

Is it Time to Go Yet?

Understanding Household Hurricane Evacuation Decisions from a Dynamic Perspective

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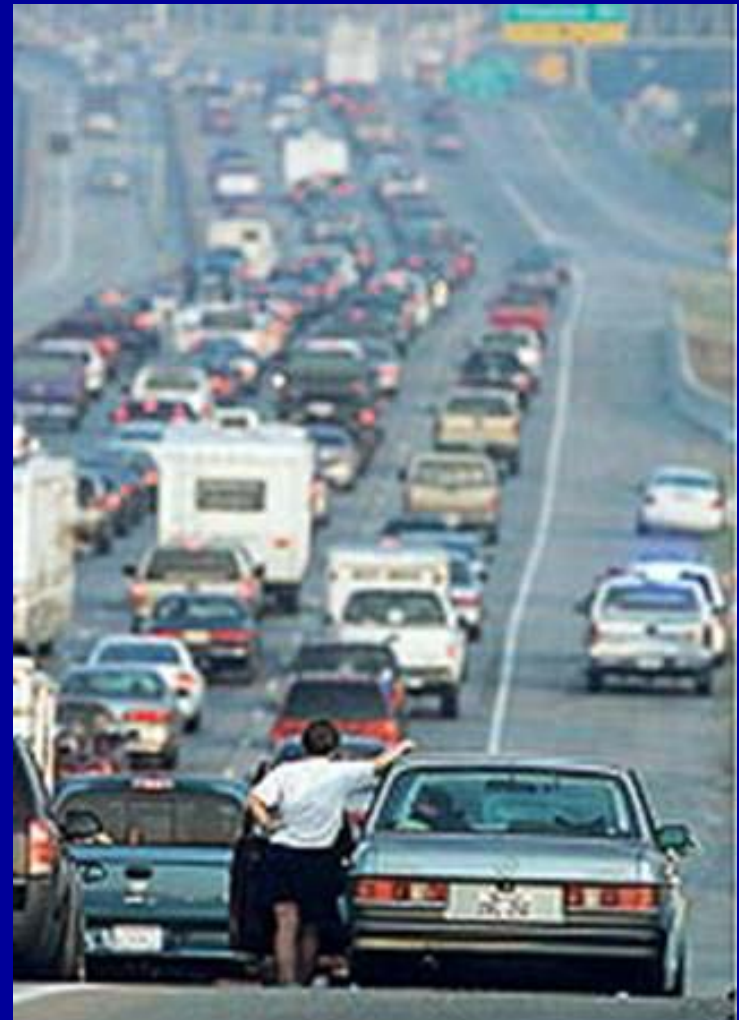
Austin College: Department of Economics

Florida International University: Intn'l Hurricane Research Center

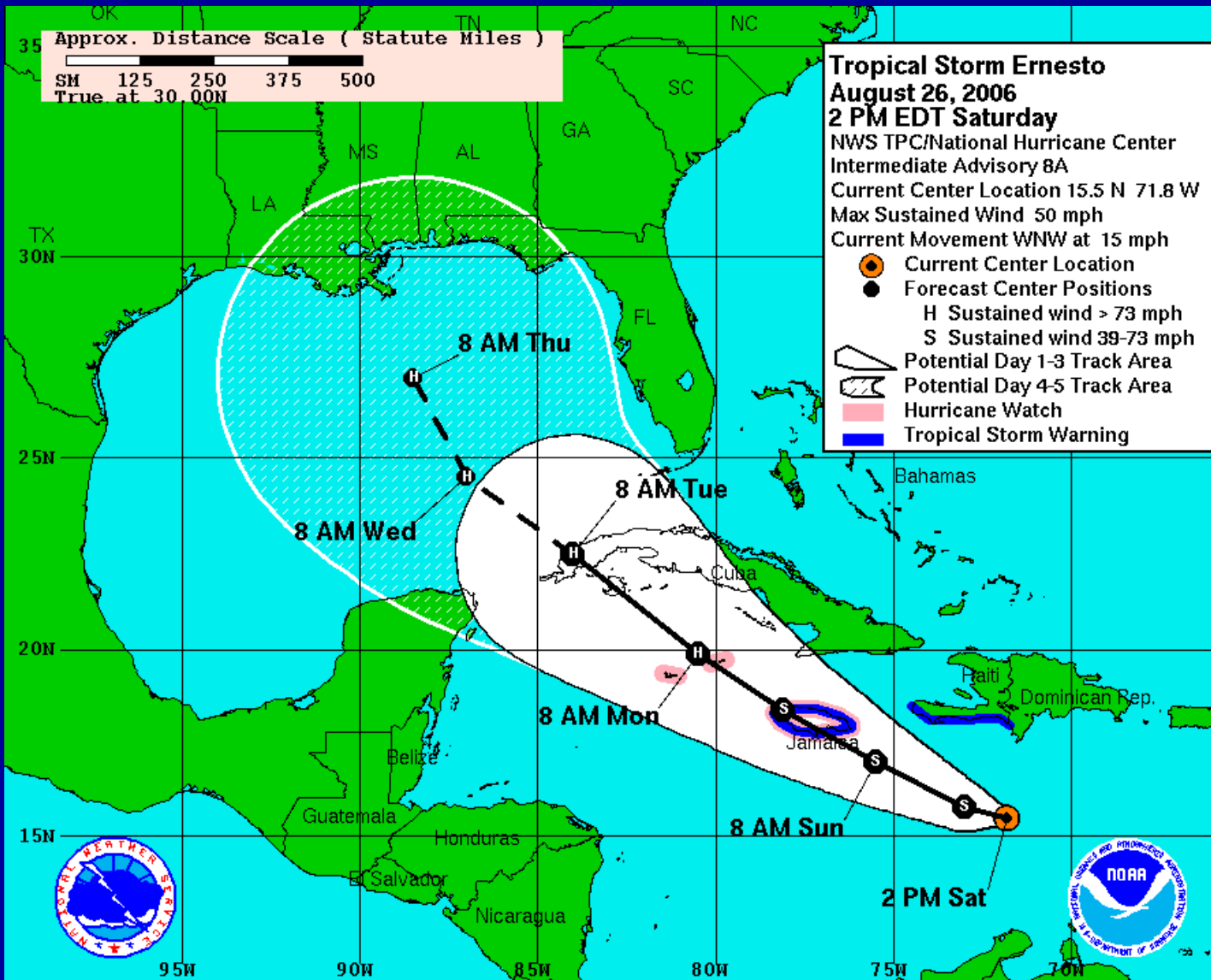
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What We Know About Hurricane Evacuation

Timely evacuation plays a critical role



Forecast Uncertainty

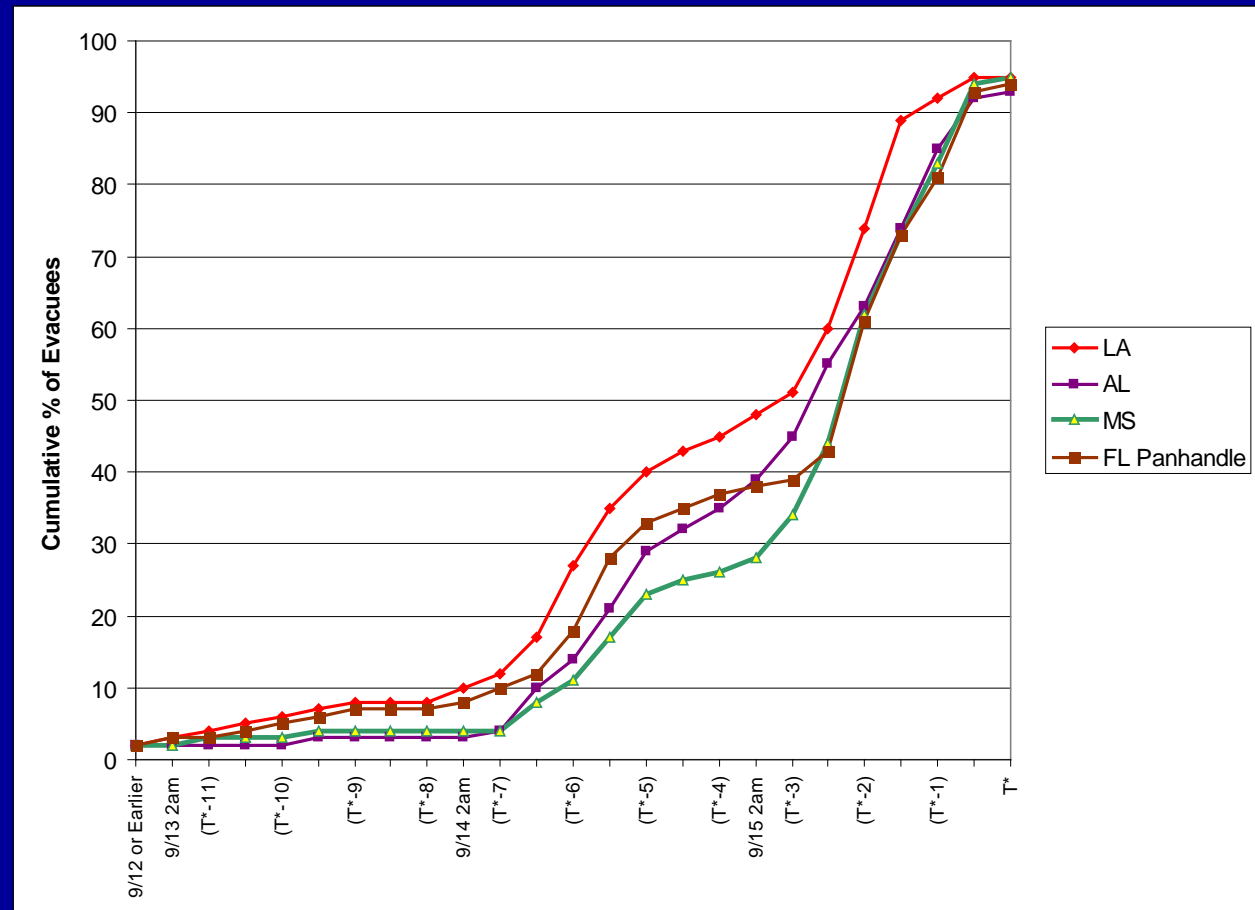


*NHC
Average
Error
Cone*

Heterogeneous Evacuation Behavior

Empirical evidence indicates some households evacuate while others wait

Hurricane
Ivan
Evacuation
Timing



Other factors affecting timing

- Household type, e.g., transient vs. resident
- Response to official evacuation order
- Normal waking hours on the 2 days prior to anticipated landfall
- Daylight hours
- Forecast consistency

However, no clear and/or consistent driving factor has emerged

Evacuation Research Needs

*“... modeling of evacuation behavioral response in more precise and comprehensive ways”
(Gladwin et al., 2005)*

- Dynamic nature
- Risk perceptions
- Beliefs
- Constraints
- Non-linear warning system

A Dynamic Model of Evacuation

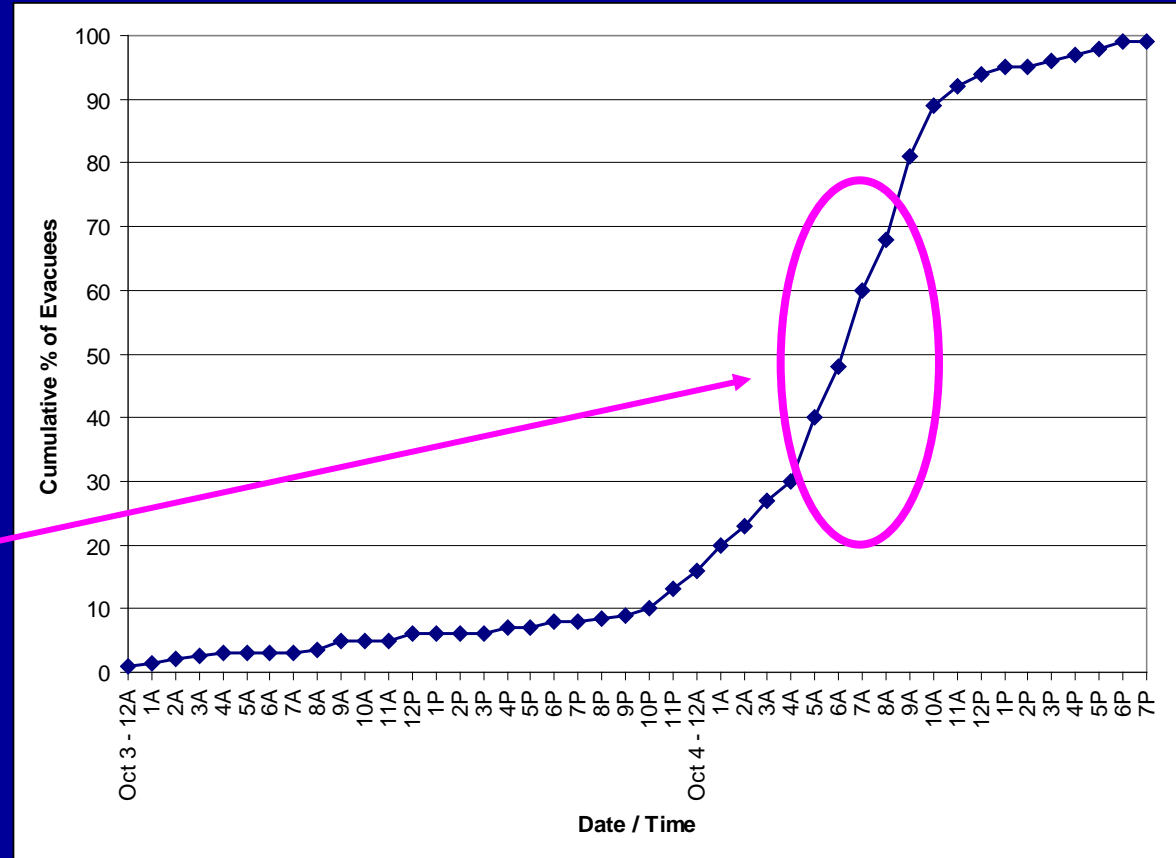
- Economic behavioral model of the *optimal time* for a household to evacuate provided with uncertain forecast data
- Evacuate over time when:

Costs of Evacuating Now < *Expected Value of Waiting*

- Model *calibrated* with historical storm forecast, cost of evacuation, and cost of not evacuating data

Hurricane Opal Evacuation Timing

**Why are majority
of evacuees
leaving in this
time period?**



- Actionable *policies* aimed at affecting the timing of evacuations are addressed

Multi-Period Model

Realistic Evacuation Decision Model

- 6 hour evacuation time period associated with NHC forecast advisory
- Each advisory contains a 12, 24, 36, 48, 72, 96, and 120 hour forecast of track & intensity
- Assuming known timing of hurricane landfall at T
 - T^* is the last safe possible period to evacuate \Rightarrow 6 hours prior to T
 - Over a 5-day forecast period have (T^*-19) , (T^*-18) , ..., (T^*-1) , T^* evacuation periods

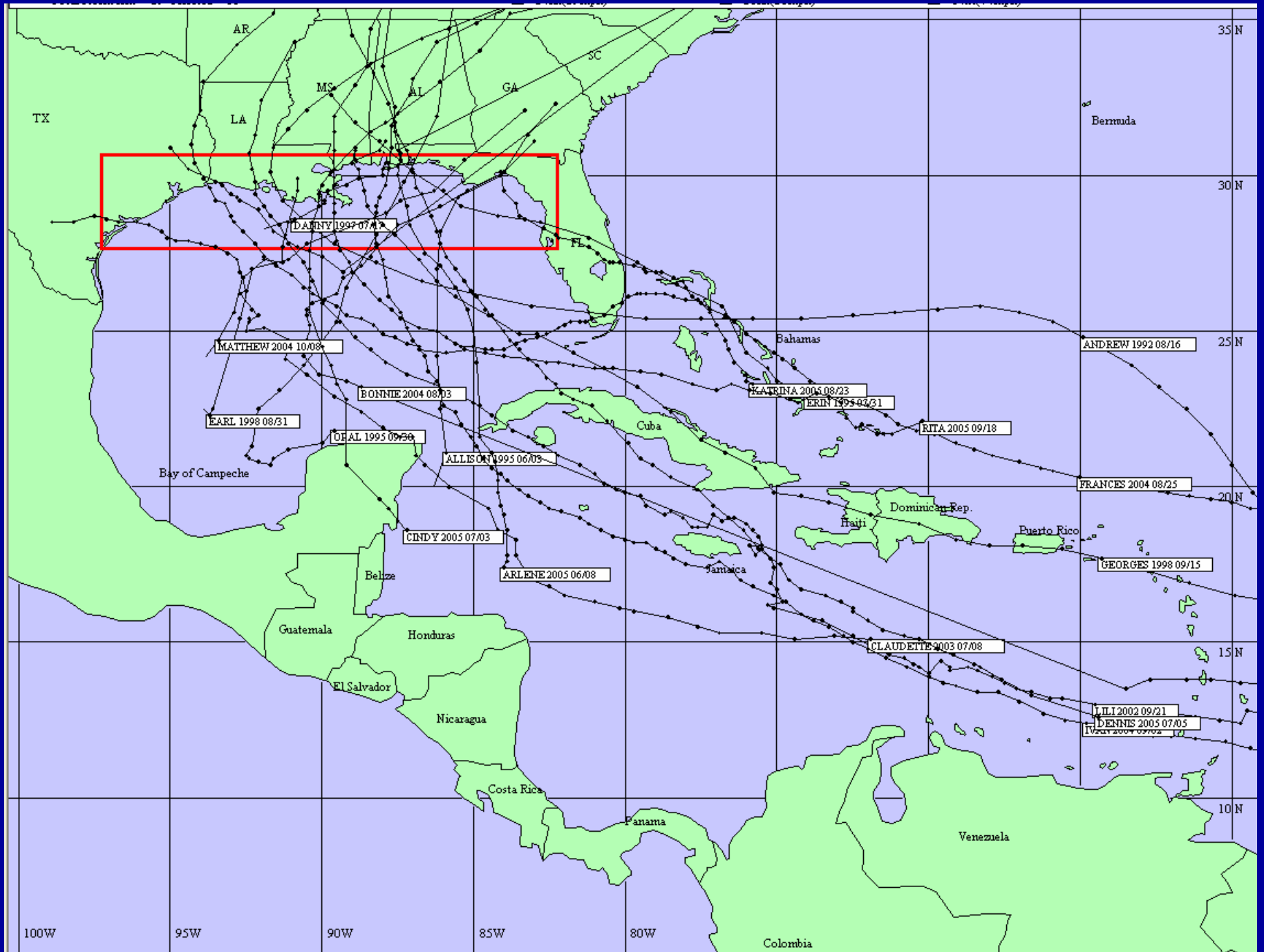
In each evacuation decision time period households face the binary choice of either to evacuate, or to wait one more time period for a revised hurricane forecast

How to choose?

- Households **minimize** the costs of evacuating now vs. the expected value of waiting
- These values predicated upon the uncertain track and intensity information
 - Uncertainty captured in a constructed “**Hurricane Risk Index**”, $\theta(T^*-n)$
 - $\theta(T^*-n)$ is a random variable that we assume follows a Markov process

Solution Inputs

1. for $n = 0, 1, \dots, 19$, j possible hurricane risk indices, $\theta_{(T^*-n)}$, and their associated probability distributions
2. for $n = 0, 1, \dots, 19$, the costs of evacuation
3. for T , the expected costs of not evacuating



Hurricane Forecast Risk Index

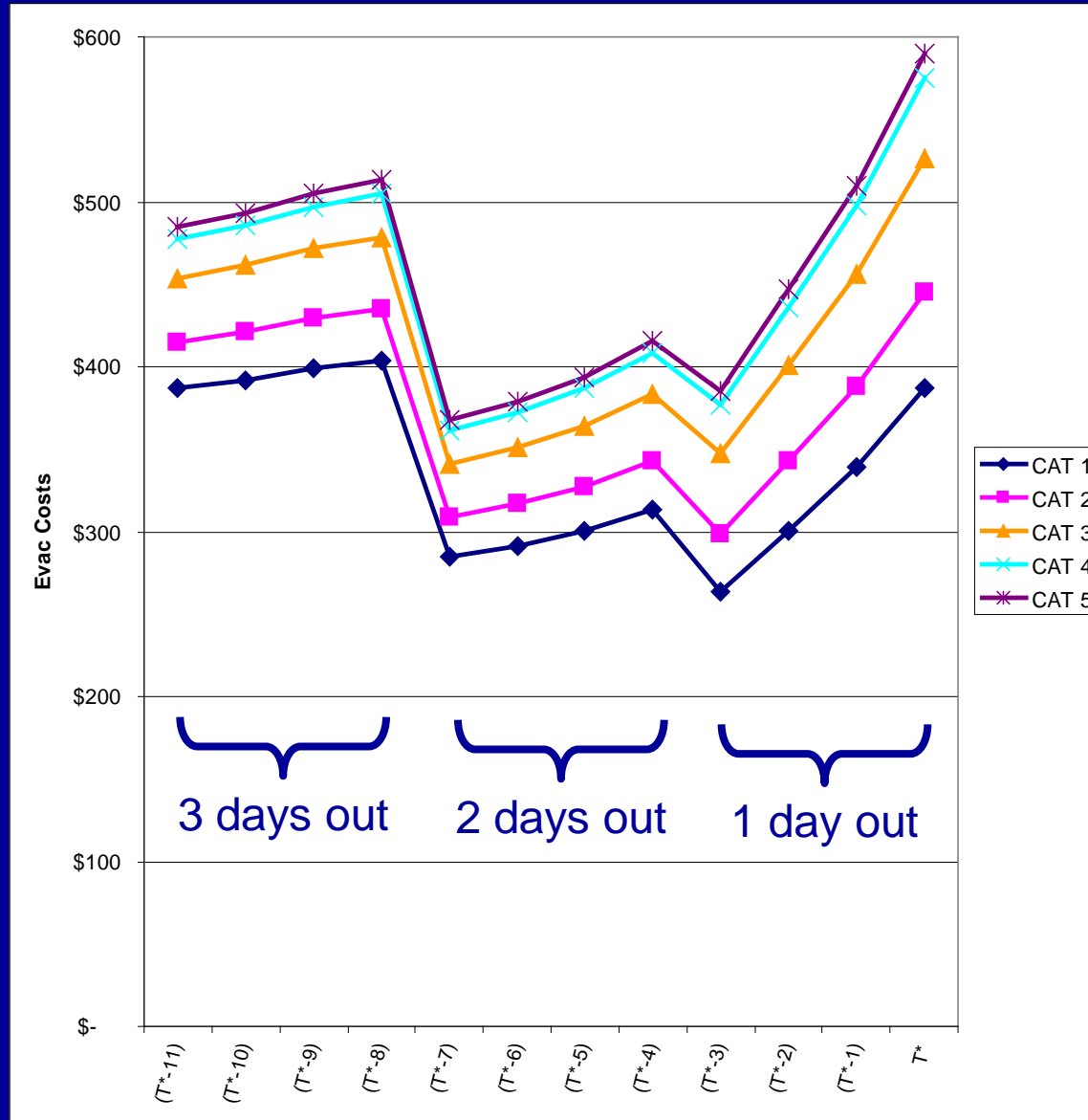


Combine the intensity and track forecast information into a single value

Location Specific Hurricane forecast risk index

(T*-n) Advisory	Forecast (hr)	Landfall Date	Wind (mph)	<u>0</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>	<u>5</u>	<u>Risk Index</u>
(T*-11)	72	7/10 2 PM	121	82%	0%	5%	8%	5%	0%	0.54
(T*-10)	72	7/10 8 PM	115	81%	1%	6%	9%	3%	0%	0.51
(T*-9)	48	7/10 2 AM	132	82%	0%	0%	8%	10%	0%	0.64
(T*-8)	48	7/10 8 AM	132	80%	0%	0%	9%	11%	0%	0.71
(T*-7)	48	7/10 2 PM	126	78%	0%	1%	12%	8%	0%	0.73
(T*-6)	48	7/10 8 PM	115	75%	0%	9%	14%	2%	0%	0.67
(T*-5)	36	7/10 2 PM	126	68%	0%	0%	21%	11%	0%	1.07
(T*-4)	24	7/10 8 AM	109	64%	0%	20%	16%	0%	0%	0.88
(T*-3)	24	7/10 2 PM	126	65%	0%	0%	24%	11%	0%	1.16
(T*-2)	12	7/10 8 AM	138	62%	0%	0%	1%	37%	0%	1.51
(T*-1)	12	7/10 2 PM	144	50%	0%	0%	0%	50%	0%	2.00
T*		7/10 11 AM	138	6%	0%	0%	0%	94%	0%	3.76
Landfall (T)		7/10 3 PM	120							

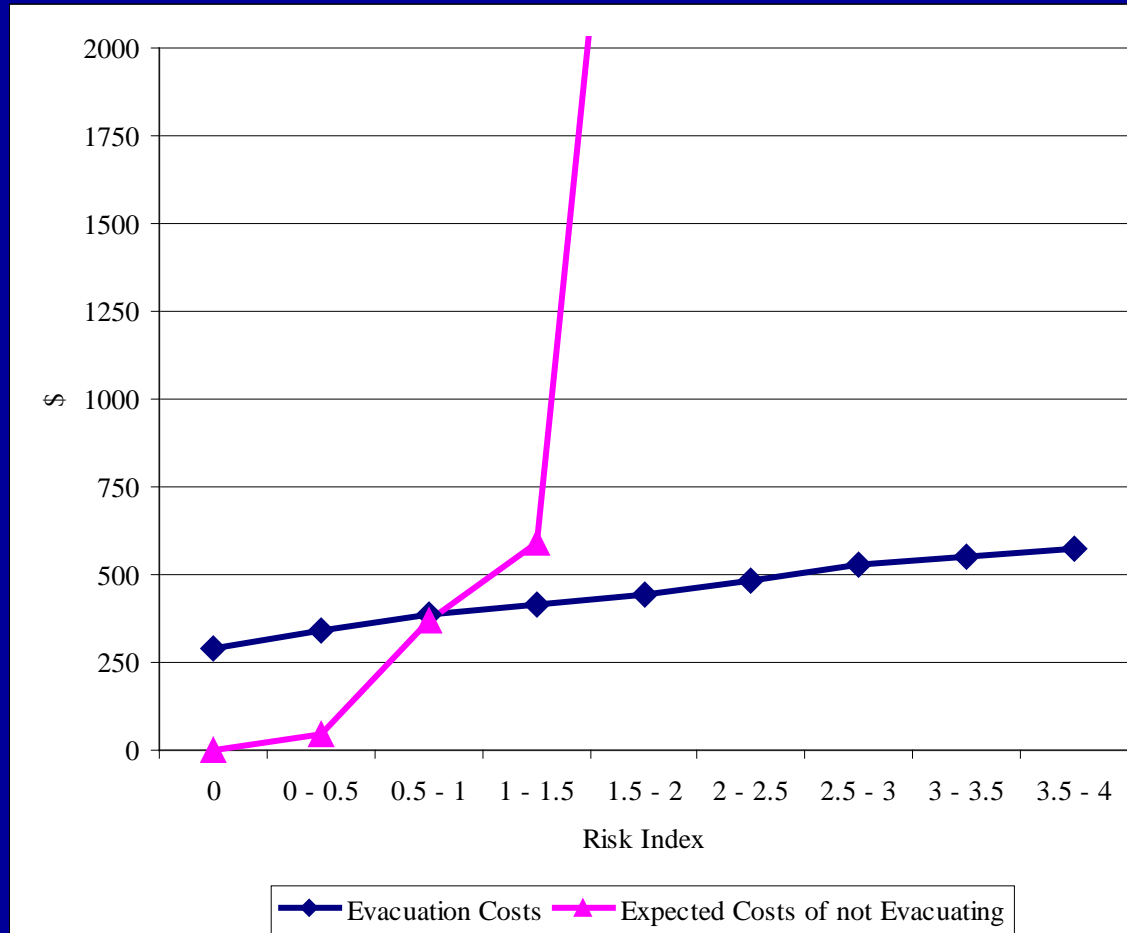
Cost of Evacuation



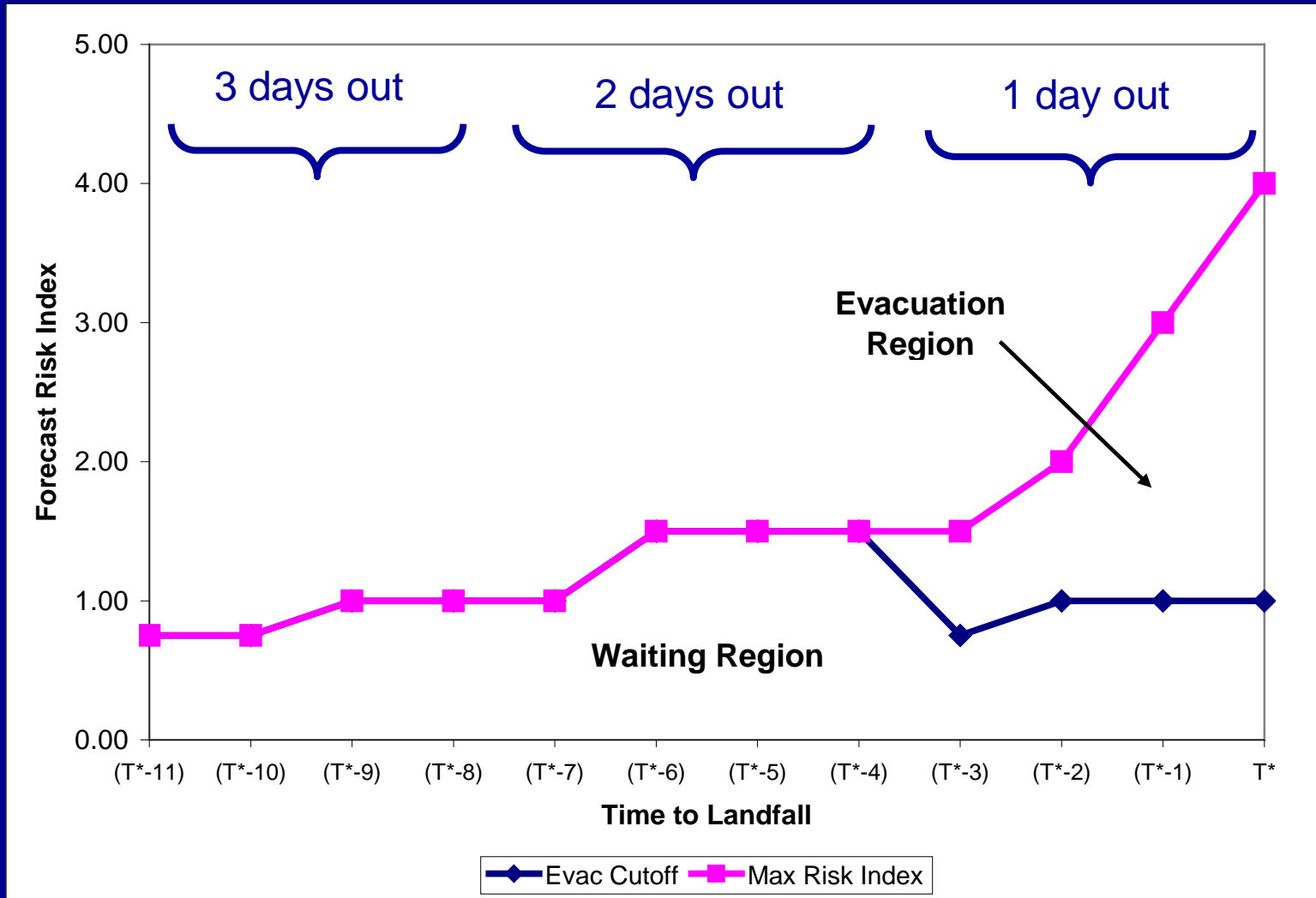
Expected Costs of Not Evacuating

CAT	Prob of injury	Expected Cost (\$)
0	0.000%	\$ 0
1	0.050%	\$ 1,694
2	0.200%	\$ 6,775
3	0.450%	\$ 15,244
4	0.850%	\$ 28,795
5	0.950%	\$ 32,182

Model solution intuition – a unique risk index cutoff exists

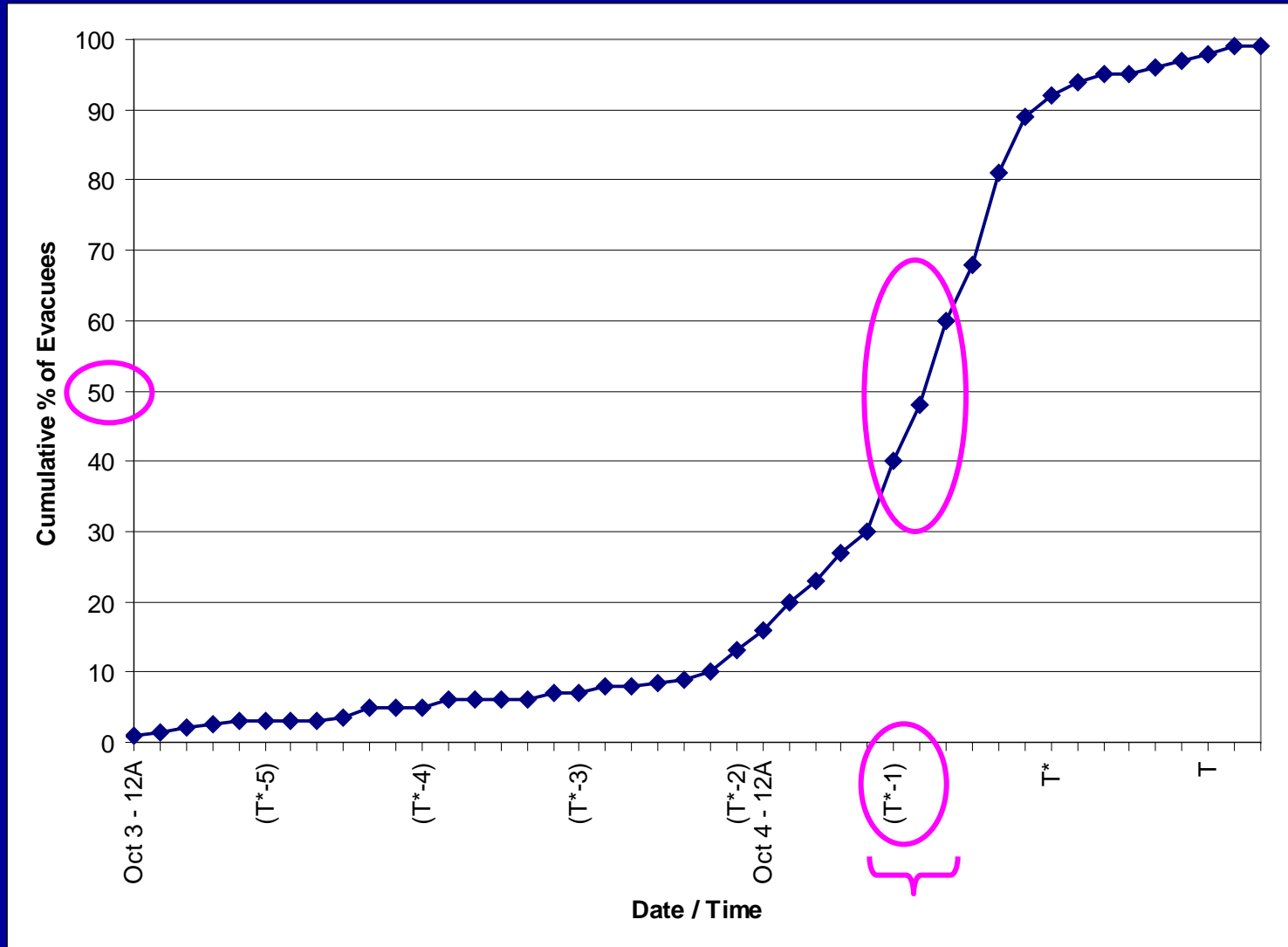


Average Household Optimal Evacuation Results

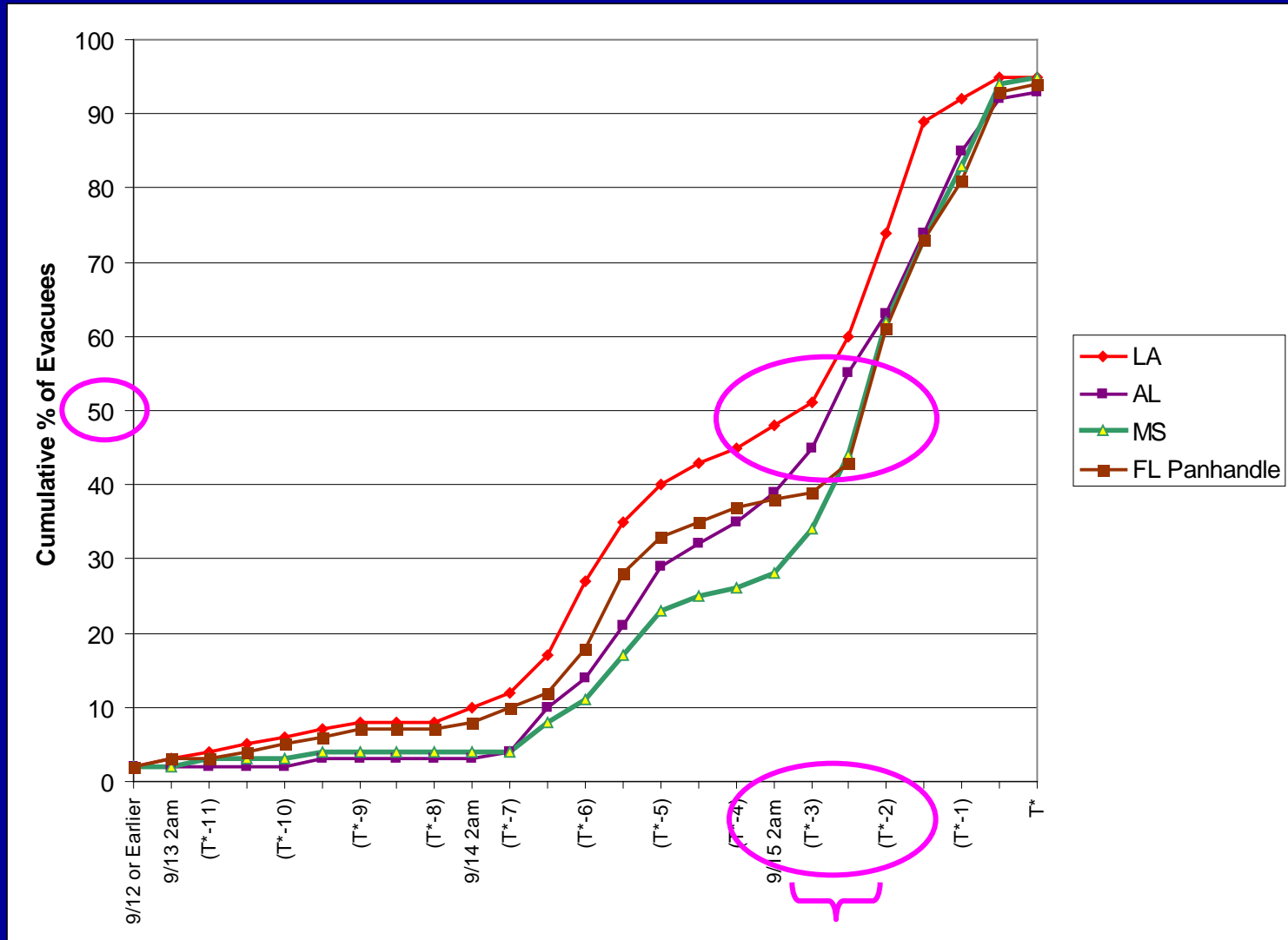


Model Robustness

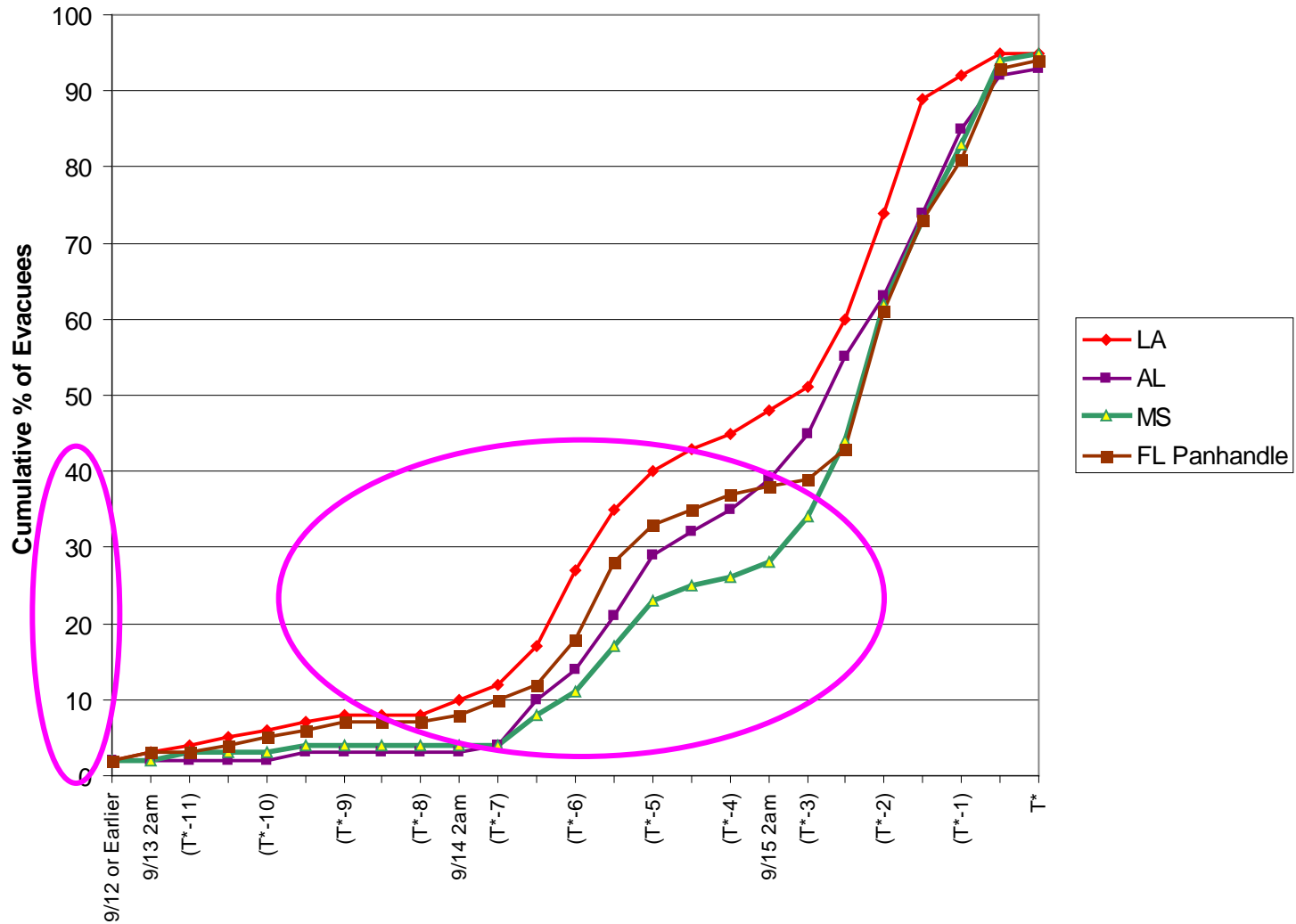
Hurricane Opal Evacuation Timing



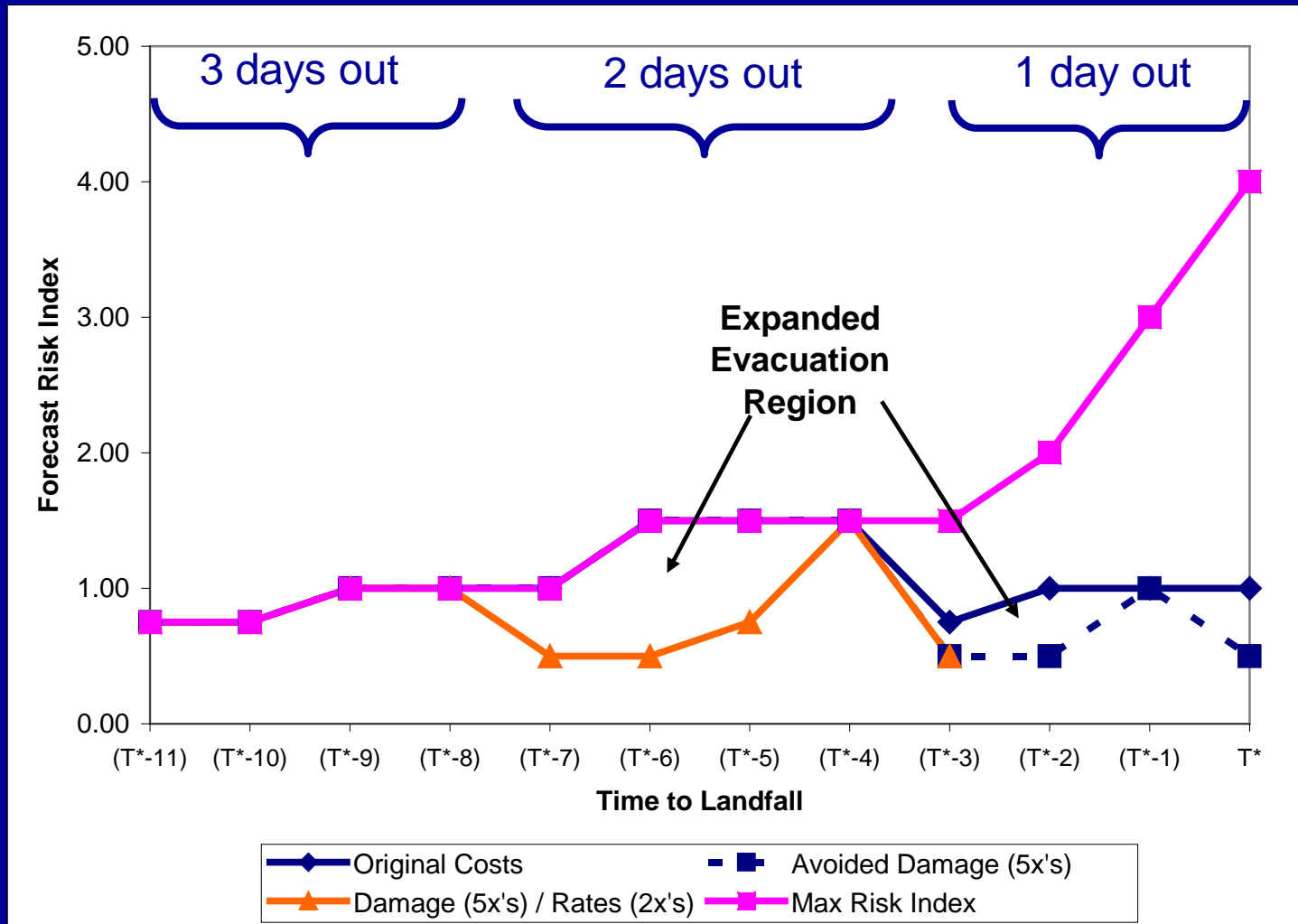
Hurricane Ivan Evacuation Timing



What about “early” evacuees

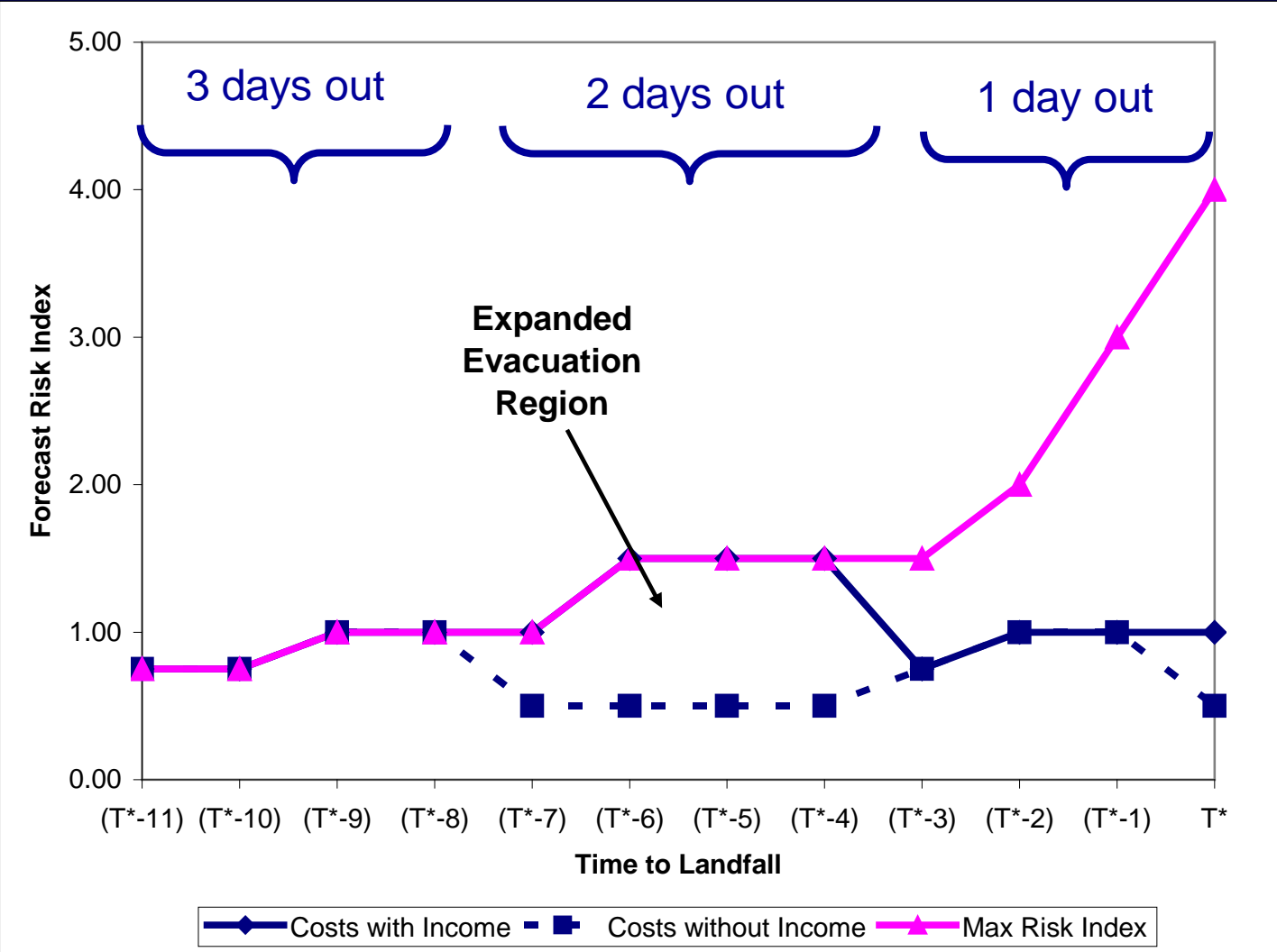


High Damage Household Type

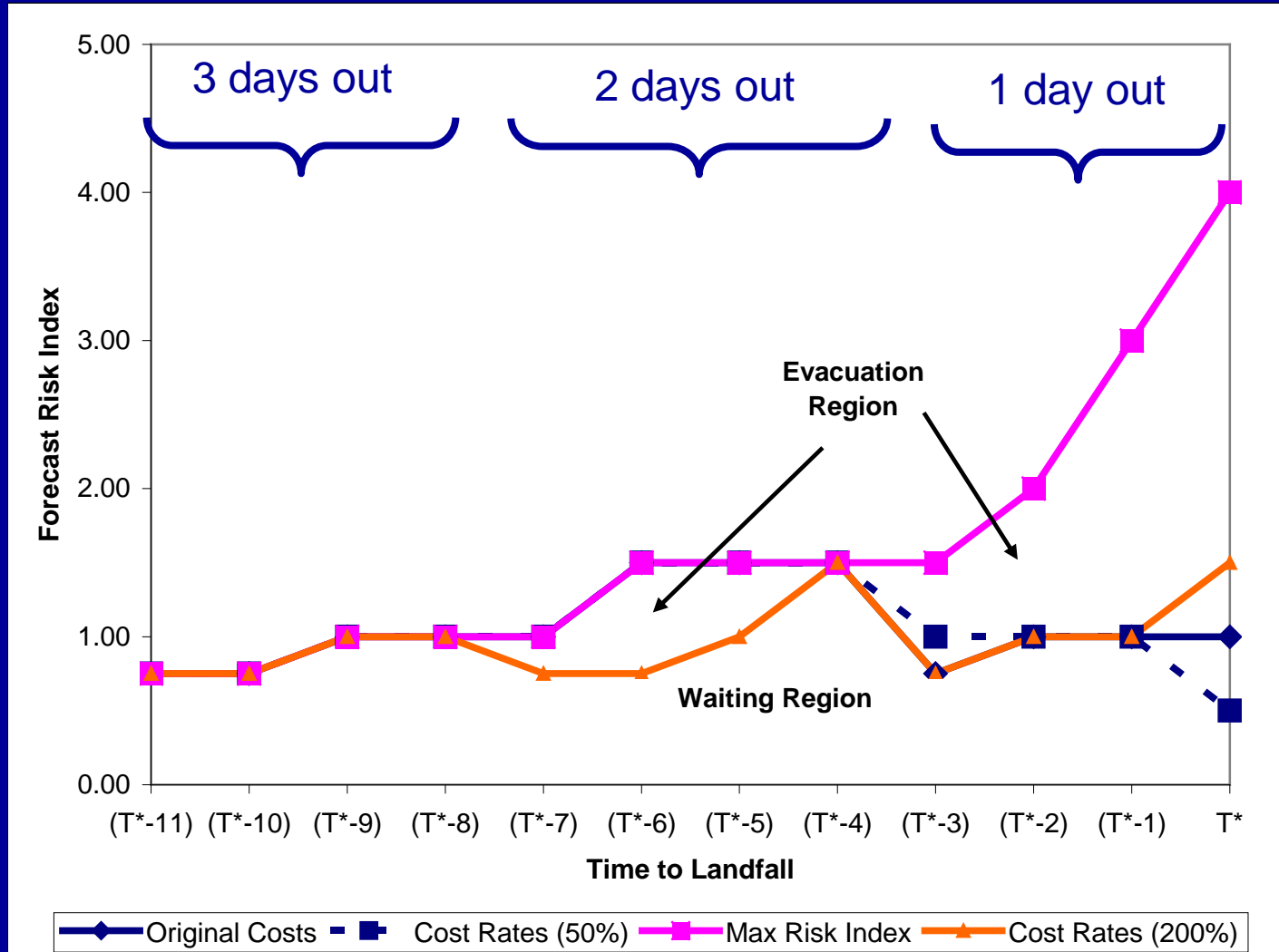


Policy Implications

Salaried vs. Hourly Evacuees



Cost Rate Increases / Decreases



Conclusions

- A good start!
- Need for better data
 - Forecast
 - Costs
 - Latest NHC products
- More sophisticated modeling
- Verify empirically
- How do people really use forecasts