Schooling for Refugee Children

Joint work with

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Refugee Children

How can a host country increase the availability of high-quality education opportunities for refugee children without over-burdening their existing infrastructure?

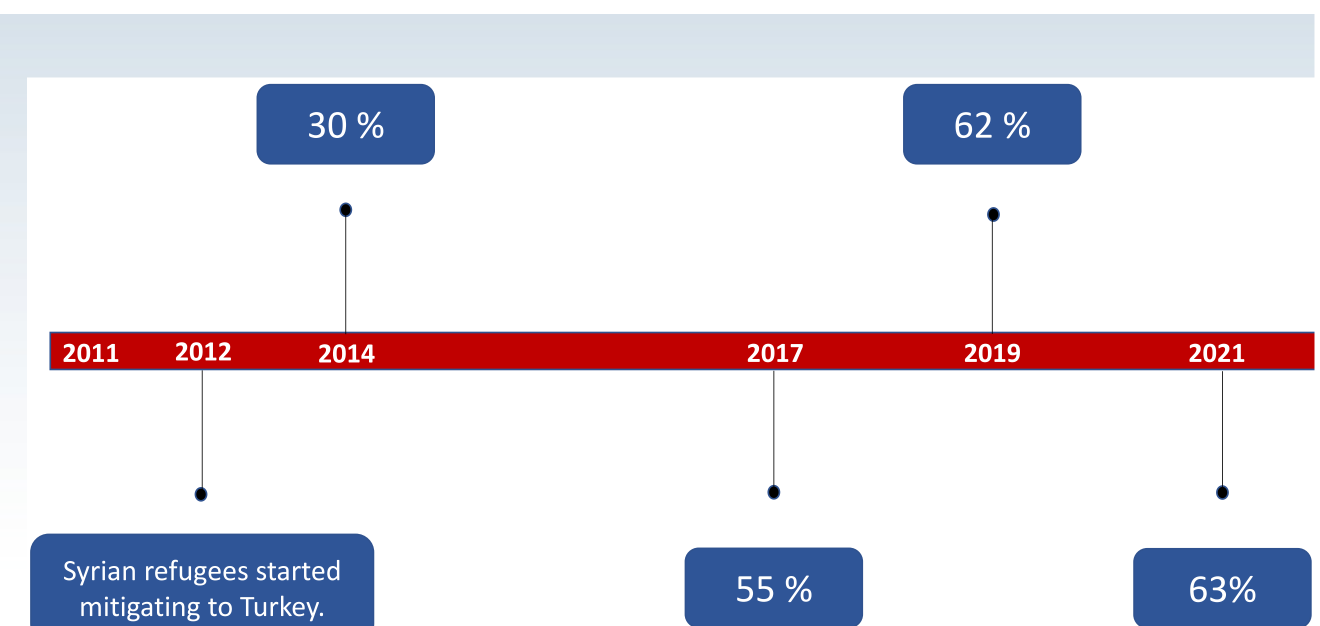
30 million refugees in the world

42% of them are children

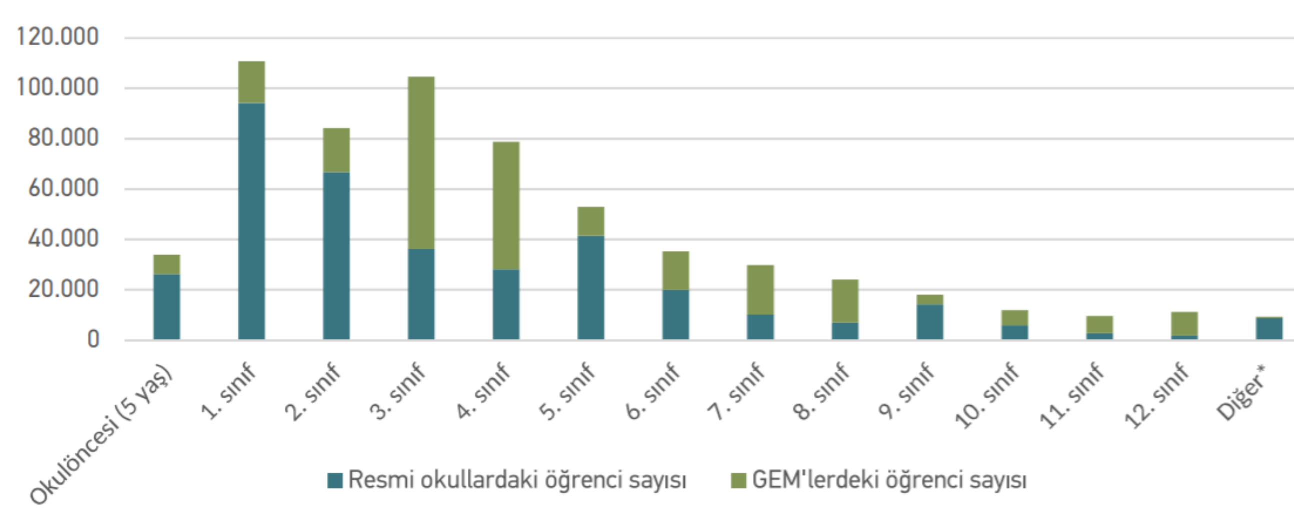
High drop-out rates, child labor, “lost generation”

There are over 1.2 M Syrian children in the compulsory education age (5-18).

There were also 450 thousand Syrian babies born in Turkey in 2019, which indicates a future increase in this number [7].



Grafik 4: Sınıf Düzeylerine Göre Okul Türü Ayrımında Öğrenci Sayıları, Kasım 2017



Kaynak: MEB Hayat Boyu Öğrenme Genel Müdürlüğü Göç ve Acil Durum Eğitim Daire Başkanlığı (2017) kaynağındaki 13.11.2017 tarihli verilerle oluşturuldu. Not: "Diğer" kategorisi, lise hazırlık sınıflarında öğrenim gören 45 öğrenciye ek olarak GEM'lerdeki destekleme ve yetiştirme sınıflarındaki -sırasıyla 497 ve 86- öğrenci sayısını ve açık okullara kayıtlı 8.598 öğrenciyi kapsıyor.

Actions taken by the Turkish Government

Central Schools

Regulations in Turkey give Syrian refugee children the right to enroll in Turkish State schools.

Temporary Education Centers

Temporary education centers (TECs), both inside of the refugee camps and in the parts of the cities where refugees are densely populated, were opened with the purpose of catching Syrian refugees up with Syrian syllabus.

Financial and Psychological Support Programs

- United Nations has funded 10 million for the schooling of Syrian children in Turkey and campaigns have been run to initiate families to send their children to school.
- Teachers who are trained in the language spoken and the socioemotional states of children are assigned to some selected schools.
- PIKTES, a project managed by the Ministry of Education to improve the access of Syrian kids to education has been initiated and applied.

Refugee Children Schooling in Turkey

- The crisis was assumed to be **temporary, for years.**
- Two schooling options supported by the Turkish Ministry of Education.

Central School Registration

- Transition/language requirements
- Lack of capacity
- Bilingual – proper pedagogical training
- Fear of discrimination

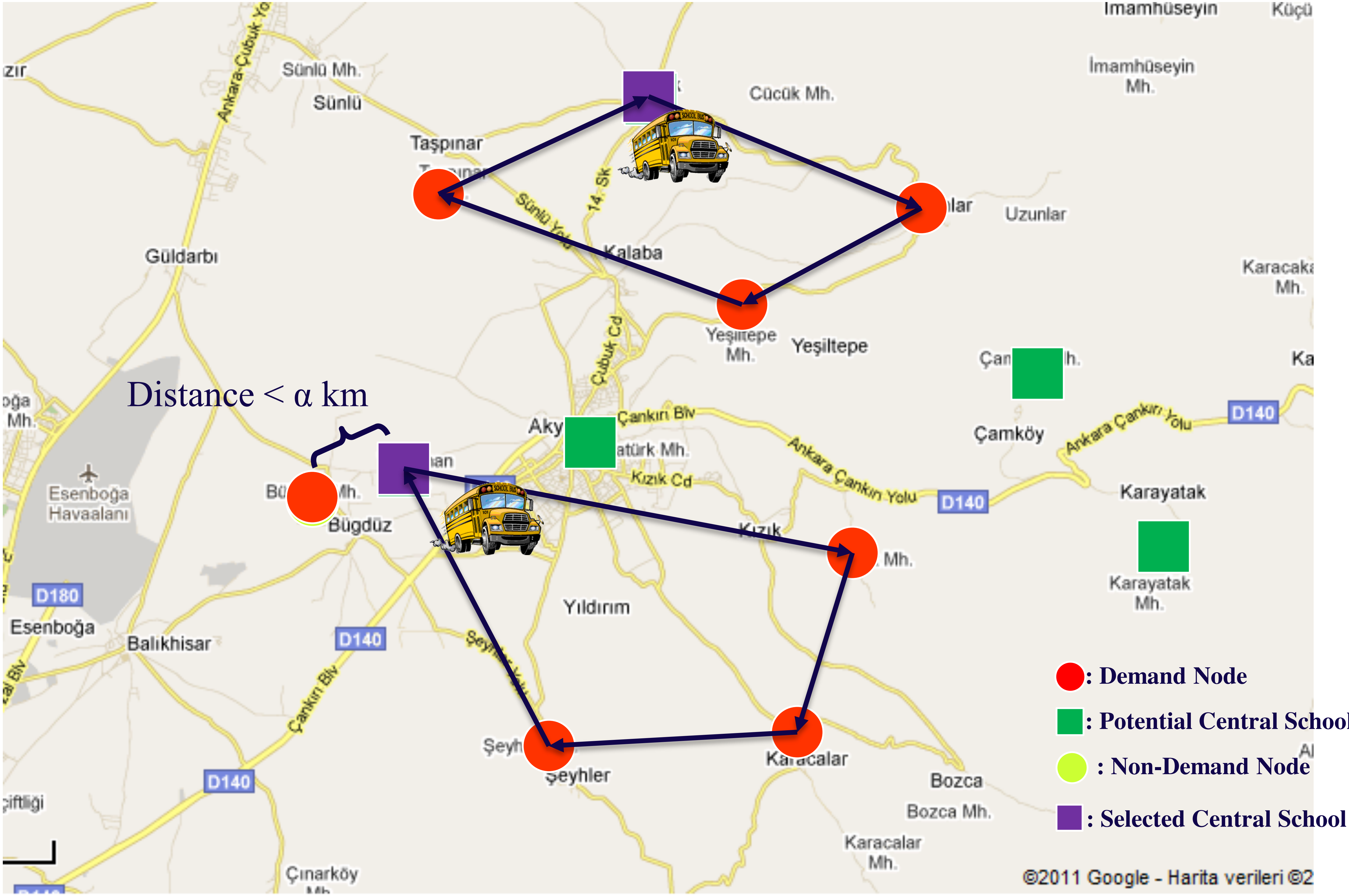
Temporary Education Centers

- Follows the Syrian Syllabi
- Out-of-use buildings
- Rumors of closing since 2016 (Still not closed as of 2022)

Availability ≠ Accessibility

- Field reports and interviews illustrate that ease of transportation is crucial in maintaining children's attendance to education (Coskun, 2016),(Usta, 2018).
- We combine strategic decisions of location and assignment with transportation decisions in order to provide an accessible education system.

Selective Location Routing Problem


Distance < α km
: Demand Node
: Potential Central School
: Non-Demand Node
: Selected Central School
Sünlü Mh.
Sünlü
Taşpınar
Cücük Mh.
İmamhüseyin Mh.
Uzunlar
Güldarbı
Kalaba
Yeşiltepe Mh.
Yeşiltepe
Çamköy
Karayatak
Karayatak Mh.
Buğdüz
Esenboğa Havaalanı
Esenboğa
Balıkhisar
Yıldırım
Şeyhler
Karacalar
Bozca
Bozca Mh.
Karacalar Mh.
Çınarköy
Ankara-Çubuk Yolu
Sünlü Yolu
Çubuk Cd
Çankırı Blv
Kızık Cd
Ankara Çankırı Yolu
D140
D180
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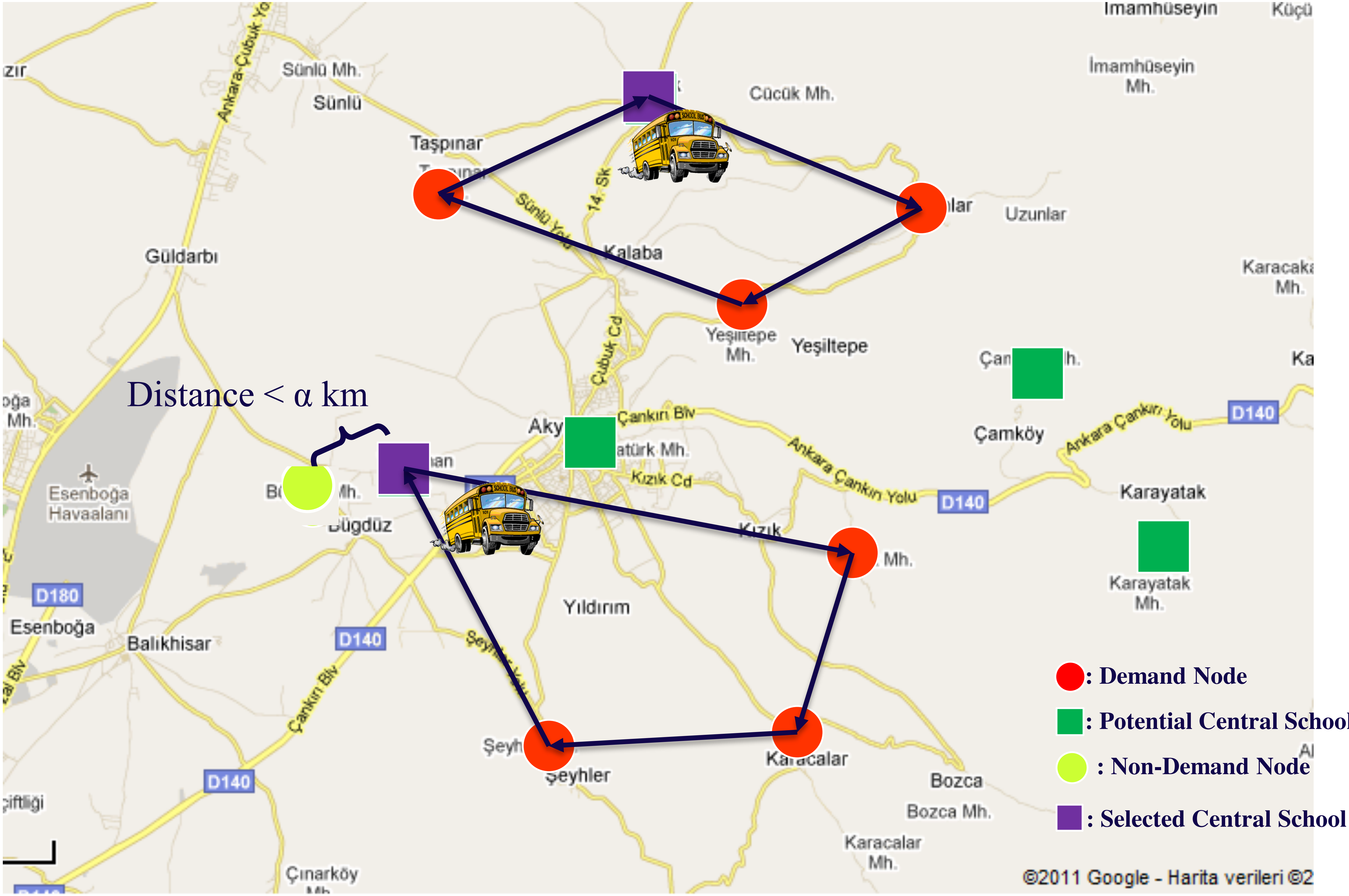
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Sünlü Yolu
Çubuk Cd
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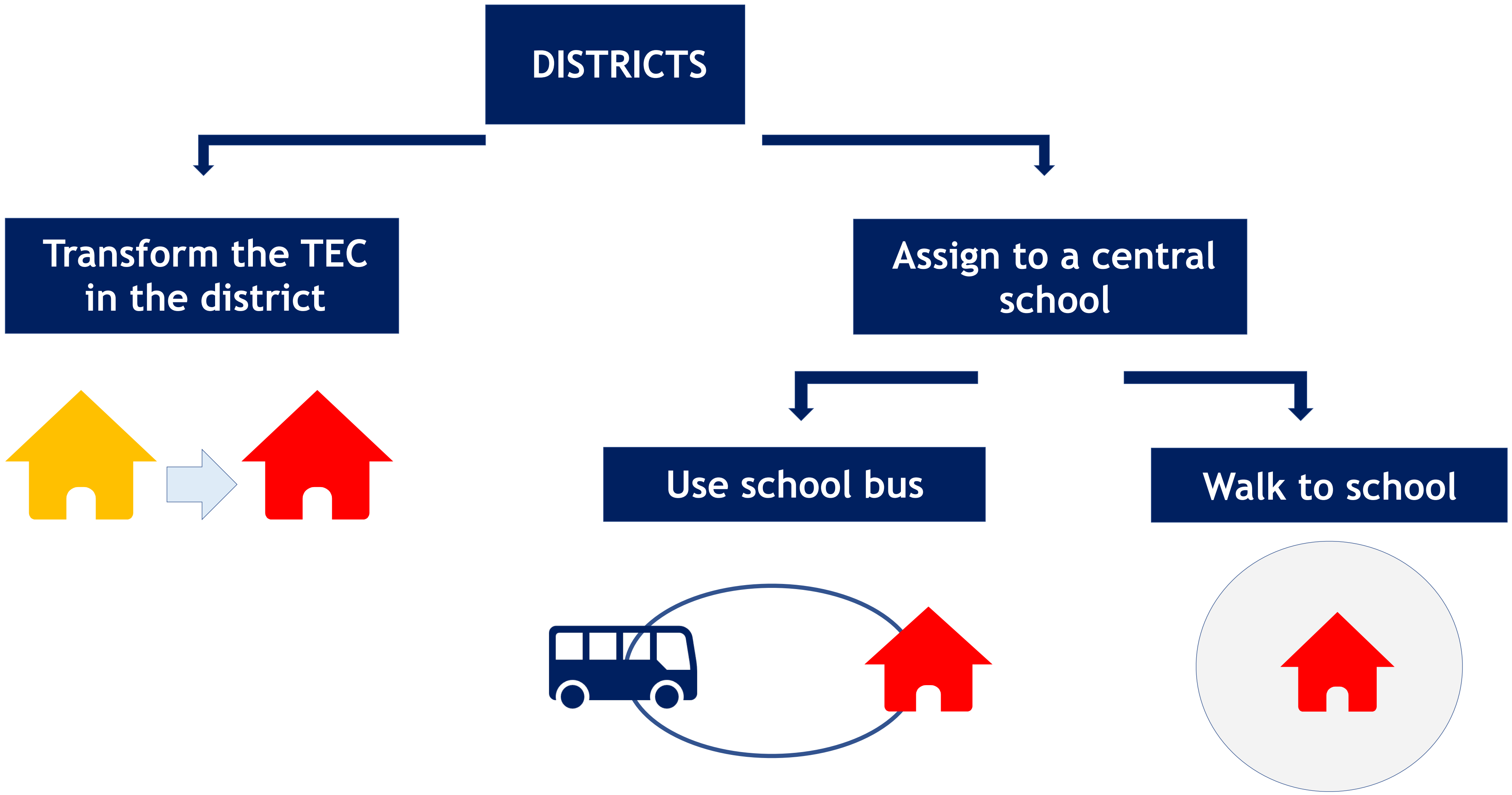
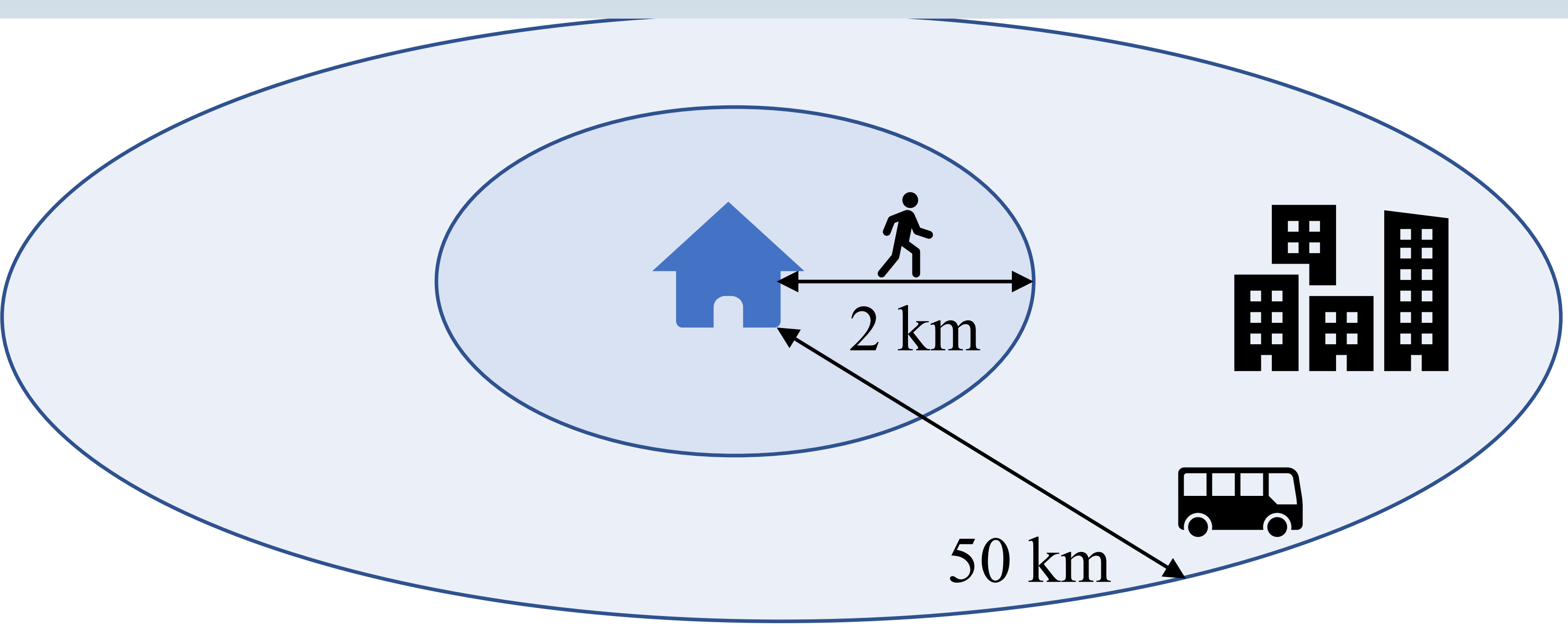
Refugee Children Schooling Definition



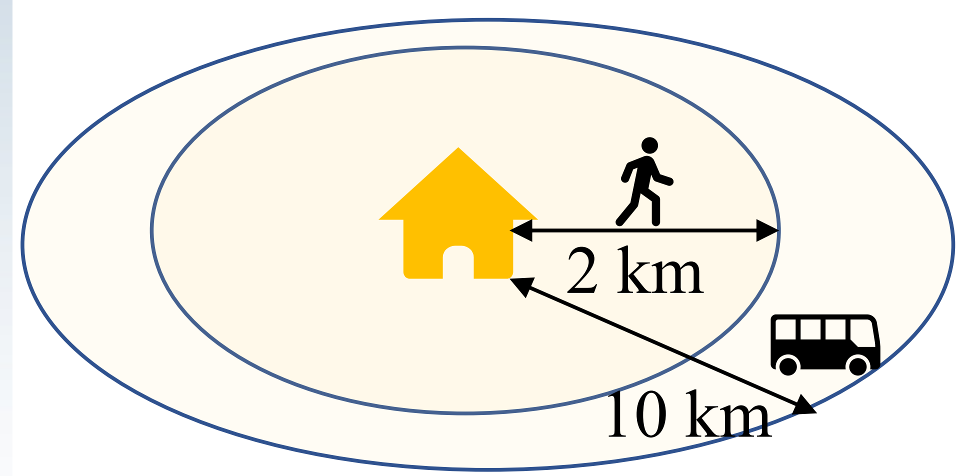
TEC s and Central schools

Opportunities of TECs

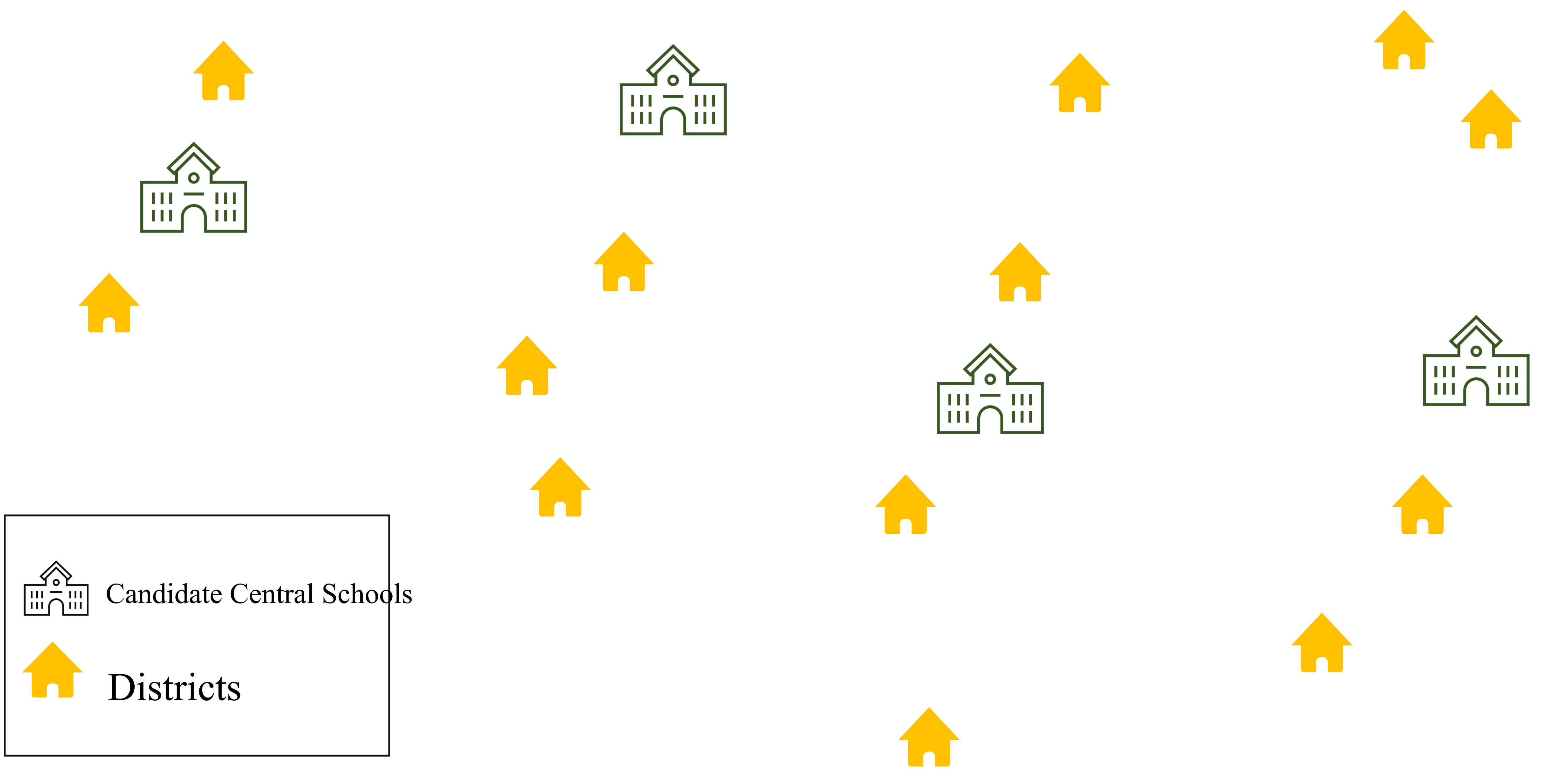
- Locations are initially selected to be close (2km -10km)
- Less worrisome - discrimination/bullying

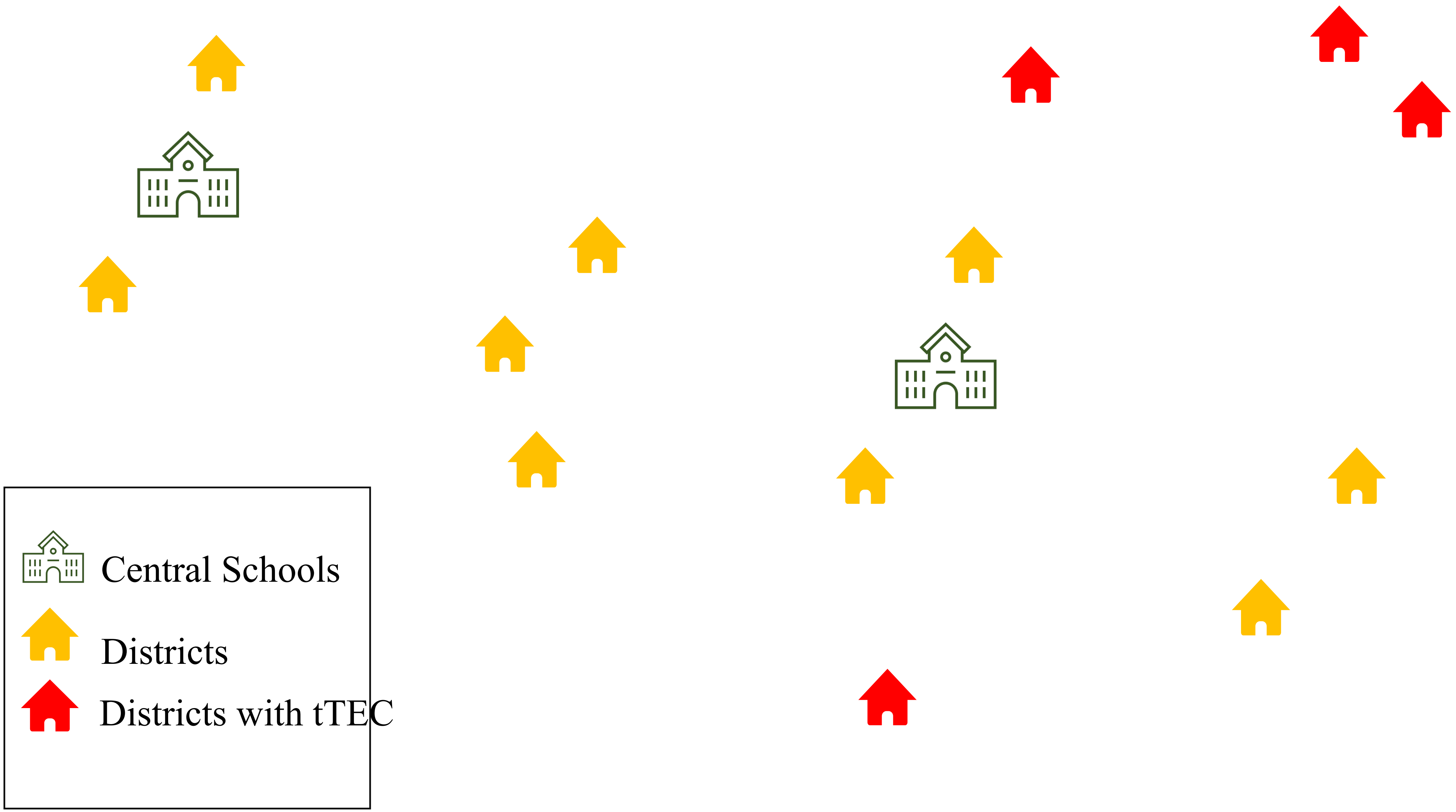


Central School

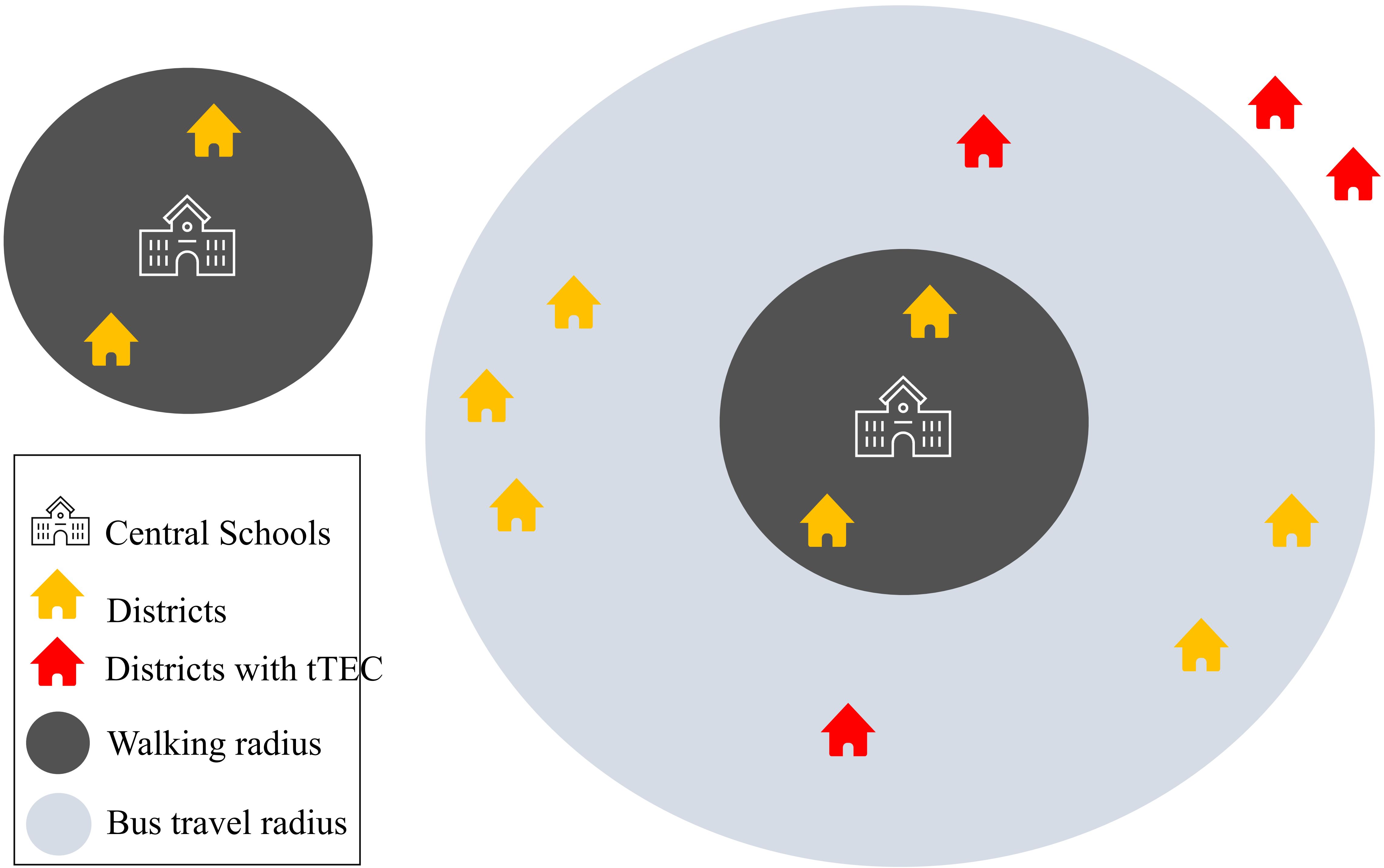


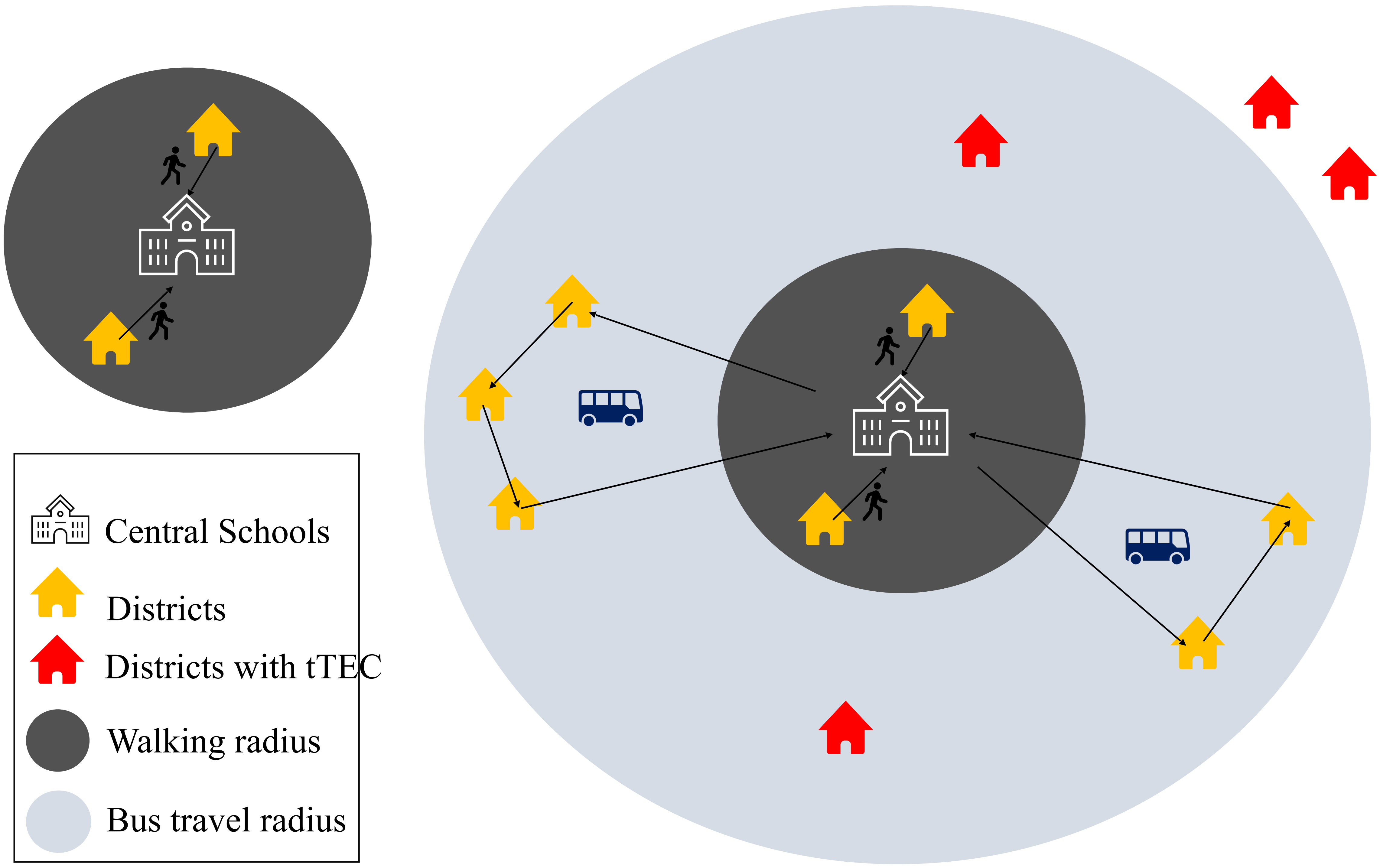
TECs


Candidate Central Schools
Districts



Central Schools
Districts
Districts with tTEC


Central Schools
Districts
Districts with tTEC
Walking radius
Bus travel radius


Central Schools
Districts
Districts with tTEC
Walking radius
Bus travel radius

- Central school locations
- tTEC locations

→ **Strategic Decisions**

- Assignment of districts to central schools
- Transportation mode between districs and central schools

→ **Tactical Decisions**

Schooling assignment problem

- School bus routes

→ **Operational Decisions**

+

Selective Location Routing Problem

A New Selective Location Routing Problem

Location Routing

- Selection of central schools
- Assignment of districts to central schools
- Determination the transportation route
- Selection of TECs to transform

Location decision on the demand nodes

+

Selective Routing

- Students may be walking to school
- The TEC in the district may be transformed

Compulsory Selectiveness

Optional Selectiveness

Create selectiveness for routing

Operational Dynamics

Based on Turkish Government's legislations

- Children closer than 2 kilometers must walk to school.
- Children cannot be transported to a school further than 50 kilometers.
- Transformed TECs serve only the children in that district.

Based operational requirements

- Central schools have capacity limitations.
- School buses have capacity limitations.
- A central school might have zero, one or more incoming school busses.

Parameters

Let:

$\mathcal{G} = (\mathcal{V}, \mathcal{E})$

$\mathcal{V} = \mathcal{D} \cup \mathcal{C}$

$\mathcal{D}$: set of districts

$\mathcal{C}$: set of candidate central schools

$\mathcal{E} = \{\{i, j\} : i, j \in \mathcal{V}\}$

H : upper bound on the number of central schools

K : upper bound on the number of tTECs

L_{ij} : distance between nodes $i \in \mathcal{V}$ and $j \in \mathcal{V}$

γ : allowable walking distance between a district and a central school

θ : allowable bus travel distance between a district and a central school

M : number of school busses available

P_i : population of refugee children in district $i \in \mathcal{D}$

QS : capacity of central schools (number of children)

Q : capacity of school busses (number of children)

$$\gamma_{ij} = \begin{cases} 1, & \text{distance between nodes } i \in \mathcal{D} \text{ and } j \in \mathcal{C} \text{ is less than } \gamma \\ 0, & \text{otherwise} \end{cases}$$

$$s_i = \begin{cases} 1, & \text{if a district is included in the bus route } i \in \mathcal{D} \\ 0, & \text{otherwise} \end{cases}$$

$$f_i = \begin{cases} 1, & \text{if there is a tTEC located in district } i \in \mathcal{D} \\ 0, & \text{otherwise} \end{cases}$$

$$z_j = \begin{cases} 1, & \text{if candidate school } j \in \mathcal{C} \text{ is selected as a central school} \\ 0, & \text{otherwise} \end{cases}$$

$$x_{ijk} = \begin{cases} 1, & \text{if the bus travels from node } i \in \mathcal{V} \text{ to } j \in \mathcal{V} \text{ to reach} \\ & \text{central school } k \in \mathcal{C} \\ 0, & \text{otherwise} \end{cases}$$

3 index formulation with school index to represent assignments

Omitted assignment decision variables and reduced vehicle indices for a tractable formulation

$$n_{ik} = \begin{cases} 1, & \text{if children in district } i \in \mathcal{D} \text{ walk to central school } k \in \mathcal{C} \\ 0, & \text{otherwise} \end{cases}$$

$$y_{ijk} = \text{the load of school bus when it travels from node } i \in \mathcal{V} \text{ to } j \in \mathcal{V} \text{ to reach central school } k \in \mathcal{C}$$

Flow based formulation

$$\min \sum_{i \in \mathcal{V}} \sum_{i \in \mathcal{V}} \sum_{k \in \mathcal{C}} L_{ij} \cdot y_{ijk}$$

Minimize the weighted distance travelled by school busses

$$\text{s.t.} \quad \sum_{j \in \mathcal{V}} \sum_{k \in \mathcal{C}} x_{ijk} = s_i \qquad \forall i \in \mathcal{D}$$

$$\sum_{j \in \mathcal{V}} \sum_{k \in \mathcal{C}} x_{jik} = s_i \qquad \forall i \in \mathcal{D}$$

$$\sum_{i \in \mathcal{V}} x_{ijk} = \sum_{r \in \mathcal{V}} x_{jrk} \qquad \forall k \in \mathcal{C}, \forall j \in \mathcal{V}$$

Routing constraints

$$s_i + f_i + \sum_{k \in \mathcal{C}} n_{ik} = 1 \qquad \forall i \in \mathcal{D}$$

Assign every district to a schooling option

$$1 - \gamma_{ik} \cdot z_k \geq s_i + f_i \qquad \forall i \in \mathcal{D}, \forall k \in \mathcal{C}$$

Compulsory selectiveness: children in the walkin
distance must walk to school

$$\gamma_{ik} \cdot z_k \geq n_{ik} \qquad \forall i \in \mathcal{D}, \forall k \in \mathcal{C}$$

Allowable walking distance

$$\sum_{i\in\mathcal{V}}\sum_{j\in\mathcal{C}}\sum_{k\in\mathcal{C}} x_{ijk} \le M$$

$$\sum_{k\in\mathcal{C}} z_k \le H$$

$$\sum_{i\in D} f_i \le K$$

Budget Constraints

- School busses
- Central Schools
- Transformed TECs

$$x_{ijk} \le z_k \qquad \forall i,j \in \mathcal{V}, \forall k \in \mathcal{C}$$

Flow only into central schools

$$x_{ijk} = 0 \qquad \forall j,k \in \mathcal{C}, \forall i \in \mathcal{D}, j \neq k$$

If the flow is not directed towards a central school, it cannot enter it

$$y_{ijk} \ge x_{ijk} \qquad \forall i,j \in \mathcal{V}, \forall k \in \mathcal{C}$$

$$y_{kik} = x_{kik} \qquad \forall k \in \mathcal{C}, i \in \mathcal{D}$$

$$\sum_{j\in\mathcal{V}} y_{ijk} = \sum_{r\in\mathcal{V}} y_{rik} + \sum_{j\in\mathcal{V}} P_i \cdot x_{ijk} \qquad \forall i \in \mathcal{D}, \forall k \in \mathcal{C}$$

Flow Constraints

- Only on used edges
- Initialization
- Flow balance

$$x_{ijk} \cdot L_{ik} \leq \theta \qquad \forall i \in \mathcal{D}, j \in \mathcal{V}, \forall k \in \mathcal{C}$$

Allowable bus travel distance

$$y_{ijk} - x_{ijk} \leq Q \cdot x_{ijk} \qquad \forall i, j \in \mathcal{V}, \forall k \in \mathcal{C}$$

$$\sum_{i \in \mathcal{D}} (y_{ikk} - x_{ikk}) + \sum_{i \in \mathcal{D}} P_i \cdot n_{ik} \leq QS \qquad \forall k \in \mathcal{C}$$

Capacity Constraints

School busses

Central Schools

$$z_k + \sum_{j: L_{ij} > L_{ik}} n_{ij} \leq 1 \qquad \forall i \in \mathcal{D}, \forall k \in \mathcal{C}$$

Nearest assignment constraints for walking

For improved accesibility

$$y_{ijk} \in \mathbb{Z}^+ \qquad \forall i, j \in \mathcal{V}, k \in \mathcal{C}$$

$$x_{ijk} \in \{0, 1\} \qquad \forall i, j \in \mathcal{V}, k \in \mathcal{C}$$

$$n_{ik} \in \{0, 1\} \qquad \forall i \in \mathcal{D}, k \in \mathcal{C}$$

$$z_k \in \{0, 1\} \qquad \forall k \in \mathcal{C}$$

$$f_i, s_i \in \{0, 1\} \qquad \forall i \in \mathcal{D}$$

Shortcomings of SLRP:

Infeasibilities in further scarcity of resources **+** Not tractable for tight instances

↓

A maximum covering model: Maximum Covering SLRP (MC-SLRP)

$$\max \quad \sum_{i\in\mathcal{D}}\sum_{j\in\mathcal{V}}\sum_{k\in\mathcal{C}} P_i \cdot x_{ijk} + \sum_{i\in\mathcal{D}}\sum_{j\in\mathcal{C}} P_i \cdot n_{ij} + \sum_{i\in\mathcal{D}} P_i \cdot f_i \qquad (5.25)$$

$$\text{s.t.} \quad (5.2) - (5.4),\ (5.6) - (5.24)$$

$$s_i + f_i + \sum_{j\in\mathcal{C}} n_{ij} \leq 1 \qquad \forall i \in \mathcal{D} \qquad (5.5^*)$$

$$\min \sum_{i\in\mathcal{V}}\sum_{i\in\mathcal{V}}\sum_{k\in\mathcal{C}} L_{ij}\cdot y_{ijk}$$

Minimize the weighted distance travelled by school busses

$$\text{s.t.} \quad \sum_{j\in\mathcal{V}}\sum_{k\in\mathcal{C}} x_{ijk} = s_i \qquad \forall i \in \mathcal{D}$$

$$\sum_{j\in\mathcal{V}}\sum_{k\in\mathcal{C}} x_{jik} = s_i \qquad \forall i \in \mathcal{D}$$

$$\sum_{i\in\mathcal{V}} x_{ijk} = \sum_{r\in\mathcal{V}} x_{jrk} \qquad \forall k \in \mathcal{C}, \forall j \in \mathcal{V}$$

Routing constraints

$$s_i + f_i + \sum_{k\in\mathcal{C}} n_{ik} = 1 \qquad \forall i \in \mathcal{D}$$

Assign every district to a schooling option

$$1 - \gamma_{ik}\cdot z_k \geq s_i + f_i \qquad \forall i \in \mathcal{D}, \forall k \in \mathcal{C}$$

Compulsory selectiveness: children in the walkin
distance must walk to school

$$\gamma_{ik}\cdot z_k \geq n_{ik} \qquad \forall i \in \mathcal{D}, \forall k \in \mathcal{C}$$

Allowable walking distance

$$\min \sum_{i \in \mathcal{V}} \sum_{i \in \mathcal{V}} \sum_{k \in \mathcal{C}} L_{ij} \cdot y_{ijk} \qquad \max \sum_{i \in \mathcal{D}} \sum_{j \in \mathcal{V}} \sum_{k \in \mathcal{C}} P_i \cdot x_{ijk} + \sum_{i \in \mathcal{D}} \sum_{j \in \mathcal{C}} P_i \cdot n_{ij} + \sum_{i \in \mathcal{D}} P_i \cdot f_i$$

s.t.

$$\sum_{j \in \mathcal{V}} \sum_{k \in \mathcal{C}} x_{ijk} = s_i \qquad \forall i \in \mathcal{D}$$

$$\sum_{j \in \mathcal{V}} \sum_{k \in \mathcal{C}} x_{jik} = s_i \qquad \forall i \in \mathcal{D}$$

$$\sum_{i \in \mathcal{V}} x_{ijk} = \sum_{r \in \mathcal{V}} x_{jrk} \qquad \forall k \in \mathcal{C}, \forall j \in \mathcal{V}$$

Routing constraints

$$s_i + f_i + \sum_{k \in \mathcal{C}} n_{ik} = 1 \qquad s_i + f_i + \sum_{j \in \mathcal{C}} n_{ij} \leq 1$$

Assign every district to a schooling option

$$1 - \gamma_{ik} \cdot z_k \geq s_i + f_i \qquad \forall i \in \mathcal{D}, \forall k \in \mathcal{C}$$

Compulsory selectiveness: children in the walkin
distance must walk to school

$$\gamma_{ik} \cdot z_k \geq n_{ik} \qquad \forall i \in \mathcal{D}, \forall k \in \mathcal{C}$$

Allowable walking distance

Data

Kilis: The most refugee-dense province of the Turkey: 47% of Kilis population is Syrian Refugees

Data

Real locations of high schools in Kilis

Candidate Central Schools

15

Real locations of villages and refugee camps in Kilis

Refugee Districts

42

Randomly generated population

Children population in each district

462

Performances of SLRP and MC-SLRP

Central Schools	tTECs	Bus Travel Distance (km)		Expected Attendance		Solution Time (secs)	
		SLRP	MC-SLRP	SLRP	MC-SLRP	SLRP	MC-SLRP
7	10	210.5	752.2	76%	63%	36.1	15.8
7	7	239.5	879.5	81%	52%	36.0	23.0
7	5	265.7	1096.9	79%	49%	110.2	19.3
6	10	220.6	752.2	82%	63%	28.0	16.9
6	7	239.9	879.5	80%	52%	44.8	23.9
6	5	279.3	1021.5	78%	51%	184.2	20.7
5	10	224.5	752.2	82%	63%	38.7	18.2
5	7	267.6	977.7	79%	52%	289.7	41.4
5	5	303.3	1091.3	77%	47%	1099.9	19.7
4	10	266.8	752.2	82%	63%	161.0	16.9
4	7	288.0	1115.1	80%	53%	1180.4	37.4

Performances of SLRP and MC-SLRP

Central Schools	tTECs	Solution Time (mins)		Gap	
		SLRP	MC-SLRP	SLRP	MC-SLRP
4	5	180	0.32	no integer solution found	0%
4	3	180	2.78	no integer solution found	0%
3	10	180	0.29	6.63%	0%
3	7	3.12	93.54	infeasible	0%
3	5	1.27	35.29	infeasible	0%
3	3	1.51	27.99	infeasible	0%
2	5	0.86	180	infeasible	0.68%
1	5	0.33	1.15	infeasible	0%

Differences of solution times increase even more when these bounds are tighter. For majority of the instances, CLPEX cannot find an optimal solution for SLRP.

Performances of SLRP and MC-SLRP

Central Schools	tTECs	Bus Travel Distance (km)		Expected Attendance		Solution Time (secs)	
		SLRP	MC-SLRP	SLRP	MC-SLRP	SLRP	MC-SLRP
7	10	210.5	752.2	76%	63%	36.1	15.8
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4	7	288.0	1115.1	80%	53%	1180.4	37.4

Expected attendance rates considers the distance between each district and its assigned school.

Expected attendance diminishes with increasing distance

Attendance-based SLRP (A-SLRP)

How to incorporate "attendance" behavior into SLRP

A model that considers attendance rates of children with respect to distance:

Attendance-based SLRP (A-SLRP)

$$\max \sum_{i\in\mathcal{D}}\sum_{j\in\mathcal{V}}\sum_{k\in\mathcal{C}} P_i \cdot x_{ijk} + \sum_{i\in\mathcal{D}}\sum_{j\in\mathcal{C}} P_i \cdot n_{ij} + \sum_{i\in\mathcal{D}} P_i \cdot f_i$$

$$\max \sum_{i\in\mathcal{D}}\sum_{j\in\mathcal{V}}\sum_{k\in\mathcal{C}} \phi^b_{ik} \cdot P_i \cdot x_{ijk} + \sum_{i\in\mathcal{D}}\sum_{j\in\mathcal{C}} \phi^w_{ik} \cdot P_i \cdot n_{ik} + \sum_{i\in\mathcal{D}} P_i \cdot f_i \qquad (5.26)$$

Subject to max cover model constraints

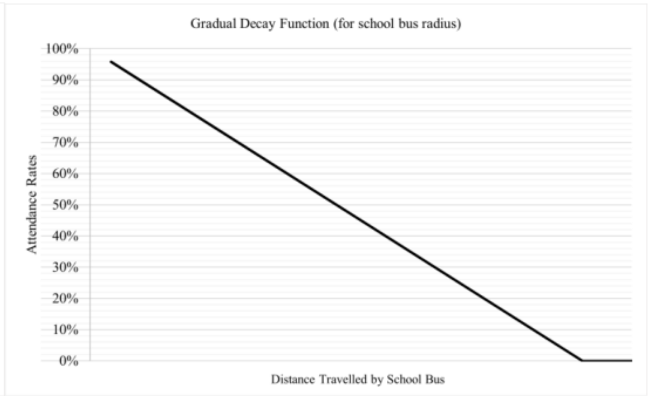
Attendance-based SLRP (A-SLRP)

Gradual Decay Functions: to represent children's behaviour of attending their assigned schools

Uniform Decay:

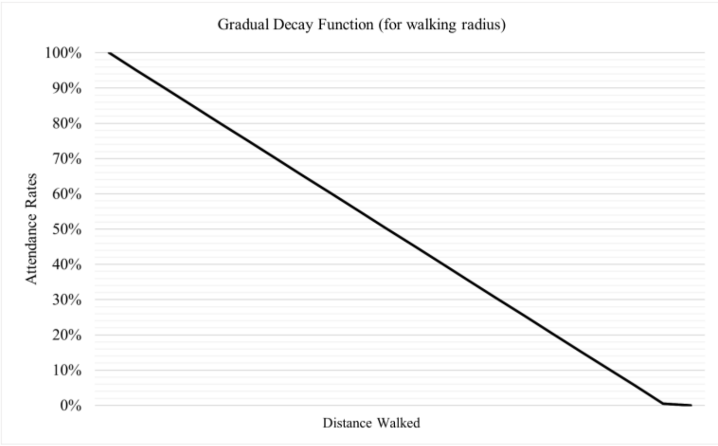
ϕ^{w}_{ik}:Attendance rates of children in district $i \in \mathcal{D}$ when they walk to school $k \in \mathcal{C}$

$$\phi^{w}_{ik} = \begin{cases} 1, & L_{ik} = 0 \\ (\gamma - L_{ik})/(\gamma), & 0 < L_{ik} \leq \gamma \\ 0, & \gamma < L_{ik} \end{cases}$$



ϕ^{b}_{ik}:Attendance rates of children in district $i \in \mathcal{D}$ when they take the school bus to school $k \in \mathcal{C}$

$$\phi^{b}_{ik} = \begin{cases} 1, & L_{ik} = 0 \\ (\theta - L_{ik})/(\theta - \gamma), & \gamma < L_{ik} \leq \theta \\ 0, & \theta < L_{ik} \end{cases}$$



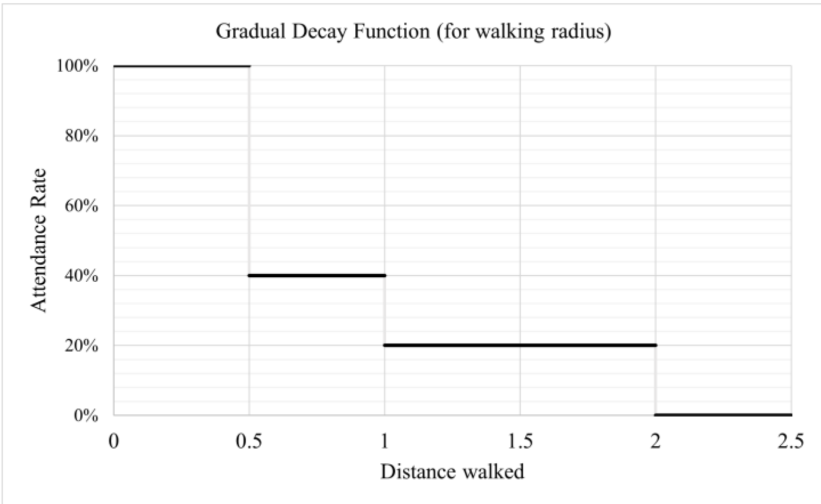
Attendance-based SLRP (A-SLRP)

Gradual Decay Functions: to represent children's behaviour of attending their assigned schools

Step-wise Decay:

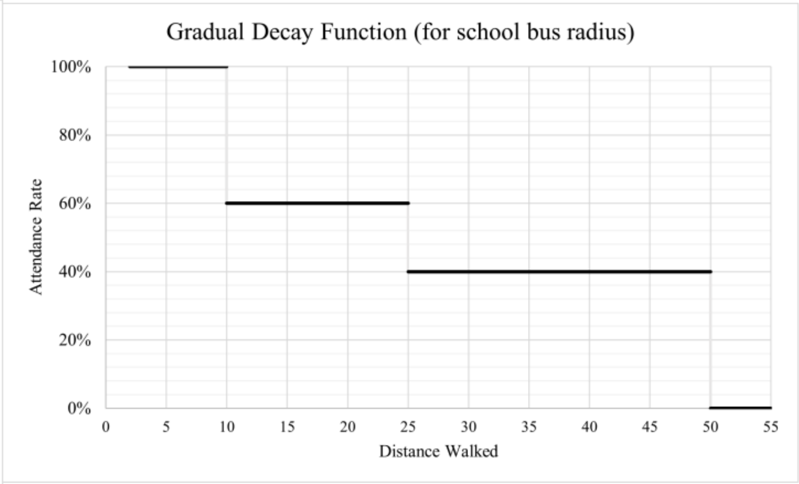
ϕ^w_{ik}: Attendance rates of children in district $i \in \mathcal{D}$ when they walk to school $k \in \mathcal{C}$

$$\phi^w_{ik} = \begin{cases} 1, & 0 \leq L_{ik} \leq 0.5 \\ 0.4, & 0.5 < L_{ik} \leq 1 \\ 0.2, & 1 < L_{ik} \leq \gamma \\ 0, & \gamma < L_{ik} \end{cases}$$



ϕ^b_{ik}: Attendance rates of children in district $i \in \mathcal{D}$ when they take the school bus to school $k \in \mathcal{C}$

$$\phi^b_{ik} = \begin{cases} 1, & \gamma < L_{ik} \leq 10 \\ 0.6, & 10 < L_{ik} \leq 25 \\ 0.4, & 25 < L_{ik} \leq \theta \\ 0, & \theta < L_{ik} \text{ and } \gamma > L_{ik} \end{cases}$$



2-Stage Approach for A-SLRP

2-Stage Approach

A-SLRP →

Location Allocation

- **Locations**
  - Central schools
  - tTECs
- **Assignments**
  - Districts to central schools
  - Districts to school busses
  - School busses to central schools
- **Transportation modes**

Routing

- VRP for each central school: single depot, non-selective demand points

2-Stage Approach for A-SLRP

2-Stage Approach

A-SLRP → Location Allocation / Routing

Location Allocation

$$f_i = \begin{cases} 1, & \text{if there is a TEC located in district } i \in \mathcal{D} \\ 0, & \text{otherwise} \end{cases}$$

$$z_k = \begin{cases} 1, & \text{if candidate school } k \in \mathcal{C} \text{ is selected as a central school} \\ 0, & \text{otherwise} \end{cases}$$

$$n_{ik} = \begin{cases} 1, & \text{if children in district } i \in \mathcal{D} \text{ walk to central school } k \in \mathcal{C} \\ 0, & \text{otherwise} \end{cases}$$

$$\overline{x}_{ijk} = \begin{cases} 1, & \text{if node } i \in \mathcal{D} \text{ is assigned to central school } k \in \mathcal{C} \text{ and school bus } t \in \mathcal{B} \\ 0, & \text{otherwise} \end{cases}$$

$$m_{kt} = \begin{cases} 1, & \text{school bus } t \in \mathcal{B} \text{ is assigned to central school } k \in \mathcal{C} \\ 0, & \text{otherwise} \end{cases}$$

Routing

$$u_{ij} = \begin{cases} 1, & \text{if the bus travels from node } i \in \mathcal{N}_k \text{ to } j \in \mathcal{N}_k \\ 0, & \text{otherwise} \end{cases}$$

$$y_{ij} = \text{the load of school bus when it travels from node } i \in \mathcal{N}_k \text{ to } j \in \mathcal{N}_k$$

2-Stage Approach: Location Allocation

$$\max \sum_{i\in\mathcal{D}}\sum_{k\in\mathcal{C}}\sum_{t\in\mathcal{B}} \phi^{b}_{ik}\cdot P_i\cdot \overline{x}_{ikt} + \sum_{i\in\mathcal{D}}\sum_{k\in\mathcal{C}} \phi^{w}_{ik}\cdot P_i \cdot n_{ik} + \sum_{i\in\mathcal{D}} P_i\cdot f_i \quad (5.27)$$

s.t.

Location
$$s_i + f_i + \sum_{k\in\mathcal{C}} n_{ik} \le 1 \qquad \forall i\in\mathcal{D} \quad (5.28)$$

Location
$$1-\gamma_{ik}\cdot z_k \ge s_i + f_i \qquad \forall i\in\mathcal{D}, \forall k\in\mathcal{C} \quad (5.29)$$

Assignment
$$\gamma_{ik}\cdot z_k \ge n_{ik} \qquad \forall i\in\mathcal{D}, \forall k\in\mathcal{C} \quad (5.30)$$

Budget
$$\sum_{k\in\mathcal{C}} z_k \le H \quad (5.31)$$
$$\sum_{i\in\mathcal{D}} f_i \le K \quad (5.32)$$

Assignment of Districts
$$\sum_{k\in\mathcal{C}}\sum_{t\in\mathcal{B}} \overline{x}_{ikt} = s_i \qquad \forall i\in\mathcal{D} \quad (5.33)$$
$$\overline{x}_{ikt} \le z_k \qquad \forall i\in\mathcal{D}, \forall k\in\mathcal{C}, \forall t\in\mathcal{B} \quad (5.34)$$
$$\overline{x}_{ikt}\cdot L_{ik} \le \theta \qquad \forall i\in\mathcal{D}, \forall k\in\mathcal{C}, \forall t\in\mathcal{B} \quad (5.35)$$

Assignment of buses
$$m_{kt} \le z_k \qquad \forall k\in\mathcal{C}, \forall t\in\mathcal{B} \quad (5.36)$$
$$\sum_{k\in\mathcal{C}} m_{kt} \le 1 \qquad \forall t\in\mathcal{B} \quad (5.37)$$

Assignment of buses
$$\overline{x}_{ikt} \le m_{kt} \qquad \forall i\in\mathcal{D}, \forall k\in\mathcal{C}, \forall t\in\mathcal{B}$$

Capacities
$$\sum_{i\in\mathcal{D}} P_i\cdot \overline{x}_{ikt} \le Q \qquad \forall k\in\mathcal{C}, \forall t\in\mathcal{B} \quad (5.39)$$
$$\sum_{i\in\mathcal{D}}\sum_{t\in\mathcal{B}} P_i\cdot \overline{x}_{ikt} + \sum_{i\in D} P_i\cdot n_{ik} \le QS \qquad \forall k\in\mathcal{C}$$

$$\overline{x}_{ikt}\in\{0,1\} \qquad \forall i\in\mathcal{D}, k\in\mathcal{C}, t\in B \quad (5.41)$$
$$n_{ik}\in\{0,1\} \qquad \forall i\in\mathcal{D}, k\in\mathcal{C} \quad (5.42)$$
$$m_{kt}\in\{0,1\} \qquad k\in\mathcal{C}, \forall t\in B \quad (5.43)$$
$$z_k\in\{0,1\} \qquad \forall k\in\mathcal{C} \quad (5.44)$$
$$f_i, s_i\in\{0,1\} \qquad \forall i\in\mathcal{D} \quad (5.45)$$

Arbitrary district-bus assignments for second stage feasibility

Routing

for each $k \in \mathcal{C}$ with $z_k = 1$, solve the sub-problem:

$$\min \quad \sum_{i \in \mathcal{N}_k} \sum_{i \in \mathcal{N}_k} L_{ij} \cdot u_{ij} \tag{5.48}$$

$$\text{s.t.} \quad \sum_{j \in \mathcal{N}_k} u_{ij} = 1 \qquad \forall i \in \mathcal{D}_k$$

Non-selective sub-problem

$$\sum_{j \in \mathcal{N}_k} u_{ji} = 1 \qquad \forall i \in \mathcal{D}_k \tag{5.50}$$

$$\sum_{j \in \mathcal{N}_k} u_{j0} = m_k$$

$$\sum_{j \in \mathcal{N}_k} u_{0j} = m_k$$

Predetermined number of school buses

$$y_{ij} \geq u_{ij} \qquad \forall i, j \in \mathcal{N}_k$$

$$y_{0j} = u_{0j} \qquad \forall i \in \mathcal{D}_k$$

$$\sum_{j \in \mathcal{N}_k} y_{ij} = \sum_{r \in \mathcal{N}_k} y_{ri} + \sum_{j \in \mathcal{N}_k} P_i \cdot u_{ij} \qquad \forall i \in \mathcal{D}_k \tag{5.55}$$

Flow based formulation

$$y_{ij} \leq Q \cdot u_{ij} \qquad \forall i, j \in \mathcal{N}_k$$

New district-bus assignments

$$u_{ij} \in \{0, 1\} \qquad \forall i, j \in \mathcal{N}_k \tag{5.57}$$

$$y_{ij} \in \mathbb{Z}^+ \qquad \forall i, j \in \mathcal{N}_k \tag{5.58}$$

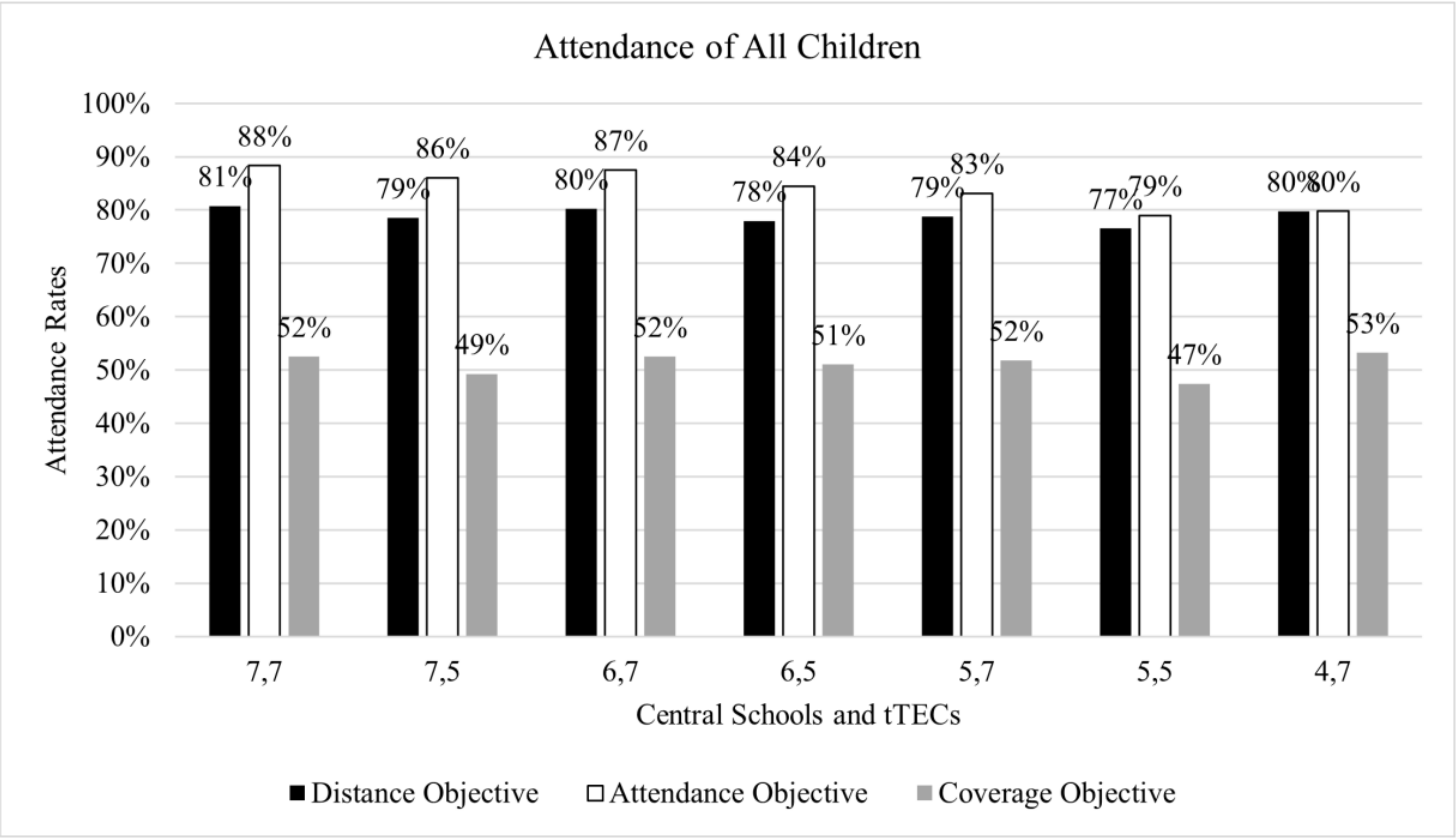
Performance of 2-Stage Approach

Central Schools	tTECs	A-SLRP Exact Model		2-Stage Approach		
		Solution Time (mins)	Gap	First stage Solution Time	Second stage Solution Time	Gap
7	7	<1	0%	<1	<1	0%
7	5	180	0.29%	<1	<1	0%
6	7	180	0.04%	<1	<1	0%
6	5	180	1.47%	<1	<1	0%
5	7	180	0.98%	<1	<1	0%
5	5	3.23	0%	<1	<1	0%
4	7	6.68	0%	<1	<1	0%
4	5	180	2.03%	<1	<1	0%
3	7	180	0.18%	<1	<1	0%
3	5	180	0.28%	<1	<1	0%
2	5	29.41	0%	<1	<1	0%
1	5	1.04	0%	<1	<1	0%

CLPEX cannot find an optimal solution for A-SLRP with the exact model, for many of the instances.

2-Stage obtains optimal results within less than a minute for every instance and provides a practical beneficiary-oriented tool for reinforcing schooling accessibility for refugee children.

Performance of A-SLRP



Summary

MC-SLRP

- Benchmarking model.
- Short solution times with CPLEX.
- Performs poorly in terms of both accessibility and cost

SLRP

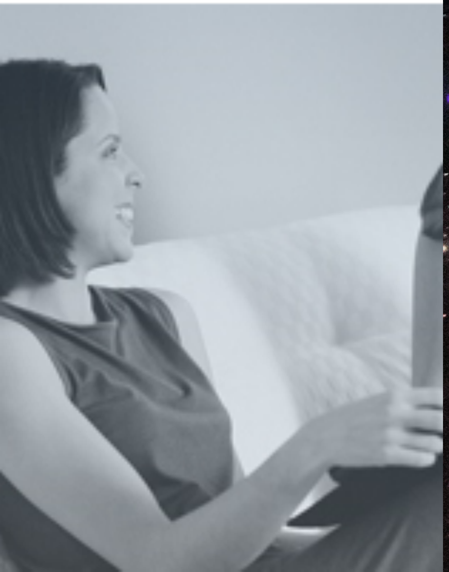
- Combines three levels of decisions
- Performs well in terms of both accesibility and cost. Considers the interests of beneficiaries, MoNE, and refugee children.
- Cannot be solved by CPLEX for tighther instances.
- Yields no solutions in the scarcity of the resources.

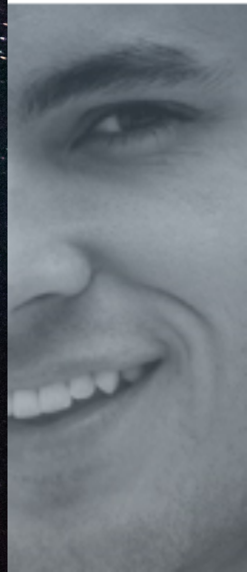
A-SLRP

- Considers attendance rates of children with gradual decay functions.
- Performs well in terms of both accesibility.
- Decomposable and 2-Stage Approach finds optimal solutions in less than a minute.

What Else?


COVID 19 Applications

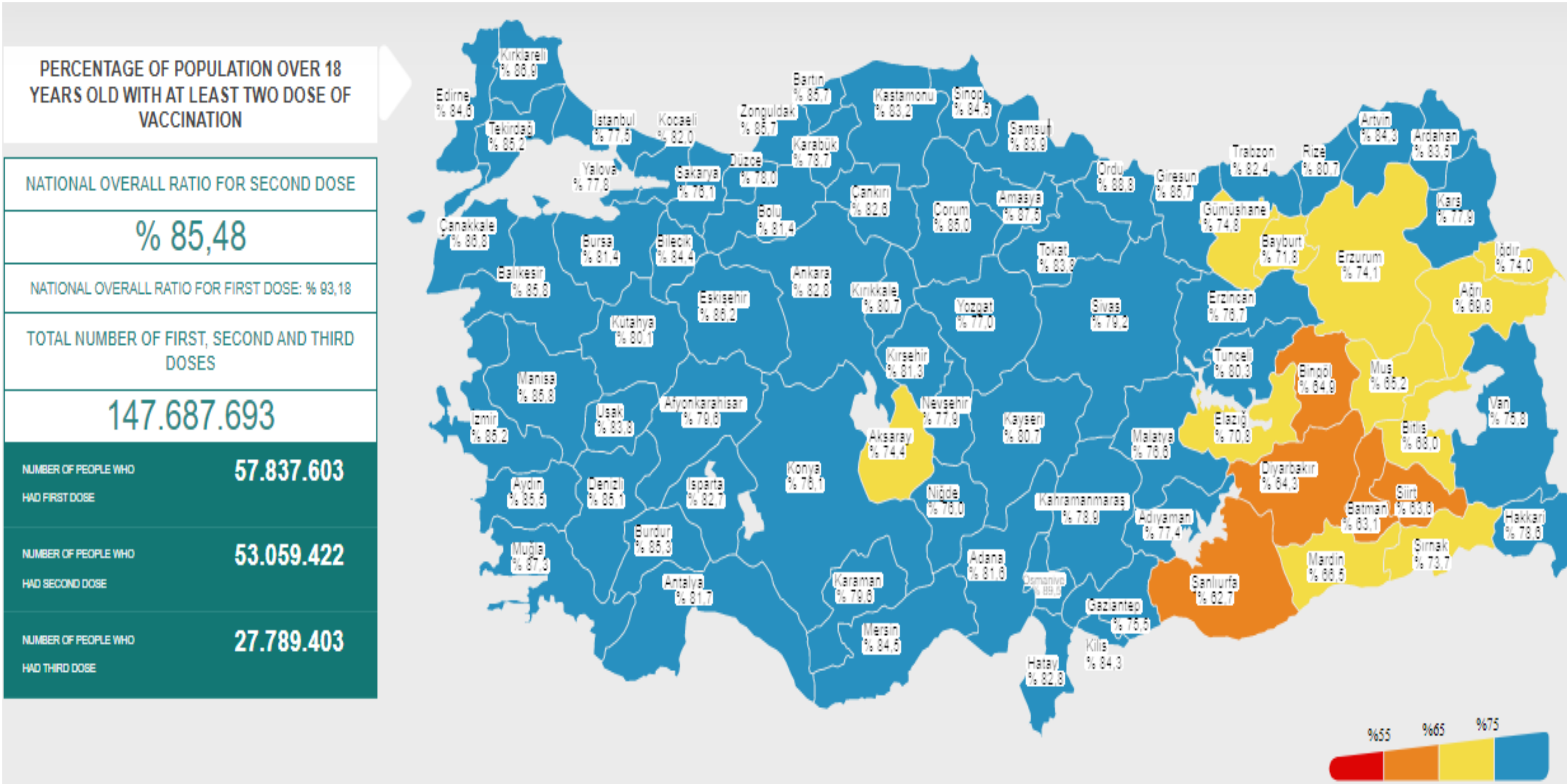




Vaccine Logistics


Vaccine Logistics
Joint work with
Çağla Dursunoglu
Oya Karaşan
Özlem Karsu
Manoj Dora

- The percentage of people who received the first dose of vaccine is **93.18%**, and the percentage of people who received the second dose of vaccine is **85.48%** in Turkey by May 24, 2022.[1]

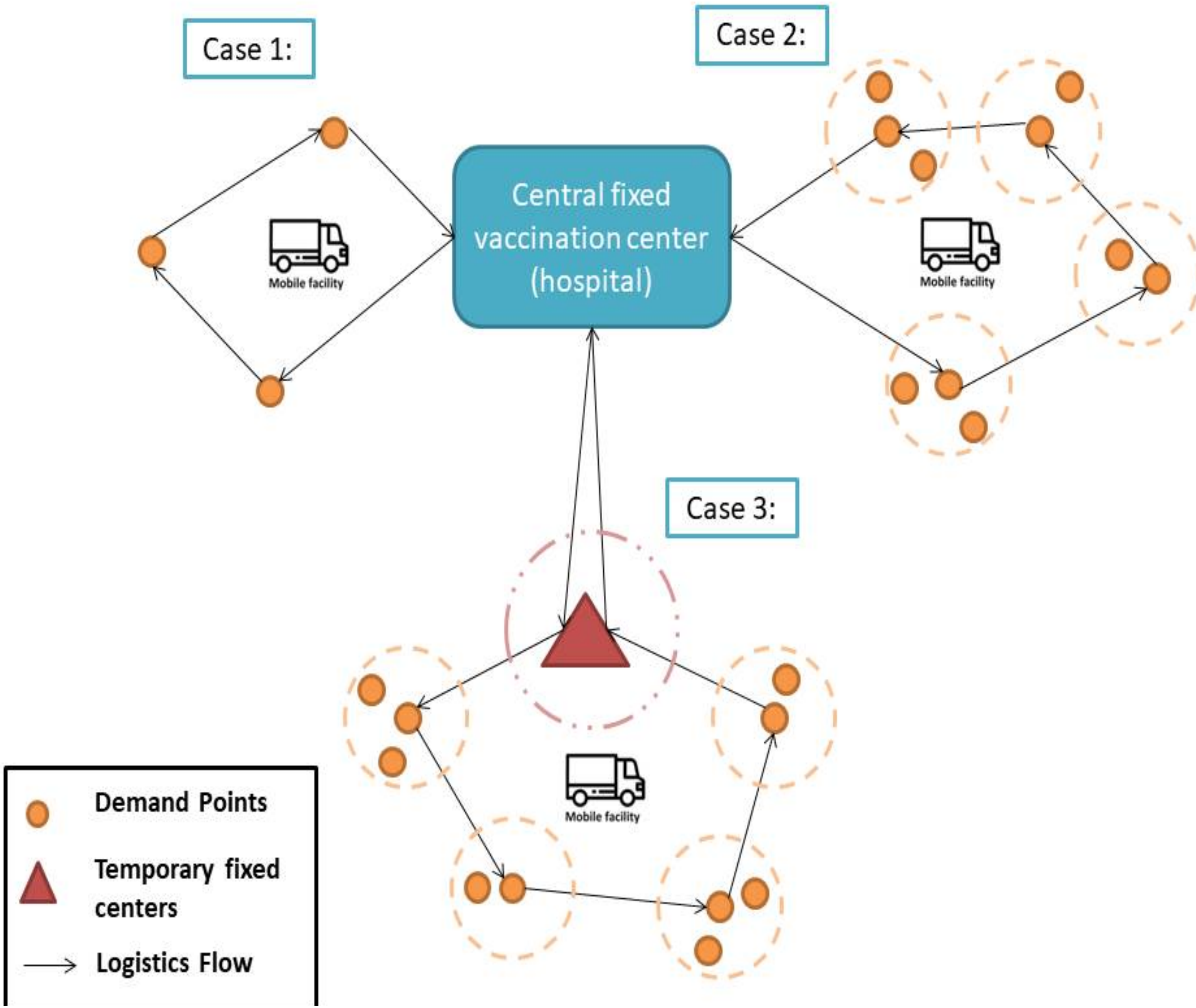


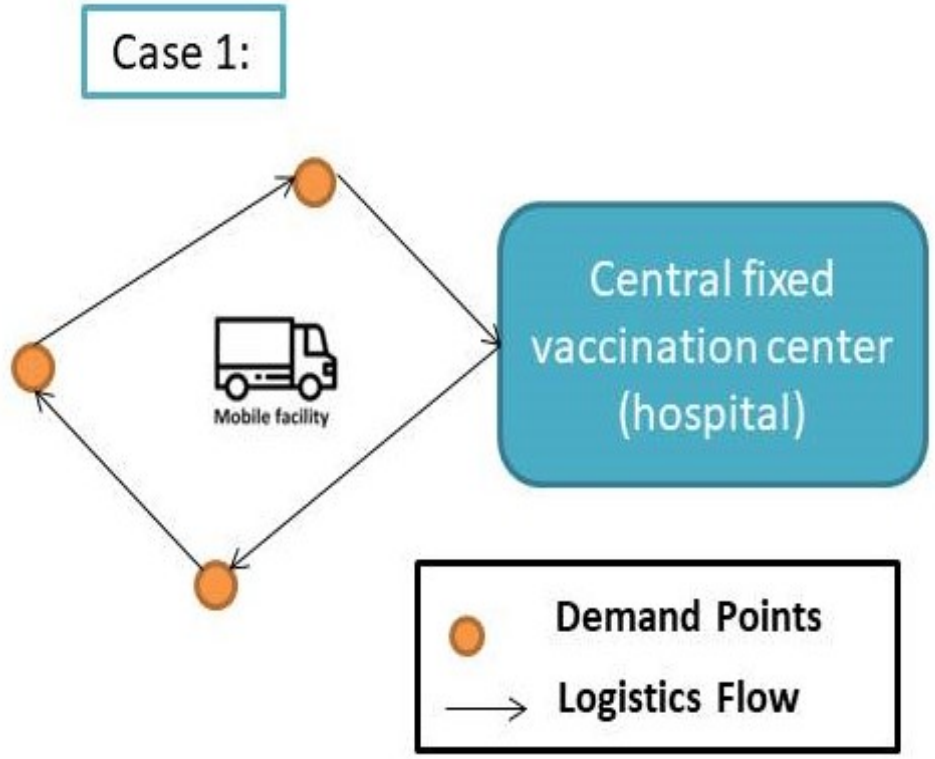
[1] Source: "COVID-19 Aşısı Bilgilendirme Platformu." Covid-19 Vaccination Information Platform, covid19asi.saglik.gov.tr/siteagaci. Accessed 24 May. 2022.

Vaccination Strategies:

- Fixed Centers
  - Generally hospitals and health centers
  - May require travel for vaccination
  - May exclude vulnerable part of community
- Drive Through Vaccination Centers
  - Accessible to car owners
  - Limited accessibility and availability
  - Exclude a large proportion of community living in high-density urban centers and areas with high transmission rate
- Walk-in vaccination sites (Local Vaccination sites)
  - Fixed sites providing access to vaccines within walking distance
  - Aims to increase availability by reaching disadvantaged areas
- Mobile Vaccination Clinics
  - Mobility provides flexibility for vaccination services
  - Prioritize accessibility of vaccines to those facing mobility or transportation barriers.

- Three cases can be considered within the context





Home-care Service by Small Mobile Units

- Only home-care visits are considered and there is no changing vaccination potential.

Possible Operational Dynamics of Case 1:

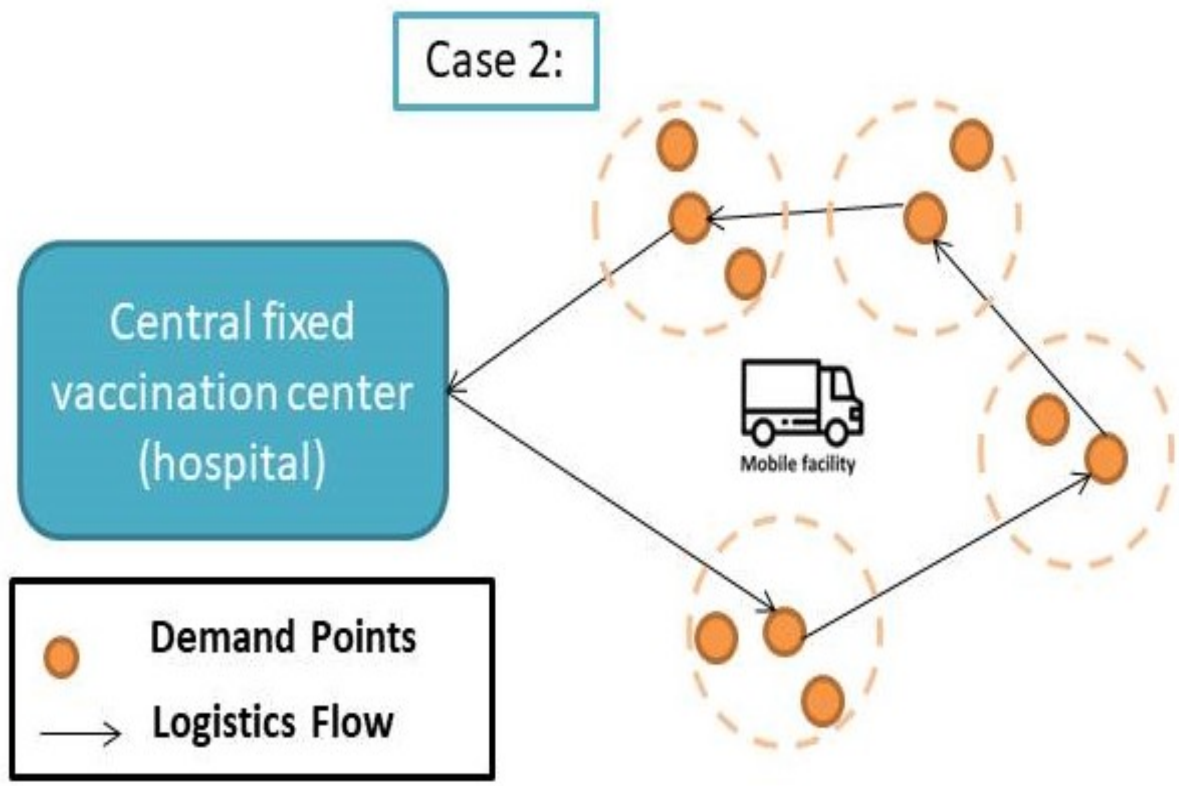
✓ Total time spent (service + travel) shouldn't exceed a pre-determined time

✓ Small mobile units only serve to a point at a time and moves to another one

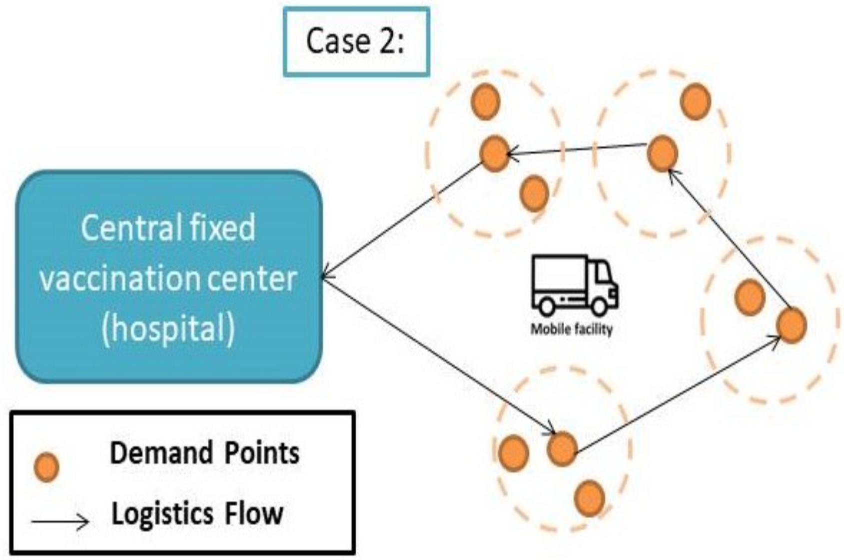
✓ All vehicles return to the central health center/hospital at the end of each shift.

$\Longrightarrow$ "Selective" Distance Constrained Vehicle Routing Problem

Half-Mobile Facility Service



- A predefined number of mobile vaccination centers departing from central vaccination center
- Mobile vaccination centers stay at certain points
- Mobility is an option during day time

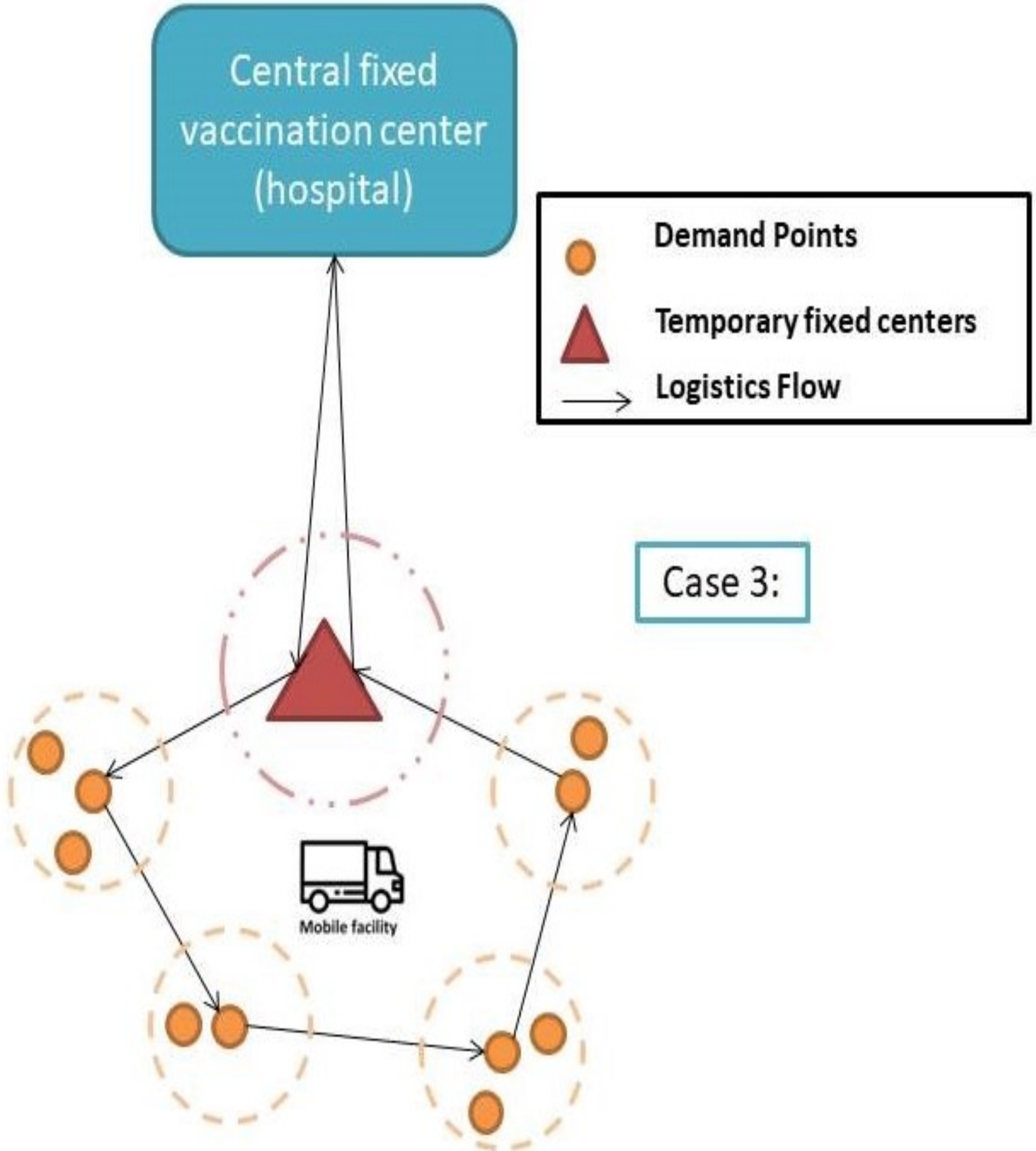


Possible Operational Dynamics of Case 2:

- ✓ High vaccination potential when mobile vaccination centers arrive in the district
  - It may diminish after a certain time
- ✓ People in the neighborhood of a visited district can walk for vaccination
  - For convenience: if a district is covered rather than visited, the vaccination is expected to be less since vaccination potential may be less
  - There is a correlation between the willingness of patients in covered districts to reach mobile centers and the distance to the visited district.
- ✓ All mobile centers return to the central health center/hospital at the end of each day.

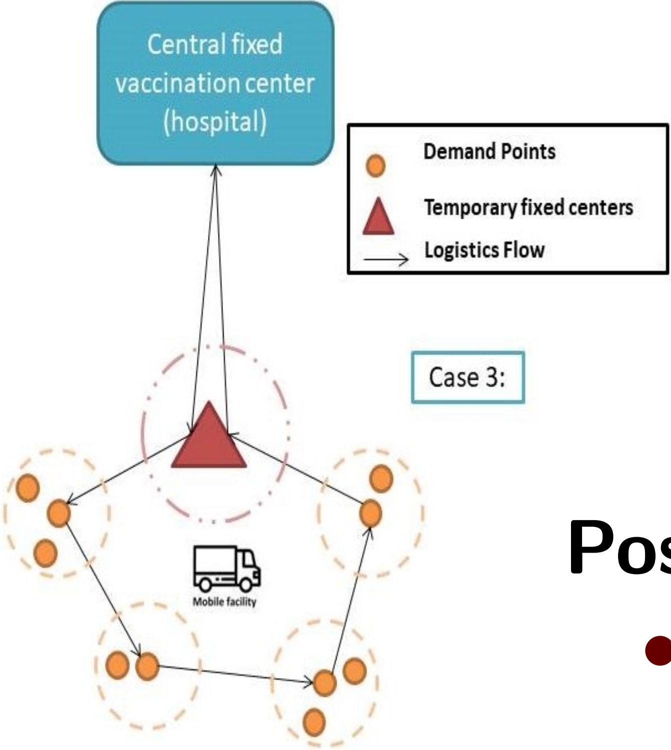
$\Longrightarrow$ Case 1 + Coverage aspect

$\Longrightarrow$ "Selective" Distance Constrained VRP + Coverage aspect



Tent and Half-Mobile Facility Service

- A predefined number of temporary fixed centers
- Temporary fixed centers are located at certain points
- A predefined number of mobile vaccination units departs from temporary fixed centers.
- Mobile vaccination units dynamics same with Case 2 (Half-Mobile Facility Service)



Possible Operational Dynamics of Case 3:

- For Temporary Fixed Locations:
  - ✓ **Temporary fixed centers are also located to dispatch half-mobile vaccination units (mini-location)**
  - ✓ **People in the neighborhood of a temporary fixed centers can walk on for vaccination**
  - ✓ **Operates one shift (8 hours)**
- For Half-Mobile Facilities
  - ✓ All vehicles return to the temporary fixed centers at the end of the shift
  - ✓ Same dynamics with Case 1 (Half-Mobile Facility Service)
    - ✓ Diminishing vaccination potential with respect to time and coverage.

$\Longrightarrow$ Case 2+ Location

$\Longrightarrow$ "Selective" Location and Routing Problem

- An interesting and different application
- Location of stopping points
- Routing
- Accessibility…
- Fairness…

An interesting additional decision and challenge

Duration of stay