DRAFT FOR COMMENT

Concept Proposal
Barrier Reduction Model (BRM)

A Model for Examining the Effectiveness of Alternative Barrier Reduction Policies to the Introduction of New Technologies

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Concept Proposal

The Barrier Reduction Model (BRM): A Model for Examining the Effectiveness of Alternative Barrier Reduction Policies to the Introduction of New Health Technologies

This short note describes a concept for a simulation model to help understand what it might take (time and money and programs) to relieve access barriers to the introduction of new health care interventions in poor countries. The idea of the BRM model is to allow the user to calculate the coverage, costs, time and other consequences of alternative policies for relieving access barriers to the introduction of particular health interventions. It is intended as tool for planning the implementation of new health technologies in countries and regions where the formal health system is inadequate to reach most people, particularly poor people. Secondarily, BRM is a tool for guiding future research priorities concerning what evidence is really needed to make decisions about relieving access barriers.

The model is a short term planning device. It is built on a current assessment of access barriers in each country and provides estimates of the likely results of various barrier reduction strategies as modeled by the user of the model. It also is able to answer questions about the best combinations of barrier reduction policies to meet time and money constraints, The model does not make long term projections of benefits and costs of these strategies, which might require including certain benefits and costs of health system impacts, workforce productivity, economic development, and the like.

Even though the model is limited in scope, it is clear that available data is inadequate to understand the prevalence of specific access barriers to a new intervention, to know how effective barrier reduction programs will be in overcoming these barriers, and to make projections of uptake of the new technology over time if nothing is done to reduce access barriers. Implementation of the model will require collecting consensus opinions on these key parameters from country experts to supplement available survey data.

Key Terms

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
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<tbody>
<tr>
<td>Intervention</td>
<td>The health enhancing technology being introduced (vaccine, MCH program, etc.)</td>
</tr>
<tr>
<td>Access Barrier</td>
<td>The factor which impedes effective demand for the intervention (such as inability to pay, too far a distance to travel, lack of awareness of the intervention)</td>
</tr>
<tr>
<td>Technique</td>
<td>The barrier reducing policy instrument or program such as health insurance, community health workers, social marketing to create awareness, financial incentives for consumers and providers, etc,</td>
</tr>
</tbody>
</table>
Cell   Population subgroup, the basic demographic building block of the model. Generally means a breakdown of country population by income status and by urban/rural location.

Segment Sub set of the population in a cell according to which barrier or barriers are constraining the availability and their willingness to consume a new intervention.

**BRM Concept Summary**

The starting point of the model allows the user to pick a population (a country or a subset of that country’s population), a particular intervention (one of several types of vaccines and other emerging technologies), and to specify one or more access barrier programs (techniques) in order to get estimates of the resources required (time, money) to achieve target levels of utilization of the new technology. The model has a baseline scenario, which estimates costs, time and uptake of the intervention in the country if the intervention is introduced passively, without explicit barrier reducing programs.

Having determined the baseline, the model would allow users to specify scenarios composed of combinations of access barrier reducing programs to accompany the technology launch, and for each scenario the model would compute the expected utilization response, the program costs, and the elapsed time needed to reach a target threshold. These scenario results would be compared to the (passive) baseline policy scenario and to other scenarios created by the user. The model also provides a capability for optimization, or selecting the best combination of programs for achieving maximum coverage within given time and budget constraints.

Six types of parameters are used by the BRM: (1) the baseline prevalence of specific access barriers in each segment (cell) of the population (urban poor, rural poor, etc.), (2) the average utilization response per unit of time for each technique or program of barrier reduction in each of the population cells (e.g., per CHW per month), (3) the upper limit on the utilization response for each technique in each cell, (4) assumptions supplied by the user about usage targets, the available budget and time, and which programs (techniques) are to be used, with which levels of intensity, (5) the nature of the intervention including the number of doses required, the timetable for them, and assumptions about the follow through compliance rates for each cell, and the (6) costs for each technique, including both the fixed costs to implement this technique and the cost per unit of utilization.

The model allows scenarios to be constructed that apply user-selected techniques to populations that have a pre-specified distribution of access barriers. In general, the kinds of access barriers and known remedies are shown in Table 1 below. The barriers we worry about for formal care services and products are usually such things as: Supply barriers such as lack of available supply sources and/or cold chain channels, and lack of...
motivation of providers. Demand barriers that limit persons from actively seeking health services are usually described as inability to pay, lack of awareness, inadequate knowledge to decide, distrust or contrary beliefs, and geographic isolation and distance-to-source. This grid would be different for particular interventions (vaccine, treated nets, MCH programs, etc.). Sometimes they occur alone for a segment of the population, while other segments require 2 or possibly more techniques for relieving access barriers.

**Table 1 Illustrative Techniques for Relieving Access Barriers**

<table>
<thead>
<tr>
<th>Techniques</th>
<th>Access Barrier</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A. Supply or Availability</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Visiting Nurses from facilities</td>
<td>Distance</td>
<td>Nurses (tethered to facilities) who do circuit visiting programs</td>
</tr>
<tr>
<td>2. scheduled magnet clinics</td>
<td>Distance</td>
<td>A well publicized program of visits by providers to regular vaccination sites</td>
</tr>
<tr>
<td>3. creating more permanent clinics</td>
<td>Distance</td>
<td>For a broader range of services</td>
</tr>
<tr>
<td>4. Provider payment incentives</td>
<td>All</td>
<td>This increases provider motivation and the yield of all other techniques</td>
</tr>
<tr>
<td><strong>B. Demand</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. subsidize price to be zero</td>
<td>Ability to pay</td>
<td>The baseline scenario assumes vaccination is compensable service of providers as mitigated by preexisting insurance or other subsidy programs</td>
</tr>
<tr>
<td>6. subsidize price to be below zero</td>
<td>All</td>
<td>This increases the consumer motivation and the yield of all other techniques</td>
</tr>
<tr>
<td>7. social marketing</td>
<td>Awareness</td>
<td>general publicity campaigns</td>
</tr>
<tr>
<td>8. targeted H. Education Programs</td>
<td>knowledge</td>
<td>tailored to the vaccine introduction and its benefits</td>
</tr>
<tr>
<td>9. Community Health Workers</td>
<td>knowledge, distance</td>
<td>trained and deployed specific to the vaccine program, without training to give the vaccine itself</td>
</tr>
</tbody>
</table>

The table shows a number of access barrier reducing techniques. The two that deal with increasing the incentives for higher usage are different than the others. Programs that encourage providers (formal, contracted NGOs, or even CHWs) to seek higher volumes through some program of incentives will motivate the providers to take steps to increase income by recruiting qualifying candidates. This ‘added motivation’ should increase the yield of all barrier reducing programs. And, it should also increase the yield (uptake, and time to uptake) of the baseline scenario (shifting the ‘S’ curve to the left). Similarly, the idea of paying bonuses in the form of conditional cash payments (CCTs) to qualifying consumers to be vaccinated is a motivating factor, and would increase the yield of
whatever barrier reduction program is implemented, including the baseline ‘passive’ program.

There are important limitations of the BRM model. It is designed with the idea in mind of selecting a program or combination of programs to accompany a launch of a new technology. The model, as conceived here, does not provide for phased or sequential introduction of programs. The user can alter the ‘bundle’ of programs within and across population cells freely, but cannot introduce programs in sequence; the idea is to select a ‘program’ to accompany the launch that is able to achieve the required results, or is able to achieve the best results for given resource constraints. Second, the BRM does not explicitly deal with all barriers to introduction of a new technology in country; certain provincial or district regulatory barriers may exist that will take time (if not money) to resolve. As designed, the model does not incorporate these kinds of barriers and programs to overcome them. Essentially, the BRM assumes that upon approval in the country, the new technology is launched along with all barrier-reducing programs.

Third, the model is not able to be based on available statistics or research evidence. For each population cell (rich/poor, urban/rural in a province or district) data need to be input into the model for the extent of the particular access barriers listed in the Table 1. Similarly, the baseline projection of uptake over time for the intervention absent any barrier-reduction programs needs to be modeled. Unfortunately, this model is intended to be used with new intervention, for which there is no experience, and whatever experience may appear relevant from the experience in one country is of dubious value in modeling access problems and baseline uptake in other countries of interest. So, the data needed (see the six types of data required by the model listed earlier) cannot be directly obtained but must be taken from a combination of user assumption, by using some data from surveys and research studies, and by consensus judgments of in-country experts. As some country implementation experience is gained for each new technology it should be possible to provide some default parameters in the model.

The model is intended to be a computational aid to the users. As a software tool, it might be composed of 10 modules:

1. a **home page** that allows the user to choose among functions (view or create a scenario, create or modify input data, export data or scenario results to excel)

2. a **population data input module**---that allows the user to populate or revise a small data set of necessary parameters for running the scenarios

3. **Access module** – this module contains the data developed for the prevalence of particular access barriers in the various population cells (rural poor, urban poor, etc.) which are need to define the limits on the uptake from particular barrier reduction programs used in the model
4. **Intervention module** --- this would allow a place for storing data and default parameters for particular interventions (vaccine 1, vaccine 2, MCH intervention 1, etc.). The user would see this only in the scenario construction module.

5. **Country/region module** --- a place to store data pertaining to countries and regions.

6. **Technique module** --- a set of parameters for costs and for yield per time period that apply to particular techniques for barrier reduction. These can be pre specified at the country or by using international default values. Users can also specify their own techniques or combine techniques and revise parameters accordingly.

7. **Scenario creation module** --- that allows the user to create country solutions, and facilitate revising, saving and retrieving these scenarios: This module would have the user select (1) population to use, (2) technique(s) for increasing access, (3) reports and comparisons to be produced, (4) to specify ‘what if’ situations including sensitivity analyses, and (5) if optimization constraints are to be used

8. **Reporting Module** --- The reporting module would allow the users to see charts and graphs containing results of a particular scenario compared to other scenarios, including the baseline projection of uptake if no explicit programs of barrier reduction are undertaken.

9. **Optimization module** --- allows the user to specify time and money constraints to create solutions. The user would see this as part of the scenario module, but it is actually a separate part of the model.

10. **Export and print module** --- allows the user to create export or print files from modules.

**How Would the Model Work**

The model would calculate utilization, costs and time for scenarios wherein users choose techniques for relieving access barriers to the introduction of a new medical intervention. The results are dependent on population characteristics, the access barrier configuration assumptions for the chosen population, parameters reflecting costs and yield of techniques of overcoming barriers, and other user-selected parameters and constraints. Figure 1, explains how the model would work.
Figure 1: Optimization Based Barrier Reduction Model

**Optimization Based Barrier Reduction Model: Master Flowchart**

1. **Initial Settings**
   - Country Selection
   - Region/Prov. Selection
   - Urban/Rural Selection
   - Poor/Rich Selection
   - Intervention Selection (Vaccination Default)
   - Time Horizon Selection (e.g. 5 Y)

2. **Scenario Choices**
   - Solution Choice
     - With ABR(s)
     - User Defined ABR(s)
     - No ABR
     - Evidence Based ABR(s)
   - Optimization?
     - LP Optimized ABR(s)

3. **Scenario Functions**
   - Applying Existing Supply/Demand Parameters
     - Unit Cost
     - Pop./Year to be Covered
     - Illustrate Results & Graph Trajectories
   - Applying User Preferences for ABRs
     - Unit Cost
     - Pop./Year to be Covered
     - Illustrate Results & Graph Trajectories
   - Prioritizing Barriers
     - Unit Cost
     - Pop./Year to be Covered
     - Illustrate Results & Graph Trajectories
   - Determining best combination of ABRs
     - Unit Cost
     - Pop./Year to be Covered
     - Illustrate Results & Graph Trajectories
   - Defining Objective Function: Max Coverage, Min Cost, etc.
   - Defining Linear Constraints
   - Constructing a classic LP problem
   - Solving LP (by Simplex etc.)

4. **Scenario Outputs**
   - Scenario Results, Comparisons, and Sensitivity Analyses
   - Illustrate Results & Graph Trajectories

**Scenario Functions**

- Illustrate Results & Graph Trajectories
- Illustrate Results & Graph Trajectories
- Illustrate Results & Graph Trajectories
- Illustrate Results & Graph Trajectories
The building block of the model is the population cell defined for a particular region of interest (a province, a region of a country, or an entire country) and cells within that population which are defined according to access barriers they may experience. The population cell can be determined in Figure 1 in the upper layer called “Initial Settings” by collecting the initial information about the target population.

These cells might be shown as Table 2 below, indicating the kinds of access barriers and combinations of barriers that might be relevant. The cells of a province include key access categories: urban poor, urban not poor, rural poor, rural not poor. Two additional cells are created in the model. (1) the rural poor cell is partitioned to include one group of geographically identifiable persons reflect facing complex barrier situations (geographic locations where the people are isolated, very poor, and illiterate). (2) regular users of formal care by someone in the family.

For each of the six cells, the model would assemble data on the prevalence at baseline of the access categories shown in Table 2. These ‘segments’ or partitions of the cell population become the basis for setting limits of the effectiveness of barrier reduction techniques. The decision on the limitations of the effectiveness of barrier reduction techniques are implemented in the third layer of the Flowchart 1. In this layer depending on the scenario chosen by user in previous layer (layer two) setting the limitation on each barrier reduction technique enables the model to switch from a less effective technique to one or a combination of more techniques with higher level of efficacy.

Within every Cell, there are several types of barriers, and in the case of remediable barriers, they sometimes can occur in combination. The kinds of barriers the model required data on within each cell are as follows;

- What fraction of the population is subject to trust or belief barriers that might cap the potential for vaccination uptake?
- What fraction of the population in the cell is subject to only a single barrier? Which one?
- What fraction of the population is subject to a situation of two barriers? Which two?

These questions ought to be answered by user in the upper layer in Figure 1 (Initial Settings layer) or otherwise retrieved from stored data for each cell once the cell selection has been completed by user in the upper layer.
Table 2  The Structure of Baseline Access Barrier Categories Used in the Model

<table>
<thead>
<tr>
<th>Cells</th>
<th>Single Barriers</th>
<th>Secondary Barriers (2)</th>
<th>Complex Barriers (3)</th>
<th># access barrier segments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Regular user of formal care in the family</td>
<td>Trust or Belief Awareness only</td>
<td>None</td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>2. Urban non Poor</td>
<td>Trust of Belief Awareness only</td>
<td>None</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>3. Urban Poor</td>
<td>Trust or belief Knowledge only</td>
<td>Knowledge and ATP</td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>4. Rural Non Poor</td>
<td>Trust or Belief Knowledge only</td>
<td>Distance and Knowledge</td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>5. Rural Poor</td>
<td>Trust or belief Knowledge only</td>
<td>Distance and Knowledge</td>
<td></td>
<td>7</td>
</tr>
<tr>
<td>6. Rural Complex Poor (geographically identifiable)</td>
<td>Trust or belief</td>
<td>None</td>
<td>Knowledge, ATP, and Distance</td>
<td>2</td>
</tr>
</tbody>
</table>

For example, if we know that the 25% of the persons in Cell 1 have a barrier of “awareness only”, then we know that a techniques for removing awareness barriers (such as social marketing or advertising/promotion campaign of some sort) has an upper limit on uptake of only 25% of the persons in that cell. Cell 2 is more complicated, since it has three population segments where persons with barriers might be found. Across all of the cells, we have 22 possible configurations of access barriers, plus six (one segment per cell) where persons without barriers might logically be found. These persons, free from identifiable access barriers, form the basis for the baseline uptake scenario for the vaccine (discussed more in the next section).

This segmentation of the population, and the associated numbers of people per segment, become the basis for setting limits on the upper limits of effectiveness for particular interventions which in turn determine how each of the scenarios function to reach a solution set in the third layer in Figure 1 above.
Baseline Access Situation and Baseline Scenario of Uptake

A map of access barriers and technologies to overcome them is needed to understand options for creating scenario solutions. The prevalence of people in the cells is illustrated by Table 3 below. It illustrates the kind of Cell segments that are used by the model to set limits on the use of particular barrier-reducing programs.

Table 3 and the baseline access situation may be partly informed by country specific survey data from W.H.O (World Health Survey) or the World Bank’s LSMS, or the DHS (from USAID) or the household utilization and expenditure survey for NHA might all be useful in approximating the baseline access configuration of the population. Surveys might be particularly useful in sizing segments according to (1) extent of the barrier of not having connections to the formal sector, (2) literacy (education) and related knowledge barriers, and (3) indicators relating to the extent to which trust belief may prohibit uptake at all. The survey data, to the extent it exists, may also permit a more useful texture for the extent of poverty or wealth barriers. Surveys may be useful in defining the extent of distance barriers, though other data might be more useful (geographic variation in the density of providers).

Table 3  Illustrative Data for the Urban Poor Cell

<table>
<thead>
<tr>
<th>Barrier Prevalence In the cell</th>
<th>% Cell Population consider this the only Barrier</th>
<th>% Cell Population consider this barrier as a secondary</th>
</tr>
</thead>
<tbody>
<tr>
<td>No formal care</td>
<td>20%</td>
<td>10%</td>
</tr>
<tr>
<td>No awareness</td>
<td>25%</td>
<td>15%</td>
</tr>
<tr>
<td>No knowledge</td>
<td>90%</td>
<td>15%</td>
</tr>
<tr>
<td>Too Far</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>No ability to pay</td>
<td>100%</td>
<td>55%</td>
</tr>
<tr>
<td>No trust</td>
<td>10%</td>
<td>5%</td>
</tr>
<tr>
<td>no barriers</td>
<td>0%</td>
<td></td>
</tr>
</tbody>
</table>

The baseline access situation, as illustrated in Table 3 is very important here because it forms the basis for baseline scenario for the BRM. The baseline scenario represents the uptake, time and money required to introduce the vaccine (or whatever) passively in the cell (and by aggregation to the region or country). This uptake path represents (completed course vaccinations) over time. Figure 2 below represents this relationship.

The assumptions behind this projection of utilization are:
- Vaccine provided to formal care providers (public and private) and public health officials
- Full price for the vaccine, as mitigated by insurance and other programs in the country at baseline
• Passive introduction, without social marketing or extraordinary (expensive) publicity

The baseline projection would represent a passive introduction of the new intervention and it would be the primary comparison to be made with user defined scenarios about access barrier reduction programs. This baseline timeline of uptake (and related costs) would reflect the expected relationship of uptake over time, possibly following some form of “S” shaped curve often seen in technology diffusion studies of health care products and services, and is illustrated in Figure 2 below. This shape suggests that at first very slow uptake is achieved as only ‘early adopters’ seek care. This is followed by more rapid diffusion of the technology as ‘followers’ seek service as publicity and confidence builds. After the majority of users have sought care, the last phase of diffusion occurs as the remaining ‘late adopters’ finally get around to seeking the service. The parameters of baseline model of diffusion for the intervention is very important, because it is the reference point for measuring the differential impact of particular barrier reduction scenarios. The parameters that are key to the baseline projection of uptake are:

• what is the upper limit on usage in this population (or cell population) if no special access-reducing programs are implemented
• how long does it take to get to this level of utilization?

**Figure 2  Baseline Model or Path of Technology Uptake**

![Baseline Model or Path of Technology Uptake](image-url)
The effect of the “barriers” is assumed to be the gap between the “s” curve and the achieving 100% population compliance within the minimum time required by the course of treatment (for a vaccine, possible 3-4 doses over 12-18 months). So, the reason for achieving, say, 25 percent penetration after three years reflects the consequences of access barriers. The model allow the user to specify program scenarios that eat into this access barrier problem, essentially shifting the ‘s’ curve to the northwest (shortening elapsed time, or increasing penetration rate, or both) If the baseline scenario is mis-specified, then the program effects (which are added to the baseline situation) will be overly optimistic or unduly pessimistic.

Where to get data for the baseline (passive introduction) scenario? While the particular shape may follow some empirical evidence about introduction of similar products in similar situations (a default option for the model perhaps) we also expect that the baseline model will need to be informed by professional opinion in-country. The literature on technology introduction may provide some evidence on which to base this relationship, but for a new technology data for estimation is not going to be available. The best guide we have is going to be the baseline access situation that is available from consensus judgments of local experts.

A simple illustration of how the model might work is based on 2 subgroups of population with remedial barriers: one segment with only one barrier, and a second segment with 2 barriers. The models specifies two constants and two production functions for access barrier reduction for a particular technology (say CHWs to remedy a primary barrier of distance for one segment, and to help reduce knowledge and distance barriers occurring for another segment of the cell population: Two technologies of remedy are illustrates: T1 is the primary barrier facing this cells population. T2 is a second technique, when coupled with T1, can relieve the access barriers for the population suffering from both barriers

- $F = \text{the fraction of the population reachable through formal channels and otherwise assumed to not have an access barrier}$
- $UL = \text{upper limit on the } \% \text{ of the population that are so distrustful or isolated as to not be practically reachable by removing access barriers.}$
- $U(t) = P(T1) (t) \text{ to a limit of the number of persons who face a primary barrier}$
- $U(t) = S(T1,T2) (t) \text{ to a limit of the number of persons whose are reachable through secondary access barrier reduction using both T1 and T2 ---- leaving the balance of persons in the cell who are not reachable}$

The production functions posit uptake of the technology as rate per time period, subject to an upper limit on the number of persons who can be reachable, either with this technology alone or as a secondary barrier reduction activity. The simple graph below (Figure 3) displays the result in terms of utilization. The first segment of the population (horizontal axis) is reachable via supply push through the formal sector, the second
segment is reached by using this technology alone as a primary vehicle for overcoming a single access barrier, and the third segment represents barrier alleviation through joint application of this and another technology. The final segment is presumed to be unreachable.

**Figure 3 Simple View of Usage**

![Graph illustrating utilization levels](image)

### Specifying Productivity of the Access Creation Techniques

The level of productivity or yield from a technology would be specified in each cell according to levels set by local experts. The value would be the level of utilization achievable by the barrier reduction technique among population suffering from this barrier alone. The level should be an approximation of the ‘typical’ households we might expect to find in the cell facing this access barrier and for a preset level of intensity of the technique (how many CHWs per village, or per 1000 persons). The productivity would be set at ‘typical’ level of utilization capture per time period (say 35 vaccinated persons a month per CHW when they are applied at an intensity of 1 per 1000 persons in villages). The BRM will also include a user option (in creating a scenario) to specify the level of intensity of each selected technique (CHWs, etc.) The ‘slider button’ feature would allow the user to select the intensity for each technique in the scenario. That feature would apply a ‘factor’ (the default is the typical level of intensity of the technique and equals 1.0) to the productivity (and to the variable costs of the technique). The slider button might look like:
When segments of the population have multiple barriers, and require multiple techniques for creating utilization the situation is more complicated, though based on the parameters about productivity defined above. The production function in these segments requires multiple inputs (a factor that eliminates the knowledge barrier, and another technology for eliminating the ability to pay problem). Sometimes, as for CHWs, multiple access barriers can be jointly resolved with a particular intervention. For these situations the productivity of the technology in relieving barriers for different situations needs to be specified by local consensus at the beginning.

The way productivity would be estimated for populations requiring multiple techniques to overcome multiple barriers would be as follows. We assume that the techniques (for removing knowledge and income barriers) are not substitutable. Both problems need relief or no utilization will occur. This yields a simple solution. The rate of utilization used in such instances is the lowest of the two interventions, or lowest of the three interventions if there are three techniques being combined. Essentially the multiple interventions would be assumed to be implemented in lockstep, or fixed proportions and achieve a level of utilization per time period equal to the lowest rate assumed for the individual techniques.

**Costs**

The costs of techniques for relieving access barriers will be defined within population segment and will be taken from the literature to the extent possible. The assumptions about production are consistent with a base cost, of the form

\[ C(t) = C(P) = A(P) + B(U(P)) \]

This has a fixed cost to set up the particular technology at a given level of intensity, and a variable cost per unit (or per time period) of utilization achieved. Changes in the intensity of the technology will alter costs. More intensity will reduce time to achieve the potential
utilization, but it will increase set up and unit costs. For population segments requiring two or more interventions, the costs are simply the sum of fixed and variable components.

A picture of the access program costs associated with barrier reduction in an illustrative cell is shown in Figure 4 below. The shape of total costs in the segments reflect fixed costs of initiating programs and the variable costs of operating them. The unit variable costs are higher as we move from easier-to-reduce-barriers on the left to the more difficult segments on the right. The first segment is quite cheap---supplying the intervention through formal channels. The second segment deals with those people who would consume if only they were made aware--- so the costs shown represent fixed costs of a social marketing campaign (for example). The third segment have barrier(s) removable by putting CHWs in place, and such a program has both fixed and variable costs. On the far right, is a more difficult segment that requires more than one intervention and the costs are both fixed and variable.

Figure 4 Costs of Reaching the Rural Poor

Total Costs

a,b,c,d = fixed costs of programs
i,j,k,m = variable costs per success
are the slopes

100% Coverage of Intervention

formal channels

awareness building

CSWs

in conjunction with other interventions
Time

By assumption, we know that each technique can produce utilization at some rate per time, and we know what costs are per technique (fixed and variable with volume). The basic operation of the model will ask the user to specify how much elapsed time is available for the scenario (a year, 2 years, or unlimited). The time horizon is one of the essential parameters that have to be determined by user in the Initial Settings layer of the Figure 1. This will allow the model to compute the level of achieved utilization (subject to whatever potential limitations there are) and the costs. Optimization questions related to time can also be answered by the model, including (1) for a segment or cell of the population, we can calculate how much time it will take to close the gap in utilization (between the fraction that will get it without access barrier reduction, and the upper limit on potential utilization), and how much it will cost. Or, it could tell us how high the utilization will be if we have only a fixed amount of money to spend. These are optimization questions.

Compliance Parameters

The model projects utilization of the new technology according to the clinical requirement. For most vaccines more than one dose is required, with follow up doses occurring over many months. This kind of intervention clearly is more difficult to achieve compliance because effort is required not only to get otherwise-reluctant people to the point of service once, but also to get them to return multiple times (a similar problem occurs for modeling antenatal care compliance). The model specifies the clinical requirements of doses and time period for each intervention. The model also captures related compliance realities by specifying a parameter for the probability-of-retuning for the next dose. For example, if this probability is 0.9, then the expected utilization for a second dose is 0.9 as high as the getting to the first dose, and the expected utilization for a third dose is only 0.81. If a fourth dose is required for a vaccine, then the expected utilization of completing the required protocol is only 0.73 as high as getting to the first dose. This is a huge limiting factor in achieving high uptake for multi dose interventions.

Scenario Construction

Scenario specification is the way users control what the model is doing. We imagine a full screen of choice parameters which would enable the user to select what the model is doing and what comparisons might be sought by the user. Much of the selections regarding different scenarios are performed in one of the two layers titled Scenario Choices and Scenario Functions in Flowchart 1.

Several basic scenarios are defined for barrier reduction. Users are also required to specify other scenarios. They can specify a single barrier reduction technique, or several in sequence. The scenario specification module of the software also allow the user to focus attention on one segment or more than one segment of the population.
Each intervention could be considered the sole intervention for relieving access problems and achieving the theoretical maximum utilization. To do this would require a specification of the cost-output function for different segments of the cell population. This might look like the figures below (Figure 3). The advantage of this specification is that the cost of trying to use a single access reduction remedy (like financial incentives) could be modeled by CPM, and compared with other tools and mixed-mode solutions. It is also possible to use an optimization function to select the most effective tool for different segments of the cell population.

Several scenarios can be specified for vaccines or other interventions. Some might include:

1. --- Model supplied **Baseline Scenario**, given the current situation of access barriers in the Country, the time path of uptake from a passive introduction of the Intervention. This involves providing the intervention through public and private formal care sites in the region/country

User defined **Supply Barrier Reduction Scenarios**

2. --- Increasing the number of geographic places or sources of delivery by resolving cold-chain problems via generator enabled sites or by building facilities.

3. --- Increasing the motivation of formal sector providers by a program of incentives for successfully vaccinating (e.g. the multi-dose protocol) certain target populations

Users can also specify Demand **Barrier Reduction Scenarios**. These scenarios require users to specify which technology, and intensity parameters. Some examples of such scenarios are:

4. --- **Social Marketing or Publicity Scenario**, to relieve the barrier of lack of awareness of the intervention

5. --- **CSWs** placed in towns and villages in **Rural Areas only** and trained to administer interventions, to relieve access barriers of awareness, knowledge, and distance

6. --- **Financial incentives** (CCTs) for households to come to care sites to receive the intervention, to reach the persons with barriers in the **urban sites**

7. --- **A combination** of 3, 5 and 6 plus financial incentives for the CSWs and providers, to reach the most difficult to reach population segments in **rural areas**.

Users would be able to define now barrier reduction techniques (or combinations) using the scenario module. The software will need a module for “managing scenarios”, as this will be a complex activity for the user and a tool will be needed for both (1) specifying complex sets of parameters for a particular scenario, and (2) for storing and retrieving scenarios, all within the two layers of Scenario Choices and Functions in Figure 1.
Outcomes of the BRM

For each scenario selected by the user the following outcomes would be generated by the BRM as showed in the lowest layer of the Figure 1 titled Scenario Outputs:

- Uptake of the intervention cumulative by year (analogous to the ‘s’ curve) by cell and total
- Uptake of the intervention cumulative by year for each barrier reduction technique used in the scenario
- Prevalence or incidence of the disease following the application of the scenario intervention(s) compared to the baseline
- Prevalence or Incidence Gap remaining (100% - prevalence rate)
- Burden of the Disease that remains
- Time to achieve 10%, 20% 30%,, threshold utilization rates
- Cumulative Cost of the Access Reduction Program to reach the scenario Prevalence Rate
- Cost of each access barrier reduction program per case averted by this scenario
- Equity distribution of disease prevalence across the four basic population cells (urban non poor, urban poor, rural non poor, rural poor)—three measures (a) the ratio of usage per capita for the urban rich cell to the same ratio for the rural poor, and (B) that ratio for the urban relative to rural, and (c) that ratio for the Rich relative to the poor—these measures would be made by year so the temporal impact on equity can be seen (e.g., equity may worsen, then stabilize in one scenario of programs, while a different pattern is seen in another scenario)

Other standard reports available from the model will be:

1. Compare the outcomes for a set of scenarios identified by the user for the study region.
2. Compare the outcomes for each of the basic population cells for a scenario (e.g. a side by side display of all outcomes for each of the population cells).
3. The optimization report comparing results for the fixed budget scenario, the fixed time scenario, and the doubly constrained case
4. Compare optimization results for several different countries for the same disease and set of techniques for achieving access.
5. For one country, compare the optimization results for each of several medical interventions available

Optimization

The basic model allows scenarios to be built to allow different parameters to be selected to create outcomes of the sort identified earlier. Essentially these scenarios apply the parameters to the limit of coverage, answering the question, “what would cost to cover
the maximum number of people per intervention given the parameters of the scenario?" Or, alternatively, given a cost, how long would it take to achieve the limits on utilization? Or, a third scenario, if we specified a limit on both time available and budget, what would the maximum utilization be? And, finally, for these questions, what combinations of techniques will produce these solutions? For example, would we prefer to use CHWs or incentives? Would we be better off using CHWs deployed more intensively, or less so?

The exact optimization approach used by the model to deal with specific objective functions and user supplied constraints will likely vary according to whether an algorithm has been defined for this exact type of problem. In any case the optimization processes will be applied only in the right half of the layer titled Scenario Functions in Figure 1. Under the two scenarios of No ABR and User Defined ABRs in Scenario Functions layer of Figure 1 the model does not perform any optimization because by definition the baseline scenario is a forecast of the continuation of trends under existing health system situation. Likewise in the User Defined scenario we assume that the user based on her experience and knowledge has discretion over what to be employed from the set of available barrier reduction choices therefore the model does not intervene with user options meaning that no principle of optimization would be applied in the two boxes located in the left half of the Scenario Functions layer of Figure 1.

In the rightmost box of the Scenario Functions layer of Figure 1, the most intelligent module of the BRM will be employed in order to optimize the uptake of the health technology. The solution set in scenario 4 ought to be chosen subject to the donor’s budget constraints, among other necessary conditions and considerations. This module will be developed based on one of the two known techniques of computational optimization: 1) fine tuning of ABRs by means of repetition of simulation while incrementally changing the key parameters, and 2) mathematical optimization by means of Linear Programming (LP) techniques. In this scenario, the decision about the best optimization method among the two aforementioned options would be made in the process of evolution of the BRM. If the linearity preconditions imposed by LP techniques for both the objective function and constraints are reasonably met, the mathematical optimization would be preferred over the fine tuning method. A basic example of a relevant objective function here would be uptake of a new vaccine and constraints could be the budget and other resource constraints.

**Complexity and Severity of population situations**

The productivity (yield) situation for each access barrier reduction technique will be a parameter set by local officials or users to reflect the typical intensity of applying this technique. The default productivity also assumes some typical level of severity of the access barriers themselves in the population segment. The model can easily accommodate the possibility of selecting more or less severe barrier situations, which can be used to create scenarios of interest to the user (e.g. how much would cost and time change if particular were more severe than assumed? This is particularly useful in understanding
the productivity of the hard-to-reach populations suffering from many barriers—and productivity of the barrier reduction techniques may be much poorer than other populations because of the severity of the barriers for these complex groups.

There are two ways of thinking about how to downgrade productivity for particular techniques of barrier reduction for these complex populations, both based on the use of ‘factors’ assigned by users that are applied to the production and cost algorithms. One approach would be to let the user create a ‘factor’ for each barrier (in the scenario selection process) reflecting level of severity for that barrier (distance, poverty, knowledge, etc.). This would be done using the same idea as for electing levels of intensity of technique described earlier. If the particular access barrier is more severe than the default (say 1.5 or 2.0) then the productivity of any barrier reduction technique would be divided by this value (and unit costs multiplied by the factor). Any techniques applied to this segment of the more severe population would have this factor applied in this way.

A second approach is to create a factor for certain measureable barriers like distance, like literacy, and like poverty. For each of these we can set up a ‘slider’ feature that has values of the measure (e.g. a literacy rate, a density of population or formal care, or a per capita income). Default parameters for the productivity (and costs) would be based on some typical cell assumptions (the rural poor). But when considering the complex population the user could elect a lower literacy assumption (and a factor that reduces productivity and increases costs), or more remote and less medically dense population, or a more aggravated poverty situation. These factors would be multiplicative in their influence on the yield of a particular intervention which may create knowledge (and literacy matters), or resolve distance and ability to pay barriers. Here, the issue is how to exactly link literacy rate to the yield of knowledge creation technologies?

We could also consider creating a factor relating to the performance (and cost) of all barrier reducing techniques in a cell or country. This factor might follow the country to country variation in quality of governance, or Hansen et al (2003) rankings of access barriers. Using such readily available data we could introduce country level factor (where 1.0 is average) into the cost model (however specified) that will increase the cost of utilization (or decrease utilization for a given cost outlay) as a consequence of various unspecified problems in getting things done in the health system.

**Data Sources**

Little data is going to be available for this model from the research literature. The research needed to understand the parameters of access barrier reduction modeling is considerable. There are three problems. In cases where some data on technique effectiveness or cost is available, it is unlikely to generalize to particular countries or to the situation of a new kind of vaccine or other intervention. Second, the access configuration for particular interventions in particular countries is not going to be fully available, and will need to be supplemented by survey approximations (as discussed
earlier) and by local experts using an intense, guided consensus process. Implementation of data gathering in a specific country would require several weeks of work with in-country researchers and other informed officials to go through a process of consensus building to reach workable assumptions. In some cases the experts may not reach agreement, and a range of values may result. These ranges can be used to define particular scenarios and may be of great interest in doing sensitivity analyses.

Model Development Strategy

The development strategy would be based on a two step pilot for establishing proof of concept. The pilot would use, in phases, 3 countries and 2 hypothetical interventions. This approach is based on the view that much of the unknown at this point concerns how much ‘data’ can be gleaned from local experts about the access situation of the country and about the potential yield of particular interventions. The following 8 steps would constitute the pilot:

1. formally assess requirements for the model with Gates staff, and redo the concept to make certain the concept is properly configured as to outputs, inputs, user flexibility, etc. As a conceptual tool the Flowchart 1 will be also revised accordingly to illustrate the flow of sequential and parallel tasks that has to be performed by the model but also to illustrate the way that user interact with the software application.
2. select a single pilot country, a single intervention, identify several in country experts to work with on model formation
3. spend 2-3 weeks in country, collecting data, guiding the local experts to create assumptions for the model
4. revise the model concept for this application, and prepare software after presentation to advisors
5. present pilot model and results to Foundation, with advisors present
6. make decision about proceeding to phase 2 of the pilot (1) another intervention in this same country, and (2) two more countries for doing both interventions (so at the end of the pilot phase we would have 3 countries and two interventions in the model)
7. revise the model to incorporate the lessons of the additional intervention and the additional countries with the advice of the advisors.
8. produce a pilot report that (1) demonstrates the model results for both interventions in the three countries, (2) examines the differences across interventions and countries as to reasonableness, (3) examine sensitivity of the model results to all key parameters and identify priorities for research to estimate these parameters, (4) recommendations based on the pilot for improving the model, and (5) based on pilot results, estimate the steps and effort levels and costs necessary to implement the model in a single country for 5 interventions.