Modeling Referral Networks to Avert Maternal Death in Ethiopia

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Presentation Overview

• Referral background
• Setting: Ethiopia
• Network Analysis
  – Objectives, data and methods
  – Defining referral networks
  – Model building and preliminary results
• Next steps in Ethiopia
REFERRAL BACKGROUND
What and why referral?

- **Defined:** upward movement in the seeking of care within the health system.
  - Emergency Referral

- **Referral is key in the field of maternal and newborn health**
  - “under-documented, under-researched and under-theorized.”

- **Referral utilizes current resources through linkages in a system**
  - Cheaper
  - Short to medium-term solutions
### Time between the beginning of a complication and death

<table>
<thead>
<tr>
<th>Complication</th>
<th>Hours</th>
<th>Days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hemorrhage</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Postpartum</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Antepartum</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>Ruptured uterus</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Eclampsia</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Obstructed labor</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Infection</td>
<td>6</td>
<td></td>
</tr>
</tbody>
</table>
Referral has the potential to reduce all 3 delays:

- **DELAY #1**: Deciding to seek care
- **DELAY #2**: Reaching a facility
- **DELAY #3**: Receiving adequate care

Onset of Complication  
Recovery or death
Pyramidal structure & bypassing

Regional Hospital

District Hospital

Health center/post/dispensary

Community

Receiver

Transport

Sender

Adapted from Jahn & De Brouwere, 2001
Requisites of a functioning referral system

Communication

Transport

Functioning referral center

Protocols for senders & receivers

SETTING: ETHIOPIA
Setting: Ethiopia

- Population: 73 million
- Area: 1.1 million km²
  - Twice the size of Texas
## Tigray and Amhara – Key Indicators

<table>
<thead>
<tr>
<th></th>
<th>Tigray</th>
<th>Amhara</th>
<th>National</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population (2007 Census)</td>
<td>4,400,000</td>
<td>17,200,000</td>
<td>73,900,000</td>
</tr>
<tr>
<td>Number of hospitals</td>
<td>14</td>
<td>18</td>
<td>112</td>
</tr>
<tr>
<td>Percent minimum recommended (CEmOC)</td>
<td>55%</td>
<td>18%</td>
<td>39%</td>
</tr>
<tr>
<td>Institutional delivery rate</td>
<td>9%</td>
<td>5%</td>
<td>7%</td>
</tr>
<tr>
<td>Cesarean delivery rate</td>
<td>0.7%</td>
<td>0.2%</td>
<td>0.6%</td>
</tr>
<tr>
<td>Percent of health centers with desired staffing</td>
<td>45%</td>
<td>2%</td>
<td>na</td>
</tr>
</tbody>
</table>
OVERVIEW OF DATA AND METHODS
Background for this activity

- **Ethiopia Needs Assessment for EmONC conducted**
  - 797 Healthcare facilities
  - Geocoded

- **Staff saw potential GIS use**

- **Emergency Referral Network Analysis**
  - Strengthening referral systems could save lives in *short and medium term*, even as longer term strategies are implemented
Objectives:

1. Model current referral system
2. Identify facilities 2+ hours from closest receiving facility
3. Model short and medium term solutions to reduce travel time
Data

1. Ethiopia EmONC Assessment
3. Digital Elevation Model
4. Road Network Data
Road Network Discrepancies
Road Network Discrepancies
Methods

1. Define Sender and Referral Facilities
2. Model Current Referral Network
3. Model Referral Scenarios
   - Build facility catchment areas
Defining facilities

• **Tier A ( Receivers )**
  – conducted cesarean delivery in 3 months prior to the assessment

• **Tier B ( Senders )**
  – all other facilities

• Identified referral networks based on shortest travel time to a Tier A facility
Facility Locations: Tier A
Amhara and Tigray Regions, Ethiopia

Legend
- Tier A - Receivers

Road (P13)
Type
- All-weather roads (asphalt)
- All-weather roads (gravel)
- Dry-weather roads
- Motorable tracks (status uncertain)
- unknown

Tigray
Amhara
Ethiopia

Date of Production: March 2010
Version: HD13. Tier
Healthcare Facility Data Source: AWD-ETHIO 2009
Road Networks Data Source: IAGG, DEPHA
Lake and River Data Source: DEPHA
Model Current Referral Network

Key Variable: Travel Time

- Calculated **direct travel time** for each Tier B facility based on:
  - Distance on road network
  - Road surface
  - Season

- Calculated **adjusted travel time** based on:
  - Motorized transportation available on site
  - Communication (if no transportation)
### Key Variable – Travel Time

<table>
<thead>
<tr>
<th>Factors</th>
<th>Tier B Facility #1</th>
<th>Tier B Facility #2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct travel time (min) to closest Tier A</td>
<td>48</td>
<td>118</td>
</tr>
<tr>
<td>- Road Surface (in GIS)</td>
<td>(in GIS)</td>
<td>(in GIS)</td>
</tr>
<tr>
<td>- Season</td>
<td>Dry</td>
<td>Dry</td>
</tr>
<tr>
<td>Transportation on site</td>
<td>No ( (48 \times 2 = 96) )</td>
<td>Yes ( (118 \times 1 = 118) )</td>
</tr>
<tr>
<td>Communication</td>
<td>No ( (96 + 30 = 126) )</td>
<td>N/A</td>
</tr>
<tr>
<td>Adjusted travel time (min)</td>
<td>126</td>
<td>118</td>
</tr>
</tbody>
</table>
Referral Networks of Tier A Facilities

Road Conditions: Dry Season
Amhara and Tigray Regions, Ethiopia

Legend

+ Tier A
• Tier B

Road (P13)
Type
— All-weather roads (asphalt)
— All-weather roads (gravel)
— Dry-weather roads
— Motorable tracks (status uncertain)
— unknown

Map showing referral networks and road conditions in the Amhara and Tigray Regions of Ethiopia, categorized by tier and road type.
Tier B Facilities Greater than 2 Hours from Closest Tier A

Road Conditions: Dry Season

Amhara and Tigray Regions, Ethiopia

Legend

Tier B - Senders
Distance to Closest Tier A Facility
- Less than 2 hours
- More than 2 hours
- Tier A

Road (P13)
Type
- All-weather roads (asphalt)
- All-weather roads (gravel)
- Dry-weather roads
- Motorable tracks (status uncertain)

unknown

Tigray

Amhara

Ethiopia

Date of Production: August 2019
Version: ND13 Tier
Healthcare Facility Data Source: AMOC Ethiopia 2009
Road Networks Data Source: XROAD, DEPHA
Lake and River Data Source: DEPHA

Kilometers
Percentage of facilities within 60 and 120 minutes to closest Tier A facility

<table>
<thead>
<tr>
<th>Cumulative Minutes to Closest Tier A Facility</th>
<th>Count</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Under 60</td>
<td>77</td>
<td>35.8%</td>
</tr>
<tr>
<td>61 to 120</td>
<td>64</td>
<td>29.8%</td>
</tr>
<tr>
<td>More than 120</td>
<td>74</td>
<td>34.4%</td>
</tr>
</tbody>
</table>
Model building

• **Build Catchment Areas**
• Model 0: Status Quo
• Model 1: All facilities have motorized transportation and communication
• Model 2: Upgrading strategic Tier B facilities to Tier A facilities
• Model 3: Improved road surfaces
• Optimal model: what is the best outcome with the lowest input (additional phones/vehicles)
Study Area
Amhara and Benishangul-Gumuz Regions, Ethiopia
Road Conditions: Dry Season

Legend
- Tier A Facility (UFI)
- Tier B Facility
- Tier B Catchment Areas

Date of Production: June 2010
Population Source: Oak Ridge National Laboratory, UNEDF 1994
Healthcare Facility Data Source: AMDD Ethiopia 2009
Road Networks: AECL, Tans
Road Network Data Source: IGAD, DEPHA
Lake and River Data Source: DEPHA

Location of Study Area (Green)
Ethiopia
Creating Catchment Areas

- An area that “should” be served by a facility
- Cost Distance Raster in ArcGIS
  - Slope
  - Rivers/terrain
- Once created, calculated population
Cost Back Link Direction: Pixel to Source Pixel (clinic)
Amhara and Tigray Regions, Ethiopia

Legend

Fac_Sudy

Tier
- 1
- 2

Legend

CostBack_1_cmt
Source (0)
Right (1)
Lower-Right (2)
Down (3)
Lower-Left (4)
Left (5)
Upper-Left (6)
Up (7)
Upper-Right (8)

dem_studyprj

Value

High : 4517
Low : 146

Date of Production: March 2010
Version: ND11. Tiers
Healthcare Facility Data Source: MCH Ethiopia 2008
Road Network Data Source: IGAD, DPHIA
Lake and River Data Source: DPHIA
Cost Back Link Direction: Pixel to Source Pixel (clinic)
Amhara and Tigray Regions, Ethiopia

Legend
pop11_points_cmt1
GRID_CODE
- 2 - 170
- 171 - 878
- 879 - 2457
- 2458 - 5367
- 5368 - 11623

Fac_Study
Tier
- 1
- 2

CostBac_1_cmt
pop_study12.img
Value
High : 15942
Low : 0

dem_studyprj
Value
High : 4517

Data produced: March 2010
Valen. 91.87% on grid
Road Network Data Source: IARD, DEPHA
Lake and River Data Source: DEPHA

N 0 4 8 16 24
Kilometers
Referral Networks with Facility Catchment Areas
Population Density by Catchment Area

Amhara and Benishangul-Gumuz Regions, Ethiopia

Road Conditions: Dry Season

Legend

- Tier A Facility (UFI)

Population Density (sq km)

- 5.975 - 100.0
- 100.1 - 200.0
- 200.1 - 300.0
- 300.1 - 400.0
- 400.1 - 500.0
Model building

- Build Catchment Areas
- Model 0: Status Quo
- Model 1: All facilities have motorized transportation and communication
- Model 2: Upgrading strategic Tier B facilities to Tier A facilities
Facility Catchment Areas Beyond 2-hour Travel Time

Model 0: STATUS QUO

<table>
<thead>
<tr>
<th>Total Population</th>
<th>Population Currently with Access</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>10,019,395</td>
<td>5,626,099</td>
<td>56.2%</td>
</tr>
</tbody>
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Model building

- Build Catchment Areas
- Model 0: Status Quo
- Model 1: All facilities have motorized transportation /communication
- Model 2: Upgrading strategic Tier B facilities to Tier A facilities
Facility Catchment Areas Beyond 2-hour Travel Time

Model 0: STATUS QUO

<table>
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<td></td>
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</table>

Legend:
- Tier A Facility (UFI)
- Tier B Facility
- Tier A Boundary
- Minutes from Tier B to Tier A
  - Minutes: 0 - 120
  - 121 - 419
Facility Catchment Areas Beyond 2-hour Travel Time

MODEL 1: Each facility has motorized transportation

Legend
- Tier A Facility (UFI)
- Tier B Facility
- Tier A Boundary
- Minutes from Tier B to Tier A
  - Minutes
    - 0 - 120
    - 121 - 240

Amhara and Benishangul-Gumuz Regions, Ethiopia
Road Conditions: Dry Season
Date of Production: June 2010
Population Source: Oak Ridge National Laboratory, UNEF 1994
Healthcare Facility Data Source: AMID Ethiopia 2009
Road Network: ADEE-Tars
Road Network Data Source: IGAD, DPATH
Lake and River Data Source: DPATH

Kilometers
Model 1: Increase in population served by ensuring that every Tier B facility has a motorized vehicle

<table>
<thead>
<tr>
<th>Referral Network</th>
<th>Total Population</th>
<th>Population Currently with Access*</th>
<th>Population with Access in Model 1</th>
<th>Overall Increase in Population Access</th>
</tr>
</thead>
<tbody>
<tr>
<td>1412 – Pawe</td>
<td>1,338,664</td>
<td>646,721</td>
<td>646,721</td>
<td>48.3%</td>
</tr>
<tr>
<td>1505 – Debre Tabor</td>
<td>2,723,313</td>
<td>2,182,465</td>
<td>2,447,996</td>
<td>80.1%</td>
</tr>
<tr>
<td>1543 – Felege Hiwot</td>
<td>2,156,109</td>
<td>1,151,324</td>
<td>1,994,981</td>
<td>53.4%</td>
</tr>
<tr>
<td>1623 – Debre Markos</td>
<td>3,801,309</td>
<td>1,645,589</td>
<td>2,660,041</td>
<td>43.3%</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>10,019,395</strong></td>
<td><strong>5,626,099</strong></td>
<td><strong>7,749,739</strong></td>
<td><strong>56.2%</strong></td>
</tr>
</tbody>
</table>

*Only for persons at the Tier B facility*
Facility institutional delivery rates

Amhara and Benishangul-Gumuz Regions, Ethiopia
Road Conditions: Dry Season

Legend

Tier A Facility (UFI)

Tier B Facility

Tier B Catchment Areas

Institutional delivery rate

0.5% - 11.8%

11.9% - 23%

23.1% - 34.3%

34.4% - 45.5%

45.6% - 56.7%
Referral Network Routes Along Roadways
Amhara and Benishangul-Gumuz Regions, Ethiopia
Road Conditions: Dry Season

MODEL 2: Facility #1615 is upgraded to a Tier A

Legend
- TA_1615_point_model2
- Tier A Facility (UFI)
- Tier B Facility
- Routes_1
- TA_1412_bdryprj_Clipped_model2
- TA_1543_bdryprj_Clipped_model2
- TA_1615_bdryprj_Clipped_model2
- TA_1623_bdryprj_Clipped_model2

Road Type
- All-weather roads (asphalt)
- All-weather roads (gravel)
- Dry-weather roads
- Motorable tracks (white)
- unknown

Date of Production: June 2010
Population Source: Oak Ridge National Laboratory, UNDP 1994
Healthcare Facility Data Source: AMED Ethiopia 2009
Road Network Data Source: IGAD, DEPHA
Lake and River Data Source: DEPHA

Kilometers
Facility Catchment Areas Beyond 2-hour Travel Time

Model 0: STATUS QUO
Facility Catchment Areas Beyond 2-hour Travel Time
Model 2: Increase in population served by upgrading Fenote Selam District Hospital to a Tier A

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td>1,945,023</td>
<td>293,895</td>
<td>781,640</td>
<td>+487,745 25.1%</td>
</tr>
</tbody>
</table>
Next Steps in Ethiopia

Further modeling
- Combinations of models (ex. Motorized vehicles plus upgrading)
- Improved road surfaces
- Optimal model: what is the best outcome with the lowest input (additional phones/vehicles)
- Costing

Federal MoH Working Group on Referral
- Site selection for new ambulances
- Testing new management models
- Transfer of methods and validation of assumptions