IE 482: Article Presentation

# Rural Health

15.04.2019

Ceylin Sever
Güliz Başak Özkan
Sudenur Soysal

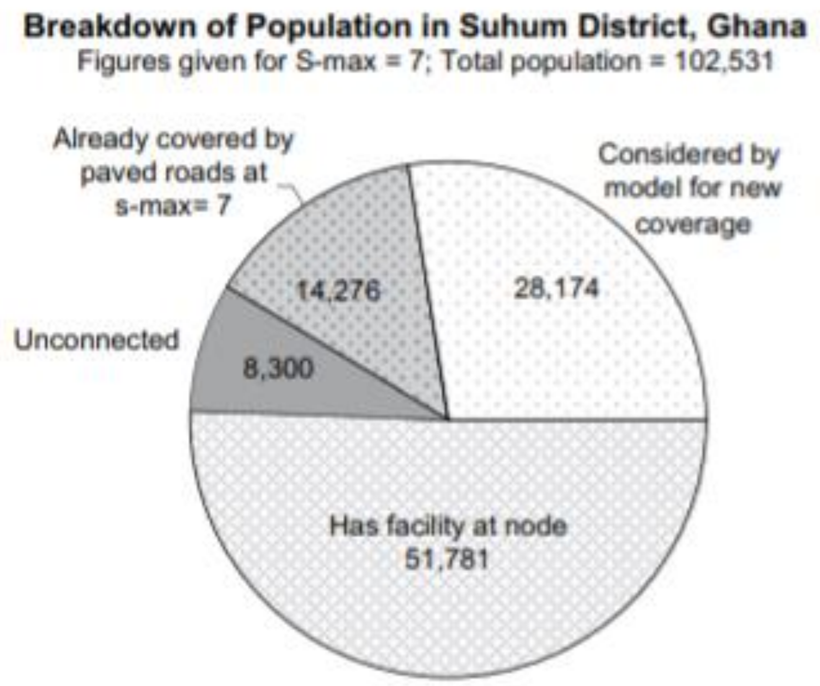
# Big Picture


Suhum district of Ghana

Accessibility of health facilities in case of cataract, flood

Three roads - trail (impassable), dirt road(impassable), paved road

# Current Situation



# Improvement

**Goal:** Increasing health service access by making road improvements by all-season road connectivity

**Method:** Maximal covering network improvement model (MC-NIP)

Focused on transportation network (infrastructure) rather than location of the facilities (fixed location)

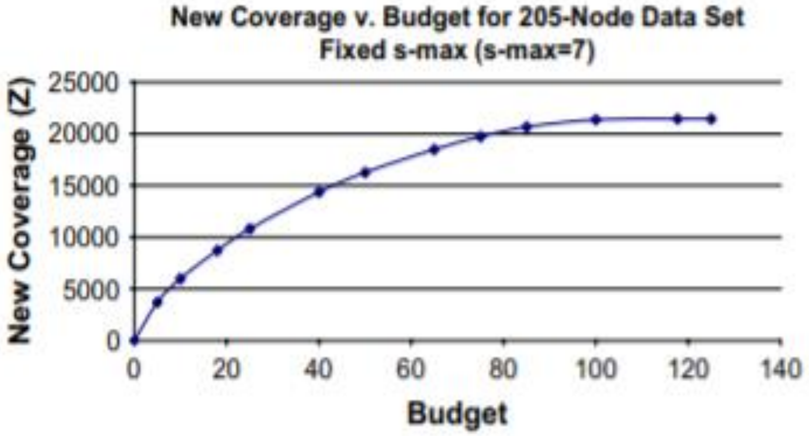



**Fig. 3.** Tradeoff curve depicting additional population covered associated with increases in road investment.

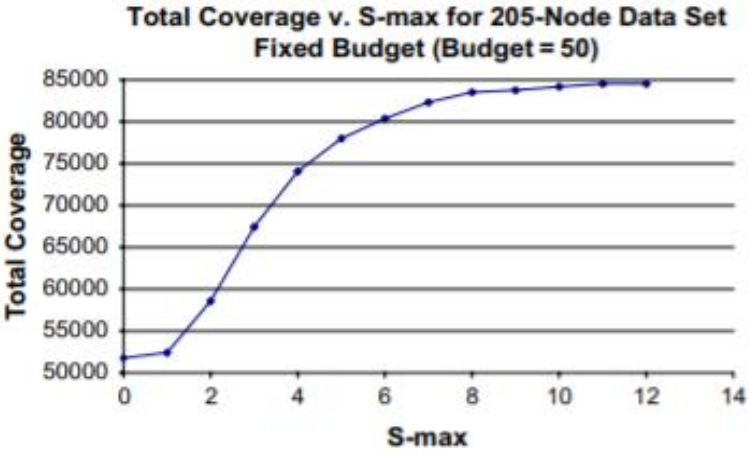



**Fig. 4.** Tradeoff curve of added coverage as a function of increasing maximal service distance *S*, while holding the budget fixed at 50.

# Method

Improving accessibility to rural health services: The maximal covering network improvement problem

Lisa Murawski [a], Richard L. Church [b,*]

[a] California Legislative Analyst Office, 925 L Street - Suite 1000, Sacramento, CA 95814, USA
[b] Department of Geography, University of California at Santa Barbara, Santa Barbara, CA 93106-4060, USA

- ★ Geographic Information System Software (ARC/GIS)
- ★ Excel
- ★ Visual Basic
- ★ ILOG-CPLEX

# Parameters

$A = \{(i,j) \mid i < j$, where nodes $i$ and $j$ are directly connected by a road or trail$\}$.

$B =$ the budget for road improvement.

$S =$ the maximal distance standard for measuring access to health services.

$a_i =$ the population of village $i$.

$d_{ij} =$ distance of arc $(i,j) \in A$.

$c_{ij} =$ cost of upgrading road arc $(i,j) \in A$ to an all-season road, based upon current road condition.

$SP_{ij} =$ the shortest distance between nodes $i$ and $j$ on network $G$.

# Parameters

$U = \{(i,j) \mid (i,j) \in A$ and $c_{ij} > 0\}$, the set of road arcs that are not "all-season".

$F = \{j \mid$ village $j$ houses a medical clinic$\}$, the set of villages housing a health clinic.

$D = \{i \mid$ village $i$ does not currently receive all weather access to clinic services$\}$.

$D_s = \{i \in D \mid$ village $i$ is within $s$ distance of a clinic$\}$, the set of villages that are not currently served with all season road access, but are candidates for such access by virtue that they are within $s$ distance of one or more clinics.

$F_i = \{j \mid SP_{ij} \leq s$ where $j \in F\}$, the set of clinics that are within the maximal access distance $s$ to village $i$.

$\Omega_{ij} = \{(a,b) \mid$ arc $(a,b) \in A$ and could be used in an accessible path between $i$ and $j\}$.

# Decision Variables

$$H_{ab} = \begin{cases} 1, \text{ if arc}(a,b)\text{is upgraded to an all season road} & (a,b) \in U \\ 0, \text{ otherwise} \end{cases}$$

$$y_{ij} = \begin{cases} 1, \text{if village } i \text{ and health clinic at } j \text{ are connected} & i \in D_s \text{ where } F_i \neq \phi, \\ \text{by an all season route within coverage distance } s \\ 0, \text{ otherwise} \end{cases}$$

$$P_{ab}^{ij} = \begin{cases} 1, \text{if a paved all season route between } i \text{ and } j & (a,b) \in \Omega_{ij} \text{ such that } i \neq a \\ \text{uses arc}(a,b)\text{in the direction of } a \text{ to } b \\ 0, \text{otherwise} \end{cases}$$

$$P_{ba}^{ij} = \begin{cases} 1, \text{if a paved all season route between } i \text{ and } j & (a,b) \in \Omega_{ij} \text{ such that } i \neq a \\ \text{uses arc } (a,b) \text{ in the direction of } b \text{ to } a \\ 0, \text{ otherwise} \end{cases}$$

# Model

$$\text{Maximize } Z = \sum_{i \in D_s} \sum_{j \in F_i} a_i y_{ij} \qquad (1)$$

$$\sum_{(a,i) \in \Omega_{ij}} P_{ai}^{ij} = y_{ij} \quad \text{for each } i \in D_s \text{ and } j \in F_i \qquad (2)$$

$$\sum_{(a,k) \in \Omega_{ij} \text{ or } (k,a) \in \Omega_{ij}} P_{ak}^{ij} - \sum_{(a,k) \in \Omega_{ij} \text{ or } (k,a) \in \Omega_{ij}} P_{kb}^{ij} = 0$$

$$\text{for each } i \in D_s \text{ and } j \in F_i \text{ where } k \neq i \text{ and } k \neq j \qquad (3)$$

$$P_{ab}^{ij} + P_{ba}^{ij} \leq H_{ab} \quad \text{for each } (a,b) \in \Omega_{ij}, \text{where } i \in D_s \text{ and } j \in F_i$$

$$\text{when } (a,b) \in U, i \neq a, i \neq b, j \neq a, j \neq b \qquad (4)$$

# Model

$$P_{ab}^{ij} \le H_{ab} \quad \text{for each } (a,b) \in \Omega_{ij}, \text{ where } i \in D_s \text{ and } j \in F_i$$

$$\text{when } b = i \text{ and } (a,b) \in U, \text{ or when } a = j \text{ and } (a,b) \in U \quad (5)$$

$$\sum_{(a,b)\in\Omega_{ij}} \left(P_{ab}^{ij} + P_{ba}^{ij}\right) d_{ab} \le s^* y_{ij} \quad \text{for each } i \in D_s \text{ and } j \in F_i \quad (6)$$

$$\sum_{j\in F_i} y_{ij} \le 1 \quad \text{for each } i \in D_s \quad (7)$$

$$\sum_{(a,b)\in U} c_{ab} H_{ab} \le B \quad (8)$$

# Model

$$H_{ab} \in \{0, 1\} \quad \text{for all arcs } (a, b) \in U, \tag{9}$$

$$P_{ab}^{ij} \in \{0, 1\} \quad \text{and} \quad P_{ba}^{ij} \in \{0, 1\}$$

$$\text{for all } i \in D_s \text{ and } j \in F_i \text{ and arcs } (a, b) \in \Omega_{ij}, \tag{10}$$

$$y_{ij} \in \{0, 1\} \quad \text{for all } i \in D_s \text{ and } j \in F_i \tag{11}$$

# Additional Examples

- **The Broccoli Project**
- maximum amount of people for the lowest number of devices deployed.

# Additional Examples

★ **Planning Model for Rural Roads**

**Goal:**the proposed planning model aims to provide only the basic minimum road accessibility to villages.

➔ This model generates a basic rural road network providing access to each village to a larger center.

The objective function of this model is to minimize the cost

## ➔ Existing rural road network for study area

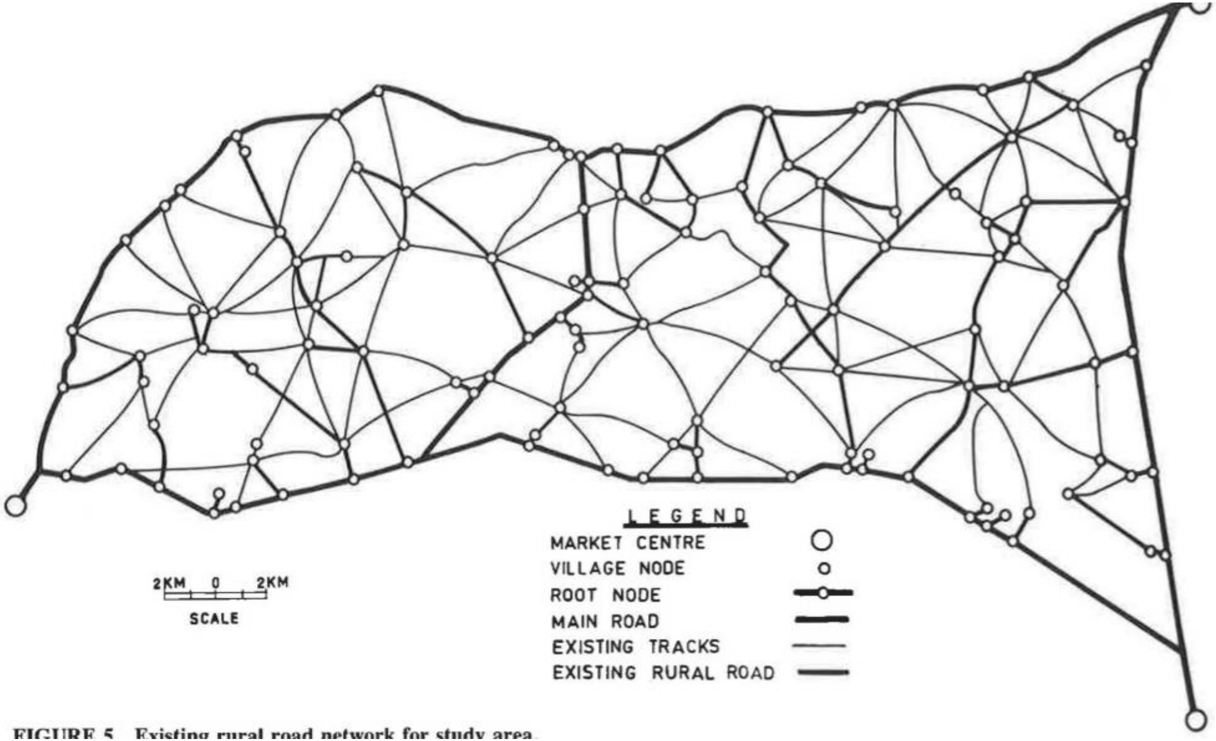



FIGURE 5 Existing rural road network for study area.

## ➔ Optimum rural road network for study area

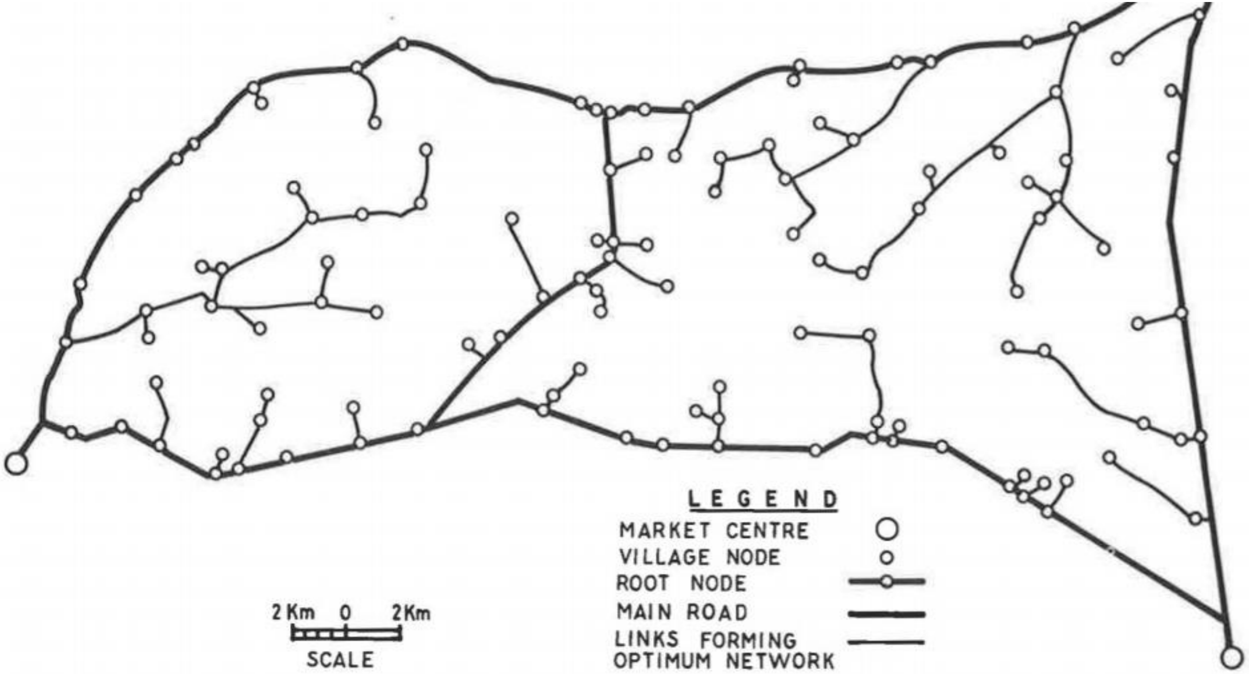



**FIGURE 7** Optimum rural road network for study area.

# Alternative Actions

- Telpher Line System
  - impassable roads
  - cost of the system is approximately 10 million dollars
  - maintenance cost (keep the cable oiled etc)

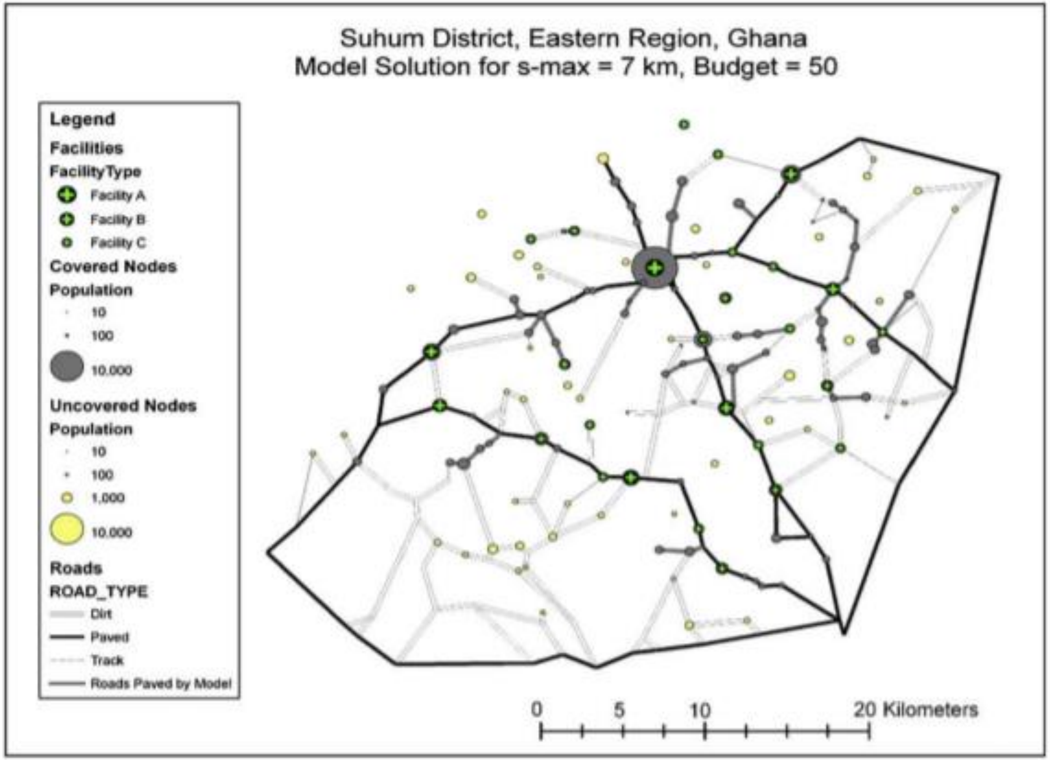
# Alternative Actions

★ All/ Four Wheel Drive System
  - the vehicle is optimized for off-road driving going through mud
  - cost of vehicle is around 50.000 dollars
  - the area of Suhum is small enough

# Correctness

- Fix budget is 50 but currency unit is not clear
    - The road construction cost is around 2 million dollars.
    - Telpher line system cost is around 10 millon dollars.
    - All wheel drive system vehicle cost is around 600.000 dollars.(10 vehicles)

# Conclusion



Suhum District, Eastern Region, Ghana
Model Solution for s-max = 7 km, Budget = 50
Legend
Facilities
FacilityType
Facility A
Facility B
Facility C
Covered Nodes
Population
10
100
10,000
Uncovered Nodes
Population
10
100
1,000
10,000
Roads
ROAD_TYPE
Dirt
Paved
Track
Roads Paved by Model
0
5
10
20 Kilometers

# Comparison

## General Situation in Turkey

| road classification | impassable |
|---|---|
| highway | - |
| national highway | 207 |
| county road | 1144 |
| total sum | 1351 |

# Specific Examples from Turkey

Bitlis

Tablo 7: Bitlis İli Satıh Cinslerine Göre Köy Yolları Ağı (Km) [10]

| İL | ASFALT | BETON | STABİLİZE | TESVİYELİ | HAM YOL | TOPLAM(Km) |
|---|---|---|---|---|---|---|
| BİTLİS | 373 | - | 657 | 1070 | 38 | **2.138** |

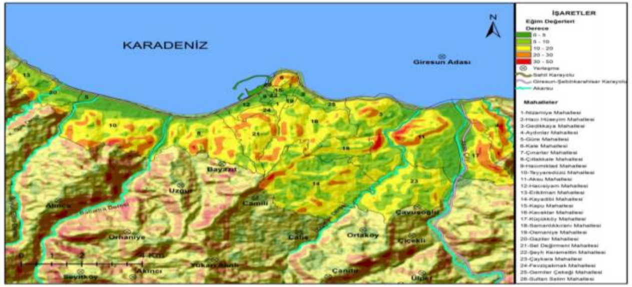
Konya

Çizelge 3. 11. Konya Devlet, İl ve Köy yollarının durumu

| Yolun Niteliği | Devlet Yolu (km) | İl Yolu (km) | Köy Yolu (km) | Yolların Niteliksel Toplamları (km) |
|---|---|---|---|---|
| Asfalt | 1.379 | 1.501 | 3.453 | 6.333 |
| Stabilize | 0 | 16 | 2.662 | 2.678 |
| Tesviye | 0 | 0 | 514 | 514 |
| Ham | 0 | 0 | 195 | 195 |
| TOPLAM | 1.379 | 1.517 | 6.824 | 9.720 |

Giresun

**Foto 4.** Kent yerleşim alanında meydana gelen sel ve taşkınlardan bir görünüm




**Şekil 3.** Giresun kenti ve yakın çevresinin eğim haritası.

## Proposed Solutions

Pavement

Urbanization in Rural Areas

Improvement in Drainage Systems

# References


http://dergipark.gov.tr/download/article-file/41739

http://acikerisim.selcuk.edu.tr:8080/xmlui/bitstream/handle/123456789/9431/212343.pdf?sequence=1&isAllowed=y

http://tucaum.ankara.edu.tr/wp-content/uploads/sites/280/2016/12/Int_semp_BC17.pdf

http://www.mimarlarodasiankara.org/_media/4/teleferik.pdf

http://www.kgm.gov.tr/SiteCollectionDocuments/KGMdocuments/Kurumsal/FaaliyetRaporu/2017Faaliyet.pdf

Ashok Kumar, H. T. Tillotson, **Planning Model for Rural Roads**

Lisa Murawski, Richard L. Church, **Improving accessibility to rural health services: The maximal covering network improvement problem**