Automated Dynamic Planning and Execution (ADP&E) For Partially Observable Game Models: Search and Rescue Application

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Outline

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2. Background
3. Objectives
4. Problem Domain
5. ADP&E Approach
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    ii. Problem Scope (Model)
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Motivation

- *An extension of previous work that demonstrated the viability of using an evolutionary search to play the game RISK*
- *RISK is a non-cooperative stochastic game model, where searching deeply for viable alternatives weighs strongly in game play (much like in chess)*
- *Wanted to extend the approach for partially observable games, thus a Search and Rescue application was developed (explained in detail later)*
- *To keep things simple at first, game is cooperative with no looting or competition from multiple planners*
- *Thus, there is only one player or planner used in this case and the objective is to be as efficient as possible (i.e., best time), given partial information*
- *Unlike RISK, search was limited in depth, because planning in a unknown environment deeply produced plans that required constant re-planning*
- *Instead, work concentrates on increasing its decision-making capabilities in a short-time scale and planning for many simultaneous vehicles (i.e., agents)*

Background

The *planning applications* of concern here are ones with the following characteristics:

- Available model of the environment (real or game)
- Known state transitions (possibly stochastic)
- Finite set of available actions
- Finite set of measurable goals

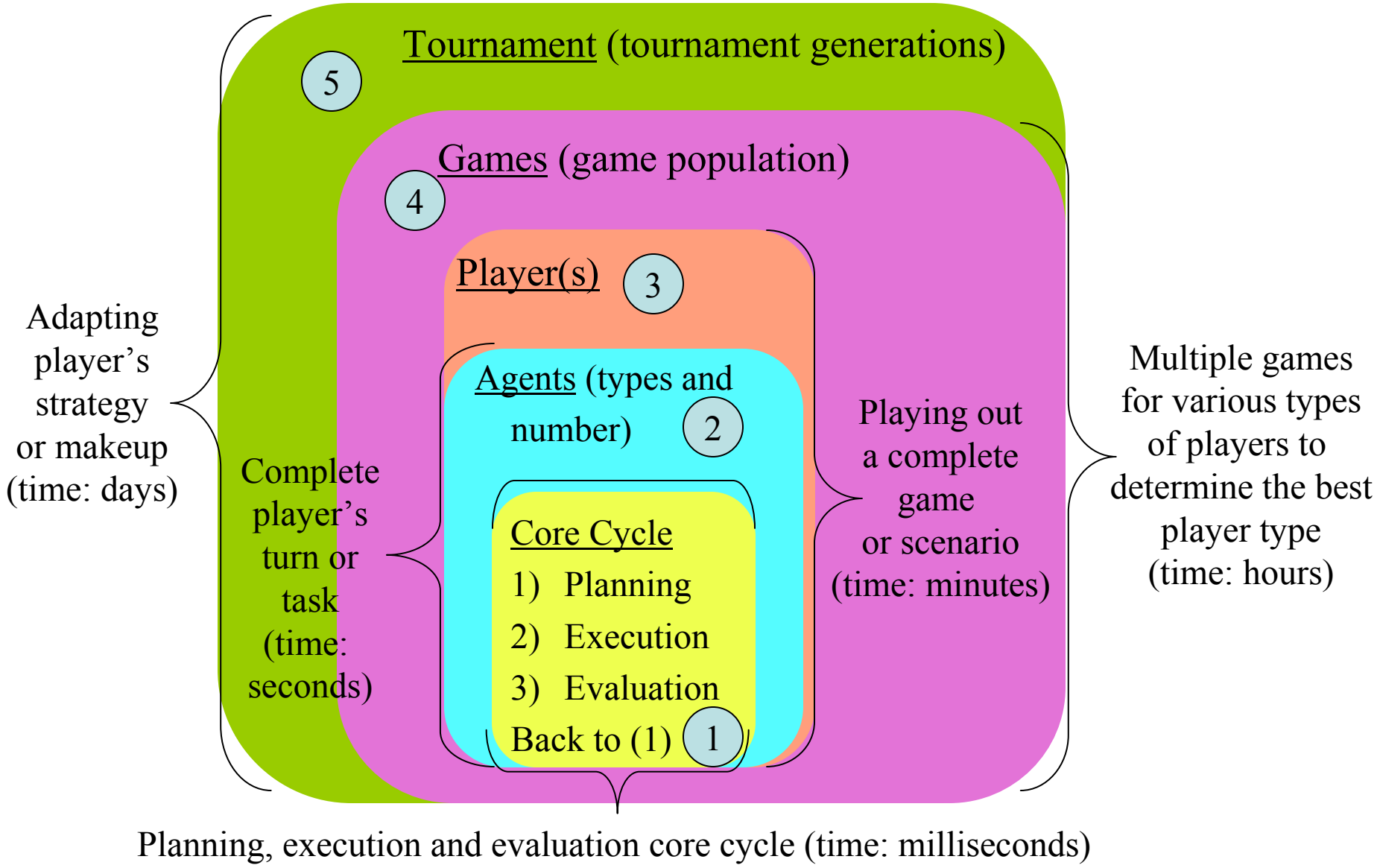
Objectives

(1) develop a well-defined, scalable, flexible, and tractable conceptual model for planning and executing in simulated environments

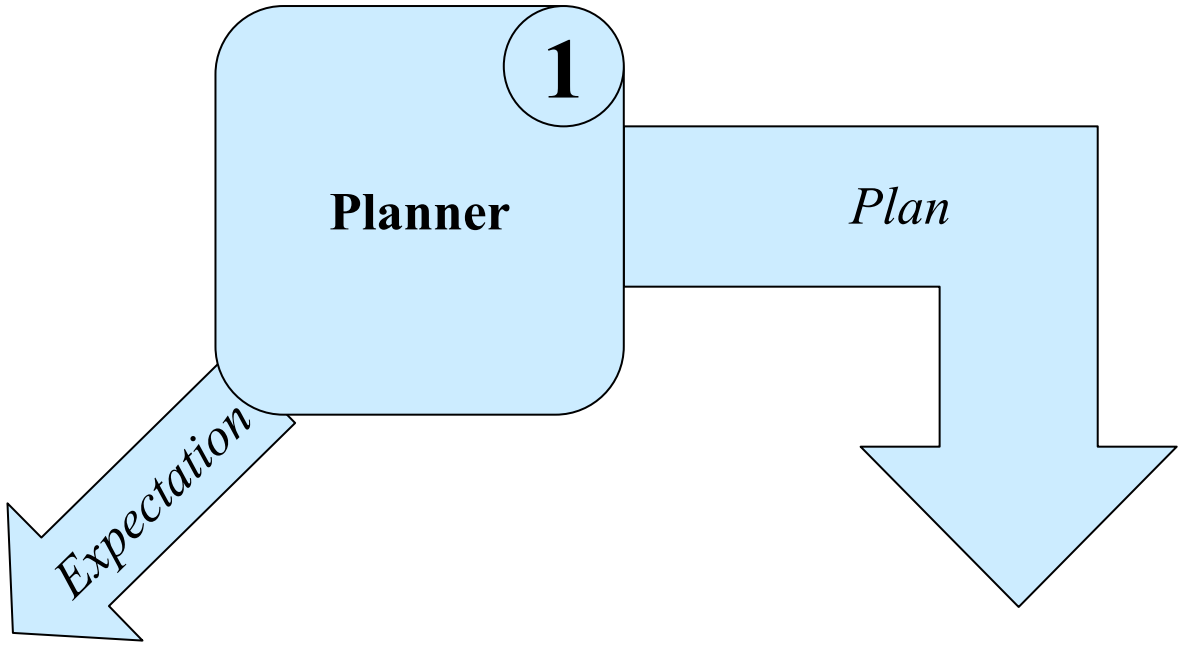
(2) design and implement an ADP&E framework that handles partially observable models well

(3) design and implement a methodology for adapting internal parameters within the ADP&E framework to improve the overall planning process

ADP&E Approach



Planner (Core Cycle Part 1)

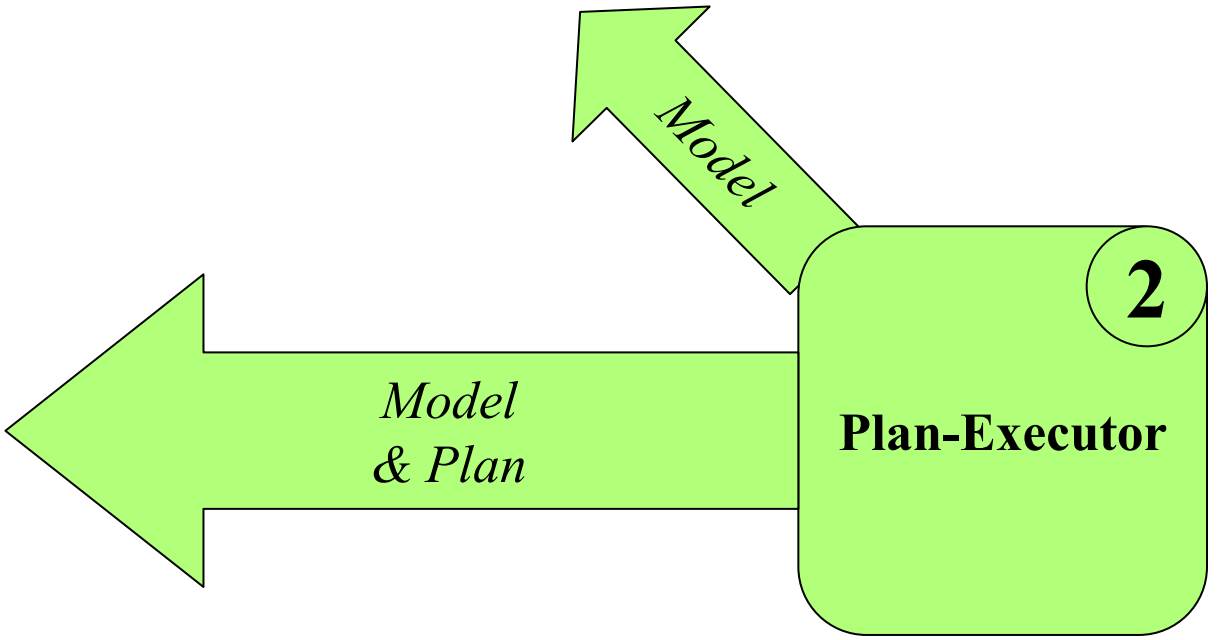


- ***Planner*** generates individual actions and links them together to form plans

- Expectations are the most desirable state achieved of all generated plans as measured by the goals

- The most desirable plan is passed to the plan-executor (part 2) while its expectations are passed to the plan-evaluator (part 3)

Plan-Executor (Core Cycle Part 2)

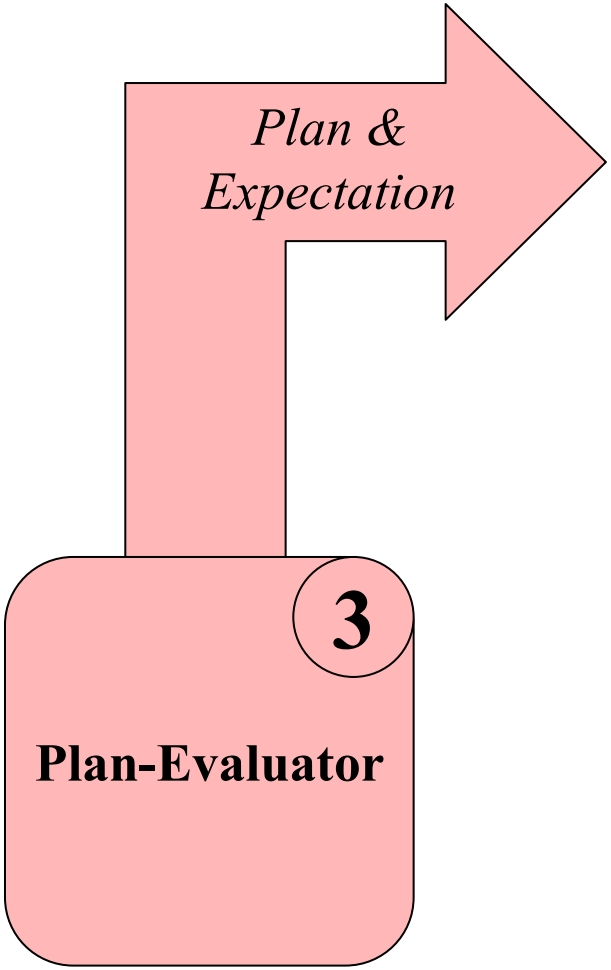


- ***Plan-Executor*** executes the plan in time order for a pre-defined amount of time or task completion

- The model is the simulated environment as sensed by the player

- The remainder of the plan not executed is passed to the plan-evaluator (part 3), while the sensed model changes are passed to both the planner (part 1) and plan-evaluator (part 1)

Plan-Evaluator (Core Cycle Part 3)

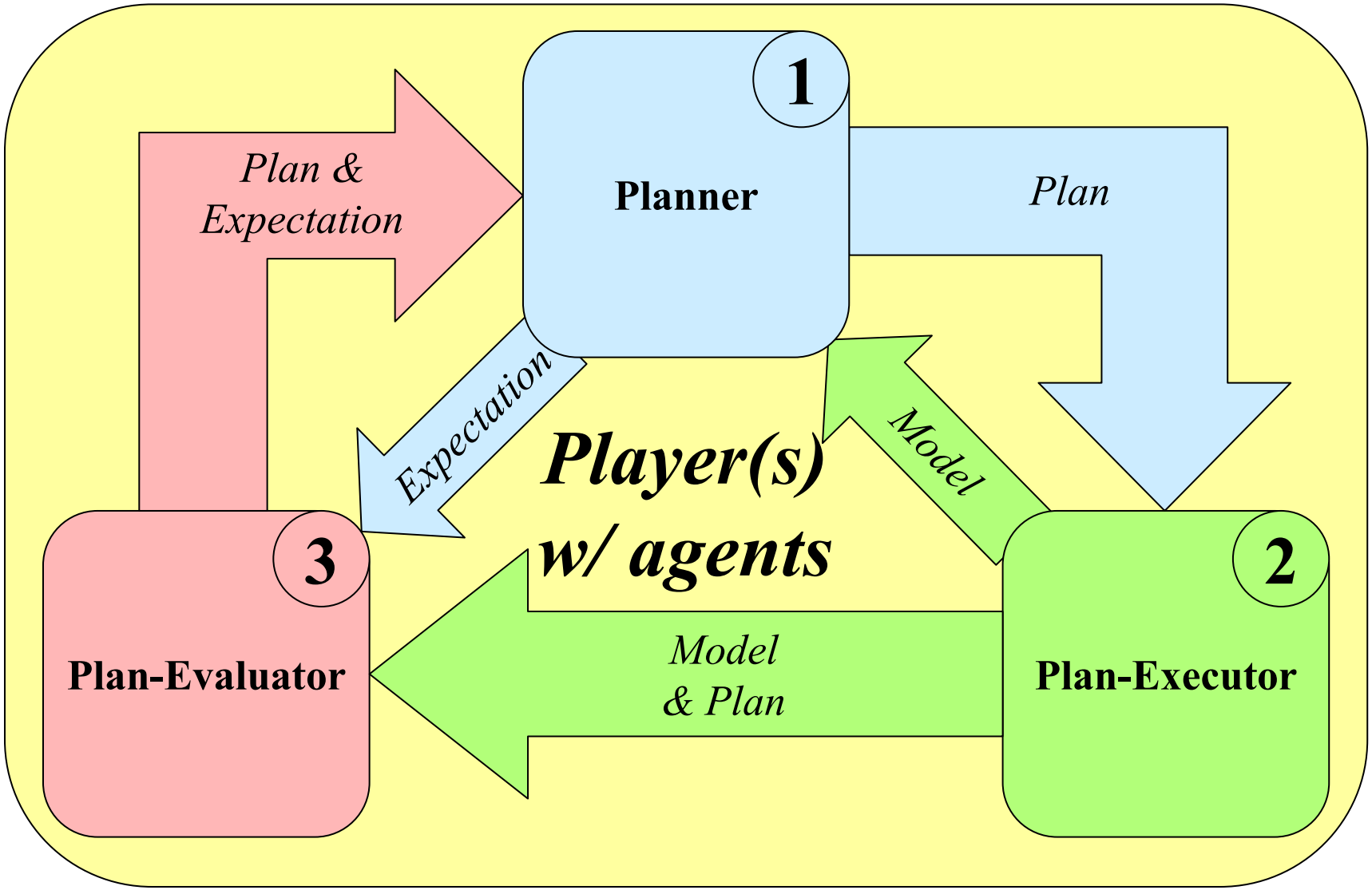


- ***Plan-Evaluator*** evaluates the plan based on model changes and goals

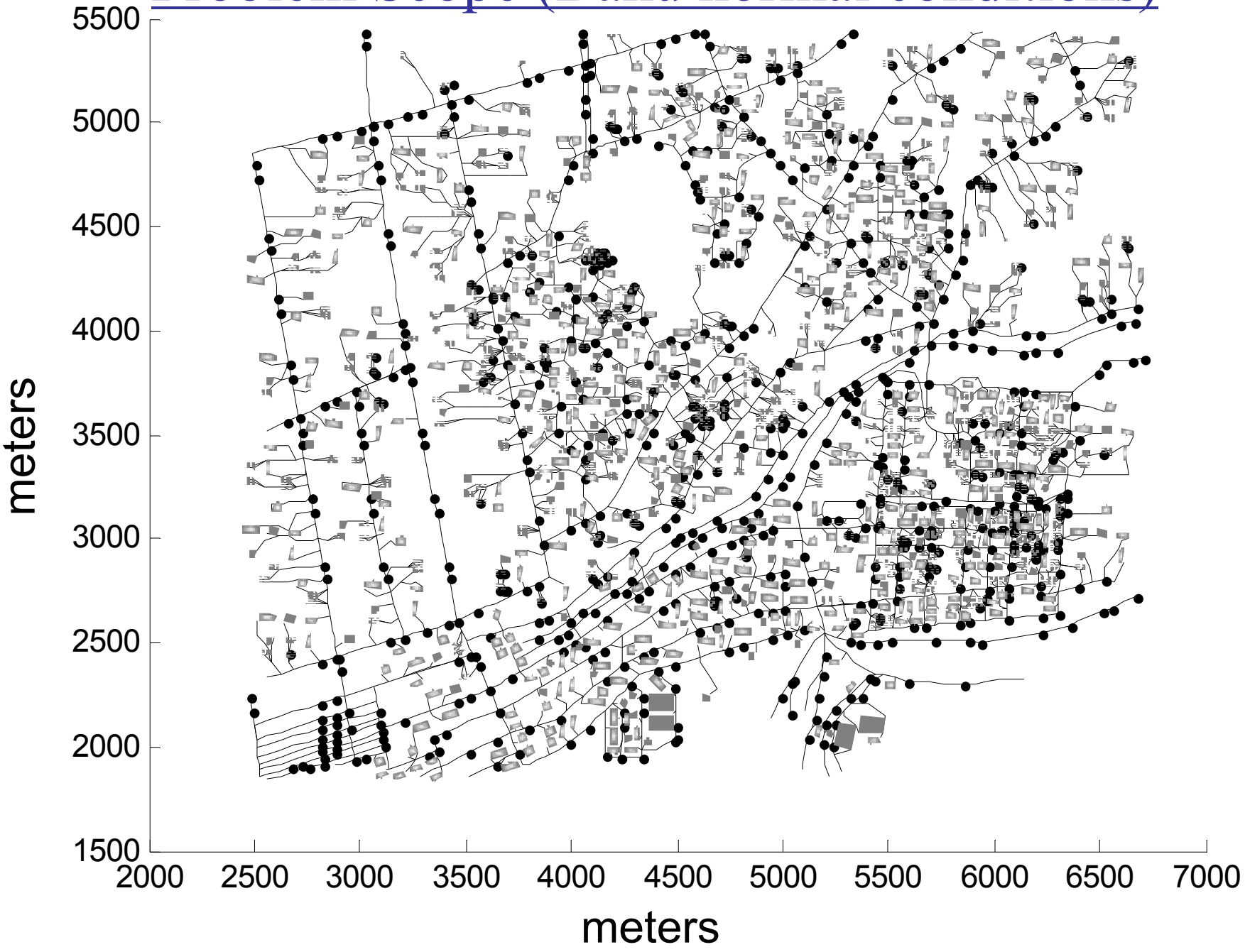
- Expectations are the most desirable state achieved using the remaining plan as measured by the goals

- The evaluated plan and its current expectations are passed to the planner (part 1)

ADP&E Core Cycle



Problem Scope (Baku normal conditions)



Reality Environment Model

Unknown Water Level

- Connectivity model changes
  - Boats (maximum 6040 waypoints: level 0)
  - Busses (maximum 5821 waypoints: level -28)
- Some buildings under water
- Building floor access changes
- Helicopters (constant 5223 waypoints)

Trees down (Connectivity model changes for Busses)

People in Unknown Locations (20,000 survivors)

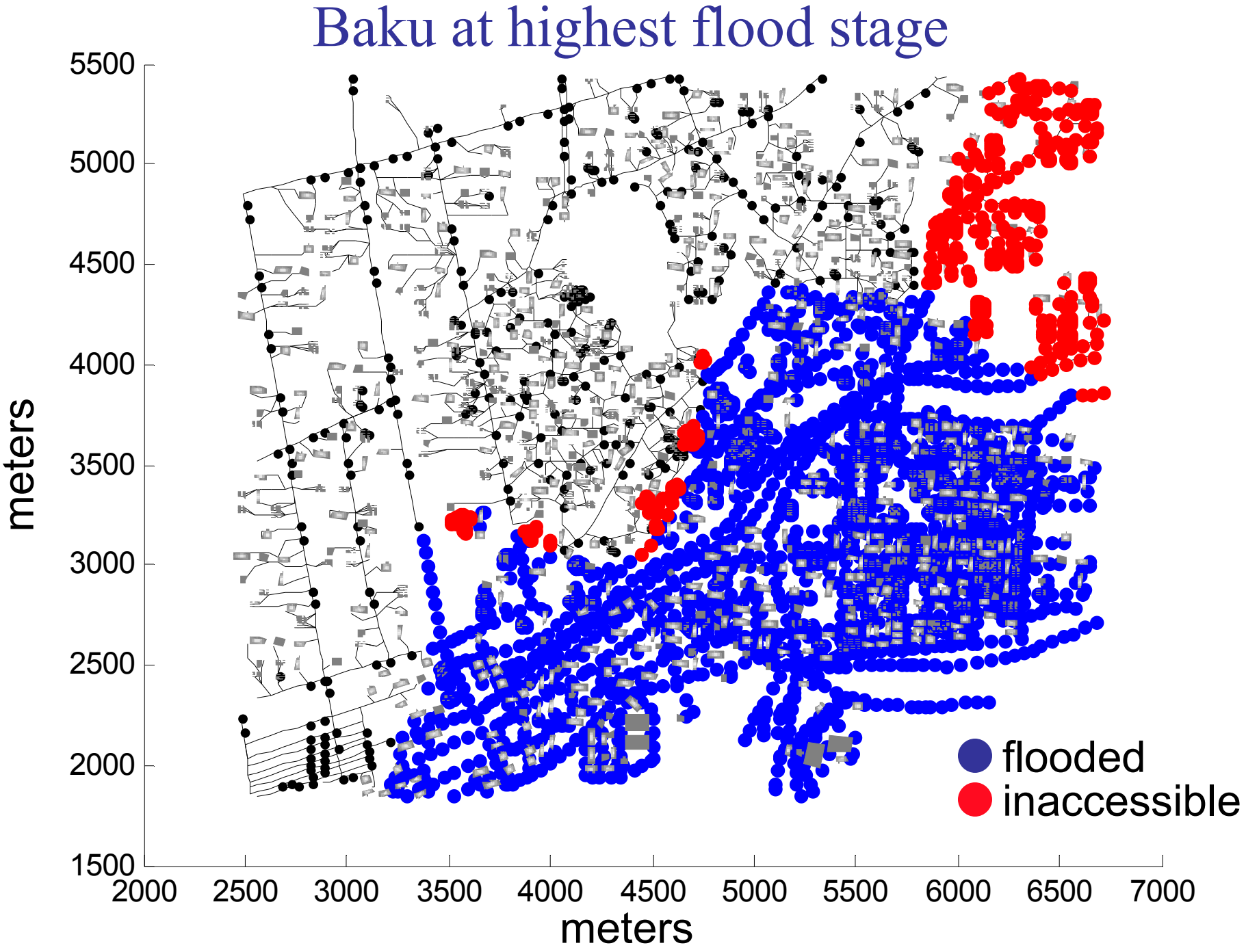
- Randomly select floor (above water) to place survivors
- Randomly select number of people to place (up to 10)

Vehicle Bases

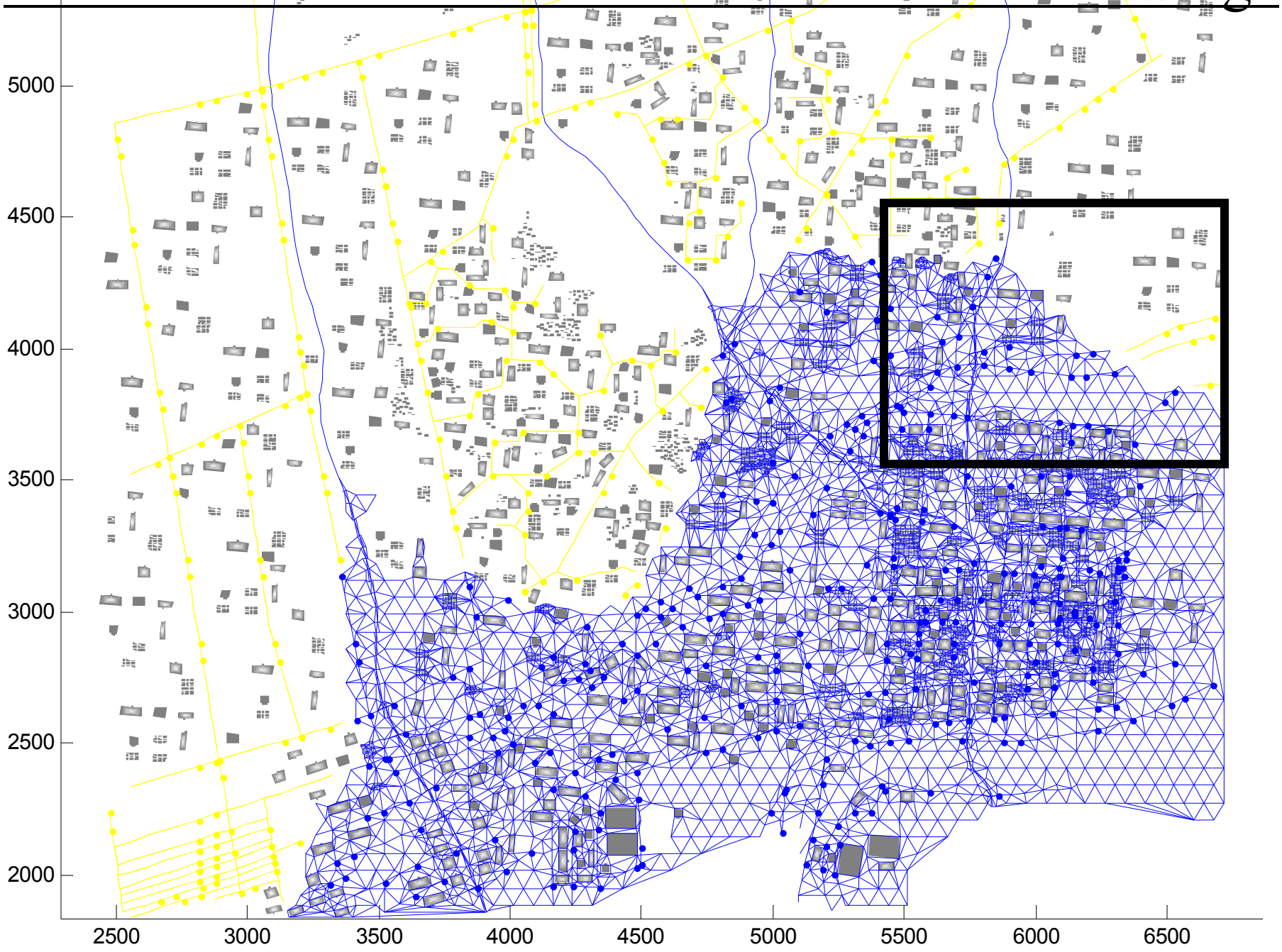
- 4 boat bases up river
- 1 bus station on high ground
- 1 helicopter pad

Pick Up Locations

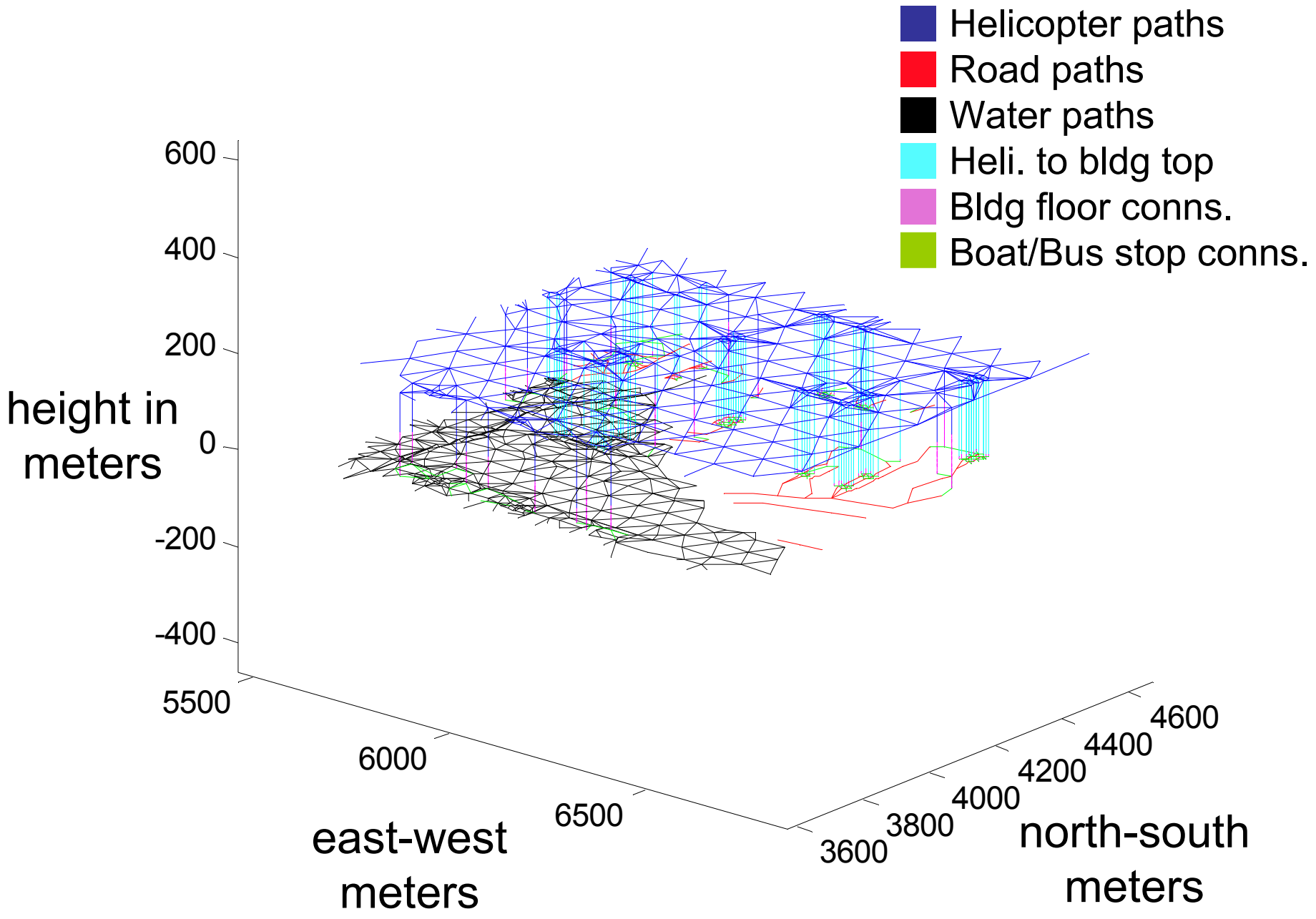
- 902 maximum boats stops
- 2135 maximum bus stops
- 3649 maximum roof tops


Baku at highest flood stage
meters
meters
5500
5000
4500
4000
3500
3000
2500
2000
1500
2000
2500
3000
3500
4000
4500
5000
5500
6000
6500
7000
flooded
inaccessible

True Boat and Bus Access at Maximum Flood Stage



Waypoint Connection Model at Maximum Flood Stage



Agent Actuators

Boats (Number: 8)

- Speeds (Two): 0 for search/rescue; 30 for travel
- Delivery: go from/to building/base on water path
- Search/Rescue: go near buildings via open water
- Fuel capacity: return to base after 2 hours
- Passenger capacity: 20

Busses (Number: 8)

- Speeds (Two): 0 for search/rescue; 50 for travel
- Delivery: go from/to building/base on road paths
- Search/Rescue: go near buildings via open roads
- Fuel capacity: return to base after 8 hours
- Passenger capacity: 50

Helicopters (Number: 4)

- Speeds (Three): 0 for search/rescue; 30 for survey; 100 for travel
- Delivery: go directly to a building/base
- Search/Rescue: hover over building or land at base
- Survey: go among building to review road/water access
- Fuel capacity: return to base after 1.5 hours
- Passenger capacity: 10 for rescue, 0 for survey

Agent Sensors

Boats (2 state: movement/search)

- Determines Open Routes through tactile interaction (rescue)
- Determines where Survivors are through tactile interaction (search)

Busses (2 state: movement/search)

- Determines Open Routes through tactile interaction (rescue)
- Determines where Survivors are through tactile interaction (search)

Helicopters (2 states: survey/search)

- Determines Open Routes for Boats and Busses through 3D Line of Sight (survey)
- Determines where Survivors are through tactile interaction (search)

Goal: Minimize Temporal Costs

Search Times (seconds)

- Boat Floor Search Time = 300
- Bus Floor Search Time = 200
- Helicopter Floor Search Time = 600

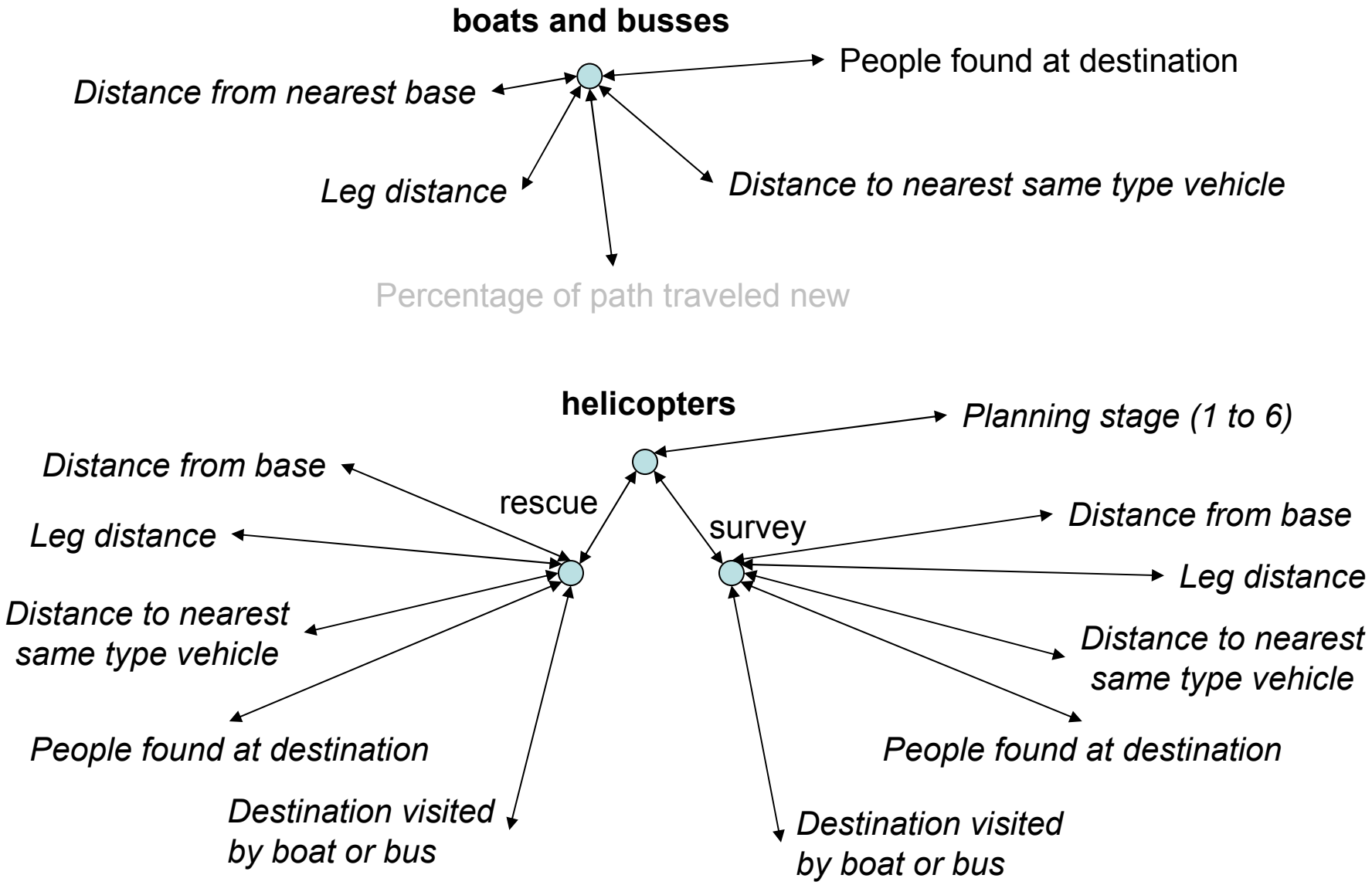
Evacuation Times (seconds/person)

- Boat Evacuate Floor Time = 40
- Bus Evacuate Floor Time = 20
- Helicopter Evacuate Floor Time = 60

Delays (seconds)

- Road Block Delay = 600 (Bus Only)
- Back Track Delay = 60 (Bus Only)
- Drop Off Delay = 300
- Turn Around Delay = 30
- No Bldg Delay = 120 (Boat Only)
- Stop No Search Delay = 60 (Execution and Evaluation Phase Only)
- Base Delay No Orders = 1200
- Travel Delay No Orders = 120

Features Used for Decision-Making



Feature Setup

- With the exception of rescue vs. survey helicopters, each feature has three parameters

- Three parameters are weight, α and β for beta distribution

- Weight is importance of feature and beta distribution determines method of selection of action

Learning: Tournament Play

- Tournaments have 100 players competing
- Twenty best return for next generation
- Next twenty, mutate the weights {4, 4, 5, 5}
- Next twenty, mutate the beta dist. {8, 8, 10, 10} and survey/rescue {6}
- Next twenty, crossover the weights {4, 4, 5, 5}
- Next twenty, crossover the beta dist. {8, 8, 10, 10} and survey/rescue {6}

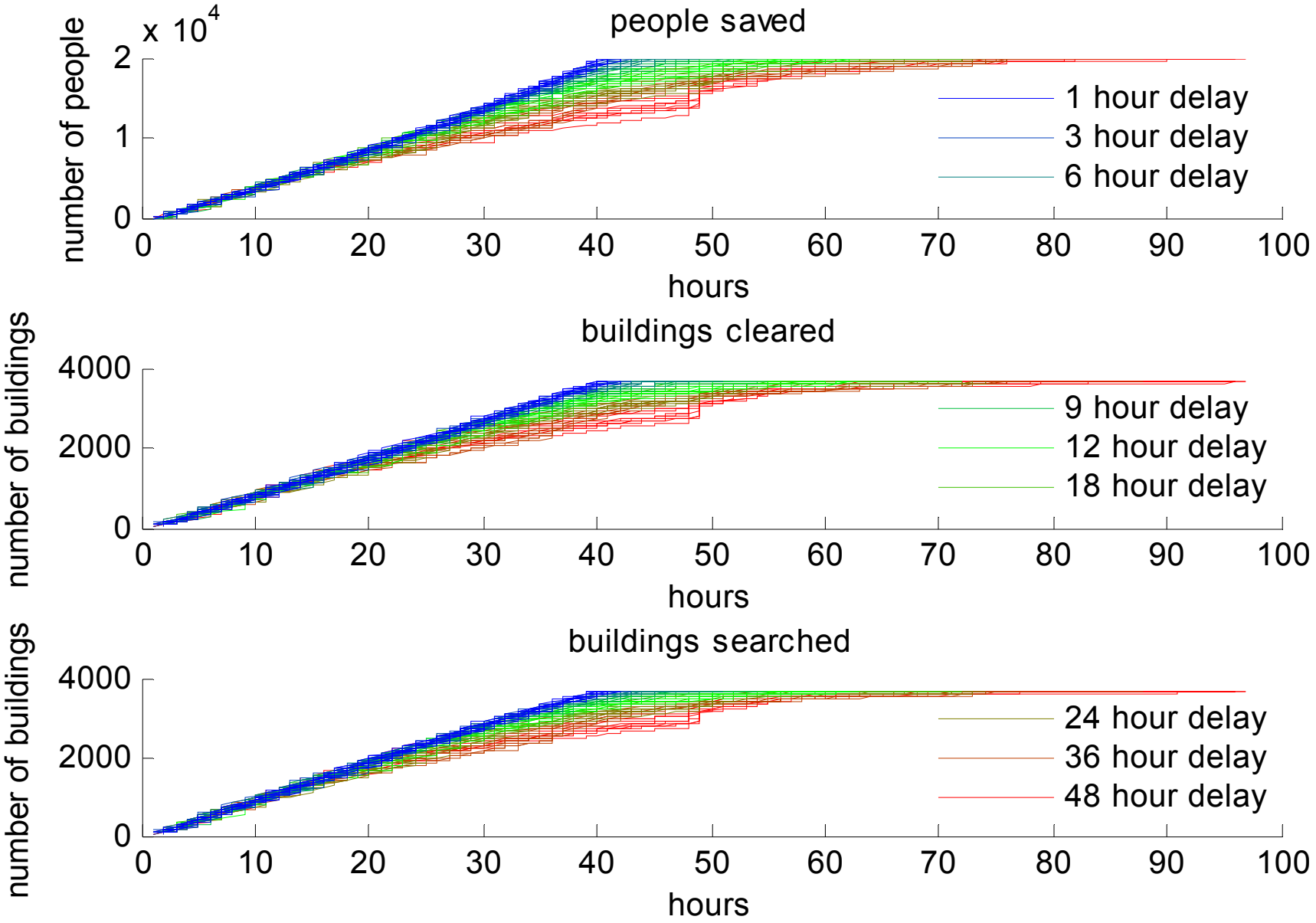
Results

Outline

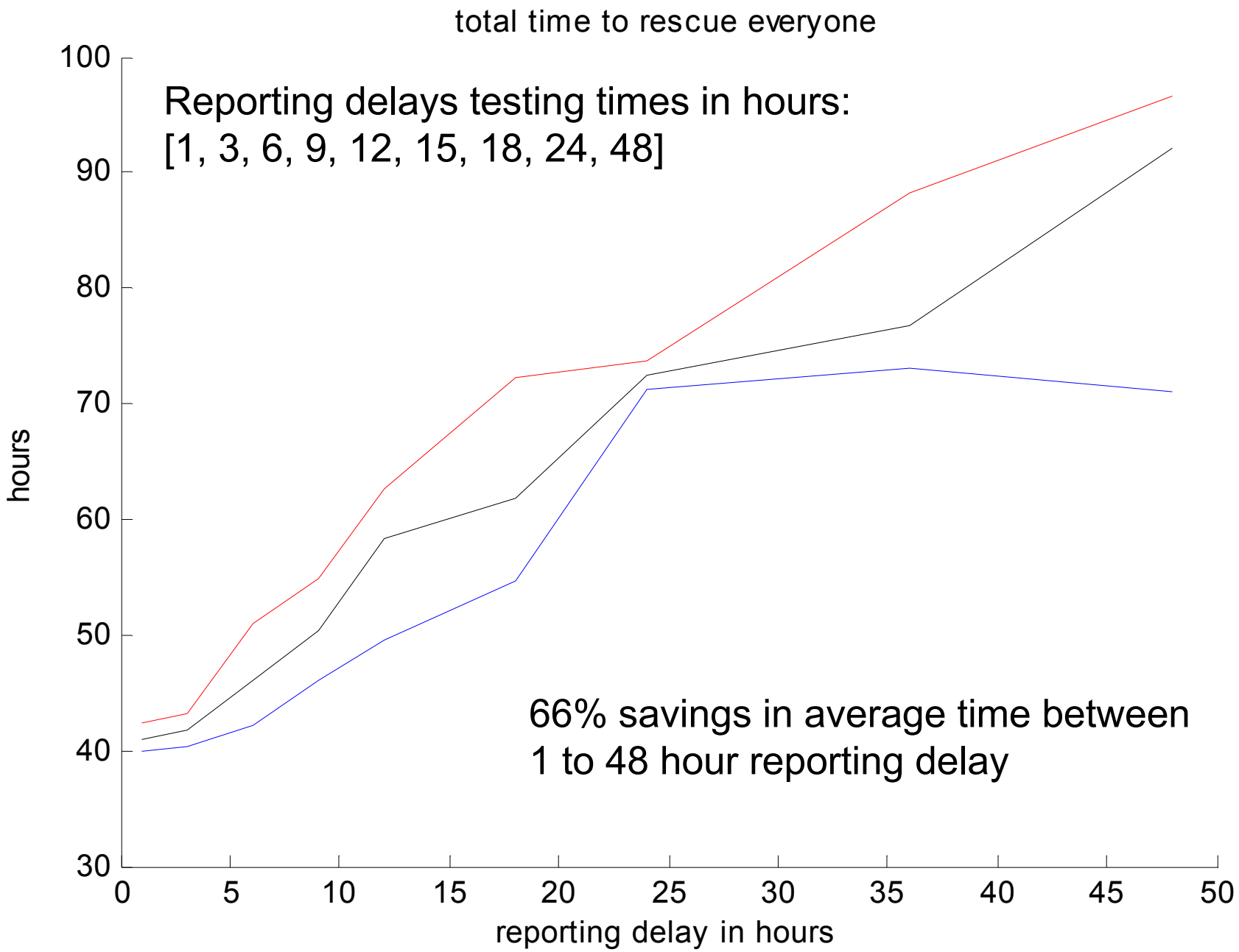
- Planner Model Update (using learned parameters below)

- Learning Decision Parameters
  - Converging 60 parameters
    - 6 to determine how many survey vs. rescue helicopters to deploy (1 parameter for six time phases)
    - 5 weights for each decision feature for both types of helicopters
    - 4 weights for both boats and busses
    - 2 parameters per weight for all vehicles
  - 6 + (5x2) + (4x2) + 2x[(5x2) + (4x2)] = 60

Simulated Results: 10 cases for each reporting delay



Results Summary: Updating Planner Model is Critical



Results

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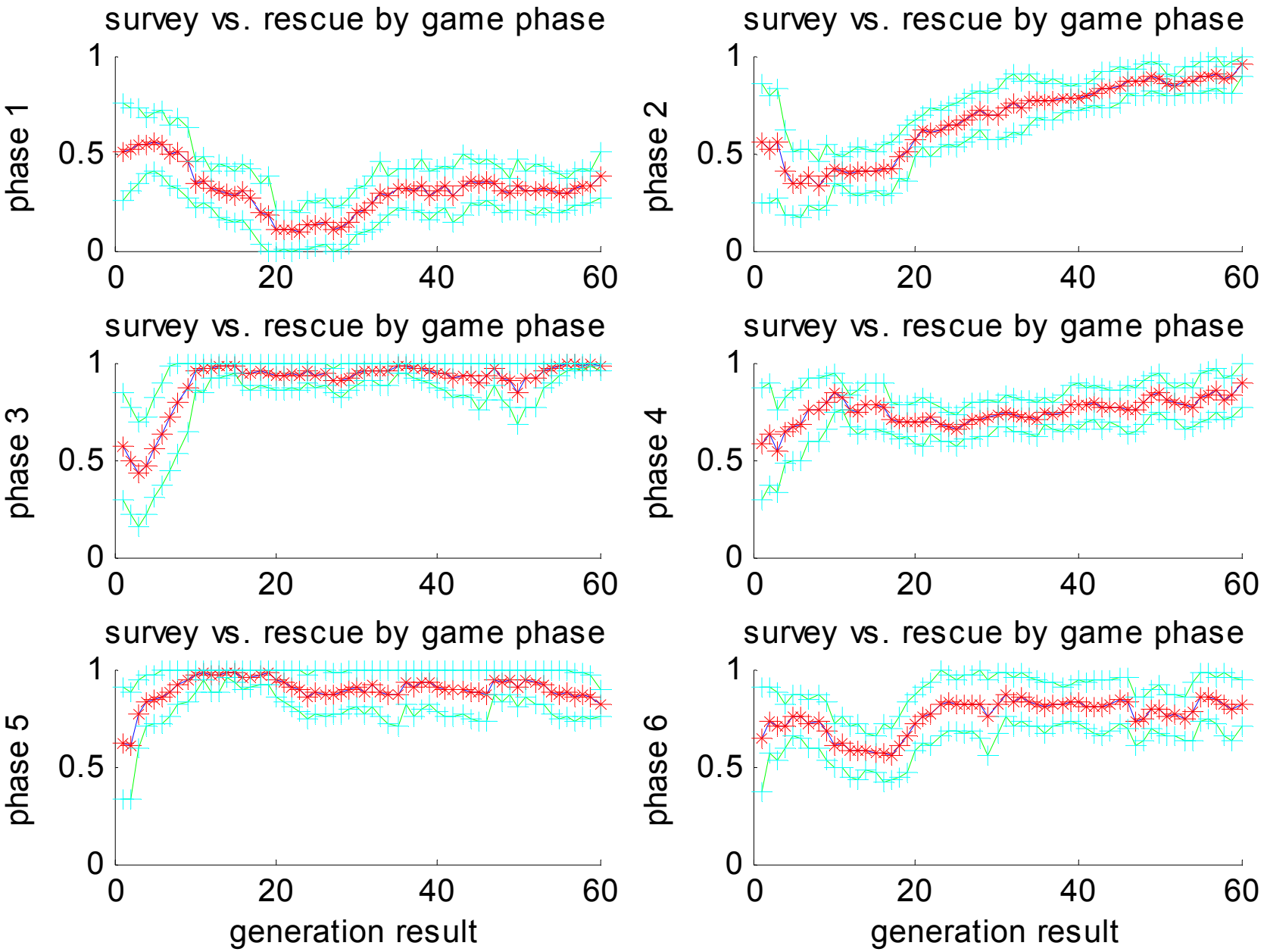
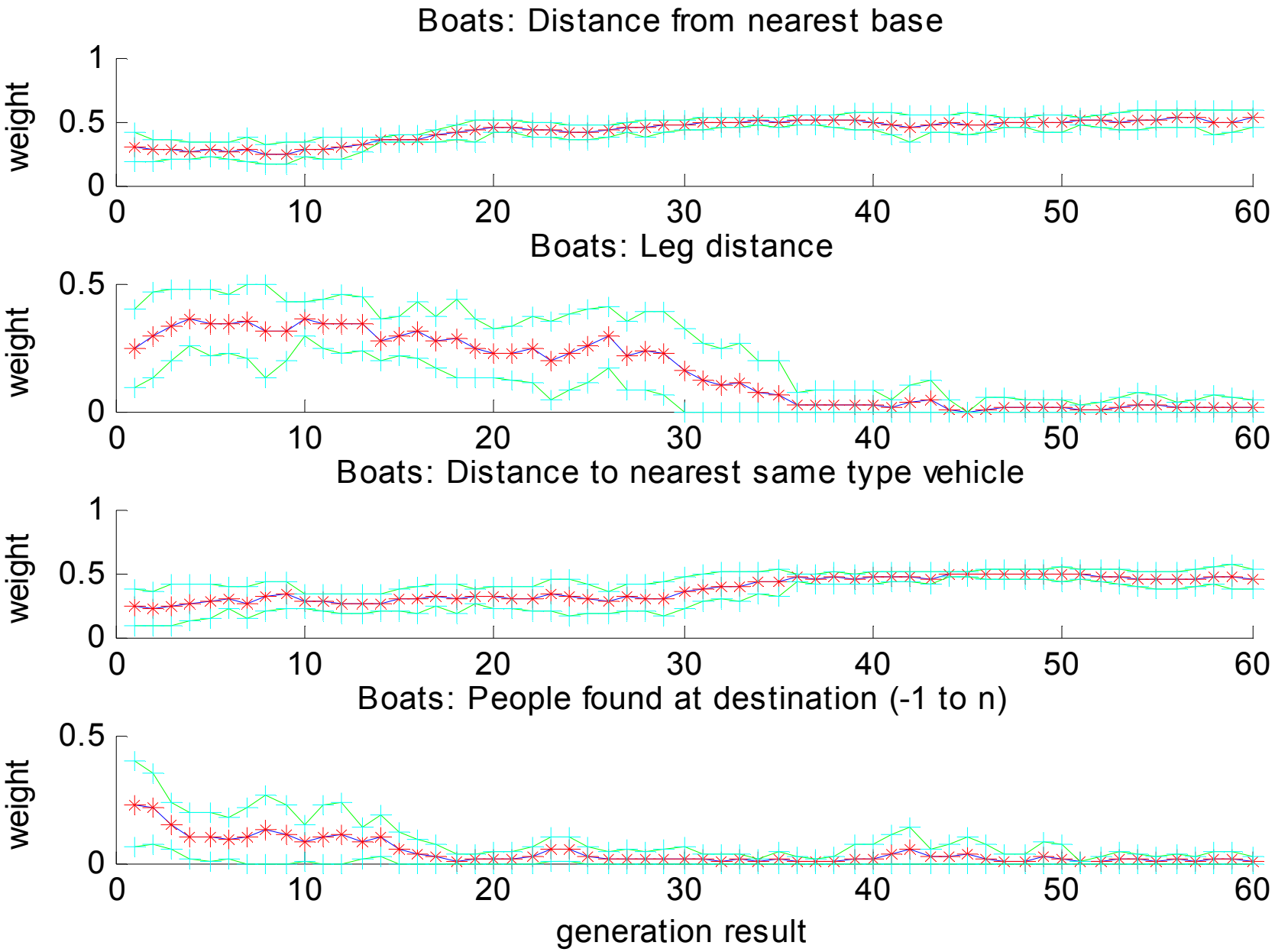
    - 6 to determine how many survey vs. rescue helicopters to deploy (1 parameter for six time phases)
    - 5 weights for each decision feature for both types of helicopters
    - 4 weights for both boats and busses
    - 2 parameters per weight for all vehicles (Beta Distribution: α, β)
  - 6 + (5x2) + (4x2) + 2x[(5x2) + (4x2)] = 60

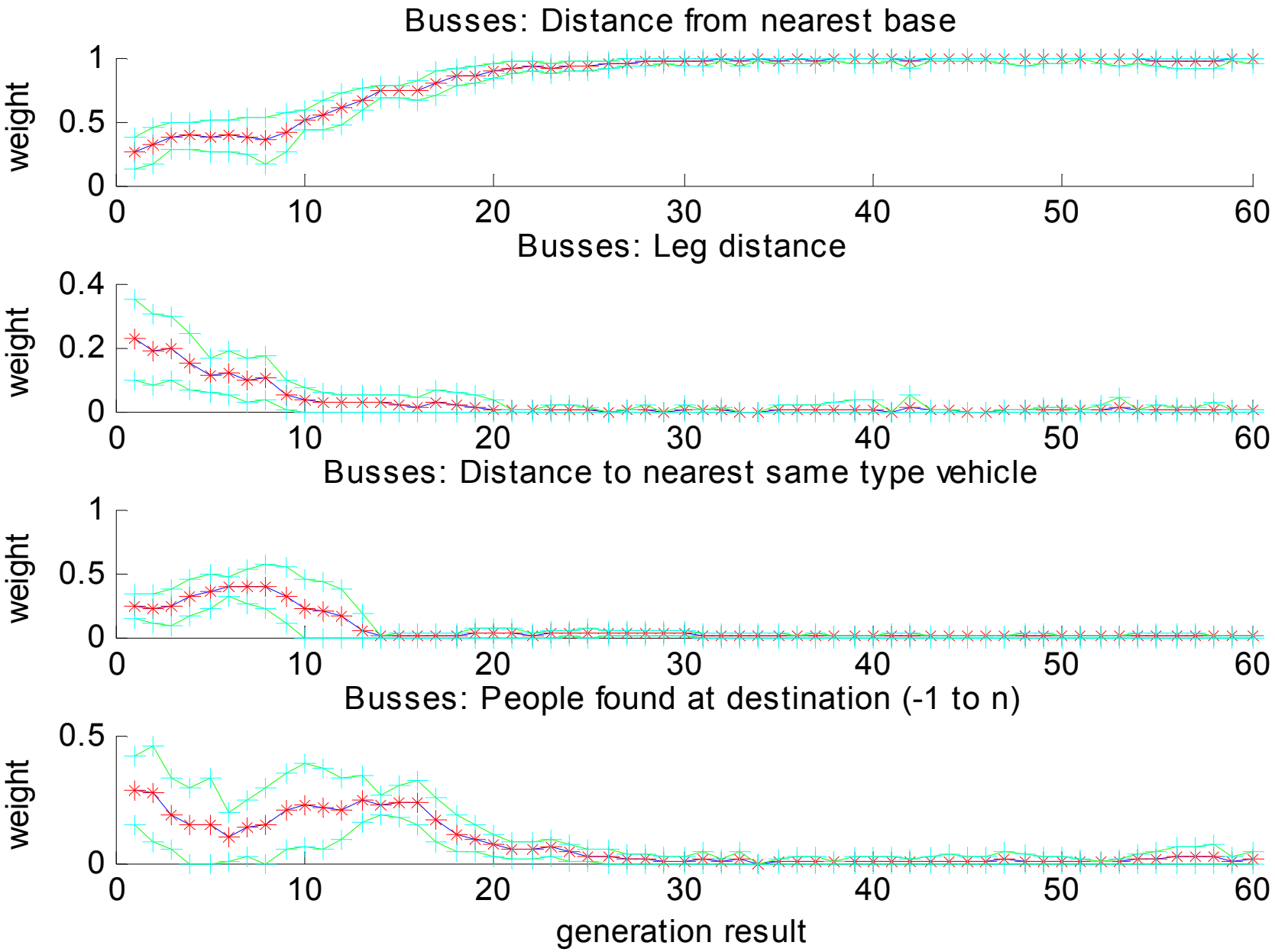
Result: Survey or Rescue Helicopters



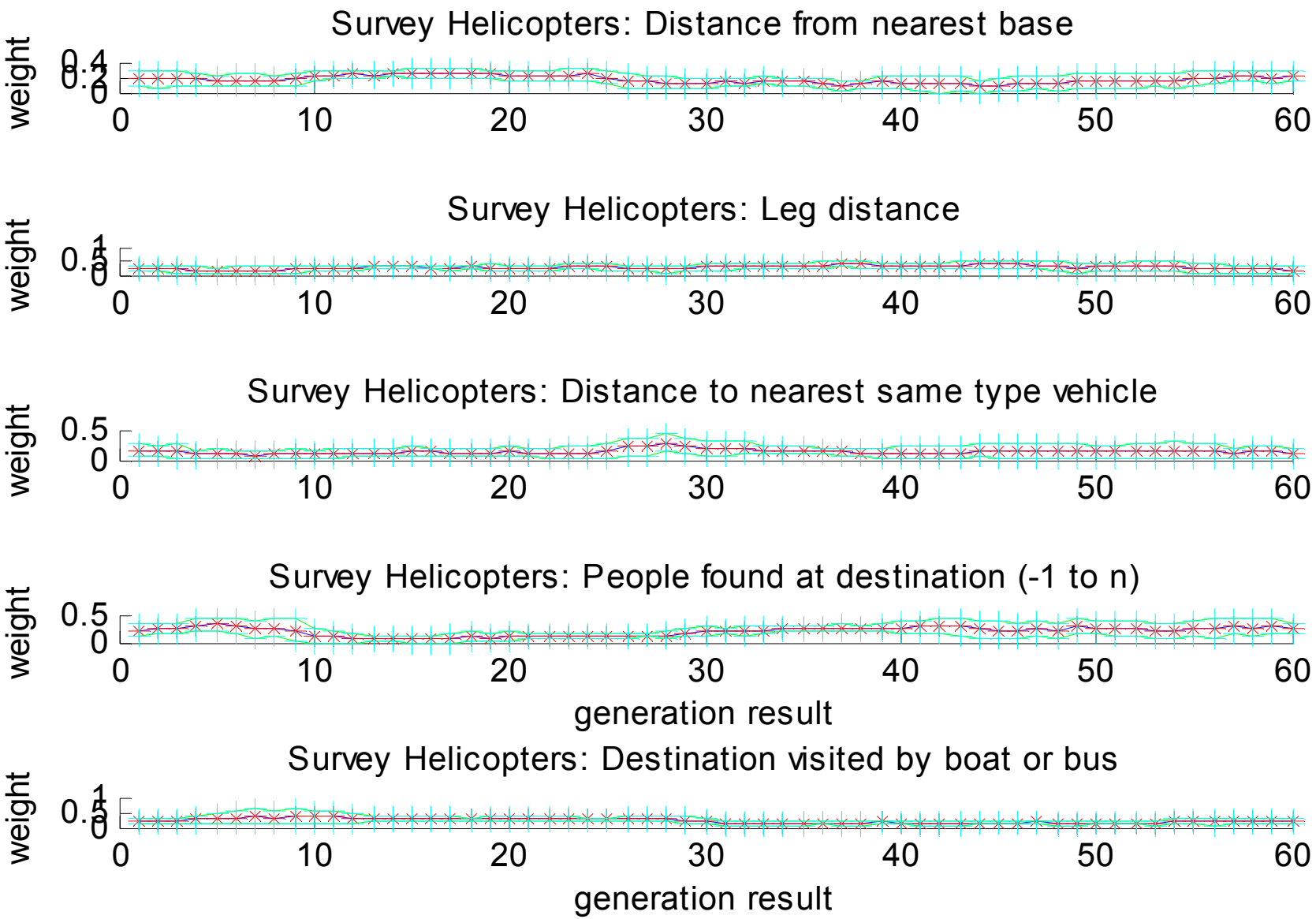
Boats: Goal Weights



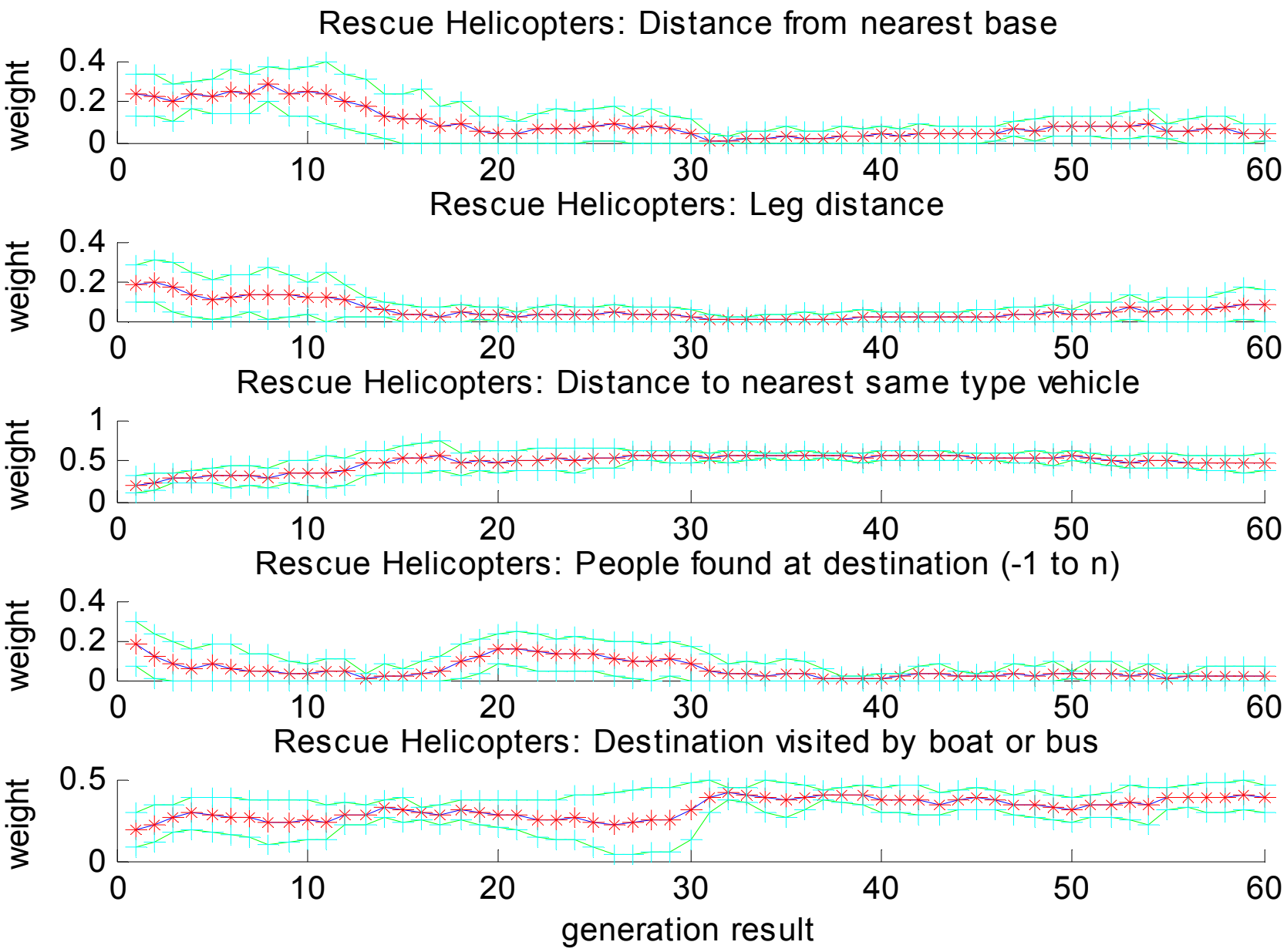
Busses: Goal Weights



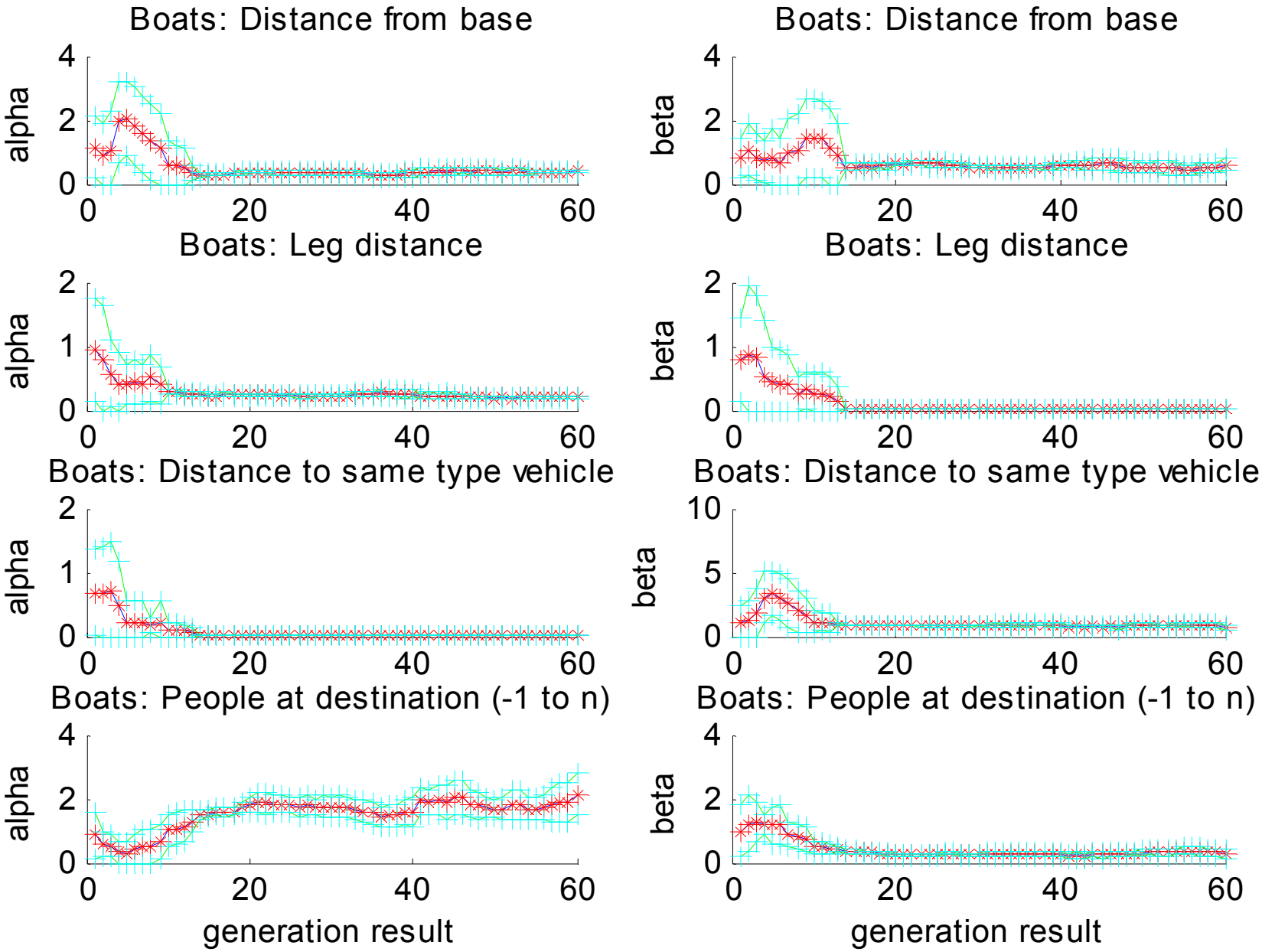
Survey Helicopters: Goal Weights



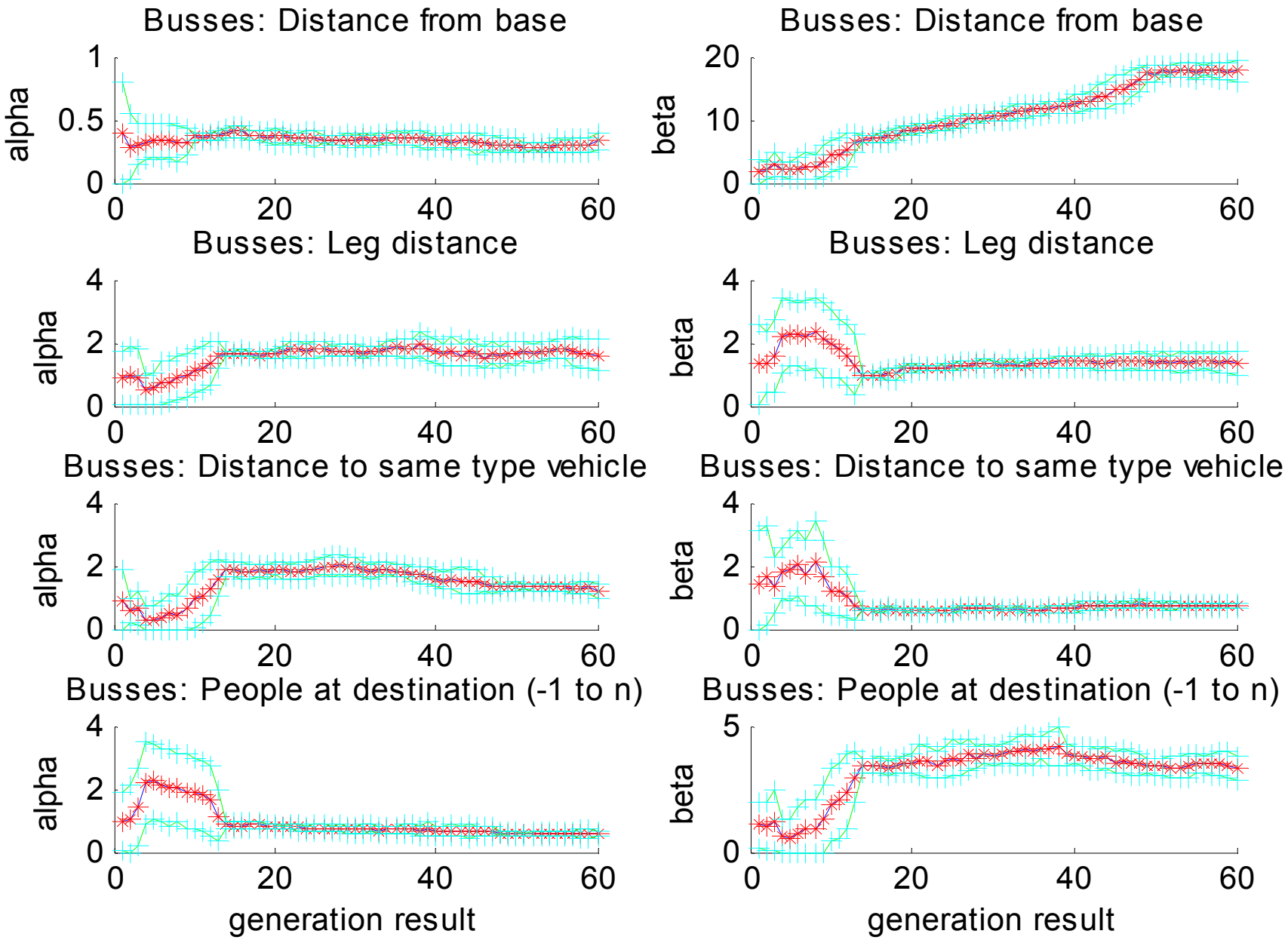
Rescue Helicopters: Goal Weights



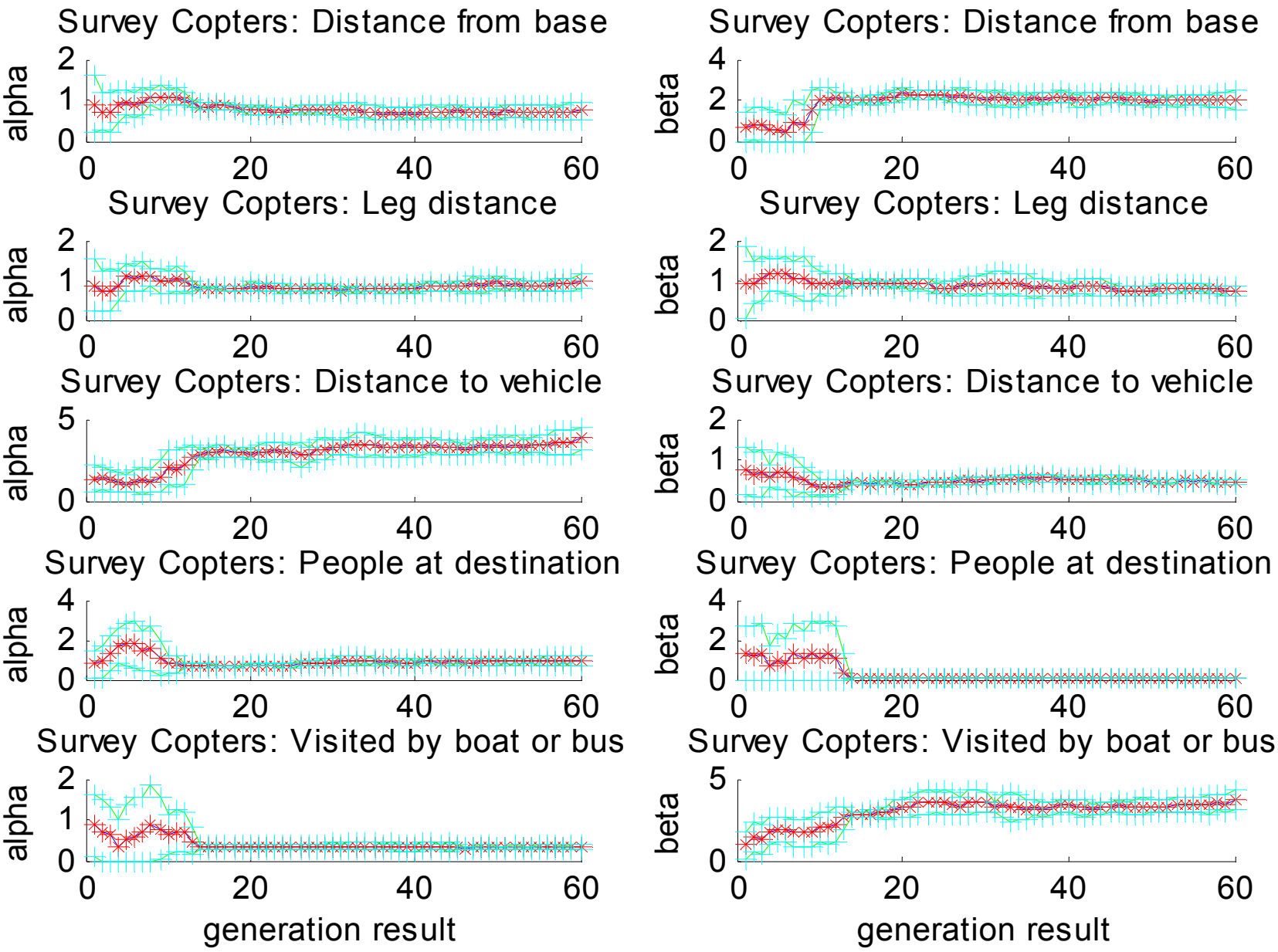
Boats: Decision Parameters



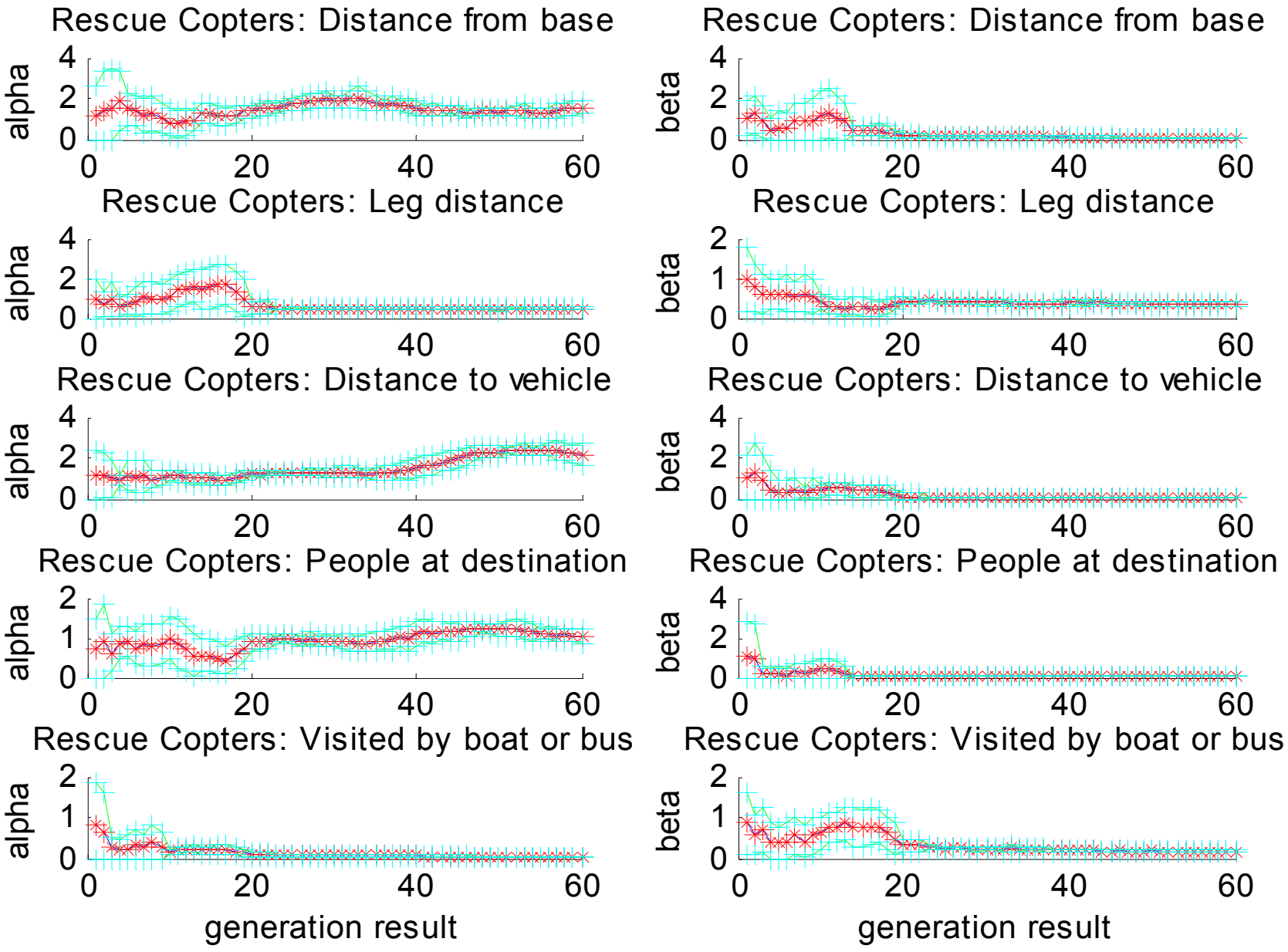
Busses: Decision Parameters

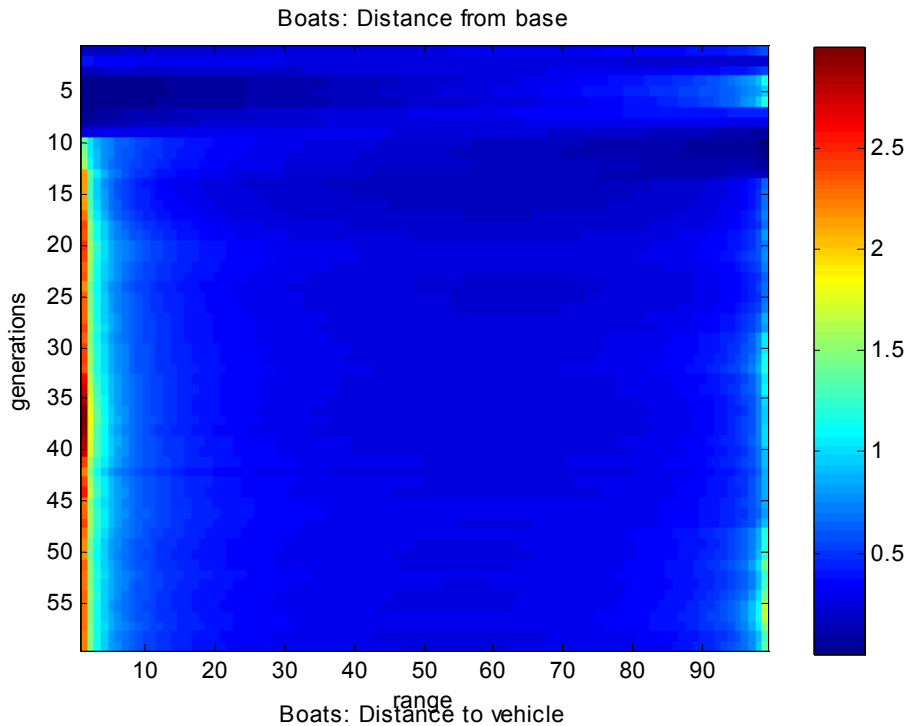


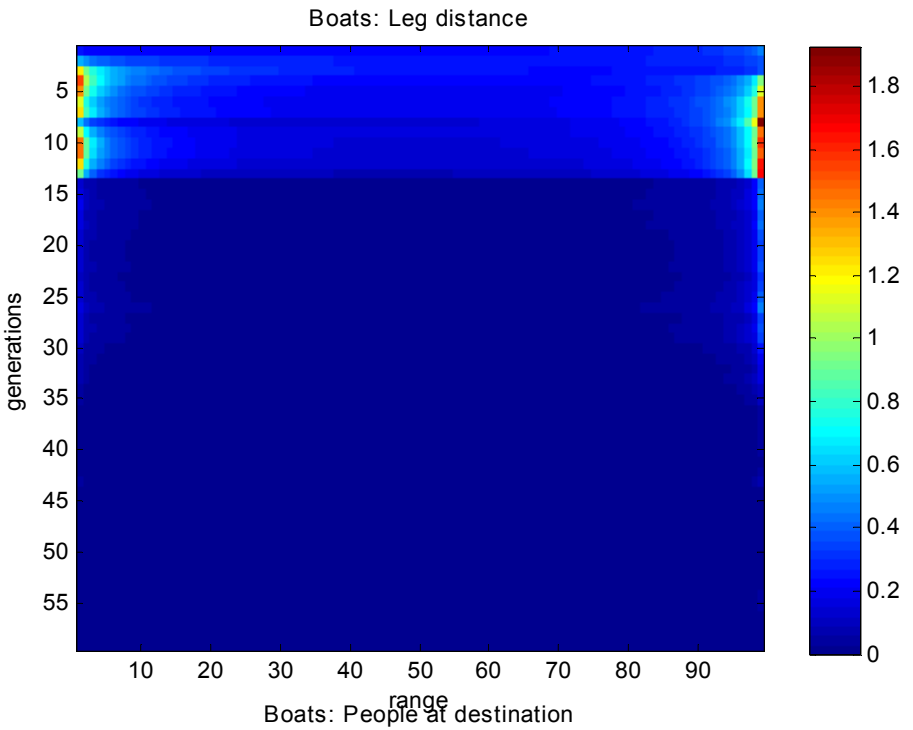
Survey Helicopters: Decision Parameters



Rescue Helicopters: Decision Parameters




Boats: Distance from base
generations
range
5
10
15
20
25
30
35
40
45
50
55
10
20
30
40
50
60
70
80
90
0.5
1
1.5
2
2.5


Boats: Leg distance
generations
range
5
10
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30
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50
55
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20
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0.2
0.4
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0.8
1
1.2
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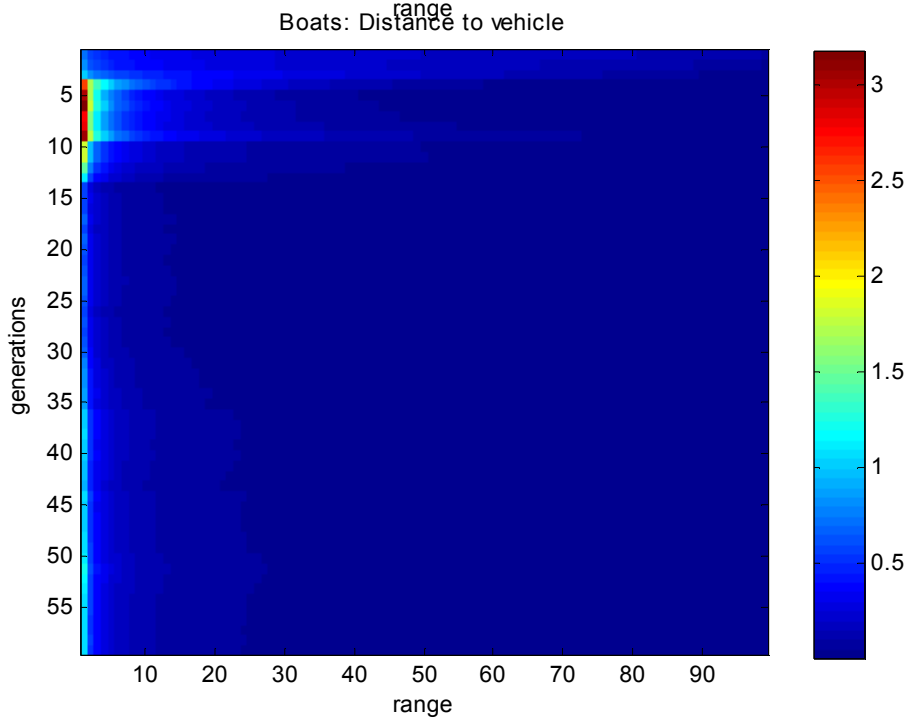
1.6
1.8


Boats: Distance to vehicle
generations
range
5
10
15
20
25
30
35
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0.5
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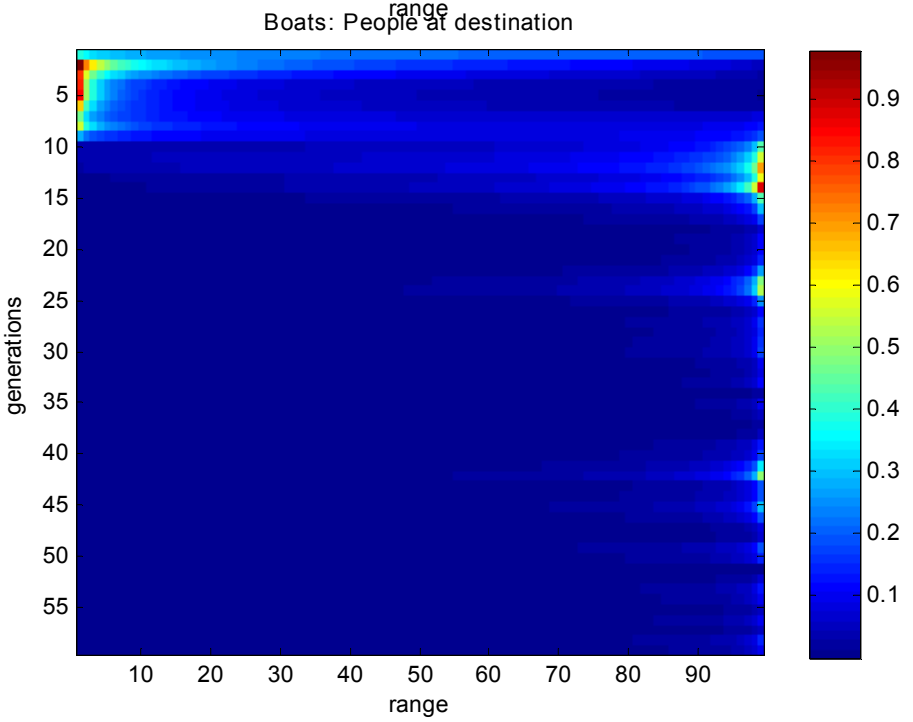
Boats: People at destination
generations
range
5
10
15
20
25
30
35
40
45
50
55
10
20
30
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50
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0.2
0.3
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0.5
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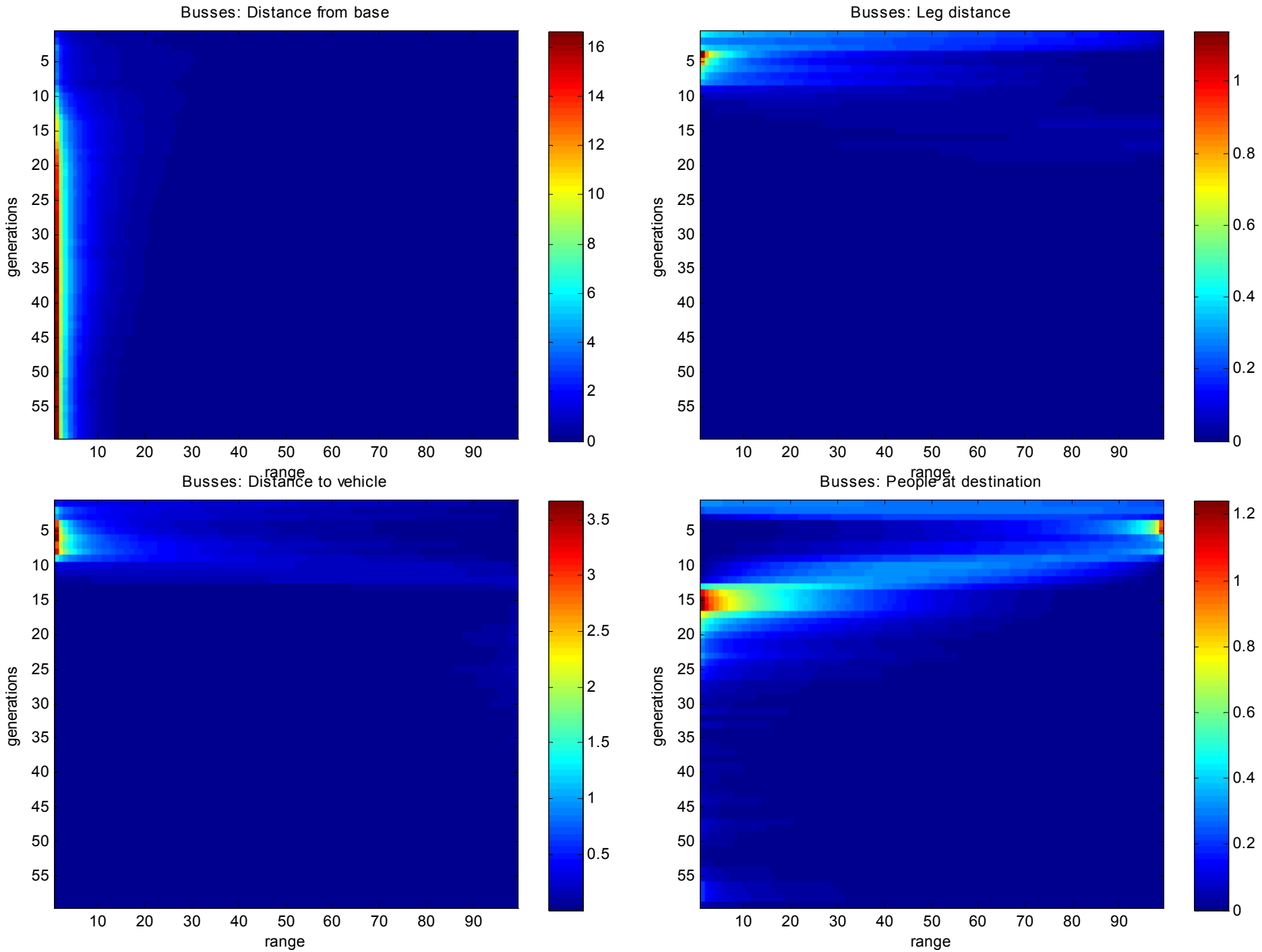
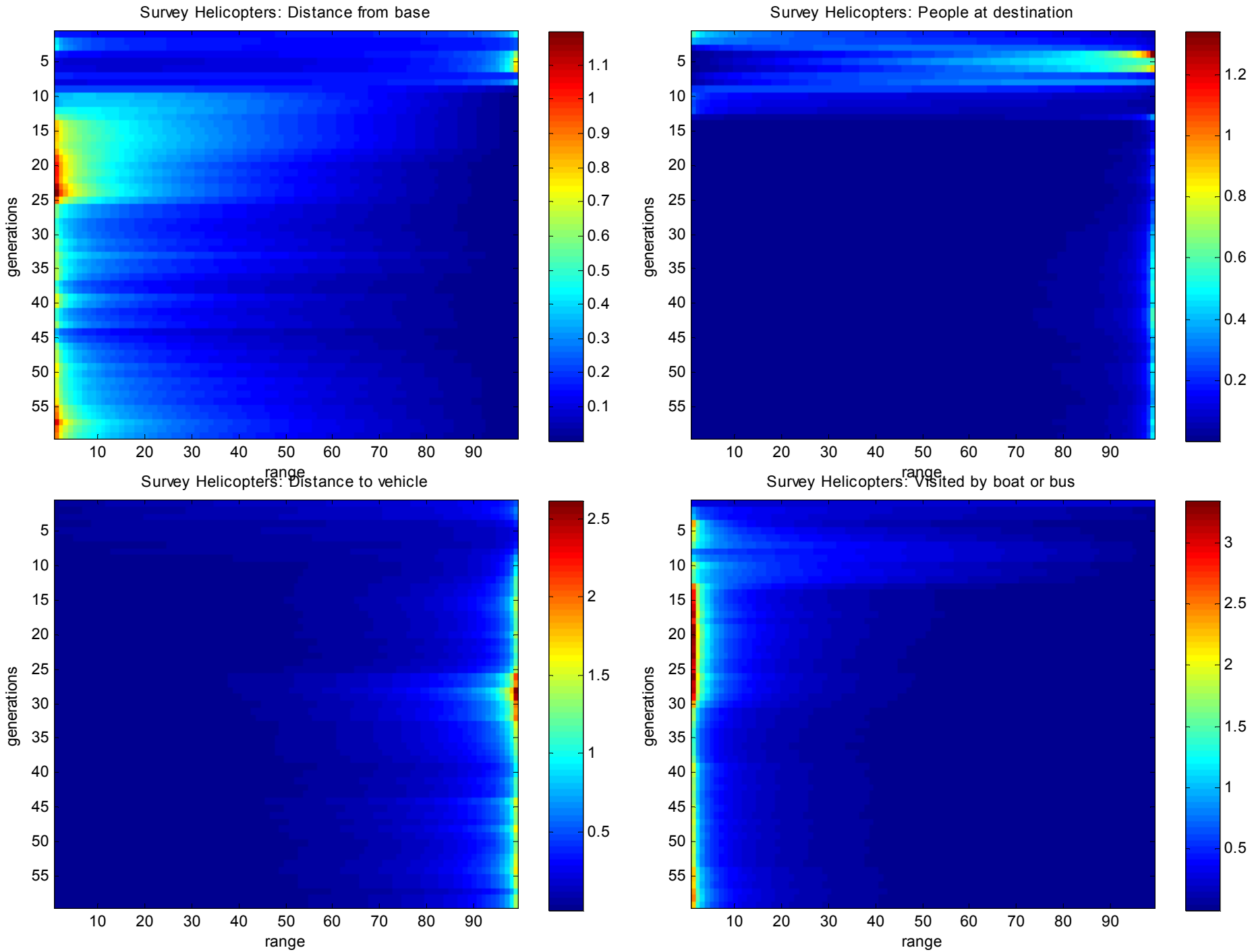
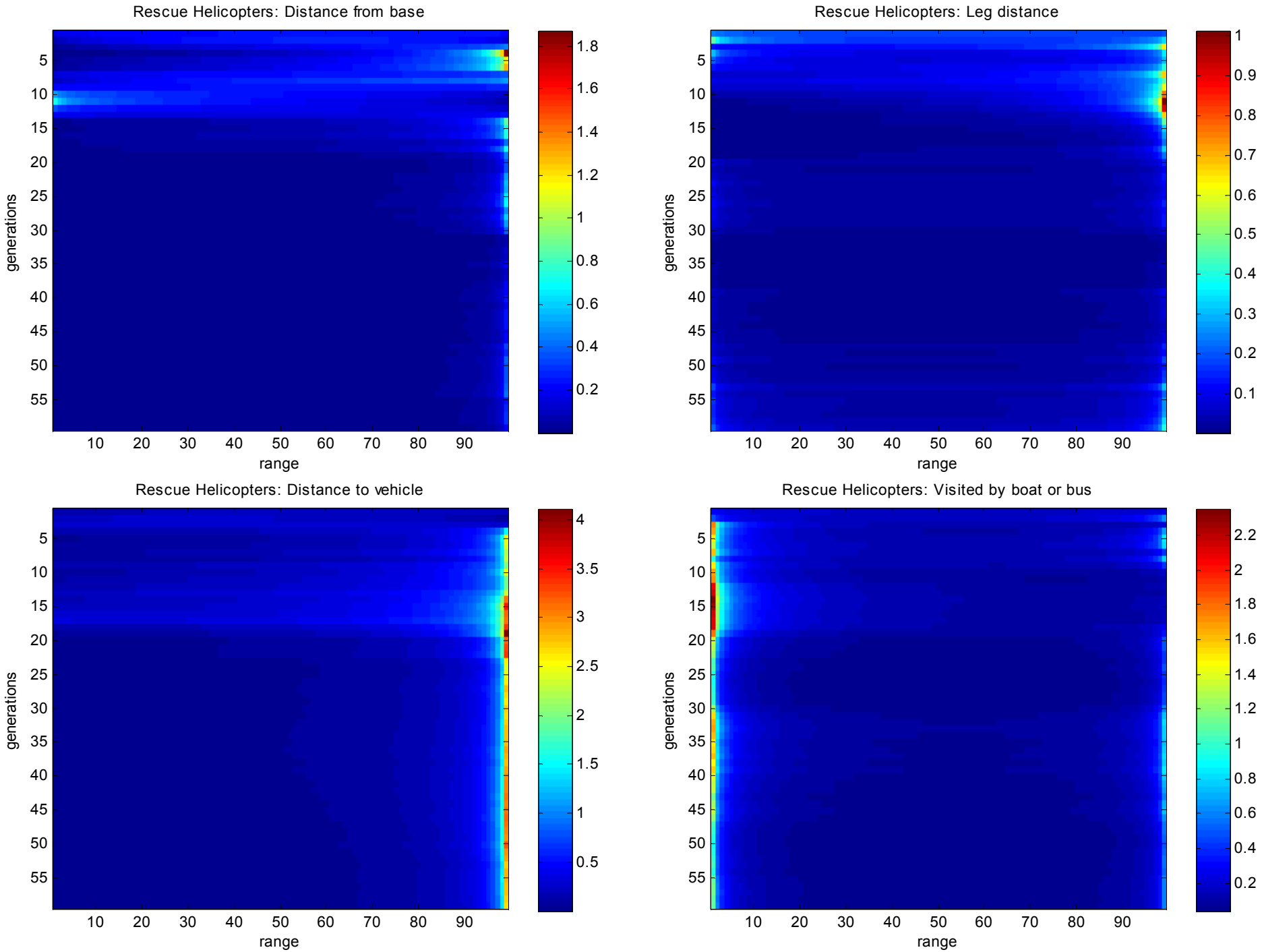
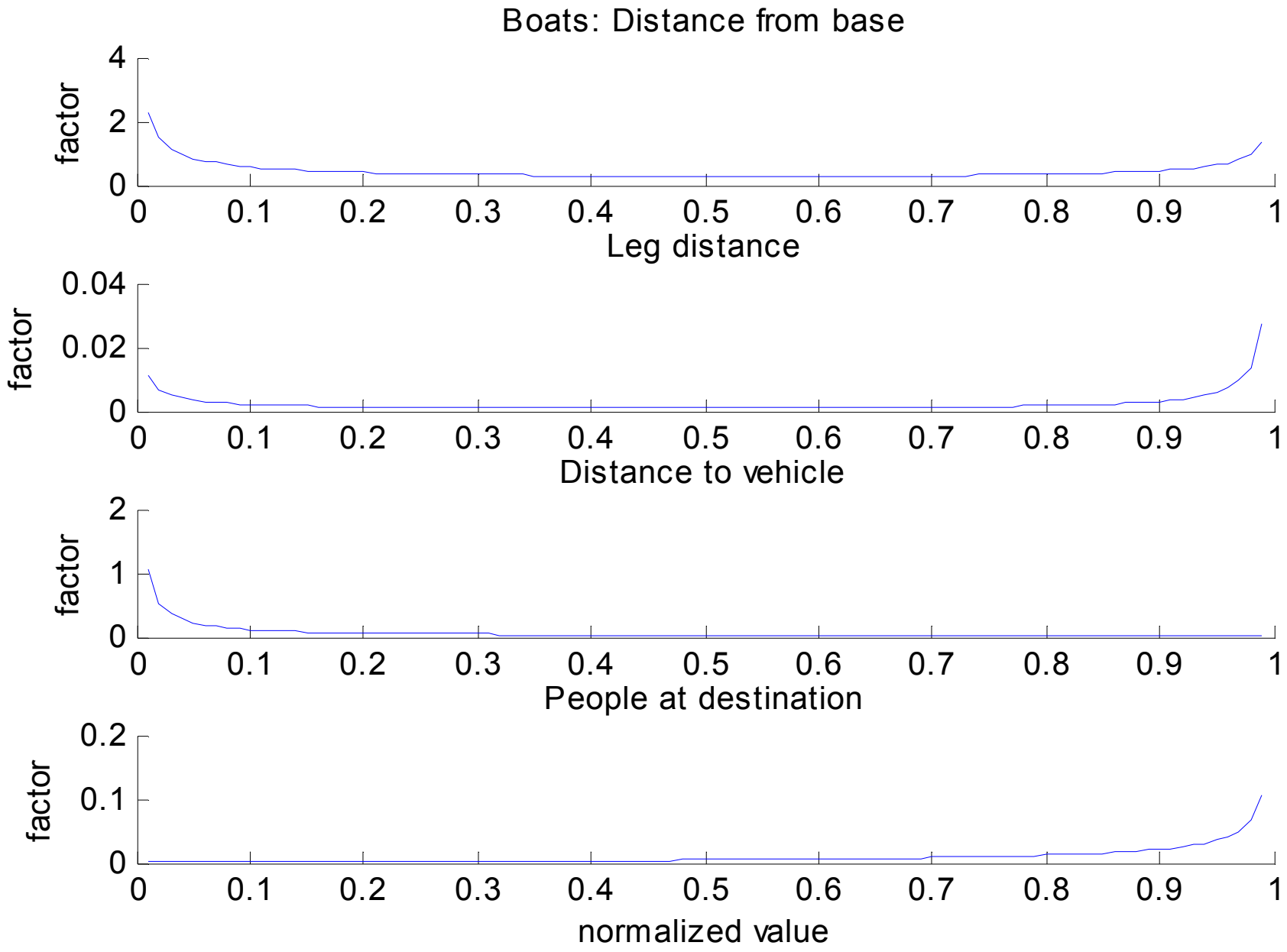
0.7
0.8
0.9


Busses: Distance from base
generations
range
Busses: Leg distance
generations
range
Busses: Distance to vehicle
generations
range
Busses: People at destination
generations
range

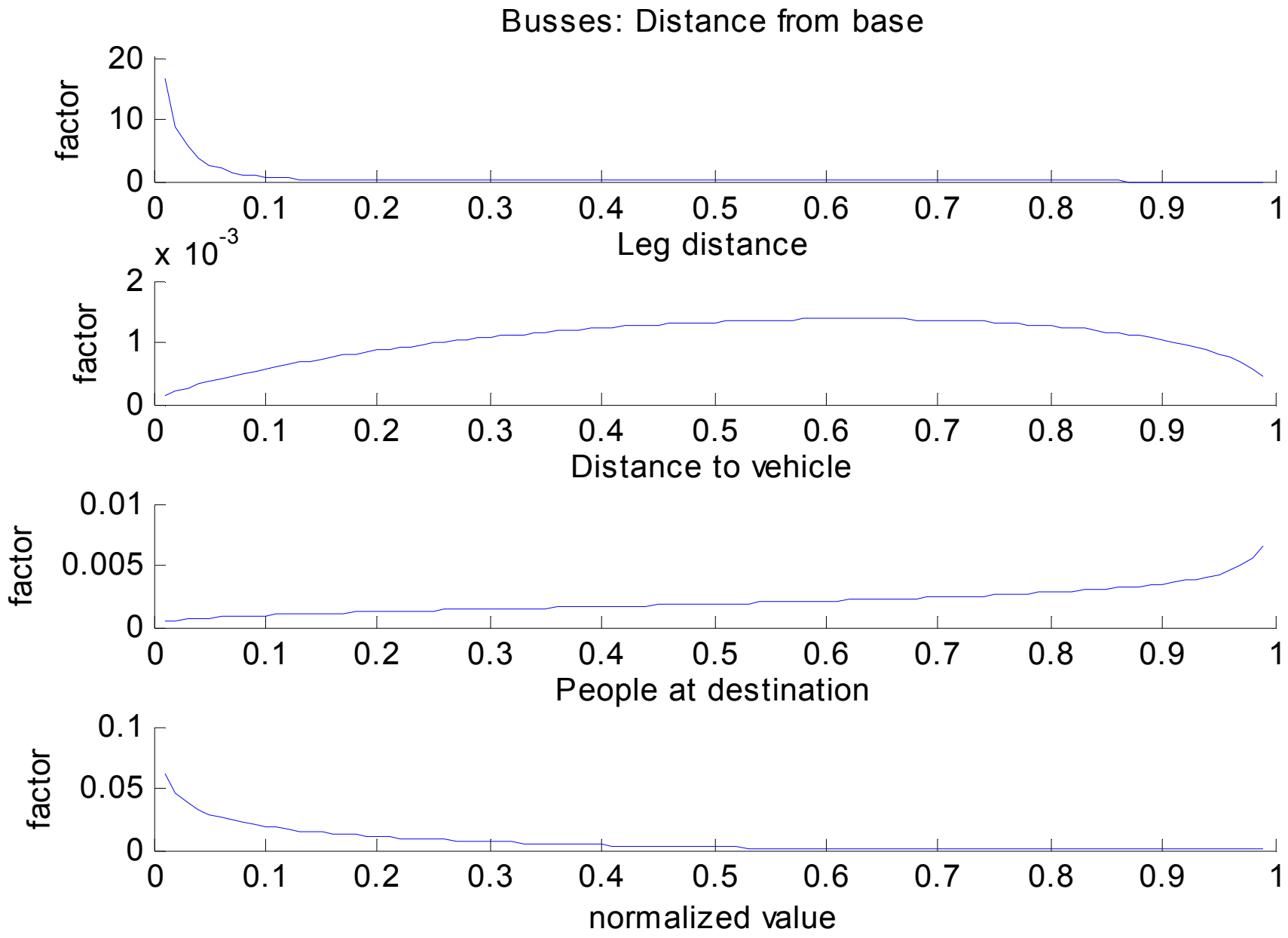

Survey Helicopters: Distance from base
generations
range
Survey Helicopters: People at destination
generations
range
Survey Helicopters: Distance to vehicle
generations
range
Survey Helicopters: Visited by boat or bus
generations
range


Rescue Helicopters: Distance from base
generations
range
Rescue Helicopters: Leg distance
generations
range
Rescue Helicopters: Distance to vehicle
generations
range
Rescue Helicopters: Visited by boat or bus
generations
range

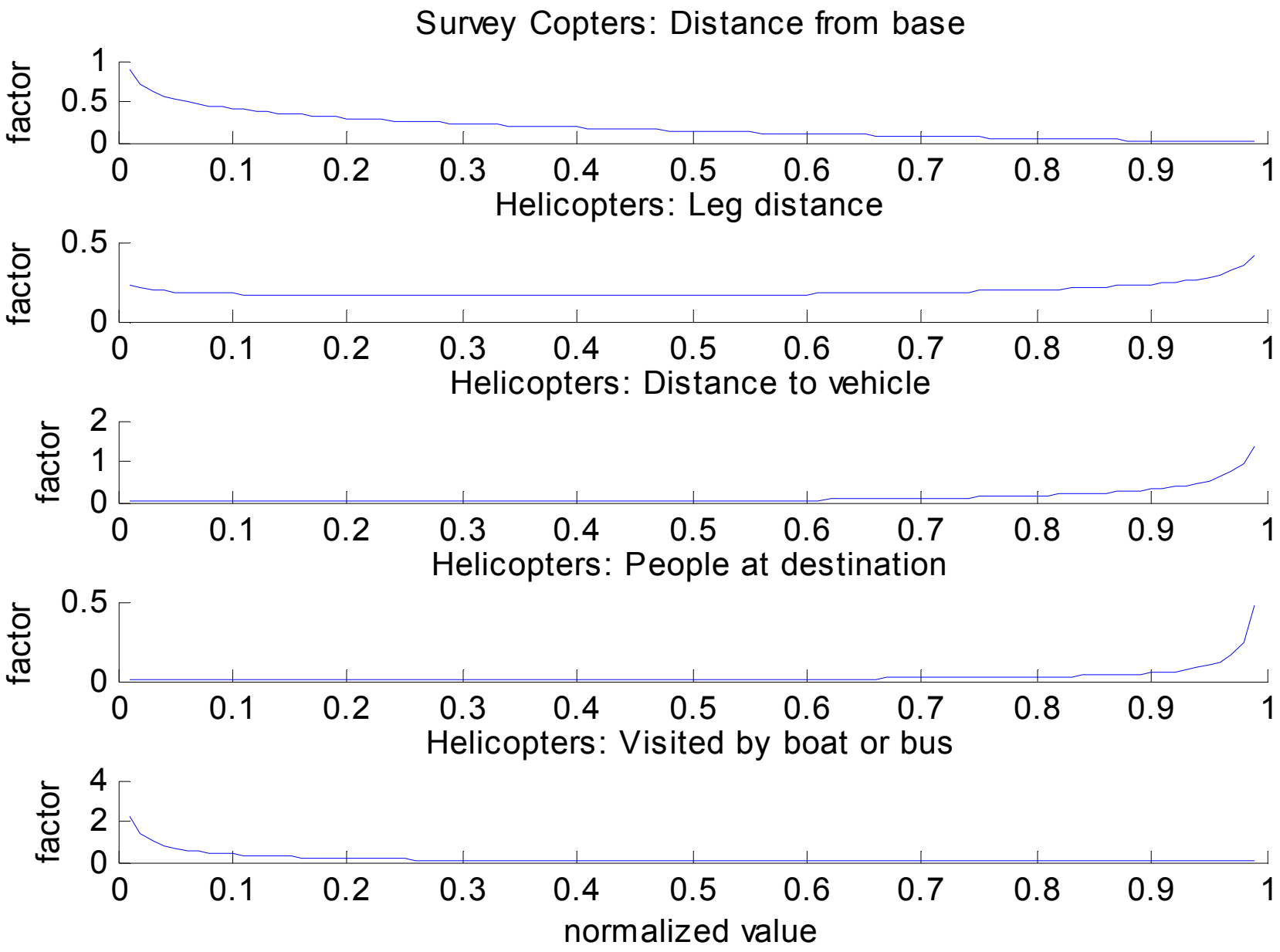
Boats: Decision Beta Density



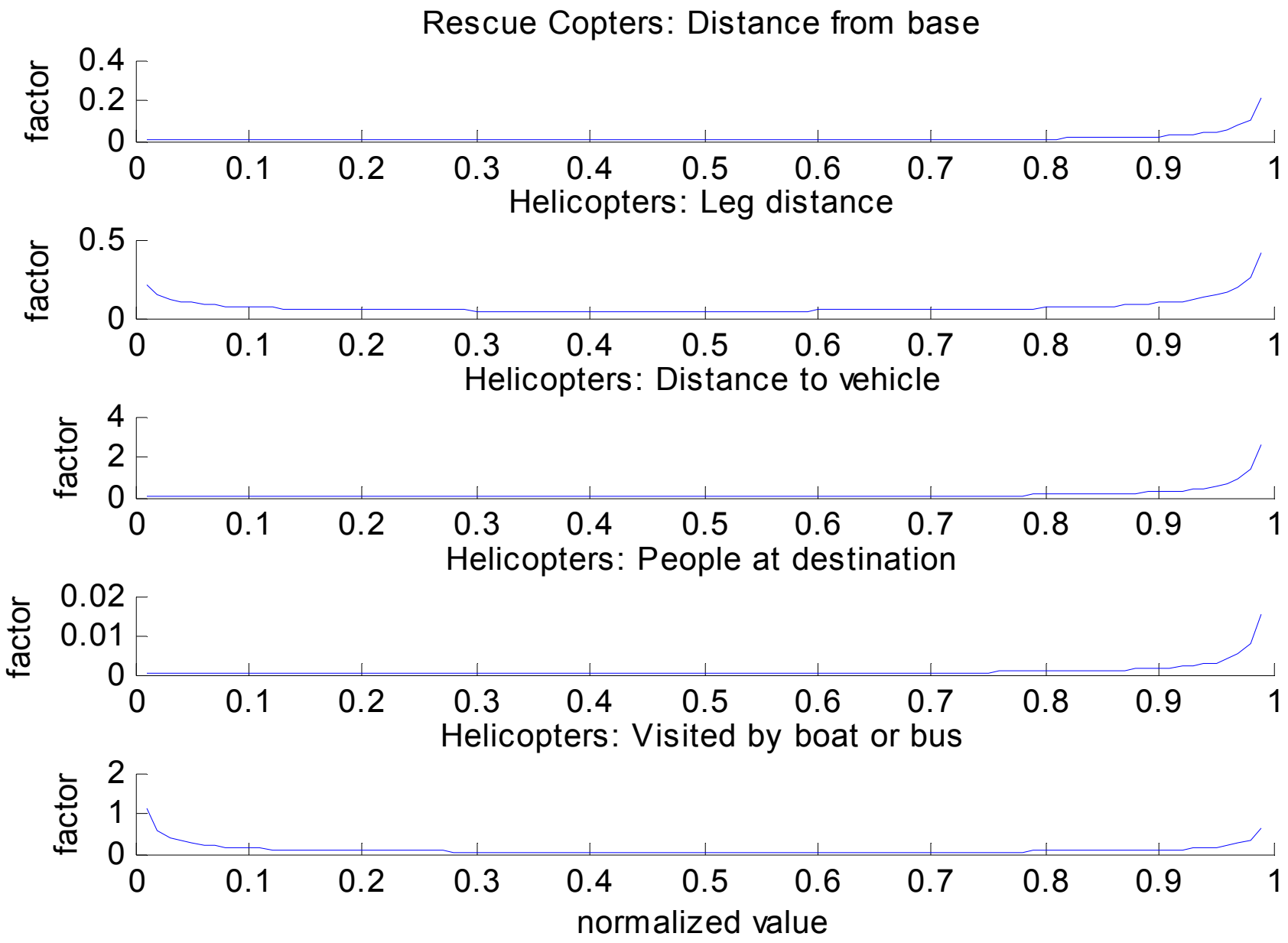
Busses: Decision Beta Density



Survey Helicopters: Decision Beta Density



Rescue Helicopters: Decision Beta Density



Results of Learning Decision Parameters