Simulation of Pareto-optimal solution for Stakeholders of Lake Maggiore

*ILO-6. Multi-Objective Optimization and Visualization*

Written By:

Bryce Mihalevich

Prepared For:

David Rosenberg

CEE6490 – Integrated River Basins/

Watershed Planning and Management

March 22, 2016

**Introduction**

The management of water resources are heavily influenced by the objectives of associated stakeholders. However, it is common that not all stakeholder objectives align with one another’s and therefore tradeoffs must be made to resolve accommodate respective stakeholders. One method of resolving these objective conflicts is by using Pareto optimality and multi-dimensional data visualization (MDDV) and analysis tools. These tools were used in this assessment to simulate four stakeholders, flood protection, irrigation, hydropower, and recreation of Lake Maggiore, Italy, and three reservoir operation rules. This report demonstrate that MDDV software can be used to describe Pareto optimal surfaces and provides reservoir operation recommendations that reasonably balance the objectives of the four stakeholders.

**Methods**

Performance indicators and decision variables were provided to students as a .csv file obtainable from Canvas (Rosenburg, 2016). Data was loaded into a MDDV software called DiscoveryDV (DecisionVis LLC, 2014). Using this software, the data was explored by changing the dimension variables and performing a Pareto sort of the results. Marking was used to visualize the minimal points of a performance indicator against decision variable (Figure 1). Since irrigation and hydropower share performance indicators (Figure 2) only one was evaluated. Once each performance indicator was marked for each decision variable a 3D plot was created using flood, irrigation, and recreation indicators (Figure 3). This plot allowed a reasonable reservoir operation recommendation to be made. Questions asked during the lab exercise are provided in Appendix 1.

**Results and Discussion**

Analysis of the data after Pareto sorting and marking optimal points, revealed a viable solution of the three decision variables (x1: 0.699; x2: 68; x3: 0.667). In turn, the stakeholder tradeoffs from this recommendation are 2.61 m, 10.46 m3/d, 10.46 m3/d, and 5.23 m3 for average flood intensity, unmet hydropower demand, unmet irrigation demand, and average storage deficit, respectively. While this solution was chosen from many Pareto optimal points, this solution provides minimal tradeoffs to each stakeholder. These values represent a tradeoff of 10.82%, 9.29%, 9.29% and 45.48%, respectively, above the minimum values of each performance indicator. I believe that this solution is acceptable because it values food availability, power, and safety highest. I see these as being essential to sustain life and good health while I believe recreation demand to be

**Conclusion**

**References**

Rosenberg, David (2016). HW06\_alts.csv. Accessed from Utah State University Canvas for CEE 6490 - Integrated River Basins/ Watershed Planning and Management.

DecisionVis LLC (2014). DiscoveryDV, Version 0.42. Accessed from https://www.decisionvis.com/

Mihaelvich, Bryce (2016). GitHub Repository for Water Resources CEE6490. https://github.com/brycemihal/water\_resrouces\_CEE6490/tree/master/ILO\_6.

**Appendix 1: ILO – 6 Lab Exercise Questions**

*1.d.iii.a How many visualization dimensions (i.e., objectives) can the software represent?*

Discovery DV can illustrate up to 11 dimensions.

*1.d.iii.b How many dimensions is the Lake Maggorie data set?*

The Lake Maggorie data set contains 7 dimensions.

*1.e. What is the relationship between these two objectives?*

For x: FloodIntensity and y: UnmetIrrDemand there is a week correlation between lower flood intensity and less unmet irrigation demand.

For x: UnmetHydroDemand and y: UnmetIrrDemand there a positive one-to-one relationship.

*2.b. Is there just one optimal point or many, composing a Pareto front?*

For all solutions there are many points included in the Pareto sort, representing the Pareto front. These represent the potential solutions considering respective tradeoffs.

*3. Record your observations.*

The 3D four dimension plot with the performance indicators listed in the lab guidelines creates a Pareto solution around the spatial ideal point located at the bottom right corner with low to high recreation benefit depicted with red to blue markers, respectively (Figure x). Since irrigation and hydropower demand are a one-to-one ratio this plot could be simplified with only one of these performance indicators resulting in a 2D plot with one less dimension (Figure). A configuration of x: FloodIntensity, y: UnmetIrrDemand, z: UnmetRecreationDemand, and c: UnmetHydroDemand provides a 3D four dimension plot where the spatial ideal point is in the bottom back corner and the UnmetHydroDemand is a redundant dimension illustrated with red to blue markers in the same direction of UnmetIrrDemand (Figure).