

## Summary Sheet

**Topic:** “Predicted effect of regionalized delivery care on neonatal mortality, utilization, financial risk, and patient utility in Malawi: an agent-based modeling analysis”

**Mission:** Authors assessed maternal healthcare regionalization (concentration of select services in higher-level facilities) through the use of an agent-based simulation model.

### Model:

1. **Scenarios:** Four regionalization scenarios were compared with the status quo
  - a. **SQ:** Women give birth at all levels of the health system (central hospitals, district hospitals, rural and community hospitals, and others)
  - b. **S1:** Restricted deliveries to facilities currently capable of providing C-Sections
  - c. **S2:** Restricted deliveries to S1 + Select facilities upgraded to provide C-Sections
  - d. **S3:** Restricted deliveries to facilities providing over 5 basic emergency obstetric/neonatal services in the preceding 3 months
  - e. **S4:** Restricted deliveries to S3 + select facilities upgraded to provide at least 5 basic emergency obstetric and neonatal care services.

Additional scenarios analyzed: Effects of upgrading obstetric readiness of ALL facilities, removing ALL user fees, and upgrading without restriction. Heterogeneity and parameter uncertainty were incorporated to create 95% PCI.

2. **Utilization function:** Incorporated patient-specific and health-facility-specific characteristics. Factors included neonatal mortality, utilization, travel distance, median out-of-pocket expenditure, and proportion of women facing catastrophic expenditure.
3. **Data collected:**
  - a. Facilities where the women gave birth were modeled
  - b. GPS location, Facility Type, Facility Management (private, NGO, Public)
  - c. Whether Fees were charged
  - d. Basic obstetric readiness score (availability of equipment and resources for obstetric care)
4. **Design details:**
  - a. Agent-based model with a synthetic cohort of 20,000 women with the following parameters adjusted to represent a random sample of pregnant women:  
*GPS locations, wealth, parity, age, literacy, education, marital status, urbanicity*  
*The number of antenatal visits, multiple gestations, and predicted risky deliveries*
  - b. Population density and poverty distribution were derived from the WorldPop project.
  - c. Data derived from the 2013 Millennium Development Goal Endline (MDGE) Survey in Malawi:  
*Parity, age, literacy, education, marital status, antenatal visits, risky delivery, and multiple gestation probabilities*
  - d. Travel routes and distances were calculated by the A\* search algorithm.

- e. Average incomes and out-of-pocket costs for delivery were taken from previously published literature.
- f. Each women's choice was modeled as a two-step process, on the basis of the choice function published by [Yorlets and Colleagues](#).
- g. Choice function was based on discrete-choice methodology applied to women in the MDGE survey and the 540 delivery facilities where they could give birth.
- h. Wealth, literacy, parity, antenatal care, predicted risk of delivery and predicted need for cesarean section served as individual characteristics, whereas distance, indicators of facility quality, fees, and facility type served as choice-specific characteristics.
- i. Conditional logistic regression determined the relative importance of these characteristics and the latent classes that underlay individual preferences
- j. Each woman in our study was first probabilistically assigned to a latent preference class, on the basis of her wealth, literacy, parity, receipt of antenatal care, predicted risk of delivery, and predicted cesarean section.
- k. Conditional on membership in each latent class, the woman was matched to her most likely delivery facility.
- l. An expense was defined as catastrophic when it was greater than 10% of a woman's yearly expenditure. (**Threshold**)
- m. All delivery facilities within 100 km of a woman were included in her choice set.
- n. Factors influencing each woman's facility selection were the following: facility type, basic obstetric readiness score, road distance, and whether the facility charged fees for delivery.
- o. We calculated the probability of delivery at each facility and the woman was then assigned, probabilistically, to deliver at a single facility.
- p. The woman then travelled through Malawi's road network to her assigned facility, and neonatal mortality was then probabilistically determined (Distance to the facility and travel time to reach it, its obstetric readiness score, its type, and whether fees were charged were recorded).

## Results:

| Description                                     | Neonatal mortality decrease, per 1000 livebirths (95% PCI) | Women travelling further for care, % (95% PCI) | Mean increased travel distance, km (95% PCI) | Utility decrement (km required to overcome)* | Risk of catastrophic expenditure, % chance (95% PCI) | Mean per-capita out-of-pocket expenditures, US\$ (95% PCI) | Deliveries by caesarean section, % (95% PCI) |
|---|--|--|--|--|--|--|--|
| Scenario 1 Current caesarean section hospitals  | 11.4 (9.8-13.1)  | 65.4% (64.6-66.2)                              | 7.2 (4.5-9.9)                                | 15.8   | 14.7% (14.5-14.9)                                    | \$19.59 (19.31-19.87)                                      | 14.7 (14.5-14.9)                             |
| Scenario 2 Expanded caesarean section hospitals | 11.6 (10.2-13.1)   | 57.7% (57.1-58.3)                              | 4.4 (1.5-7.2)                                | 9.5  | 11.3% (11.0-11.5)                                    | \$14.07 (13.77-14.37)                                      | 10.4 (10.2-10.6)                             |
| Scenario 3 Current BEmONC hospitals             | -1.4 (-3.0-0.2)  | 42.6% (42.3-42.9)                              | 1.7 (-1.2-4.5)                               | 3.9  | 7.8% (7.5-8.1)                                       | \$7.68 (7.39-7.96)   | 5.2 (5.0-5.4)                                |
| Scenario 4 Expanded BEmONC hospitals            | -1.1 (-2.7-0.6)  | 37.3% (37.0-37.7)                              | 1.1 (-1.8-4.0)                               | 2.6  | 7.5% (7.2-7.8)                                       | \$7.33 (7.03-7.62)   | 5.0 (4.8-5.2)                                |

PCI=posterior credible interval. BEmONC=basic emergency obstetric and neonatal care. \*The utility decrement is presented as the number of km that a woman would have to be moved closer to her delivery facility to overcome the utility difference.

Table: Summary of the predicted results of each of the four regionalisation scenarios, compared with the status quo

To incorporate parameter uncertainty and heterogeneity, the model was run 200 times for each cohort and scenario combination, leading to 1000 runs of the model (200 for the status quo, and 200 each for the regionalization scenarios), for a total of 20,000,000 individual patients. Modeling was done in **AnyLogic** (version 8.1), with the analysis done in **R** (version 3.4.0). Results are presented as mean (95% posterior credible interval [PCI]).

Women were predicted to fall into two classes of preference, with 65.7% (95% PCI 63.8–67.6) of women falling into a class whose decision-making was significantly driven by distance and user fees, and the remaining falling into a class showing a preference for delivery at a central hospital and for increased obstetric readiness among facilities. (Maybe send out a survey?)

1. **S1** reduced mortality by 11.4 deaths per 1000 live births, the cesarian section rate rose by 14.7%, travel distance increased by 7.2 km, out-of-pocket costs tripled, and the risk of catastrophic expenditures increased from 6.4% to 14.7%.
2. **S2** reduced mortality by 11.6 deaths per 1000 live births, the C-section rate rose by 10.4%, travel distance increased by 4.4 km, out-of-pocket costs tripled, and the risk of catastrophic expenditures increased from 6.4% to 11.3%.
3. **S3** and **S4** had no effect on neonatal mortality and no effect on C-section rate.

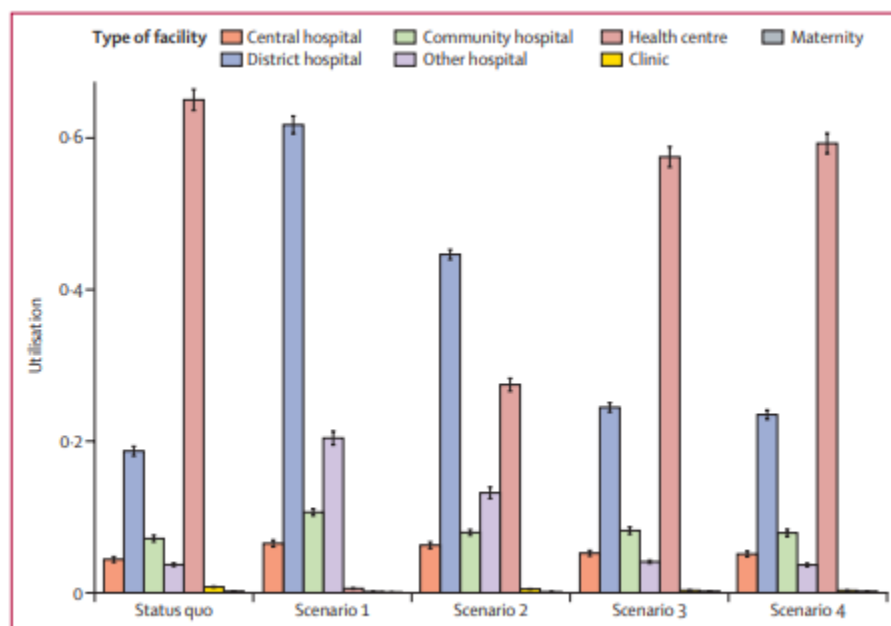


Figure 1: Use of delivery services under each scenario

### Concluding remarks:

1. Scenario 1 would shift the burden of delivery care away from health centers to district and private hospitals. All regionalization scenarios saw women choosing facilities with higher obstetric readiness scores.
2. *When compared with the status quo, regionalization scenarios were predicted to decrease women's utility, despite using facilities with better obstetric readiness (table). This implies that, if they were allowed a choice, they would still prefer a setting of decentralized delivery care.*
3. Scenarios 1 and 2 worsened financial risk for the entire population, whereas scenarios 3 and 4 worsened financial risk for the poorest 40% of the population.
4. We found that no policy (decrease/remove user fees, etc.) was sufficient to overcome the population-level utility decrement predicted to follow regionalization strategies.
5. *We found that focusing on basic emergency obstetric and neonatal care capabilities is insufficient to improve neonatal mortality significantly.*

6. *However, because of the increased distance, regionalization was associated with a predicted increase in disutility among pregnant women, primarily among the poor and less educated, who make up two-thirds of the population in Malawi. This utility decrement was not predicted to be overcome by making delivery free or by further increasing the obstetric readiness at the regionalized centers.*
7. Because women's utility is strongly dependent on distance, policies aimed at decreasing the transportation barrier that women face might improve utility.

#### **Model limitations:**

1. Although we used a global reference measure of obstetric service readiness, its relationship to perceived quality among women is unknown. As such, our conclusion that improved readiness could not overcome the utility decrement produced by regionalization scenarios should be interpreted with caution, especially because evidence from other settings has shown an increase in satisfaction among patients who bypassed lower-level facilities.
2. The actual amount of money charged at any of the delivery centers was not available in the dataset; all that was available was a binary indication of whether fees were charged.
3. Because of an absence of data to predict the changes in facilities that result from policy interventions, the time horizon for this study was limited to one delivery. This limit introduces an assumption that the current mortality estimates, derived from the published literature, will remain consistent in the face of increased demand.

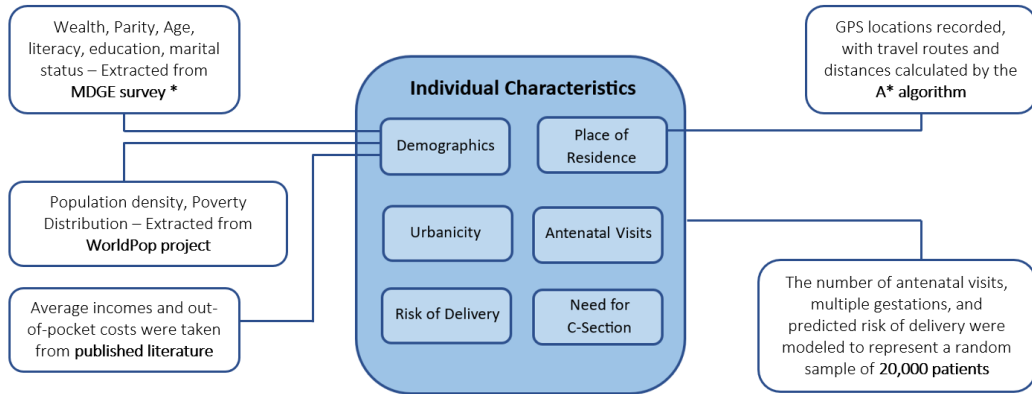
#### **Model Validation:**

1. The status quo for maternal delivery in Malawi was modeled first to serve as validation. Results for each regionalization strategy were then modeled and compared with the status quo.
2. The primary outcomes of our study were neonatal mortality, the location of delivery, and the distance travelled for delivery. The secondary outcome was the assessment of individual utility.
3. Outputs of the status quo scenario were compared with the known joint distribution of wealth and location in Malawi, the distribution of maternal delivery across facility types, and the estimated preference class breakdown from [Yorlets and colleagues](#).
4. Because the utility is not quantifiable and because valid cost data were not available, a so-called willingness to travel calculation was undertaken to make the utility more concrete (**Utility function quantization can be discussed**).
5. Utility differences between the status quo and each regionalization strategy were converted to the number of km that a woman would have to travel to overcome this utility difference.

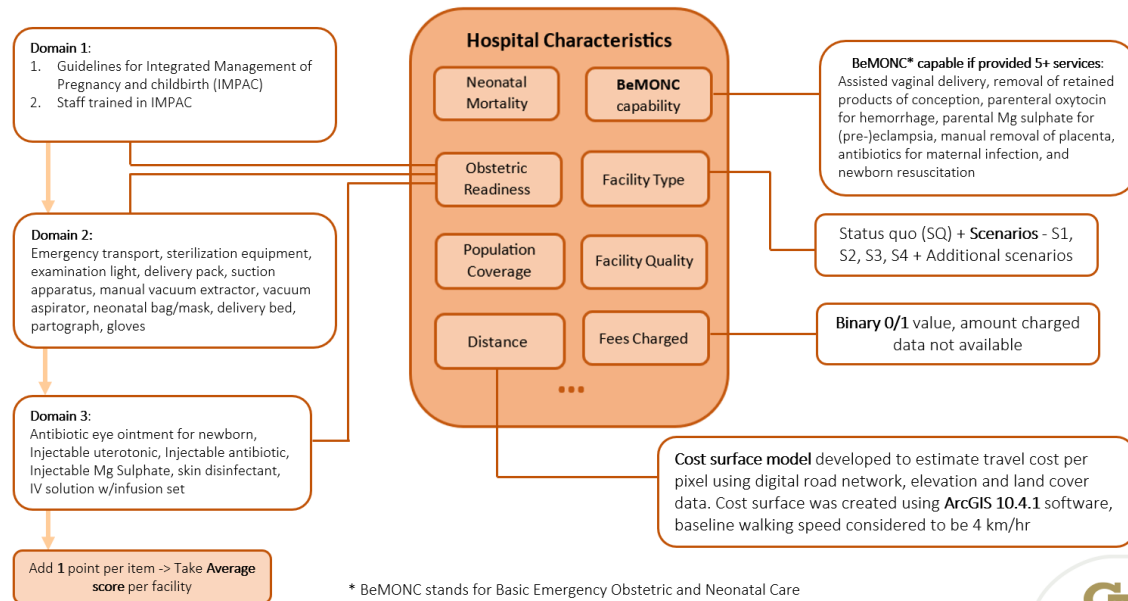
### **Author's suggestions:**

1. Regarding regionalization of maternal delivery services, the predicted increase in demand at district hospitals, along with the predicted outsourcing of demand to the private and non-governmental sectors, might aid policymakers in targeting the scale-up and distribution of the workforce. Additionally, although delivery at home in Malawi is discouraged, the increased disutility due to regionalization might result in an increase in home deliveries, for which the ministry should be prepared.
2. Regionalization strategies focusing only on basic obstetric care are likely to result in minimal reductions in mortality, while still requiring women to travel further for their care. The expected benefits of regionalization should be weighed against these potential staff-related and patient-related consequences, and regionalization policies should incorporate measures such as improved transportation and increased protection against financial risk to mitigate the potential inequity that they generate

## Agent-based model Outline:

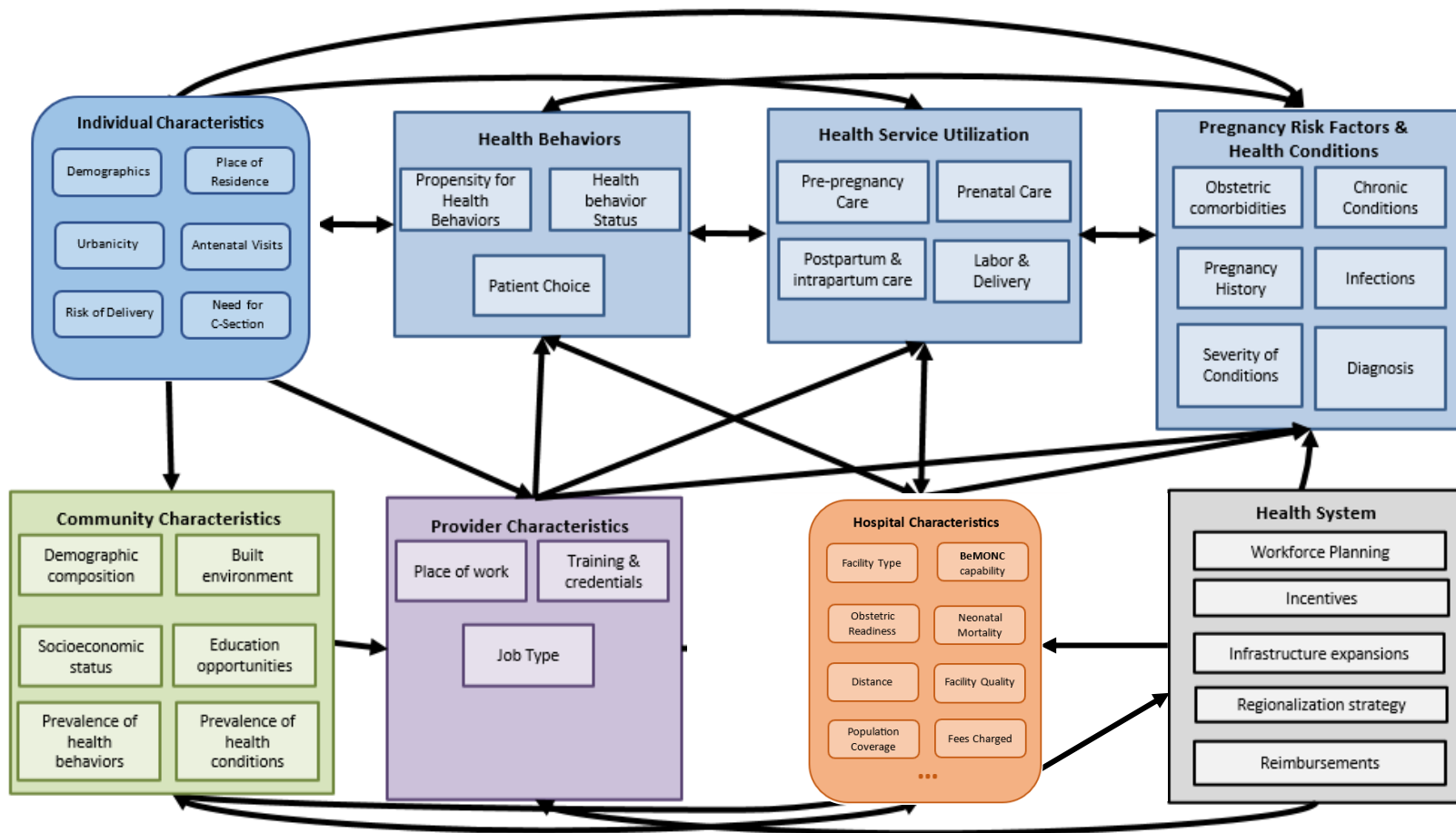


\* Millennium development Goal Endline (MDGE) survey 2013 was undertaken as part of the UN's MDGs, currently replaced as of 2015 by the Sustainable Development Goals (SDG's) which covers broader sustainability measures for 2030



\* BeMONC stands for Basic Emergency Obstetric and Neonatal Care





Agent-based model outline