הפקולטה למדעי ההנדסה
המחלקה להנדסת תעשייה וניהול

אוניברסיטת בן-גוריון בנגב
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Preparedness for an Earthquake Disaster: Modeling Optimized Deployment of Emergency Treatment Sites

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Introduction

- Managing disasters (McLoughlin, 1985) includes 4 stages: **Mitigation, Preparedness, Response, Recovery**
- The first 72 hours (Fawcett at al., 2000) are most critical for saving lives
- According to Ministry of Health (MOH) **Emergency Treatment Sites (ETS)** are part of the first response and their **locations** should be **determined in advance.**
- **ETS** is Emergency Healthcare **Temporary facility** (Ahmadi-Javid et al., 2017) differ from **Permanent emergency facility,** for moderate and light condition casualties aim easing hospital's burden
- Our research define the ETS which location and amount determine in advance, as **"Rigid" concept** with **Main ETSs** and suggests an alternative **"Flexible" concept** that include both **Minor & Main ETSs**

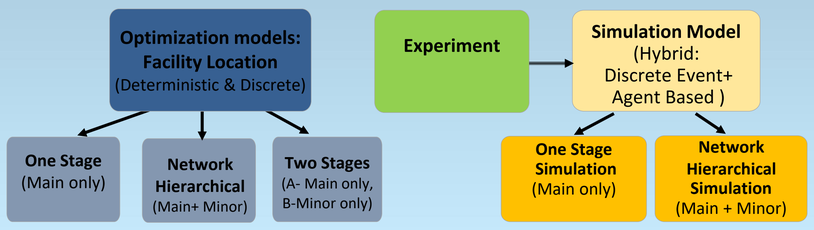
Motivation

Improve earthquake preparedness of medical response during first hours after an event!

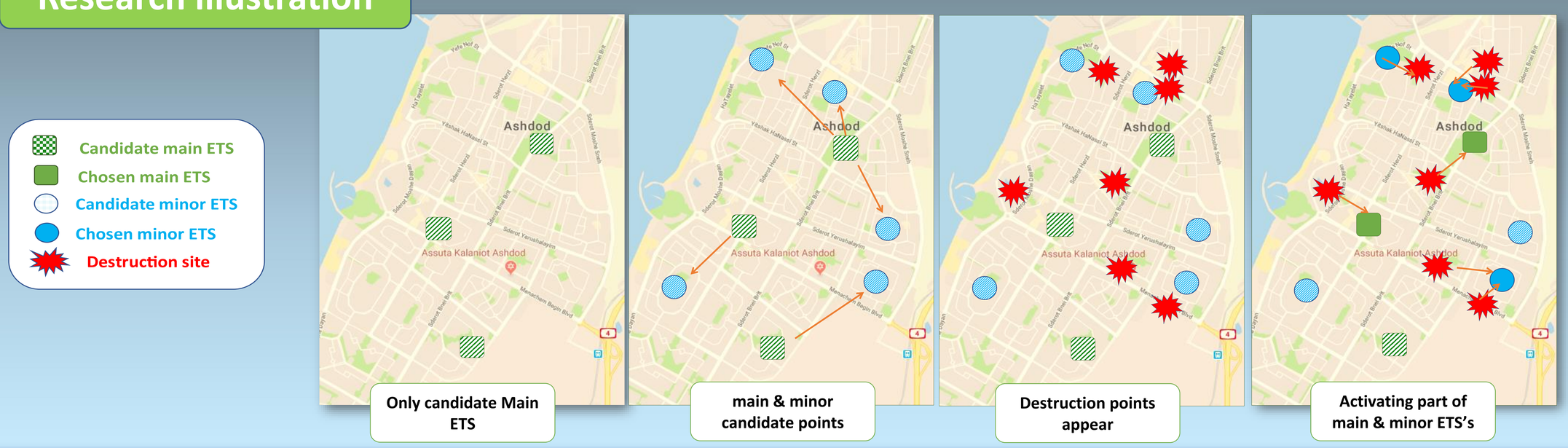
Objective

Modeling an alternative "Flexible" deployment of ETS and examining efficiency of "Flexible" vs "Rigid" concepts after earthquakes

Research methodology



Research illustration



Mathematical models

Goal programing, Bi-objective, MILP

Rigid Model A: Rigid concept (Main ETS) $min \quad \sum_{k}^{K}\sum_{j}^{J} s_{kj}\, DS_{kj}\, C_k + D * f$

Flexible Model B: One Stage , Flexible concept (Main+Minor) , synchronic

$$min \quad \sum_{j}^{J}\sum_{i}^{I} z_{ji}\, DB_{ji}\, ME + \sum_{k}^{K}\sum_{i}^{I} t_{ki}\, DM_{ki}\, C_k + \sum_{k}^{K}\sum_{j}^{J} s_{kj}\, DS_{kj}\, C_k + D * f$$

Flexible Model C: Two Stage, Flexible concept (Main+Minor) , two stage

Simulation

- **Target** - The simulation focus on transferring casualties from destruction sites to Main or Minor ETS.
- **Resources** – rescuers, main & minor ETS candidate points
- **Entities** - casualties
- **Method** - Implementation of the two concepts (rigid & flexible) For 100 Different earthquake scenarios (different destructions sites , 30 replications each)
- **Results** - % of casualties that got treatment in ETS's
  Avg . Evacuation Distance per casualty

Using R-studio, simmer package

Mathematical VS Simulation models*

Parameter	Mathematical models	Simulation
Locations of ETS candidates sets points	Given in advance	Given in advance
Amount & Locations of destructions sites	7 points given in advance	Generate randomly 4-10 destruction points
Distance from point to point	Calculated in advance	Calculated in advance / ad hock
Walking duration of casualties & rescuers	Not considered	Gamma distribution based on the experiment results
Arrival rate of rescuers X ~ exp	Not considered	x~exp(1/10) , 1 arrivals per 10 minute
Rescue teams breaks	Not considered	Every 3 hours
The influence of terrain (Easy, medium, hard) on velocity	Not considered	Uniform probability assumed (1,1.2,1.4)

* *Partial sample*

METRICS & PARAMETERS

Metric 1:
The average distance a treated casualty walks. A proxy of his evacuation duration.

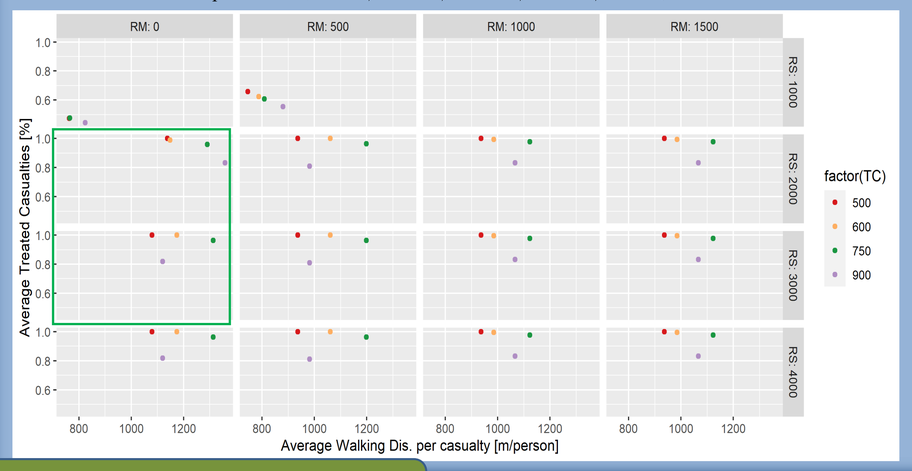
Metric 2:
The proportion of treated casualties by all ETSs compared to total casualties in the area

- **TC** – total number of casualties (may accept the following values: 500, 600, 750, 900)
- **RS** – maximal possible distance from the destruction site to the main ETS (ranging from 1000 to 4000 meters)
- **RM** – maximal possible distance from destruction site to minor ETS (which receives the values: 500, 1000, 100 meters)
- **MS** – maximal patient capacity in the main ETS (which receives the values: 250, 300, 450)
- **MM** – maximal patient capacity in minor ETS (50 or 100)

RESULTS

A TOTAL COMPARISON OF SIMULATION RESULTS – RIGID & FLEXIBLE

A TOTAL COMPARISON OF MATHEMATICAL RESULTS – RIGID & FLEXIBLE



Conclusions

- ✓ The analysis in the study shows that there is **substitutability** between the two objectives (the avg. distance & the proportion of treated casualties) in both **mathematical and simulation** models.
- ✓ In the **mathematical** model **the flexible model is equal or better than rigid model** and was found to be **robust** in the **stochastic simulation** as well
- ✓ In the **mathematical** models – the decision makers should give **their preference** (weight/penalty) to the proportion of the treated casualties' objectives which may affect the final solution

Innovation & Contribution

- ✓ A new **"Flexible concept"** using **"Minor ETS"** as part of preparedness in contrast to the "Rigid concept" .
- ✓ The proposed **decision support tool model**, can be adapted to any specific defined area/city according to damage forecasts or a real-time damage report by adding adjusted parameters and assumptions.
- ✓ The model can be implemented in the phase of **preparation** or in real time reaction **as response** and allow local authority to function **automatically and autonomously.**