TEMPORARY LOGISTIC HUBS PREPOSITIONING FOR PREPAREDNESS AND RESPONSE DISASTER OPERATIONS

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OUTLINES

- Introduction
- Types of hubs in humanitarian logistics
- Maximal covering location problem
- The gap between the old and the proposed solution
- Numerical example and results
- Future directions

Introduction

Large scale natural disasters like earthquake, flooding, typhon,

pandemic disease cause catastrophic consequences to human life

Introduction

- 6th February, 2023, 4:17AM, Mw 7.8 earthquake struck Sothern and central Turkey and northern and western Syria
- Casualties: 57,759 death and 121,704 injured in both Turkey and Syria (Wikipedia)


photo : Salem Mohammadi


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Introduction

- Aftermath of natural disasters results in the following challenges:
- **Evacuees, displaced and injured people**
- High **demands** for relief items
- **Emergency supplies**

INTRODUCTION

- Affected people need:
- Evacuation to shelters
- Medical treatment
- Relief items





INTRODUCTION/The aim of the research

- Save human life, property loss and infrastructure by:
- **Emergency and humanitarian logistics**
- **Disaster operations management**
- **Optimization modeling utilization**
- **Hubs pre-positioning and stock level of relief items**
- **(Define the number and the locations of different temporary hubs specifically: the warehouses and shelters)**

Four sequential stages occurring during the life cycle of the disaster:

Mitigation stage –Actions to prevent the onset of the disaster or moderate its effects

Preparedness stage aims at decreasing the response time by the advanced procurement and pre-positioning of needed supplies, locations of temporary hubs

Response stage, the disaster mitigations plans are activated and the emergency supplies are mobilized.

Recovery phase is the final step of emergency relief (i.e., retrieving the victims, rebuilding the infrastructure, and mitigating damages in the disaster zones)

Emergency logistics-Challenges

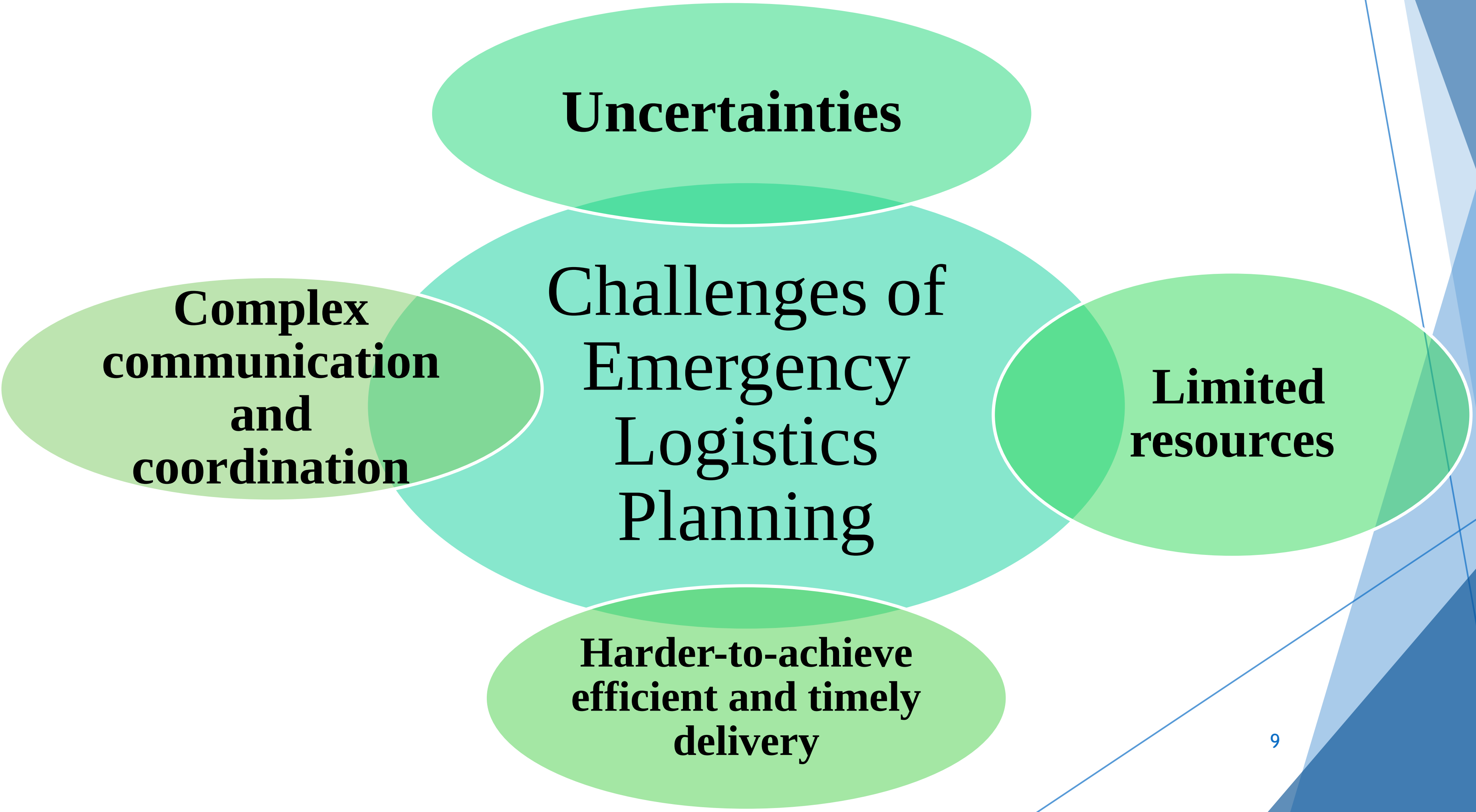
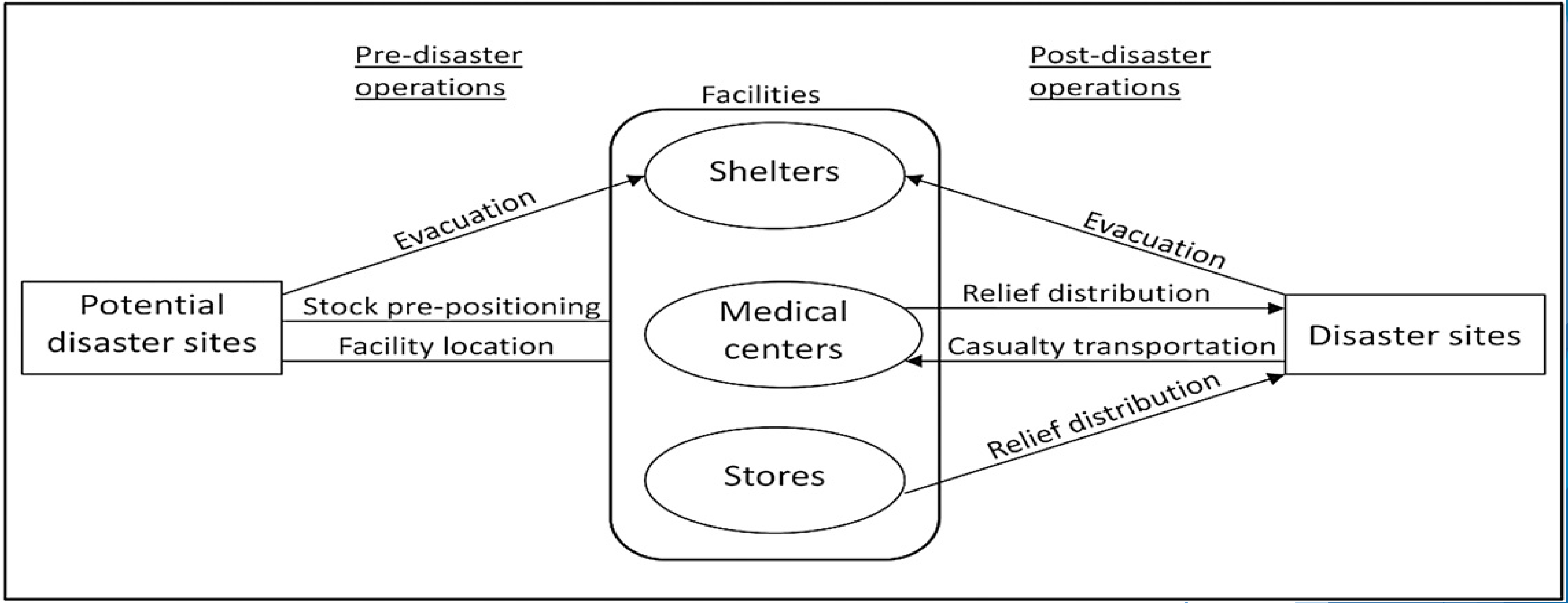


Fig. 1. Framework for disaster operations and associated facilities and flows (emergency logistic operations)



Introduction- Hubs utilization in humanitarian logistics

- Hub is a type of facility that serves the people in certain geographic location
- **Types of the hubs according to the nature of the hubs**
- **Permanent hubs-** warehouses that located in safe area and disaster resistant buildings-Global hubs
- **Temporary hubs-** tents, shelters, schools, mosques, churches, stadium -points of distribution POSs

Introduction- Hubs using in humanitarian logistics

- **Types of hubs according to the function of the hubs**
- **Production hubs** such as personal protective items production units (face mask production hubs)
- **Example for temporary production hub** is a type of production hubs filling textile sacks with sand for building temporary dams to prevent the river from flooding (extension dams)
- **Warehouses hubs** that are used in storing the stock of relief items such as: water, canned food, blankets, hygienic materials and medicine
- **Medical hubs** such as temporary or mobile medical clinics like some kinds of medical equipped tents, buses, permanent hospitals

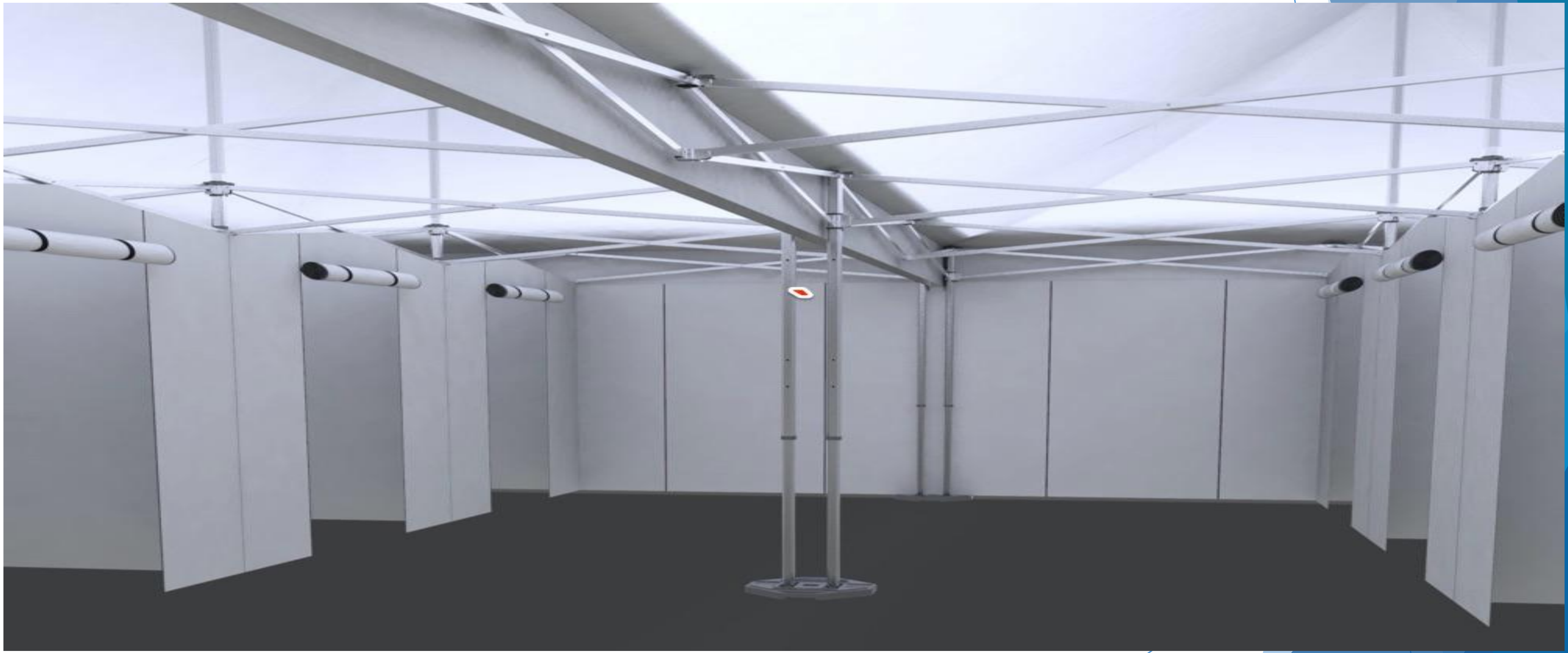
Introduction- Hubs using in Service Sector

- **Service sector hubs** like pharmacies, banks, markets and malls
- Service sector hubs are used in **clever or smart cities** and new capitals in some countries such as Indonesia, Saudi Arabia-new brand city will be established
- **Set and maximal covering problem and location theory** are used to define the proper and economical locations of these hubs to serve all the population related to the geographic area

Examples of different hubs- Temporary hospital

Hospital surge intensive care unit

Hospital tents

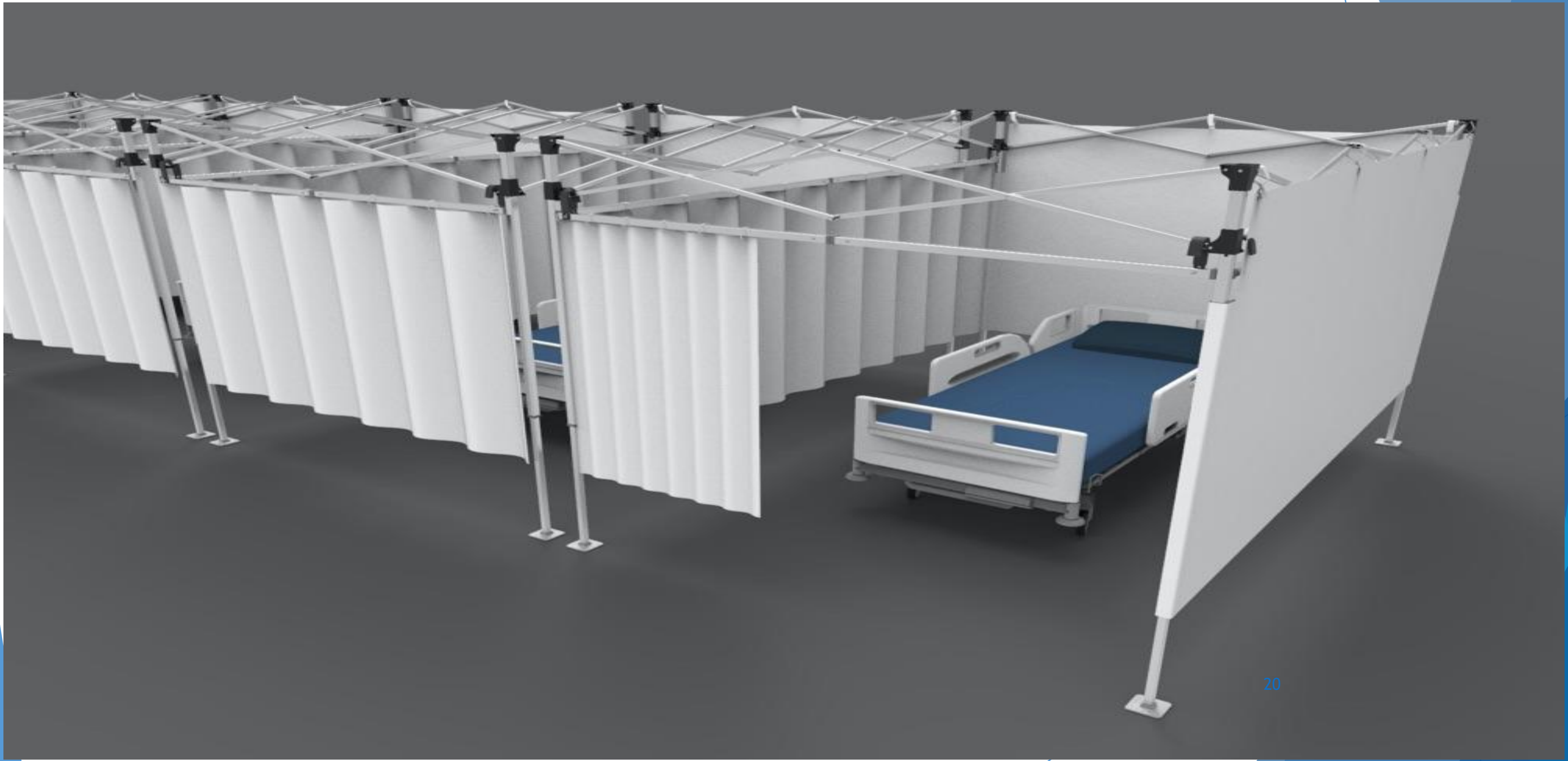


Using stadium area to locate temporary hospital (case of China)

Using stadium area to locate temporary hospital (case of China)

Temporary hospital-tent/ intensive care unit

Pop-up-medical-partition-system-for-field-hospitals



Shower trailer

Patient Screening Facility

Dry storage

4:25 38%

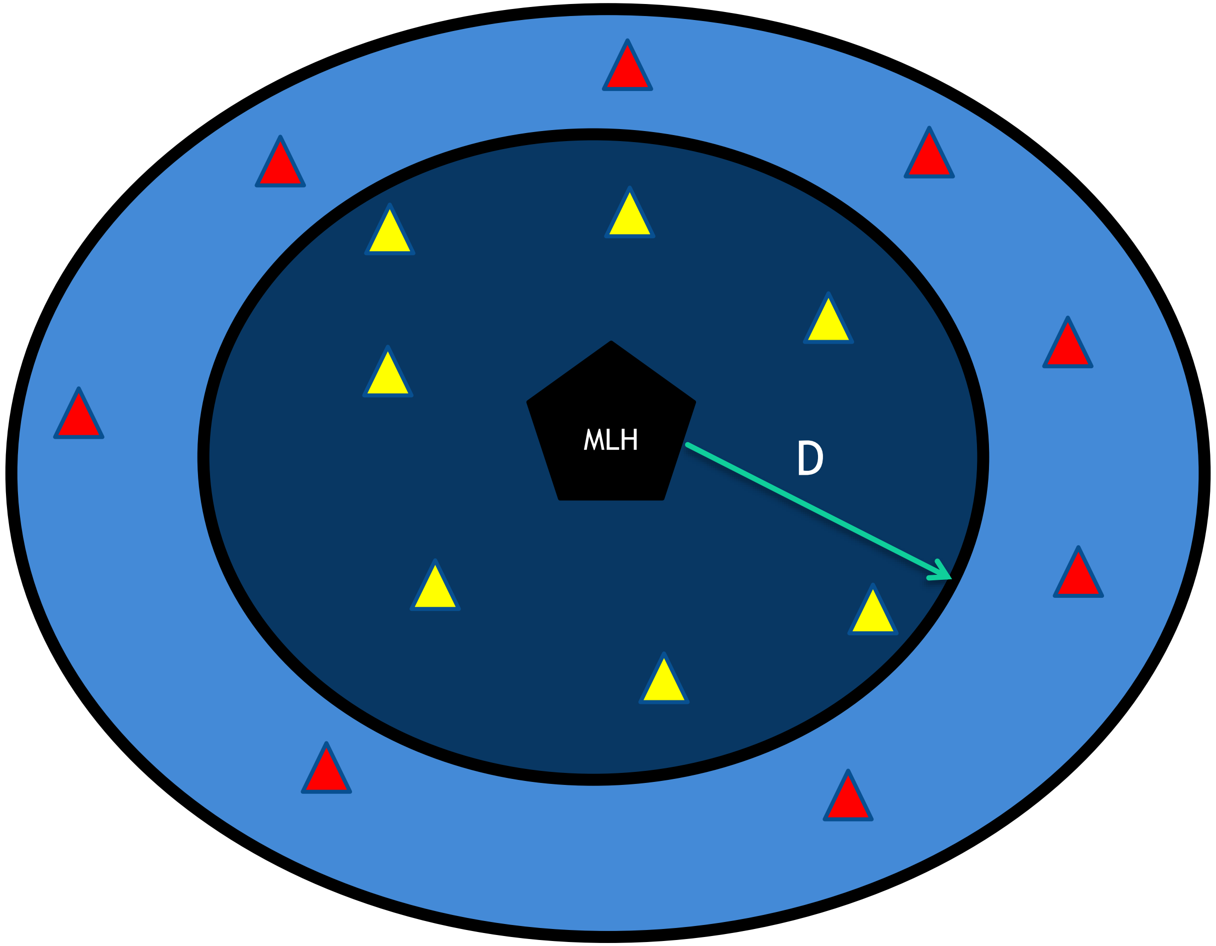
Temporary hospital facilities
Quarantine tents
Premises for medical personnel

PORTABLE BUILDINGS

The aim of the study

- Develop a robust methodology using a **modified version of the maximal coverage location problem** to serve all demand points using limited number of temporary logistic hubs

Figure 2: Coverage Area (Maharjan et al., 2020)



D : Coverage distance within which mobile logistic hubs (MLHs)
△: PoDs covered within the stipulated coverage distance
▲: PoDs uncovered within the coverage distance

- The original idea was proposed by Mahrajan et al.(2020)
- The authors found the **optimal locations of the hubs** in Nepal that exposes to 3 types of disasters: earthquake, flooding and landslide

- The following **constraints** were added to the mathematical model to serve **reachable** areas only:
- **Transportation accessibility**
- **Level of development**
- **Disaster safety**

The gap between the proposed model and Nepal paper

Our study	Nepal paper
Reachable area and isolated area	Only reachable area
The risk of facility factor is considered	The risk of facility factor did not considered
Road and aerial transportation (UAV, DRONES)	Road transportation
Real life information (accuracy and reality)	Not accurate information

The contribution of the new study

- **The objective function** : Maximize the total number of demand points that are served within the specified reachable and isolated coverage area.
- Risk of facility status used 2 types of factors:
- **Crime rate**= number of criminal actions/number of population
- **Damage degree**=number of the collapsed buildings/total number of the buildings
- **UAV system** and **aerial image** analysis method are developed to evaluate the damage degree of earthquake area using specific types of **drones**. (Chen et al., 2016)

Unmanned aerial autonomous helicopters (UAV) or drones Types

Kaman K-max (United States Marine Corps)

Scout B1-100 (courtesy of Aeroscout GmbH, Switzerland)

Colibri I (Universidad Politécnica de Madrid www.vision4uav.eu)

UVH-29E (Credit: UAVOS GmbH www.uavos.com)

Muli-Rotor UAV (Hexacopter)

Black Hornet Nano Helicopter (Photo: Richard Watt/MOD)

Fig. 8. Avidrone 210TL.
Canadian Avidrone Aerospace has introduced the CAV it developed in May 2019 (20-40kg payload)
The range of both is up to 97 kilometers,

Mathematical model-Optimization modelling

- The modified MCLP has been formulated as a **static, single-stage deterministic problem** based on the following assumptions:

- (1) The locations of MLHs are assumed to be in district headquarters.
- (2) All PoDs have road access to and from the candidate MLH locations.
- (3) The PoDs are either fully covered or uncovered. There is no provision for partial
- * The coverage follows binary requirements.

The original mathematical formulation is as follows:

$$\text{Maximize} \sum y_i \tag{1}$$

$$\text{S.T.} \sum x_{j \in S_i} \geq y_i \, \forall i \in I \tag{2}$$

$$\sum x_j \leq P \tag{3}$$

$$\sum T_j x_j \geq N_T \sum x_j \quad \forall j \in J \tag{4}$$

$$\sum D_j x_j \geq N_D \sum x_j \quad \forall j \in J \tag{5}$$

$$\sum V_j x_j \leq N_V \sum x_j \quad \forall j \in J \tag{6}$$

$$x_j \in \{0,\ 1\} \, \forall j \in J \tag{7}$$

$$y_i \in \{0,\ 1\} \, \forall i \in I \tag{8}$$

Where,

I = denotes the set of PODs;

J = denotes the set of MLHs;

D = coverage distance; the distance beyond which a PoDs is considered uncovered;

P = number of MLHs to be located;

d_{ij} = the shortest distance from node i to node j;

$$x_j = \begin{cases} 1 \text{ if an MLH is located at candidate site } j \in J \\ 0 \text{ if otherwise;} \end{cases}$$

$S_i = \{j \in J | d_{ij} \leq D\}$;

$$y_i = \begin{cases} 1 \text{ if a POD is covered within the coverage distance} \\ 0 \text{ if otherwise;} \end{cases}$$

N_T = the minimum threshold value for transportation accessibility;

N_D = the minimum threshold value for development index;

N_V = the maximum threshold value for disaster vulnerability index;

T_j = the transportation accessibility index value for candidate site j;

D_j = the development index value for candidate site j;

V_j = the disaster vulnerability index value for candidate site j.

The proposed new constraints

- Damage degree constraint: Dd
- $\sum Ddjxj \leq NDd \sum xj \qquad\qquad \forall j \epsilon J$

- Crime rate constraint: Cr
- $\sum CRjxj \leq NCr \sum xj \qquad\qquad \forall j \epsilon J$

Model implementation-The parameters

- D=100 KM   (coverage distance)
- P=12 Mobile logistic hubs
- NT=30 KM (transportation accessibility)
- ND=0.37 (level of development)
- NV=0.55 (disaster vulnerability)
- NDD=0.30 (maximum damage degree)
- NC=0.05 (maximum crime rate)

Model implementation and results

- The MLH model was implemented for a network of **33 PoDs** and **59 candidate MLHs**, **Lingo 18** soft ware was used to solve the problem
- **Run time 7 seconds**
- Total variables=2040
- 92 integer variables
- 39 total constraints

Figure 4 : the percentage of demand points covered by a varying number of mobile logistic hubs

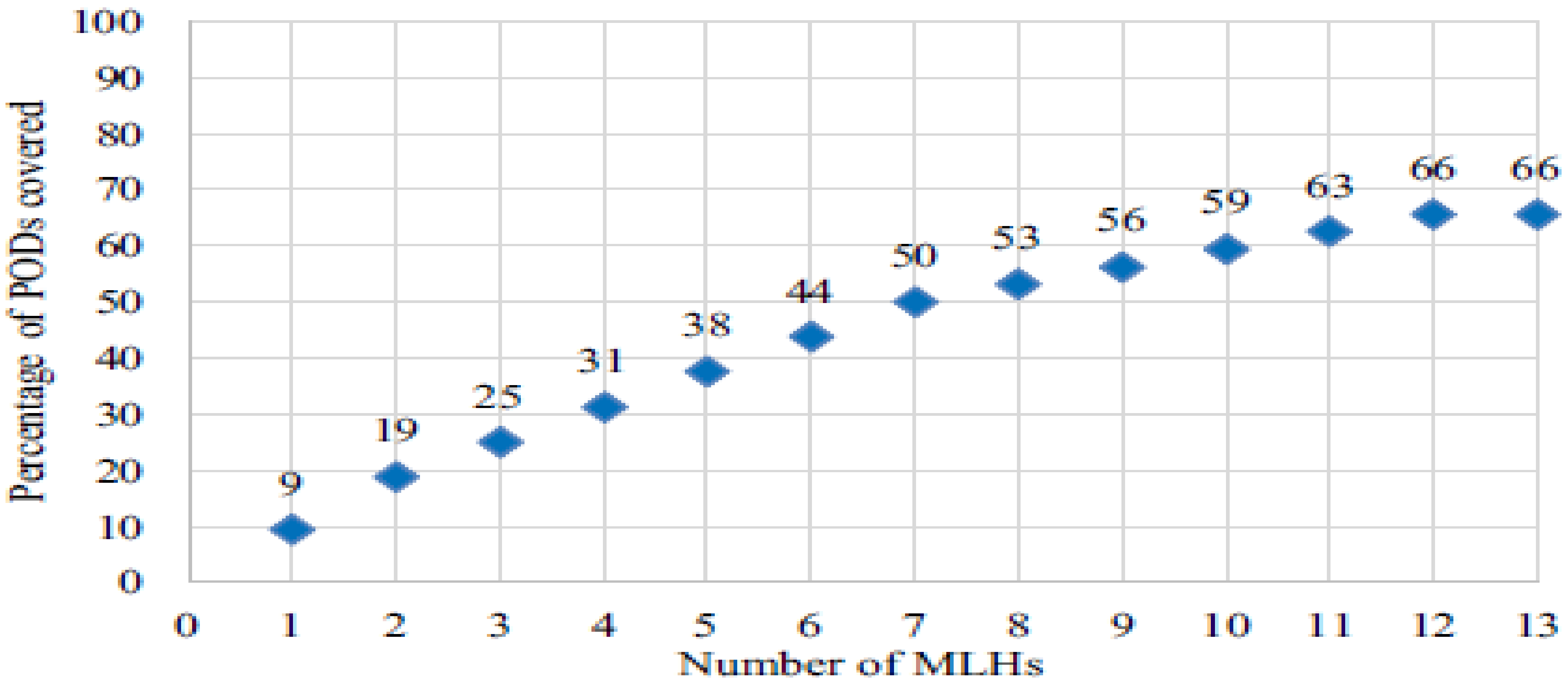


Table 1:The Allocation of PODs to MLHs

S.N.	MLH locations	PoDs covered		
1	Achham	Accham	Bajura	
2	Bhojpur	Bhojpur		
3	Dadheldhura	Baitadi	Dadeldhura	Doti
4	Gulmi	Gulmi		
5	Ilam	Illam	Panchthar	
6	Khotang	Khotang		
7	Mahottari	Dhanusa	Mahottari	Sindhuli
8	Okhaldhunga	Okhaldhunga	Solukhumbu	
9	Pyuthan	Pyuthan	Rolpa	
10	Ramechhap	Ramechhap		
11	Salyan	Rukum West	Salyan	
12	Tanahu	Lamjung		

Results of the model with comparison

Parameters	Old model	New model
Candidates Temporary hubs out of 59 candidate	12	11
Reachable covered demand points out of 33	22	20
Isolated covered demand points	0	13
Percentage of coverage	66%	100%

The result: The new model is more real and accurate, it can be used to cover all demand points

Future directions

- For future directions, we can use the system of **truck drone (tandems)** method at the same time to serve all demand points: reachable and isolated
- **Bio-Sensors** can be used to define the locations of the victims under debris using **artificial intelligence**
- **Debris removal is crucial**

- Thank You
- Any Questions?