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I. Introduction and General Methodology to 6-Step Methodology

The economic benefit of investing in flour fortification to reduce key micronutrient deficiencies via flour fortification is a major message in advocacy to establish national programs. At the global level, the Copenhagen Consensus Challenges Papers and other analyses have established a clear and widely accepted methodology for demonstrating high benefit cost ratios (BCR) for flour fortification with iron, folic acid, vitamin A and other micronutrients. However, effective and persuasive advocacy for national programs often requires more than citing global analyses and conclusions. A national analysis, based on a specific national nutrition, health and economic environment provides the most persuasive framing for the message that flour fortification is an exceptional national development investment that provides a great “bang for the buck.”

This Microsoft excel-based computer model is a tool to develop a Benefit Cost Analysis (BCA) for wheat flour fortification within a concrete and relevant national context. The excel modeling tool includes 17 color-coded worksheets, each of which refer to the 6 specific steps shown in the table above. Each color code is associated with specific kinds of calculation or projection. The steps are as follows:

Step 1 Estimate Baseline Loss in (USD/yr): Based on best-available evidence convert impacts of micronutrient deficiencies into associated national economic losses. 4 **Red**-coded worksheets refer to calculations for mortality attributed to vitamin and mineral deficiencies and 2 **Green**-coded worksheets project the depressed productivity of current and future workers associated with iron deficiency and anemia.

Step 2 *Project Coverage of Fortified Flour (in %):* Based on knowledge of the industrial and consumer environment project the proportion of population that consumes fortified flour and therefore may receive a benefit. These calculations are included in the Orange-coded *Cons Cov* worksheet.

Step 3 Project Potential Effectiveness (in %): Based on consumption data used in step #2 above, calculate the average dose of micronutrient delivered delivered and project the effectiveness of that dose. Effectiveness is defined as the percent of people who are converted from a deficient to sufficient micronutrient status by consuming flour fortification. These projections are included in the Orange-coded *Effectiveness* worksheet

Step 4 Calculate the Potential Benefit: Multiplying baseline loss by the percent of population covered and the potential percent effectiveness provides a projection for reduced baseline losses. These reduced losses represent the benefits of flour fortification. The calculation for economic losses over 10 years of intervention is provided in Blue-coded worksheet *SUM DA.* The projection for reduced mortality is provided in Blue-coded worksheet *SUM Mort.*

Step 5 Estimate the Cost of Fortification: The tool provides an approach to budgeting the full cost of flour fortification including: cost of fortificant premix procurement along with capacity building, capital investment and recurring costs for both industry and government activities. The 3 **Purple**-coded worksheets provide for data inputs and estimates for the industrial and government costs of fortification. Estimated annual costs are summarized over a 10-year period in the Blue-coded worksheet SUM Costs.

Step 6 Calculate the Benefit Cost Ratio (#): Dividing the cost of fortification by the benefits of fortification provides the benefit cost ratio (BCR). A result >1 indicates a positive benefit cost or return on investment. This calculation is done over 10 years in the Blue-coded worksheet *BCR*

Summary 6-Step Logic Model to Derive Benefit Cost Ratio											
	1. Baseline Loss		**2. Coverage**		**3. Effective**		**4. Benefits**		**5. Cost**		**6. Benefit Cost Ratio**
Unit	$/yr.	**X**	%	**X**	%	**=**	$/yr.	**/**	$/yr.	**=**	#
Worksheet Color Code	Red & Green		Orange		Orange		Blue		Purple		Blue

II. National Data and Statistics: Yellow Worksheets:

In addition to the 17 worksheets focusing on the impact of micronutrient deficiencies along with the coverage, effectiveness and cost of interventions, two Yellow-coded worksheets are provides for inputs of national health, nutrition, economic and labor statistics used throughout the model. The algorithms in the model are driven by the data in the yellow highlighted cells in these two worksheets. In some cases, this national data may not be available. Therefore, the tool offers optional approaches to estimating these data points in the yellow cells. By inputting other more available national data in the dark orange cells, the excel tool will provide an estimate,

If you would like to use the modeling tool to estimate the benefit-cost ratio of a wheat flour fortification program (including iron, folic acid and vitamin A) in your own country, follow these guidelines to use the workbook properly. If you have not already downloaded the list of indicators posted on the website, click here to get a copy. Don't worry if some of the indicators are not tracked by your country; you can make estimates where necessary. On the Yellow-coded worksheets there are five main types of cells.

- **Yellow (national data) cells.** These represent the key data needed to drive the algorithms in the computer model. They are the only cells in the tool that you need to fill-in country-specific data or estimate.

- **Dark Orange (choice) cells.** For these cells, you have a choice. You can follow the assumption provided, or if you have relevant national data, you can insert your own figure. However, be aware that going with the later option will delete any underlying formulas.

- **Blue (duplication) cells.** These merely show data that has been transferred from a previous worksheet within the modeling tool. Do not change these.

- **Green (pre-populated) cells.** These cells were pre-populated with commonly utilized figures or findings from peer-reviewed journals for very specific reasons. Examples include relative risks, percent deficits, discount rate, and nutrient intake requirements. You are advised not the change these.

- **Light Orange (calculated) Cells.** The modeling tool includes many embedded formulas. When you add the country-specific data, the modeling tool will automatically make calculations and populate other cells of the workbook. Beside each cell that is calculated, you will see a note reflecting the same. You should not alter the formulas or the results of the calculations.

Once all the yellow cells are filled-in, either directly or by the provided algorithms in the other cells, the benefit cost ratio (BCR) will be automatically calculated. You can find it in the last worksheet titled "BCR".

The default excel file is filled in with data from a fictional country, Fortifitopia. For Fortifitopia, the BCR is 17.7:1 meaning that for every $1 dollar spent on the fortification program, roughly $18 dollars are saved by averting health care costs, lost productivity, and premature death.

Yellow Sheet 1 Demo & Health: National Demographics and Health Data

This worksheet includes demographic and health data needed to drive the calculations, including the size of key risk groups; mortality rates for key risk groups and prevalence rates for micronutrient deficiencies. The yellow cells represent the key numbers required to drive the model. These key data points are:

- Demography
  - Annual births,
  - Annual Population Growth Rate
  - Annual Birth Rate
- Mortality Data
  - Maternal Mortality
  - 6-59 month Mortality
  - Neonatal Mortality
- Prevalence of Micronutrient Deficiencies
  - VAD among children 6-59 months
  - Pre Anemia and Iron Deficiency Anemia among Pregnant Women
  - Iron Deficiency Anemia in Children 6-59 months
  - Iron Deficiency Anemia Working Age Women
  - Iron Deficiency Anemia in Working Age Men

In some cases, this national data may not be available. Therefore, filling in the dark orange cells will provide other data points that enable the excel tool to automatically make the estimates for you.

Yellow Sheet 2 Econ Worksheet: National Labor and Economic Statistics

This worksheet includes information needed to translate the number of people suffering from economic deficits associated with their micronutrient deficiency into financial terms, i.e. currency. The key data needed to drive the calculations in the model are highlighted in yellow cells and include:

- Labor Participation Rates for men, women and all workers
- Average Length of Working Life
  - Average age of entering workforce
  - Average length of work life
  - Average age of maternal death
- Wage Structure
  - Average Annual Earnings per working adult participating in the labor force
  - Average Annual Earnings per working adult engaged in manual labor
  - Average Annual Earnings per working female engaged in manual labor

In some cases, this national data may not be available. Therefore, filling in the dark orange cells will provide other data points that enable the excel tool to automatically make the estimates for you

III. Step 1 National Damage Assessment Report: Mortality and Economic Deficits Attributed to Micronutrient Deficiencies: Red and Green Worksheets

Step 1, projecting the baseline human and economic loss from micronutrient deficiencies is sometimes called a national Damage Assessment Report (DAR). The DAR is a “consequence model,” a statistical modeling methodology that describes the impact of the status quo, in this case the human and economic consequences associated with the prevalence of several micronutrient deficiencies. The scientific literature has developed substantial evidence defining higher risks of mortality and morbidity as well as deficits in mental development and on-the-job productivity emerging from a range of micronutrient deficits including anemia, iron deficiency, vitamin A deficiency and folic acid related neural tube defects. This evidence, a foundation of the BCA, is expressed as relative risk (RR) or deficit (%) as shown in the table below. In the Red and Green-coded excel worksheets, these “coefficients of loss” from the scientific literature are highlighted as green cells. As outlined in the table below, the DAR projects economic losses emerging from six distinct indicators among 3 risk groups.

Coefficients of Loss from the Literature Applied in Consequence Modeling for BCA				
Condition/Indicator	Risk Group	Consequence	Risk or Deficit	Source
Maternal Anemia	Pregnant Women	Neonatal Mortality	RR 1.45	Lancet, 2013
Maternal Anemia		Maternal Mortality	RR 1.41[1]	Lancet, 2008
Maternal Folic Acid Deficiency		Birth Defect/Mortality	RR 1.38	Cochrane Review, 2012
Childhood Vitamin A Deficiency:	Children 6-59m	Mortality 6-59 Month	RR 1.32	Lancet, 2013
Childhood Anemia/Iron Deficiency		Future Productivity	5%	Copenhagen Consensus
Anemia working age adults	Adult	Current Productivity	5%-17%	Copenhagen Consensus

While the biological processes defined in the global evidence may be virtually universal, the national context determines the scale of human economic consequences. For example, average national earnings and employment rate determine the actual economic value of lost work potential. Therefore, the global evidence of risk or deficit from micronutrient deficiencies is applied to national health, demographic and economic data to project the magnitude of annual loss - specifically based on national circumstances. The algorithm to estimate these national economic consequences of the status quo, shown in the table below, is applied to each indicator. The results are then added together to define a baseline of national economic losses that the evidence associates with anemia, iron deficiency, folic acid-related Neural Tube Defects (NTDs) and Vitamin A Deficiency.

Algorithm to Project Economic Losses from Individual Indicators								
Size of Population Affected	X	Potential Earning	X	Labor Participation Rate (%)	X	Coefficient Of Risk or Deficit	=	Annual Loss
National Data: Prevalence #		National Data $/yr		National Data %		Global Literature RR or %		Calculated $/yr

Four of the six indicators that make up this baseline loss are the higher mortality risks associated with pregnant women and children that have anemia, vitamin A deficiency or folic acid associated birth

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[1] per 1 g/dL Hb increase

defects. Estimating the number of deaths associated with micronutrient deficiencies requires an additional calculation. The logic model for projecting mortality based on both the relative risk (RR) found in the global literature as well as the national context of mortality and micronutrient deficiency is illustrated in the table below. The calculation is based not only on the higher risk of mortality taken from the global literature but also national prevalence and mortality rates.

Methodology for Projecting Mortality from Malnutrition Indicators								
Prevalence	X	**Relative Risk of Mortality**	=	**PAR: Population Attributable Risk**	X	**Mortality in Risk Group Affected**	=	**# Deaths/yr.**
National Data %		Global Literature #		PAR Calculation[2] %		National Data # Deaths/Yr		

While the value of human life cannot be captured in simple financial terms, from a cold economic perspective, the BCA values a lost life simply as a lost worker and consequent loss of lifetime earnings. For a child born today, this "earnings stream" would not have begun for ~15 years when the child might have entered the workforce - and those earnings stretch another 40-50 years into the future.[3] The literature from both psychology and economics agree that people place a higher value on benefits they can consume in the present than benefits that accrue in the future - and the further off into the future, the lower the perceived value. This means that a dollar in future economic benefits from reduced child mortality or increased future productivity will be perceived as less valuable than a dollar invested in flour fortification today. To adjust and make the BCA projections credible, future benefits are "discounted" via a Net Present Value (NPV). The NPV is a formula that discounts future benefits to reflect their perceived current value by applying an interest rate.[4] This enables future earnings to be expressed as a current loss, although at a significant discount - the NPV of future earnings of today's children is ~20% or less of their "gross" lifetime earnings.

[2] The Population Attributable Risk (PAR) is a function of the prevalence of the nutrition indicator along with the severity of the mortality risk as expressed by the Relative Risk (RR). It is calculated with the following formula: (Prevalence*(RR-1))/(1+(Prev*(RR-1))).

[3] For delay of earnings stream the study takes the difference of the average age of the cohort and the entry into the work force, assumed to be 15 years of age. For infant deaths the earnings stream is assumed to be 15 years in the future; for children who die in the 6-59 month period the delay is assumed to be 13 years; for cognitive delays in children < 5 years the delay is assumed to be an average of 12.5 years in the future.

[4] For this BCA, a 3% discount rate, recommended by the World Bank for social investments, is used to calculate NPV of lost future earnings due to the various indicators of malnutrition. This is subjective. A "social discount rate" is not related to inflation or bank interest charges but merely reflects the subjective time preference for current over future consumption or savings (World Bank, Development Report 1993: Investing in Health. Oxford University Press World Bank 1993).

Red Sheet 3 VAD: Mortality Associated with Vitamin A Deficiency (VAD) in Children

Inadequate intake of vitamin A compromises the immune system, leading to risks of common illnesses progressing to more severe forms, including death. These risks are especially high during periods of rapid physical growth and consequent increases in nutritional requirements – such as in early childhood. A 1993 meta-analysis by Beaton et al reviewed a number of vitamin A interventions concluding that children ages 6-59 months living in vitamin A deficient areas and receiving vitamin A supplements were 23% less likely to die than those not receiving supplements.[5] Since 1993 additional analyses have confirmed this finding, with the most recent Cochrane Review finding a 24% mortality reduction. From the mortality reduction found in the Cochrane review, the BCA model derives a mortality relative risk of RR 1.32. This relative risk along with the national VAD prevalence rate enables calculation of Population Attributable Risk (PAR). Applying the PAR to the total deaths among children 6-59 months provides a projection for VAD associated deaths. The table below illustrates the algorithm to project annual mortality associated with the current prevalence of vitamin A deficiency along with location of the relevant cell in the worksheet.

Mortality Associated with Vitamin A Deficiency								
A. VAD Prevalence		B. RR Mortality		C. Population Attributable Risk		D. Mortality 6-59 months		E. Annual Deaths Attributed to VAD
% From National Data	**X**	1.32 Derived from Literature	**=**	Calculated from A and B	**X**	# From national Data	**=**	Column D x Column C
Cell: B3		Cell: B5		Cell: B6		Cell: B2		Cell: B7

The number of annual deaths is then valued as the NPV of lost earnings due to preventable mortality. This estimate is based on the key labor statistics provided in the yellow-coded worksheets: average wage, proportion of workers employed and average years from workforce entry to exit. Based on the assumption that the average age of VAD associated death is age 2 years, the NPV calculation is based on an estimated 13-year delay until entering the workforce and the beginning of the earnings stream.

Algorithm to Project Economic Losses from VAD Associated Deaths										
# VAD Associated Deaths		Potential Annual Earning		Labor Participation Rate (%)		Years of Work Life		NPV Calculation @ 3%		NPV of Annual Losses
Calculated #	X	National Data $/yr.	X	National Data %	X	Workforce Entry to Exit # Years	X	Discount Algorithm with 13 years delay to earnings stream	=	$/yr
Cell B7		Cell B9		Cell B10		In Cell B11		In Cell B11		Cell B11

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[5] Beaton GH, Martorell R. Aronson KA et al. Effectiveness of vitamin A supplementation in the control of young child morbidity and mortality in developing countries. Toronto, Canada: University of Toronto, 1993.

Red Sheet 4 Neonatal: Neonatal Death Attributed to Anemia in Pregnancy

Nutrition status of pregnant women is a powerful predictor of birth outcomes, including survival. A number of studies, with datasets from hundreds of thousands of children, have found strong links between maternal anemia and child mortality. The most recent Lancet Nutrition Review concludes: "there is strong biological plausibility for a causal link between maternal IDA and adverse birth outcomes." Among the most comprehensive studies cited in the Lancet is from Dibley et al, an analysis that pooled data from a very large 12-year database taken from Indonesian national demographic and health surveys. The large dataset shows that risk of death in children <5 years fell 34% when mothers consumed iron-folic acid supplements during pregnancy.[6] The protective effect was greatest for deaths on the first day of life (RR 0.40) but also extended to the neonatal period (RR 0.69). Since neonatal deaths are routinely reported national health statistics, the BCA takes the protective value of RR 0.69 found by Dibley in Indonesia and derives a RR of 1.45 for neonatal mortality associated with maternal iron deficiency anemia. The table below illustrates the algorithm to project annual mortality associated with the current prevalence of anemia in pregnant women along with location of the relevant cell in the worksheet.

Algorithm for Neonatal Mortality Associated with Anemia in Pregnant Women								
A. IDA Prevalence	**X**	B. RR Mortality	**=**	C. Population Attributable Risk	**X**	D. Mortality 6-59 months	**=**	E. Annual Deaths Attributed to VAD
% From National Data		1.45 Derived from Literature		Calculated from A and B		# From National Data		Column D x Column C
Cell B3		Cell B5		Cell B6		Cell B2		Cell B7

The number of annual deaths is valued as the NPV of a lifetime of lost earnings. This is based on the key labor statistics in the Yellow-coded worksheets: average wage, proportion of workers employed and average years from workforce entry to exit. Since neonatal mortality occurs in the first month of life, the NPV is assumes 15 years before the child would enter workforce and the earnings stream begins.

Algorithm to Project Economic Losses from Neonatal Deaths Associated With Anemia in Pregnancy										
# VAD Associated Deaths		Potential Annual Earning		Labor Participation Rate (%)		Years of Work Life		NPV Calculation @ 3%		NPV of Annual Losses
Calculated #	X	National Data $/yr.	X	National Data %	X	Workforce Entry to Exit # Years	X	Discount Algorithm with 13 years delay to earnings stream	=	$/yr
Cell B7		Cell B9		Cell B10		In Cell B11		In Cell B11		Cell B11

[6] Dibley MJ, Titaley CR, d'Este C, et al. Iron and folic acid supplements in pregnancy improve child survival in Indonesia. *Am J Clin Nutr* 2012; **95:** 220–30.

Red Sheet 5 NTD: Mortality and Disability Associated with Folic Acid related Neural Tube Defects: Neural Tube Defects (NTDs), including serious birth defects such as spina bifida and anencephaly, are a significant cause of death and disability worldwide. A Cochrane Review including five folic acid supplementation trials identified a 72% reduction in incidence of neural tube defects.[7] The BCA applies this finding as the proportion of NTDs that are preventable via sufficient added folic acid nutrition. However, NTD incidence is not available in countries with no comprehensive birth registries. Therefore, based on the global data, as a conservative starting point for the analysis, the BCA model uses a default rate of 1.5 NTDs /1000 births.[8] In addition to NTD incidence, the fatality rate among NTD cases is also usually unknown. Given the life-threatening nature of NTDs along with low access to needed pediatric neurosurgery in developing countries, the model conservatively assumes a fatality rate of 90%. Based on these assumptions, the logic model for calculating deaths related to folic acid preventable NTDs is shown in the table below along with location of worksheet cells with relevant data.

Logic Model for Projecting NTD Annual Cases and Deaths						
A. Number w/ Annual NTDs		B. Associated with Folic Acid		C. Mortality Risk		**Total Annual Deaths**
Annual Births x 1.5/1000 (default)	**X**	72% Folic Acid Preventable	**X**	90% (default)	**=**	A x B x C
Cell B3 x Demo Cell B8		Cell B4		Cell B6		Cell B7

The BCA Model further assumes that among the surviving 10% of individuals with NTDs, 1/3rd will suffer lifelong disability with a 100% loss of productivity. The remaining 2/3rds will be moderately disabled and consequently achieve only 50% of their potential work performance. The table below shows logic model of annual work "years" lost due to severe and moderate disability among survivors.

Logic Model for Projecting Lost Work Years Among NTD Survivors NTD						
A. Annual NTDs Survivors		B. Disability Status		C. Loss of Productivity		**Annual Work/Years Lost**
Total NTD less Total Fatality Cell B8	**X**	Severe: 33% (B11)	**X**	Severe: 100%	**=**	A x B x C
		Moderate: 67% (B12)		Moderate: 50%		A x B x C

The economic losses are then calculated for the three groups, mortality, severe disability and moderate disability as follows:

Algorithm to Project Economic Losses from Neonatal Maternal Anemia Associated Deaths										
Number Affected		Potential Earning		% Labor Participation		Work Life		NPV Calculation @ 3%		NPV of Losses
# Deaths: 100% Cell B7	X	National Data $/yr.	X	National Data %	X	From workforce entry to exit # Years	X	Discount Algorithm with 15 years delay to earnings stream	=	$/yr
# Severe: 100%										Cell B19

[7] De-Regil LM, Fernandez-Gaxiola AC, Dowswell T, et al. Effects and safety of periconceptional folate supplementation for preventing birth defects. Cochrane Database Syst Rev 2010; 10: CD007950.

[8] A publication of The March of Dimes suggests a globally recurring rate of 2.4/1000 births (with very wide variation amongst countries).

Cell B11		Cell B14		Cell B15		Econ Cell B15		Cells B16, 17, 18		
Moderate: 50% Cell B12										

Red Sheet 6 Mat Mortality: Maternal Mortality Associated Iron Deficiency Anemia

The Lancet Nutrition Series states "anaemia in pregnancy increased the risk of maternal mortality." The review includes an analysis of 10 studies finding an odds ratio for maternal deaths of OR 0.71 per 1g/dL greater mean hemoglobin in late pregnancy.[9] Based on this protective effect, the BCA derives a RR 1.41 for maternal mortality risk associated with each a 1g/dL deficit in hemoglobin. This projection includes additional algorithms developed by Stolzfus et al to convert prevalence of iron deficiency and anemia to population mean hemoglobin and to estimate the population mean Hb in the absence of iron deficiency (the algorithm is found in the hidden lines of the excel sheet lines 20-31).[10] The difference of these two values represents the deficit to which the RR of 1.41 is applied to derive a PAR. The table below illustrates the logic model and shows location of data in the worksheet cells.

Algorithm to Project Maternal Mortality Associated with Iron Deficiency Anemia								
A. Difference Hb Mean vs. w/no ID	**X**	B. RR Mortality	**=**	C. Population Attributable Risk	**X**	D. Maternal Mortality	**=**	E. Annual Deaths Attributed to
% From National Data g/dL deficit		1.41 Derived from Literature		Calculated from A and B		# From national Data		Column D x Column C
Cell: B11		Cell: B12		Cell: B13		Cell: B5		Cell B14

The number of annual maternal deaths is then valued as lost earnings beginning from the average age of maternal death to average age of workforce exit as shown in the table below.

Algorithm to Project Economic Losses from Maternal Mortality Associated with Iron Deficiency Anemia										
Size of Population Affected	X	Potential Earning	X	Labor Participation Rate (%)	X	Work Life	X	NPV Calculation @ 3%	=	NPV of Annual Losses
National Data #/deaths/yr.		National Data $/yr		National Data %		Age of Death to Workforce Exit		Discount Algorithm		$/yr.
Cell: B14		Cell: B16		Cell B17:		Econ Sheet		In Cell B18		Cell B18

[9] Stoltzfus RJ, Mullany L, Black RE. Iron deficiency anaemia. In: Ezzati M, Lopez AD, Rodgers A, Murray CLJ, eds. Comparative quantification of health risks Geneva: World Health Organization, 2004: 163–209.
[10] IBID

Green Sheet 8 IDA Kids: Depressed Future Productivity of Children

A range of evidence links both anemia and iron deficiency in young children to cognitive and development delays. A *Journal of Nutrition* review observed a consistently positive impact of iron intervention on cognitive scores, generally ranging from 0.5 to 1 Standard Deviation (SD) and concluded "available evidence satisfies all of the conditions needed to conclude that iron deficiency causes cognitive deficits and developmental delays."[11] Compared to their well-nourished peers, children with anemia or iron deficiency score poorly on tests of cognitive function, psychomotor development and fine motor skills. Given their lower activity level, they interact less frequently with their environment and thus fail to acquire physical and intellectual skills at normal rates. In turn, these early childhood deficits determine their ability to capitalize on educational opportunities and later employment opportunities, resulting in an adult productivity deficit.[12]

The literature from nutrition and economic science suggests that the scale of developmental deficits associated with iron deficiency in children <5 years old children are linked with a 4% drop in earnings.[13] However, follow up of intervention studies showing cognitive improvements from iron supplementation of children <5 years found that these were sustained into adolescence with a correlation coefficient 0.62.[14] The BCA applies this correlation coefficient of 0.62 to findings of 4% earnings deficit to arrive at a coefficient of 2.5% lower future earnings and productivity.[15] For the purposes of estimating the time lag until these children enter the workforce, the model assumes an average age of 2.5 years – suggesting 12.5 years until entry into the workforce at age 15. The table below outlines the logic model for this algorithm along with the location of the data in the worksheet cells.

Algorithm to Project Economic Losses from Maternal Mortality Associated with Anemia										
Size of Population Affected[16]		Potential Earning		Labor Participation Rate (%)		Work Life		NPV Calculation @ 3%		NPV of Annual Losses
National Data #	X	National Data $/yr	X	National Data %	X	Work Exit Total Years	X	Discount Algorithm w/12.5 yrs delay to earnings stream	=	$/yr
Cell: B7		Cell: B9		Cell: B10		From Eco Sheet		In Cell: B12		Cell: B12

[11] Haas, J. and Brownlie T., Iron Deficiency and Reduced Work Capacity: A Critical Review of the Research *Journal of Nutrition.* 2001;131

[12] Behrman (1993), Behrman and Deolalikar (1989), Deolalikar (1988), Foster and Rosenzweig (1993), Glick and Sahn (1997), Haddad and Bouis (1991), Schultz (1996), Strauss and Thomas (1998) and Thomas and Strauss (1997) Behrman (1993), Behrman and Deolalikar (1989), Deolalikar (1988), Foster and Rosenzweig (1993), Glick and Sahn (1997), Haddad and Bouis (1991), Schultz (1996), Strauss and Thomas (1998) and Thomas and Strauss (1997)

[13] Horton & Ross The Economics of Iron Deficiency Food Policy 28 (2003) 51–75

[14] Pollitt et al. 1995 and Jensen, 1980 in Horton & Ross The Economics of Iron Deficiency Food Policy 28 (2003) 51–75

[15] Horton & Ross The Economics of Iron Deficiency Food Policy 28 (2003) 51–75

[16] Assumes IDA rates as estimated in Demo Health (Cell B6) but adds additional estimate for children with iron deficiency but no anemia (Cell B8) at rate of 50% (Cell B7)

Green Sheet 9 IDA Adults: Depressed Current Productivity: Anemia in Adult Workers

Weakness, fatigue and lethargy brought on by anemia in adults results in measurable productivity deficits in the manual labor. A substantial literature shows a negative impact on indicators of work performance. Including:

- The output of iron supplemented rubber tree tappers involved in heavy manual labor in Indonesia was found 17% higher than non-supplemented co-workers.[17]
- There is also evidence anemia impairs less physically demanding work in "blue collar labor" or manufacturing not requiring significant physical exertion on the order to 5%.[18] [19] [20]
- Based on an extensive review of the literature, Ross & Horton estimate a 5% deficit among all manual or "blue collar" manufacturing work and an additional 12% loss for heavy manual labor such as agriculture and construction.[21]

The BCA Model applies 5% deficit to manual laborers with anemia and an additional 12% loss among those involved in heavy manual labor. In addition to correcting for distinct male and female labor participation rates, in order to conform with the evidence indicating that this anemia related work deficit is restricted to manual labor, the model applies an additional screen to exclude individuals in administrative, managerial, education and other "white collar" jobs. There is a range of labor statistics that can be used to estimate the proportion of labor force engaged in manual labor. As a default, the BCA uses the most widely available data: simply the percent of men and women working in the agricultural and industrial sectors. Heavy manual labor is assumed to be 15% of manual labor. Since adult work performance deficits occur in the present, there is no discounting for future value or NPV calculation.

<table>
<tr><th colspan="13">Projection Algorithm for Productivity Loss Associated with Anemia in Adults with Manual Jobs</th></tr>
<tr><td>Number w/ Deficit or Risk</td><td></td><td>Average Earnings</td><td></td><td>Manual Labor Force Participation</td><td></td><td>Manual Labor %</td><td></td><td>Coefficient Deficit</td><td></td><td>Coefficient Deficit</td><td></td><td>Annual Loss</td></tr>
<tr><td>Working Age Female</td><td rowspan="4">X</td><td>Nat Data %</td><td rowspan="4">X</td><td>Nat Data %</td><td rowspan="4">X</td><td>Nat Data %</td><td rowspan="4">X</td><td rowspan="2">5% for Manual Labor</td><td rowspan="4">+</td><td rowspan="2">+12% for Heavy Labor</td><td rowspan="4">=</td><td>$/yr</td></tr>
<tr><td>Cell B5</td><td>Cell B11</td><td>Cell B6</td><td>Cell C8</td><td rowspan="3">Cell D20</td></tr>
<tr><td>Working Age Males</td><td>Nat Data %</td><td>Nat Data %</td><td>Nat Data %</td><td rowspan="2">Cell B15 & C18</td><td rowspan="2">Cells B16 & C18</td></tr>
<tr><td>Cell C5</td><td>Cell C11</td><td>Cell C6</td><td>Cell C8</td></tr>
</table>

[17] Basta S. S., Soekirman D. S., Karyadi D., Scrimshaw N. S. Iron deficiency anemia and the productivity of adult males in Indonesia. Am. J. Clin. Nutr. 1979;32:916-925

[18] Li R., Chen X., Yan H., Deurenberg P., Garby L., Hautvast J.G.A.J. Functional consequences of iron supplementation in iron-deficient female cotton workers in Beijing, China. Am. J. Clin. Nutr. 1994;59:908-913

[19] Scholz B. D., Gross R., Schultink W., Sastroamidjojo S. Anaemia is associated with reduced productivity of women workers in even less-physically-strenuous tasks. Br. J. Nutr. 1997;77:47-57

[20] Unturo J., Gross R., Schultink W. Association between BMI and hemoglobin and work productivity among Indonesian female factory workers. Eur. J. Clin. Nutr. 1998;52:131-135

[21] Ross L Horton S The Economic Consequences of Iron Deficiency, Micronutrient Initiative 1998

IV. Step 1 Summary Mortality and Productivity Losses Blue Worksheets:

Blue Sheet 7 SUM Mort Summary of Mortality Projections

This sheet summarizes the annual and 10-year mortality attributed to anemia, folic acid deficiency and vitamin A deficiency. These are summarized separately because these deaths represent a human tragedy extending far beyond an economic analysis.

Blue Sheet 10 SUM DAR Summary National Damage Assessment Report

This sheet summarizes the annual and 10-year economic impact of all six measured indicators. This summary or national Damage Assessment Report (DAR) represents the baseline for the BCA analysis. Further, this spreadsheet will be a powerful advocacy tool communicating the economic impact of micronutrient deficiencies. Key advocacy framings will relate the dollars/year lost to micronutrients to the overall GDP; to the projected GDP growth; and other key goals for national economic development.

V. Steps 2 & 3 Coverage and Effectiveness of Flour Fortification: Orange Worksheets

Orange Sheet 11 Cons Cov Consumption and Coverage of Wheat Flour and Associated Products
The National Damage Assessment Report (DAR) provides a baseline of losses associated with micronutrient deficiencies based on national demographic, health, nutrition, labor and economic statistics. While this provides a baseline of national loss, the projected benefits of flour fortification are also based on the national flour industry and market situation, which will in turn determine the cost of implementing the program and its effectiveness in reducing micronutrient deficiencies. This worksheet requires some knowledge of the industrial, market and consumer environment for wheat flour.

The cost as well as the benefit of flour fortification is largely based on how many people consume flour and how much flour they consume. Data inputs into the yellow cells of this worksheet include daily flour consumption in kg/dy and percent of the population regularly consuming flour – along with estimates for 10-year changes in the flour market coverage. This data, along with demographic data provided in earlier sheets, enable the projection of several key parameters.

- First, the average flour consumption figure (Cell B2) will be used in the Orange Coded *Effectiveness Worksheet* to inform the selection of fortification levels; calculate the dose of micronutrients delivered to consumers; and enable general informed estimates for effectiveness of a fortification in reducing prevalence of micronutrient deficiencies among consumers.

- Second, the proportion of the population regularly consuming flour (Cell B3), including changes over 10 over years (Cells B4-6), represents the potential coverage or proportion of the population benefiting from flour fortification.

- Third, based on knowledge of the local market and regulatory environment, this sheet requires defined targets for the proportion of total national flour consumption fortified over the next 10 years (Cells E9-18) is defined. Essentially, this requires defining fortification program objectives for proportion of supply that is fortified annually.

- These 3 data points: the proportion of flour fortified, total number of flour consumers, and the average daily consumption per consumer enables a projection for the total metric tons of flour to be fortified on an annual basis over 10 years (Cells F9-18).[22] Metric ton of fortified flour is a key unit determining fortificant premix requirements and therefore the major cost of the program. The cost per metric ton is calculated in the Purple-coded worksheets.

[22] The formula is: (Number of Consumers (kg/MT) X National Population X Percent Consuming Flour X Percent of Flour fortified)/1000 = Metric tons per year fortified

Orange Sheet 12 Effect Est: Estimates for the Effectiveness of Flour Fortification

In the WHO *Guidelines for the Fortification of Wheat Flour with Micronutrients,* fortification addition levels are recommended based on average individual daily flour consumption (in grams per day among actual consumers). A key table this publication is provided below.

WHO Guidelines for the Fortification of Wheat Flour with Micronutrients						
Nutrient	**Flour Extraction Rate**	**Compound**	**Level of nutrient to be added in parts per million (ppm) by estimated average per capita wheat flour availability (g/day)**			
			<75 g/d	75-149 g/d	150-300 g/d	>300 g/day
Iron	Low	NaFeEDTA	40	40	20	15
		Ferrous Sulfate	60	60	30	20
		Ferrous Fumarate	60	60	30	20
		Electrolytic Iron	NR	NR	60	40
	High	NaFeEDTA	40	40	20	15
Folic Acid	Low or High	Folic Acid	5.0	2.6	1.3	1.0
Vitamin B_{12}	Low or High	Cyanocobalamin	0.04	0.02	0.01	0.008
Vitamin A	Low or High	Vitamin A Palmitate	5.9	3	1.5	1
Zinc	Low	Zinc Oxide	95	55	40	30
	High	Zinc Oxide	100	100	80	70

Consumption Data entered into the Orange-coded *Cons Cov* Worksheet to determine total national flour consumption is converted into grams per day (Cell B2) to enable selection of appropriate fortificant addition levels. Consumption among children is a critical parameter, but in the absence of substantial consumption surveys, this is usually not known. Additional yellow cells enable estimates for the proportion flour consumed by children relative to that consumed by adults (Cells B3-4). The default provided in the BCA is based on FAO/WHO recommendations for calorie needs of children < 3 years and 4-6 years in proportion to adults. An average of these two figures will be used to represent child flour consumption.

The two estimates, daily flour consumption among key risk groups and added level of fortificants enable a calculation for average added units of the targeted micronutrients delivered by flour fortification – and also the proportion of WHO Recommended Nutrition Intakes (RNI) and WHO Estimated Average Requirements (EAR) that could be potentially delivered to women and children through this initiative. These calculations are made for added iron provided to women of reproductive age and children 6-59 months (Lines 7-18); folic acid for women of reproductive age (Lines 20-27); and VAD in children 6-59 months (Lines 29-36).

The proportion of RNI or EAR delivered along with evidence from flour fortification trials and national evaluations provides some evidence-based foundation for projecting the percent reduction in the prevalence of vitamin A deficiency, anemia and iron deficiency and folic acid associated NTDs. An effectiveness estimate is the concrete and specific projected decrease in a health risk that can be expected among wheat flour consumers in your country assuming a fortification program is implemented properly. The effectiveness estimate is the bottom line objective of the flour fortification program. While the evidence for reductions in anemia, neural tube defects along with vitamin A and iron deficiencies is relatively consistent, for a number of reasons, the robustness and clarity of the literature varies.

- The evidence for impact of iron fortification on anemia and iron deficiency varies significantly by risk group along with prevalence of non-dietary causes of anemia such as malaria, hook-worm, HIV and other micronutrient deficiencies. As indicated in the table below, a significant impact has been documented for national flour fortification programs in several countries across several risk groups for both anemia and iron deficiency.

Country	Risk Group	Condition	Pre-Fortification	Post-Fortification	% Reduction
Venezuela	Children < 5 y	Iron Deficiency	37.2%	15.5%	58.30%
		Anemia	18.1%	17.1%	5.50%
Costa Rica	Adult Women		18.4%	10.2%	45%
Kuwait			33%	24%	27%
Oman	Pregnant Women		49%	31%	37%

- Evidence for the impact of flour fortification with folic acid on the incidence of NTDs such as spina bifida and anencephaly comes from a number of trials as well as evaluations of national flour fortification programs. A meta-analysis published in 2010 based on the most rigorous studies and evaluations found that in Argentina, Canada, Chile, South Africa and USA NTD reductions ranged from 31%-78% with an over-all reduction of 46% in the incidence of NTDs. [23]

- Since most attention has been focused on the significant benefits of vitamin A fortification with cooking oil and sugar, the literature on flour fortification is relatively thin. However, two studies suggest impact. In the Philippines, an efficacy study feeding preschool children fortified buns found that after 6 months the proportion with low vitamin A liver stores fell from 28.6% to 15.3% - essentially halving the percentage of children falling below the cut-off point.[24] A more

[23] Blencowe, H., et.al. Folic acid to reduce neonatal mortality from neural tube disorders. *International Journal of Epidemiology*, 2010 April; 39 (Suppl 1): i110–i121

[24] Cabalda AB, Tengco LW, Solon JA, Sarol JN Jr, Rayco-Solon P, Solon FS. Efficacy of pandesal baked from wheat flour fortified with iron and vitamin a in improving the iron and anthropometric status of anemic schoolchildren in the Philippines. *J Am Coll Nutr. 2009 Oct;28(5):591-600*

recent large scale effectiveness trial in Bangladesh, found that the percentage of children with serum retinol values of <0.70 µmol/L at 6 months decreased from 22.5% to 7.4% - a reduction of nearly 2/3rds. [25]

For more information on the effectiveness of flour fortification please consult a summary of trials and program evaluations on the FFI website. The worksheet requires you to input separate and specific effectiveness estimates for each indicator. This may seem a daunting and risky task – but you need to establish a realistic, ambitious, and evidence-based estimate. One special note: At the bottom of the worksheet titled “Effect Est”, you have the option to either leave the effectiveness estimates for iron-deficiency anemia, neural tube defects and vitamin A deficiency that were utilized for Fortifitopia (a fictitious model country created to drive the excel worksheet) or alter them using your expertise and judgment. Even If you use these default Fortifitopia values for effectiveness, it’s important to understand the effectiveness trials on which these projections are based are simply a “best-effort” based on the currently available evidence. As more and more national evaluations and reliable effectiveness studies become available, these projections will in turn become more reliable.

[25] D. W. Klemm, Keith P. West, Jr., Amanda C. Palmer, Quentin Johnson, Philip Randall, Peter Ranum, and Christine Northrop-Clewes V*itamin A fortification of wheat flour: Considerations and current recommendations* Food and Nutrition Bulletin, vol. 31, no. 1(supplement)© 2010, The United Nations University.

VI. Step 4 Summary Benefits of Flour Fortification: Blue Worksheets 13 and 14

Blue Worksheet 13 Sum Mort Benefit: Summary Projections for Reduced Mortality

Estimates for coverage and effectiveness from the Orange-coded worksheets are applied to total micronutrient associated mortality from the Red-coded worksheets (and summarized in the Blue-coded *SUM Mort* worksheet) to project reduced mortality from flour fortification. Based on the BCA logic below, the total mortality attributed to the various micronutrient deficiencies in the Red-coded worksheets is reduced in proportion to the number of people who are covered by the flour fortification program (from Orange-coded *Cons Cov* Worksheet) and the effectiveness of fortified flour in protecting consumers from the micronutrient deficiency (from Orange Coded *Effectiveness* Worksheet). The logic model for the calculation is shown in the table below.

Baseline Mortality Red Sheet		**Coverage Orange Sheet**		**Effectiveness Orange Sheet**		**Benefits**
VAD Deaths				**%**		**# Saved Lives**
Neonatal Death	**X**		**X**	**%**	**=**	**# Saved Lives**
Maternal Death		%		**%**		**# Saved Lives**
NTD Death				**%**		**# Saved Lives**
SUM: Total Mortality				**%**		**SUM Total Saved Lives**

Blue Worksheet 14 Sum Fin Benefit*:* Summary Projections for Financial Benefits

Estimates for coverage and effectiveness from the Orange-coded worksheets are applied to total baseline financial losses calculated from both the Red and Green-coded worksheets and summarized in the Blue-coded *SUM DAR* or National DAR to project the savings or reduced baseline loss. These savings represent the economic benefits of the flour fortification program. The table below shows the logic model for this key projection.

Baseline $/yr. Loss from Red & Green Worksheets		**Coverage From Orange Worksheet**		**Effectiveness From Orange Worksheet**		**Benefits**
VAD Deaths in 6-59 months				%		$/yr. increased workforce
Neonatal Deaths	**X**		**X**	%	**=**	$/yr. increased workforce
Maternal Death				%		$/yr. increased workforce
NTD Death, Disability & Care		%		%		$/yr. increased workforce
Iron Deficiency in Children				%		$/yr. improved productivity
Anemia in Adult Workers				%		$/yr. improved productivity
SUM: Total Loss in $/yr.				%		SUM: Total benefit in $/yr.

VII. Step 5 The Cost of Flour Fortification: Purple Worksheets

Purple Worksheet 15 Premix: Cost of Premix Procurement for National Flour Fortification Program
Based on the micronutrient levels selected in the Orange-coded Worksheet *Effectiveness*, this worksheet roughly designs the appropriate premix and estimates the cost per kilogram of premix (based on information from premix suppliers). Please note: The worksheet requires added inputs for the iron compound selected (from Orange worksheet *Effectiveness*). In addition to differing bioavailability, the various iron compounds (Cell C8) have different proportions of iron/kg (Cell D8) as well as widely varying prices (Cell G8). The light brown table provides the information you need to fill in these cells. In addition, you will also need to fill-in an addition rate (Cell E14). This is done simply by adding 20-25% to the total weight of nutrients (Cell E12) and rounding up to an even number (divisible by 50). While the model will provide estimates for base cost or nutrient cost per kilogram of premix (H18), only default assumptions are included for cost of transport (H15) and applicable duties (H20) and taxes (H21).

Based on the fortification addition rate (Cell E14) and the base premix cost per kilogram (Cell H22), a cost of premix per metric ton is calculated (Cell E23). This cost per metric ton is a critical advocacy figure enabling targeted calculations for key audiences, including incremental annual cost per mill, per person and nationally.

Purple Worksheet 16 Mill: The Industrial Costs of Flour Fortification
This includes four yellow cells to be filled in with basic national milling industry data including: number of mills (Cell C5), number of milling lines (Cell C4), average wage for affected mill person (Cell C9) and an estimate for the scale of overhead or administrative costs as percent of over-all premix costs (Cell C15). The model then projects capital investment and training costs based on number of mills as well as recurring cost of implementation, process monitoring and management based on volume of flour fortified. The true cost of management and overhead as well as customary mark-up or profit is unknown and widely variable. As a default, the model uses 5% of the cost of premix.

The figures in this worksheet, together with estimates for the targeted amount of flour fortified per year (from the Orange Worksheet 11 *Cons Cov*) and the premix cost per metric ton of flour (from the target metric tons of flour fortified per year and in the Purple Worksheet 15 Premix*)* for premix cost per metric ton of flour enable the tool to calculate an annual and 10-year estimate of all industrial costs including both cash financing and in-kind efforts. While new mill personnel may not be required, the model estimates the additional time required from current personnel that who would be assigned to the fortification process in order to put monetary values on the level of effort, or in-kind costs or opportunity costs to the mill.

Purple Worksheet 17 Govt: Public Cost for Food Control, Communication, Monitoring & Evaluation

Government costs for food control, public education, monitoring and evaluation will vary dramatically based on a number of factors. This worksheet contains a number of yellow cells to input best estimates for the cost of capacity building, advocacy, food control and initial social marketing that may be required. While these estimates will vary widely depending on the national environment, the BCA includes 3 key best practices, which will impact the cost:

- Cost of food control and inspection assumes bas each mill will be inspected 4 times annually.
- Monitoring of the retail marketplace (as opposed mills) will be every two years.
- Biological and other impact evaluation included in larger comprehensive national surveys (DHS).

VIII. Step 6 Summary Cost and Benefit Cost Ratio: Blue Worksheets 18 and 19

Blue Worksheet 18 SUM COST: Summary 10-Year Public and Private Costs of Flour Fortification
This worksheet takes the annual costs estimated by the 3 Purple-coded worksheets and extends these over 10 years based on the total metric tons of fortified flour projected in the Orange Worksheet 11 *Cons and Coverage*. These costs presume the program is new and that fortification begins after six months required for procurement and installation of equipment and capacity building of both the public and private sectors. The period that may be required for developing standards and legislation can vary dramatically based on a number of country specific factors and is not included.

Blue Worksheet 19 BCR: 10 Year Benefit Cost Ratio for Flour Fortification Program
Based on the two Blue-coded Summary Worksheets, 14 *SUM Fin Ben* and 18 *SUM Cost*, this worksheet does the simple exercise of dividing annual benefits by annual program costs to derive an annual benefit cost ratio. Total 10-year benefits and costs are added up and divided to define a 10-year BCR. The BCR assumes benefits of fortification require 12 months of continuous fortified flour consumption. Benefits lag costs by one year. Since the BCA model assumes that fortification does not begin until halfway through Year 1 of the program, the benefits stream does not begin until 6 months into Year 2 of the program. Therefore, Year 1 incurs costs but no benefits and Year 2 incurs a full year of costs but only 6 months of benefits.

The table below shows the full logic model for the BCA along with the Color-coded Worksheets that inform the 5 basic components of the model.

Logic Model and Worksheet Source to Derive Benefit Cost Ratio											
	Baseline Loss		**Coverage**		**Effective**		**Benefits**		**Cost**		**Benefit Cost Ratio**
Unit	$/yr.	**X**	%	**X**	%	**=**	$/yr.	**/**	$/yr.	**=**	#
Color Code	Blue 10 SUM DAR		Orange 11 Cons Cov		Orange 12 Effect		Blue 14 Sum Fin Ben		Blue 18 SUM Cost		Blue 19 BCR