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# On the Use of Fuzzy Multi-Objective Optimization Versus Efficiency Analysis: *An Application to the Nurse Scheduling Problem*

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# Motivation

- Nurse Scheduling Problem
  - Nursing workforce shortage: supply < demand
  - Quality of care & patient safety concerns → legislation specifying nurse to patient ratios
  - Services sector = 80% GNP & 70% workforce
- Multi-Criteria Decision Analysis
  - GP, AHP, LP, etc.
- Fuzzy Logic

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# Presentation Outline

- Literature Review
- Methodology
- Model
- Results & Conclusions
- Limitations & Future Research

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# Literature Review

- Nurse Scheduling Problem (NSP) concept
- Findings:
  - Search Routines (Aickelin et al., 2004; Dowsland et al., 2000; Rosenbloom et al., 1987)
  - Single Objective
    - Service-based objectives (Jaunard et. al, 1998; Dowsland, 1998)
    - Economic-based objectives (Bard et al., 2005)
  - MCDM:
    - Goal Programming (Azaiez et al., 2005; Ferland et al., 2001; Ozkarahan et al., 1988)
    - Bi-Criteria IP Model (Wright, et al. 2006)
- Opportunities

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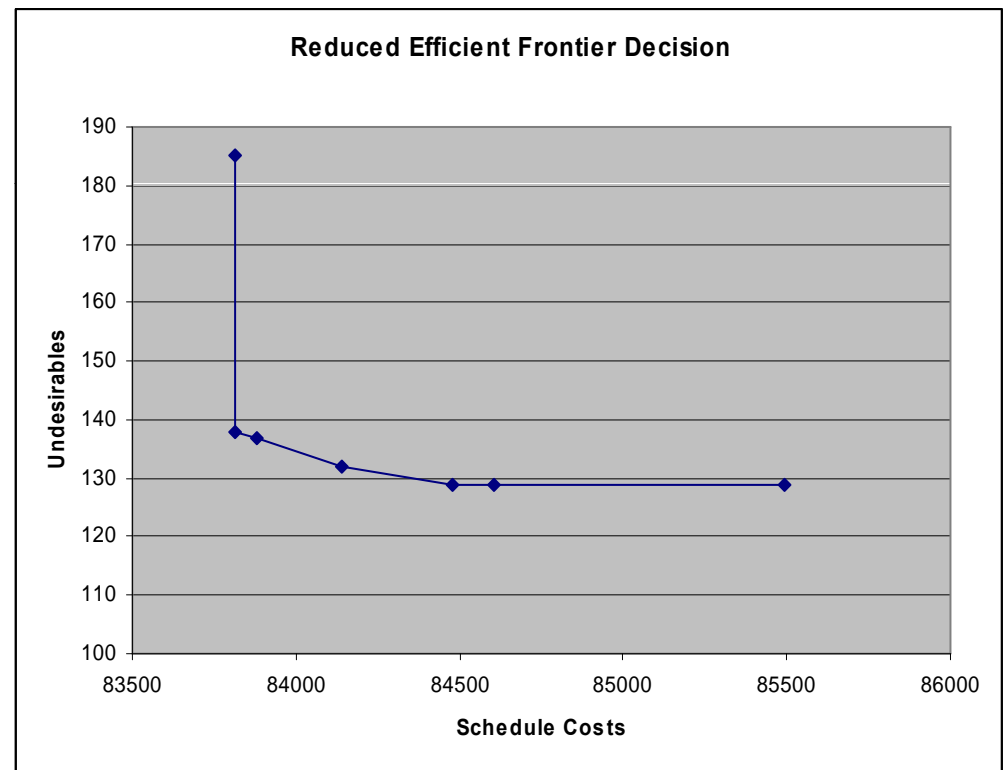
# Research Questions

- How can we develop a NS model that:
  - includes more than two objectives, and
  - incorporates the DM knowledge *a priori*?
- How does a fuzzy optimization approach compare to an efficient frontier approach in MCDM?

# Methodology

- Wright et al. efficient frontier model
  - 40 nurses & 35 shifts

$\beta$	Nurse Wages	Undesirable Shifts and WEs
1	83811	185
1	83811	138
1.001	83878	137
1.004	84143	132
1.008	84477	129
1.01	84608	129
10	85490	129



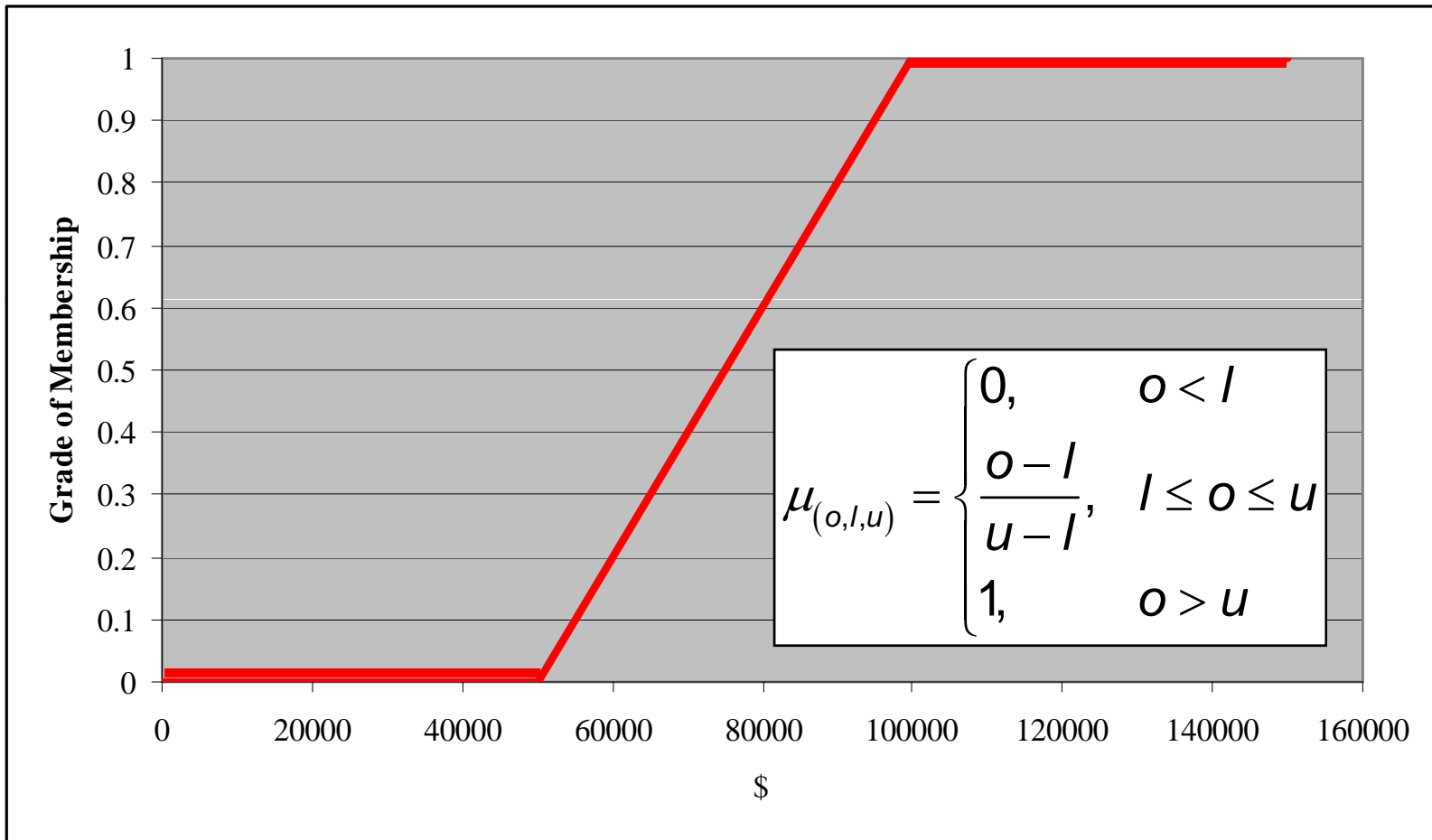
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## Methodology (cont.)

- Fuzzy logic:
  - DM tool
  - Representation of vagueness
  - Format appealing to managers
  - More natural representation of preferences
  - Basic concept:
    - Fuzzy membership function

# Methodology (cont.)

## Profits Membership Function

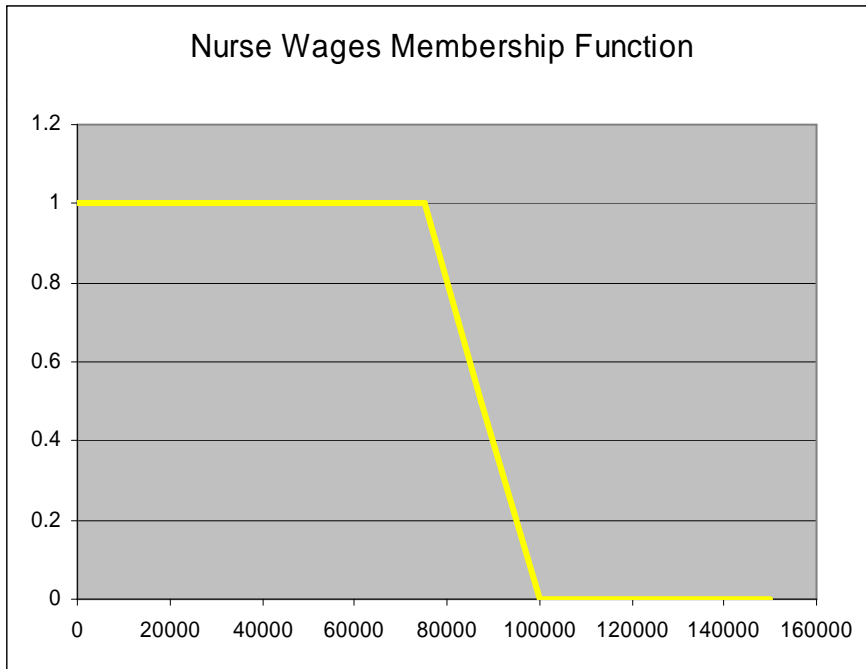


# Methodology (Cont.)

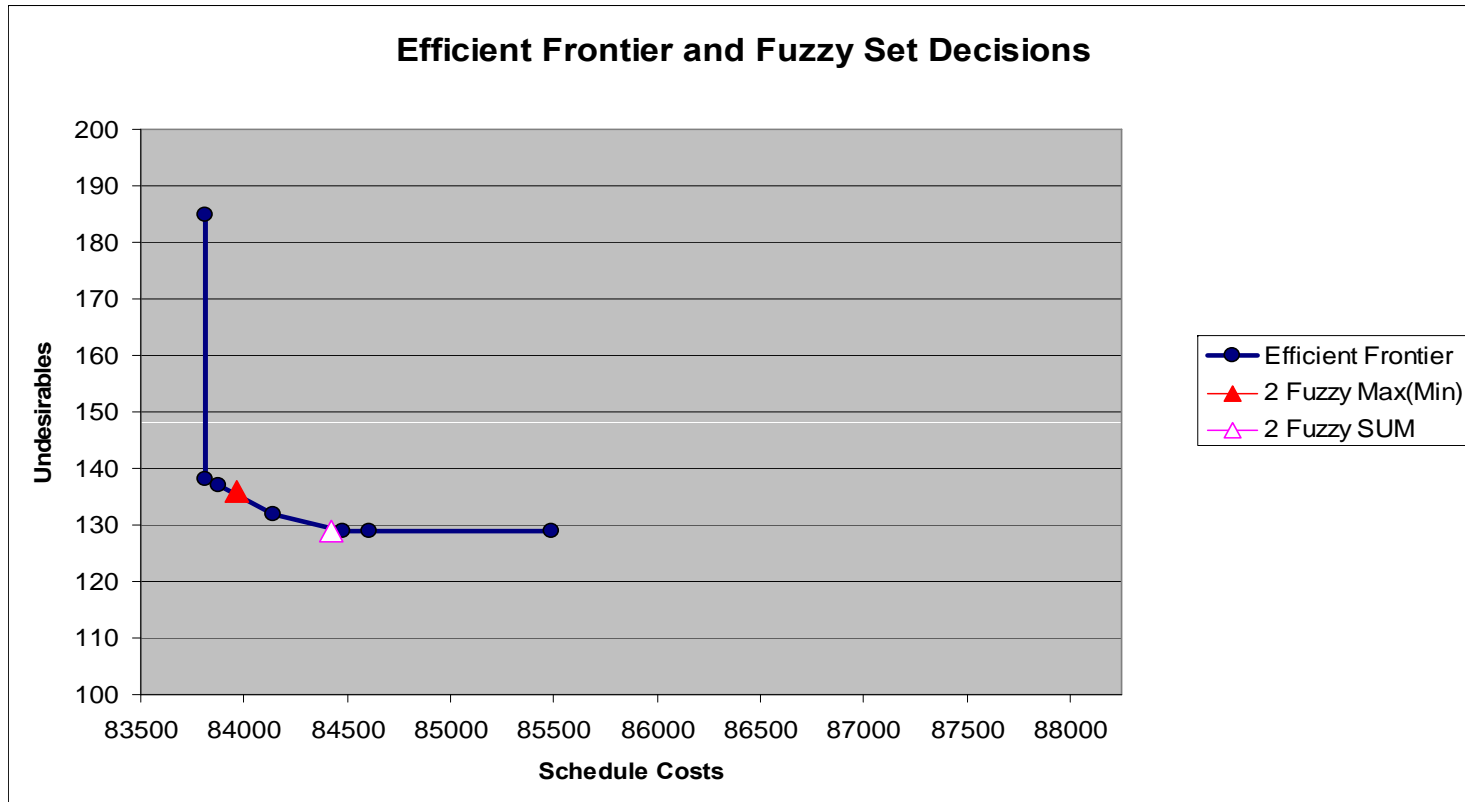
- Models:
  - Fuzzy two objective model
    - Undesirables
    - Nurse wages
  - Fuzzy four objective models
    - Scenario A: decompose two objective model
    - Scenario B: modified DM preferences
  
- Operators:
  - Max(Sum)
  - Max(Min)
  
- Software:
  - Premium Solver Platform

# Fuzzy Two Objective Model

	Efficient Frontier		Fuzzy Objective	
	Lower Limit	Upper Limit	Highly Satisfied	Not Satisfied
Nurse Wages	Minimize		\$ 75,000	\$ 100,000
Undesirables	N/A	323	100	200



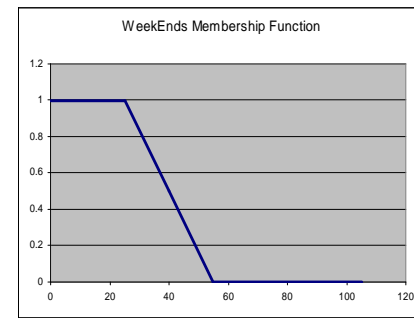
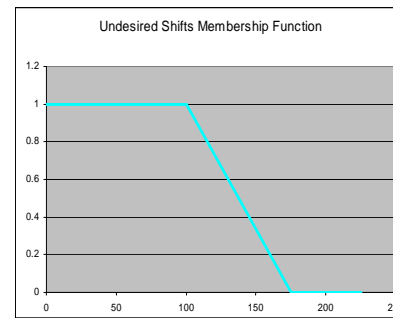
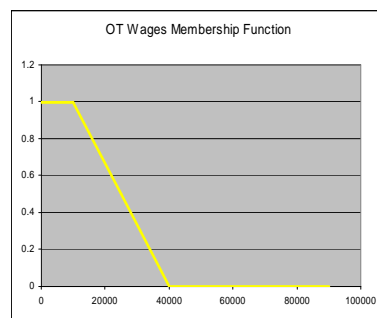
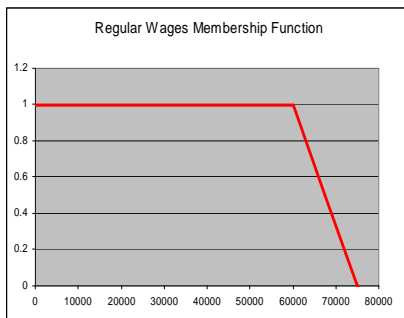
# Results – 2 Objective Comparison Model



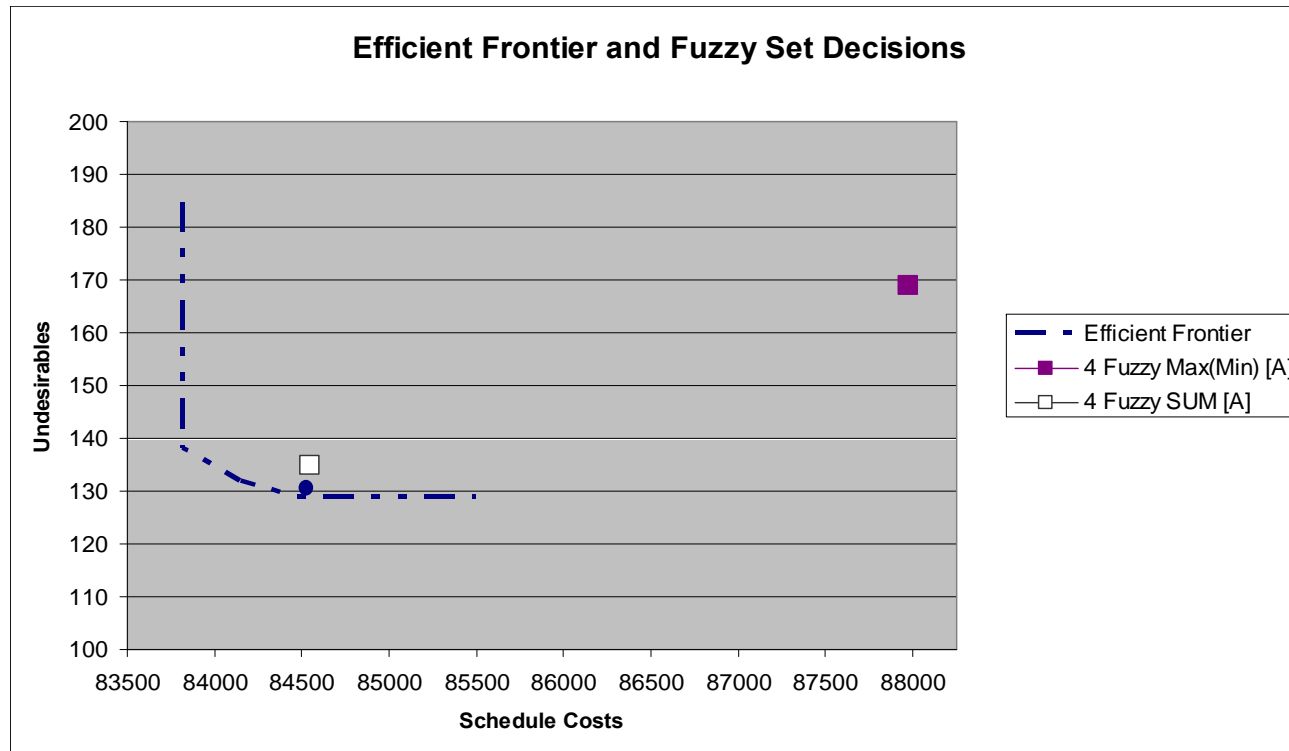
Results	Nurse Wages	Undesirables
Max(Min)	\$ 83,967	136
Max(Sum)	\$ 84,424	129

# Fuzzy Four Objective Model – Decision A

	Efficient Frontier		Fuzzy Objective	
	Lower Limit	Upper Limit	Highly Satisfied	Not Satisfied
Regular Wages	Minimize		\$ 60,000	\$ 75,000
OT Wages			\$ 10,000	\$ 40,000
Undesired Shifts	N/A	218	55	175
Undesired WE	N/A	105	25	100



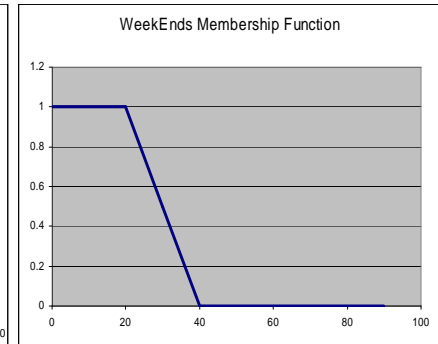
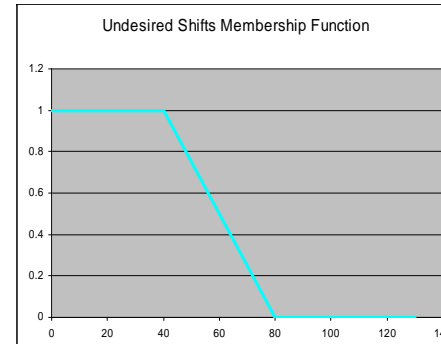
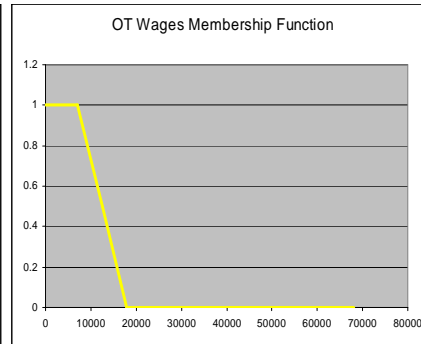
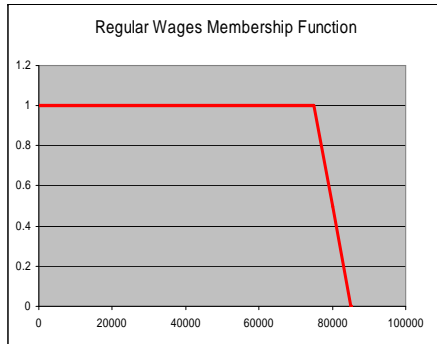
# Results – 4 Fuzzy Objectives (Decision A)



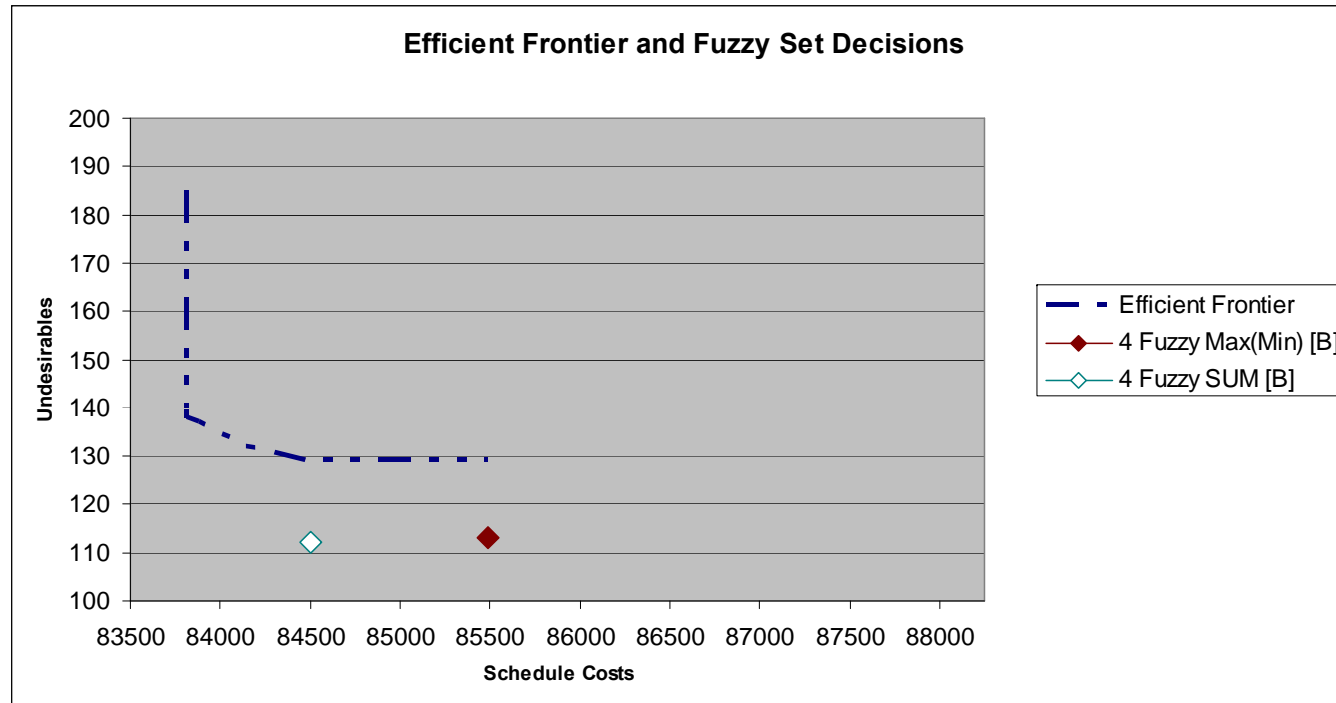
Results	Nurse Wages		Undesirables	
	Regular	OT	Shifts	WE
Max(Min)	\$ 66,014	\$ 21,958	130	39
Max(Sum)	\$ 66,752	\$17,798	100	35

# Fuzzy Four Objective Model – Decision B

	Efficient Frontier		Fuzzy Objective	
	Lower Limit	Upper Limit	Highly Satisfied	Not Satisfied
Regular Wages	Minimize		\$ 75,000	\$ 85,000
OT Wages			\$ 7,000	\$ 18,000
Undesired Shifts	N/A	218	40	80
Undesired WE	N/A	105	20	40



# Results – 4 Fuzzy Objectives (Decision B)



Results	Nurse Wages		Undesirables	
	Regular	OT	Shifts	WE
Max(Min)	\$ 67,853	\$17,636	79	34
Max(Sum)	\$ 67,853	\$16,654	79	33

# Conclusions and Implications

- 2 Objective fuzzy model ➡ similar results
  - Validation and Verification tool
- 4 Objective fuzzy model ➡ better?

## Advantages:

- Multiple objectives (  $> 2$  )
- ↑ granularity
- DM preferences *a priori*
- Natural representation of DM knowledge
- Simple and generalizable

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## Limitations

- No empirical validation using actual DMs
- Only tested nurse scheduling problem
- Only explored linear membership functions

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# Future Research

- Empirically validate model using actual DMs
- Shape of membership functions
  - Nonlinear effects
- More objectives
- Other service application areas

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# Summary

- Fuzzy optimization approach
  - > 2 objectives
  - DM preferences *a priori* rather than *post hoc*
- Results validate fuzzy approach
- Future research opportunities
  
- Q & A