NORTHERN
ILLINOIS
UNIVERSITY

Building Evacuation

By
Reinaldo Moraga

Department of Industrial and Systems Engineering
College of Engineering & Engineering Technology
DeKalb, IL

Building evacuation

- Collaboration with Argonne-TRACC focused on basically two aspects:
  - Generation of inter-exit times to obtain a more accurate curve for the evacuation demand.
  - Determine the time at which a building should be evacuated.

Part A: Inter-exit times

- The idea is to fine tune the current version of TRANSIMS trip tables.

Going from WILLIS Tower to Home

VEHICLE	START	ORIGIN	ARRIVE	DESTINATION
1	4.40pm	WT	6.00pm	Home

- If an event happens at 9.00am, the starting time has to be modified according to certain evacuation demand model.

Part A: Inter-exit times (cont.)

NORTHERN ILLINOIS UNIVERSITY

New START = Time of previous Exit + $\boxed{\text{Inter-exit time}}$

- The idea is to create a generator of inter-exit times for a building in order to establish the starting time of evacuation trips.

NORTHERN ILLINOIS UNIVERSITY

Part A: Inter-exit times (cont.)

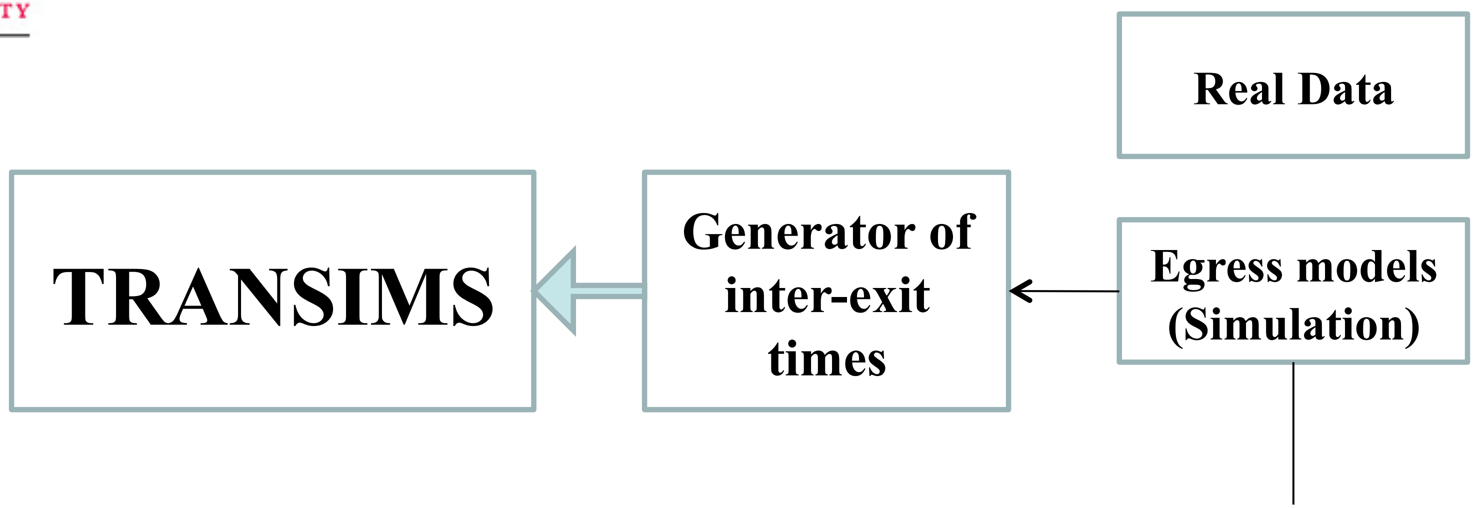
Major challenges:

- Data from past experiences of real world building evacuations.
- Literature does not provide this type of specific information.

Currently:

- Argonne is using Fuzzy Logic based approximations.

Part A: Inter-exit times (cont.)



Depends on factors such as:
- Time response of evacuees
- Type of building
- Floor layouts
- Distance from the event
- etc.

NORTHERN ILLINOIS UNIVERSITY

Part A: Methodology

1. Obtain data on evacuation times by using agent-based available software such as Simulex (egress modeling) for high buildings.
2. Design a Monte-Carlo algorithm using the data collected in (1).
   – Based on a Non-stationary Poisson process.
3. Integrate the generator designed in (2) with the generation of trip tables for TRANSIMS.

NORTHERN ILLINOIS UNIVERSITY

Part A: Simulex

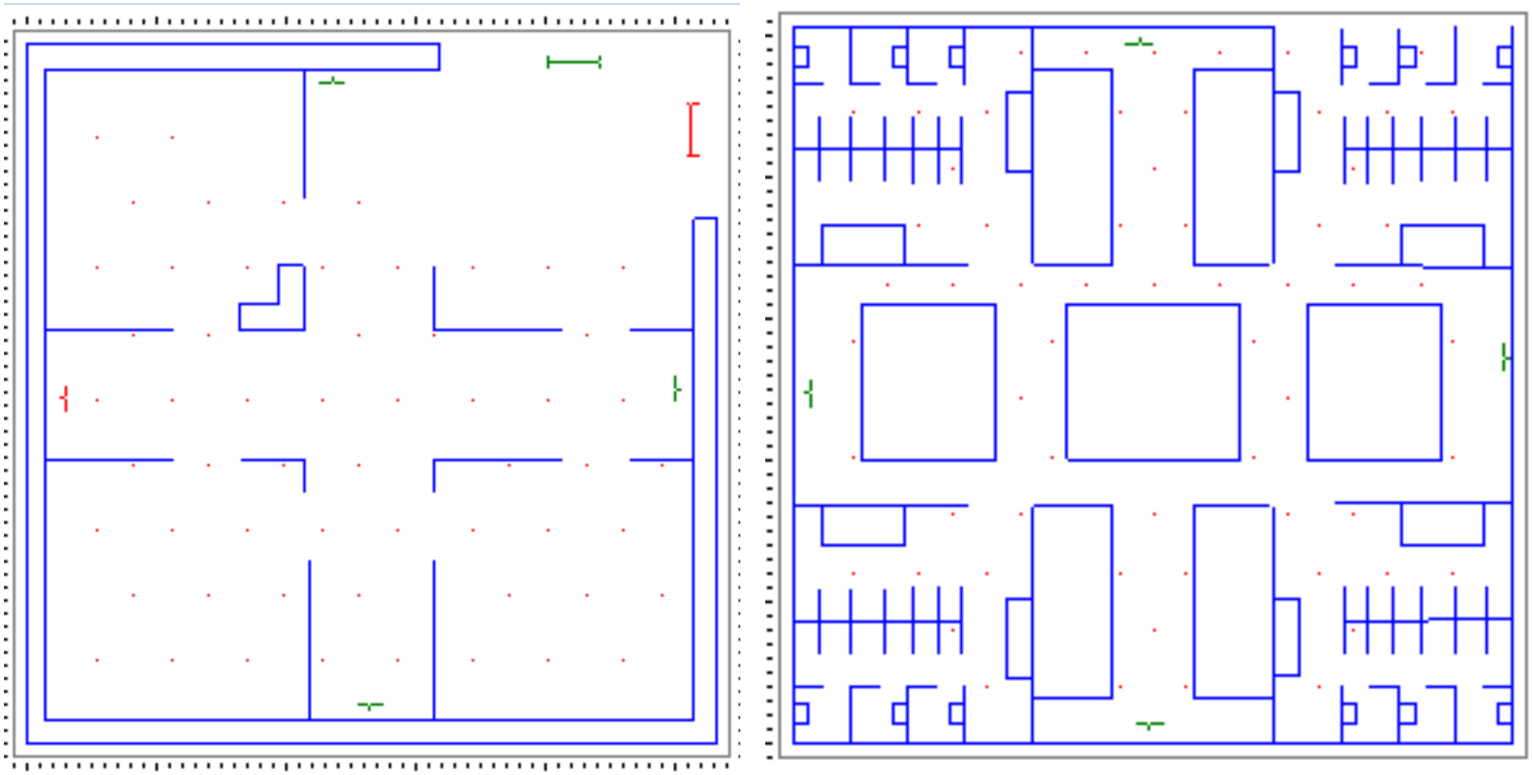


Figure 1: (a) Ground floor (b) General floor

NORTHERN
ILLINOIS
UNIVERSITY

Part A: Simulex (cont.)

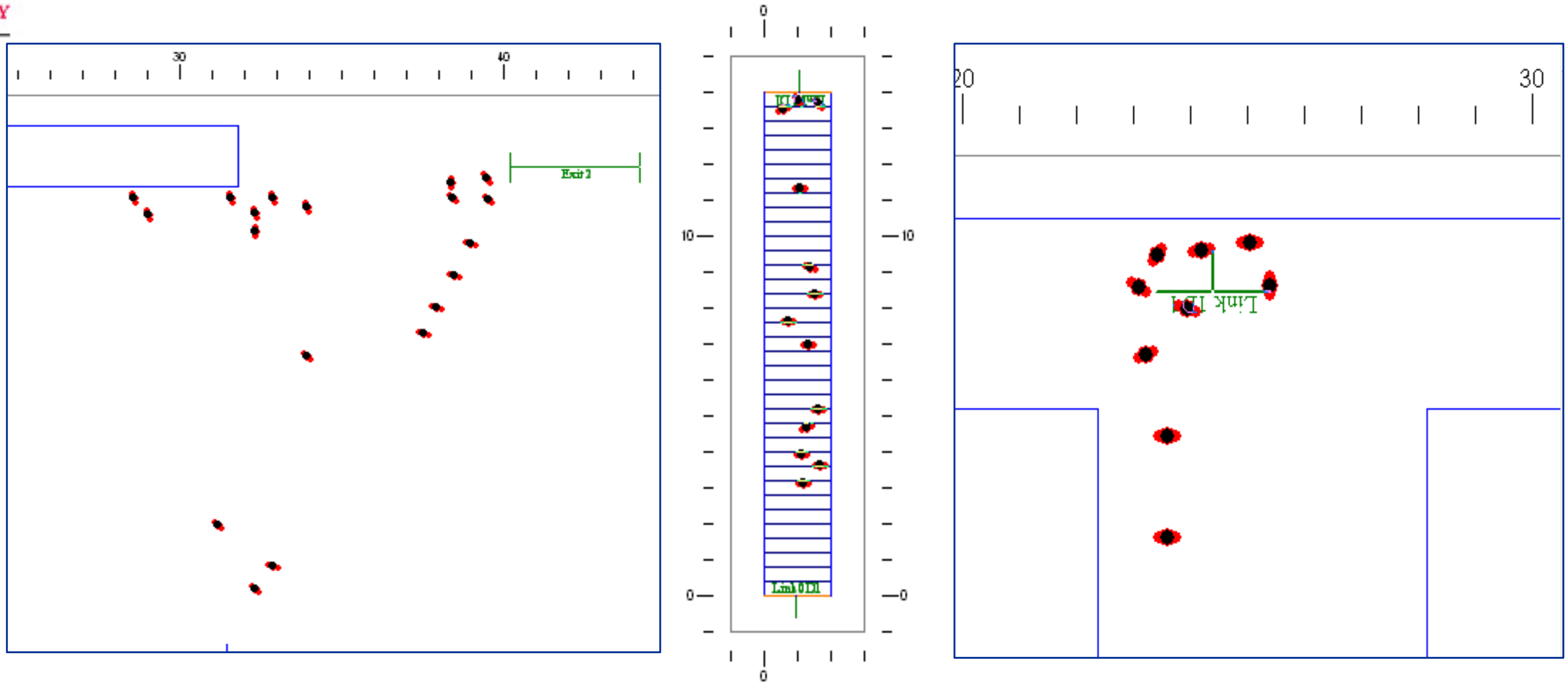


Figure 2: People reaching one of the ground exit point, people coming down the stairs, and people going to the stair exit point.

Part A: Simulex (cont.)

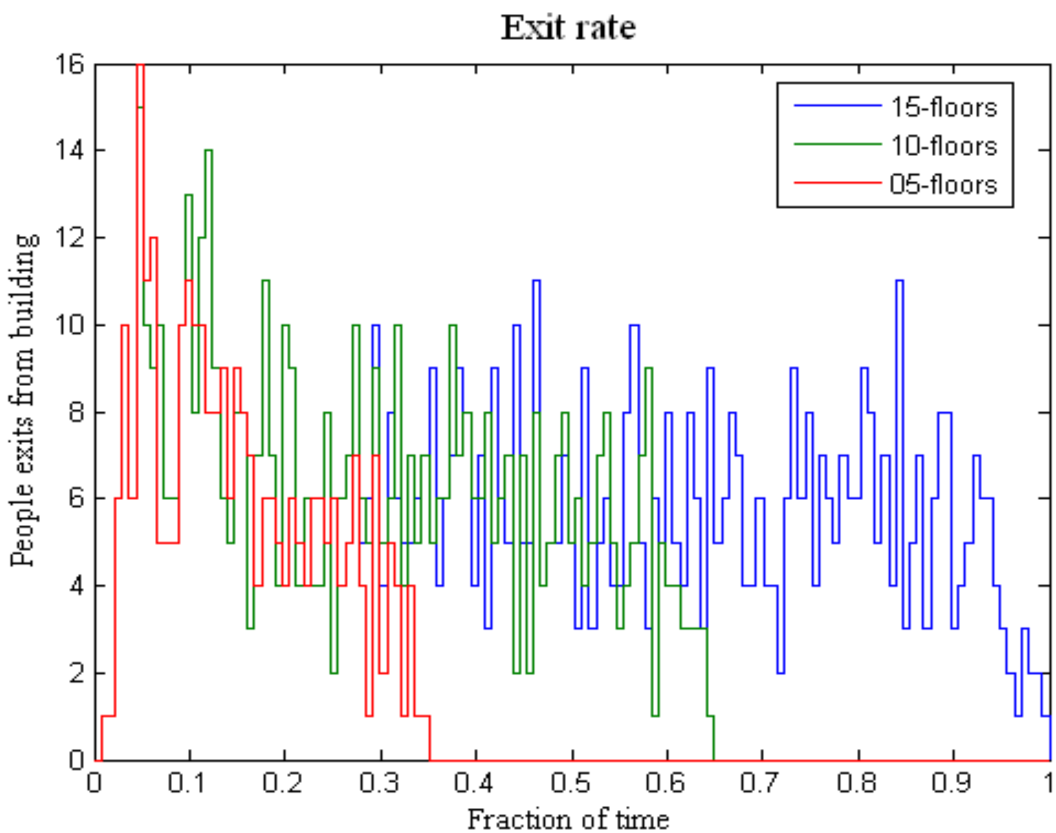


Figure 3: People exits from building over time (measured as a fraction of the total evacuation time, τ/T)

Part A: Non-stationary Poisson Process

- Non-stationary Poisson processes (NSPPs) can be fitted to many natural phenomena and behavioral patterns.
- The instantaneous rate function is $\lambda(\tau) \geq 0$ for all continuous times τ, and the cumulative rate function $\Lambda(\tau) = \int_0^{\tau} \lambda(s)ds$
- The number of events in the interval $[\tau_1, \tau_2]$ then follows a Poisson distribution with mean $\int_{\tau_1}^{\tau_2} \lambda(s)ds = \Lambda(\tau_2) - \Lambda(\tau_1)$.

NORTHERN ILLINOIS UNIVERSITY

Part A: NSPP Generation

1	**Define nf and α;**	Number of floors (nf) and fraction of elderly people (α)
2	**Set N=59nf;**	Total number of people in the building
3	**Ts=round(17.78nf);** **Te=round(32.38nf);**	Evacuation time for pure staff people Evacuation time for pure elderly people
4	**For i =1: N,**	For a desired number of exit events n to be generated.
5	**u = rand(0,1);**	A random number is generated from a uniform(0,1).
6	**$a(i)$ = -ln(u)/N;**	An inter-event time is calculated using a stationary rate 1 Poisson process standardized by N—the building population that needs to be evacuated.
7	**$y(i) = y(i-1) + a(i)$;**	Calculate the moment at which next evacuation event is going to occur.
8	**$s(i) = F^{-1}(y(i))$;**	Calculate the exit time of event i for staff people.
9	**$e(i) = F^{-1}(y(i))$;**	Calculate the exit time of event i for elderly people.
10	**$t(i)=(1-\alpha)s(i)Ts$ $+\alpha e(i)Te$;**	Calculate the exit time of event i for mixed people.
11	**End**	
12	**Report t**	

Part A: NSPP Generation

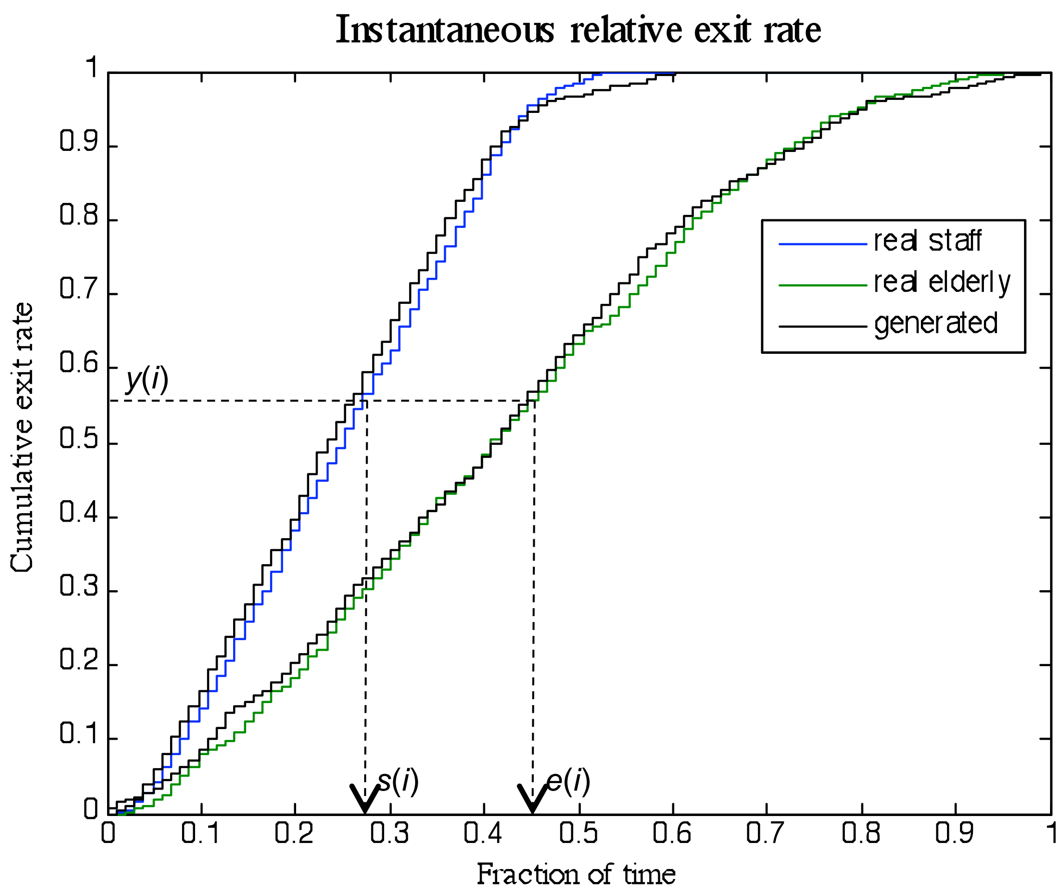


Figure 4: Verification of cumulative exit rate functions for 15-floor building

Nonparametric test:
- No significant difference
- Very small MSE

Part A: Prediction

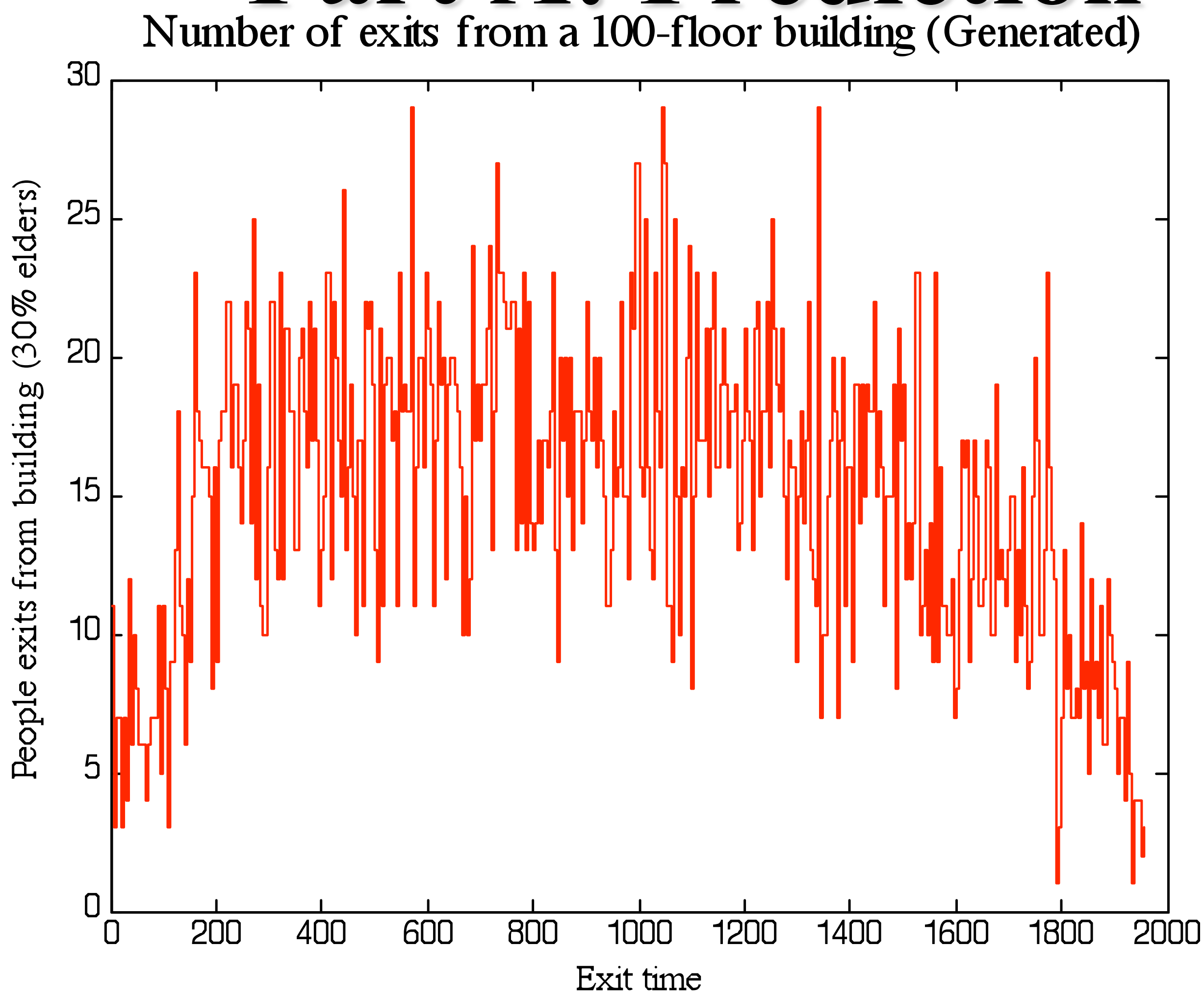


Figure 7: People exits from a 100-floor building, assuming 30% elderly people.

Comments/Future work

NORTHERN ILLINOIS UNIVERSITY

- Model validation with real world building evacuation scenarios represents a challenge.
- Extending the models to the evacuation of shopping centers, residential buildings and stadiums (currently master project).
- SIMULEX uses optimistic values for the configuration of agents. We are verifying with videos of people evacuating from buildings of recent earthquakes.
- Working on word of mouth modeling to see how the spread of news impact evacuation response times.