarios dentro del virtual environment creado con `mkvirtualenv JoseAndres -p python3`

```
[ ]: %pip install --upgrade pip
      %pip install gurobipy
      %pip install numpy
      %pip install matplotlib
      %pip install nbconvert
      %pip install jupyter_contrib_nbextensions
```

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Requirement already satisfied: pip in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (23.1.2)
Note: you may need to restart the kernel to use updated packages.
Requirement already satisfied: gurobipy in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (10.0.2)
Note: you may need to restart the kernel to use updated packages.
Requirement already satisfied: numpy in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (1.25.0)
Note: you may need to restart the kernel to use updated packages.
Requirement already satisfied: matplotlib in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (3.7.2)
Requirement already satisfied: contourpy>=1.0.1 in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from
matplotlib) (1.1.0)
Requirement already satisfied: cyclor>=0.10 in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from
matplotlib) (0.11.0)
Requirement already satisfied: fonttools>=4.22.0 in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from
matplotlib) (4.40.0)
Requirement already satisfied: kiwisolver>=1.0.1 in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from
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matplotlib) (1.4.4)
Requirement already satisfied: numpy>=1.20 in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from
matplotlib) (1.25.0)
Requirement already satisfied: packaging>=20.0 in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from
matplotlib) (23.1)
Requirement already satisfied: pillow>=6.2.0 in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from
matplotlib) (10.0.0)
Requirement already satisfied: pyparsing<3.1,>=2.3.1 in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from
matplotlib) (3.0.9)
Requirement already satisfied: python-dateutil>=2.7 in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from
matplotlib) (2.8.2)
Requirement already satisfied: six>=1.5 in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from python-
dateutil>=2.7->matplotlib) (1.16.0)
Note: you may need to restart the kernel to use updated packages.
Requirement already satisfied: nbconvert in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (7.6.0)
Requirement already satisfied: beautifulsoup4 in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from nbconvert)
(4.12.2)
Requirement already satisfied: bleach!=5.0.0 in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from nbconvert)
(6.0.0)
Requirement already satisfied: defusedxml in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from nbconvert)
(0.7.1)
Requirement already satisfied: jinja2>=3.0 in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from nbconvert)
(3.1.2)
Requirement already satisfied: jupyter-core>=4.7 in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from nbconvert)
(5.3.1)
Requirement already satisfied: jupyterlab-pygments in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from nbconvert)
(0.2.2)
Requirement already satisfied: markupsafe>=2.0 in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from nbconvert)
(2.1.3)
Requirement already satisfied: mistune<4,>=2.0.3 in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from nbconvert)
(3.0.1)
Requirement already satisfied: nbclient>=0.5.0 in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from nbconvert)

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(0.8.0)
Requirement already satisfied: nbformat>=5.7 in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from nbconvert)
(5.9.0)
Requirement already satisfied: packaging in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from nbconvert)
(23.1)
Requirement already satisfied: pandocfilters>=1.4.1 in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from nbconvert)
(1.5.0)
Requirement already satisfied: pygments>=2.4.1 in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from nbconvert)
(2.15.1)
Requirement already satisfied: tinycss2 in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from nbconvert)
(1.2.1)
Requirement already satisfied: traitlets>=5.1 in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from nbconvert)
(5.9.0)
Requirement already satisfied: six>=1.9.0 in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from
bleach!=5.0.0->nbconvert) (1.16.0)
Requirement already satisfied: webencodings in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from
bleach!=5.0.0->nbconvert) (0.5.1)
Requirement already satisfied: platformdirs>=2.5 in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from jupyter-
core>=4.7->nbconvert) (3.8.0)
Requirement already satisfied: jupyter-client>=6.1.12 in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from
nbclient>=0.5.0->nbconvert) (7.4.9)
Requirement already satisfied: fastjsonschema in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from
nbformat>=5.7->nbconvert) (2.17.1)
Requirement already satisfied: jsonschema>=2.6 in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from
nbformat>=5.7->nbconvert) (4.18.0)
Requirement already satisfied: soupsieve>1.2 in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from
beautifulsoup4->nbconvert) (2.4.1)
Requirement already satisfied: attrs>=22.2.0 in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from
jsonschema>=2.6->nbformat>=5.7->nbconvert) (23.1.0)
Requirement already satisfied: jsonschema-specifications>=2023.03.6 in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from
jsonschema>=2.6->nbformat>=5.7->nbconvert) (2023.6.1)
Requirement already satisfied: referencing>=0.28.4 in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from

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jsonschema>=2.6->nbformat>=5.7->nbconvert) (0.29.1)
Requirement already satisfied: rpds-py>=0.7.1 in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from
jsonschema>=2.6->nbformat>=5.7->nbconvert) (0.8.6)
Requirement already satisfied: entrypoints in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from jupyter-
client>=6.1.12->nbclient>=0.5.0->nbconvert) (0.4)
Requirement already satisfied: nest-asyncio>=1.5.4 in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from jupyter-
client>=6.1.12->nbclient>=0.5.0->nbconvert) (1.5.6)
Requirement already satisfied: python-dateutil>=2.8.2 in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from jupyter-
client>=6.1.12->nbclient>=0.5.0->nbconvert) (2.8.2)
Requirement already satisfied: pyzmq>=23.0 in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from jupyter-
client>=6.1.12->nbclient>=0.5.0->nbconvert) (24.0.1)
Requirement already satisfied: tornado>=6.2 in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from jupyter-
client>=6.1.12->nbclient>=0.5.0->nbconvert) (6.3.2)
Note: you may need to restart the kernel to use updated packages.
Collecting jupyter_contrib_nbextensions
  Using cached jupyter_contrib_nbextensions-0.7.0.tar.gz (23.5 MB)
  Preparing metadata (setup.py) ... done
Requirement already satisfied: ipython_genutils in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from
jupyter_contrib_nbextensions) (0.2.0)
Collecting jupyter_contrib_core>=0.3.3 (from jupyter_contrib_nbextensions)
  Using cached jupyter_contrib_core-0.4.2.tar.gz (17 kB)
  Preparing metadata (setup.py) ... done
Requirement already satisfied: jupyter_core in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from
jupyter_contrib_nbextensions) (5.3.1)
Collecting jupyter_highlight_selected_word>=0.1.1 (from
jupyter_contrib_nbextensions)
  Using cached jupyter_highlight_selected_word-0.2.0-py2.py3-none-any.whl (11
kB)
Collecting jupyter_nbextensions_configurator>=0.4.0 (from
jupyter_contrib_nbextensions)
  Downloading jupyter_nbextensions_configurator-0.6.3-py2.py3-none-any.whl (466
kB)

466.9/466.9

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Requirement already satisfied: nbconvert>=6.0 in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from
jupyter_contrib_nbextensions) (7.6.0)
Requirement already satisfied: notebook>=6.0 in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from

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jupyter_contrib_nbextensions) (6.5.4)
Requirement already satisfied: tornado in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from
jupyter_contrib_nbextensions) (6.3.2)
Requirement already satisfied: traitlets>=4.1 in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from
jupyter_contrib_nbextensions) (5.9.0)
Collecting lxml (from jupyter_contrib_nbextensions)
  Downloading lxml-4.9.3-cp310-cp310-manylinux_2_28_x86_64.whl (7.9 MB)
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55.7 MB/s eta 0:00:00a 0:00:01
Requirement already satisfied: setuptools in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from
jupyter_contrib_core>=0.3.3->jupyter_contrib_nbextensions) (67.4.0)
Requirement already satisfied: pyyaml in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from
jupyter_nbextensions_configurator>=0.4.0->jupyter_contrib_nbextensions) (6.0)
Requirement already satisfied: beautifulsoup4 in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from
nbconvert>=6.0->jupyter_contrib_nbextensions) (4.12.2)
Requirement already satisfied: bleach!=5.0.0 in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from
nbconvert>=6.0->jupyter_contrib_nbextensions) (6.0.0)
Requirement already satisfied: defusedxml in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from
nbconvert>=6.0->jupyter_contrib_nbextensions) (0.7.1)
Requirement already satisfied: Jinja2>=3.0 in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from
nbconvert>=6.0->jupyter_contrib_nbextensions) (3.1.2)
Requirement already satisfied: jupyterlab-pygments in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from
nbconvert>=6.0->jupyter_contrib_nbextensions) (0.2.2)
Requirement already satisfied: MarkupSafe>=2.0 in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from
nbconvert>=6.0->jupyter_contrib_nbextensions) (2.1.3)
Requirement already satisfied: mistune<4,>=2.0.3 in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from
nbconvert>=6.0->jupyter_contrib_nbextensions) (3.0.1)
Requirement already satisfied: nbclient>=0.5.0 in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from
nbconvert>=6.0->jupyter_contrib_nbextensions) (0.8.0)
Requirement already satisfied: nbformat>=5.7 in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from
nbconvert>=6.0->jupyter_contrib_nbextensions) (5.9.0)
Requirement already satisfied: packaging in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from
nbconvert>=6.0->jupyter_contrib_nbextensions) (23.1)
Requirement already satisfied: pandocfilters>=1.4.1 in

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/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from
nbconvert>=6.0->jupyter_contrib_nbextensions) (1.5.0)
Requirement already satisfied: pygments>=2.4.1 in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from
nbconvert>=6.0->jupyter_contrib_nbextensions) (2.15.1)
Requirement already satisfied: tinycss2 in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from
nbconvert>=6.0->jupyter_contrib_nbextensions) (1.2.1)
Requirement already satisfied: platformdirs>=2.5 in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from
jupyter_core->jupyter_contrib_nbextensions) (3.8.0)
Requirement already satisfied: pyzmq>=17 in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from
notebook>=6.0->jupyter_contrib_nbextensions) (24.0.1)
Requirement already satisfied: argon2-cffi in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from
notebook>=6.0->jupyter_contrib_nbextensions) (21.3.0)
Requirement already satisfied: jupyter-client>=5.3.4 in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from
notebook>=6.0->jupyter_contrib_nbextensions) (7.4.9)
Requirement already satisfied: nest-asyncio>=1.5 in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from
notebook>=6.0->jupyter_contrib_nbextensions) (1.5.6)
Requirement already satisfied: ipykernel in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from
notebook>=6.0->jupyter_contrib_nbextensions) (6.24.0)
Requirement already satisfied: Send2Trash>=1.8.0 in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from
notebook>=6.0->jupyter_contrib_nbextensions) (1.8.2)
Requirement already satisfied: terminado>=0.8.3 in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from
notebook>=6.0->jupyter_contrib_nbextensions) (0.17.1)
Requirement already satisfied: prometheus-client in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from
notebook>=6.0->jupyter_contrib_nbextensions) (0.17.0)
Requirement already satisfied: nbclassic>=0.4.7 in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from
notebook>=6.0->jupyter_contrib_nbextensions) (1.0.0)
Requirement already satisfied: six>=1.9.0 in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from
bleach!=5.0.0->nbconvert>=6.0->jupyter_contrib_nbextensions) (1.16.0)
Requirement already satisfied: webencodings in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from
bleach!=5.0.0->nbconvert>=6.0->jupyter_contrib_nbextensions) (0.5.1)
Requirement already satisfied: entrypoints in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from jupyter-
client>=5.3.4->notebook>=6.0->jupyter_contrib_nbextensions) (0.4)
Requirement already satisfied: python-dateutil>=2.8.2 in

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/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from jupyter-client>=5.3.4->notebook>=6.0->jupyter_contrib_nbextensions) (2.8.2)
 Requirement already satisfied: jupyter-server>=1.8 in
 /home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from nbclassic>=0.4.7->notebook>=6.0->jupyter_contrib_nbextensions) (2.7.0)
 Requirement already satisfied: notebook-shim>=0.2.3 in
 /home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from nbclassic>=0.4.7->notebook>=6.0->jupyter_contrib_nbextensions) (0.2.3)
 Requirement already satisfied: fastjsonschema in
 /home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from nbformat>=5.7->nbconvert>=6.0->jupyter_contrib_nbextensions) (2.17.1)
 Requirement already satisfied: jsonschema>=2.6 in
 /home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from nbformat>=5.7->nbconvert>=6.0->jupyter_contrib_nbextensions) (4.18.0)
 Requirement already satisfied: ptyprocess in
 /home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from terminado>=0.8.3->notebook>=6.0->jupyter_contrib_nbextensions) (0.7.0)
 Requirement already satisfied: argon2-cffi-bindings in
 /home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from argon2-cffi->notebook>=6.0->jupyter_contrib_nbextensions) (21.2.0)
 Requirement already satisfied: soupsieve>1.2 in
 /home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from beautifulsoup4->nbconvert>=6.0->jupyter_contrib_nbextensions) (2.4.1)
 Requirement already satisfied: comm>=0.1.1 in
 /home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from ipykernel->notebook>=6.0->jupyter_contrib_nbextensions) (0.1.3)
 Requirement already satisfied: debugpy>=1.6.5 in
 /home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from ipykernel->notebook>=6.0->jupyter_contrib_nbextensions) (1.6.7)
 Requirement already satisfied: ipython>=7.23.1 in
 /home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from ipykernel->notebook>=6.0->jupyter_contrib_nbextensions) (8.14.0)
 Requirement already satisfied: matplotlib-inline>=0.1 in
 /home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from ipykernel->notebook>=6.0->jupyter_contrib_nbextensions) (0.1.6)
 Requirement already satisfied: psutil in
 /home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from ipykernel->notebook>=6.0->jupyter_contrib_nbextensions) (5.9.5)
 Requirement already satisfied: backcall in
 /home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from ipython>=7.23.1->ipykernel->notebook>=6.0->jupyter_contrib_nbextensions) (0.2.0)
 Requirement already satisfied: decorator in
 /home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from ipython>=7.23.1->ipykernel->notebook>=6.0->jupyter_contrib_nbextensions) (5.1.1)
 Requirement already satisfied: jedi>=0.16 in
 /home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from ipython>=7.23.1->ipykernel->notebook>=6.0->jupyter_contrib_nbextensions) (0.18.2)

Requirement already satisfied: pickleshare in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from
ipython>=7.23.1->ipykernel->notebook>=6.0->jupyter_contrib_nbextensions) (0.7.5)

Requirement already satisfied: prompt-toolkit!=3.0.37,<3.1.0,>=3.0.30 in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from
ipython>=7.23.1->ipykernel->notebook>=6.0->jupyter_contrib_nbextensions)
(3.0.39)

Requirement already satisfied: stack-data in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from
ipython>=7.23.1->ipykernel->notebook>=6.0->jupyter_contrib_nbextensions) (0.6.2)

Requirement already satisfied: pexpect>4.3 in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from
ipython>=7.23.1->ipykernel->notebook>=6.0->jupyter_contrib_nbextensions) (4.8.0)

Requirement already satisfied: attrs>=22.2.0 in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from
jsonschema>=2.6->nbformat>=5.7->nbconvert>=6.0->jupyter_contrib_nbextensions)
(23.1.0)

Requirement already satisfied: jsonschema-specifications>=2023.03.6 in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from
jsonschema>=2.6->nbformat>=5.7->nbconvert>=6.0->jupyter_contrib_nbextensions)
(2023.6.1)

Requirement already satisfied: referencing>=0.28.4 in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from
jsonschema>=2.6->nbformat>=5.7->nbconvert>=6.0->jupyter_contrib_nbextensions)
(0.29.1)

Requirement already satisfied: rpds-py>=0.7.1 in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from
jsonschema>=2.6->nbformat>=5.7->nbconvert>=6.0->jupyter_contrib_nbextensions)
(0.8.6)

Requirement already satisfied: anyio>=3.1.0 in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from jupyter-
server>=1.8->nbclassic>=0.4.7->notebook>=6.0->jupyter_contrib_nbextensions)
(3.7.1)

Requirement already satisfied: jupyter-events>=0.6.0 in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from jupyter-
server>=1.8->nbclassic>=0.4.7->notebook>=6.0->jupyter_contrib_nbextensions)
(0.6.3)

Requirement already satisfied: jupyter-server-terminals in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from jupyter-
server>=1.8->nbclassic>=0.4.7->notebook>=6.0->jupyter_contrib_nbextensions)
(0.4.4)

Requirement already satisfied: overrides in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from jupyter-
server>=1.8->nbclassic>=0.4.7->notebook>=6.0->jupyter_contrib_nbextensions)
(7.3.1)

Requirement already satisfied: websocket-client in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from jupyter-
server>=1.8->nbclassic>=0.4.7->notebook>=6.0->jupyter_contrib_nbextensions)

(1.6.1)
Requirement already satisfied: cffi>=1.0.1 in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from
argon2-cffi-bindings->argon2-cffi->notebook>=6.0->jupyter_contrib_nbextensions)
(1.15.1)
Requirement already satisfied: idna>=2.8 in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from
anyio>=3.1.0->jupyter-
server>=1.8->nbclassic>=0.4.7->notebook>=6.0->jupyter_contrib_nbextensions)
(3.4)
Requirement already satisfied: sniffio>=1.1 in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from
anyio>=3.1.0->jupyter-
server>=1.8->nbclassic>=0.4.7->notebook>=6.0->jupyter_contrib_nbextensions)
(1.3.0)
Requirement already satisfied: exceptiongroup in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from
anyio>=3.1.0->jupyter-
server>=1.8->nbclassic>=0.4.7->notebook>=6.0->jupyter_contrib_nbextensions)
(1.1.2)
Requirement already satisfied: pycparser in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from
cffi>=1.0.1->argon2-cffi-
bindings->argon2-cffi->notebook>=6.0->jupyter_contrib_nbextensions) (2.21)
Requirement already satisfied: parso<0.9.0,>=0.8.0 in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from jedi>=0.16
->ipython>=7.23.1->ipykernel->notebook>=6.0->jupyter_contrib_nbextensions)
(0.8.3)
Requirement already satisfied: python-json-logger>=2.0.4 in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from jupyter-
events>=0.6.0->jupyter-
server>=1.8->nbclassic>=0.4.7->notebook>=6.0->jupyter_contrib_nbextensions)
(2.0.7)
Requirement already satisfied: rfc3339-validator in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from jupyter-
events>=0.6.0->jupyter-
server>=1.8->nbclassic>=0.4.7->notebook>=6.0->jupyter_contrib_nbextensions)
(0.1.4)
Requirement already satisfied: rfc3986-validator>=0.1.1 in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from jupyter-
events>=0.6.0->jupyter-
server>=1.8->nbclassic>=0.4.7->notebook>=6.0->jupyter_contrib_nbextensions)
(0.1.1)
Requirement already satisfied: wcwidth in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from prompt-too
lkit!=3.0.37,<3.1.0,>=3.0.30->ipython>=7.23.1->ipykernel->notebook>=6.0-
>jupyter_contrib_nbextensions) (0.2.6)
Requirement already satisfied: executing>=1.2.0 in

```

/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from stack-
data->ipython>=7.23.1->ipykernel->notebook>=6.0->jupyter_contrib_nbextensions)
(1.2.0)
Requirement already satisfied: asttokens>=2.1.0 in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from stack-
data->ipython>=7.23.1->ipykernel->notebook>=6.0->jupyter_contrib_nbextensions)
(2.2.1)
Requirement already satisfied: pure-eval in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from stack-
data->ipython>=7.23.1->ipykernel->notebook>=6.0->jupyter_contrib_nbextensions)
(0.2.2)
Requirement already satisfied: fqdn in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from
jsonschema>=2.6->nbformat>=5.7->nbconvert>=6.0->jupyter_contrib_nbextensions)
(1.5.1)
Requirement already satisfied: isoduration in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from
jsonschema>=2.6->nbformat>=5.7->nbconvert>=6.0->jupyter_contrib_nbextensions)
(20.11.0)
Requirement already satisfied: jsonpointer>1.13 in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from
jsonschema>=2.6->nbformat>=5.7->nbconvert>=6.0->jupyter_contrib_nbextensions)
(2.4)
Requirement already satisfied: uri-template in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from
jsonschema>=2.6->nbformat>=5.7->nbconvert>=6.0->jupyter_contrib_nbextensions)
(1.3.0)
Requirement already satisfied: webcolors>=1.11 in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from
jsonschema>=2.6->nbformat>=5.7->nbconvert>=6.0->jupyter_contrib_nbextensions)
(1.13)
Requirement already satisfied: arrow>=0.15.0 in
/home/juan/.virtualenvs/JoseAndres/lib/python3.10/site-packages (from isoduratio
n->jsonschema>=2.6->nbformat>=5.7->nbconvert>=6.0->jupyter_contrib_nbextensions)
(1.2.3)
Building wheels for collected packages: jupyter_contrib_nbextensions,
jupyter_contrib_core
  Building wheel for jupyter_contrib_nbextensions (setup.py) ... done
  Created wheel for jupyter_contrib_nbextensions:
filename=jupyter_contrib_nbextensions-0.7.0-py2.py3-none-any.whl size=23428784
sha256=e4e70a100328d495bbfdc0e74e51f0bd897f2a44bcadc9726acc07323f5eab98
  Stored in directory: /home/juan/.cache/pip/wheels/ea/cc/7d/99ef154f984726b1201
c0f72cfe9c9d7c5132c1a2ae4d8677f
  Building wheel for jupyter_contrib_core (setup.py) ... done
  Created wheel for jupyter_contrib_core:
filename=jupyter_contrib_core-0.4.2-py2.py3-none-any.whl size=17483
sha256=7a13ef021b5cdd27bd1f2509251f9943cbdebd7c6ee7e723ae0a53197bc8f1f7
  Stored in directory: /home/juan/.cache/pip/wheels/a9/52/88/e0643cdfd68f0562087

```

918c37dd583378648dbc3df68b907f7

Successfully built jupyter_contrib_nbextensions jupyter_contrib_core
Installing collected packages: jupyter_highlight_selected_word, lxml,
jupyter_contrib_core, jupyter_nbextensions_configurator,
jupyter_contrib_nbextensions
Successfully installed jupyter_contrib_core-0.4.2
jupyter_contrib_nbextensions-0.7.0 jupyter_highlight_selected_word-0.2.0
jupyter_nbextensions_configurator-0.6.3 lxml-4.9.3
Note: you may need to restart the kernel to use updated packages.

```
[ ]: from gurobipy import * # es el modelo de optimización y hay que cargarlo con
      ↪ pip (ver celda de arriba)
import numpy as np
import matplotlib.pyplot as plt
import matplotlib.patches as mpatches
from itertools import cycle
import random
```

```
[ ]: # Nodos
n = 11 # Número de nodos
clientes = [i for i in range(n) if i!=0] # Un conjunto de clientes que no
      ↪ incluye el valor "0"
nodos = [0] + clientes # Un conjunto de nodos, que son el número de clientes
      ↪ mas "0"
arcos = [(i, j) for i in nodos for j in nodos if i!=j] # Todos los arcos entre
      ↪ dos puntos
```

```
[ ]: # Demanda
np.random.seed(0)
q = {n:np.random.randint(10, 15) for n in clientes}
q[0] = 0 # El nodo 0 no tiene demanda
```

```
[ ]: # Ventanas temporales
e = {0:0, 1:10, 2:10, 3:10, 4:20, 5:20, 6:20, 7:40, 8:40, 9:40, 10:40} # Mínimo
      ↪ tiempo de llegada
l = {0:200, 1:100, 2:100, 3:100, 4:150, 5:150, 6:150, 7:180, 8:180, 9:180, 10:
      ↪ 180} # Máximo tiempo de llegada
# El formato es -> numero_nodo:tiempo_entrega
# Por ejemplo, 2:10 indica que el mínimo tiempo de llegada al nodo 2 es de 10
      ↪ minutos.
# Como 0 es el depot, tiene como hora máxima de llegada el mayor valor de
      ↪ todos, ya que es el último nodo cuando acaba la jornada laboral

s = {n:np.random.randint(3,5) for n in clientes} # Tiempo de servicio en el
      ↪ nodo i
# Valor aleatorio entre 3 y 5 minutos para la entrega de los productos en cada
      ↪ nodo
```

```
s[0] = 0 # El tiempo de servicio en el nodo "0" es 0
```

```
[ ]: # Vehículos
vehiculos = [1, 2, 3, 4]

#Q = 50
Q = {1:50, 2:50, 3:25, 4:25} # Cada vehículo(1, 2, 3, 4) y su capacidad (25 o 50)
```

```
[ ]: # Coordenadas
X = np.random.rand(len(nodos))*100
Y = np.random.rand(len(nodos))*100
```

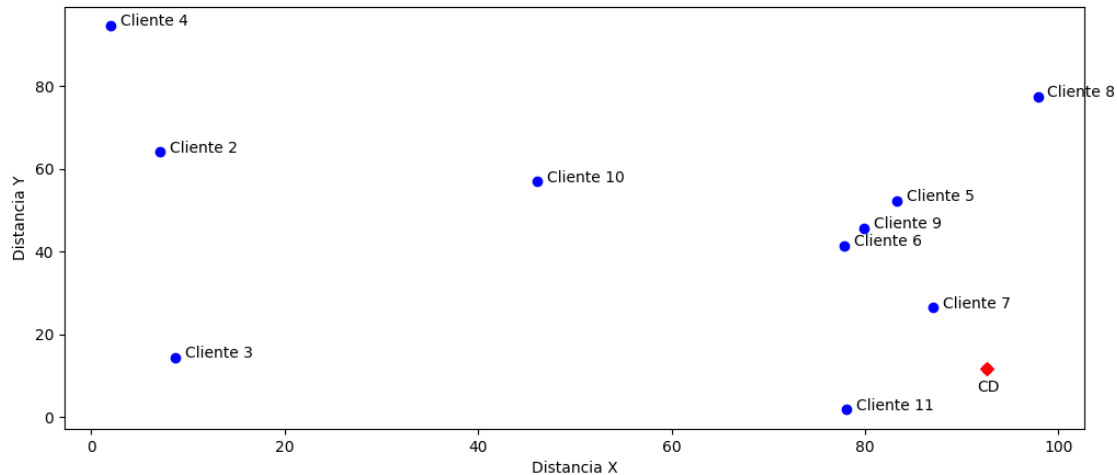
```
[ ]: # Definicion de distancias y tiempos
distancia = {(i, j): np.hypot(X[i] - X[j], Y[i] - Y[j]) for i in nodos for j in nodos if i!=j}
tiempo = {(i, j): np.hypot(X[i] - X[j], Y[i] - Y[j]) for i in nodos for j in nodos if i!=j}
# Por simplicidad voy a asumir que la distancia y el tiempo son iguales.
```

```
[ ]: plt.figure(figsize=(12, 5))
plt.scatter(X, Y, color = 'blue') # Puntos de entrega en azul

# Centro de distribucion
plt.scatter(X[0], Y[0], color = 'red', marker = 'D') # Depot en rojo, marcado como un diamante
plt.annotate("CD", (X[0] - 1, Y[0] - 5.5), fontsize = 10)
# Cada {d} corresponde con los valores (0, e[0], l[0]), EN ORDEN
# Cuando escribo t_{d}, "_" indica que el valor ser sub ndice de t
for i in clientes:
    plt.annotate(f'Cliente {i+1}', (X[i] + 1, Y[i]), fontsize = 10)
# Como se ha explicado antes:  $q_i = q[i]$  /  $t_i = (e[i], l[i])$ 

plt.xlabel("Distancia X")
plt.ylabel("Distancia Y")
# plt.title("Nodos Problema de Ruteo de Vehiculos con Ventanas Temporales")

plt.show()
```



```
[ ]: # Creación de los arcos
arco_var = [(i, j, k) for i in nodos for j in nodos for k in vehiculos if i!=j]
arco_tiempos = [(i, k) for i in nodos for k in vehiculos]
```

```
[ ]: # Modelo aqui fallaba porque no cargabais el gurobipy (modelo de optimización
    ↪ VRPTW)
model = Model('VRPTW')
```

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```
[ ]: # Variables de decisión
x = model.addVars(arco_var, vtype=GRB.BINARY, name = 'x')
t = model.addVars(arco_tiempos, vtype=GRB.CONTINUOUS, name = 't')

# Función objetivo
model.setObjective(quicksum(distancia[i, j] * x[i, j, k] for i, j, k in
    ↪ arco_var), GRB.MINIMIZE)
```

```
[ ]: # Restricciones
# 1. Llegadas y salidas del centro de distribución
model.addConstrs(quicksum(x[0, j, k] for j in clientes) <= 1 for k in vehiculos)
model.addConstrs(quicksum(x[i, 0, k] for i in clientes) <= 1 for k in vehiculos)

# 2. Un vehiculo por nodo
model.addConstrs(quicksum(x[i, j, k] for j in nodos for k in vehiculos if i!=j)
    ↪ == 1 for i in clientes)

# 3. Conservación de flujo
model.addConstrs(quicksum(x[i, j, k] for j in nodos if i!=j) - quicksum(x[j, i,
    ↪ k] for j in nodos if i!=j) == 0 for i in nodos for k in vehiculos)
```

```

# 4. Capacidad del vehículo
model.addConstrs(quicksum(q[i]*quicksum(x[i, j, k] for j in nodos if i!=j) for
    i in clientes) <= Q[k] for k in vehiculos)

# 5. Ventana de tiempo
model.addConstrs((x[i, j, k] == 1) >> (t[i, k] + s[i] + tiempo[i, j] == t[j,
    k]) for i in clientes for j in clientes for k in vehiculos if i!=j)

model.addConstrs(t[i, k] >= e[i] for i, k in arco_tiempos)
model.addConstrs(t[i, k] <= l[i] for i, k in arco_tiempos)

```

```

[ ]: {(0, 1): <gurobi.Constr *Awaiting Model Update*>,
      (0, 2): <gurobi.Constr *Awaiting Model Update*>,
      (0, 3): <gurobi.Constr *Awaiting Model Update*>,
      (0, 4): <gurobi.Constr *Awaiting Model Update*>,
      (1, 1): <gurobi.Constr *Awaiting Model Update*>,
      (1, 2): <gurobi.Constr *Awaiting Model Update*>,
      (1, 3): <gurobi.Constr *Awaiting Model Update*>,
      (1, 4): <gurobi.Constr *Awaiting Model Update*>,
      (2, 1): <gurobi.Constr *Awaiting Model Update*>,
      (2, 2): <gurobi.Constr *Awaiting Model Update*>,
      (2, 3): <gurobi.Constr *Awaiting Model Update*>,
      (2, 4): <gurobi.Constr *Awaiting Model Update*>,
      (3, 1): <gurobi.Constr *Awaiting Model Update*>,
      (3, 2): <gurobi.Constr *Awaiting Model Update*>,
      (3, 3): <gurobi.Constr *Awaiting Model Update*>,
      (3, 4): <gurobi.Constr *Awaiting Model Update*>,
      (4, 1): <gurobi.Constr *Awaiting Model Update*>,
      (4, 2): <gurobi.Constr *Awaiting Model Update*>,
      (4, 3): <gurobi.Constr *Awaiting Model Update*>,
      (4, 4): <gurobi.Constr *Awaiting Model Update*>,
      (5, 1): <gurobi.Constr *Awaiting Model Update*>,
      (5, 2): <gurobi.Constr *Awaiting Model Update*>,
      (5, 3): <gurobi.Constr *Awaiting Model Update*>,
      (5, 4): <gurobi.Constr *Awaiting Model Update*>,
      (6, 1): <gurobi.Constr *Awaiting Model Update*>,
      (6, 2): <gurobi.Constr *Awaiting Model Update*>,
      (6, 3): <gurobi.Constr *Awaiting Model Update*>,
      (6, 4): <gurobi.Constr *Awaiting Model Update*>,
      (7, 1): <gurobi.Constr *Awaiting Model Update*>,
      (7, 2): <gurobi.Constr *Awaiting Model Update*>,
      (7, 3): <gurobi.Constr *Awaiting Model Update*>,
      (7, 4): <gurobi.Constr *Awaiting Model Update*>,
      (8, 1): <gurobi.Constr *Awaiting Model Update*>,
      (8, 2): <gurobi.Constr *Awaiting Model Update*>,
      (8, 3): <gurobi.Constr *Awaiting Model Update*>,
      (8, 4): <gurobi.Constr *Awaiting Model Update*>,

```

```
(9, 1): <gurobi.Constr *Awaiting Model Update*>,
(9, 2): <gurobi.Constr *Awaiting Model Update*>,
(9, 3): <gurobi.Constr *Awaiting Model Update*>,
(9, 4): <gurobi.Constr *Awaiting Model Update*>,
(10, 1): <gurobi.Constr *Awaiting Model Update*>,
(10, 2): <gurobi.Constr *Awaiting Model Update*>,
(10, 3): <gurobi.Constr *Awaiting Model Update*>,
(10, 4): <gurobi.Constr *Awaiting Model Update*>}
```

```
[ ]: # Calcula la solución mas optima
```

```
model.optimize()
```

Gurobi Optimizer version 10.0.2 build v10.0.2rc0 (linux64)

CPU model: Intel(R) Core(TM) i9-10900X CPU @ 3.70GHz, instruction set
[SSE2|AVX|AVX2|AVX512]

Thread count: 10 physical cores, 20 logical processors, using up to 20 threads

Optimize a model with 154 rows, 484 columns and 1848 nonzeros

Model fingerprint: 0x4eb22e20

Model has 360 general constraints

Variable types: 44 continuous, 440 integer (440 binary)

Coefficient statistics:

Matrix range [1e+00, 1e+01]

CPU model: Intel(R) Core(TM) i9-10900X CPU @ 3.70GHz, instruction set
[SSE2|AVX|AVX2|AVX512]

Thread count: 10 physical cores, 20 logical processors, using up to 20 threads

Optimize a model with 154 rows, 484 columns and 1848 nonzeros

Model fingerprint: 0x4eb22e20

Model has 360 general constraints

Variable types: 44 continuous, 440 integer (440 binary)

Coefficient statistics:

Matrix range [1e+00, 1e+01]

Objective range [5e+00, 1e+02]

Bounds range [1e+00, 1e+00]

RHS range [1e+00, 2e+02]

GenCon rhs range [8e+00, 1e+02]

GenCon coe range [1e+00, 1e+00]

Presolve added 414 rows and 0 columns

Presolve removed 0 rows and 64 columns

Presolve time: 0.06s

Presolved: 568 rows, 420 columns, 4042 nonzeros

Variable types: 102 continuous, 318 integer (318 binary)

Found heuristic solution: objective 851.1598825

Root relaxation: objective 2.949996e+02, 75 iterations, 0.00 seconds (0.00 work units)

Nodes			Current Node			Objective Bounds			Work	
Expl	Unexpl		Obj	Depth	IntInf	Incumbent	BestBd	Gap	It/Node	Time
H	0	0	294.99956	0	20	851.15988	294.99956	65.3%	-	0s
	0	0				684.0377782	294.99956	56.9%	-	0s
	0	0	331.40082	0	31	684.03778	331.40082	51.6%	-	0s
	0	0	337.32502	0	33	684.03778	337.32502	50.7%	-	0s
	0	0	339.02333	0	28	684.03778	339.02333	50.4%	-	0s
H	0	0	380.57033	0	39	684.03778	380.57033	44.4%	-	0s
	0	0				642.1405527	380.78534	40.7%	-	0s
	0	0	380.78534	0	42	642.14055	380.78534	40.7%	-	0s
	0	0	396.53632	0	44	642.14055	396.53632	38.2%	-	0s
	0	0	396.53632	0	30	642.14055	396.53632	38.2%	-	0s
	0	0	396.53632	0	30	642.14055	396.53632	38.2%	-	0s
	0	0	396.53632	0	30	642.14055	396.53632	38.2%	-	0s
	0	0	398.52653	0	42	642.14055	398.52653	37.9%	-	0s
	0	0	402.32826	0	57	642.14055	402.32826	37.3%	-	0s
	0	0	402.32826	0	54	642.14055	402.32826	37.3%	-	0s
H	0	0	405.54919	0	47	642.14055	405.54919	36.8%	-	0s
	0	0	406.37879	0	48	642.14055	406.37879	36.7%	-	0s
	0	0	406.37879	0	50	642.14055	406.37879	36.7%	-	0s
	0	0	411.36660	0	58	642.14055	411.36660	35.9%	-	0s
	0	0				620.4466125	411.36660	33.7%	-	0s
H	0	0				587.2142124	411.36660	29.9%	-	0s
	0	0	411.36660	0	59	587.21421	411.36660	29.9%	-	0s
	0	0	412.72953	0	52	587.21421	412.72953	29.7%	-	0s
	0	0	412.72953	0	52	587.21421	412.72953	29.7%	-	0s
	0	0	412.72953	0	52	587.21421	412.72953	29.7%	-	0s
	0	0	412.72953	0	52	587.21421	412.72953	29.7%	-	0s
	0	0	417.63645	0	44	587.21421	417.63645	28.9%	-	0s
	0	0	417.63645	0	56	587.21421	417.63645	28.9%	-	0s
	0	0	417.63645	0	56	587.21421	417.63645	28.9%	-	0s
	0	0	417.63645	0	47	587.21421	417.63645	28.9%	-	0s
	0	0	418.33030	0	48	587.21421	418.33030	28.8%	-	0s
	0	0	418.33030	0	48	587.21421	418.33030	28.8%	-	0s
	0	0	418.33030	0	48	587.21421	418.33030	28.8%	-	0s
	0	0	418.33030	0	52	587.21421	418.33030	28.8%	-	0s
	0	0	418.33030	0	52	587.21421	418.33030	28.8%	-	0s
	0	0	418.33030	0	42	587.21421	418.33030	28.8%	-	0s
	0	0	418.47124	0	47	587.21421	418.47124	28.7%	-	0s
	0	0	418.47124	0	48	587.21421	418.47124	28.7%	-	0s
	0	0	418.47124	0	48	587.21421	418.47124	28.7%	-	0s
	0	0	424.60843	0	50	587.21421	424.60843	27.7%	-	0s
	0	0	424.60843	0	50	587.21421	424.60843	27.7%	-	0s
	0	0	424.60843	0	40	587.21421	424.60843	27.7%	-	0s
	0	0	424.60843	0	52	587.21421	424.60843	27.7%	-	0s
	0	0	424.60843	0	52	587.21421	424.60843	27.7%	-	0s
	0	0	424.60843	0	69	587.21421	424.60843	27.7%	-	0s
	0	0	427.24548	0	69	587.21421	427.24548	27.2%	-	0s
	0	0	427.24548	0	69	587.21421	427.24548	27.2%	-	0s
	0	0	427.24548	0	69	587.21421	427.24548	27.2%	-	0s
	0	0	427.24548	0	56	587.21421	427.24548	27.2%	-	0s
	0	0	427.24548	0	56	587.21421	427.24548	27.2%	-	0s
	0	2	427.24548	0	56	587.21421	427.24548	27.2%	-	0s

Cutting planes:

Gomory: 8
Cover: 19
Implied bound: 78
Clique: 23
MIR: 47
StrongCG: 3
GUB cover: 1
Zero half: 26
RLT: 49
Relax-and-lift: 19

Explored 2968 nodes (47940 simplex iterations) in 0.92 seconds (0.86 work units)
Thread count was 20 (of 20 available processors)

Solution count 5: 587.214 620.447 642.141 ... 851.16

Optimal solution found (tolerance 1.00e-04)

Best objective 5.872142124377e+02, best bound 5.872142124377e+02, gap 0.0000%

```
[ ]: # Imprimir la solución
print("Función objetivo:", str(round(model.ObjVal, 2)))
for v in model.getVars():
    if v.x > 0.9:
        print(str(v.VarName)+"="+str(v.x))

# Graficar la solución
rutas = []
truck = []
K = vehiculos
N = nodos
for k in vehiculos:
    for i in nodos:
        if i!=0 and x[0, i, k].x > 0.9:
            aux = [0, i]
            while i!=0:
                j = i
                for h in nodos:
                    if j!=h and x[j, h, k].x > 0.9:
                        aux.append(h)
                        i = h
            rutas.append(aux)
            truck.append(k)
print(rutas)
print(truck)

# Acumulacion de tiempos
```

```

tiempo_acum = list()
for n in range(len(rutas)):
    for k in range(len(rutas[n])-1):
        if k == 0:
            aux = [0]
        else:
            i = rutas[n][k]
            j = rutas[n][k + 1]
            t = tiempo[i, j] + s[i] + aux[-1]
            aux.append(t)
    tiempo_acum.append(aux)

# Gráfica solución
plt.figure(figsize=(12, 5))
plt.scatter(X, Y, color = 'blue')

# Centro de distribución
plt.scatter(X[0], Y[0], color = 'red', marker = 'D')
plt.annotate("CD", (X[0] - 1, Y[0] - 5.5), fontsize = 10)

# Representación de las rutas
Color = ['blue', 'green', 'red', 'yellow', 'purple', 'orange', 'black', 'brown']

for r in range(len(rutas)):
    for n in range(len(rutas[r])-1): # Debido a que el último punto será j y no
        ↪ puede ser n + 1
        i = rutas[r][n]
        j = rutas[r][n + 1]
        plt.plot([X[i], X[j]], [Y[i], Y[j]], color = Color[r], alpha = 0.4)

for r in range(len(tiempo_acum)):
    for n in range(len(tiempo_acum[r])):
        i = rutas[r][n]
        plt.annotate('$q_{%d} = %d$ | $t_{%d} = %d$' %(i, q[i], i,
        ↪ tiempo_acum[r][n]), (X[i]+1, Y[i]), fontsize = 10)

patch = [mpatches.Patch(color = Color[n], label = "vehículo "+str(truck[n])+ "
        ↪ cap = "+str(Q[truck[n]])) for n in range(len(truck))]

# plt.legend(handles=patch, loc='best')
plt.xlabel("Distancia X")
plt.ylabel("Distancia Y")
# plt.title("Problema de Ruteo de Vehículos con Ventanas Temporales")

plt.show()

```

Función objetivo: 587.21
 x[0,3,2]=1.0
 x[0,5,3]=1.0
 x[0,6,4]=1.0
 x[0,9,1]=1.0
 x[1,2,2]=1.0
 x[2,10,2]=1.0
 x[3,1,2]=1.0
 x[4,0,1]=1.0
 x[5,8,3]=1.0
 x[6,0,4]=1.0
 x[7,4,1]=1.0
 x[8,0,3]=1.0
 x[9,7,1]=1.0
 x[10,0,2]=1.0
 t[1,1]=100.0
 t[1,2]=47.31715519507497
 t[1,3]=10.0
 t[1,4]=10.0
 t[2,1]=10.0
 t[2,2]=100.0
 t[2,3]=10.0
 t[2,4]=100.0
 t[3,1]=100.0
 t[3,2]=13.421570625124822
 t[3,3]=10.000000000000002
 t[3,4]=10.0
 t[4,1]=150.00000000000001
 t[4,2]=20.000000000000014
 t[4,3]=150.0
 t[4,4]=150.0
 t[5,1]=150.0
 t[5,2]=150.00000000000006
 t[5,3]=150.0
 t[5,4]=20.0
 t[6,1]=150.0
 t[6,2]=20.0
 t[6,3]=150.0
 t[6,4]=20.0
 t[7,1]=116.84285081574512
 t[7,2]=40.00000000000001
 t[7,3]=39.99999999999997
 t[7,4]=40.0
 t[8,1]=40.000000000000114
 t[8,2]=40.0
 t[8,3]=157.65012134249957
 t[8,4]=40.0
 t[9,1]=58.18440511058404

