Using fuzzy logic to provide decision support for water distribution

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Rationale

- "Access to water and sanitation are recognized by the United Nations as human rights, reflecting the fundamental nature of these basics in every person's life", (UNHR, Geneva, 27 November 2002, Right to water- Fact sheet No. 35, p. 3).

- The human right to safe drinking water was first recognized by the UN General Assembly and the Human Rights Council as part of binding international law in July 2010. (UN Resolution 64/292, 2010)

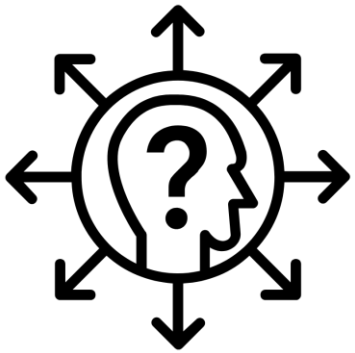
- Trinidad and Tobago is committed to achieving WHO and UN Mandates of equitable supply and adequate water in terms of volume, pressures and quality.

- There exists systemic limitations to the delivery of 24/7 supply, necessitating Intermittent Water Supply (IWS) via scheduling.

Problem

- Trinidad and Tobago produces approximately 243 million gpd, which translates to (187 Imp. Gallons per person per day) for a population of 1.3 million.
- This more than satisfies the WHO/UN minimal stipulation threshold for human daily needs of 7.3 mˆ3 (1606 Imperial Gallons) per person per year (4.3-5.5 Imp. Gallons) per person per day .
- In absolute terms TT is not a water scarce nation.
- Definitions of scarcity:-
  - Absolute scarcity- (Butler & Memon, (2006)
  - Technical and Economic scarcity- (Totsuka et al. 2004)

"Once water supply demands are unable to be satisfied, partially or not at all, in terms of equitable distribution of quantity, pressures and quality, a water scarcity scenario exists" (Kumar, 1998).



Problem cont'd

- Because TT falls in the category of Technical/Economic scarcity, WASA is compelled to implement IWS as a supply/demand management strategy.

- What is Intermittent Water Supply (IWS)?

  "The filling and emptying of water distribution networks, that are otherwise empty, for prescribed or varied periods of time, so as to, temporarily serve users connected to said network." (Vairavamoorthy et al. 2007b, 2008).

Problem cont'd

Reasons for Intermittent Scheduling of water supply

- Demand and supply imbalance
- Demand management strategy
- Network incapacity
- Leakage and water loss control

"Endless combinations of the challenges posed by deficiencies of modified and adapted water supply systems are the very reasons for intermittent water supply" (De Marchis, et al, 2011).

Additional reasons for Intermittent Scheduling of water supply specific to Trinidad and Tobago

- *Dry Season- Up to 40% Production Loss- Surface Water Sources*
- *Wet Season- Reduced Production from Clogged Screens, Turbidity*
- *Inability to Maximize Annual Rainfall-1800mm-2200mm*
- *Impounding Reservoirs Capacity- Unable to Sustain Dry Season Demand*
- *Comparatively large private water storage capacity*

IWS Solution

- Need for an analytical tool to model IWS conditions
- Traditional mathematical models are inadequate for IWS systems
- Fuzzy Logic is ideal for IWS analysis and decision making

Fuzzy Logic Solution

✓ Operations personnel have varying years of experience and competencies. As disruptions and other IWS systems challenges (uncertainties) arise, each individual will perform possibly different tasks to achieve the identical, preferred outcome (schedule compliance).

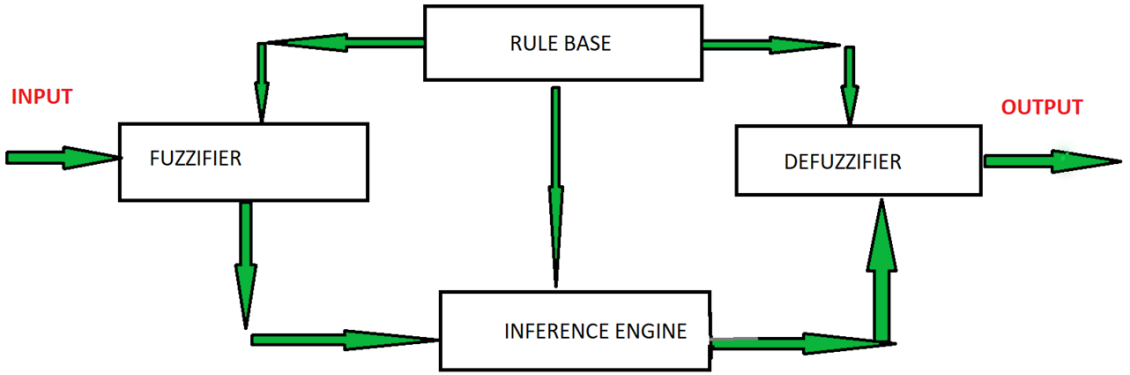
✓ Development of a Fuzzy Logic algorithm is possible by encoding the Operators knowledge/experience and ensuing actions in the form of “If-Then” rules of thumb, capturing the multitude of IWS scenarios.

✓ A Fuzzy Inference system is now able to test how close the result is to the actual reality, by executing the rules created, and producing an approximate output.

✓ Manipulating the IWS inputs, that the control rules process, is an example of how Fuzzy Logic can be used to manage a non-linear system, whereby control rules are developed via a linguistic system.

The FL system

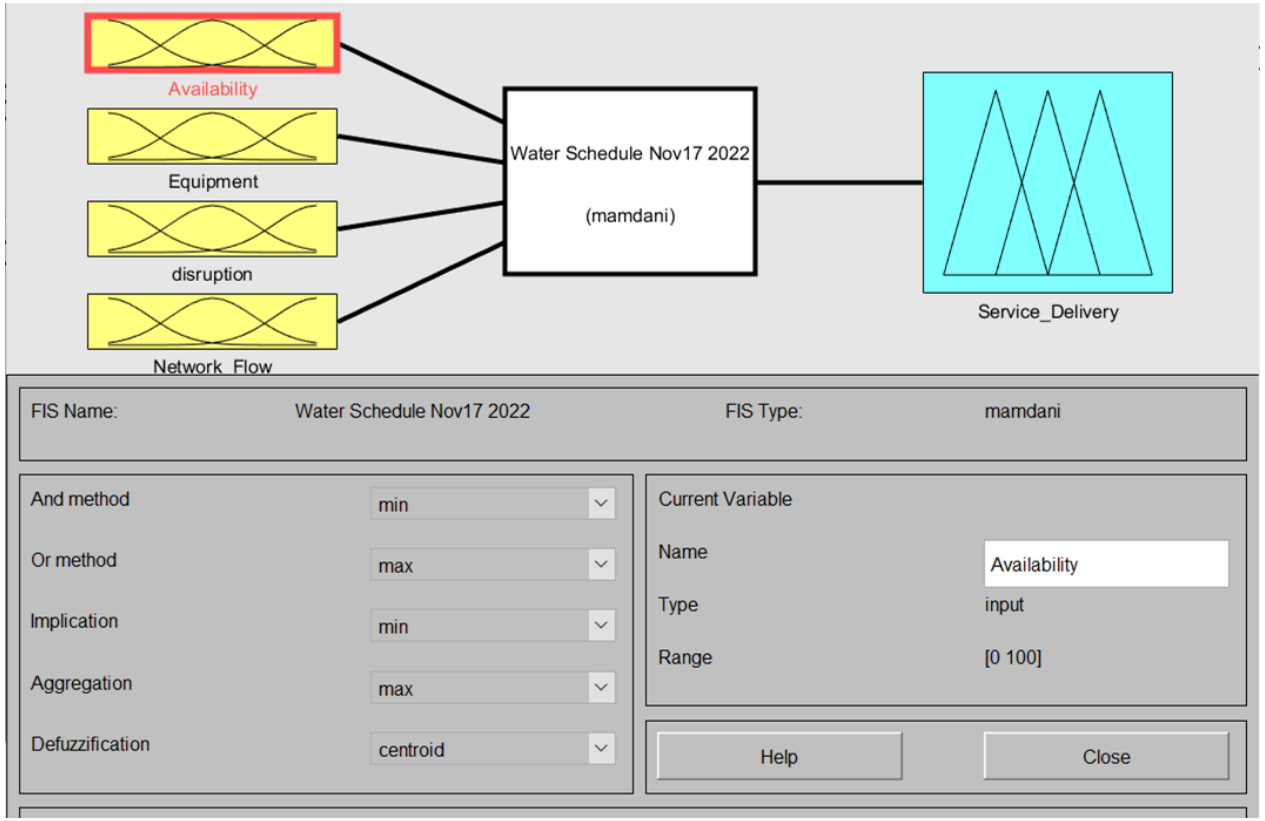
- Inputs – Availability, Equipment, Disruption, Network Flow
- Fuzzy Inference System
- Defuzzifier – Mamdani
- Outputs – Service Delivery



FUZZY LOGIC ARCHITECTURE

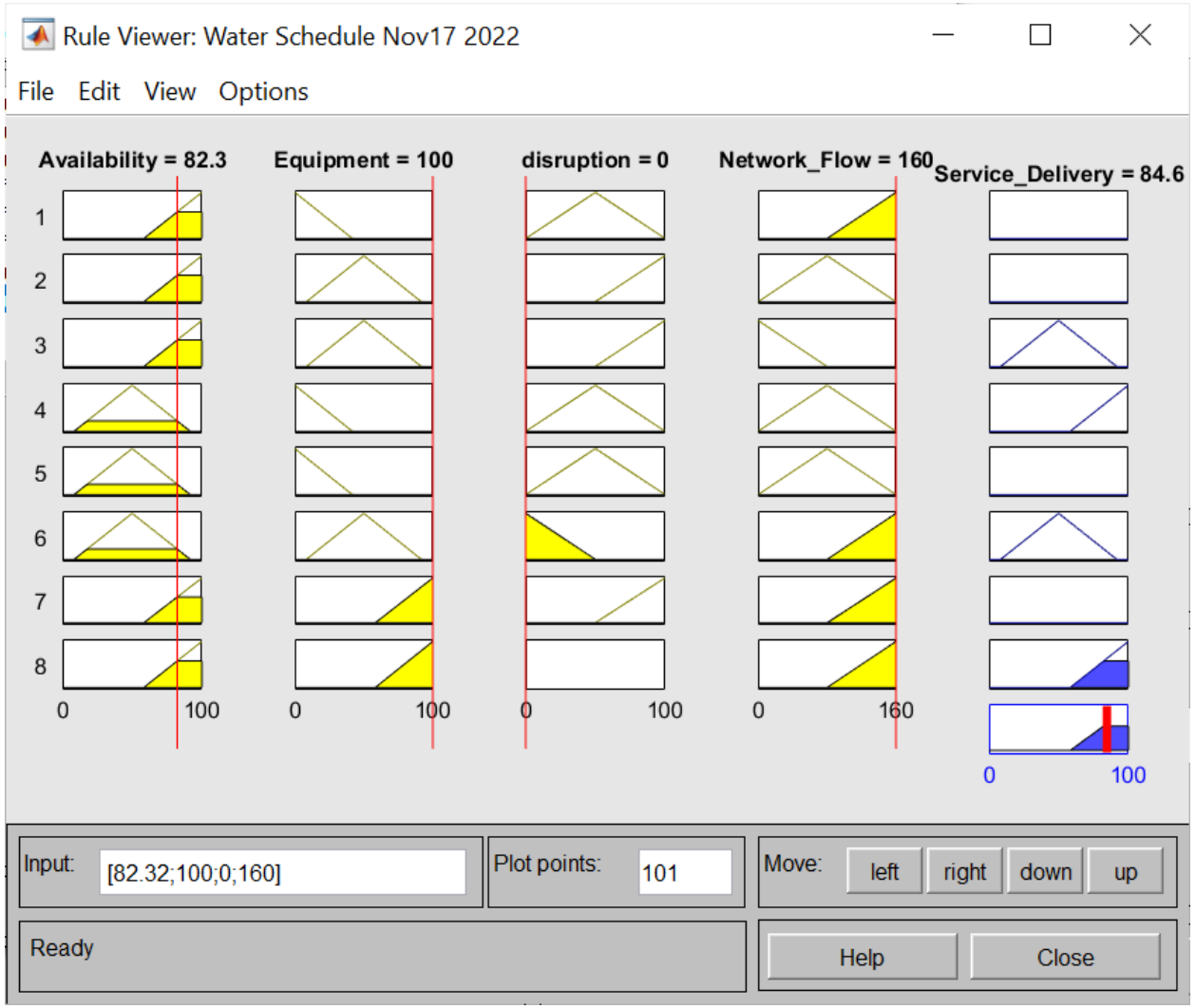
Method

- Intensive literature review regarding regional and international systems
- Interviews with multiple levels of staff at WASA – operators on distribution network, managers who look at reports detailing challenges, decision makers, schedule planners
- Collection of data for a network in the South region
- Use of Matlab to code the FL system
- Simulate and test the system with Matlab, compare results to that obtained by operators



The FL system cont'd

Initial Testing



Conclusions

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- The decision support system could mimic the decisions of trained operators in the first instance
- Fuzzy logic proved to be a useful tool in designing the decision support system
- For this tool to be effective, it would require some level of automation in the IWS distribution network
- It has the potential for providing a consistent service delivery as per the supply available

Recommendations

- Add another layer of granularity to design – go down to the “actual” valving level
- Simulation and further testing accordingly

References

- Butler & Memon, 2006
- Kumar, 1998
- De Marchis, et al, 2011
- Totsuka et al. 2004
- UNHR, Geneva, 27 November 2002, Right to water- Fact sheet No. 35, p. 3
- UN Resolution 64/292, 2010
- Vairavamoorthy et al. 2007b, 2008