Disaster Resilient Cities: An OR Approach to Disaster Management

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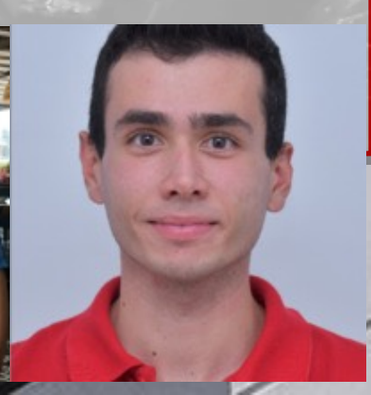
G. İkizler, E. Şentürk, Defne Tan, Egehan Uğraş

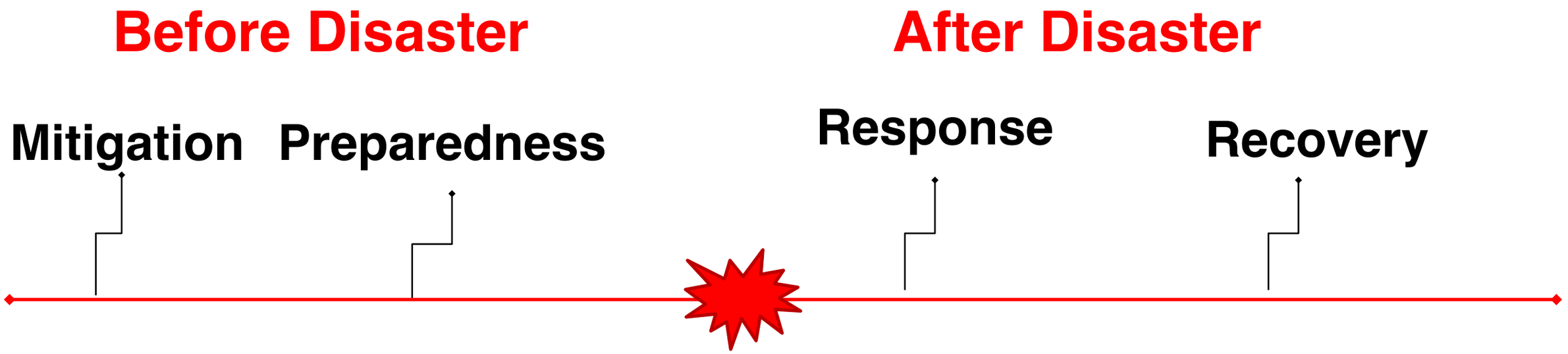


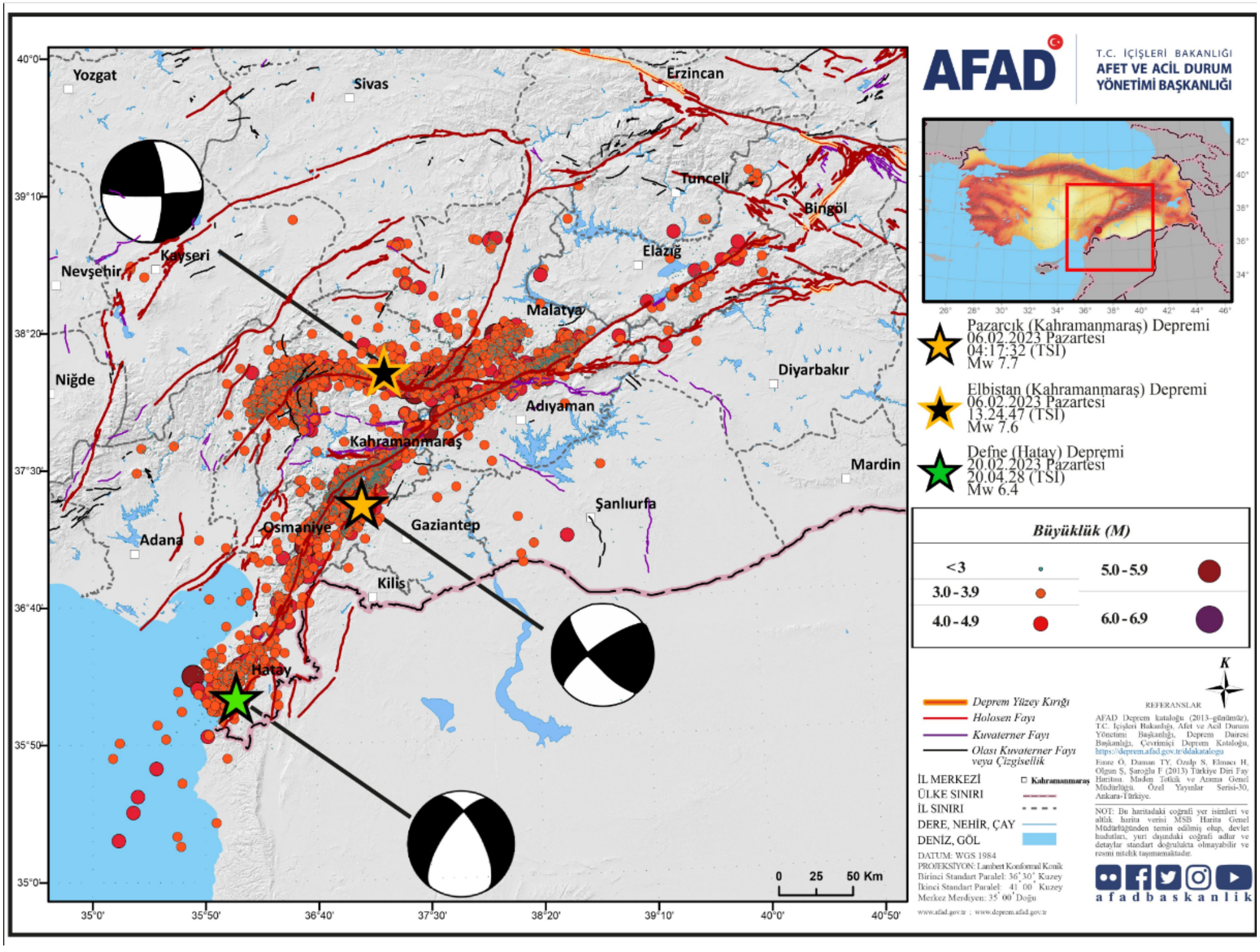






Disaster Management in Literature

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Birinci Standart Paralel: 36° 30' Kuzey
İkinci Standart Paralel: 41° 00' Kuzey
Merkez Meridyen: 35° 00' Doğu
www.afad.gov.tr ; www.deprem.afad.gov.tr
REFERANSLAR
AFAD Deprem kataloğu (2013–günümüz), T.C. İçişleri Bakanlığı, Afet ve Acil Durum Yönetimi Başkanlığı, Deprem Dairesi Başkanlığı, Çevrimiçi Deprem Kataloğu, https://deprem.afad.gov.tr/ddakatalogu
Emre Ö, Duman TY, Özalp S, Elmacı H, Olgun Ş, Şaroğlu F (2013) Türkiye Diri Fay Haritası. Maden Tetkik ve Arama Genel Müdürlüğü. Özel Yayınlar Serisi-30, Ankara-Türkiye.
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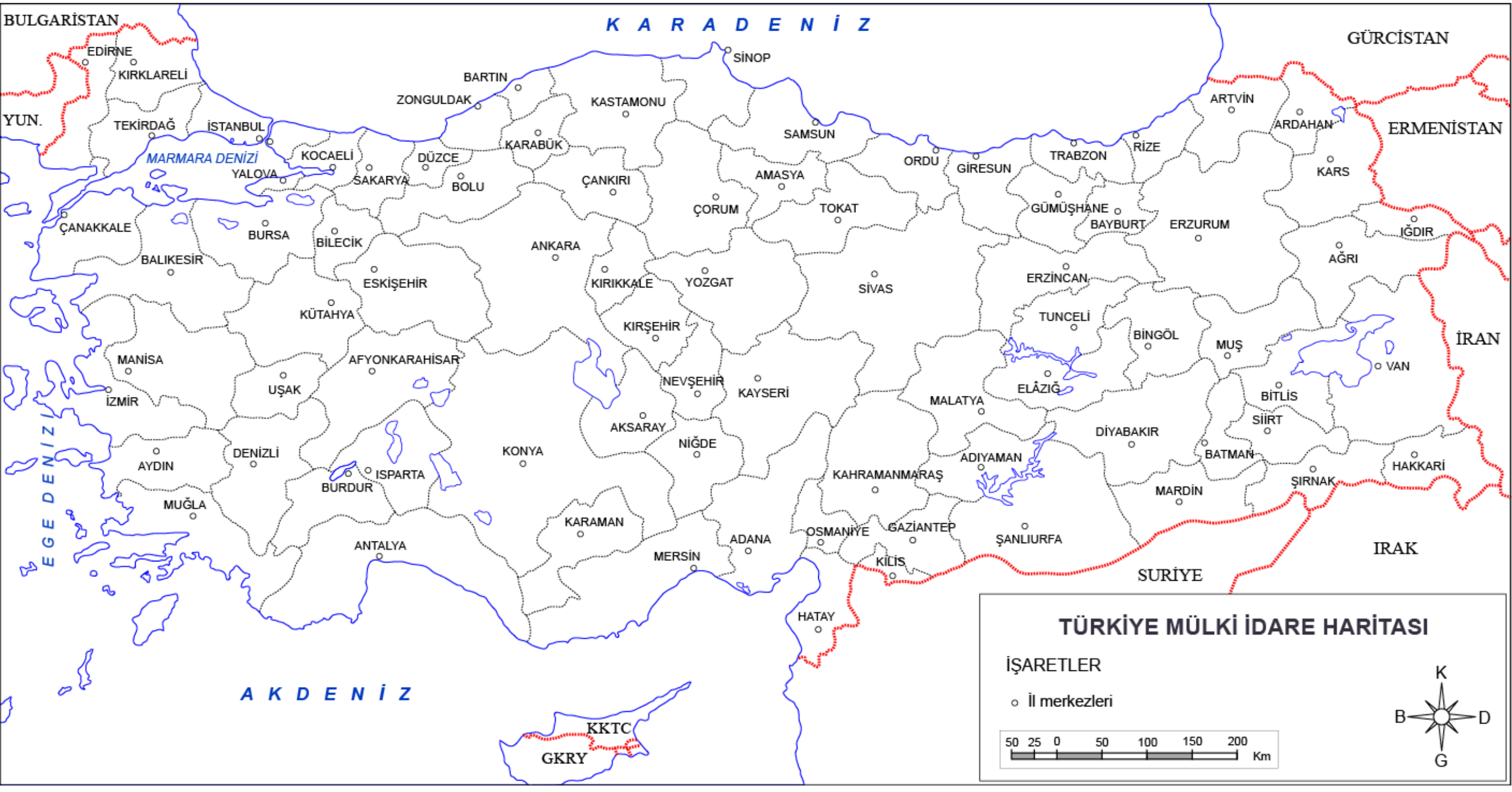
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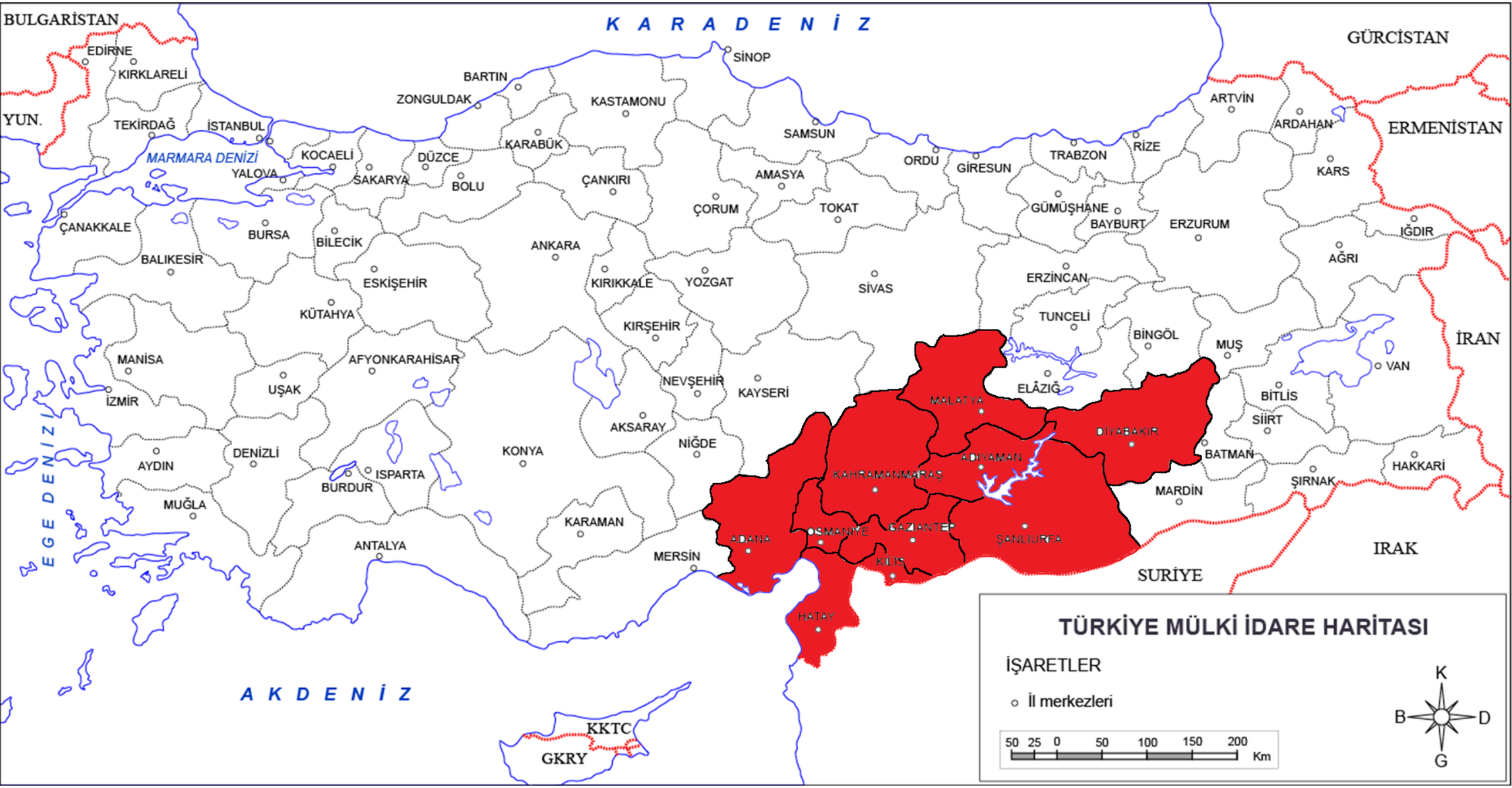
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Panels and Workshops on Resilient Cities

İstanbul
Adana
Mersin
Diyarbakır
Gemlik

Disaster Logistics


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İMAMOĞLU: "ARTIK HİÇBİR ŞEY ESKİSİ GİBİ OLAMAZ"
SON DAKİKA


ipaistanbul 15d
Prof. Dr. Bahar Yetiş, lojistik boyutu çalışma grubu değerlendirme notlarını paylaşıyor.
Lojistik Boyutu
İSTANBUL BÜYÜKŞEHİR BELEDİYESİ
İSTANBUL
DEPREM ÇALIŞMA GRUBU
TOPLANTISI
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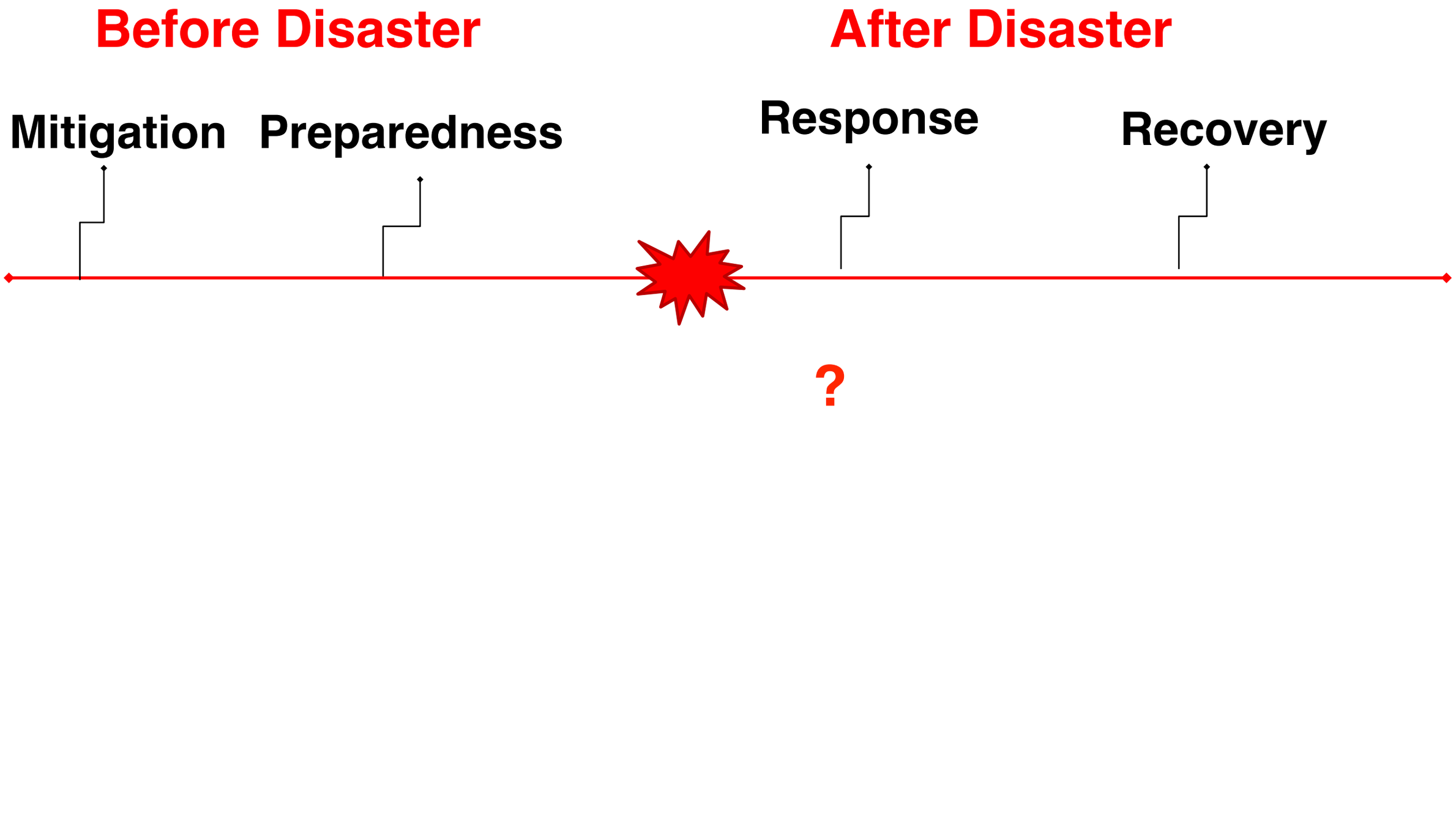
ÇALIŞMA TOPLANTISI
16 MART 2023

Disaster Management in Literature



Disaster response

Disaster

Acute phase

(First 72 hrs)

Early recovery

(First 100 days)

Preparedness | Response | Recovery | Mitigation

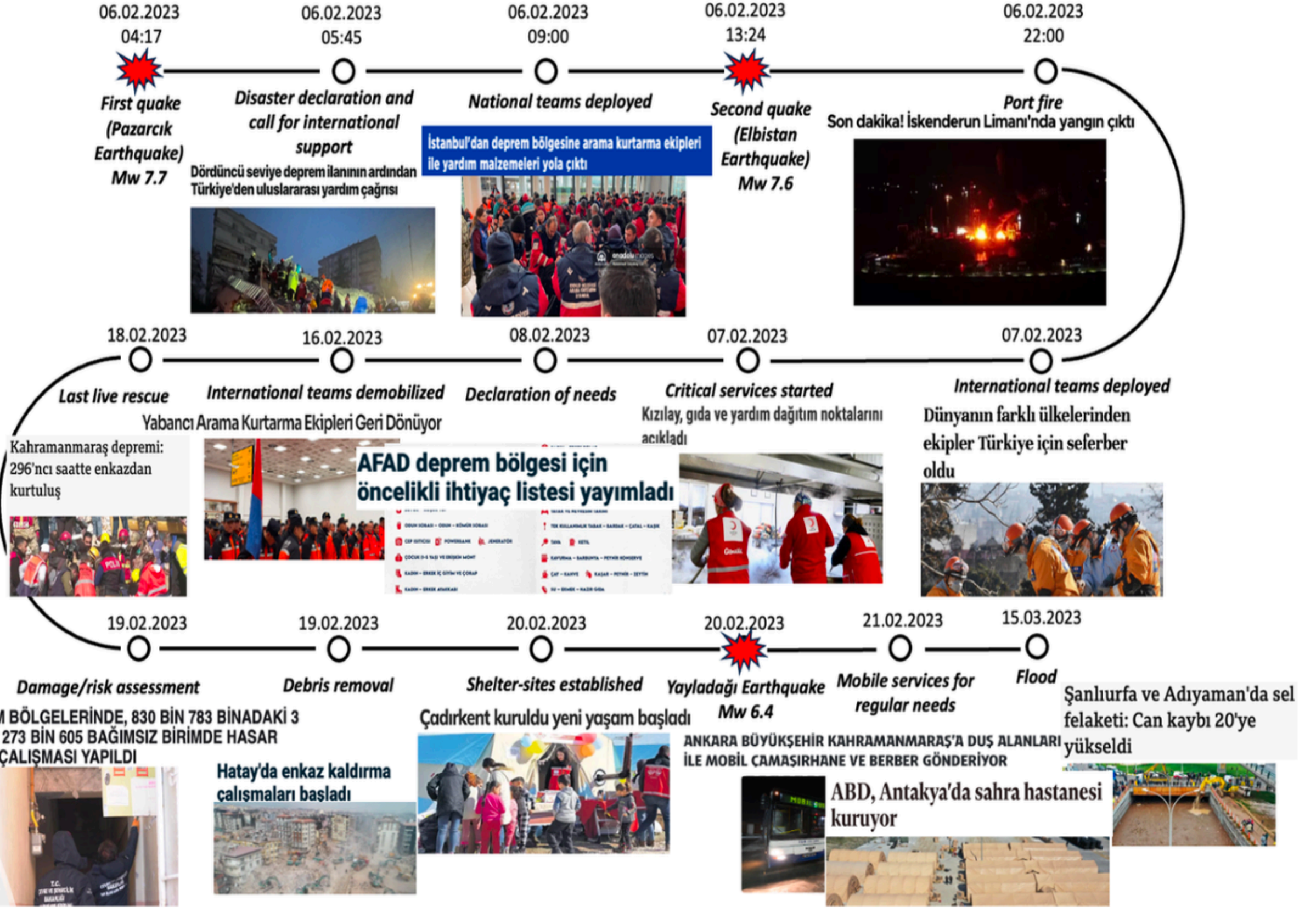


Figure 2: Timeline of events after Kahramanmaraş earthquakes.

Disaster response

More information is available for decision-makers
Urgency of needs decreases
Main activities change
Main demand locations change

Event-based transition between phases

Event-based transition between phases

Immediate response

Late response

Dark period	**Gray period**	**Light gray period**	
“Local response”	“USAR”	“Debris removal”	“Sheltering”

Event-based transition between phases

Immediate response

Late response

Dark period	**Gray period**	**Light gray period**	
"Local response"	"USAR"	"Debris removal"	"Sheltering"
Disaster	Disaster declaration Arrival of first USAR team	USAR teams demobilize	Shelter sites established

Figure 3: Immediate response phases and projection onto Kahramanmaraş earthquakes (SCM: supply chain management).

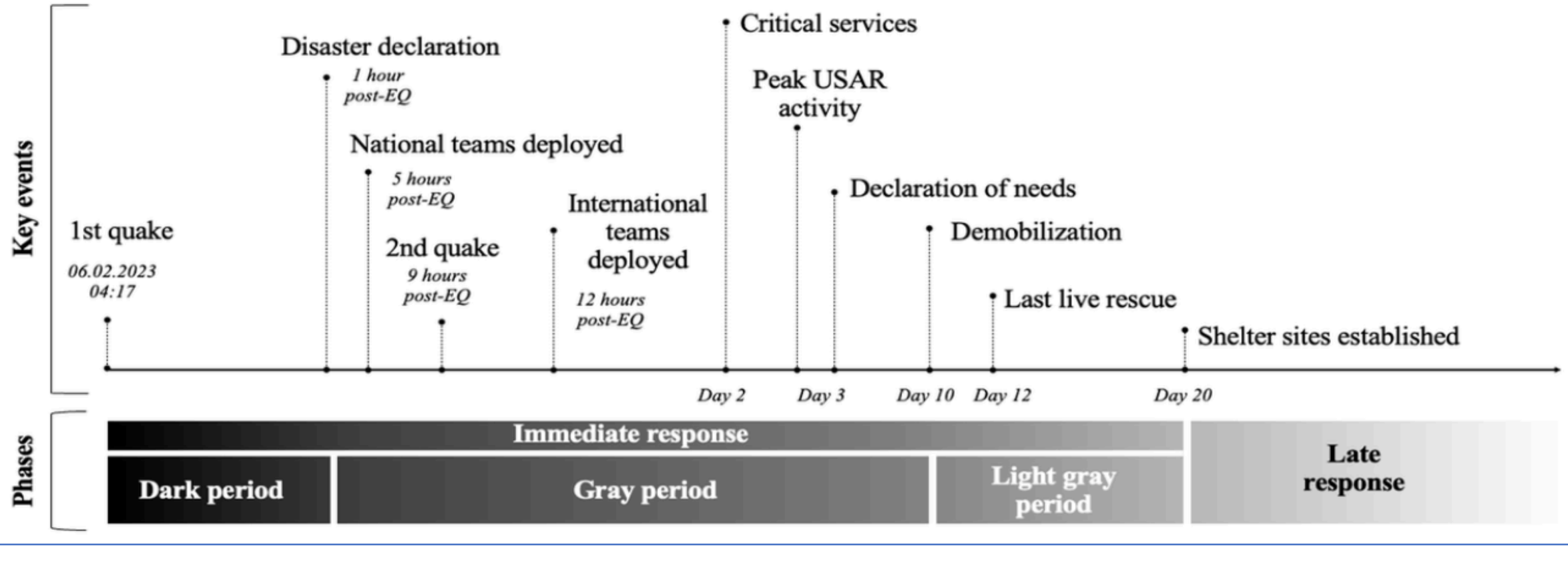


Figure 3: Immediate response phases and projection onto Kahramanmaraş earthquakes (SCM: supply chain management).

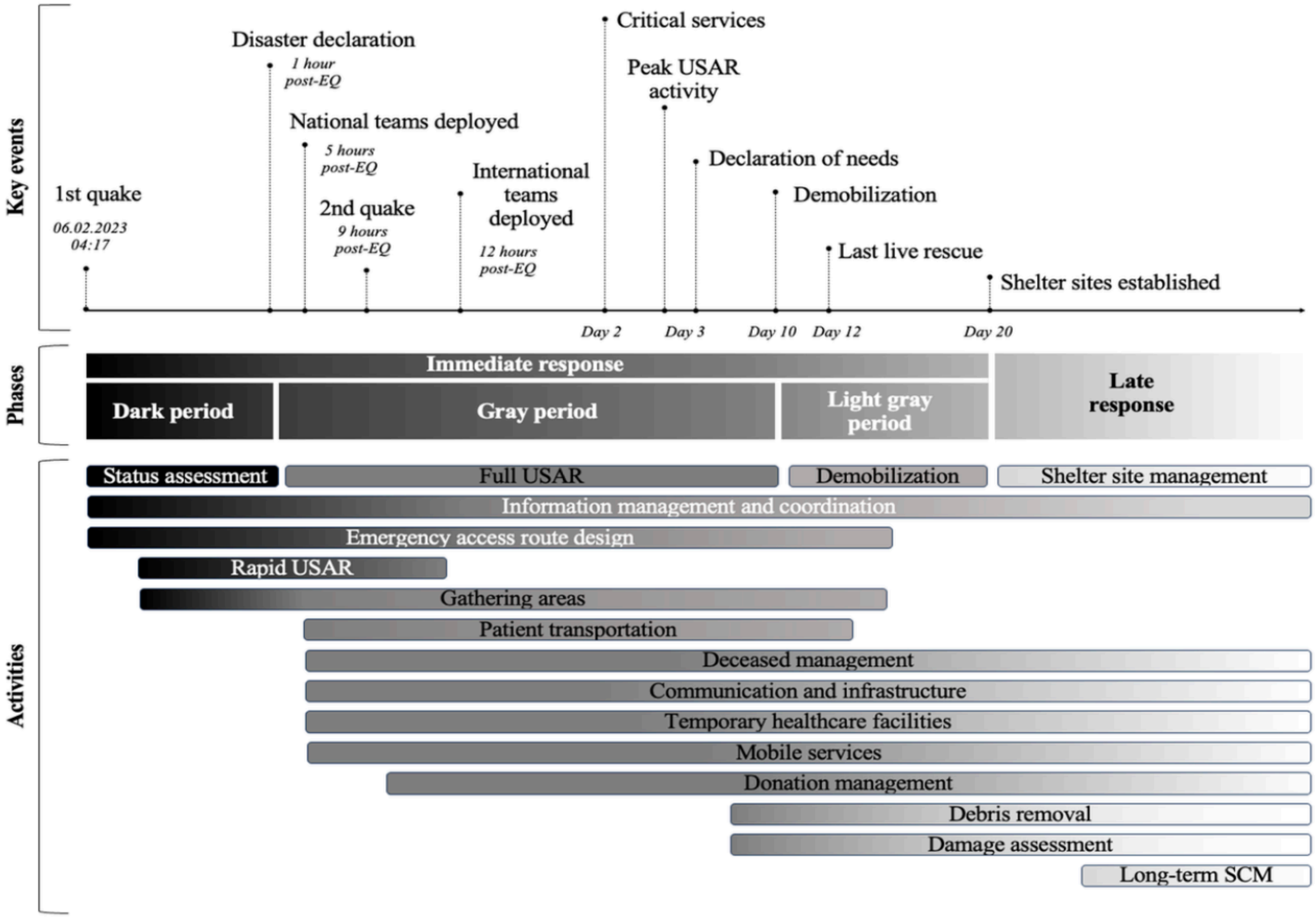


Figure 3: Immediate response phases and projection onto Kahramanmaraş earthquakes (SCM: supply chain management).

Disaster response from an OR perspective

- Introducing a detailed time-dependent classification framework for the response stage
- Providing a comprehensive guideline for OR researchers

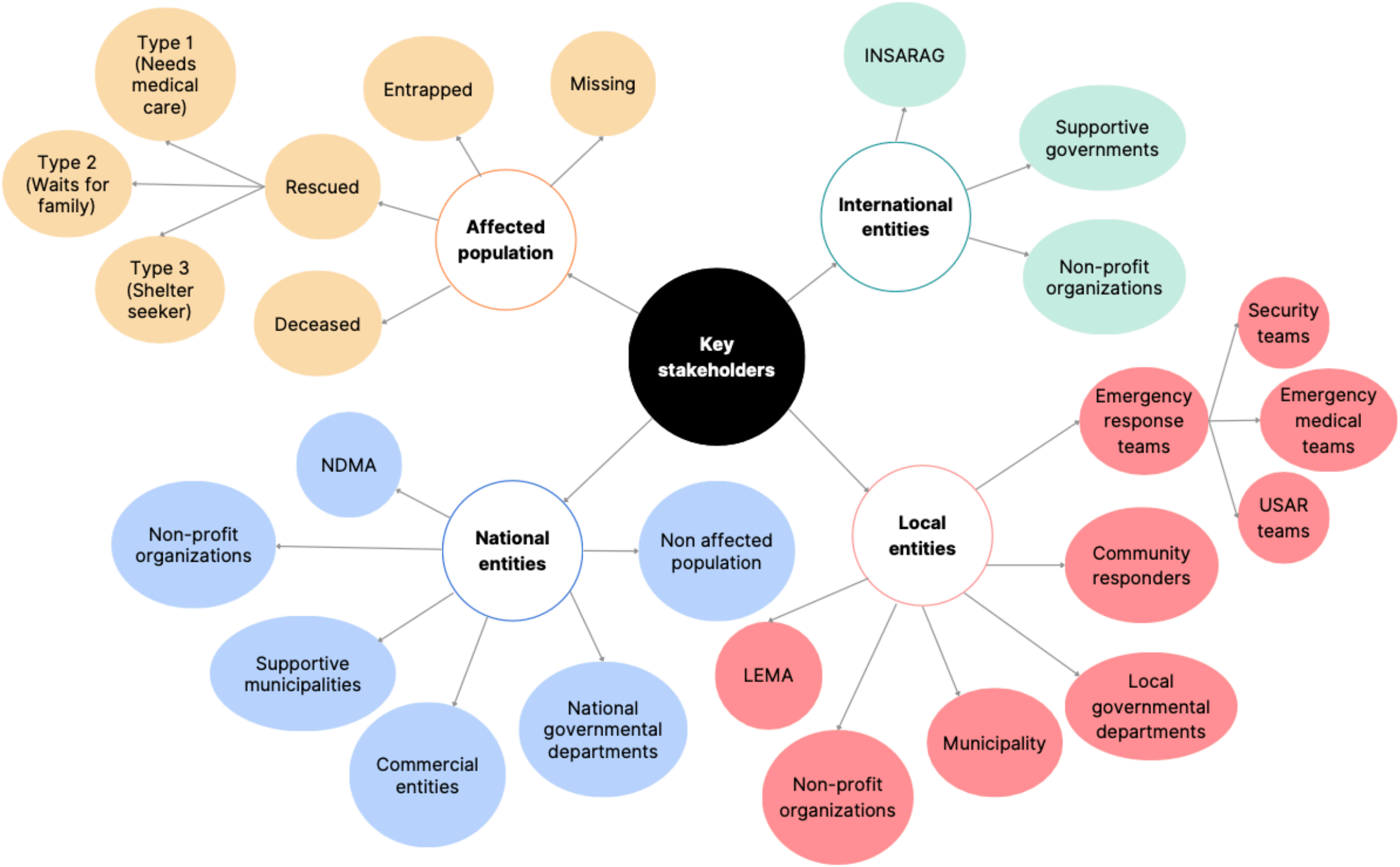


Figure 4: Key stakeholders during immediate response.

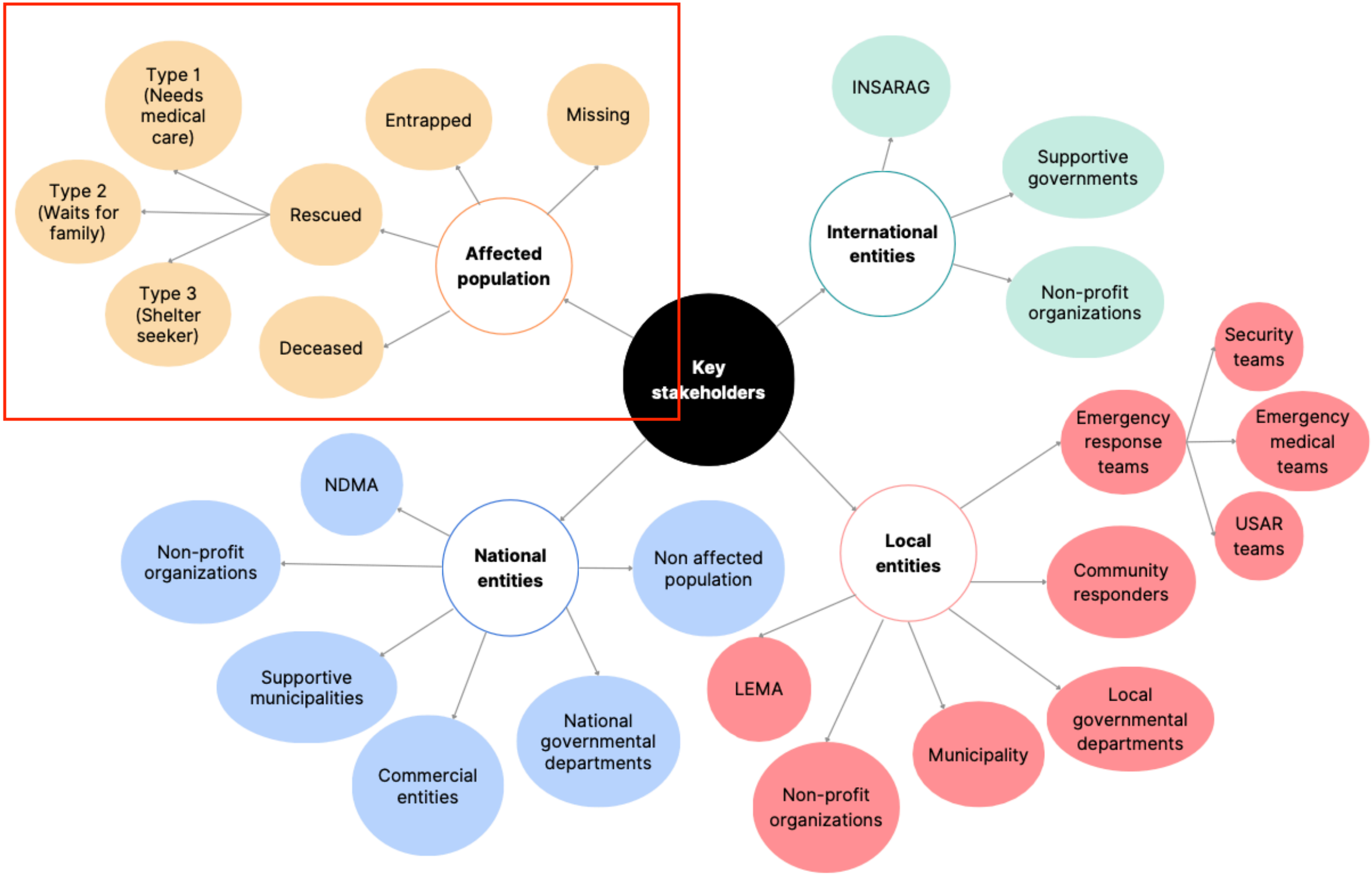
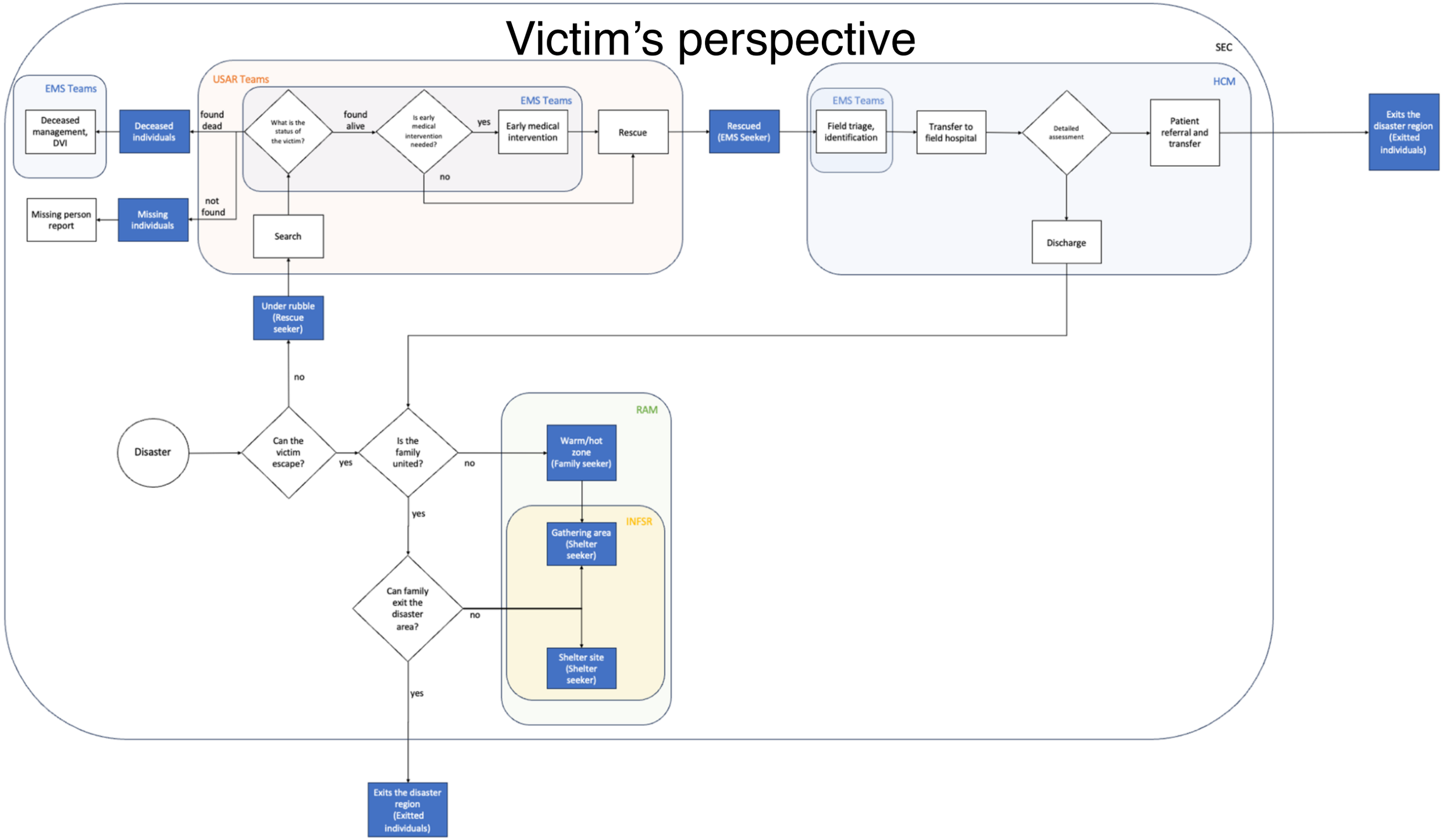
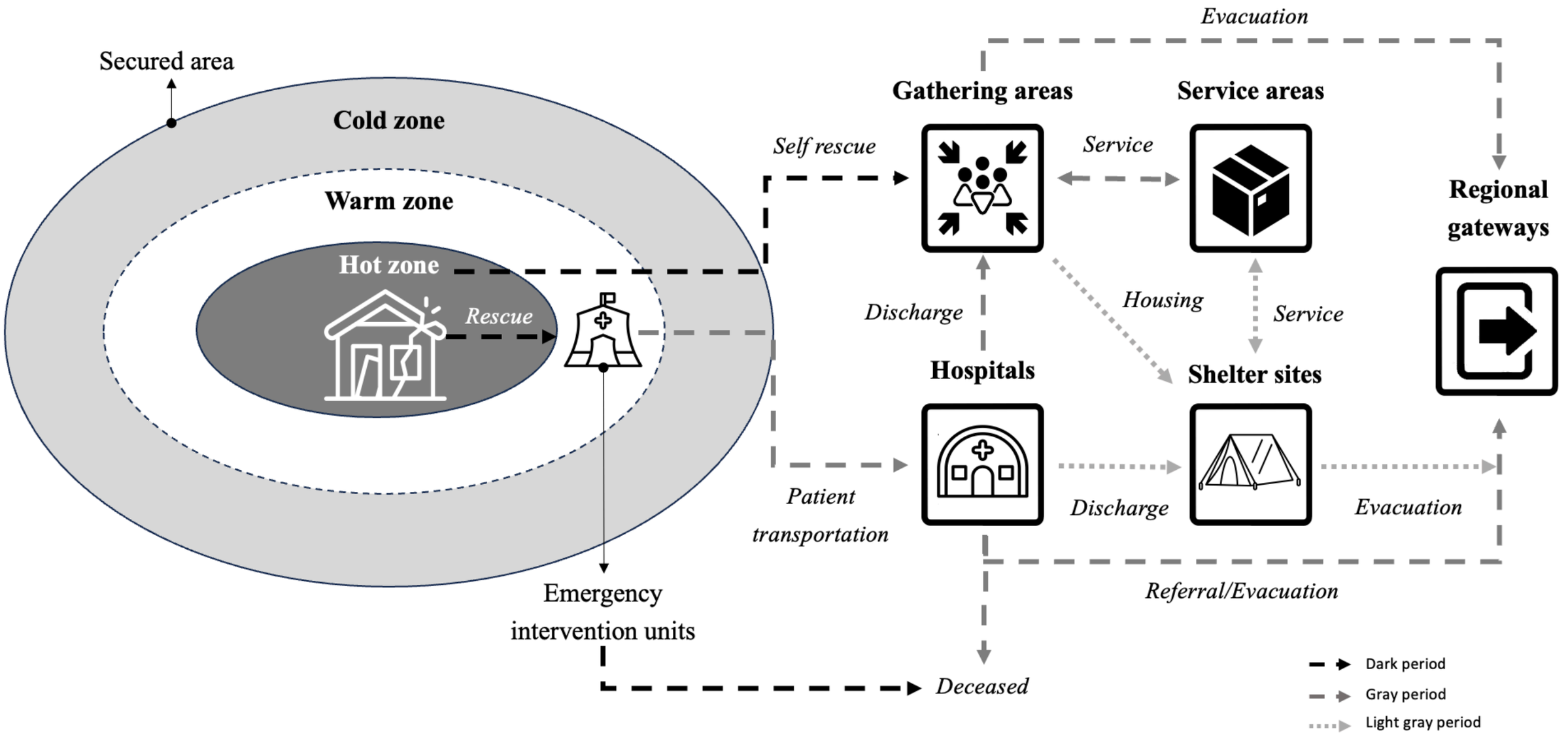
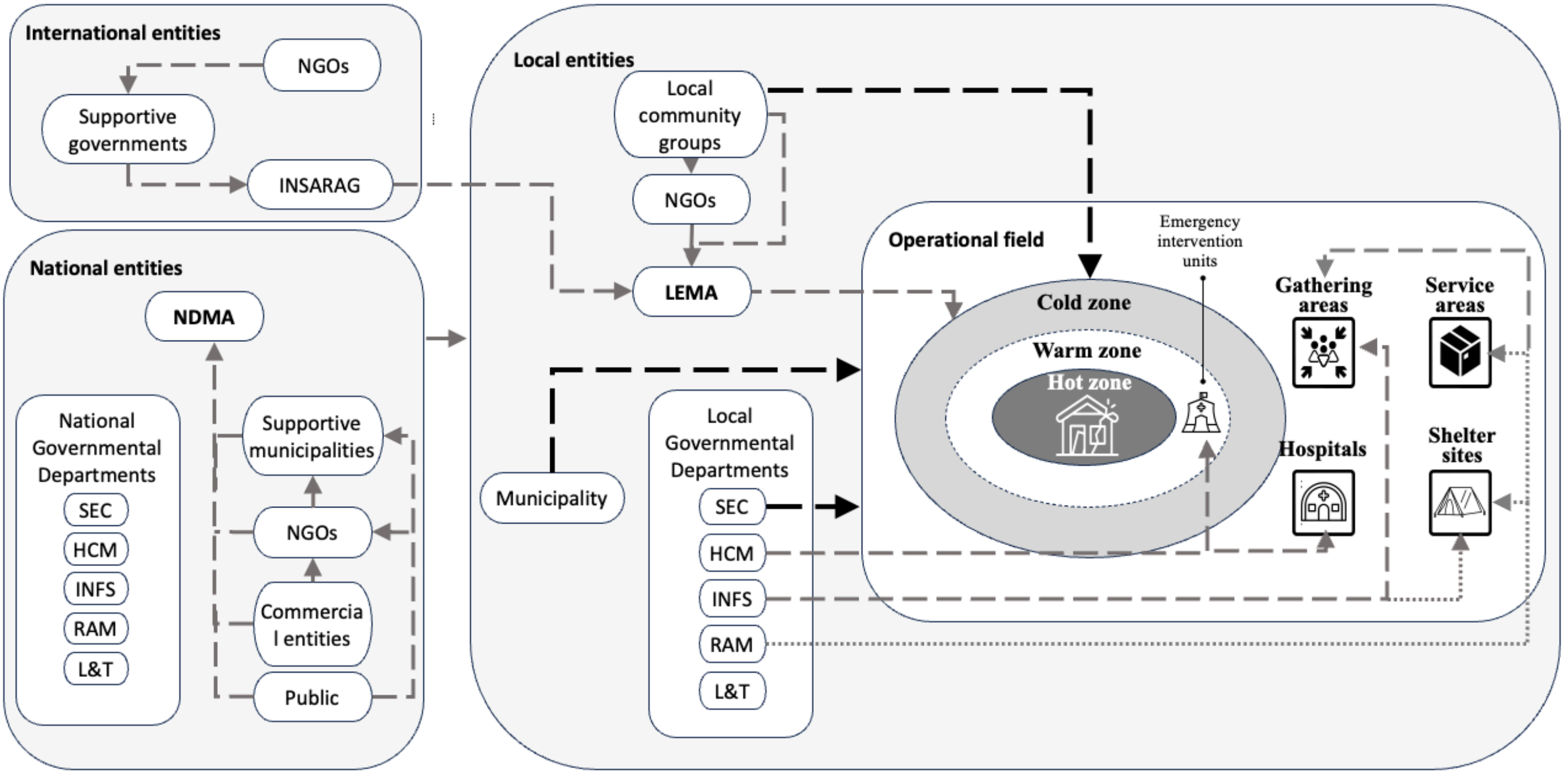


Figure 4: Key stakeholders during immediate response.

Victim's perspective



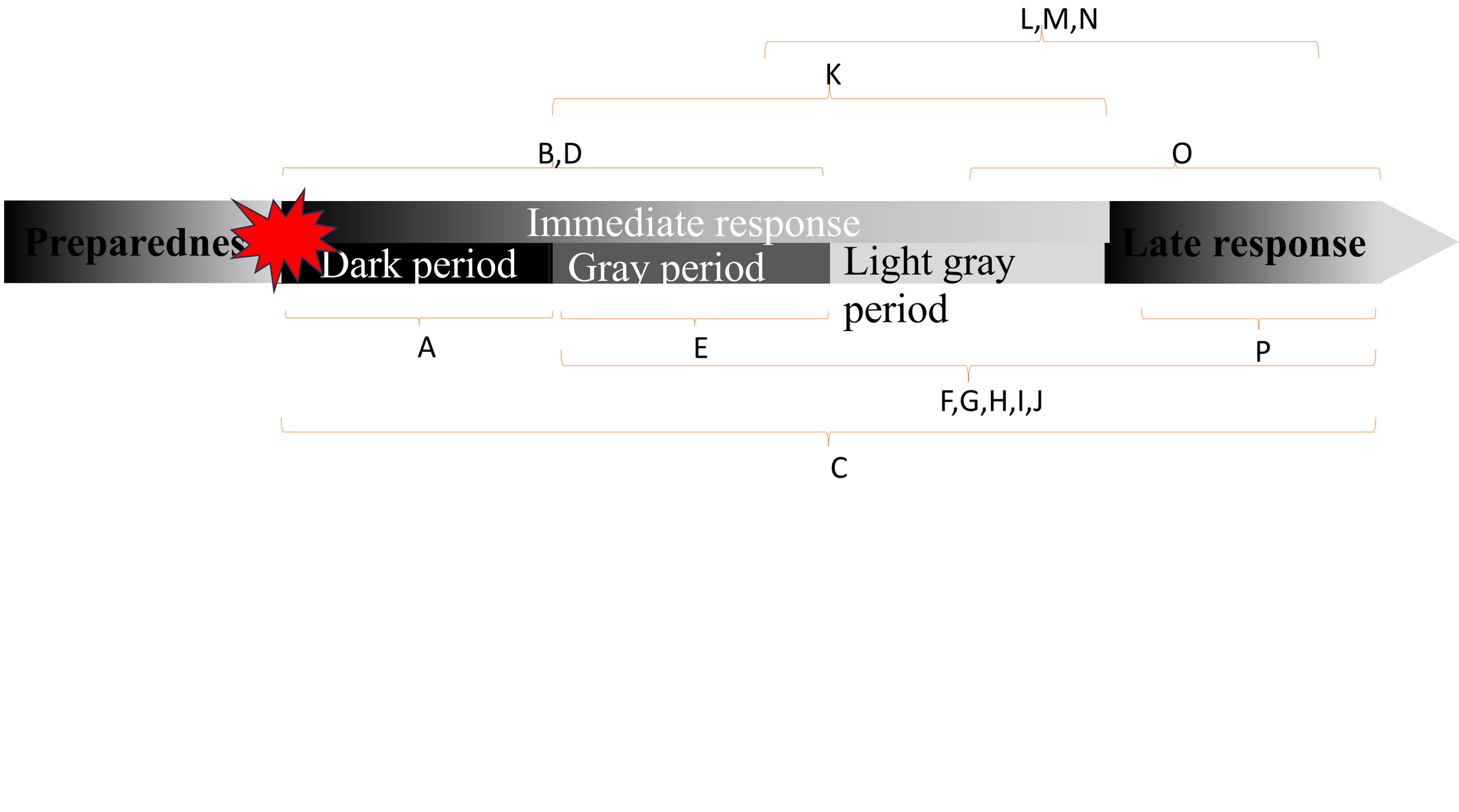

Secured area
Cold zone
Warm zone
Hot zone
Rescue
Emergency
intervention units
Evacuation
Gathering areas
Service areas
Regional
gateways
Self rescue
Service
Discharge
Housing
Service
Hospitals
Shelter sites
Patient
transportation
Discharge
Evacuation
Referral/Evacuation
Deceased
Dark period
Gray period
Light gray period



SEC: Security
HCM: Healthcare management
INFS: Infrastructure
RAM: Relief aid management
L&T: Logistics and transportation

Disaster response from an OR perspective

- Introducing a detailed time-dependent classification framework for the response stage
- Providing a comprehensive guideline for OR researchers


L,M,N
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Preparedness
Immediate response
Late response
Dark period
Gray period
Light gray period
A
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F,G,H,I,J
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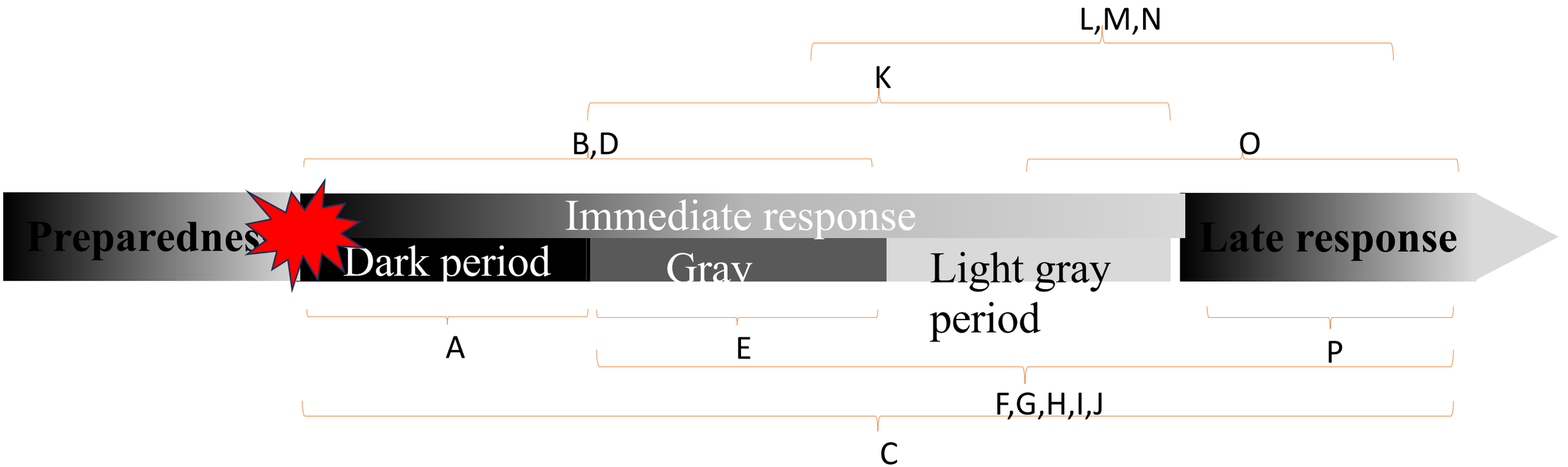


A. Status assessment
B. Emergency response operations
C. Information management and coordination
D. Emergency access routes
E. Casualty management
F. Deceased management
G. Communication and infrastructure
H. Medical service management
I. Mobile service management
J. Temporary healthcare facilities
K. Gathering areas
L. Donation management
M. Debris and waste management
N. Structural risk/damage assessment
O. Shelter site management
P. Long-term supply chain management

Subphase	Problem type	Decisions	Service type	Objectives	Uncertainties	Limitations
		Location Routing Resource allocation Team formation Team scheduling Clustering/prioritization Network design				
		Relief items Workforce Equipment Fleet Accommodation				
				Response time Coverage Accessibility Fairness Reliability Cost		
					Link capacities Supply type Supply amount/capacity Demand locations Demand amount	
						Number of facilities Size of fleet Capacity Competency levels

Table 5: Main OR problems during dark period.

Disaster management activity	OR problem	Potential constraints	Potential objectives
Establishment of coordination centers	FL	Status of candidate locations and EARs	Reliability, accessibility
Wide area exploration	VRP, TS	Range of vehicles, size of fleet, geographical limitations	Covered area, total assessment time
Prioritization and sectorization	C/P	Information availability	Demand-based value of covered locations
Emergency access route design	ND, C/P	Damage to roads/bridges, demand locations	Reliability, accessibility, coverage

VR: vehicle routing, FL: facility location, TS: team scheduling, ND: network design, C/P: clustering/prioritization

		Decisions						Service type					Objectives						Uncertainties				Limitations			
Subphase	Problem type	Location	Routing	Resource allocation	Team formation	Team scheduling	Clustering/prioritization	Network design	Relief items	Workforce	Equipment	Fleet	Accommodation	Response time	Coverage	Accessibility	Fairness	Reliability	Cost	Link capacities	Supply type	Supply amount/capacity	Demand locations	Demand amount	Number of facilities	Size of fleet	Capacity	Competency levels
Dark period	Wide area exploration		+		+				+	+	+			+	+							+	+	+		+	+	
	Emergency access route design						+	+							+	+		+		+			+				+	
	Establishment of coordination centers	+						+	+	+					+	+		+		+		+			+		+	
	Prioritization and sectorization			+			+								+		+			+			+	+					

Table 6: Main OR problems during gray period.

Disaster management activity	OR problem	Potential constraints	Potential objectives
Search and rescue	VRP, TS	Number of teams, competency levels, equipment availability, integration and coordination among teams, task hand overs and resting periods, status of EARs, type of collapses	Response time, number of live rescues, idle time of teams and equipment
On-site triage and first aid	FL, TS	Number of medical units/on-site facilities, availability of workforce and medical items, severity level of patients	Number of attended patients
Patient transportation	VRP	Size of ambulance fleet, status of EARs, severity level of patients, capacity of referred facilities	Transportation time, number of attended patients
Deceased management and identification	VRP, FL	Availability of forensic evidence, capacity of facilities (e.g., ghusl rooms, morgues and cemeteries), size of workforce and fleet	Number of attended/identified bodies
Establishment of communication networks	FL, ND	Number of stations, budget, covering range of stations	Covered area
Gathering areas	FL	Volume of demand, status and capacity of selected sites	Covered demand, reliability, accessibility
Mobile services	VRP, RA	Number of units, available workforce, frequency of demand, available inventory, consumption rate of goods, volume of demand	Covered demand, visiting frequency

VR: vehicle routing, FL: facility location, RA: resource allocation, TS: team scheduling, ND: network design, C/P: clustering/prioritization

Subphase	Problem type	Decisions						Service type					Objectives						Uncertainties					Limitations			
		Location	Routing	Resource allocation	Team formation	Team scheduling	Clustering/prioritization	Network design	Relief items	Workforce	Equipment	Fleet	Accommodation	Response time	Coverage	Accessibility	Fairness	Reliability	Cost	Link capacities	Supply type	Supply amount/capacity	Demand locations	Demand amount	Number of facilities	Size of fleet	Capacity	Competency levels
Dark period	Wide area exploration		+			+				+	+	+			+	+						+	+	+			+	+	
	Emergency access route design						+	+							+	+		+		+			+				+	
	Establishment of coordination centers	+						+	+	+					+	+		+		+		+			+		+	
	Prioritization and sectorization			+			+								+		+			+			+	+					
Gray period	Search and rescue		+		+	+				+	+	+		+	+		+			+	+	+	+	+			+	+	+
	On-site triage and first aid	+				+				+	+	+			+		+			+		+	+	+		+	+	+	
	Patient transportation		+			+				+	+	+		+	+		+			+		+	+	+				+	+	
	Deceased management and identification	+	+							+	+	+		+	+					+		+	+	+		+	+	+	
	Establishment of communication network	+					+			+		+			+				+	+			+			+		+	+	
	Gathering areas	+											+		+	+		+				+	+	+		+		+		
	Mobile service management	+	+	+			+		+						+	+	+			+	+	+		+				+	+	

Table 7: Main OR problems during light gray period.

Disaster management activity	OR problem	Potential constraints	Potential objectives
Mobile services	VRP, RA	Number of units, available workforce, frequency of demand, available inventory, consumption rate of goods, volume of demand	Covered demand, visiting frequency
Management of field hospitals	FL,TS	Budget, status of selected sites, availability of workforce and equipment, distance to critical locations	Covered demand, set-up and operating cost
Debris removal	TS, VRP	Availability of workforce and equipment, size of fleet	Number of opened roads/bridges, accessibility to critical locations
Structural damage/risk assessment	TS, VRP	Availability of workforce and equipment, size of fleet	Number of assessed structures, accuracy of assessments
Restoration and demolition	TS, VRP	Availability of workforce and (heavy) equipment, size of fleet	Number of restored/demolished structures
Shelter site management	FL, VRP, TS, RA	Capacity and status of selected sites, distance to critical locations, infrastructural limitations, demand types based on population groups	Covered demand, reliability, fairness, accessibility, cost-efficiency
Donation management	FL, VRP, TS, RA	Donor unpredictability, multi-actor structure, risk of donation pollution, capacity of facilities, availability of workforce	Covered demand, minimizing waste and demand-supply mismatch, inventory and distribution cost

VR: vehicle routing, FL: facility location, RA: resource allocation, TS: team scheduling

		Decisions							Service type					Objectives						Uncertainties					Limitations			
Subphase	Problem type	Location	Routing	Resource allocation	Team formation	Team scheduling	Clustering/prioritization	Network design	Relief items	Workforce	Equipment	Fleet	Accommodation	Response time	Coverage	Accessibility	Fairness	Reliability	Cost	Link capacities	Supply type	Supply amount/capacity	Demand locations	Demand amount	Number of facilities	Size of fleet	Capacity	Competency levels
Dark period	Wide area exploration		+			+				+	+	+			+	+							+	+			+	+	
	Emergency access route design						+	+							+	+		+		+			+				+	
	Establishment of coordination centers	+						+	+	+					+	+		+		+		+			+		+	
	Prioritization and sectorization			+			+								+		+			+			+	+					
Gray period	Search and rescue		+		+	+				+	+	+		+	+		+			+	+	+	+	+			+	+	+
	On-site triage and first aid	+				+				+	+	+			+		+			+			+	+	+		+	+	+
	Patient transportation		+			+				+	+	+		+	+		+			+			+	+	+			+	+
	Deceased management and identification	+	+							+	+	+		+	+					+			+	+	+		+	+	+
	Establishment of communication network	+					+			+		+			+						+			+		+			+	
	Gathering areas	+											+		+	+		+				+	+	+	+			+		
	Mobile service management	+	+	+			+		+						+	+	+			+	+	+			+			+	+	
Light gray period	Mobile service management	+	+	+			+		+						+	+	+			+	+	+			+			+	+	
	Management of field hospitals	+				+					+	+			+	+		+	+						+	+				
	Debris management	+	+			+	+				+	+			+	+	+		+								+	+	+	
	Structural damage/risk assessment		+			+	+				+	+			+	+		+	+	+								+	+	
	Restoration and demolition		+			+	+				+	+			+	+		+	+	+								+	+	
	Shelter site management	+	+	+		+			+				+		+	+	+	+	+	+					+	+				
	Donation management	+	+	+		+					+				+	+	+		+		+				+				+	+	+

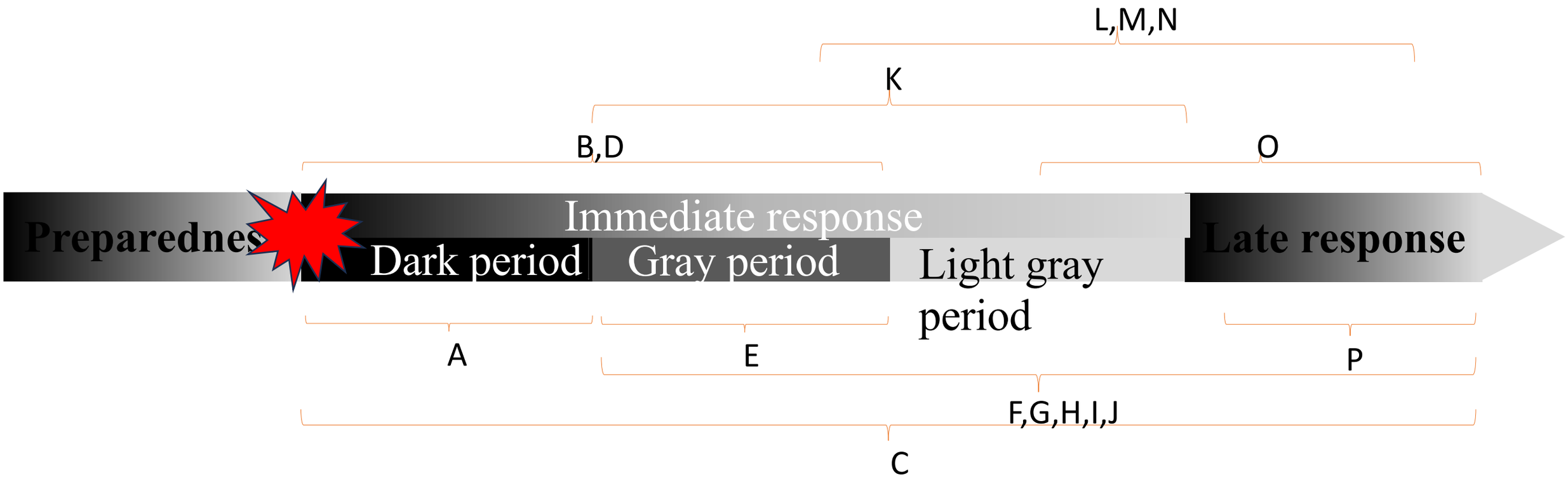
	Dark period
A. Status assessment	1. Supporting observatory and satellite imagery with local capabilities (e.g., drones, motorcycle teams), 2. Planning the use of UAVss for status assessment, 3. Scheduling, routing, and service/visit planning for teams and vehicles, 4. Identifying critical points based on the disaster's epicenter and timing.

B. Information management and coordination

Dark period	Gray period	Light gray	Late response
5. Sharing status report with stakeholders , declaration of disaster scale 6. Establishing formal communication channels, e.g., among governmental authorities 7. Establishing and organizing national coordination center	9. Facilitiating the information flow among response teams and operational bases to enable coordination in field	10. Facilitating virtual platforms for managing in-kind donations, monitoring and updating inventory levels and list of needs	
11. Centralized management of data 12. Management of regional and national coordination centers 13. Workforce and shift management for these centers			

F. Temporary healthcare facilities

Dark period	Gray period	Light gray	Late response
32. Capacity assessment of healthcare facilities and hospitals in the disaster region	33. Locating and maintaining emergency intevention units at debris locations 34. Settlement and management of mobile and stationary healthcare facilities	35. Restablishing regular healthcare services 36. Managing mobile pharmacies and clinics	
	37. Coordination of personnel/volunteer workforce and shift management at temporary health centers 38. Deployment of medical resources to disaster region based on prioritization of the affected areas		



A. Status assessment

B. Emergency response operations

C. Information management and coordination

D. Emergency access routes

E. Casualty management

F. Deceased management

G. Communication and infrastructure

H. Medical service management

I. Mobile service management

J. Temporary healthcare facilities

K. Gathering areas

L. Donation management

M. Debris and waste management

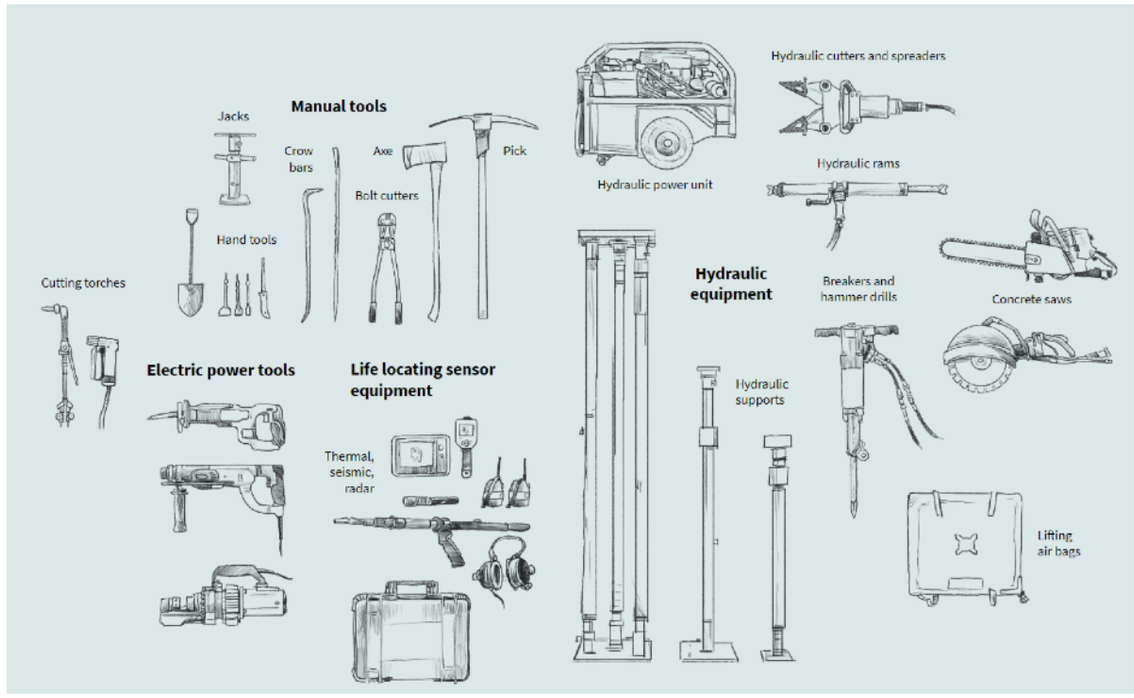
N. Structural risk/damage assessment

O. Shelter site management

P. Long-term supply chain management

Search and Rescue Operations

- Different “building collapse category” (needs different competencies) (Arranz et al., 2023)
- Different competence: AFAD, miners, fire department, volunteers, overseas SAR teams, military
- Different & same Equipment (protective equipment)
- Some teams have additional resources to support relief operations (“Beyond the Rubble”) such as medical capabilities, water purification and clearing or making safe of damaged structures.



Inclined
Columns and walls have collapsed into an incline

Overhang
Higher part of the building hangs over the lower part

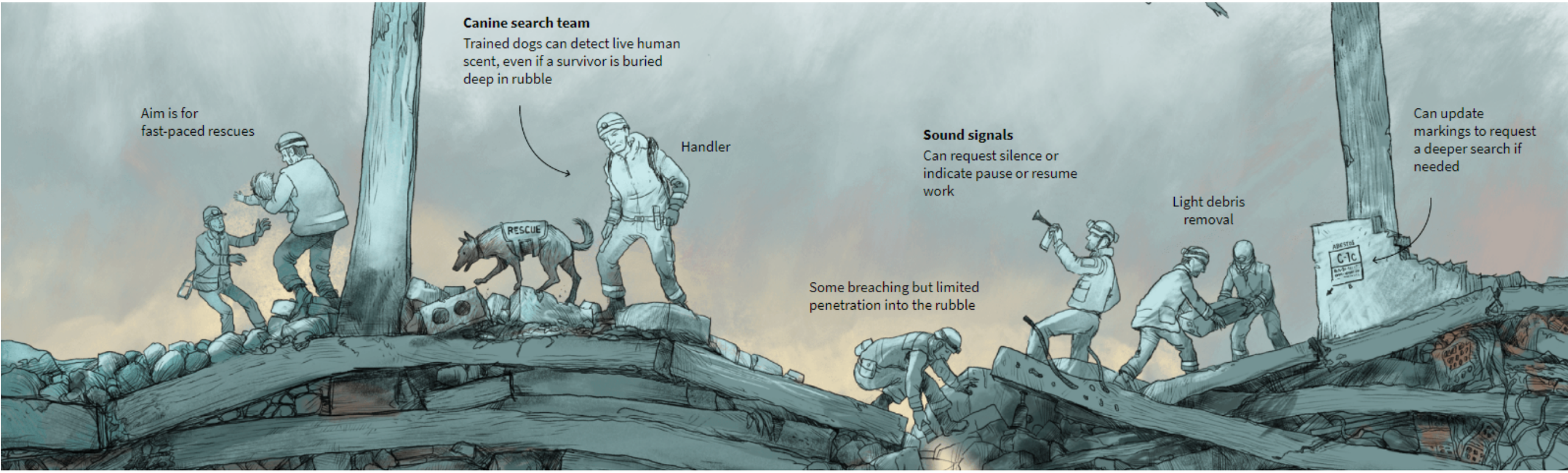
Debris heap
Some of the floors, columns and walls have collapsed into a heap of rubble

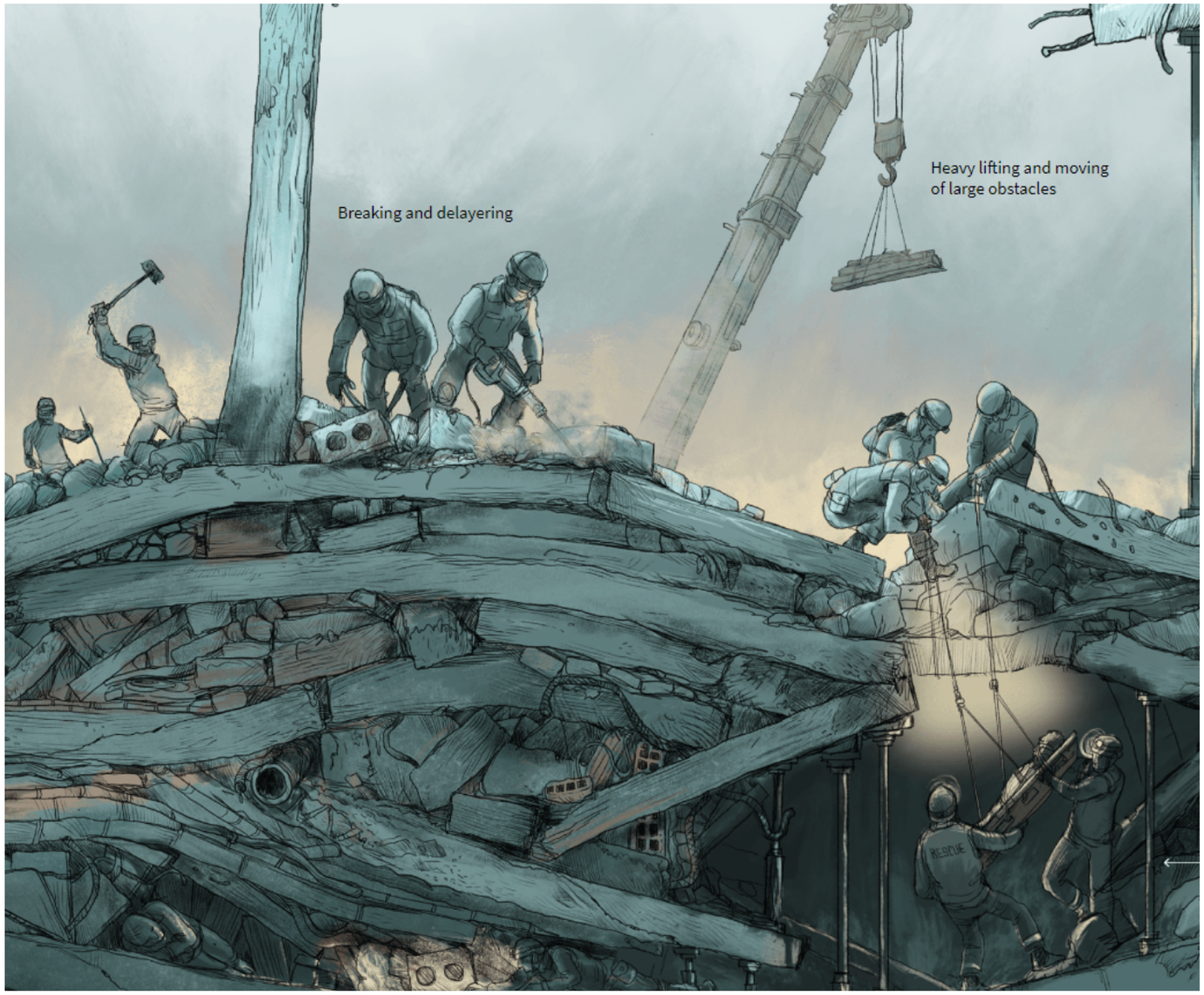
Overturn
Part or all of the building has fallen to the side

Pancake
floors have completely collapsed on top of each other

Rapid Search and Rescue

- In the early stages of response, teams conduct rapid searches to **maximize the saved lives**.
- This is done at a site within **a few hours**, then teams move to the next.
- **identify** sites where a deeper search could be worthwhile. Specially **trained dogs** are used
- Deeply entombed vicoms may not be found during this level of search





Full Search and Rescue

- This phase of operations rescues a smaller number of trapped survivors who local rescuers, first responders, could not reach.
- The process can involve **multiple teams** and **last several days.**
- **Carbon dioxide detectors** and **thermal imaging** equipment, **sensitive sound equipment**

SAR Basics

Operational Steps

Arrival → **Appointment** → **Search** → **Rescue** → **Demobilisation**

S&R Basics

Rescue Stages

STAGES	CODE	OPERATION
1ST STAGE	ASR-1	Disaster Area Exploration
2ND STAGE	ASR-2	Sectoral Review
3RD STAGE	ASR-3	Rapid Search and Rescue
4TH STAGE	ASR-4	Full Search and Rescue
5TH STAGE	ASR-5	Full Search and Rescue and Recovery

Table 1: ASR Stages defined by INSARAG [4]

SAR Basics

Sectorization and Debris Marking

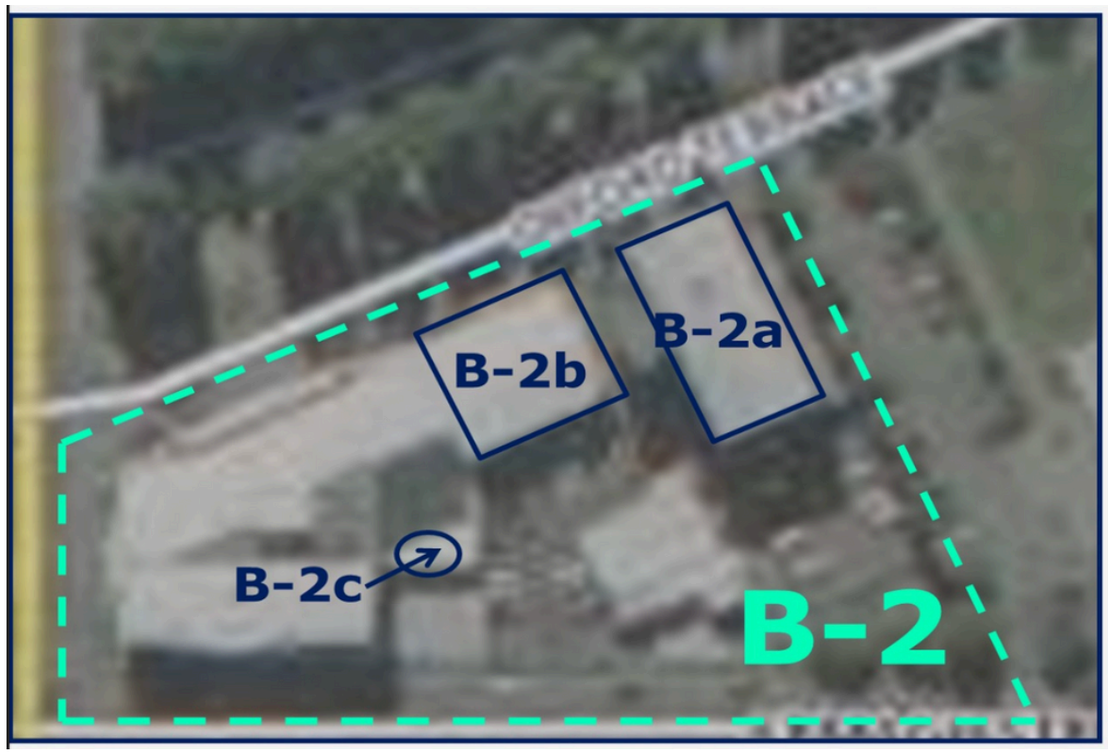


Figure 1: Worksite sectorisation [1]

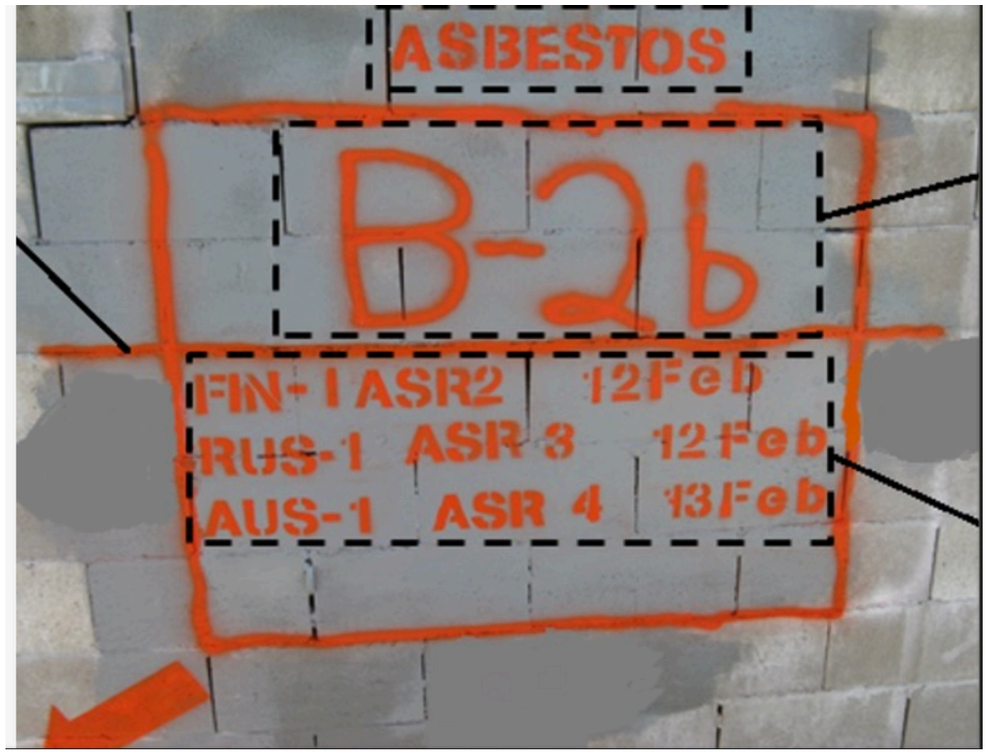
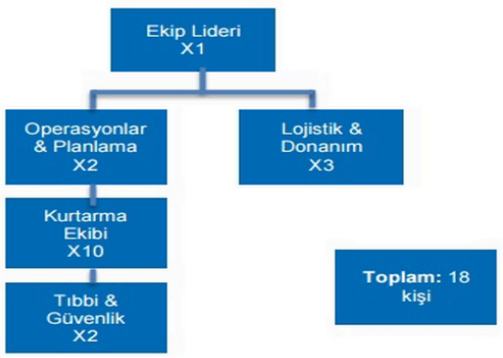


Figure 2: Debris marking [1]

SAR Teams

Team Categorization



Light SAR Team

USAR Bileşeni	Görevler	Tavsiye Edilen Kadro Tahsisi	Tavsiye Edilen Sayı (Toplam 40)
Yönetim	Komuta	Ekip Lideri	1
	Koordinasyon	Ekip Lideri Yardımcısı	1
	Planlama/Takip	Planlama Yetkilisi	1
	İrtibat/Medya/Raporlama	İrtibat Yetkilisi	1
	Değerlendirme/Analiz	Yapı Mühendisi	1
	Emniyet ve Güvenlik	Güvenlik Yetkilisi	1
	RDC/OSOCC/UCC	Koordinasyon Yetkilisi	2
Arama	Teknik Arama	Teknik Arama Uzmanı	2
	Köpekle Arama	Köpek Eğiticisi	2
	Tehlikeli Madde Değerlendirmesi	Tehlikeli Madde Uzmanı	2
Kurtarma	Kırma ve Geçit Açma; kesme; iksa; teknik halat	Kurtarma Ekibi Yöneticisi ve Kurtarma Teknisyenleri	14 (1 Ekip Lideri ve 6 Kurtarma Görevlisinden oluşan 2 ekip)
	Kaldırma ve Hareket Ettirme	Ağır Sapanla Bağlama Uzmanı	2
Tıbbi	Tıbbi Ekip Yönetimi: Tıbbi ekibin koordinasyon ve idaresi. Yerel sağlık altyapısı ile birleşme Ekibin (köpekler dahil) ve karşılaşılan afetzedelerin tedavisinin yapılması	Tıp Doktoru	1
		Doktor, Sağlık Görevlisi, Hemşire	3
Lojistik	BoO	Lojistik Ekibi Yöneticisi	1
	Su temini	Ulaştırma Uzmanı	1
	Gıda temini	Lojistikçi	1
	Ulaştırma kapasitesi ve yakıt temini	Üs Yöneticisi	2
	Haberleşme	Haberleşme Uzmanı	1

Medium SAR Team

USAR Bileşeni	Görevler	Tavsiye Edilen Kadro Tahsisi	Tavsiye Edilen Sayı (Toplam 59)
Yönetim	Komuta	Ekip Lideri	1
	Koordinasyon	Ekip Lideri Yardımcısı	1
	Planlama	Planlama Yetkilisi	1
	İrtibat/Takip	İrtibat Yetkilisi	1
	Medya/Raporlama	İrtibat Yetkilisi Yardımcısı	1
	Değerlendirme/Analiz	Yapı Mühendisi	1
	Emniyet ve Güvenlik	Güvenlik Yetkilisi	1
	RDC/OSOCC/UCC	Koordinasyon Yetkilisi	2
Arama	Teknik Arama	Teknik Arama Uzmanı	2
	Köpekle Arama	Köpek Eğiticisi	4
	Tehlikeli Madde Değerlendirme	Tehlikeli Madde Uzmanı	2
Kurtarma	Kırma ve Geçit Açma: kesme; iksa; teknik halat	Kurtarma Ekibi Yöneticisi ve Kurtarma Teknisyenleri	28 (1 Ekip Lideri ve 6 Kurtarma Görevlisinden oluşan 4 ekip)
	Kaldırma ve Hareket Ettirme	Ağır Sapanla Bağlama Uzmanı	2
Tıbbi	Ekip Tedavisi (Personel ve Köpekler) Hasta Tedavisi	Tıp Doktoru	2
		Sağlık Görevlisi/Hemşire	4
Lojistik	BoO	Lojistik Ekibi Yöneticisi	1
	Su temini	Ulaştırma Uzmanı	1
	Gıda temini	Lojistikçi	1
	Ulaştırma kapasitesi ve yakıt temini	Üs Yöneticisi	2
	Haberleşme	Haberleşme Uzmanı	1

Heavy SAR Team

Figure 3: AFAD Team Classification

Team Formation Problem

USAR Bileşeni	Görevler	Tavsiye Edilen Kadro Tahsisi	Tavsiye Edilen Sayı (Toplam 40)
Yönetim	Komuta	Ekip Lideri	1
	Koordinasyon	Ekip Lideri Yardımcısı	1
	Planlama/Takip	Planlama Yetkilisi	1
	İrtibat/Medya/Raporlama	İrtibat Yetkilisi	1
	Değerlendirme/Analiz	Yapı Mühendisi	1
	Emniyet ve Güvenlik	Güvenlik Yetkilisi	1
	RDC/OSOCC/UCC	Koordinasyon Yetkilisi	2
Arama	Teknik Arama	Teknik Arama Uzmanı	2
	Köpekle Arama	Köpek Eğiticisi	2
	Tehlikeli Madde Değerlendirmesi	Tehlikeli Madde Uzmanı	2
Kurtarma	Kırma ve Geçit Açma; kesme; iksa; teknik halat	Kurtarma Ekibi Yöneticisi ve Kurtarma Teknisyenleri	14 (1 Ekip Lideri ve 6 Kurtarma Görevlisinden oluşan 2 ekip)
	Kaldırma ve Hareket Ettirme	Ağır Sapanla Bağlama Uzmanı	2
Tıbbi	Tıbbi Ekip Yönetimi: Tıbbi ekibin koordinasyon ve idaresi. Yerel sağlık altyapısı ile birleşme Ekibin (köpekler dahil) ve karşılaşılan afetzedelerin tedavisinin yapılması	Tıp Doktoru	1
		Doktor, Sağlık Görevlisi, Hemşire	3
Lojistik	BoO	Lojistik Ekibi Yöneticisi	1
	Su temini	Ulaştırma Uzmanı	1
	Gıda temini	Lojistikçi	1
	Ulaştırma kapasitesi ve yakıt temini	Üs Yöneticisi	2
	Haberleşme	Haberleşme Uzmanı	1

Figure 9: Medium Team Requirements

- **different qualification requirements**
- **dynamic environment**
- **integration of international teams to national teams**

What happened after Maraş earthquakes?

What happened after Maraş earthquakes?

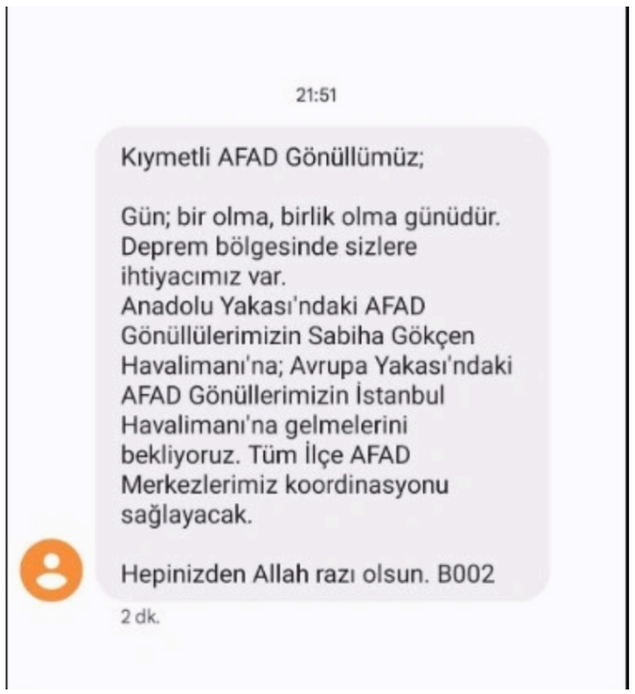


Figure 10: AFAD called volunteers around 10 PM, Feb. 6 [9]

What happened after Maraş earthquakes?

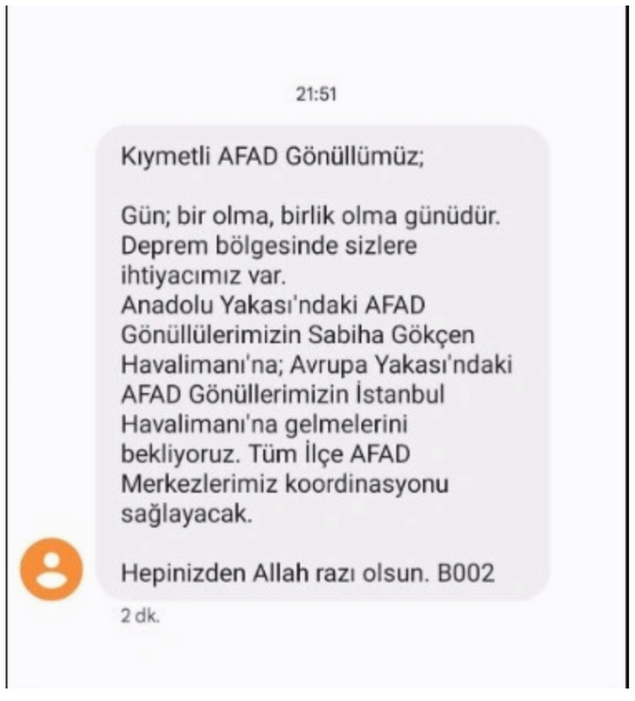


Figure 10: AFAD called volunteers around 10 PM, Feb. 6 [9]

Figure 11: Volunteer crowd in airport [10]

What happened after Maraş earthquakes?

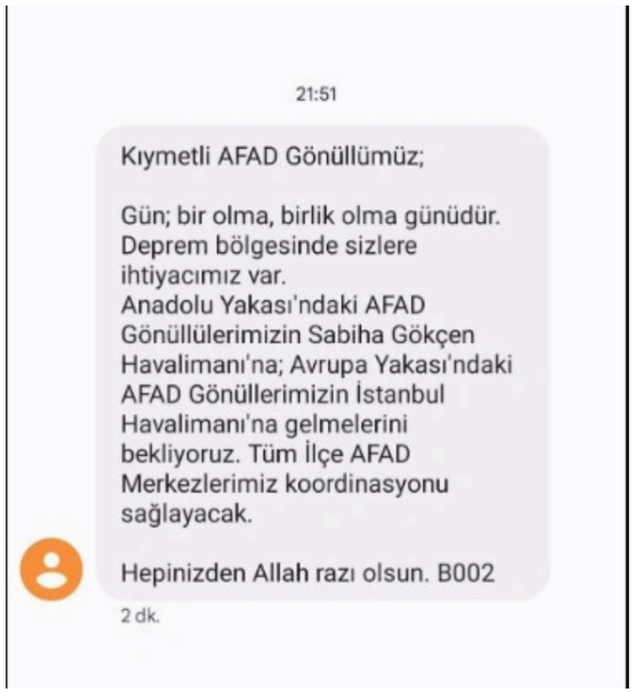


Figure 10: AFAD called volunteers around 10 PM, Feb. 6 [9]

Figure 11: Volunteer crowd in airport [10]

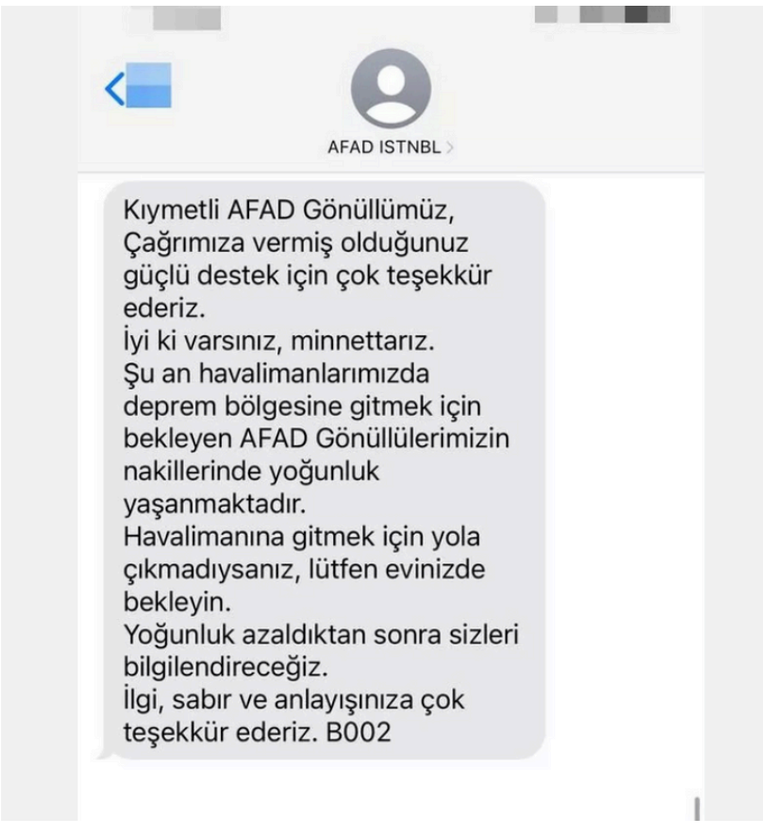


Figure 12: Appeal for volunteers not to come around 2 AM, Feb. 7 [11]

How to manage the volunteers?

How to manage the volunteers?

Problem Setting

Role	Light Team	Medium Team
Medical	1	3
Rescue	10	18
Logistics	4	6
Transmitter	2	6
Canine	0	2
Hazmat	0	2
Doctor	0	1
Total	17	38

Table 3: Number of staff required for teams

Light teams -> ability to move fast operational capability of ASR3 level

Medium teams -> move slower operational capability of ASR4 level

Medium⁻ teams

intermediate level teams, have more operational capability then light teams, less capability than medium teams

could be utilized to determine missings while completing medium teams

How many of which type should we form

We would know what expertise is needed

Mathematical Model

How many of which type should we form

We would know what expertise is needed

Sets:

- N=Set of volunteers
- R=Set of roles (1:Medical, 2:Rescue, 3: Logistics, 4: Transmitter, 5:Canine, 6:Hazmat, 7:Doctor)
- T=Set of team categories (1=Light, 2=Medium, 3=$Medium^{-}$)
- L=Set of team leaders

Parameters:

- N=number of volunteers
- L=number of leaders
- a_t = Efficiency of team category t
- $b_{ir} = \begin{cases} 1 & \text{if volunteer } i \text{ is suitable for role } r \\ 0 & \text{otherwise} \end{cases}$
- d_{tr} = Number of role r people team t needs (just for light and medium teams, i.e t $\in \{1, 2\}$)

Decision Variables:

- z_{rl}= Number of role r people assigned to team l
- $x_{ilr}= \begin{cases} 1 & \text{if volunteer } i \text{ is assigned to team } l \text{ in the role } r \\ 0 & \text{otherwise} \end{cases}$
- $y_{lt} = \begin{cases} 1 & \text{if leader } l \text{ formatted a team with team category } t \\ 0 & \text{otherwise} \end{cases}$

Mathematical Model

Model:

$$\text{maximize} \quad \sum_l \sum_t a_t y_{lt} \qquad (1)$$

maximizing efficiency level of teams

$$\text{subject to} \quad y_{lt}\ d_{tr} \leq z_{rl} \qquad \forall r \in R, \forall l \in L \ and \ \forall t \in \{1,2\} \qquad (2)$$

supplying staff demand of light and medium teams

$$\sum_l \sum_r x_{ilr} \leq 1 \qquad \forall i \in N \qquad (3)$$

a volunteer can be assigned to at most one team

$$\sum_t y_{lt} \leq 1 \qquad \forall l \in L \qquad (4)$$

a leader can be assigned to at most one team

$$z_{rl} = \sum_i x_{ilr} b_{ir} \qquad \forall l \in L, \forall r \in R \qquad (5)$$

connecting volunteer, role and team assignments

$$d_{1r} y_{l3} \leq z_{rl} \qquad \forall r \in R, \forall l \in L \qquad (6)$$

number of staff assigned to a medium⁻ team should be greater or equal than a light team and less or equal than a medium team

$$z_{rl} \leq d_{2r} \qquad \forall r \in R, \forall l \in L \qquad (7)$$

$$\sum_t y_{lt} \geq x_{ilr} \qquad \forall i \in N, \forall l \in L, \forall r \in R \qquad (8)$$

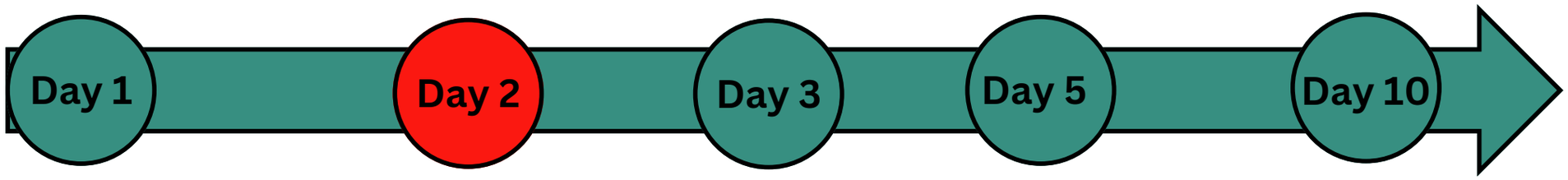
unless a leader is assigned, do not assign any volunteer to that team

$$x_{ilr}, y_{lt} \in \{0,1\} \qquad \forall i, l, r \qquad (9)$$

$$z_{rl} \geq 0 \qquad \forall l, r \qquad (10)$$

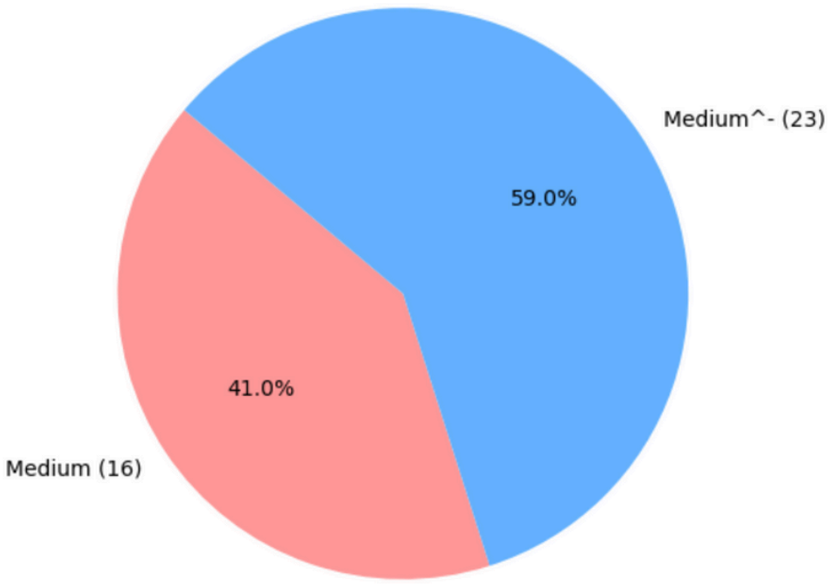
domain constraints

Computational Results

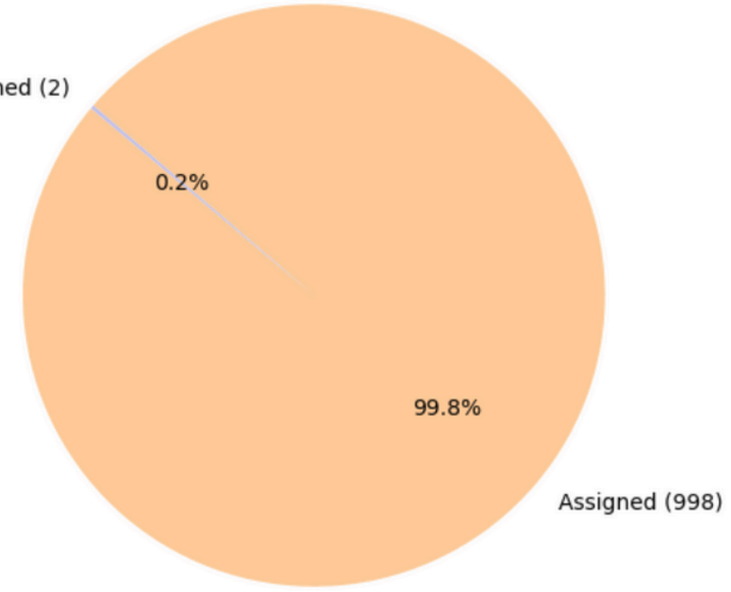


Case 5

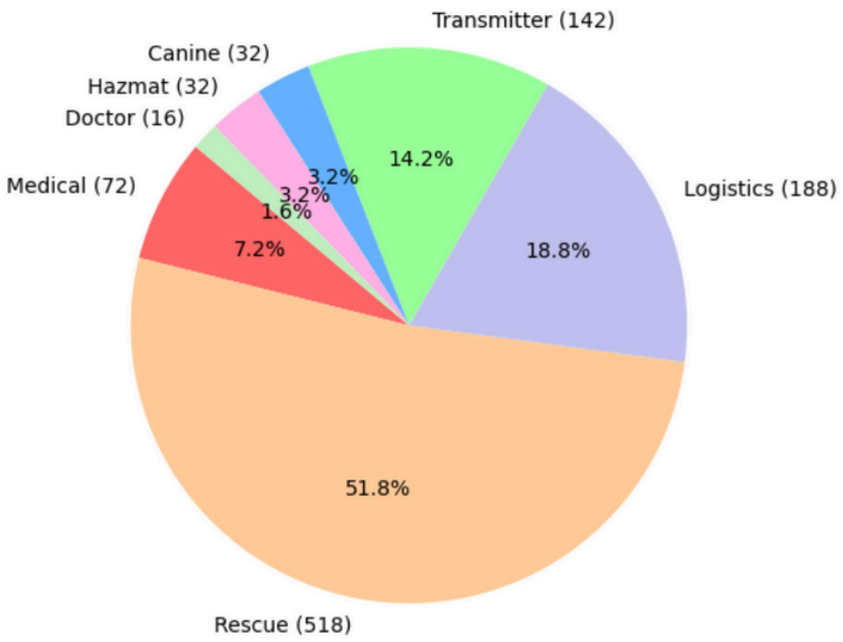
Team Type Distribution



Volunteer Assignment Status

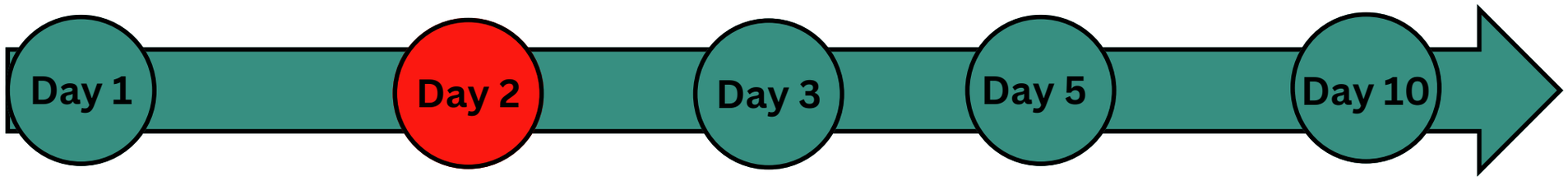


Role Distribution



arrival of experienced (retired) rescuers or SAR teams
medium teams are required to conduct ASR4 level operations

Computational Results



Case 5

Additional Staff Needed:

Role	Existing Staff	Additional Staff Needed
Medical	24	48
Rescue	230	202
Logistics	92	52
Transmitter	46	98
Canine	0	48
Hazmat	0	48
Doctor	0	24

additional staff needed to complete medium⁻ teams to medium teams

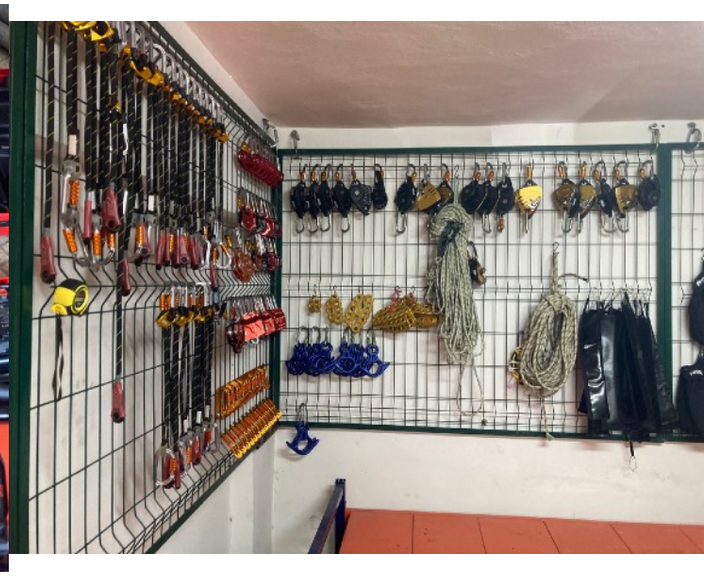
NEXT

Rapid Search and Rescue
Squad and Equipment Assignment and Scheduling

Rapid Search and Rescue
Squad and Equipment Assignment and Scheduling

- Equipments are extremely crucial.

- Each squad has their assigned set of equipments.
- The equipments can be shared by the squads “close-by”
- A truck with many equipments can also accompany a set of squads



Rapid Search and Rescue
Squad and Equipment Assignment and Scheduling

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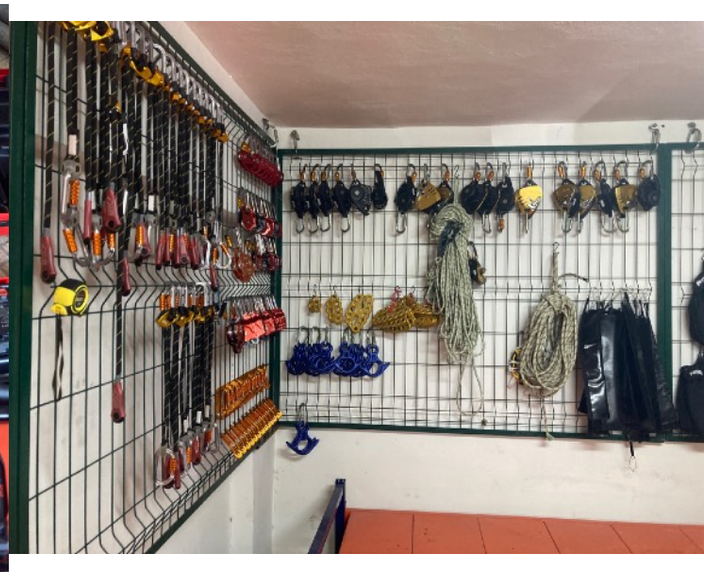
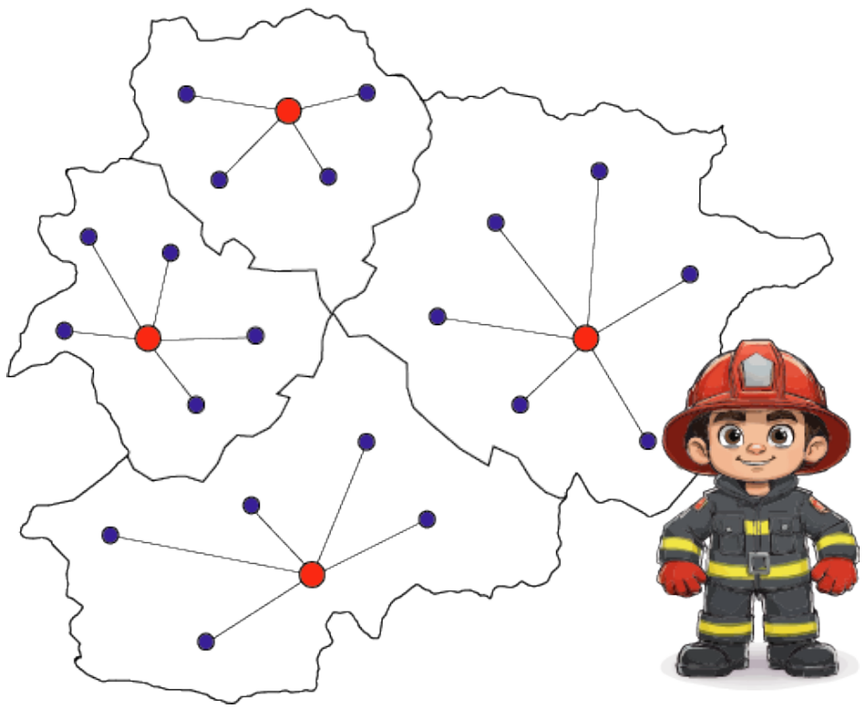


SO WHO GOES TO WHERE WITH WHAT

Problem Definition



N: Set of Regions

Parameters :

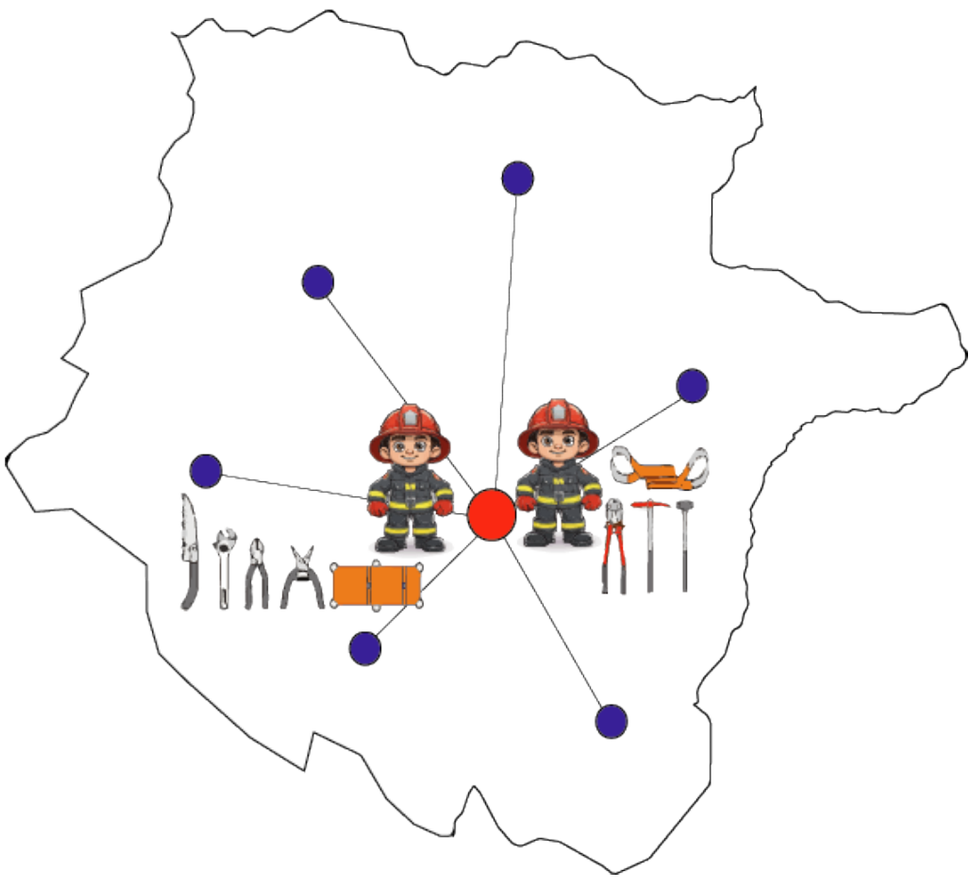
J: Set of Sectors

D_j: Job requirement for sector j

α_j, β_j: Priority and risk scores of sector j

R_{kj}: Work achieved using equipment k in sector j per unit time

$$y_{in} = \begin{cases} 1 \text{ if squad } i \in \text{I settles in } n \in N \\ 0 \text{ otherwise} \end{cases}$$



$$x_{ijkt} = \begin{cases} 1 \text{ if squad } i \text{ works in sector } j \text{ at time } t \text{ using equipment } k \\ 0 \text{ otherwise} \end{cases}$$

$$z_{ijt} = \begin{cases} 1 \text{ if squad } i \text{ works at sector } j \text{ at time } t \\ 0 \text{ otherwise} \end{cases}$$

$$f_{ijt} = \begin{cases} 1 \text{ if squad } i \text{ finishes working in sector } j \text{ at time } t \\ 0 \text{ otherwise} \end{cases}$$

$$s_{ijt} = \begin{cases} 1 \text{ if squad } i \text{ starts working in sector } j \text{ at time } t \\ 0 \text{ otherwise} \end{cases}$$

$$\min \sum_{j \in J} (D_j - P_j) \cdot (\alpha_j - \beta_j)$$

Goal is to minimize the total weighted amount of unfinished work.

$$D_j \geq P_j \quad \forall j \in J$$

$$\sum_{n \in N} y_{in} = 1 \quad \forall i \in I$$

$$z_{ijt} \leq y_{in} \quad \forall n \in N, \forall j \in J_n, \forall i \in I, \forall t \in T$$

$$\sum_{j \in J} z_{ijt} \leq 1 \quad \forall i \in I, t \in T$$

$$z_{ijt} + s_{ij(t+1)} - f_{ijt} = z_{ij(t+1)} \quad \forall i \in I, j \in J, t \in T$$

$$z_{ijt} \geq f_{ijt} \quad \forall i \in I, j \in J, t \in T$$

$$s_{ijt} \leq z_{ijt} \quad \forall i \in I, j \in J, t \in T$$

$$\sum_{i \in I} \sum_{t \in T} s_{ijt} \leq 1 \quad \forall j \in J$$

$$\sum_{i \in I} \sum_{t \in T} f_{ijt} \leq 1 \quad \forall j \in J$$

$$\sum_{i \in I} \sum_{t \in T} \sum_{k \in K} x_{ijkt} \cdot R_{kj} \geq P_j \quad \forall j \in J$$

$$\sum_{t' \in T} s_{ijt'} \geq z_{ijt} \quad \forall i \in I, j \in J, t \in T$$

$$z_{ijt} \geq x_{ijkt} \quad \forall i \in I, j \in J, t \in T, k \in K$$

$$\sum_{j \in J_n[n]} \sum_{i \in I} x_{ijkt} \leq \sum_{i \in I} y_{in} \cdot H_{ik} \quad \forall n \in N, k \in K, t \in T$$

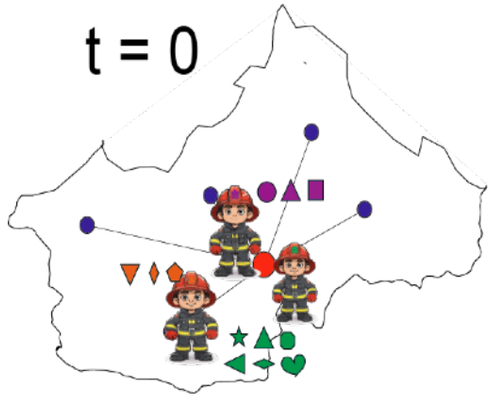
$$\sum_{i \in I} \sum_{t' \in T, t' < t} s_{ijt'} \geq \sum_{i \in I} \sum_{t' \in T, t' \leq t} f_{ijt'} \quad \forall j \in J, t \in T$$

$$W_{ijkt}, s_{ijt}, f_{ijt}, x_{in}, z_{ijt} \in \{0, 1\} \quad \forall i \in I, j \in J, k \in K, t \in T, n \in N$$

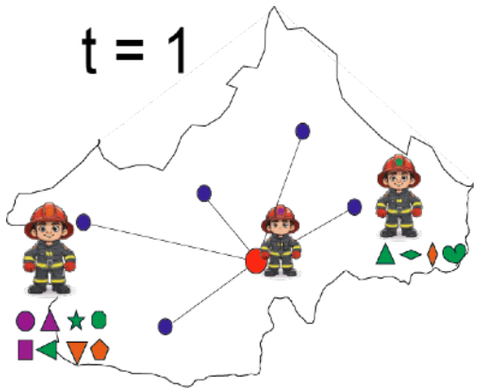
$$P_j \geq 0 \quad \forall j \in J$$

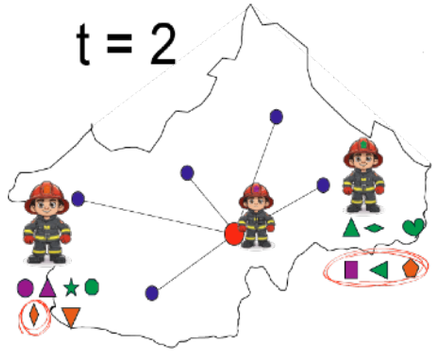
Test Results

- Squads arrive at the region center with their equipment.

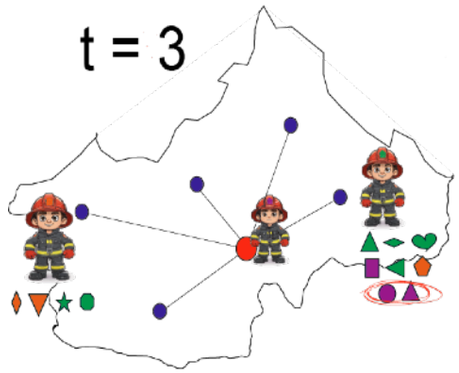


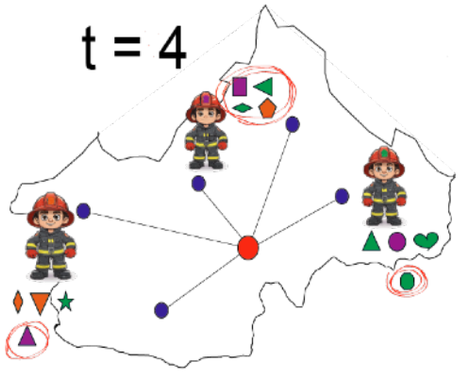
- Equipment transferred between squads

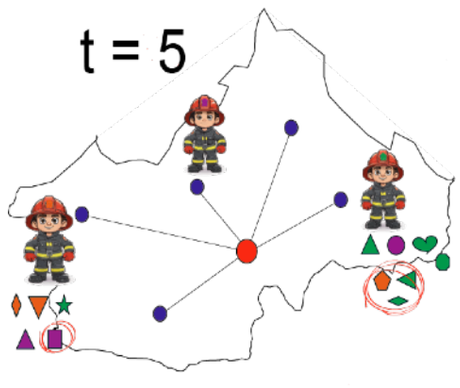


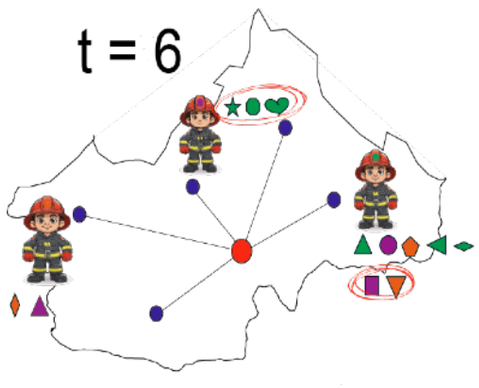


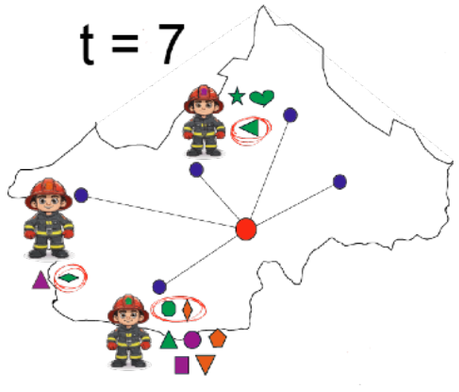
- Another squad started working

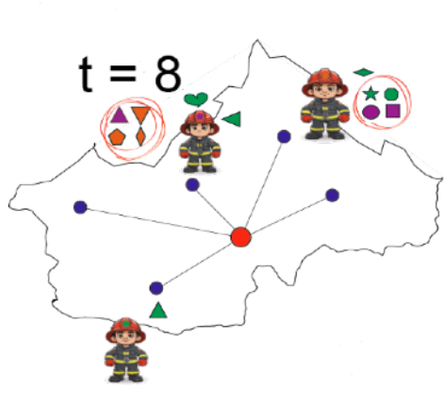


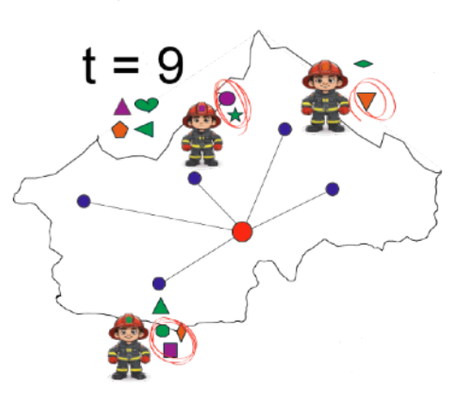












- Equipment transferred between squads

- Orange squad finished working and moved to the last sector

- Equipment transferred between squads

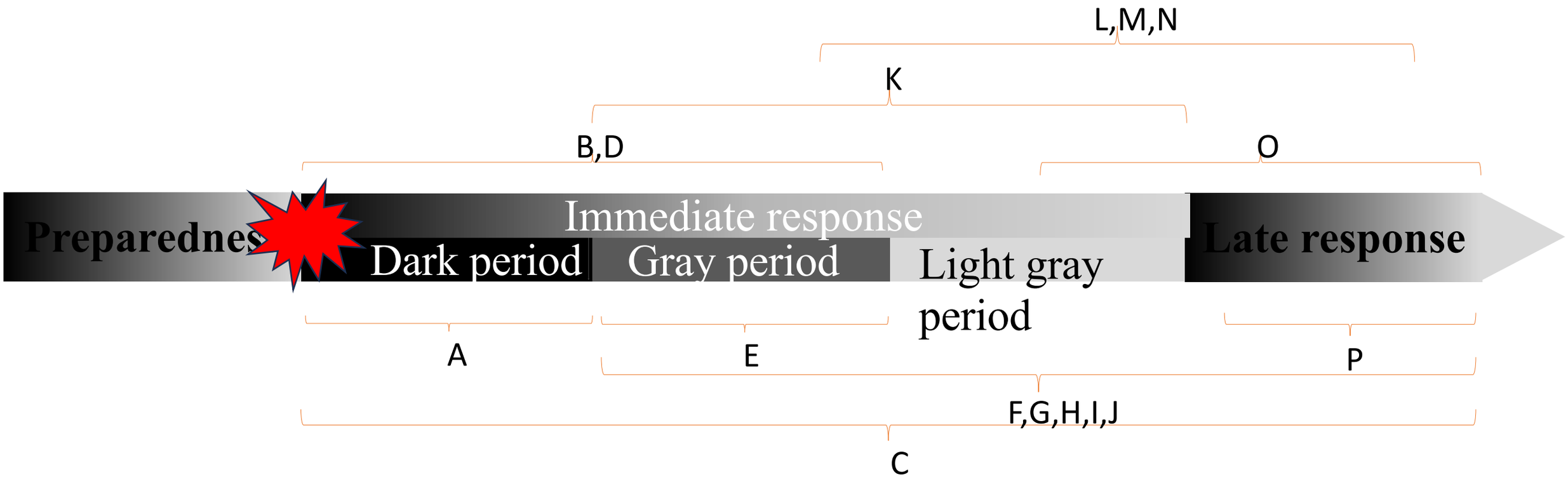
Team Formation & Search and Rescue
Squad and Equipment Assignment and Scheduling

- Basic models with very basic assumptions
- Deterministic!

- Immediate extension stochastic parameters

- Dynamic nature

- Incoming new squads and equipment
- International help



A. Status assessment

B. Emergency response operations

C. Information management and coordination

D. Emergency access routes

E. Casualty management

F. Deceased management

G. Communication and infrastructure

H. Medical service management

I. Mobile service management

J. Temporary healthcare facilities

K. Gathering areas

L. Donation management

M. Debris and waste management

N. Structural risk/damage assessment

O. Shelter site management

P. Long-term supply chain management

J. Mobile services

Dark period	Gray period	Light gray	Late response
	51. Planning of mobile services to ensure equitable access to critical needs with limited resources 52. Mobilization of service facilities		
	53. Addressing critical needs based on demand frequency 54. Team/equipment/fleet management and routing		

Mobility

- Must
  - Need to reach the victims
- To improve service and fairness
  - Cannot have facilities everywhere
  - Instead of a fixed facility, we provide (periodic) service with mobile facilities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MOBİL ÇAMAŞIRHANE
MAN


JANDARMA GENEL KOMUTANLIĞI
MOBİL MUTFAK


BENİM ŞEHRİM
KONYA BÜYÜKŞEHİR BELEDİYESİ
SOLAR MOBİL
EFON ŞARJ İSTASYONU


MOBİL TUVALET ARACI

The mobile services offered during the response phase have their own internal dynamics. These dynamics vary depending on the continuity of demand, the variety of vehicles, and the structure of the product.

Services based on demand aspects:

- One time demand (e.g distribution of blankets)
- Continuous time demand (e.g distribution of food)
- Periodic demand (e.g barber service)

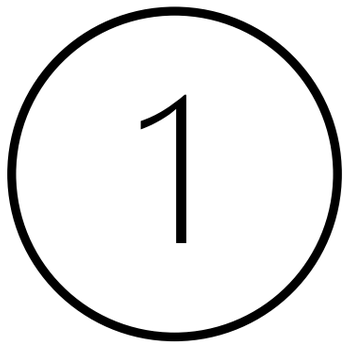
Aim: The management of mobile units with different service types in response stage

The main decisions:

- the locations of temporary fixed centers
- the locations visited by mobile centers
- the length of stay of the mobile centers
- the tours of mobile centers

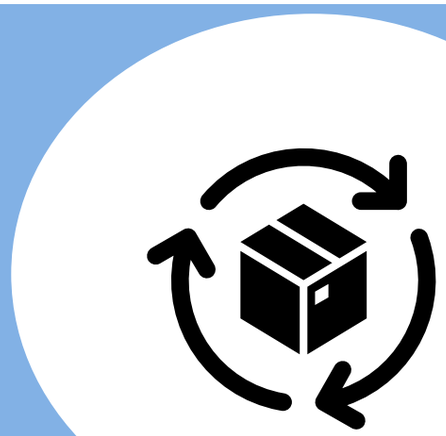
Possible Performance Measures:

- minimization of total travel time by mobile vehicles
- maximization of the total number of people getting service



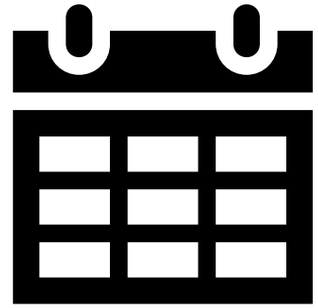
One-time Demand Services

- It involves a one-time requirement for a specific service.
- It is not expected to be repeated or continued.
- People's needs are met with a one-time service.



Continous Demand Services

- These are services that involve continuous and uninterrupted needs.
- Continuous and consistent supply is required for the requested service.



Periodic Demand Services

- These are services that involve needs occurring periodically or at regular intervals.

One-time Demand Services

Continous Demand Services

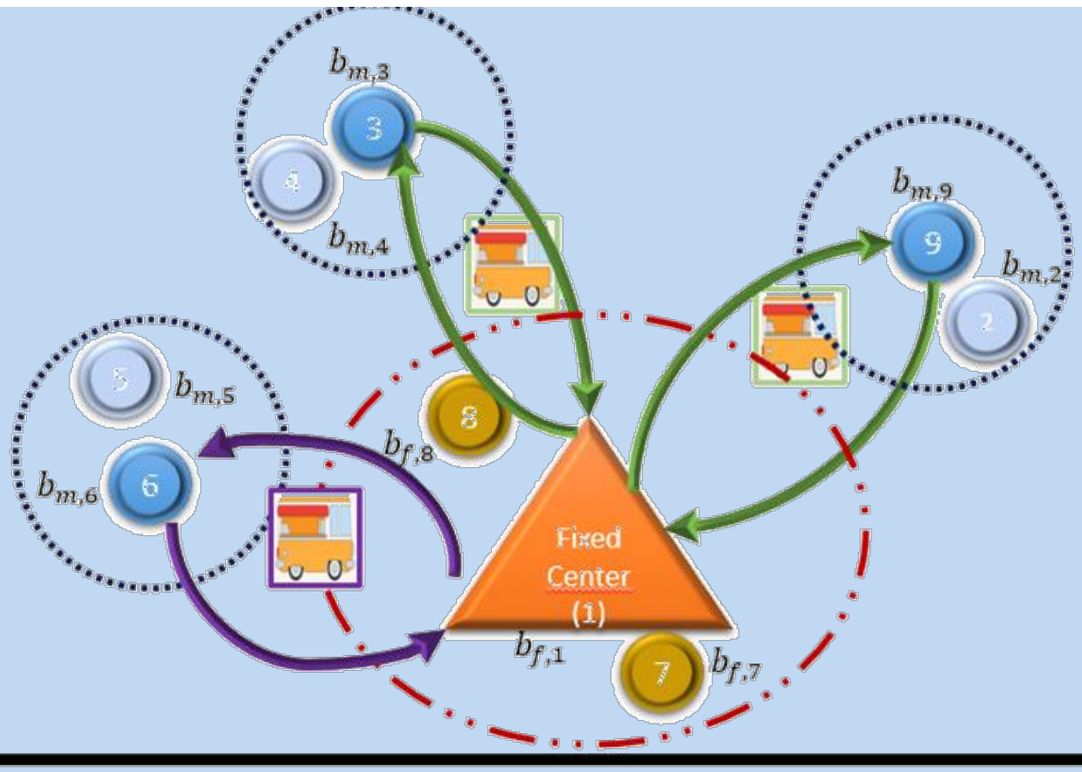
Periodic Demand Services

One-time Demand	Continuous Demand	Periodic Demand
Shelter needs (tent, blanket, pillow etc.) Clothes, shoes	Food Water bottles Hygiene (WC) Emergency Healthcare	Personal Care Maintenance Library/ Child-friendly areas Health (dentist, pharmacy) Hygiene (Showers, laundry)

1

One-time Demand Services

Problem Description



- **Fixed centers : contain the products or services necessary to meet the victim's needs and provide non-stop service to specific locations.**
- **Mobile service units: operate at and depart from those fixed centers. They have mobility option which helps them to move independently.**
- **Aim: increase the availability of the services for the victims.**

1

One-time Demand Services

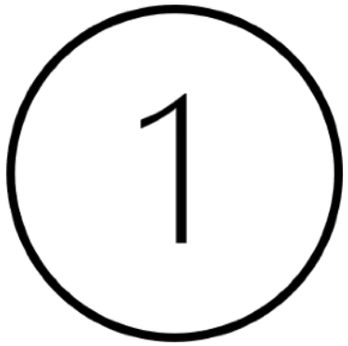
Problem Description

Main Decisions :

- **the locations for fixed centers,**
- **the locations visited by mobile centers among candidate visiting points,**
- **the length of stay of the mobile service units**

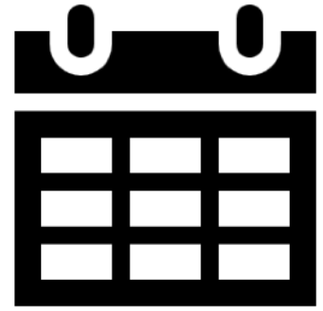
Performance Measure:

maximize the number of people service provided to reach as many the members of the community with the **scarce resources available** during the disaster period



One-time Demand Services

Continous Demand Services



Periodic Demand Services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BAY WC
BAYAN WC


ULAK
HABERLEŞME A.Ş.
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TÜRK ECZACILARI
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JANDARMA GENEL KOMUTANLIĞI
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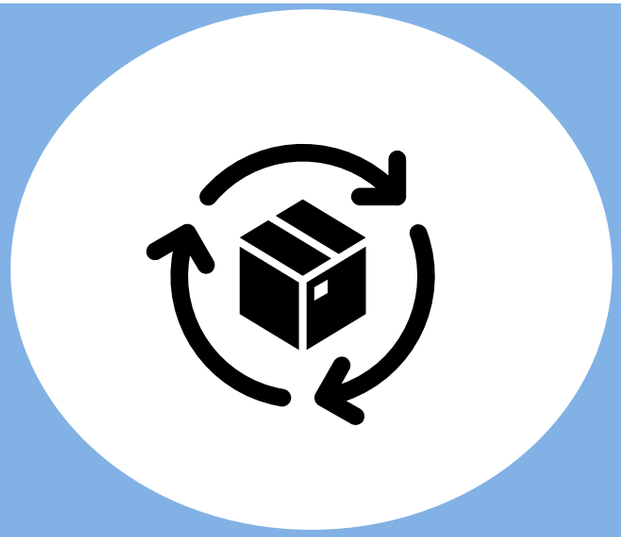
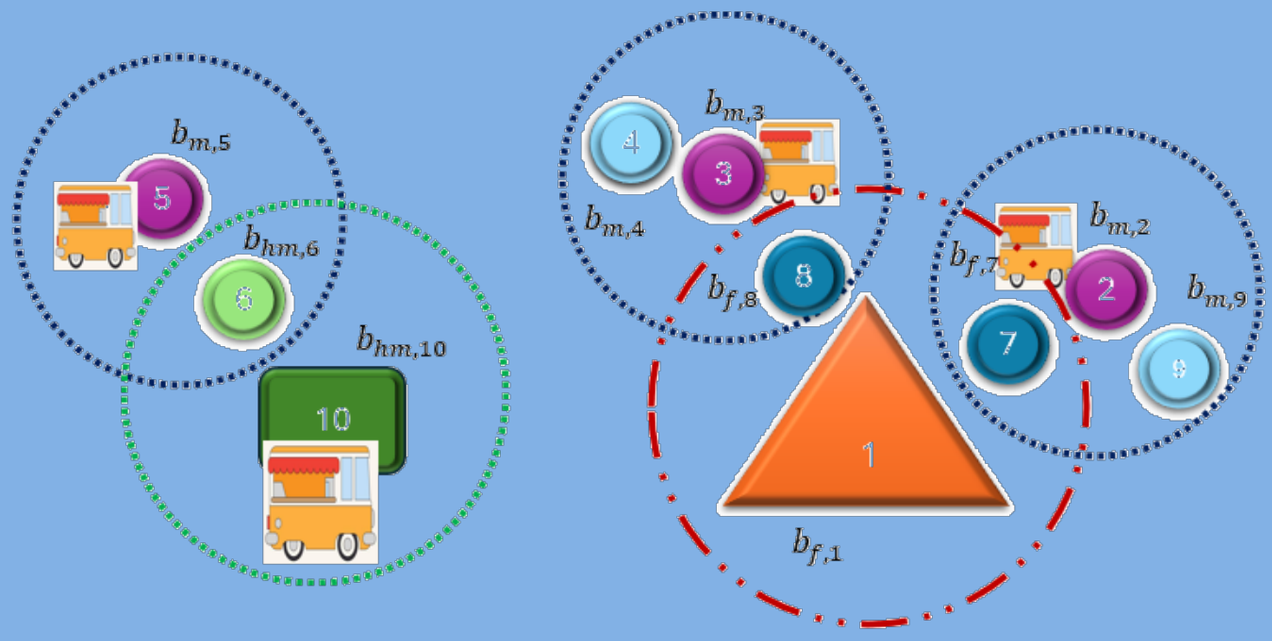
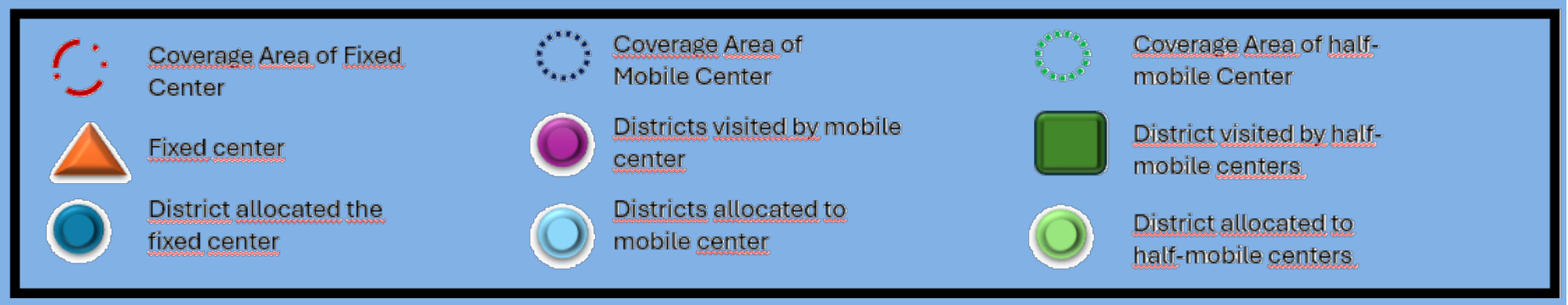


Continous Demand Services

Problem Description





Continous Demand Services

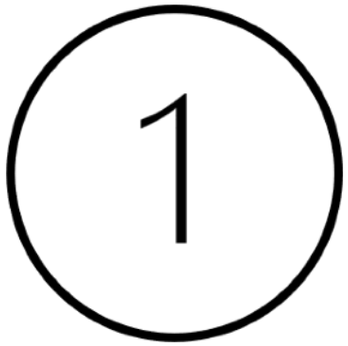
Problem Description

Main Decisions :

- **the locations of fixed centers,**
- **the locations of half-mobile centers,**
- **the locations of mobile centers,**
- **the allocations of districts to each service center**

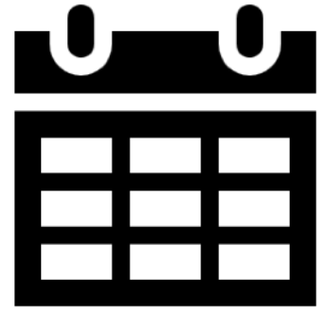
Performance Measure:

maximize the people served by each service type and demand served allocated to those center within their coverage radius



One-time Demand Services

Continous Demand Services



Periodic Demand Services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(a) Exterior.

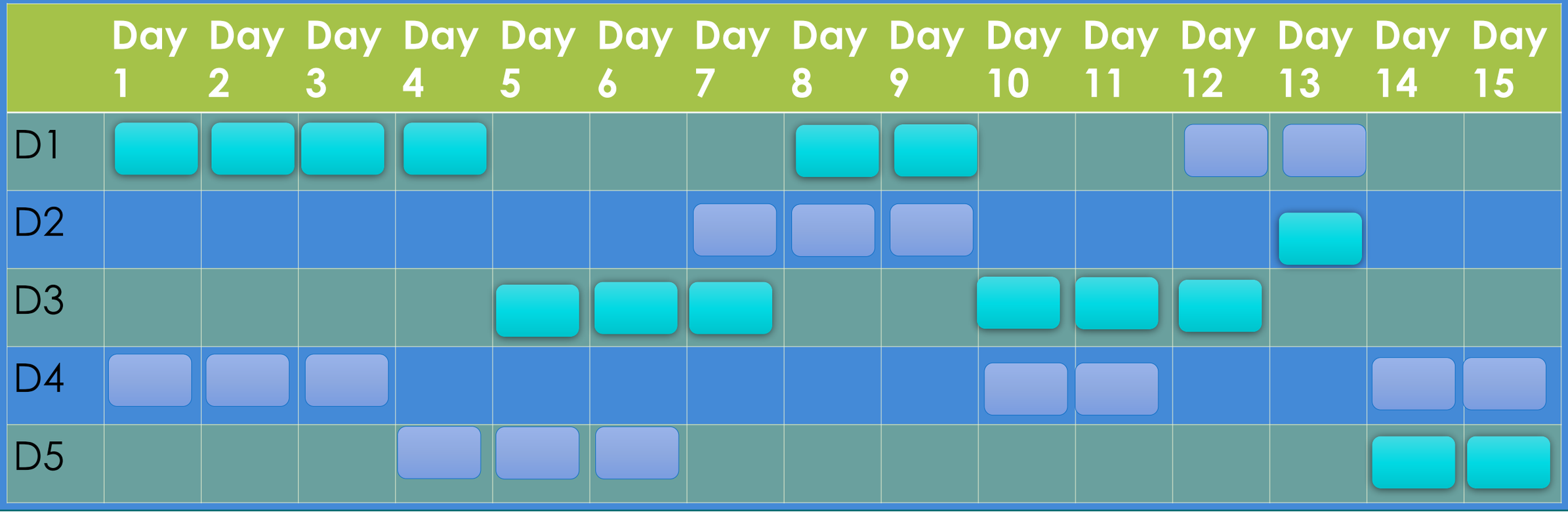
(b) Interior.

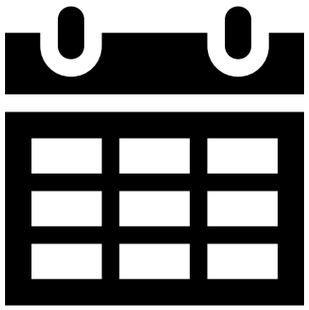
Figure 10: Mobile showers dispatched by Ankara Municipality to the disaster region after Kahramanmaraş Earthquakes (Ankara Büyükşehir Belediyesi, 2023).

Problem Description

Mobile Service Unit 1
Mobile Service Unit 2

Periodic Demand Services





Periodic Demand Services

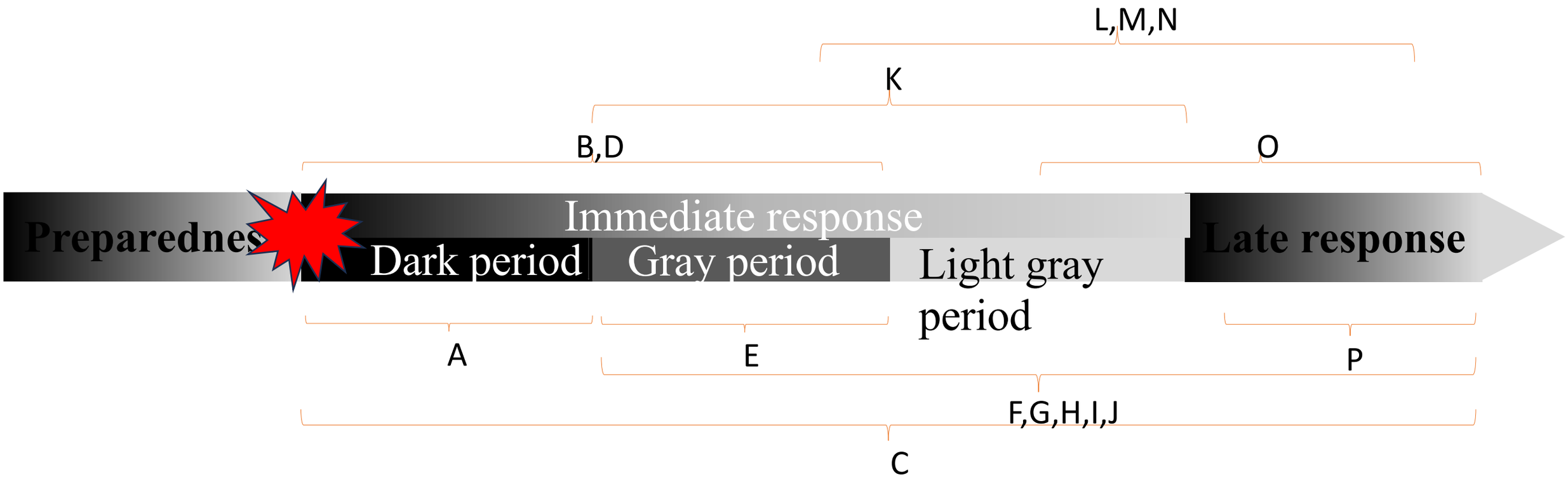
Problem Description

Main Decisions :

- **the locations visited by each service unit at each day,**
- **the length of stay of the mobile service units during each visit to a district.**

Performance Measure:

maximize the number of people service provided



A. Status assessment

B. Emergency response operations

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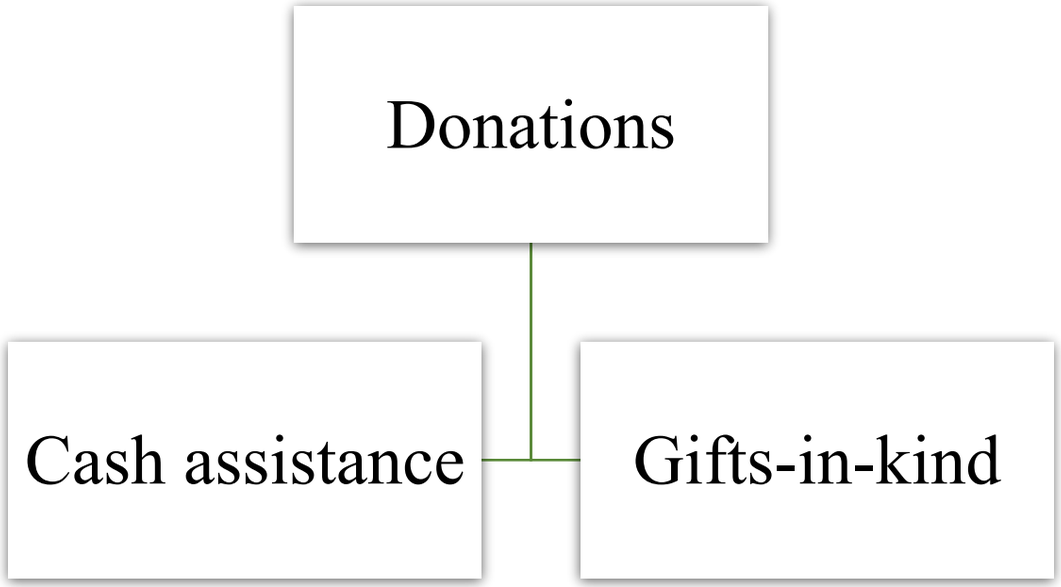
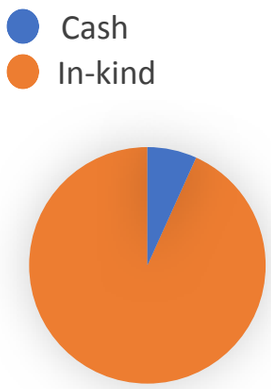
Donation management





From donors' perspective

- Better idea on resulting impact
- Provides options
- More convenient
- Sustainable

Donation management

High risk of demand-supply mismatch

Donor unpredictability

+

Multiple actors with limited to no communication

=

Donation pollution and service duplications

(a) Blockage on main roads due to excessive number of trucks carrying relief aid (Anadolu Ajansı, 2023).

(b) Unattended donations (BBC, 2023b).

Figure 9: Examples of donation pollution after Kahramanmaraş earthquakes.

Donation management

Objectives

- Demand coverage, accessibility, reliability…
- Equity
  - A main principle of humanitarian operations
  - Often conflicting with other objectives
  - Hard to quantify

Equitable donation allocation problem

National level

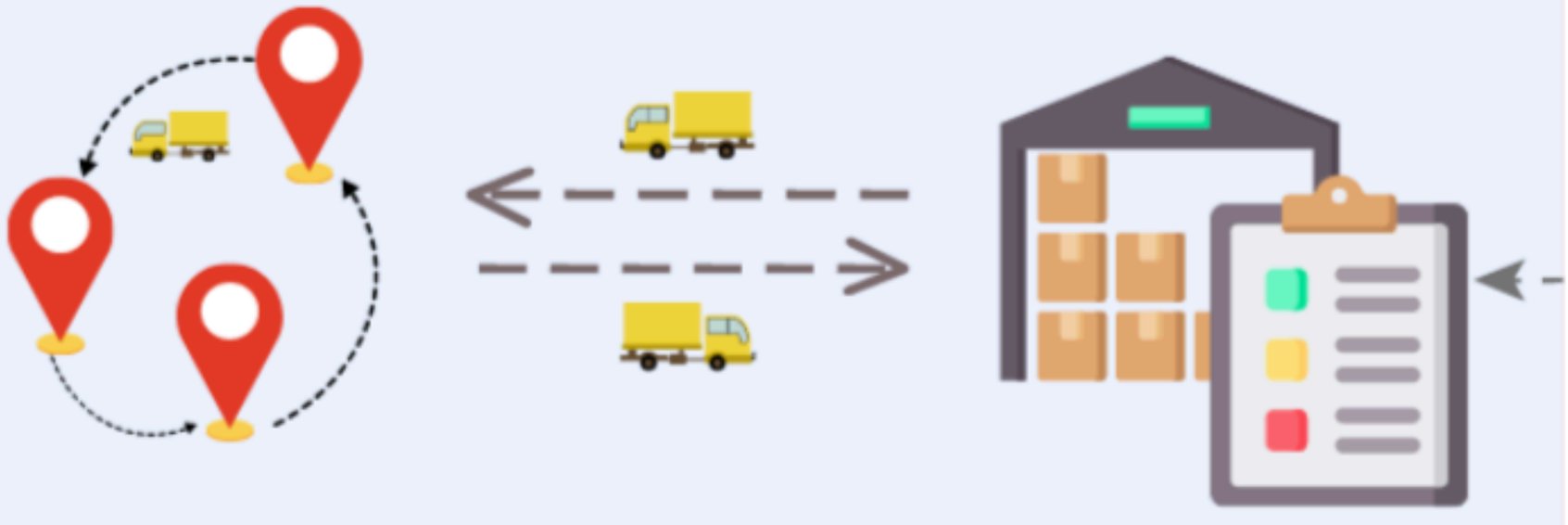
Donation management

National level

Regional level

National level

Regional level



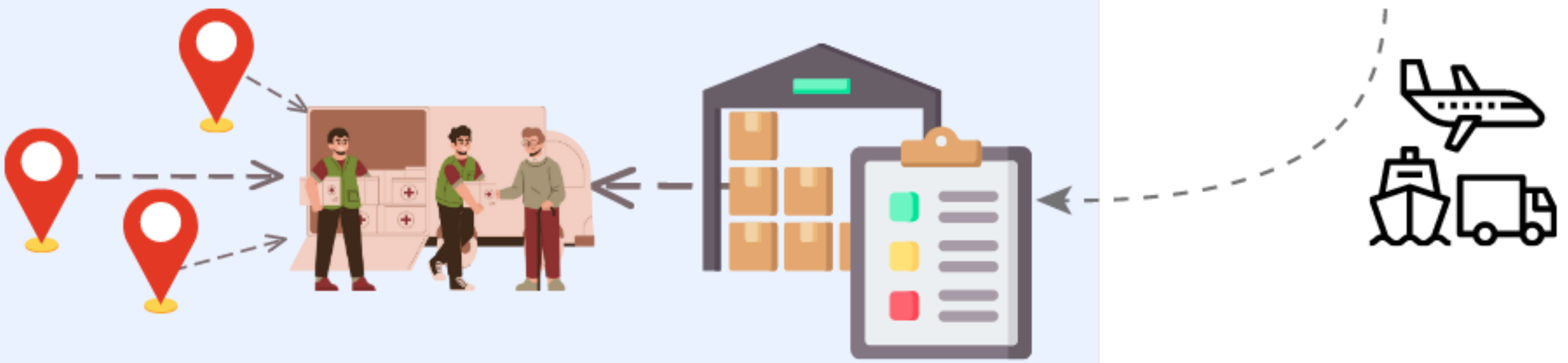
National level

Individuals

NGOs

Companies

Regional level



Problem definition

Relief type

Allocation of in-kind donations for an

- urgent,
- consumable,
- non-perishable

relief item.

A typical example is bottled water

- a reliable source of clean water
- for drinking and sanitization purposes

Fair allocation of donations to shelter sites in post-disaster phase

Allocation of a single durable commodity with recurring demand

Capacitated mobile PoDs
(# is limited with a budget)

Coverage radius

Inventory decisions for shelter sites

A deprivation cost function based on waiting time and shortage

Rawlsian approach

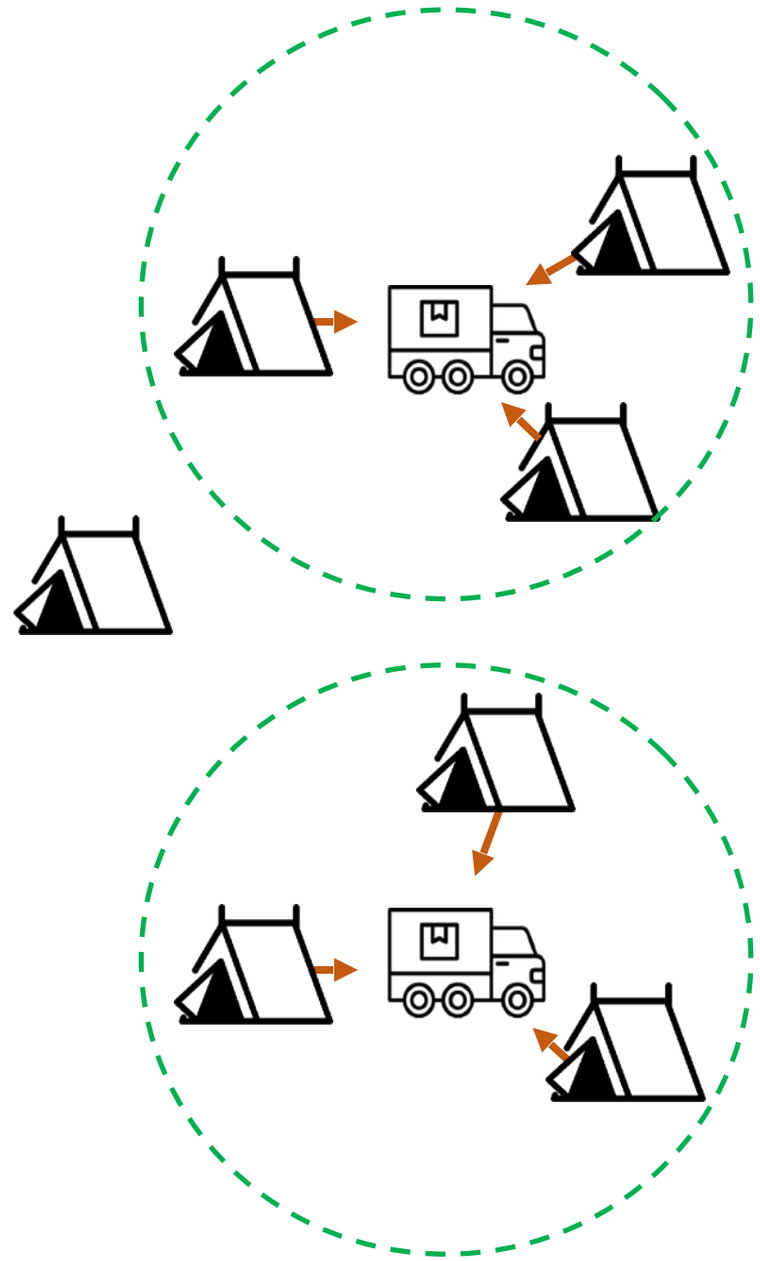
Problem definition

Decisions

In each time period, we decide

1. Location of the mobile PoDs

2. Allocated amount to each shelter site from each PoD



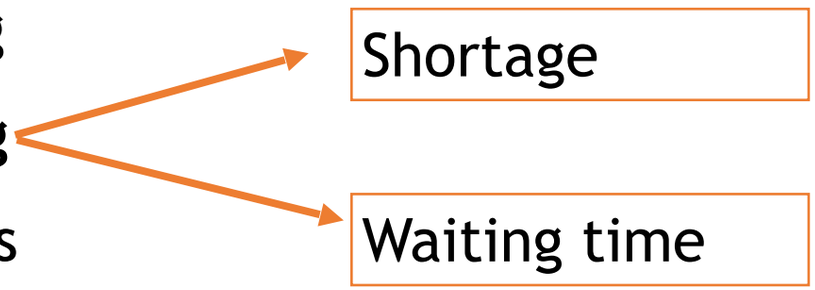
Fair allocation of donations to shelter sites in post-disaster phase

A bi-objective multi-period location-relocation-allocation-inventory problem with the aim of minimizing

- the maximum weighted **suffering**

experienced among the shelter sites

- the total distance travelled

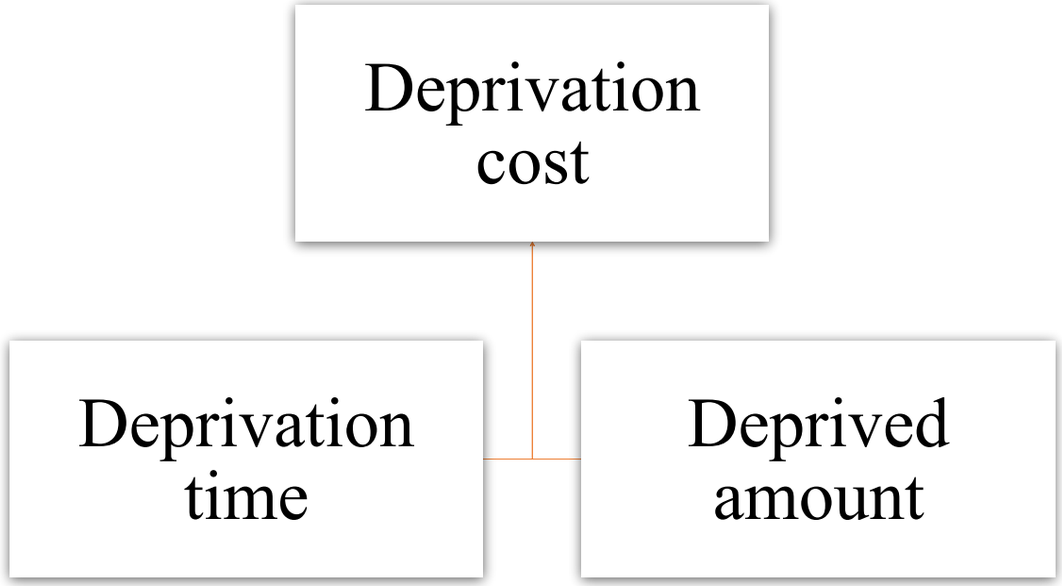


Problem definition

Objective

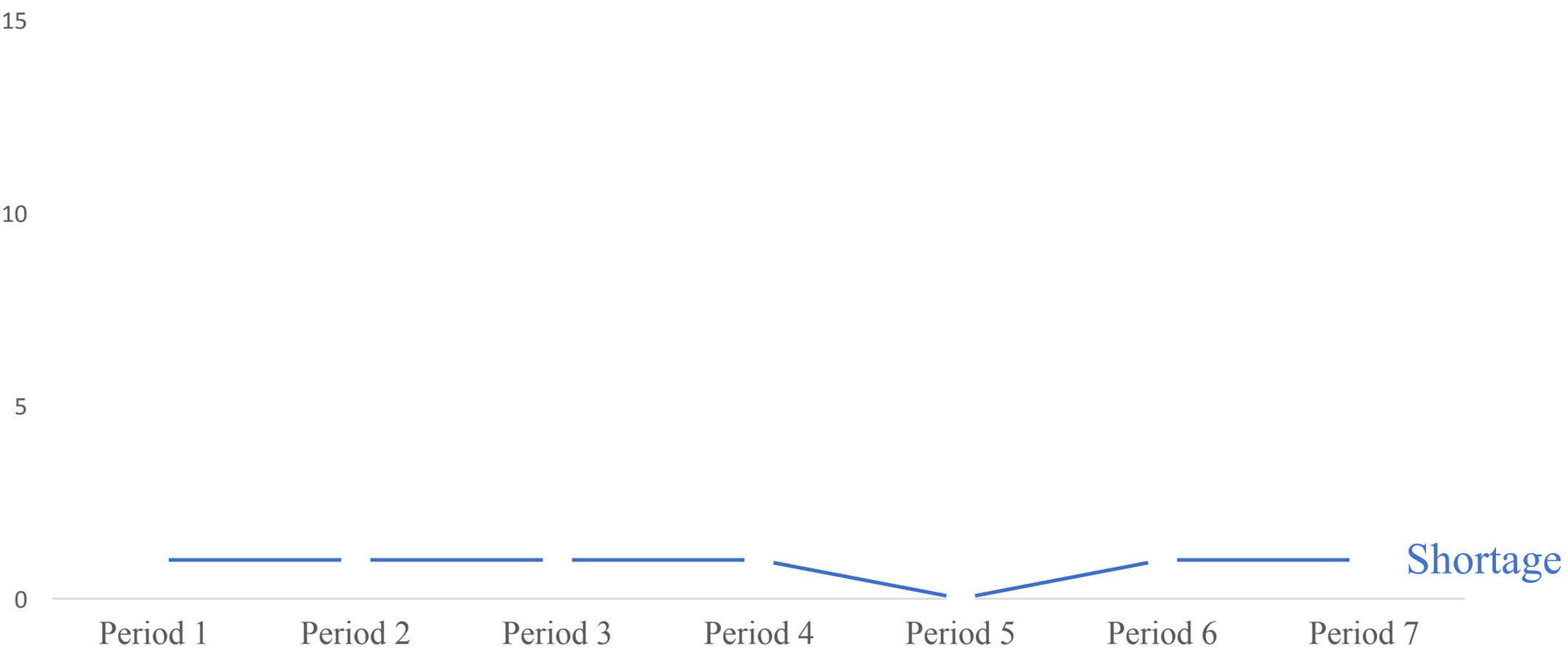
Deprivation cost

- introduced by Holguin-Veras et al. (2013)
- aims to measure a population's **"suffering"** for facing a shortage of a critical relief item



Problem definition

How to calculate deprivation cost?



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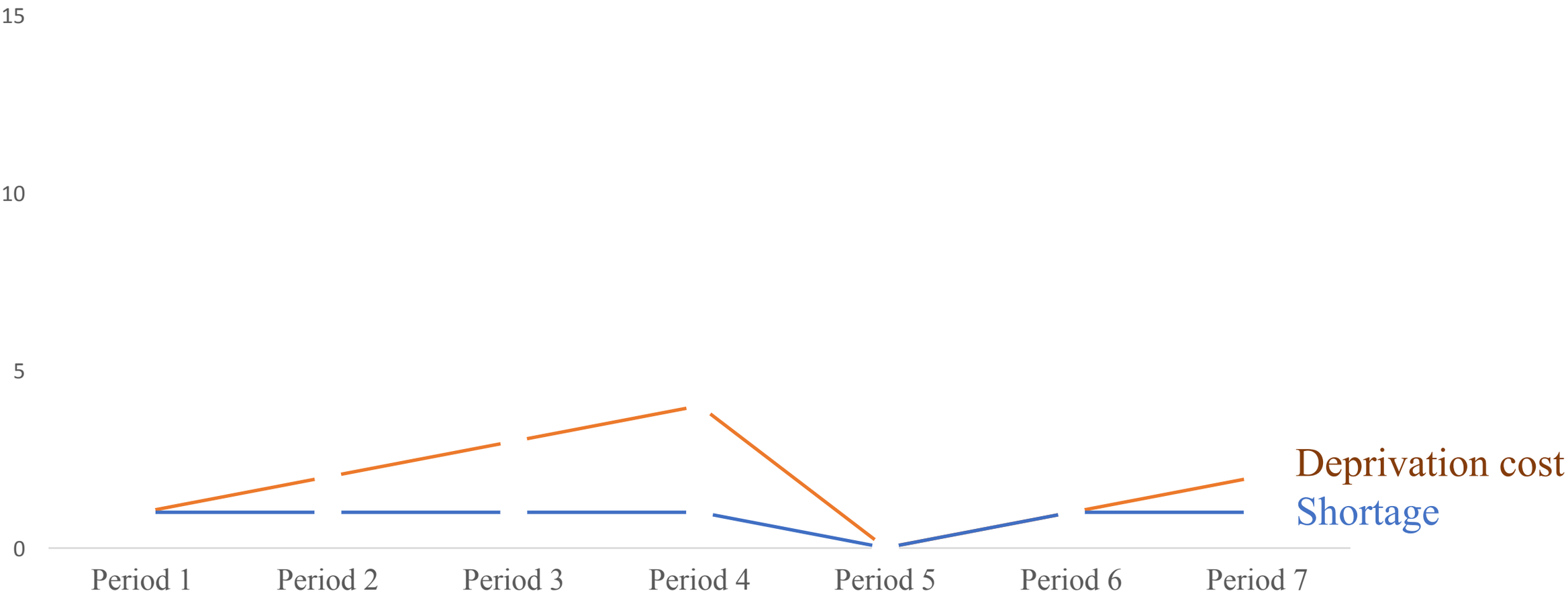

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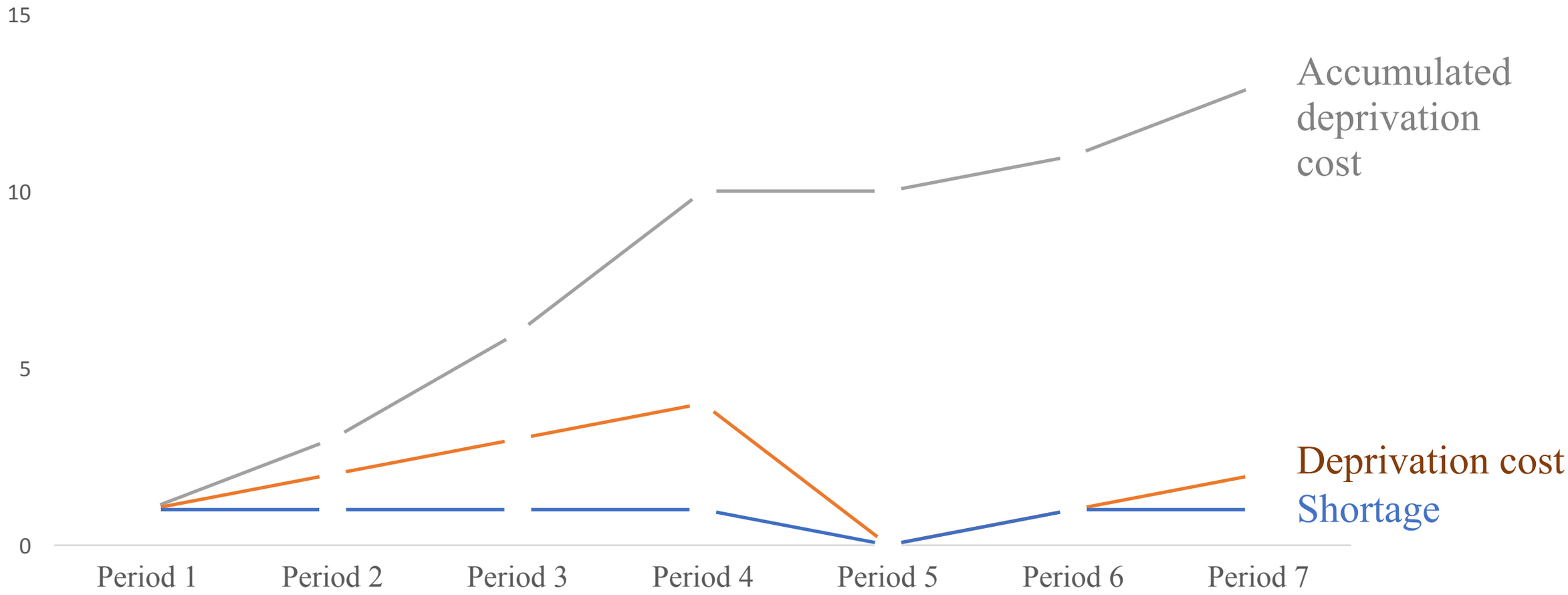


We address *the deterministic donation allocation* problem considering multiple objectives

- the maximum deprivation cost
- the total deprivation cost
- the total distance traveled by beneficiaries

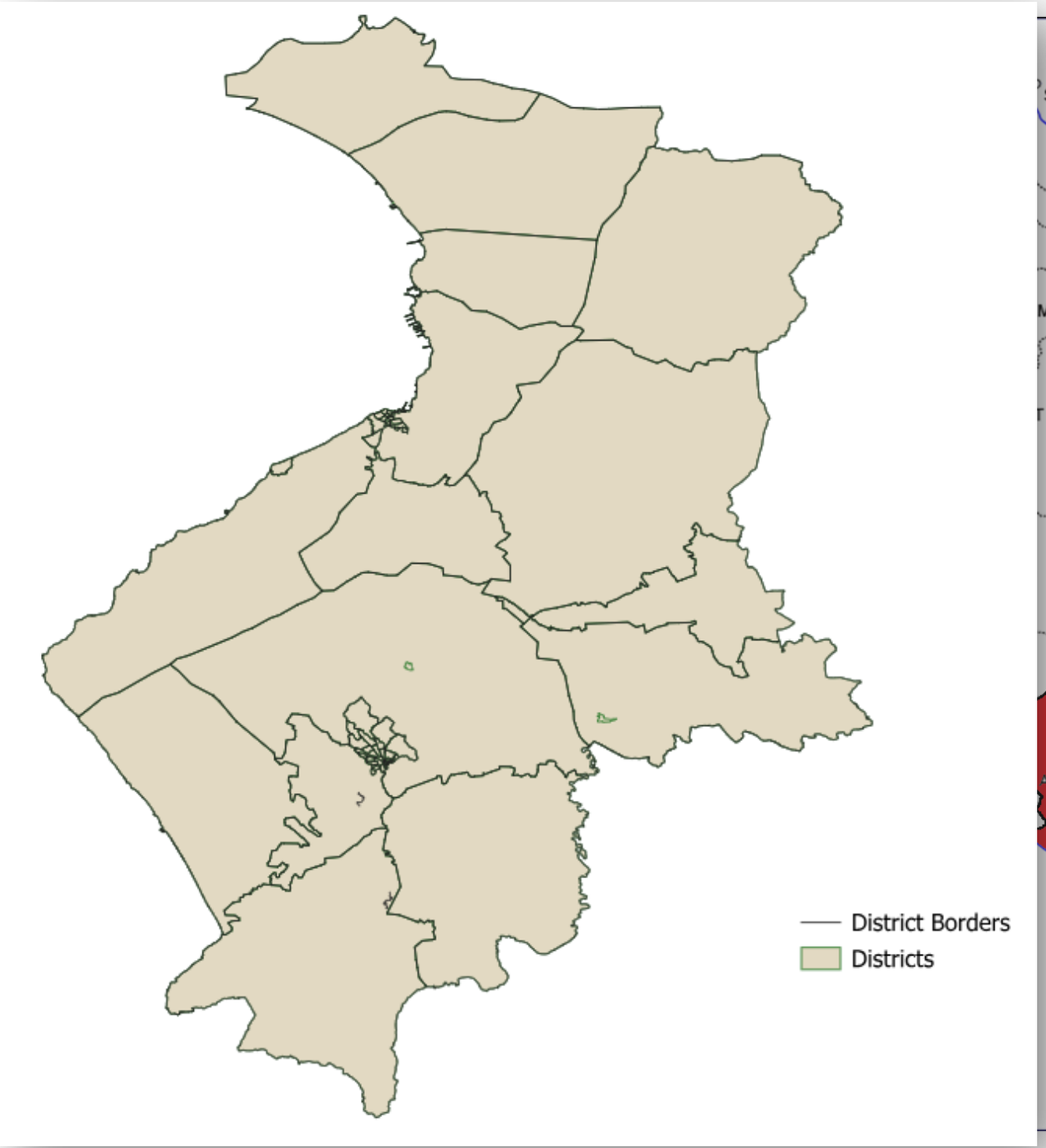
We also address *the stochastic donation allocation* problem

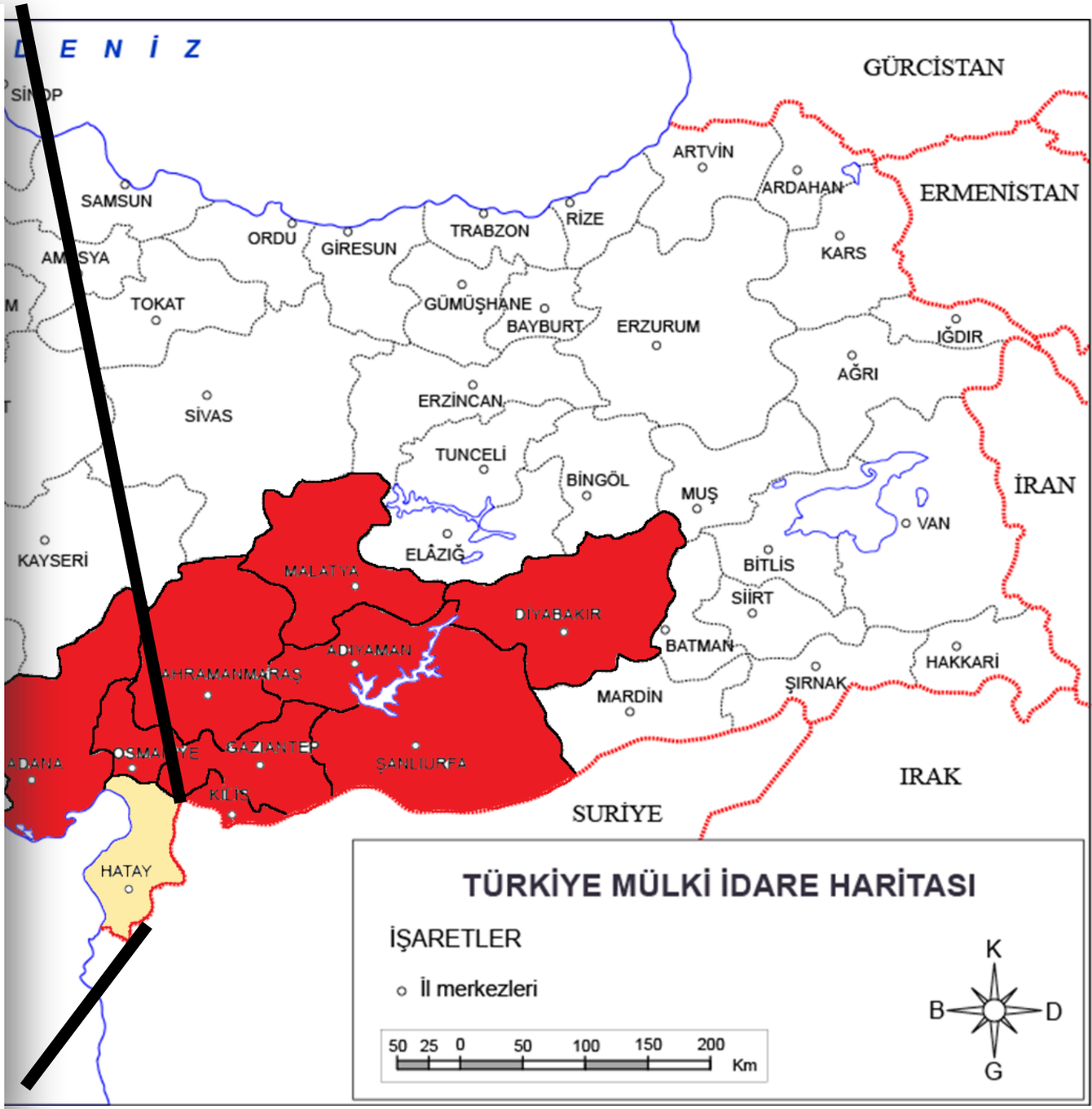
Subphase	Problem type	Location	Routing	Resource allocation	Team formation	Team scheduling	Clustering/prioritization	Network design	Relief items	Workforce	Equipment	Fleet	Accommodation	Response time	Coverage	Accessibility	Fairness	Reliability	Cost	Link capacities	Supply type	Supply amount/capacity	Demand locations	Demand amount	Number of facilities	Size of fleet	Capacity	Competency levels
		Decisions							Service type					Objectives						Uncertainties					Limitations			
Dark period	Wide area exploration		+			+				+	+	+			+	+							+	+			+	+	
	Emergency access route design						+	+							+	+		+		+			+					+	
	Establishment of coordination centers	+						+	+	+					+	+		+		+		+			+			+	
	Prioritization and sectorization			+			+								+		+			+			+	+					
Gray period	Search and rescue		+		+	+				+	+	+			+	+		+			+	+	+	+	+			+	+	+
	On-site triage and first aid	+				+				+	+	+			+		+			+			+	+	+		+	+	+	+
	Patient transportation		+			+				+	+	+			+	+		+			+		+	+	+			+	+	
	Deceased management and identification	+	+							+	+	+			+	+					+		+	+	+		+	+	+	
	Establishment of communication network	+					+			+		+			+							+		+			+		+	
	Gathering areas	+											+		+	+		+					+	+	+		+		+	
	Mobile service management	+	+	+			+		+						+	+	+				+	+			+				+	
Light gray period	Mobile service management	+	+	+			+		+						+	+	+				+	+			+				+	
	Management of field hospitals	+				+					+	+			+	+		+	+						+	+			+	
	Debris management	+	+			+	+				+	+	+		+	+	+		+								+	+	+	
	Structural damage/risk assessment		+			+	+				+	+	+		+	+		+	+	+								+	+	
	Restoration and demolition		+			+	+				+	+	+		+	+		+	+	+								+	+	
	Shelter site management	+	+	+		+			+		+	+	+	+	+	+									+		+	+		
	Donation management	+	+	+		+		+			+	+	+	+		+		+		+					+		+	+	+	

Currently 71 subproblems

What else?

Hatay – BBC


District Borders
Districts


DENİZ
GÜRCİSTAN
ERMENİSTAN
İRAN
IRAK
SURİYE
SİNOP
SAMSUN
AMASYA
TOKAT
ORDU
GİRESUN
TRABZON
RİZE
ARTVİN
ARDAHAN
KARS
IĞDIR
AĞRI
GÜMÜŞHANE
BAYBURT
ERZURUM
ERZİNCAN
SİVAS
TUNCELİ
BİNGÖL
MUŞ
VAN
BİTLİS
SİİRT
HAKKARİ
ŞIRNAK
BATMAN
MARDİN
DİYABAKIR
ELÂZIĞ
MALATYA
KAYSERİ
ADIYAMAN
KAHRAMANMARAŞ
OSMANİYE
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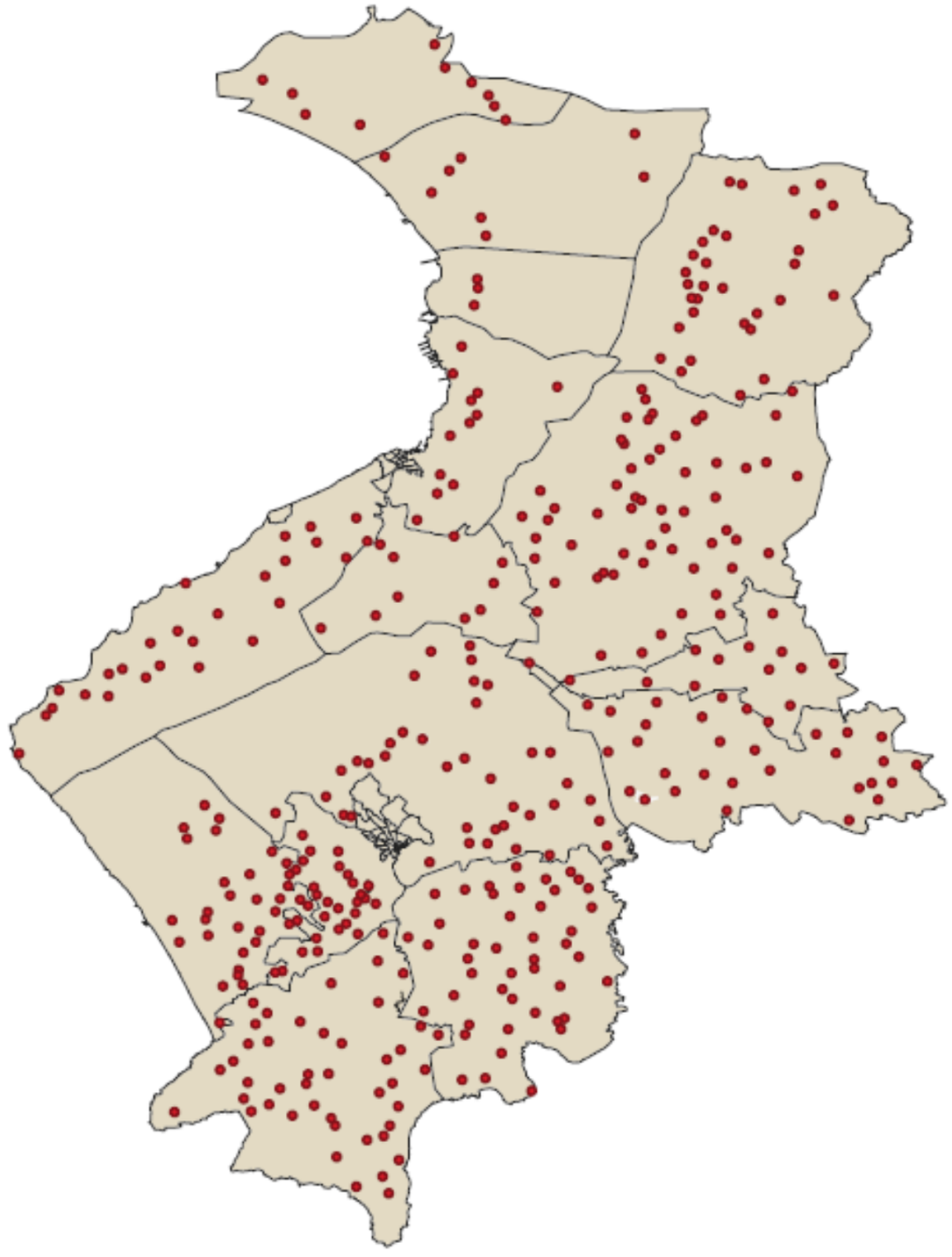
Population Points (Villages)

District Borders

Districts



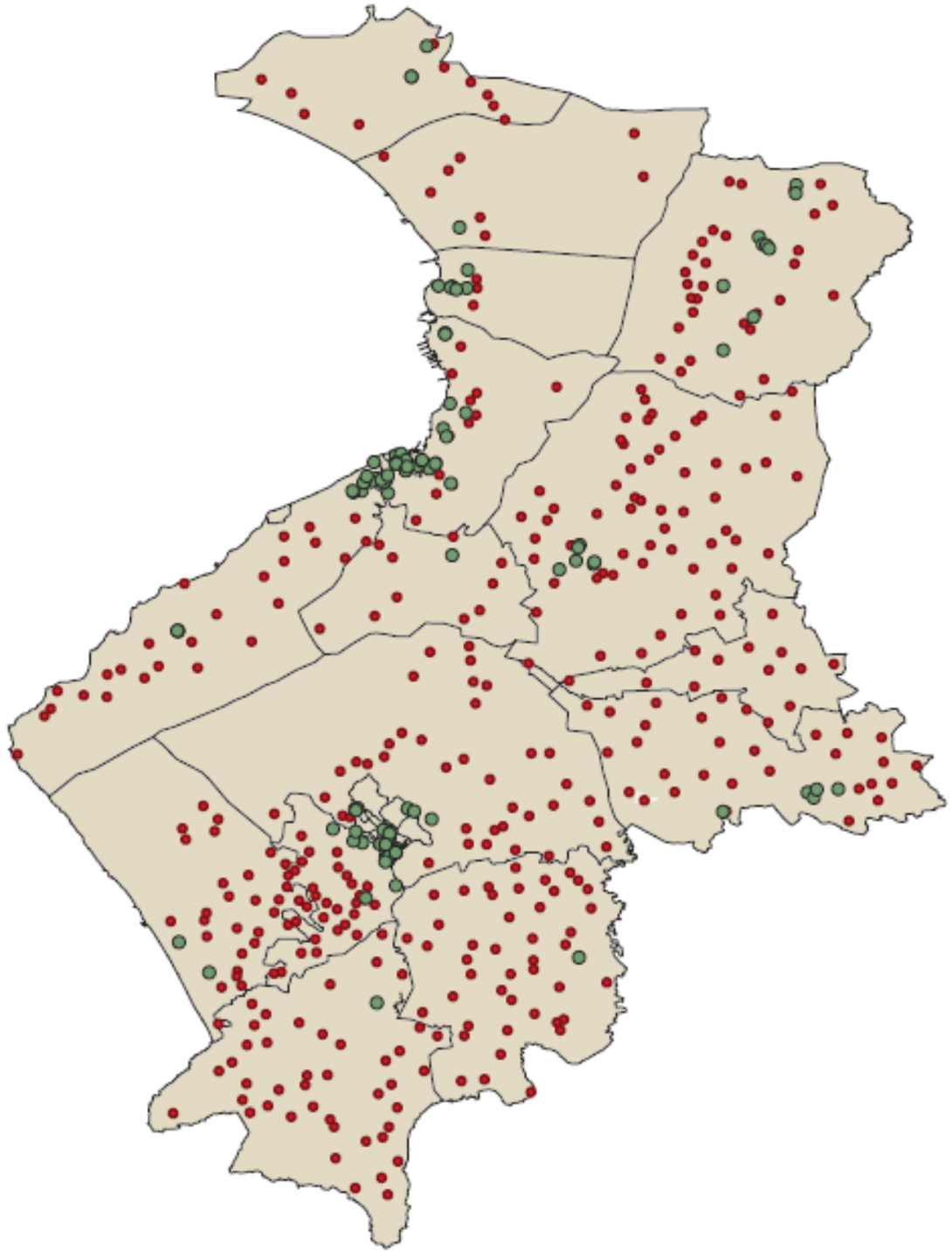
338 villages

Schools

Population Points (Villages)

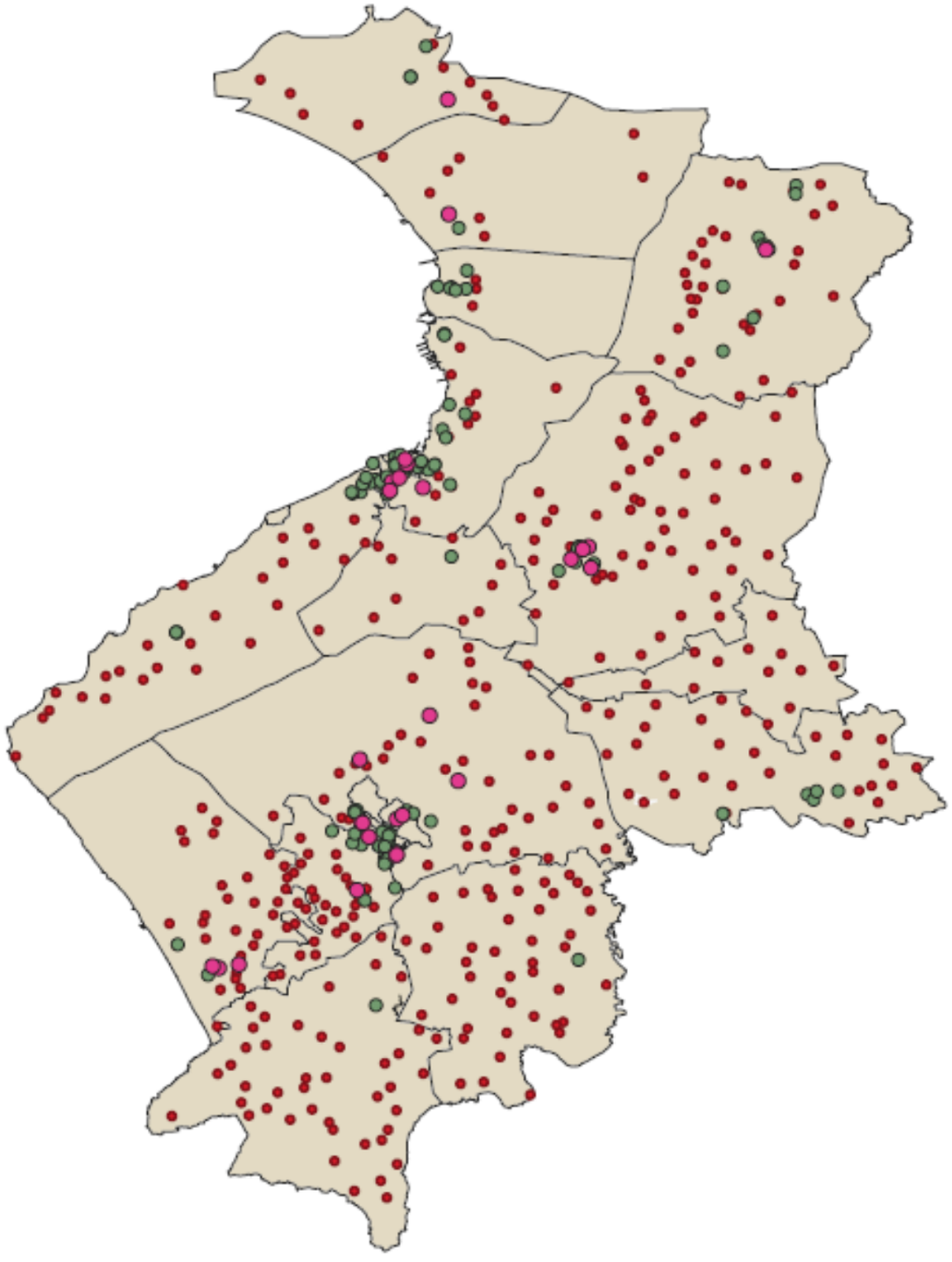
District Borders

Districts



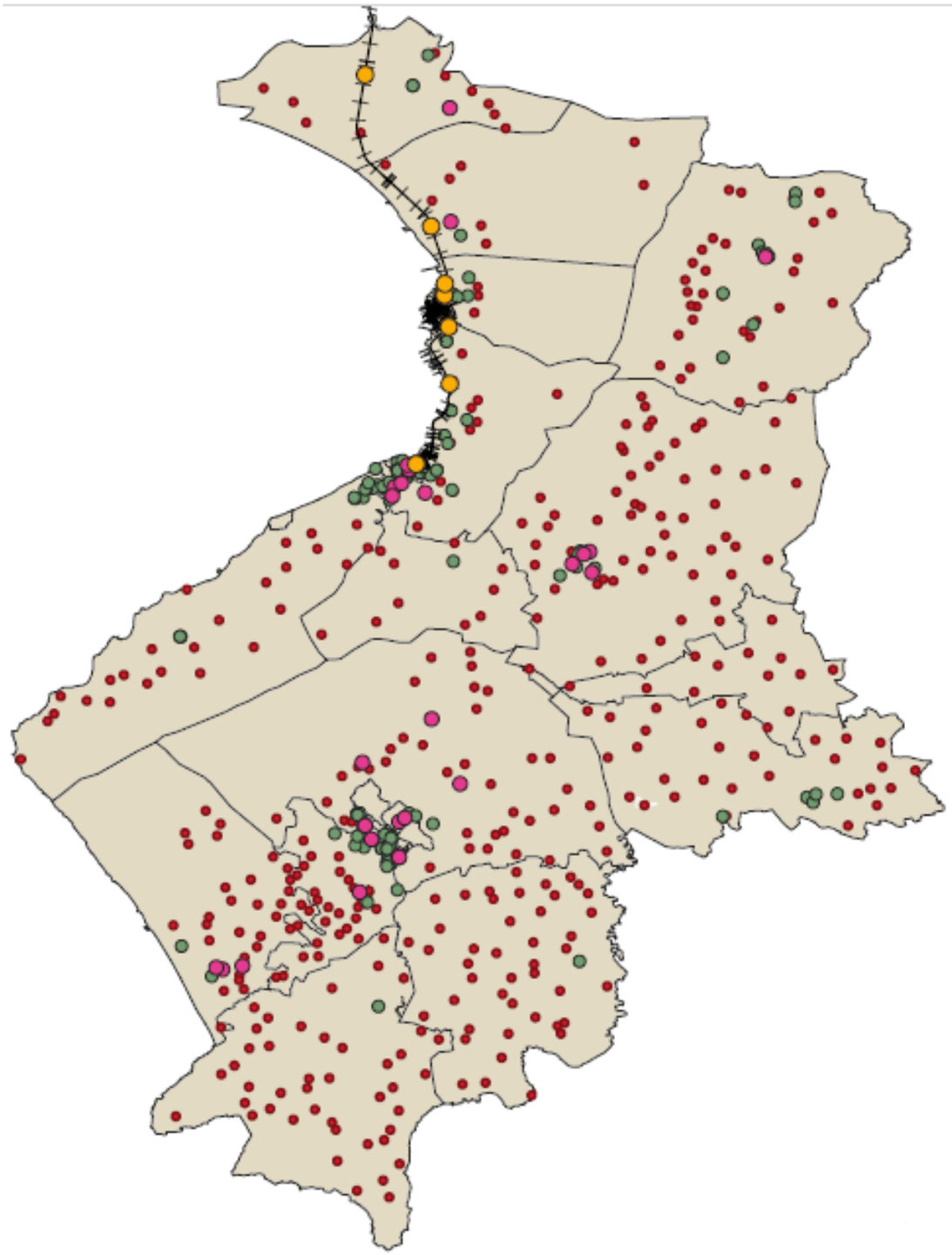
338 Villages
116 Schools

Hospitals
Schools
Population Points (Villages)
District Borders
Districts



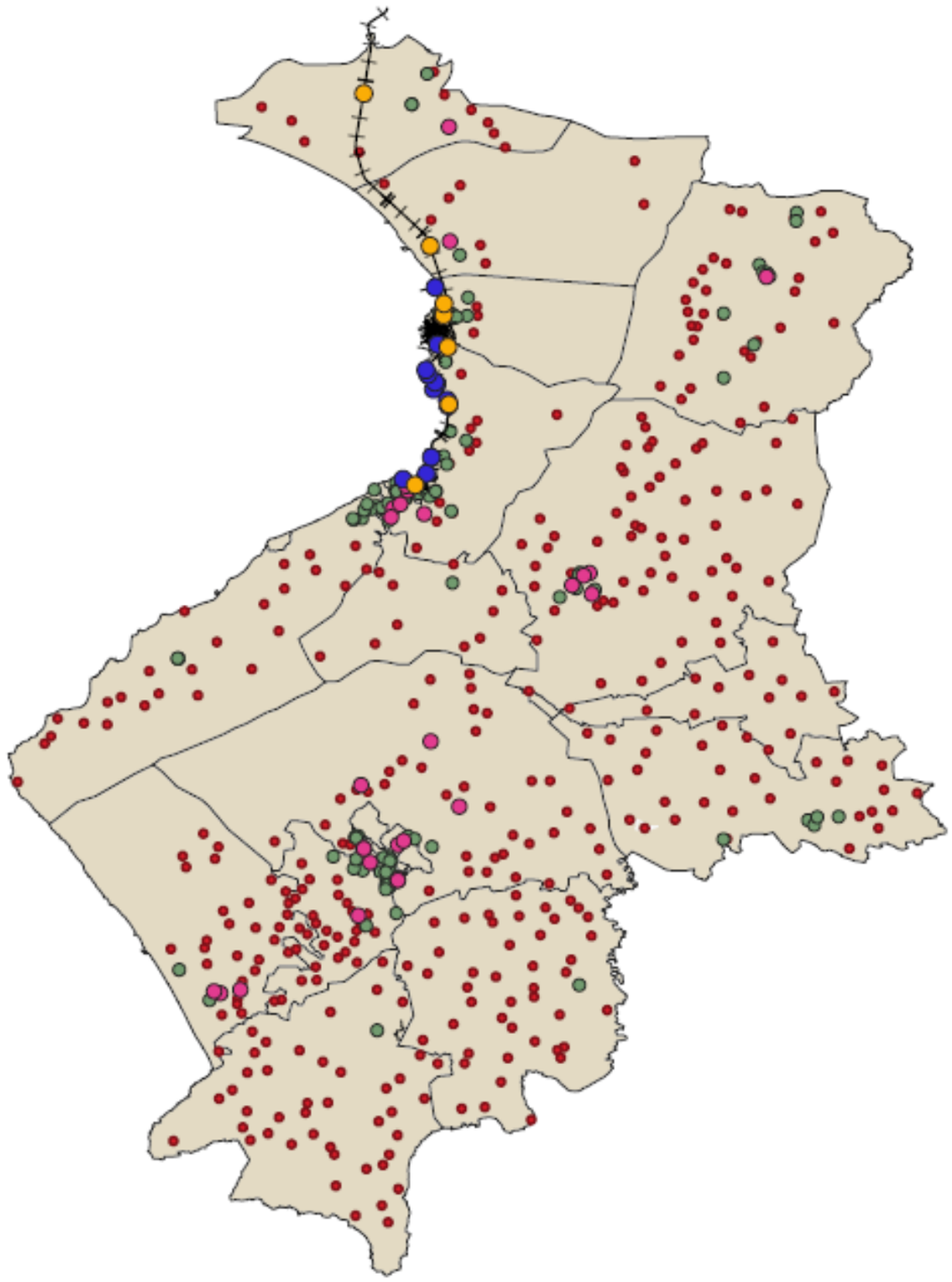
338 Villages
116 Schools
27 Hospitals

Railway Stations
Railways
Hospitals
Schools
Population Points (Villages)
District Borders
Districts



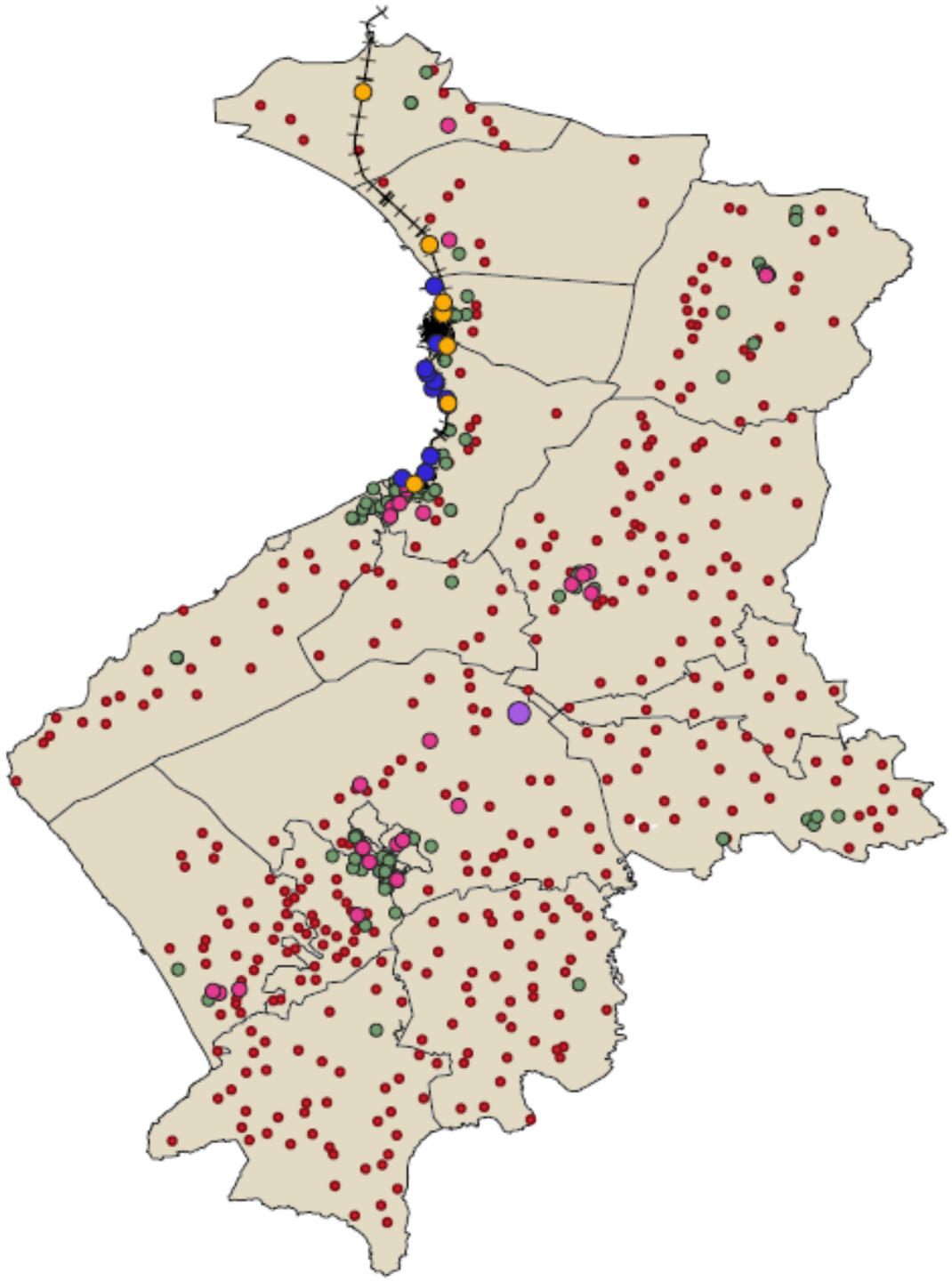
338 Villages
116 Schools
27 Hospitals
7 Railway Stations

Railway Stations
Ports
Railways
Hospitals
Schools
Population Points (Villages)
District Borders
Districts



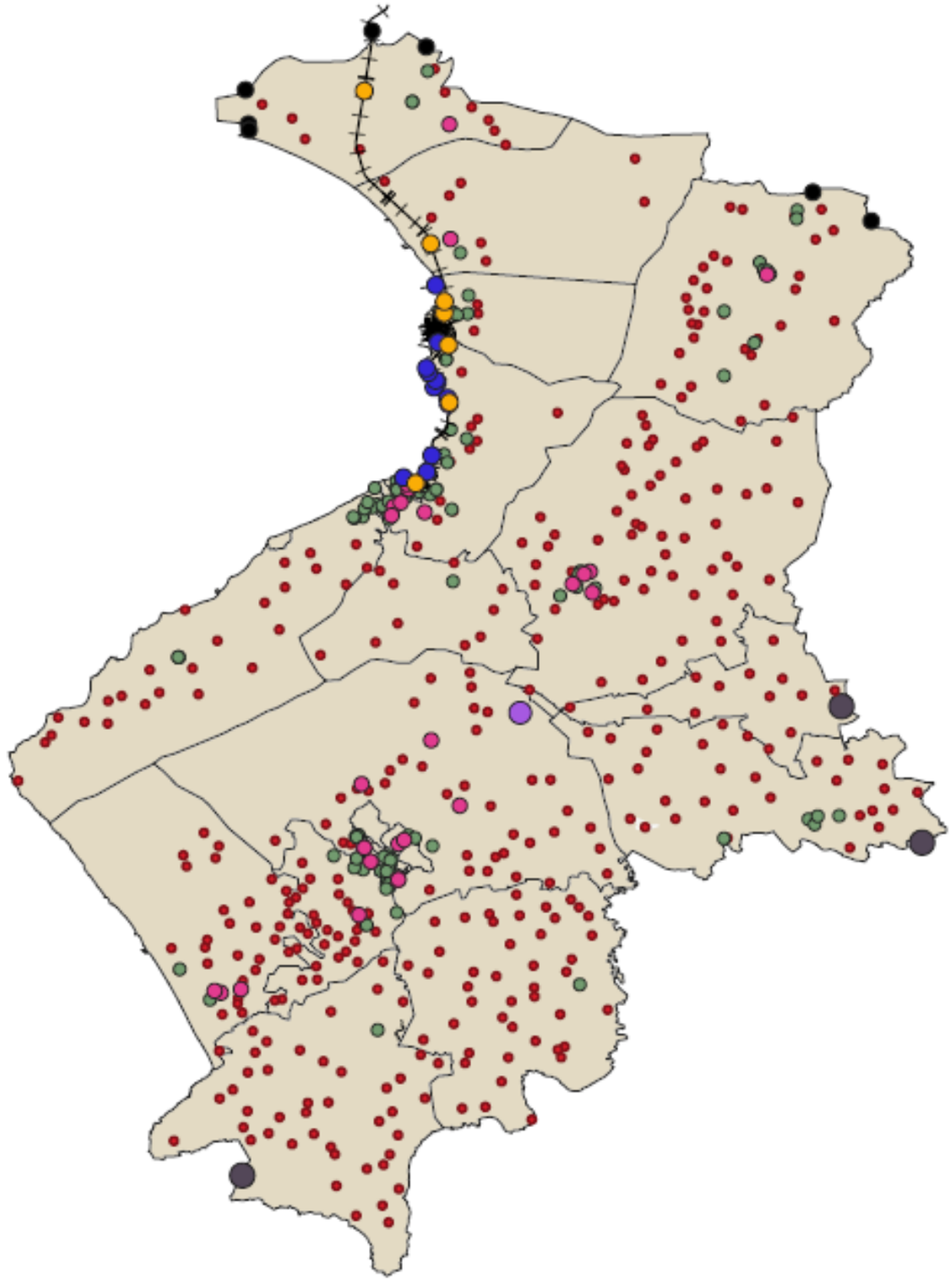
338 Villages
116 Schools
27 Hospitals
7 Railway Stations
12 Ports

Railway Stations
Ports
Railways
Hospitals
Schools
Population Points (Villages)
District Borders
Airport
Districts



338 Population Points
116 Schools
27 Hospitals
7 Railway Stations
12 Ports
1 Airport

- Railway Stations
- Ports
- Railways
- Hospitals
- Schools
- Population Points (Villages)
- Province Border Passing Points
- Border Crossing Point
- District Borders
- Airport
- Districts



338 Population Points

116 Schools

27 Hospitals

7 Railway Stations

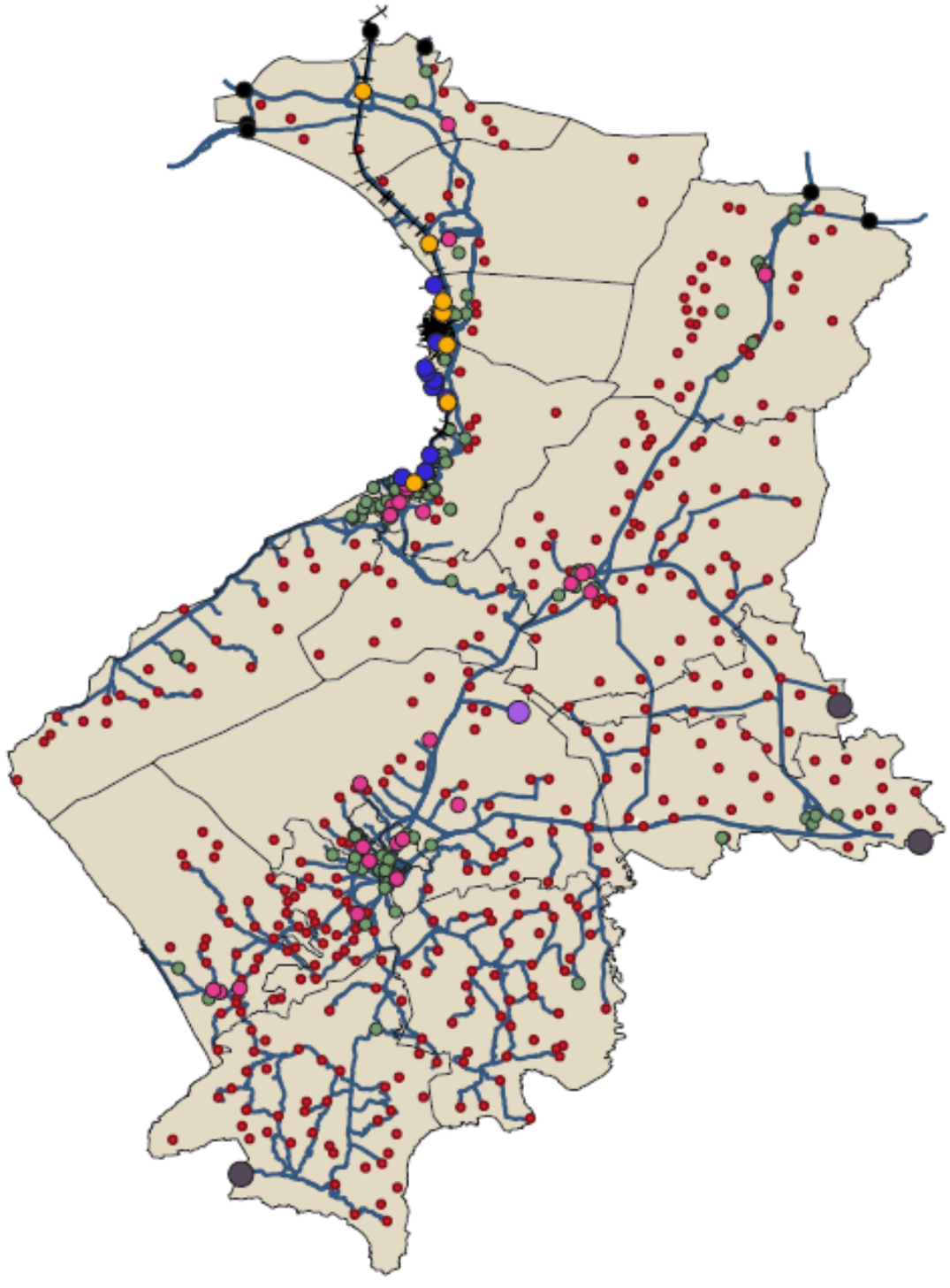
12 Ports

1 Airport

6 Province Border Passing Points

3 Border Crossing Points

- Railway Stations
- Ports
- Railways
- Hospitals
- Schools
- Population Points (Villages)
- Province Border Passing Points
- Border Crossing Point
- District Borders
- Airport
- Highway Network
- Districts



338 Population Points

116 Schools

27 Hospitals

7 Railway Stations

12 Ports

1 Airport

6 Province Border Passing Points

3 Border Crossing Points

Hospitals
Schools
Shelter Areas (Tents)
Population Points (Villages)
Airport
Highway Network
District Borders
Districts

Antakya-Defne

86 Shelter Points
(Tents)

- Hospitals
- Schools
- Shelter Areas (Tents)
- Shelter Areas (Containers)
- Population Points (Villages)
- Airport
- Highway Network
- District Borders
- Districts

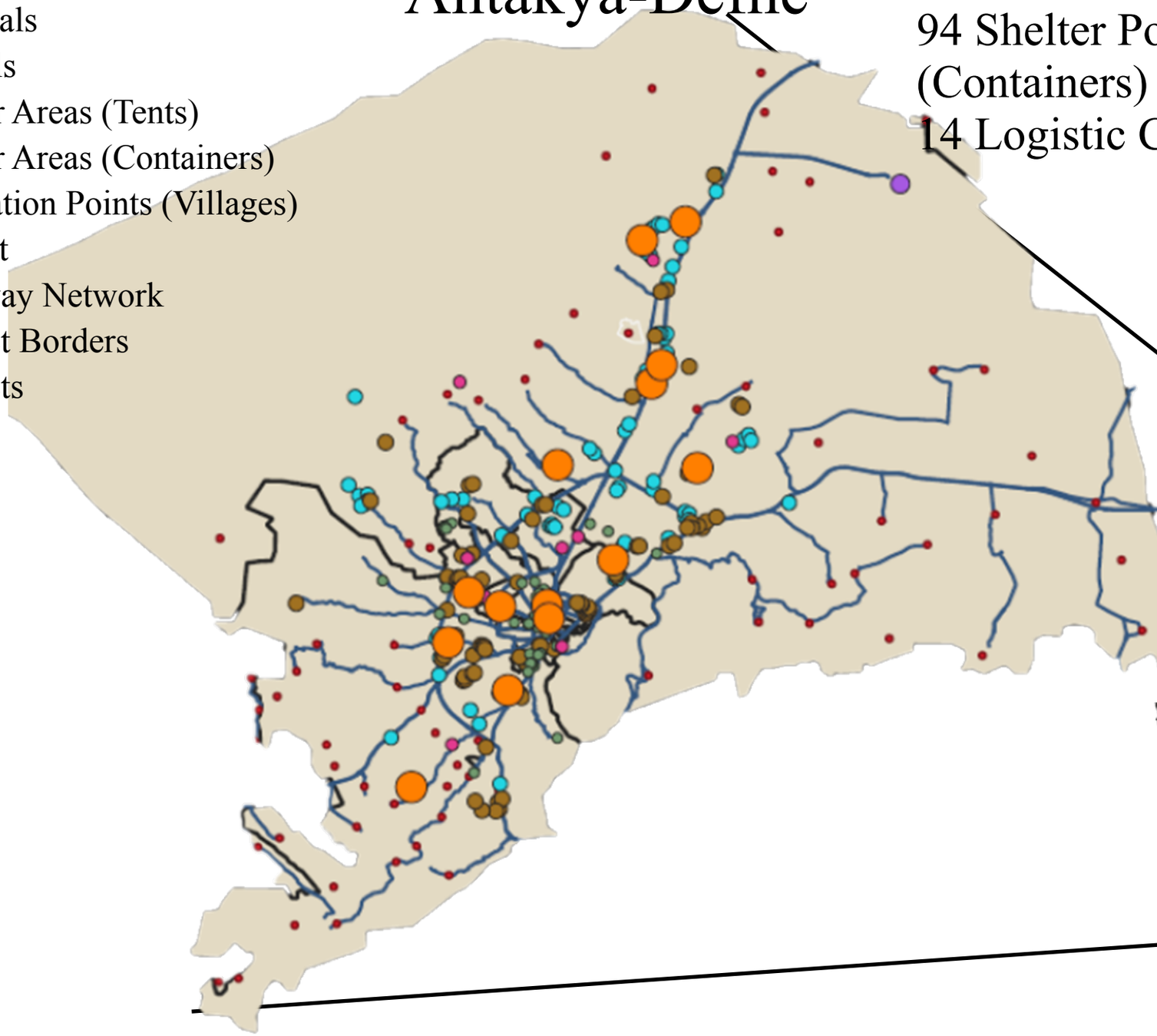
Antakya-Defne

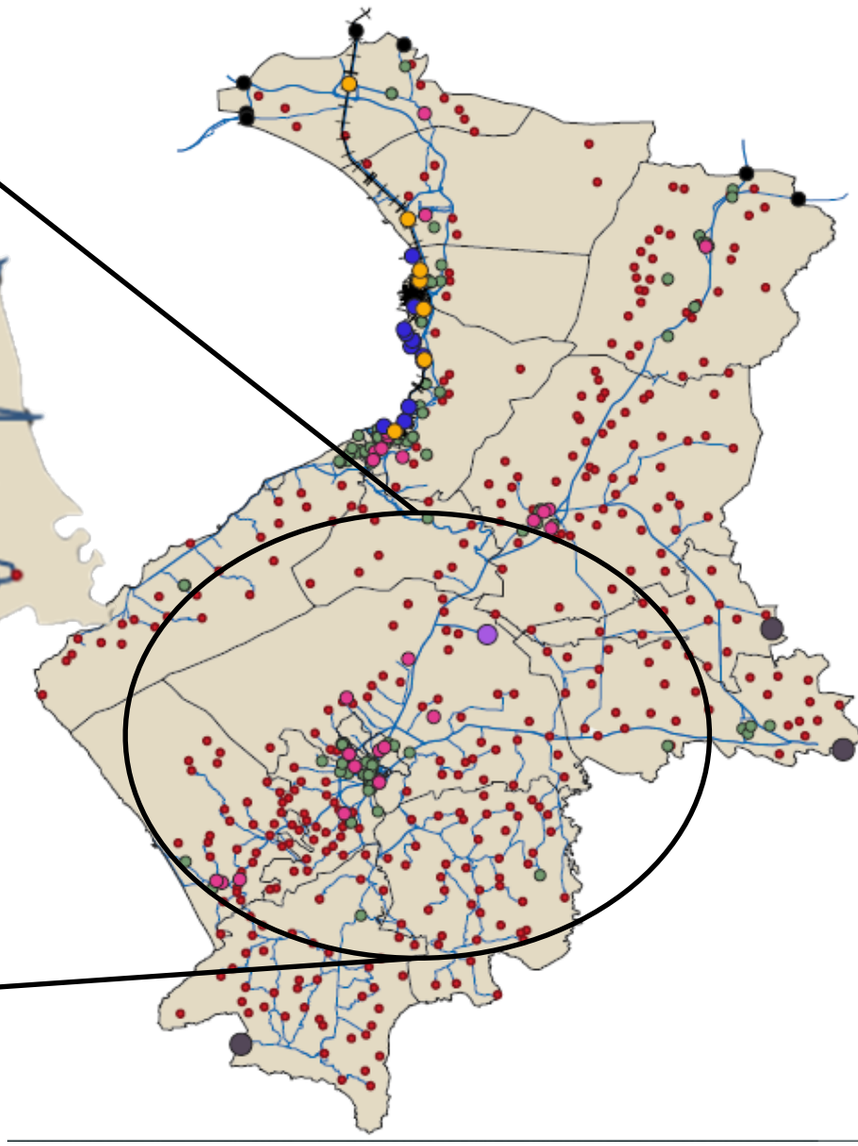
86 Shelter Points (Tents)
94 Shelter Points
(Containers)

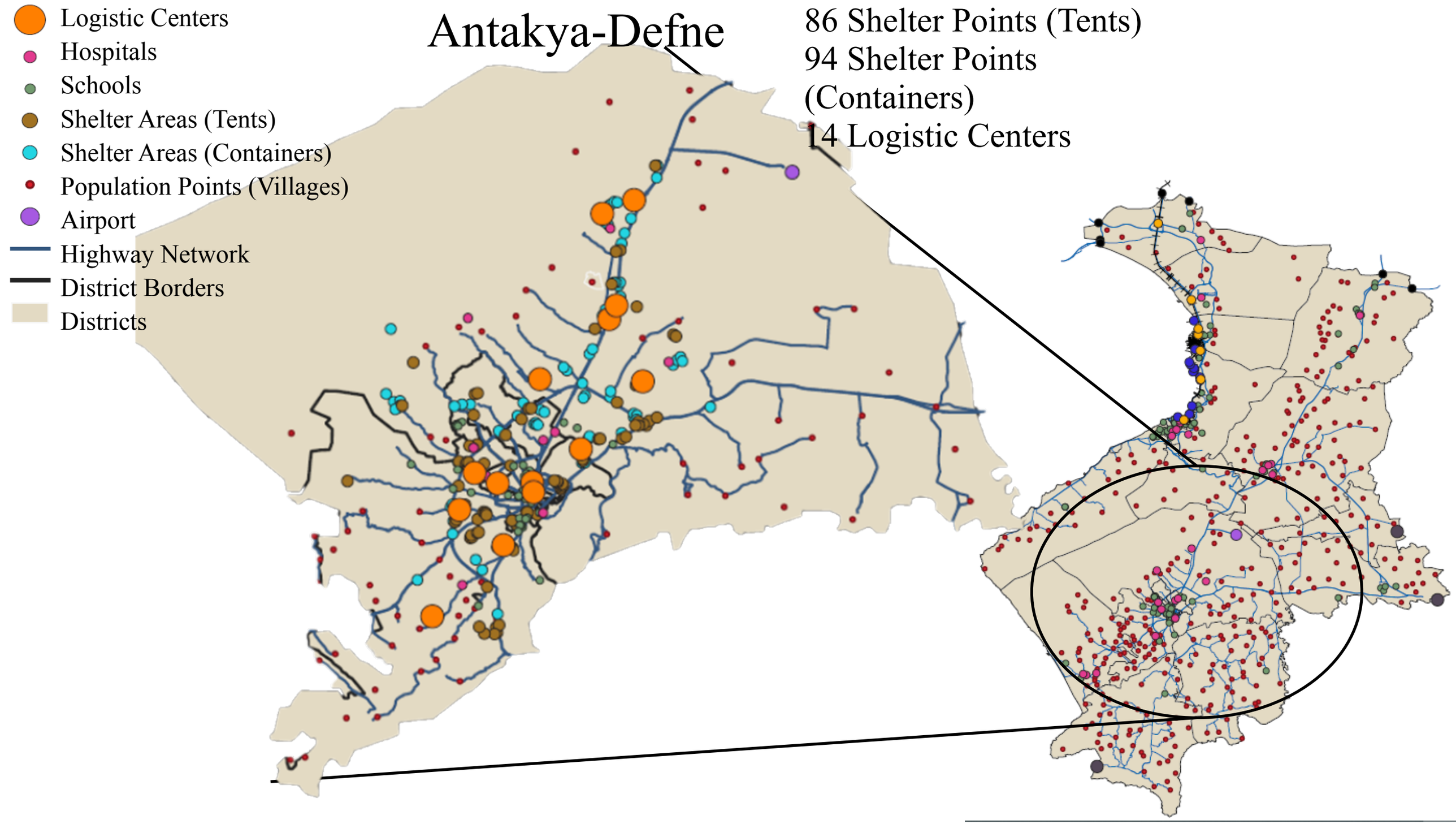
Logistic Centers
Hospitals
Schools
Shelter Areas (Tents)
Shelter Areas (Containers)
Population Points (Villages)
Airport
Highway Network
District Borders
Districts

Antakya-Defne

86 Shelter Points (Tents)
94 Shelter Points (Containers)
14 Logistic Centers



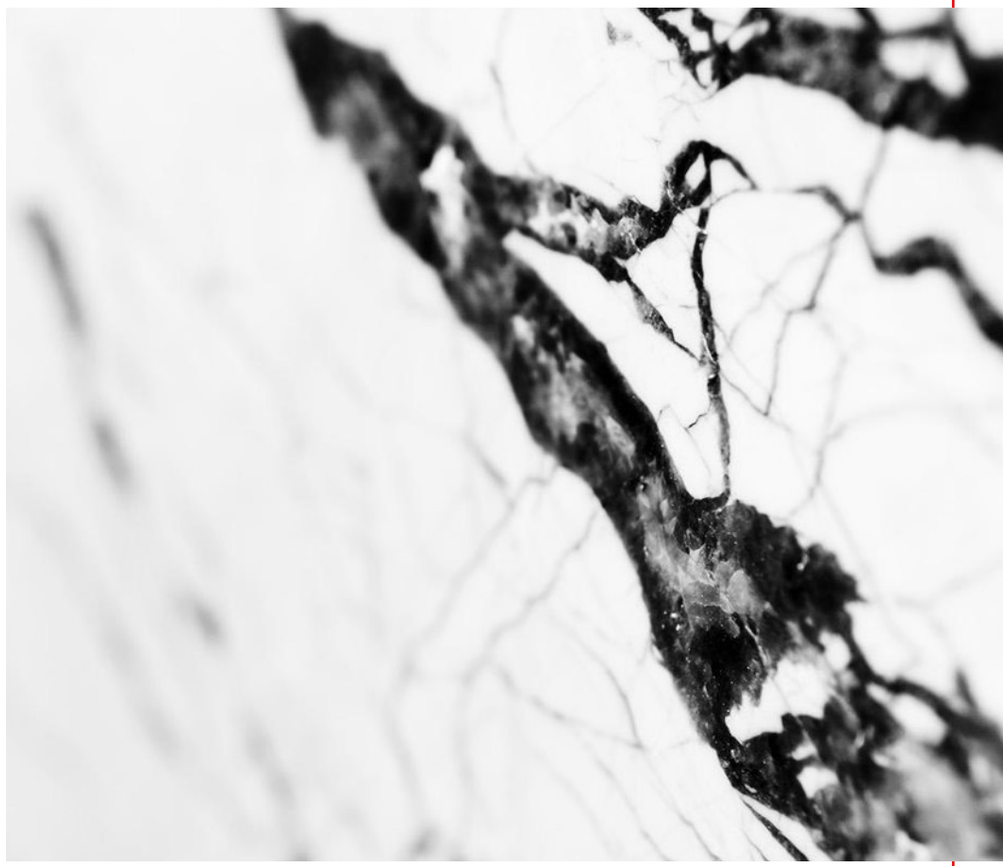




Both data sets will be ready soon:)

Thank you!

bkara@bilkent.edu.tr



Bilkent University Industrial Engineering Department

Table 3: Characteristics of main services during immediate response.

Demand type	Arrival of demand	Frequency of demand	Demand locations
Rescue	Simultaneous, immediately after disaster	One-time for sequential services	Collapsed/heavily damaged structures (hot zones)
Medical care	Staggered, immediately after rescue	One-time for sequential services	Collapsed/heavily damaged structures (warm zones), hospitals
Security	Simultaneous, immediately after disaster	Continuous	Collapsed/heavily damaged structures, hospitals, accommodation points, service points
Critical items/essentials	Staggered, after self rescue/discharge	One-time, periodic, continuous	Accommodation points, service points

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Critical items/essentials	Staggered, after self rescue/discharge	One-time, periodic, continuous	Accommodation points, service points

Table 4: Supply-side uncertainties during immediate disaster response.

Subphases	Contributing factors	
	Resource availability	Network connectivity
Dark period	Post-disaster capacity of critical facilities and local resources	Post-disaster capacity of EARs and transportation hubs
Gray period	Volume and competency level of incoming volunteers, volume/type of incoming donations, availability of equipment	Post-disaster capacity of EARs and transportation hubs, traffic due to incoming unorganized aid
Light gray period	Volume/type of incoming donations	Traffic due to incoming unorganized aid and evacuation of residents