Assignment 5: KNIME Supply Chain Optimization

1. Execute the program installation steps described in [Setting up KNIME with Extensions.]

I have followed the document properly and installed Anaconda distribution of Python and integrated it with KNIME Python Extension and create a custom environment in Anaconda. Attaching below screenshots after following the setup document.

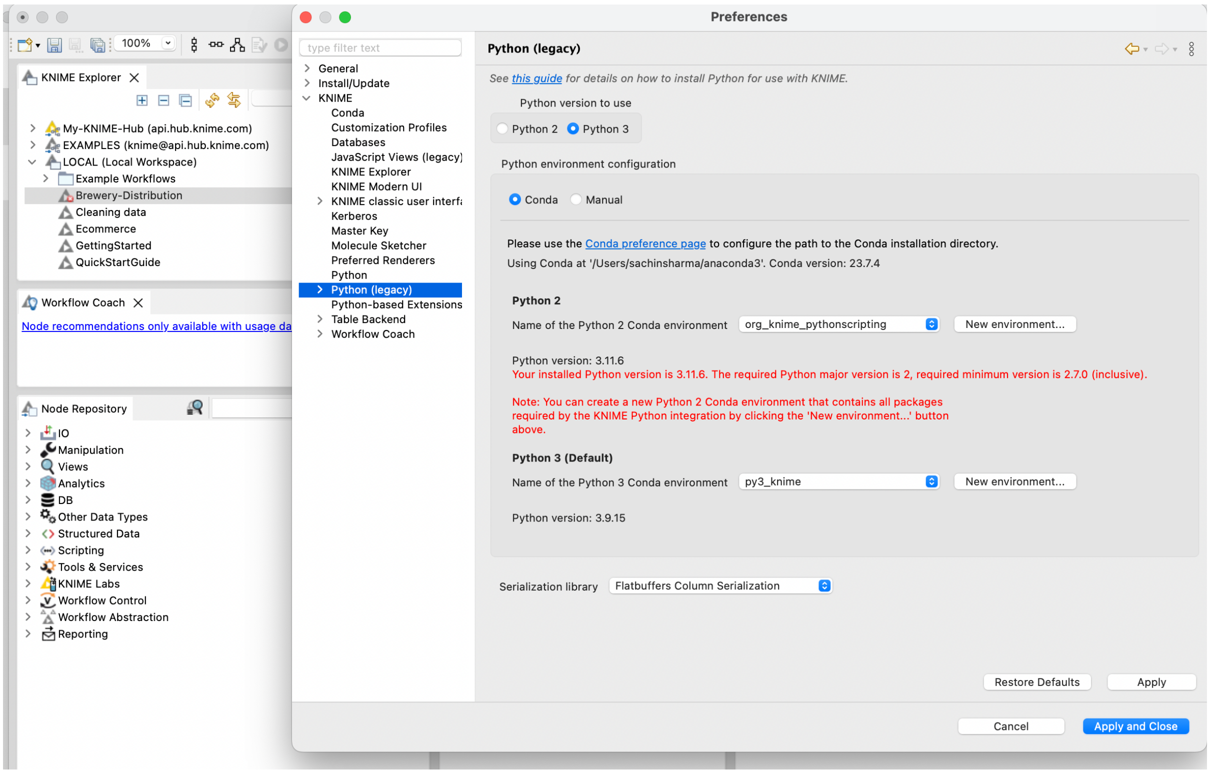

Fig 1 - KNIME Preferences setting for working with Python

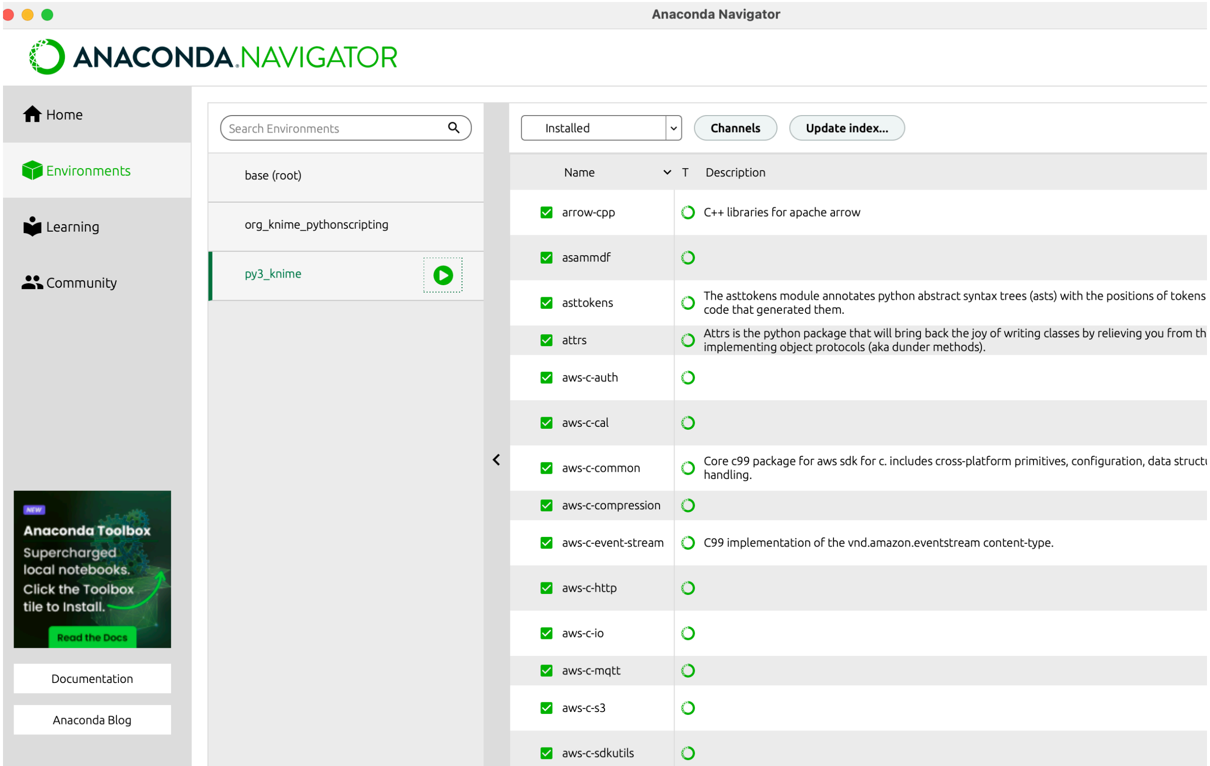

Fig 2 - Anaconda Environment list with py3_knime environment

2. Execute the Python program within KNIME and inspect the results.

We have imported the Brewery-Distribution.knwf workflow in KNIME analytics and executed the Python Script. Attaching the below screenshot after executing the Python Script.

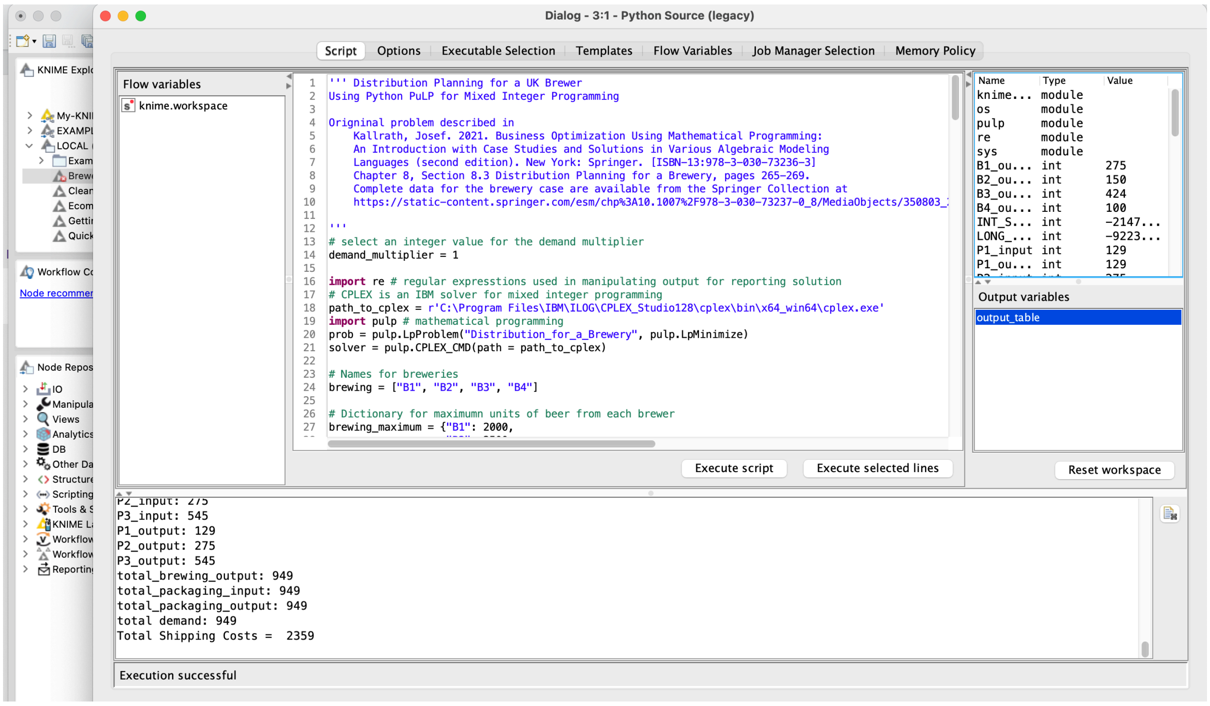

Fig 3 – Python Program Screenshot in KNIME Analytics

Analysis:

This Python code utilizes PuLP, a linear programming library, to solve a distribution planning problem for a brewery. Here's a breakdown of the analysis:

Problem Description: The problem involves optimizing the distribution of beer from breweries to packaging facilities and then to demand points (retailers and pubs). The objective is to minimize transportation costs while meeting demand constraints and capacity limitations at breweries and packaging facilities.

Data Setup: The code sets up various parameters such as maximum and minimum production capacities at breweries and packaging facilities, transportation costs between different points, and demand at each demand point.

Output:

1. **Transportation Routes**:

   - The solution assigns quantities of beer to each transportation route, indicating how much beer is transported from each brewery to each packaging facility, and from each packaging facility to each demand point.

2. **Brewing and Packaging Output:**

   - The output shows the total output from each brewery and the total input and output at each packaging facility. These values indicate how much beer is produced at each brewery and processed at each packaging facility, giving insights into production and processing capacities.

3. **Total Production and Demand:**

   - The total brewing output (`total_brewing_output`) and total demand (`total_demand`) are compared, providing an overview of whether production meets demand.

4. **Total Shipping Costs:**

   - The total shipping costs (`Total Shipping Costs`) are calculated based on the optimized solution, indicating the overall cost of transporting beer from breweries to packaging facilities and demand points.

3. What are the data files used in this workflow? Describe the content of the datasets provided in these files.

There are no data files used in this workflow rather inputs such as list, integers and dictionaries are being configured inside the python script.

Here's a breakdown of the content mentioned based on the provided Python script:

- **Demand Multiplier**: This is a scalar value used to adjust the demand for beer. It's multiplied with the base demand at each demand point to simulate different demand scenarios.

- **Names for Breweries**: The script defines a list of names representing the breweries involved in the distribution planning problem. These names are represented as strings.

- **Dictionary for Maximum Units of Beer from Each Brewer:** This dictionary contains the maximum production capacities for each brewery. The keys are brewery names, and the values represent the maximum units of beer that each brewery can produce.

- **Dictionary for Minimum Units of Beer from Each Brewer:** Similar to the maximum production capacities, this dictionary contains the minimum production thresholds for each brewery. It ensures that each brewery produces at least a certain amount of beer, possibly to maintain operational efficiency.

- **Names for Packaging Facilities:** Similar to breweries, the script defines a list of names representing the packaging facilities involved in the distribution process.

- **Dictionary for Maximum Number of Units Packaging Facilities Can Package:** This dictionary specifies the maximum packaging capacities for each packaging facility. The keys are facility names, and the values represent the maximum number of units that each facility can package.

- **Dictionary for Minimum Number of Units Packaging Facilities:** This dictionary contains the minimum packaging thresholds for each packaging facility. It ensures that each packaging facility operates at a minimum capacity.

- **Names of Demand Points:** The script defines a list of names representing the demand points, such as retailers and pubs, where the beer needs to be delivered.

- **Dictionary for Aggregate Demand at Each Demand Point:** This dictionary contains the aggregate demand for beer at each demand point.

- **List of Costs of Transportation Paths Between Breweries and Packaging Facilities:** This list represents the transportation costs between breweries and packaging facilities. It's structured as a matrix, where each row corresponds to a brewery, and each column corresponds to a packaging facility.

- **Another List of Transportation Costs Between Packaging Facilities to Demand Points:** Similar to the previous list, this list represents the transportation costs between packaging facilities and demand points. The values indicate the transportation costs from each packaging facility to each demand point.

4. **Answer the five questions provided under Supply Chain Optimization: Distribution Planning for a Brewery.**

    a. **Solve the supply chain optimization problem with initial settings of parameters for brewing, packaging, and demand. Describe the solution by providing the total cost (minimum cost) and quantities of beer being shipped between each pair of locations.**

    Here's a description of the solution after running the script with initial parameters:

    - **Total Cost (Minimum Cost):** The total shipping cost, which represents the minimum cost to meet all demand while satisfying capacity constraints, is $2359.
    - **Quantities of Beer Shipped:**
        - **From Breweries to Packaging Facilities:**
            - Brewery B1 ships 275 units of beer to Packaging Facility P2.
            - Brewery B2 ships 29 units of beer to Packaging Facility P1 and 121 units to Packaging Facility P3.
            - Brewery B3 ships 424 units of beer to Packaging Facility P3.
            - Brewery B4 ships 100 units of beer to Packaging Facility P1.
        - **From Packaging Facilities to Demand Points:**
            - Packaging Facility P1 ships 47 units to Demand Point D05, 41 units to D10, and 41 units to D15.
            - Packaging Facility P2 ships 48 units to D01, 64 units to D07, 93 units to D08, and 70 units to D14.

  - Packaging Facility P3 ships 84 units to D02, 64 units to D03, 106 units to D04, 57 units to D06, 74 units to D09, 61 units to D11, 42 units to D12, and 57 units to D13.

This solution optimally balances production and transportation to minimize costs while meeting demand and capacity constraints across the supply chain.

b. Due to low demand for its products, the brewing company is thinking about closing any brewing location that is operating at minimum capacity. Reviewing the solution to the optimization problem, which brewery would you close (if any)?

To determine which brewing location to close due to low demand, we need to review the solution to the optimization problem and identify any breweries operating at minimum capacity. In the provided solution, the breweries' production levels are as follows:

- Brewery B1: Produces 275 units, which is above its minimum capacity of 100 units.
- Brewery B2: Produces 150 units, which is above its minimum capacity of 150 units.
- Brewery B3: Produces 424 units, which is well above its minimum capacity of 200 units.
- Brewery B4: Produces 100 units, which is at its minimum capacity of 100 units.

All breweries are producing above or at their minimum capacities except Brewery B4. Brewery B4 is operating at its minimum capacity of 100 units, indicating that demand for its products may be low compared to the other breweries. If the brewing company decides to close a brewery due to low demand, Brewery B4 would be the most suitable candidate for closure.

c. Due to low demand, the company may also want to close one of its packaging facilities. Which packaging facility would you close (if any)?

To identify the packaging facility that could be closed due to low demand, we should examine the solution to the optimization problem and assess the utilization levels of each packaging facility. In the provided solution, the packaging facilities' input and output levels are as follows:

- Packaging Facility P1: Inputs 129 units and outputs 129 units.
- Packaging Facility P2: Inputs 275 units and outputs 275 units.
- Packaging Facility P3: Inputs 545 units and outputs 545 units.

All packaging facilities are operating at their full capacities, with inputs equalling outputs. There are no packaging facilities that are underutilized or operating at minimum capacity. Therefore, based on the optimization solution and considering the current demand and production levels, there is no packaging facility that would be suitable for closure due to low demand. All packaging facilities are fully utilized to meet the demand for the brewery's products.

d. Try multiplying demand by 2, 3, 4, or higher multiples. You can do this by modifying one line of the Python program. You can see the initial setting: demand_multiplier = 1 Setting the multiplier to 2, 3, 4, or higher values, will increase the level of demand, which will change the optimal solution. At what point would demand exceed the company's production capacity? At this point (full capacity), would you close any of the breweries or packaging facilities?

We executed the python program by changing the demand_multiplier setting and using different values. Here is the analysis:

- The Python Program provides optimal status for values 1, 2, 3, 4. However, when we changed the setting to 5 or greater number the solution is infeasible. However, Total brewing output, packaging input, and packaging output all sum up and matches to the total demand at this increased level.
- At demand_multiplier = 7, we find the point at which demand exceed the company's production capacity.
- Brewery B1 produces 1500 units, B2 produces 1775 units, B3 produces 2500 units, and B4 produces 0 units. Brewery B4 is not producing any beer in this scenario.
- Packaging facilities receive inputs totalling 1775, 1500, and 2500 units for P1, P2, and P3, respectively.
- Packaging facilities also output the same amount, indicating that all received input is shipped out.

- Total brewing output, packaging input, and packaging output all sum up to 5775 units, which is less than the total demand of 6643 units at this increased demand level.

Given that demand exceeds production capacity once again, optimizing operations to address this imbalance is necessary. In this scenario, it's evident that the production capacity is insufficient to meet the demand, particularly with Brewery B4 not producing any beer. Considering the imbalance in production capacity and demand, closing Brewery B4 could be a strategic decision to optimize operations and align production capacity with demand more effectively.

e. **What have you learned from this supply chain optimization problem? Explain how you might apply methods of constrained optimization in your line of work.**

This supply chain optimization problem highlights several key learnings:

- **Resource Allocation**: Optimizing resource allocation is crucial for meeting demand efficiently while minimizing costs.
- **Transportation Logistics**: Efficient transportation logistics are essential for ensuring timely delivery of products to demand points. Optimizing transportation routes and capacities can reduce shipping costs and improve customer satisfaction.
- **Capacity Planning**: Effective capacity planning involves evaluating production capacities and adjusting them to meet fluctuating demand. Understanding production constraints and demand patterns helps in making informed decisions about resource allocation and facility utilization.

- **Trade-offs and Decision Making**: Supply chain optimization often involves trade-offs between different objectives, such as minimizing costs while meeting demand or optimizing production capacities while minimizing resource utilization. Making informed decisions requires evaluating these trade-offs and considering various factors such as costs, capacity constraints, and customer requirements.

In my line of work, which involves software development and project building, methods of constrained optimization can be applied in various ways:

- **Resource Allocation**: Optimizing resource allocation for project tasks, considering factors such as skill sets, availability, and task dependencies, to ensure efficient project execution.
- **Project Scheduling**: Optimizing project schedules to minimize project duration or costs while meeting project constraints, such as deadlines, resource availability, and budget constraints.
- **Portfolio Management**: Optimizing investment portfolios to maximize returns while managing risk within specified constraints, such as investment objectives, risk tolerance, and regulatory requirements.

By applying methods of constrained optimization in these areas, we can improve operational efficiency, maximize resource utilization, and make data-driven decisions to achieve better outcomes.