The Economic Consequences Of Malnutrition in Cambodia

A Damage Assessment Report

CARD, UNICEF & WFP
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Acronyms

ARI	Acute Respiratory Infections
BMI	Body Mass Index
CARD	Council for Agriculture and Rural Development
CSES	Cambodia Socio-Economic Survey
DHS	Demographic Health Survey
EBF	Exclusive Breastfeeding
FAO	Food and Agriculture Organization
GDP	Gross Domestic Product
LBW	Low Birth Weight
MOH	Ministry of Health
NPV	Net Present Value
NTP	Neural Tube Defects
PAR	Population Attributable Risk
RNI	Recommended Nutrient Intake
RR	Relative Risk
SAM	Severe Acute Malnutrition
SD	Standard Deviation
SGA	Small Gestational Age
UNICEF	United Nation's Children's Fund
VAD	Vitamin A Deficiency
WAZ	Weight for Age in Z-score
WFP	World Food Programme
WHZ	Weight for Age in Z-score
WHO	World Health Organization

Table of Contents

List of Figures

List of Tables

Executive summary

The analysis of data on nutrition status of Cambodians from the Cambodian Demographic & Health Survey and the Ministry of Health indicates that mother's nutrition and behavior, vitamin and mineral deficiencies as well as insufficient access to food found that:

- More than half of young children face higher than normal risk of death. More than 60 thousand deaths over the next decade, ~30% of all childhood mortality in Cambodia, are linked to mother's or child's nutrition status.
- 2.5 million annual cases of childhood diarrhea and respiratory infection are associated with poor breastfeeding practices as well as vitamin A and zinc deficiencies, resulting in excess costs to the health care system and individual families.
- More than 2/3rds of children with anemia or less than normal height or weight suffer deficits in mental and physical development and perform less well in school. Consequently, as adults they will face lower productivity and earnings projected to depress GDP by >$180 million per year.
- Work performance deficits of 5% or more are projected for more than 3.3 million anemic, adults of working age whose chronic weakness and fatigue depresses labor outputs by an estimated $138 million.

The main findings are summarized in the tables below.

Table 1: Summary 10 Nutrition Indicators: Cases and Risk Groups Derived from DHS 2010

Risk Group	Nutrition Indicator	Prevalence	Cases or At Risk(000)	Risk or Deficit
388 thousand Pregnant Women	Low Body Mass Index	19%	73.9	Infant and Maternal Mortality
	Short Stature	6%	24.5	
	Anemia	53%	204.9	
	Folic Acid Deficiency	50%	194.4	
1.6 Million Children < 5 Years of Age	Suboptimal Breastfeeding	26%	202.2	Mortality & Morbidity
	Low Weight for Height	44%	628.3	Mortality
	Low Weight for Age	60%	856.7	
	Low Height for Age	65%	928.1	Growth, Development &
	Vitamin A Deficiency	22%	318.4	Mortality
	Zinc Deficiency	52%[1]	742.5	Mortality & Morbidity
	Anemia: Childhood	34%	482.7	Growth, Development &
3.3 million Adults	Anemia: Women	44%	2,445	Strength, Endurance and Productivity
	Anemia: Men	17%[2]	850.5	

Table 2: Annual Losses to Economic Activity in Cambodia: 2.6% of GDP 2013 ($000,000)

Mother's Nutrition Status & Behaviors	40.5
Underweight & Small Stature	169.3
Vitamin & Mineral Deficiencies	208.8
Total	**419**

[1] Laillou A, Pham TV, Tran NT, Le HT, Wieringa F, et al. (2012) Micronutrient Deficits Are Still Public Health Issues among Women and Young Children in Vietnam. PLoS ONE 7(4): e34906. doi:10.1371/journal.pone.0034906

[2] Based on ratio of male to female anemia found in Vietnam survey

Table 3: Summary Economic Consequences for All Indicators NPV @ 3% (Adjusted for Multiple Risks)

	NPV Lost Workforce	NPV Lost Child Productivity	Current Lost Productivity	Current Health Costs	Total	
	000,000/yr	000,000/yr	000,000/yr	000,000/yr	000,000/yr	%
Maternal Nutrition	$9.7			$0.6	$10.2	2.4%
Suboptimal Breastfeeding	$21.7			$1.9	$23.6	5.6%
Low Weight for Height	$18.8				$18.8	4.5%
Low Height for Age		$128.3			$128.3	30.6%
Low Weight for Age	$22.3				$22.3	5.3%
Zinc Deficiency	$5.7			$7.5	$13.2	3.2%
Vitamin A Deficiency	$4.6				$4.6	1.1%
Childhood Anemia		$52.7			$52.7	12.6%
Birth Defects	$5.9	$0.78		$0.03	$6.7	1.6%
IDA in Adults			$138.3		$138.3	33.0%
Annual Total	**$88.7**	**$181.7**	**$138.3**	**$10.0**	**$419**	100%

Table 4: ~30% of Mortality Among Children <5 Years of Age is Associated with Key Indicators of Malnutrition

	Annual Deaths
Mothers Nutrition Status: Low Height, Low Body Mass Index or Anemia	1,120
Non-Exclusive Breastfeeding < 6 months and Non Continued Breastfeeding 6-24 months	1,533
Low Weight for Height and/or Age (WAZ, WHZ)	2,809
Vitamin A &Zinc Deficiencies	709
Total Projected Annual Mortality	**6,170**

This report describes the magnitude losses from malnutrition in order to enable policy discussion and ultimately secure investment in programs on a scale appropriate to the extent of the burden malnutrition. The $250-$400 million in projected losses describes the scale of economic benefits that might be secured by investment in effective and affordable interventions to lower prevalence of these specific indicators of malnutrition. Given the low cost of interventions and the high baseline losses, investment in nutrition programs in Cambodia is likely to offer high returns and attractive benefit cost ratios.

Over the next decades, a growing Cambodian economy will doubtless lower the $250-400 million annual burden on national economic activity. However, nutrition status responds relatively slowly to economic growth. A recent World Bank analysis from 79 countries concluded "that income growth can play an important role in malnutrition reduction, but it is not enough. Increases in the number and effectiveness of direct nutrition interventions have a crucial role to play if nutrition goals are to be met."[3] Moreover, investments to reduce malnutrition do not only serve nutrition goals. If malnutrition continues to depress economic activity at 1.5-2.5% of GDP, Cambodia's ambitious national objective of 7% annual GDP growth will be more difficult to achieve and sustain. Investment in nutrition is an investment in achieving that national economic development goal.

[3] Harold Alderman, Simon Appleton, Lawrence Haddad, Lina Song and Yisehac Yohannes Reducing Child Malnutrition: How Far Does Income Growth Take Us? Centre for Research in Economic Development and International Trade, University of Nottingham

Background & Rationale

Freedom from hunger is achieved when “people, at all times, have physical, social and economic access to sufficient, safe and nutritious food which meets their dietary needs and food preferences for an active and healthy life.”[4] Current scientific understanding of malnutrition has expanded beyond clinical conditions like kwashiorkor and nutritional marasmus to recognize that this visible form of malnutrition represents “the small tip of the iceberg… only 1-5% of the burden of malnutrition.”[5] There is substantial evidence that more widespread conditions of undernutrition has consequences not only for health and survival but also for physical and intellectual growth, school performance and adult productivity.

Poverty and undernutrition are locked in a vicious cycle of increased mortality, poor health, and retarded cognitive and physical growth, diminished learning capacity and ultimately lower work performance, productivity and earnings. As this vicious cycle threatens health and survival, it simultaneously erodes the foundation of economic growth – peoples’ strength and energy, creative and analytical capacity, initiative and entrepreneurial drive. Therefore, achieving reduction in the prevalence of malnutrition can substantially reduce this national burden as well as generate human and social capital to fuel economic development. When indicators of child malnutrition nutrition are widespread, the aggregate burden on national economic growth can be significant. The indicators of undernutrition summarized in Table 1 below suggest a significant burden on national human, social and economic development. Data from the Cambodia Demographic and Health Survey 2010 and other sources indicate these represent nearly 8 million cases, and suggest at least 4-5 million Cambodian citizens, mainly women and children, cannot achieve their full potential as students, workers, citizens and parents.

Table 5: Summary 10 Nutrition Indicators: Cases and Risk Groups Derived from DHS 2010 (unless otherwise noted)

Risk Group	Nutrition Indicator	Prevalence	Cases or At Risk	Risk or Deficit
388 thousand Pregnant Women	Low BMI	19%	73.9	Infant and Maternal Mortality
	Low Height	6%	24.5	
	Anemia: Pregnancy	53%	204.9	
	Folic Acid Deficiency	50%[6]	194.4	
1.6 Million Children < 5 Years of Age	Suboptimal Breastfeeding	26%	202.2	Mortality & Morbidity
	Wasting	44%	628.3	Mortality
	Underweight	60%	856.7	
	Stunting	65%	928.1	Growth, Development & Productivity
	Vitamin A Deficiency	22%	318.4	Mortality
	Zinc Deficiency	52%[7]	742.5	Mortality & Morbidity
	Anemia: Childhood	34%	482.7	Growth, Development & Productivity
3.3 million Adults	Anemia: Women	44%	2,445	Strength, Endurance and Productivity
	Anemia: Men	17%[8]	850.5	

[4] World Food Summit, 1996 United Nation’s Food & Agricultural Organization, Food ftp://ftp.fao.org/es/esa/policybriefs/pb_02.pdf

[5] Latham, Michael, Human Nutrition in the Developing World, *Food and Nutrition* Series - *No. 29* FAO 1997

[6] Based on finding of 15% RNI for WR in: Pfanner, S Nurtrient Content of Cambodian Diet Based on Food Balance Sheet, unpublished, 2013

[7] Laillou A, Pham TV, Tran NT, Le HT, Wieringa F, et al. (2012) Micronutrient Deficits Are Still Public Health Issues among Women and Young Children in Vietnam. PLoS ONE 7(4): e34906. doi:10.1371/journal.pone.0034906.

[8] Based on ratio of male to female anemia found in Vietnam survey

This analysis uses a "consequence model," a modeling scenario describing the consequences of the status quo rates or prevalence for each of these indicators. For each indicator, the scientific literature has developed substantial evidence defining higher risks of mortality and morbidity as well as deficits in mental development, physical performance and on-the-job productivity – expressed as relative risk (RR) or deficit (%). However, while the biological processes defined in the global evidence may be universal, the underlying determinants and conditions are not. From country to country the context determining the scale of economic consequences emerging from malnutrition varies: birth and death rates, incidence and type of infections, access to health care, labor participation rates, average wage influence and other factors. In this consequence model to project the economic impact of malnutrition in Cambodia, globally validated coefficients of loss or deficit found in the scientific literature are applied to Cambodian health, demographic and economic data to project the magnitude of annual loss – specifically based on national circumstances. Every attempt is made to ground these global coefficients in Cambodian reality.

Table 6: Algorithm to Project Economic Losses from Individual Indicators

Number w/ Indicator		Average Earnings		Labor Force Participation		Average Work-Life		Coefficient Risk-Deficit		NPV		Annual Loss
Prevalence (%) x population of Risk Group[9]	X	$1,253 /yr[10]	X	All: 84.4%[11] Male: 88.8% Female:80.4%	X	All: 47yr[12] Male: 45yr Female:49yr	X	RR or % from Literature	X	@ 3% & 7%	=	Value or Net Present Value (NPV) of Loss /yr[13]

The general algorithm mixing global and national parameters, shown in Table 2, will be applied to each of the nutrition indicators listed in Table 1. The magnitude of human and economic consequences emerging from these nutrition indicators via 4 discrete pathways to economic loss:

- **Pathway #1**: Mortality in children with consequent lost value of a future workforce (NPV).
- **Pathway #2**: Child cognition deficit resulting in suboptimal school performance and depressed adult productivity (NPV).
- **Pathway #3**: Current value of depressed productivity in working adults.
- **Pathway #4**: Current value of excess and preventable healthcare and welfare utilization.

All losses are expressed as dollars per year in depressed or lost economic activity. However, the quality of the "currency" varies significantly. While Pathways #4, represents actual excess family resources and government budgets currently expended for health care services, pathway #3 describes lower levels of productivity of today's adults working with at less than their optimal efficiency.

[9] National prevalence taken from DHS 2010, other national surveys or in some cases appropriate regional data is used. Population, birth rate and other demographic data is Health Information System downloaded in October 2013.

[10] Average annual earnings are based on $177 per month per household found by CSES 2009 and average number of workers per household which was estimated at 1.7. Derived by dividing national population by number of individuals participating in labor force

[11] National Institute of Statistics, Cambodia Socio-Economic Survey (CSES) Cambodia Ministry of Planning 2009

[12] Average time engaged in the labor force or "working life" assumes beginning work at 15 years and extending to the full life expectancy.

[13] Formula used to calculate the NPV: (# in Risk Group w/ Deficiency X Deficit Coefficient X Labor Participation Rate) X Present Value (Discount Rate, Work Life, Annual Wage) –Present Value (Discount Rate, Years until Workforce Entry, Annual Wage) / # Annual Cohort in Risk Group

Pathways #1 and #2 attempts to capture the future productivity or earnings deficit emerging from child mortality or the life-long consequences of malnutrition in childhood. For a child born in 2014, the earnings "stream" may not begin until the child enters the work force in 2029 and those earnings stretch another 40-50 years into the future.[14] The literature both psychology and economics agrees that people place a higher value goods and services in the present than in the future – and the further off the future, the less perceived value (people will invariably choose to have one apple today rather than 2 apples tomorrow). Net Present Value (NPV) is a subjective factor used to define the value of future goods or services and express that value in current currency. An interest rate, which effectively discounts the value of the future, is the key parameter for calculating the NPV of potential future earnings of Cambodian infants and children.

For this analysis, 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.[15] This "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.[16] This enables a lifetime of future earnings to be expressed as a current annualized economic loss – although at a huge discount. While the gross lifetime earnings at today's average Cambodian wage of $1,253 approaches $60 thousand, the NPV represents only a fraction of these "gross" earnings, about $14 thousand. As a sensitivity parameter, a 7% interest rate is also used. At 7% discount the potential lifetime earnings of $60 thousand have a present value of about $5 thousand.

Caveat to the Damage Assessment Report Methodology

Converting indicators of malnutrition to economic activity and attaching a monetary value to that economic activity travels a long and winding road. First, monetizing the consequences of malnutrition is dependent on a relatively thin evidence base, complex methodologies and national health, demographic and economic statistics of uneven quality. Second, many factors beyond individual physical and intellectual potential determine earnings or work performance. Work place incentives, available technology and sense of opportunity all effect how increased human potential translates into actual improved productivity. Finally, benefits of improved nutrition extend beyond the workplace to a range of "voluntary" activities including parenting and household activities to educational improvement, entrepreneurial pursuits and community participation. In a world where improvement in nutrition, health and subsequent productivity will emerge mainly from individual choices and behaviors, the significance of these "voluntary" activities cannot be overstated. For all these reasons and more, the margin of error is large and the calculations should be considered as an order of magnitude. These are projections to focus and facilitate policy discussion and present a solid and conservative case for policy discussion. Therefore, data judgments or assumptions consciously and consistently "biased" to minimize the impact of malnutrition. Consequently, conclusions drawn may be considered conservative low-end estimates.

[14] 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.

[15] World Bank, Development Report 1993: Investing in Health. Oxford University Press World Bank 1993

[16] Ross et all, Calculating the Consequences of Micronutrient Malnutrition on Economic Productivity, Health and Survival, AED 2003

1. Pathway #1: Child Mortality Attributable to Malnutrition

The scale of the child mortality emerging from malnutrition is hidden in a negative synergy of malnutrition, infection, disease and premature death of children. Except for rare cases of kwashiorkor or nutritional marasmus, malnutrition is rarely listed as the cause of death. However, malnutrition is a distinct, measureable and often significant contributing factor to child mortality and globally is generally recognized as the underlying cause of up to 45% of all child deaths.[17]

Estimating the national impact of malnutrition on child mortality is based on current rates of child death. Current Cambodian child mortality rates, used as a baseline, are listed in Table 3 below. Of the estimated 388 thousand children born annually, about 20 thousand die before their 5th birthday, 83% during the first year of life, and about half during the first month. Other mortality rates needed for this analysis are derived from this official data as indicated in Table 3.

Table 7: Data and Estimates for the Structure of Child Mortality From DHS 201018

Risk Group	Rate	# based on 378,314 births	Source or Calculation
Under 5 Mortality	54%	20,429	DHS 2010
Child Mortality (1-5 yrs)	9%	3,405	
Infant Mortality < 1 yr	45%	17,024	
Neonatal < 1 month	27%	10,214	
Calculated			
Post Neonatal (1-11 months)		6,810	Infant minus Neonatal
1-5 months		3,972	60% Post-Neonatal
6-11 Months (50% Post Neo-natal)		2,837	40% Post Neonatal
Deaths 6-59 months		6,242	Child Mortality + 6-11 month mortality

Table 8: Child Mortality by Cause in Cambodia, 2000-2010 (WHO)

Birth trauma	11%	Diarrheal diseases	8%
Acute Respiratory Infection	16%	HIV/AIDS	1%
Malaria	2%	Prematurity	22%
Sepsis	6%	Congenital	6%
Injuries	7%	Measles	1%
Other diseases	20%		

In addition to the rates of mortality, every effort is made to ground this analysis in the specific causes of child mortality in Cambodia. Much of the evidence attributing mortality to various indicators of malnutrition is based on studies and intervention trials which established links with "all-cause mortality." However, in some cases the literature has developed disease or infection-specific risks. Therefore, in addition to country-specific mortality rates, wherever possible, this analysis is based on the underlying causes of child mortality specific to Cambodia. Since no national data has been identified, mortality from specific infections such as diarrhea, respiratory

[17] Robert E Black, Cesar G Victora, Susan P Walker, Zulfiqar A Bhutta, Parul Christian, Mercedes de Onis, Majid Ezzati, Sally Grantham-McGrego, Joanne Katz, Reynaldo Martorell, Ricardo Uauy, and the Maternal and Child Nutrition Study Group Maternal and child undernutrition and overweight in low-income and middle-income countries The Lancet, June 6, 2013

[18] National Institute of Statistics, Directorate General for Health, and ICF Macro, 2011. Cambodia Demographic and Health Survey 2010. Phnom Penh, Cambodia and Calverton, Maryland, USA: National Institute of Statistics, Directorate General for Health, and ICF Macro.

disease, measles and other infections is taken from *WHO Child Mortality by Cause 2000-2010* shown in Table 4.[19]

The sections that follow apply coefficients of risk for mortality for specific nutrition indicators found in the global scientific literature to this local context to paint a general picture of child mortality that can be attributed to current prevalence of malnutrition in Cambodia. While in individual cases the methodology involves several additional steps, the general approach is outlined in Table 5.

Table 9: Projection of Methodology for Projecting Mortality from Malnutrition Indicators

Prevalence of Indicator		Relative Risk of Mortality		PAR: Population Attributable Risk[20]		Mortality in Risk Group Affected		# Deaths/yr Attributed To Indicator
From National Statistics	X	RR From Global Literature	=	Fraction (%) of Risk Group Affected	X	# Deaths/Yr Based on National Data	=	

1.1 Maternal Nutrition

Nutrition status of pregnant women is a powerful predictor of birth outcomes, including survival. A number of studies, including data on hundreds of thousands of children, have found strong links between maternal nutrition status and child mortality. Dibley et al pooled data from a very large 12 year database taken from Indonesian national demographic and health surveys finding that risk of death in children <5 years fell 34% when mothers consumed iron-folic acid supplements during pregnancy.[21] Perhaps the strongest evidence associates indicators of maternal nutrition with likelihood of small for gestational age (SGA) or low birth weight (LBW) babies – who in turn face much higher risks of mortality than normal weight babies, especially when sophisticated neonatal and pediatric care is not available. This analysis uses the following coefficients of risk for SGA or LBW[22], and indirectly for likelihood of mortality:

- A meta-analysis of 11 trials identified 20% reduction in risk of low birth weight associated with antenatal iron supplementation.[23]
- The Lancet's recent *Maternal and child undernutrition and overweight in low-income and middle-income countries* projects mothers with Body Mass Index (BMI) of <18.5 kg/m are 1.71 times more likely to suffer SGA births than mothers with normal BMI.[24]
- The same publication also ventures that stunted mothers, with height of <145cm, face increased likelihood of SGA births with RR of 2.2.[25]

DHS 2010 finds 8.2% of births <2500 grams – at today's projected birth rate this indicates > 31 thousand cases annually. The association of maternal malnutrition with these LBW cases, and the parallel increased risk of mortality, is based on the following two-step logic model.

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[19] http://apps.who.int/gho/data/node.main.ChildMortByCauseByCountry?lang=en

[20] 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))).

[21] 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.

[22] No national data for SGA. Only for LBW. For the purposes of this analysis the evidence or data from SGA and LBW is considered equivalent

[23] Imdad A, Bhutta ZA. Routine iron/folate supplementation during pregnancy: eff ect on maternal anaemia and birth outcomes. *Paediatr Perinat Epidemiol* 2012; **26** (S1)**:** 168–77

[24][24] Supplement to: Black RE, Victora CG, Walker SP, and the Maternal and Child Nutrition Study Group. Maternal and child undernutrition and overweight in low-income and middle-income countries. *Lancet* 2013; published online June 6. http://dx.doi. org

[25] IBID

Table 10: Logic Model for Projections of Child Mortality Associated to Maternal Nutrition Status

Annual Cases LBW		Mortality linked to LBW (SGA)		Cases linked to Maternal Status		Maternal Nutrition Impact on Infant Death
31,887/yr 8.2% of Annual Births	→	Based on RR in Literature #/yr	→	Anemia: RR 1.25 BMI <18.5: RR 1.71 Height <145cm: RR 2.2	→	Based on RR In Literature #/yr

Evidence indicates that degree of mortality risk varies considerably between birth weights above and below 2000 grams. Since DHS data is reported in aggregate and does not categorize these cases by severity, we derive figures based on global data suggesting that 88.3% of LBW are 2000-2499 g and the remaining 11.7% are at very high risk, 1500-1999 grams at birth.[26] Applying this global estimate to Cambodia's 31 thousand LBW cases suggests 7.24% or >28 thousand of LBW infants weighed 2000-2499 g and 0.96% or nearly 4 thousand were severely underweight < 2000g.

Table 11: Segmenting LBW Cases in Cambodia by Severity (Based on Black et al 2008)

Birth weight	Global Analysis	Applied to 31,887 LBW in Cambodia
2000-2499g	9.55% Global Prevalence or 88.3% of LBW	28,170
1500-1990g	1.26% Global Prevalence or 11.7% of LBW	3,717

While the degree of risk varies, all these LBW cases are at significantly higher risk of mortality during the neonatal period (<1 month) and post-neonatal period (1-11months). A pooled-analysis of 22 studies from Asia, sub-Saharan Africa, and Latin America, found risk SGA babies born at term suffered high risk of mortality: RR 3.06 for neonatal mortality and 1.98 for post-neonatal mortality.[27] A Lancet 2008 review pooling 11 studies that compared to normal weight babies, found infants weighing 1500–1999 g were 8.1 times more likely to die and those weighing 2000–2499 g were 2.8 times more likely to die during the first month of life due to birth asphyxia, infection and other causes.[28] Since data for LBW but not SGA is available for Cambodia, we apply coefficients of risk, based specifically on LBW. Table 7 below shows outlines calculation suggesting >1878 neonatal deaths as a consequence of low birth weight.

Table 12: Projection of Neonatal Mortality Attributed to Low Birth Weight

Prevalence of Condition		Relative Risk Mortality		Population Attributable Risk		Annual Deaths Neonatal Deaths		Annual Deaths Attributed to LBW
2000-2499g: 7.2%	X	2.8	=	11.5%	X	10,212	=	1,211
< 2000 g: 0.96%		8.1		6.35%				667

Mortality risks faced by LBW babies who survive the neonatal period linger throughout infancy and early childhood. Since no literature has been identified specific to LBW in this post-neonatal period, we apply RR of 1.98 found by Black et al for post-neonatal mortality linked SGA (at

[26] Black et al Maternal & child undernutrition: global and regional exposures and health consequences Maternal and Child Undernutrition Study Group, Jan 17, 2008

[27] Katz J, Lee AC, Kozuki N, et al, and the CHERG Small-for-Gestational-Age-Preterm Birth Working Group. Mortality risk in preterm and small-for-gestational-age infants in low-income and middle-income countries: a pooled country analysis. *Lancet* 2013; published online June 6. http://dx.doi.org/10.1016/S0140-6736(13)60993-9.

[28] Black et al Maternal & child undernutrition: global and regional exposures and health consequences Maternal and Child Undernutrition Study Group, Jan 17, 2008

term).[29] Calculation similar to Table 7 above but based on deaths for the 1-11 month age range indicates that >500 babies will die after surviving the more acute threats faced during the neonatal period.

Table 13: Projection of Post Neonatal Mortality Attributed to Low Birth Weight

Prevalence of Condition	X	Relative Risk Mortality	=	Population Attributable Risk	X	Annual Deaths 1-11 months	=	Annual Deaths Attributed
8.2%		1.98		7.4%		7,000		521

The evidence shows factors of maternal nutrition, low height, low BMI and anemia, associated with likelihood of LBW and therefore with a share of these >1800 deaths are attributable to LBW. Prevalence rates reported in DHS 2010 for these indicators suggest the significant impact of maternal status of LBW rates and consequence survival:

- 19% born to mothers with low BMI face nearly twice the risk, RR 1.71
- 6% born to mothers with height < 145 cm are more than twice the risk, RR 2.2. [30]
- 52.7% born to anemic mothers face RR of 1.25 for LBW and its consequences. [31]

Tables 10 and 11 below outline the methodology used to apply the coefficients of risk from the literature to national prevalence rates and the estimated 1,827 neonatal and post neonatal deaths from LBW in Cambodia. The results of this calculation suggest 574 neonatal and 159 post-neonatal deaths as a consequence of currently estimated prevalence of maternal anemia, BMI and low height. These estimated >700 deaths represent nearly 40% of mortality from LBW in Cambodia.

Table 14: Projection of Neonatal Mortality Attributed to Low Birth Weight

Prevalence of Condition	X	Relative Risk of SGA Outcome	=	Population Attributable Risk	X	Annual LBW/ Neonatal Deaths	=	Excess LBW/Deaths
BMI < 18.5: 19%		1.71		11.9%				223
Height <145cm: 6%[32]		2.2		7%		1,878		132
Anemic: 52.7%		1.25		11.6%				219

Table 15: Projection of Post Neo Natal Mortality Attributed to Low Birth Weight

Prevalence of Condition	X	Relative Risk of SGA Outcome	=	Population Attributable Risk	X	Annual LBW/Post Neonatal Deaths	=	Annual Deaths Attributed
BMI< 18.5: 19%		1.71		11.9%				62
Height < 145 cm: 6%		2.2		7%		521		37
Anemic: 52.7%[33]		1.25		11.6%				61

[29] Robert E Black, Cesar G Victora, Susan P Walker, Zulfiqar A Bhutta, Parul Christian, Mercedes de Onis, Majid Ezzati, Sally Grantham-McGrego, Joanne Katz, Reynaldo Martorell, Ricardo Uauy, and the Maternal and Child Nutrition Study Group Maternal and child undernutrition and overweight in low-income and middle-income countries The Lancet, June 6, 2013.

[30] Supplement to: Black RE, Victora CG, Walker SP, and the Maternal and Child Nutrition Study Group. Maternal and child undernutrition and overweight in low-income and middle-income countries. *Lancet* 2013; published online June 6. http://dx.doi. org/10.1016/S0140-6736

[31] Imdad A, Bhutta ZA. Routine iron/folate supplementation during pregnancy: effect on maternal anemia and birth outcomes. *Paediatr Perinat Epidemiol* 2012; **26** (S1)**:** 168–77

[32] IBID

[33] Note while DHS includes data for anemia among pregnant women

1.2 Anthropometric Indicators: Height-for-Weight & Weight-for-Age

Anthropometric indicators are strong predictors of child mortality. These include of low weight-for-height (WHZ) also known as wasting and low weight-for-age (WAZ), also known as underweight. Low scores for both WHZ and WAZ have been consistently shown to increase the all-cause risk of death from infectious childhood diseases. Severe WHZ or WAZ, defined as <-3 SD below an international reference brings very significant risk of death, ranging RR 11.6 for WHZ and RR 9.4 for WAZ. The risk is lower but remains significant for moderate cases (-2 to -3 SD) and even mild cases (-1 to -2 SD).

For both WHZ and WAZ there is also evidence of infection-specific mortality risk from diarrhea, pneumonia, measles and other infections.[34] A recent pooled analysis from ten longitudinal studies including >55 thousand child-years of follow-up and 1315 child deaths updated evidence on the relative risks of mortality for these infections as summarized in Table 12.[35] The risks are highest for Severe Acute Malnutrition (SAM), defined as < minus 3 SD WHZ, but also significant for less acute WHZ or WAZ. Since impact of low WHZ or WAZ will in all probability vary based on national rates of these infections, this analysis will apply the infection-specific risks found in the literature.

Table 16: Relative Risk of Mortality Associated with Severe, Moderate and Mild Wasting (WHZ) and Underweight (WAZ)

		RR from Pneumonia	RR from Diarrhea	RR from Measles	RR Other
Wasting Low Weight for Height Including SAM	WHZ < -3SD	9.7	12.3	9.6	11.2
	WHZ -2 to -3SD	4.7	3.4	2.6	2.7
	WHZ -1 to -2SD	1.9	1.6	1	1.7
Underweight Low Weight for Age	WAZ < -3SD	10.1	11.6	7.7	8.3
	WAZ -2 to -3SD	3.1	2.9	3.1	1.6
	WAZ -1 to -2SD	1.9	1.7	1	1.5

Table 17: Prevalence of Wasting and Underweight in Children 6-59 months (DHS 2010)

	Severe	Moderate	Mild	Total
Low WHZ Prevalence	2.5%	10.9%	30.6%	44%
# Children	35,697	155,637	436,926	628,260
Low WAZ Prevalence	6.7%	28.3%	23.00%	58%
# Children	95,667	404,086	328,409	828,161

As shown in the Table 13, data from DHS 2010 suggests at least 60% of Cambodian children 6-59 months face these higher risks of death before their fifth birthday, >800 thousand underweight (WAZ) and >600 wasted (WHZ), including 35.6 thousand projected cases of SAM (<-3 SD WHZ).[36] We apply the globally established infection-specific evidence of increased mortality risk to national data for prevalence of low WHZ and WAZ as well as estimates for infection-specific cause death in Cambodia as follows:

[34] Supplement to: Black RE, Victora CG, Walker SP, and the Maternal and Child Nutrition Study Group. Maternal and child undernutrition and overweight in low-income and middle-income countries. *Lancet* 2013; published online June 6. http://dx.doi. org/10.1016/S0140-6736(13)60937-X

[35] Olofin I, McDonald CM, Ezzati M, et al, for the Nutrition Impact Model Study (anthropometry cohort pooling). Associations of suboptimal growth with all-cause and cause-specific mortality in children under fi ve years: pooled analysis of ten prospective studies. *PLoS One* (in press).

[36] The prevalence of underweight typically rises with the lower severity, as indicated by the 3 fold rise from severe to moderate. Therefore we assume for this is a conservative assumption.

- The national prevalence of WHZ and WAZ, segmented into 3 categories of severe, moderate and mild, is applied to the RR for each of the 4 infections to calculate 12 individual PARs.
- From estimated 6,300 deaths of children 6-59 months and segmented cause of death estimated by WHO, mortality is attributed to each of 4 relevant infection pathways: diarrhea, pneumonia, measles and other infections.[37]
- Each of the 12 separate PARS is applied to project cause-specific mortality rates for each infection pathway to project deaths attributable to each category of WAZ and WHZ: severe, moderate and mild wasting and underweight.

The logic model and calculations outlined in the Tables 14 and 15 indicate a total of 1,673 deaths attributable to low WHZ and 1987 deaths as a consequence of underweight.[38] While absolute risk of death from WHZ are generally more acute than for WAZ, due to the significantly wider prevalence of WAZ more deaths are attributed to underweight than wasting. Likewise, though the risks are the most severe for children classified as SAM, this model suggests 556 deaths from this acutely vulnerable group - or about 15% of WHZ and WAZ cases.

Table 18: Model for Calculation of Share of 6300 6-59 month Deaths Attributable to WHZ < -1 SD

RR of Mortality by Infection Pathway and & Severity of WHZ			Prevalence WHZ Children 6-59 m (DHS 2010)		Calculated PAR Mortality from Infection		Infection Share 6-59 month mortality (from WHO)		Mortality Attributed to WHZ by Infection
Diarrhea	12.3	X	Severe: 2.5%	=	22%	X	Diarrhea: 8%/504	=	111
	3.4	X	Moderate: 10.9%	=	20.7%	X		=	105
	1.6	X	Mild: 30.6%	=	15.5%	X		=	78
ARI	9.7	X	Severe: 2.5%	=	17.9%	X	ARI: 16%/1008	=	180
	4.7	X	Moderate: 10.9%	=	28.7%	X		=	290
	1.9	X	Mild: 30.6%	=	21.6%	X		=	218
Measles	9.6	X	Severe: 2.5%	=	17.7%	X	Measles: 1%/51	=	9
	2.6	X	Moderate: 10.9%	=	14.9%	X		=	8
	1	X	Mild: 30.6%	=	-	X		=	-
Other	11.2	X	Severe: 2.5%	=	20.3%	X	Other: 20%/1270	=	256
	2.7	X	Moderate: 10.9%	=	16.6%	X		=	197
	1.7	X	Mild: 30.6%	=	17.6%	X		=	222

[37] http://apps.who.int/gho/data/node.main.ChildMortByCauseByCountry?lang=en

[38] While these are doubtless overlapping conditions the study was provided with no data on how many children measured both low WAZ and WHZ. These will be statistically corrected together with other risks in the 6-59 month age segment.

Table 19: Model for Calculation of Share of 6300 6-59 month Deaths Attributable to WAZ < -1 SD

RR of Mortality by Infection Pathway and & Severity of WAZ			Prevalence WHZ Children 6-59 m (DHS 2010)		Calculated PAR Mortality from Infection		Infection Share 6-59 month mortality (from WHO[39])		Mortality Attributed to WHZ by Infection
Diarrhea	11.6	X	Severe: 6.7	=	11.6	X	Diarrhea: 8%/504	=	209
	2.9	X	Moderate: 28.3%	=	2.9	X		=	176
	1.7	X	Mild: 23%	=	1.7	X		=	70
ARI	9.7	X	Severe: 6.7	=	10.1	X	ARI: 16%/1008	=	371
	4.7	X	Moderate: 28.3%	=	3.1	X		=	516
	1.9	X	Mild: 23%	=	1.9	X		=	173
Measles	7.7	X	Severe: 6.7	=	7.7	X	Measles: 1%/51	=	16
	3.1	X	Moderate: 28.3%	=	3.1	X		=	19
	1	X	Mild: 23%	=	1	X		=	
Other	8.3	X	Severe: 6.7	=	8.3	X	Other: 20%/1270	=	414
	1.07	X	Moderate: 28.3%	=	1.6	X		=	23
	1	X	Mild: 23%	=	1.5	X		=	

1.3 Mortality Attributed to Suboptimal Breastfeeding

Table 20: Relative Risk Infant Mortality by Breastfeeding Behavior

	0- 6 months			6-23 months
	Predominant	Partial	None	None
Diarrhea	2.28	4.62	10.53	2.1
Pneumonia	1.75	2.49	15.13	1.92
All Mortality	1.48	2.85	14.4	3.68

Evidence from both developing and developed countries shows the critical lifesaving significance of exclusive breastfeeding during the first 6 months of life as well as of continued breastfeeding to 2 years of age.[40] A recent meta-analysis including studies from multiple counties concluded that increased mortality risk for non-breastfed versus exclusively breastfed babies ranges from RR 10.53 for diarrhea, RR 15.13 for pneumonia and RR 14.4 from all causes.[41] Compared to exclusively breasted infants, the risks were lower, but still significant for predominant and partial breastfeeding - ranging from RR 1.48 to 2.28. Not continuing breastfeeding after the first 6 months of life also brings twice the risk of mortality compared to babies benefiting from continued breastfeeding.

DHS 2010 found about 89% of Cambodian infants were exclusively breastfed during the first month – and 1.9% not breastfed at all. After the first month, exclusive breastfeeding drops significantly to about 2/3rd of infants - and the proportion not benefiting from any breastfeeding doubles to almost 4%. DHS does not segment the remaining cases into partial and predominant breastfeeding – with about partially breastfed babies facing twice the risk of mortality as the

39 Robert E Black, Cesar G Victora, Susan P Walker, Zulfiqar A Bhutta, Parul Christian, Mercedes de Onis, Majid Ezzati, Sally Grantham-McGrego, Joanne Katz, Reynaldo Martorell, Ricardo Uauy, and the Maternal and Child Nutrition Study Group Maternal and child undernutrition and overweight in low-income and middle-income countries The Lancet, June 6, 2013

40 Bernardo L. Horta, Rajiv Bahl, José C. Martines, Cesar G. Victora, Evidence on the long-term effects of breastfeeding, Systematic Reviews and Meta-Analysis, WHO 2007

41 Robert E Black, Lindsay H Allen, Zulfiqar A Bhutta, Laura E Caulfield, Mercedes de Onis, Majid Ezzati, Maternal and child undernutrition: global and regional exposures and health consequences Maternal and Child Undernutrition Study Group, Lancet January 17, 2008

predominantly breastfed. For the purposes of this analysis we make the assumption that this group is evenly divided between partial and predominant breastfeeding – 4.5% for each group. Based on this prevalence data and related assumptions, Table 17 below outlines shows the number of infants in each breastfeeding behavior segment. More than 165 thousand infants face higher risks of death as a consequence of maternal breastfeeding behaviors – including more than 20 thousand children with the very high risks from no breastfeeding.

Table 21: Rates of 3 Suboptimal Breastfeeding Behaviors for Infants < 1 month and 1-5 months

Breastfeeding Rates	< 1 month	1-5 months
No Breastfeeding rate: DHS 2010	1.9%	3.7%
Number Children with No Breastfeeding	7,388	14,388
Partial: 50% of Not EBF or None	4.5%	14.0%
Number Children with Partial Breastfeeding	17,499	54,441
Predominant: 50% of Not EBF or None	4.5%	14.0%
Number Children with Predominant Breastfeeding	17,499	54,441
Total At-Risk Children	42,386	123,270

Table 17 segments breastfeeding behaviors for < 1 month and 1-5 months because the rate of exclusive breastfeeding is higher during the first month - when mortality rates are much higher as well (estimate 2.5 times greater in the neonatal period than in the subsequent 5 months). Therefore, in order not to over-estimate the impact of suboptimal breastfeeding, projections are run separately for children <1 month and children 1-5 months as follows:

- 6 separate PARs are calculated, one for each of 3 breastfeeding behaviors via 2 infection pathways.
- Each PAR is applied to the neonatal mortality projected separately for diarrhea and ARI, based on WHO estimated for cause of child death in Cambodia.

Table 22: Projected Mortality from Suboptimal Breastfeeding Behaviors for Neonatal Period

RR of Mortality by Infection Pathway & Breastfeeding Behavior			% Suboptimal Breastfeeding Behavior (DHS2010)		Calculated PAR Mortality from Infection		Infection Share 6-59 month mortality (WHO)		Mortality Attributed to Suboptimal Breastfeeding
Diarrhea	None: 10.53	X	None: 1.9%	=	15.3%	X	8%/849	=	129
	Partial: 4.62	X	Partial: 4.5%	=	14%	X		=	118
	Predom: 2.28	X	Predom: 4.5%	=	5.4%	X		=	46
ARI	None:14.97	X	None: 1.9%	=	21%	X	16%/1680	=	352
	Partial: 2.5	X	Partial: 4.5%	=	6.3%	X		=	106
	Predom:1.66	X	Predom: 4.5%	=	2.9%	X		=	48

Table 23: Projected Mortality from Suboptimal Breastfeeding Behaviors for Infant Age 1-5 Months

RR of Mortality by Infection Pathway & Breastfeeding Behavior			% Suboptimal Breastfeeding Behavior (DHS2010)		Calculated PAR Mortality from Infection		Infection Share 6-59 month mortality (WHO)		Mortality Attributed to Suboptimal Breastfeeding
Diarrhea	None: 10.53	X	None: 3.7%	=	26.1%	X	8%/849	=	88
	Partial: 4.62	X	Partial: 14%	=	23.6%	X		=	113
	Predom: 2.28	X	Predom: 14%	=	15.2%	X		=	51
ARI	None:14.97	X	None: 3.7%	=	34.1%	X	16%/1680	=	229
	Partial: 2.5	X	Partial: 14%	=	17.4%	X		=	117
	Predom:1.66	X	Predom: 14%	=	8.5%	X		=	57

Based on the method shown in the tables above, we project about 1640 deaths due of children < 4 months of age as a consequence of suboptimal breastfeeding behaviors – about 15% of all infant mortality. This includes: 799 during the first month of life and 654 during the following 5 months as a consequence on non-exclusive breastfeeding and 187 addition deaths of children 6-24 months of age as a result of non-continued.

1.4 Mortality Associated with Micronutrient Deficiencies

1.4.1. Risk of Death in Children Associated with Vitamin A Deficiency

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 landmark 1993 meta-analysis by Beaton, Martorell and Aronson reviewing a number of vitamin A interventions and trials, concluded that children ages 6-59 months living in vitamin A deficient (VAD) areas receiving vitamin A supplements were 23% less likely to die than children not receiving supplements.[42] Since 1993 additional analysis have confirmed and refined this finding - the most recent Cochrane Review defining a 24% reduction, from which we derive a relative risk of mortality of RR 1.32 which will be applied in this analysis.[43]

There is no current national data on vitamin A deficiency in Cambodia. The last national survey of vitamin A deficiency in children, from the year 2000, found 22.3% prevalence of vitamin A deficiency. While vitamin A capsules campaigns and other improvements may have reduced this national rate, a recent study of micronutrient deficiencies among Cambodian children found 28% prevalence of VAD.[44] Recognizing the uncertainty involved, the analysis will use the 2000 figure of 22.3% prevalence, suggesting that in 2013 there are more >318 thousand children at higher risk of death as a consequence of VAD.

Based on these parameters for prevalence and risk, the table below shows logic and calculation projecting 414 deaths that might be attributed to the status quo prevalence found in the year 2000.

Table 24: Diarrhea and Measles Mortality Associated with Vitamin A Deficiency

Prevalence Conditions		RR Mortality		Population Attributable Risk		Mortality 6-59 months		Annual Deaths Attributed to VAD
22.3%	X	1.32	=	6.6%	X	6,300	=	414

1.4.2. Mortality Attributed to Zinc Deficiency

Zinc plays an essential central role in cellular tissue growth and differentiation including the immune system and the gastrointestinal tract – and the association of zinc deficiency with higher morbidity and mortality due to infectious disease has been widely observed. [45] A recent review of randomized control intervention trials showed a significant 18% reduction (RR 0.82) in all-cause

[42] 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.

[43] Robert E Black, Cesar G Victora, Susan P Walker, Zulfiqar A Bhutta, Parul Christian, Mercedes de Onis, Majid Ezzati, Sally Grantham-McGrego, Joanne Katz, Reynaldo Martorell, Ricardo Uauy, and the Maternal and Child Nutrition Study Group Maternal and child undernutrition and overweight in low-income and middle-income countries The Lancet, June 6, 2013

[44] Co-existing micronutrient deficiencies among stunted Cambodian infants and toddlers Victoria P Anderson MSc1, Susan Jack MBChB2, Didier Monchy MB3, Neang Hem2, Phearom Hok2, Karl B Bailey PhD1 and Rosalind S Gibson PhD1 Asia Pac J Clin Nutr 2008;17 (1):72-79

[45] Caulfield, L Black, R Zinc Deficiency, in Comparative Quantification of Health Risks, Volume 1, Chapter 3, WHO 2004

mortality in children aged 1–4 years.[46] 3 recent trials showed significant infection-specific impacts via lower incidence of diarrhea, ranging from RR 0.22 to RR 0.89; and pneumonia ranging from 0.36 to 0.9.[47] Based on these findings of protective effect, Black et al derive a summary and prevalence adjusted RR of mortality from diarrhea of RR 2.01 and pneumonia RR 1.96.[48]

A published review based on national food availability and established dietary requirements indicated 17% of the world's population and 19.4% of the Asian population with inadequate zinc intake.[49] A local review of zinc content available in the typical Cambodia diet as described in FAO Food Balance Sheets suggests children <5 years consume <30% of RNI for zinc.[50] While zinc deficiency is very likely among Cambodian children, there is no available national or even sub-national biochemical data. Therefore, for the purposes of this analysis, we take prevalence of zinc deficiency found in a recently published survey of Vietnamese children - with similar dietary patterns and presumably parallel deficiencies. This survey found 52% of 6-59 month olds zinc deficient.[51] Applying an estimated of 52% zinc deficiency in Cambodia suggests >700 thousand children suffer higher risks of mortality from diarrhea and ARI.

Based on these parameters for prevalence and risk, the table below shows logic and calculation projecting >500 deaths annually that might be attributed a zinc deficiency prevalence of 52% in Cambodia.

Table 25: Projection of Deaths of 6-59 month Old Attributed to Zinc Deficiency from 6,300 estimated deaths

Prevalence of Condition		Relative Risk Mortality		Population Attributable Risk		Annual Deaths Neonatal Deaths		Annual Deaths Attributed
52%	X	ARI: RR 1.96	=	33.3%	X	ARI: 16%/1,008	=	336
		Diarrhea: RR 2.01		34.4%		Diarrhea: 8%/504		174

1.4.3. Folic Acid related Neural Tube Defects

Neural Tube Defects (NTD) 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 the risk of neural tube defects.[52] A more recent systematic review had much the same findings and estimated that in 2005, 56,000 deaths worldwide were attributable to insufficient dietary folic acid.[53]

With no comprehensive birth registry, there is no data on the incidence of NTDs in Cambodia. A publication of the March of Dimes, global birth defects prevention NGO, suggested 910 cases annually.[54] Global estimates often suggest NTDs occur at a rate of 1-4 per 1,000 and a 2/1,000

[46] Brown KH, Peerson JM, Baker SK, et al. Preventive zinc supplementation among infants, preschoolers, and older prepubertal children. *Food Nutr Bull* 2009; **30** (suppl 1)**:** S12–40.

[47] Yakoob MY, Theodoratou E, Jabeen A, et al. Preventive zinc supplementation in developing countries: impact on mortality and morbidity due to diarrhea, pneumonia and malaria.

[48] Supplement to: Black RE, Victora CG, Walker SP, and the Maternal and Child Nutrition Study Group. Maternal and child undernutrition and overweight in low-income and middle-income countries. *Lancet* 2013; published online June 6. http://dx.doi. org/10.1016/S0140-6736(13)60937-X

[49] King JC. Determinants of maternal zinc status during pregnancy. *Am J Clin Nutr* 2000; **71:** S1334–43.

[50] Pfanner, S Analysis of Nurtrient Content of Cambodian Diet Based on Food Balance Sheet, unpublished, UNICEF/WFP 2013

[51] Laillou A, Pham TV, Tran NT, Le HT, Wieringa F, et al. (2012) Micronutrient Deficits Are Still Public Health Issues among Women and Young Children in Vietnam. PLoS ONE 7(4): e34906. doi:10.1371/journal.pone.0034906

[52] 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.

[53] Blencowe H, Cousens S, Modell B, et al. Folic acid to reduce neonatal mortality from neural tube disorders. Int J Epidemiol 2010;

[54] Calculated from March of Dimes, Report on Global Birth Defects, Appendix B, 2001

figure is often used to estimate cases.[55] Appling this conservative figure of 2/1000 births to the current birthrate indicates 778 annual cases, a lower number than projected by the March of Dimes. Of these we project 72% (as suggested by the Cochrane Review) or 560 cases are related to folic acid. Given the seriousness of NTDs, high rate of births outside a health facility, lack of pediatric neurosurgery and over-all high mortality rate in Cambodia we speculate 80% or 448 of these infants will die during the first year of life.

1.5 Summary of Child Mortality Attributed to 5 Malnutrition Indicators

Table 22 below summarizes findings of child mortality in Cambodia attributable to current levels of child and maternal malnutrition. Indicator by indicator projections total 7,405 deaths of children <5 years of age attributed to maternal malnutrition, underweight and wasting, suboptimal breastfeeding or micronutrient deficiencies. However, nutrition deficiencies during pregnancy, infancy and childhood coexist and affect the same child – and summing these individual findings will doubtless result in "double-counting." For example, some children may suffer both VAD and underweight or low birth weight and suboptimal breastfeeding.

DHS data, on which much of this analysis is based, does not publish data on the extent to which multiple risks of malnutrition and deficiency co-exist in the same child. Therefore, while the reality will remain unknown, we apply statistical adjustments that might begin to correct for these multiple risks - and enable a more realistic projection for total deaths attributed to these individual indicators. An algorithm recommended by Rockhill et al provides a method to statistically correct for simultaneous risks during the neonatal period, infancy 1-5 months, and period of 1-4 years. Based on the individual PAR of mortality calculated for each indicator, the algorithm develops a "hybrid" PAR, statistically adjusting for multiple risks.[56] Based on these adjustments projected mortality is 94% to 97% of individual attributions during neonatal and 1-5 month old periods when the competing risks are few and PARs relatively low. For the 6-59 month age group with more competing risks and higher PARs this adjustment factor is greater, taking 76% of the individual attributions. As indicated in the table below, after this statistical (possibly insufficient) adjustment, we conclude that the measured indicators result in >6,000 annual deaths, about 29% of all mortality in children <5 years of age. This includes 16% of neonatal deaths and more than half of deaths of children 6-59 months. The table below summarized the individual and adjusted findings.

Table 26: Total Estimated Attributable Deaths

	Individual Analysis		Adjusted Multiple Risks	
	# Deaths	% Risk Group/Age	# Deaths	% Risk Group/Age
Neonatal	**10,499 Deaths**			
Maternal Nutrition Status	574	5%	542	5%
Maternal FAD NTD	448	4%	423	4%
Suboptimal Breastfeeding	799	8%	755	7%
Total Neonatal	**1,821**	17%	**1,721**	**16%**
Infant: 1-5Months	**4,200 Deaths**			
Mothers Nutrition Status	159	4%	154	4%
Suboptimal Breastfeeding	654	16%	634	15%
Total infant 1-5-Months	**813**	19%	**788**	**19%**

[55] Personal communication, Godfrey Oakley, United States Centers for Disease Control and Prevention

[56] Rockhill et al, Use and Misuse of Population Attributable Fractions, American Journal of Public Health, January 1988,

Infant 6-59 Months	6,300 Deaths			
Breastfeeding (6-24mnts)	187	3%	144	2%
Wasting (WHZ)	1,673	27%	1,284	20%
Underweight (WAZ)	1,987	32%	1,525	24%
VAD	414	7%	318	5%
Zinc	509	8%	391	6%
Total Infants 6-59 Months	**4,771**	76%	**3,661**	**58%**
Total < 5 yrs	**7,405**	**35%**	**6,170**	**29%**

1.5.1. Estimating Value of Workforce Lost to Child Mortality

The value of this loss of life is immeasurable. However, from an economic perspective, this value is simply derived as a lost workforce - by taking a discounted net present value (NPV) of future lost earnings. The NPV includes a delayed earnings stream that presumes entry into the workforce at average of 15 years of age – a delay ranging from 15 years for perinatal and neonatal deaths to an average 13 years for the 6-59 month old cohort. Further, this cold economic perspective attributes an economic value only to the 84% of children who would be projected to participate in the labor force as adults. In other words, this economic calculation attributes no value at all to ~16% of these child deaths who are not projected to participate in the labor force and be economically active.

At average 2013 wages of $1253, 45-50 years of labor yields about $60 thousand dollars. However, at a 3% discount rate the NPV of a lifetime of lost potential future earnings total about $14.4 thousand per life. The total loss from emerging 6170 child deaths totals NPV ~$88.7 million. When the discount rate to calculate the NPV is set at 7%, the value is more than cut almost by 2/3rds to NPV $31.5 million – valuing each lost life at $5.1 thousand. In economic terms, life is very sensitive to discount rates. Clearly, this methodology does not begin to measure the value of human life.

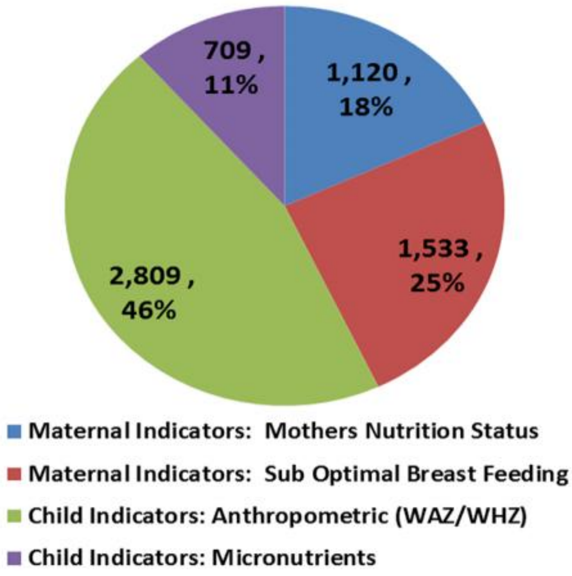
Table 27: Net Present Value of Lost Workforce due to Child Mortality @ 3%

Child Deaths Attributed to Malnutrition		Average Wage		Labor Force Participation Rate		NPV: Work life w/delayed earning stream		Net Present Value of Losses ($000,000)
6,170	X	$1,253	X	84%	X	15 years 13 years	=	**$88.7 million/Yr**

1.5.2. Perspectives on the Attributions for Child Mortality

Considering the relative share of loss represented by the various measured nutrition indictors leads to the observation that only part of these nutrition-related deaths are associated with deficit in quantity of food – lack of calories or energy - usually used as benchmark of food security in Cambodia. While the causes of wasting and underweight, which represent almost half of the attributed deaths, include lack of sufficient calories, these anthropometric indicators WHZ and WAZ are broad indicators of malnutrition and sensitive to a range of threats. WHZ and WAZ are also associated with initial birth outcome, suboptimal breastfeeding, appropriate complementary feeding, infection and related immune-boosting micronutrients. We also note that children suffering severe wasting or Severe Acute Malnutrition (SAM) while facing the highest risks of mortality, in total represent about only about 15% of the deaths associated with malnutrition. While the risks are lower, the hidden burden represented by the much higher prevalence of non-clinical or less severe cases results in a greater impact of over-all child mortality.

Figure 1: Child Mortality by indicator



More than half the attributed deaths are not associated with quantity of food or lack calories or food quantity but rather food quality, child care behaviors and the nutrition status of the mother.

- Micronutrient deficiencies, 11% of attributed deaths, reflect low quality of diet rather than lack of sufficient quantity of food. Vitamin A and zinc are most available in animal products and to some extent fruits and vegetables – and not offered by rice, cassava or other staple grains and root foods that are predominantly consumed by the poor.
- 18% of the attributed to child mortality is exclusive of child nutrition status and only associated with maternal nutrition status - maternal anemia, BMI and height and folic acid deficiency that result in low birth weight and related mortality.
- Another quarter of deaths are linked exclusively with maternal behavior and lack of optimal breastfeeding. Other potential maternal behaviors that are also linked to wasting and underweight, including child care and complementary feeding – and therefore may account for a number of deaths associated with wasting and underweight. While only 3 indicators of maternal nutrition are measured, in could be argued that maternal nutrition status impacts ability to deliver optimal child care and feeding patterns and thereby an addition pathway to mortality.

Significantly reducing the burden of childhood deaths in Cambodia will require addressing maternal nutrition and behaviors as well as micronutrient deficits – which represent 56% of the estimated mortality from malnutrition. Addressing this burden will involve a comprehensive set of interventions beyond ensuring access to increasing quantities of staple foods.

2. Pathway #2: Depressed Future Productivity of Children

Undernutrition diminishes children's cognitive development through physiological changes, by reducing the ability to participate in learning experiences, or both. Compared to their well-nourished peers, children with even mildly or moderately undernourished score poorly on tests of cognitive function, psychomotor development and fine motor skills. With lower activity level, they interact less frequently with their environment and thus fail to acquire physical and intellectual skills at normal rates. In large part these early childhood deficits determine their ability to capitalize on educational opportunities and later employment opportunities, resulting in an adult productivity deficit.[57]

Malnutrition coincides with many health and economic deprivations which affect child growth and development. Isolating the "nutrition factor" or the "child development factor" is complicated by countless interactions of nutrition, nature and nurture. However, there is substantial evidence that after correction for poverty and associated threats, nutrition has independent and additive

[57] 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)

impacts on child growth, cognition and development.[58] This report focuses on childhood anemia and stunting - indicators strongly associated with slow growth and depressed cognition as well as directly with suboptimal school performance and reduced adult earnings.

DHS 2010 reports that ~40% of Cambodian children less than 5 years of age are stunted and > 50% are anemic. No data is available currently to determine whether the total number of children suffering from either anemia or stunting is only a bit more than 50% or approaching 80-90%. While many children suffer from both anemia and stunting, data describing the extent to which these deficiencies co-exist in the same children is not available. Therefore, the individual analysis that follows will be statistically adjusted to correct, as much as possible for "double counting" of children suffering both anemia and stunting. As a result, the NPV of lost future productivity for these conditions is about 25% lower than the sum from the individual analysis.

The following sections estimate the scale of the economic consequences of the status quo. It's interesting to note that along with the global evidence presented below, recent work in Cambodia found 4.4% cognitive deficit of anemic children compared to non-anemic peers and a 5.6% deficit in cognitive scores among stunted children.[59] Children who were both anemic and stunted scored 11.1% lower on cognitive tests. This not only underscores the cognitive and future productivity impact of these conditions in Cambodia, it also suggests that the effects on anemia and stunting are additive and therefore the statistical adjustment may not be necessary.

2.1. Stunting or Small Stature

Stunting or low height-for-age is a general marker of the cumulative effects of chronic malnutrition in childhood – emerging not from a single clinical conditions but a combination of inadequate diet, infection, and suboptimal child care. Children falling more than 2 standard deviations below an international reference population developed by WHO are considered to be low height for age (HAZ) or stunted.[60] Findings *from well-nourished populations* consistently show that in a range of nations and ethnic groups, children grow at very close to the same trajectory. As shown in the attached figure from WHO, an assessment of linear growth in well-nourished children from birth to 1000 days in Brazil, Ghana, India, Norway, Oman and USA shows that despite some minor variation, the growth curves among these populations are very similar.[61],

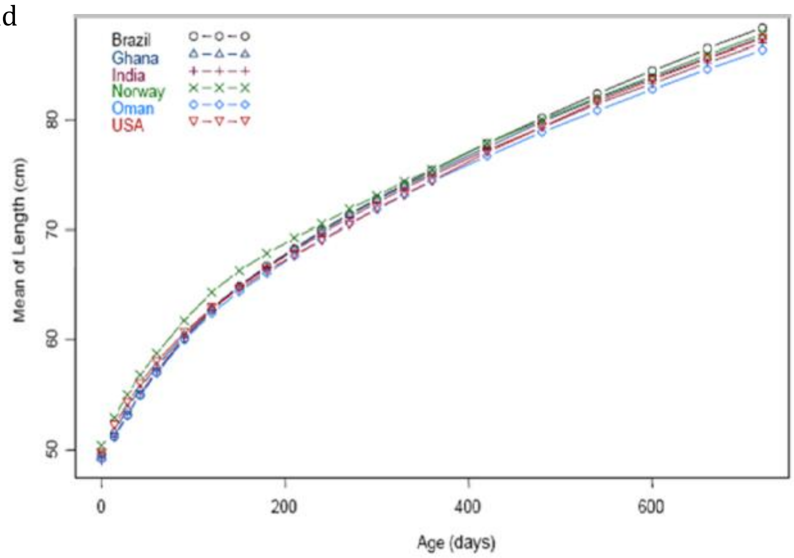


Figure 2: 5 Continent and 6 Country Comparison: Mean Length Over 1,000 Days (WHO, 2006)

While there is no average difference among these well-nourished populations, "being short" has negative effects when there is malnutrition. Stunted children suffer low physical activity, impaired

[58] Grantham- McGregor et al, Developmental Potential in the first 5 Years for Children in Developing Countries, The Lancet, VOl 369, 2007

[59] Unpublished, Wieringa et al, Winfoods Project, 2013

[60] Bulletin of the World health Organization, Vol 83, No 3, Geneva, Mar 2005

[61] WHO Multicentre Growth Reference Study Group, Assessment of Linear Growth Difference Among Populations, Acta Paediatrica. 2006 450:56-65

motor and mental development, lowered immune competence, greater severity of infections and increased mortality.[62] Numerous studies directly associate stunting with lower test scores for childhood cognition. A recent pooled analysis from 5 countries concluded that "being moderately or severely stunted was associated with lower scores for cognition in every study and the effect size varied from 0.4 to 1.5 SD."[63]

A number of studies have documented the association between stunting and future economic productivity via 2 general pathways.

- *Suboptimal School Achievement:* Stunted children start school later, progress through school less rapidly and have lower over-all schooling attainment. A review of evidence from 79 countries concluded "for every 10% increase in stunting, the proportion of children reaching the final grade of primary school dropped by 7.9%."[64] After statistically correcting for poverty, the review concluded that stunted children suffer a combined grade attainment and performance deficit of 2.91 years, suggesting "total percentage loss of adult yearly income" of 19.8%."[65]
- *Reduced earnings in manual labor.* Several studies controlling for a variety of characteristics, document a direct association between lower adult height and reduced earnings in physically demanding jobs.[66] Among sugar cane workers in the Philippines, Haddad et al concluded productivity rose 1.38% for every 1% increase in height.[67] Since severe stunting (> -3 SD) represents a 6.25% reduction in height and moderate stunting (-2 to -3 SD) represents a 4.375% deficit, this indicates severely stunted children suffer a productivity loss of 8.6% while moderate stunting results in about a 6% future deficit.[68]

Table 28: Labor Force Segmentation (CES 2009)

	Total (%)
Agriculture (primary)	57.6
Industry (Secondary)	15.9
Service (Tertiary)	26.5
Manual (Ag + Ind)	73.5

- Since the evidence shows stunting impacts productivity through two very distinct pathways, schooling and agricultural work performance, this analysis applies differing coefficient of deficit to the appropriate sectors of the Cambodian economy. As shown in Table 24, according to the National Institute of Statistics' Cambodia Socio-Economic Survey (CSES), 26.5% of the national labor force is made up of service or "tertiary" employment in business, sales, education, government and other "white collar" jobs.[69] These service sector jobs require a range of numeracy and literacy skills as well as other intellectual skills developed in school. The Lancet findings, establishing a coefficient of 19.8% deficit based on school attainment will be applied future work in the service sector. The lower deficit coefficient of 6% - 8.6% measured in the agricultural jobs will be applied

[62] Martorell, R. The role of nutrition in economic development. Nutr. Rev. 54: S66–S71(1996

[63] Psacharopoulos G, Patrinos H. Returns to investment in education: A further update. *Educ Econ* 2004; 12:111–34.

[64] Ibid

[65] Grantham- McGregor et al, Developmental Potential in the first 5 Years for Children in Developing Countries, The Lancet, VOl 369, 2007;

[66] 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)

[67] Haddad, L et al The Impact of Nutritional Status on Agricultural Productivity: Wage Evidence from the Philippines, Oxford Bulletin of Economics & Statistics, Vol 53 Feburary, 1991, 45-68 1991

[68] Burkhalter, Barton R., Victor M. Aguayo, Serigne M. Diene, Margaret B. Parlato, and Jay S. Ross *PROFILES: A Data-Based Approach to Nutrition Advocacy and Policy Development. BASICS/* USAID 1998

[69] National Institute of Statistics, Cambodia Socio-Economic Survey (CSES) Cambodia Ministry of Planning 2009

to the 74% of the labor force projected to be employed in manual labor like agriculture and manufacturing.

The DHS 2010 found 39.9% or about 570 thousand 6-59 month olds as moderately or severely stunted and ~14% are severely stunted.[70] A 19.8% deficit in earnings is applied to 26.5% or the 150 thousand of these stunted children who are projected be employed in professional, government, education and other service employment where schooling and cognitive acuity are regarded as key component of productivity.[71] The table below outlines parameters for a projecting NPV $93.7 million annually in losses from suboptimal productivity in the service sector. The parameters for the NPV calculation in Table 25 are:

- Average 2013 annual earnings of $1,253 over a 47 year work life
- No value attributed to the 15.6% of children who may not participate in the labor force (84.4% labor participation).
- NPV assumes 12.5 year delay (mid-point of 0-5 yrs) with no earnings before entering the workforce and beginning of the earning's stream.
- 3% discount rate to value earnings which stretch more than 60 years into the future.

The projected NPV $93.7 million economic burden strikes precisely in the areas of economic activity crucial to national development and migration of Cambodia to middle income nation status.

Table 29: Projecting Economic Loss from Stunting via Schooling Methodology

Number w/ Deficit or Risk		Average Earnings		Labor Force Participation		Average Work-Life		Coefficient Risk-Deficit		Discount for NPV		Annual Loss
39.9% Stunted 26% Service: 150,975 children	X	$1,253 /yr	X	84.4%	X	47.4 yr	X	19.8%	X	@ 3% & 12.5yr delay	=	NPV $93.73 million /yr

While schooling attainment in all probability enhances productivity no matter the type of job, attributing the high 19.8% deficits to stunted children whose future employment will be in manual labor seems problematic. To measure losses in agriculture and industrial sectors, we apply the coefficients of deficit found by Haddad et al in the Philippines: 8.6% loss among severely stunted and 6% deficit among moderately stunted children.[72] DHS 2010 finds 26.3% of 6-59 year olds, 276 thousand children, moderately stunted and 13.6%, or 143 thousand children, severely stunted.[73] As shown in Table 26 below, applying the relevant coefficient of deficit to the appropriate level of stunting yields a projection of NPV $73.2 million in depressed work performance and productivity in the agriculture and industry sectors. The losses for service, industry and agriculture are projected at NPV $166,906,113 in future depressed economic activity.

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[70] National Institute of Statistics, Directorate General for Health, and ICF Macro, 2011. *Cambodia Demographic and Health Survey 2010.* Phnom Penh, Cambodia and Calverton, Maryland, USA: National Institute of Statistics, Directorate General for Health, and ICF Macro.

[71] IBID

[72] Burkhalter, Barton R., Victor M. Aguayo, Serigne M. Diene, Margaret B. Parlato, and Jay S. Ross *PROFILES: A Data-Based Approach to Nutrition Advocacy and Policy Development. BASICS/* USAID 1998

[73] National Institute of Statistics, Directorate General for Health, and ICF Macro, 2011. *Cambodia Demographic and Health Survey 2010.* Phnom Penh, Cambodia and Calverton, Maryland, USA: National Institute of Statistics, Directorate General for Health, and ICF Macro.

Table 30: Projecting Economic Loss from Stunting via Direct Observation of Earning Methodology

Number w/ Deficit or Risk		Average Earnings		Labor Force Participation		Average Work-Life		Coefficient Risk-Deficit		Discount for NPV		Annual Loss
Moderate: 26.3%/ 276,013	X	$1,253 /yr	X	84.4%	X	47.4 yr	X	6.038%	X	@ 3% W/12.5 yr delay	=	NPV $73.2 million/ yr
Severe: 13.6%/ 142,729								8.625%				

2.2. Anemia in 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 SD and concluded that "available evidence satisfies all of the conditions needed to conclude that iron deficiency causes cognitive deficits and developmental delays."[74] The literature from child psychology, nutrition and economic science, find that development deficits related to iron status in children less than 5 years old children are associated a 4% drop in earnings.[75] In general studies show that iron supplementation in children < 5 years led to cognitive improvements which were sustained into adolescence with a correlation coefficient 0.62.[76]This analysis applies a correlation coefficient of 0.62 to findings of 4% earnings deficit to arrive at a coefficient of 2.5% lower future earnings and productivity.[77]

The recent DHS found 55.1% of children less than 5 years of age are anemic, more than ¾ of a million children 6-59 months. With little variation, these high levels reach across all provinces, all income groups and throughout both urban as well as rural areas. While the NPV of a small 2.5% deficit in future earning comes to only $87 per child, in aggregate, with more than half the population of children projected to suffer some earnings deficit the NPV totals > $68.5 million annually. The parameters for this projection are shown in Table 27.

Table 31: Projecting Economic Loss from Childhood Anemia

Number w/ Deficit or Risk		Average Earnings		Labor Force Participation		Average Work-Life		Coefficient Risk-Deficit		Discount for NPV		**Annual Loss**
55.1% 786,753	X	$1,253 /yr	X	84.4%	X	47.4 yr	X	2.5%	X	@ 3% With 12.5 yrs delay	=	NPV $68.5 million/ yr

2.3. Long Term Disability from Folic Acid Related Neural Tube Defects

As noted in the mortality analysis (Section 2.4.3), given lack of access to pediatric neuro-surgery and the consequent high mortality rate, there will be few survivors of NTDs like spina bifada and anencephaly. A speculated 80% fatality rate suggests 90 survivors with lifelong moderate or severe disability. For the purposes of this analysis we assume that 25% of these survivors will be severely disabled and unable to work in any way, while the remaining 3/4s are moderately disabled and ,may be able to work at some kind of employment at 50% of potential productivity

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

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

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

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

of non-disabled workers. Based on these assumptions, we speculate disability associated with folic acid-related NTDs results in annual earning loss of NPV of $780 thousand.

Table 32: Projecting Economic Loss from Stunting via Direct Observation of Earning Methodology

Number w/ Deficit or Risk		Average Earnings		Labor Force Participation		Average Work-Life		Coefficient Risk-Deficit		Discount for NPV		Annual Loss
Moderate: 67	X	$1,253 /yr	X	84.4%	X	47.4 yr	X	50%	X	@ 3% W/15y delay	=	NPV $0.786 million/yr
Severe: 22								100%				

3. Pathway #3: Depressed Current Productivity: Anemia in Adult Workers

Although this analysis focuses mainly on malnutrition in pregnant women and children, widespread anemia among adults results in current work performances deficits - and current losses to the national economy. In addition, anemia in the general population of adult women of reproductive age is a key component of maternal nutrition during early pregnancy – a key input to birth outcomes and therefore a key component of the inter-generational of the burden of malnutrition.

Weakness, fatigue and lethargy brought on by anemia results in measurable productivity deficits in the manual labor. Aerobic capacity, endurance and energy efficiency are compromised 10-50%.[78] A substantial literature shows this has 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.[79]
- 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%.[80] [81] [82]
- 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.[83]

This analysis will apply the coefficients from the Ross & Horton– 5% deficit among manual laborers and an additional 12% loss among heavy manual laborers.

The DHS 2010 found national prevalence of anemia of 44.4% among reproductive age women, ~2.5 million adult women.[84] While there is no available data for anemia in Cambodian men, given

[78] Celsing F., Blomstrand E. Effects of iron deficiency on endurance and muscle enzyme activity Med. Sci. Sports Exerc. 1986;18:156-161

[79] 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

[80] 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

[81] 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

[82] 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

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

the wide prevalence among both women and children, it stands to reason that this condition exists – but at a much lower rate. In the Philippines a national nutrition survey found anemia rates twice as high among women - 21% for women and 10% of men.[85] In Vietnam a recent survey found 40% anemia among women compared to 15% among men. [86] For the sake of his analysis we apply the 38% proportion of anemia in men versus women from Vietnam to the prevalence of anemia found in Cambodian women - to speculate a male anemia rate of 16.5%.

Table 33: Manual Labor in CSES 2009

	Women (%)	Men (%)	Total (%)
Agriculture (primary)	57.8	57.4	57.6
Industry (Secondary)	16.2	15.5	15.9
Services (Tertiary)	26	27	26.5
Agriculture + Manual labor	74	72.9	73.5

As with previous analysis, productivity deficits are only applied to individuals participating in the labor force, 88.8% for men and 80.4% for women.[87] In the case of anemia, we apply an additional screen to include only to individuals in manual labor where the evidence of deficit is clear - not to administrative, managerial, education and other "white collar" job. The most recent Cambodia Socio-Economic Survey (CSES) finds 74% of women and 72.9% of men involved in manual labor.[88] While there is no data distinguishing normal manual labor from heavy manual labor (and the definition itself may be ambiguous), based on a global analysis done for the Copenhagen Consensus we assume 15% of manual labor may be classified as heavy.[89]

Table 30 below shows calculations for national economic losses emerging from anemia among adult women and men employed in manual labor. After corrections for general labor participation and estimates for proportion employed in manual labor, the 5% productivity deficit is applied to 308 thousand anemic women workers and 83 thousand anemic men workers – with an additional 12% deficit for those assumed to be engaged in heavy manual labor. Since these are current losses no discounting is applied. Projected losses of ~$89 per year per anemic worker add up to an estimate of $138.3 million in depressed productivity of manual laborers with anemia – a significant burden on the current expansion of agriculture and industry sectors in Cambodia.

Table 34: Manual Labor in CSES 2009

Number w/ Deficit or Risk		Average Earnings		Labor Force Participation		Manual Labor %		Coefficient Deficit		Coefficient Deficit		**Annual Loss**
Female 15-64 yr: 44.4%	x	$1,253/ yr	x	80.4%	x	74%	x	5% for Manual Labor	+	+12% for Heavy Manual Labor	=	**$138.3 million /yr**
Male: 15-64yr: 16.5%				88.8%		72.9%						

[84] National Institute of Statistics, Directorate General for Health, and ICF Macro, 2011. *Cambodia Demographic and Health Survey 2010.* Phnom Penh, Cambodia and Calverton, Maryland, USA: National Institute of Statistics, Directorate General for Health, and ICF Macro.

[85] 7th National Nutrition Survey: 2008 Biochemical Survey, Philippine Food & Nutrition Research Institute 2008

[86] Nguyen PH, Nguyen KC, Le Mai B, Nguyen TV, Ha KH, Bern C, Flores R, Martorell R. Risk factors for anemia in Vietnam. The Southeast Asian Journal of Tropical Medicine and Public Health. 2006 Nov; 37(6): 1213-23

[87] National Institute of Statistics, Cambodia Socio-Economic Survey (CSES) Cambodia Ministry of Planning 2009

[88] IBID

[89] Sue Horton, Harold Alderman, Juan A. Rivera, Hunger and Malnutrition, Copenhagen Consensus, 2008

4. Pathway #4: Excess Healthcare Expenditures

Malnutrition in children contributes to impaired immunity and infection. Consequently, malnourished children may suffer more frequent or more severe illness which in turn translates into increased utilization and expense of health services. This can generate a significant financial burden both on individual families as well as the health care system. While there are also significant in-kind and opportunity costs to families and communities involved in caring for sick children, only direct financial costs will be estimated.

4.1. Excess Healthcare Costs Due to Suboptimal Breastfeeding

Table 35: RR of Diarrhea and ARI by Breastfeeding Status[90]

Age Segment	Breastfeeding Behavior	Diarrhea Cases	ARI Cases
		RR	RR
0-6 months	None	2.65	2.48
	Partial	1.68	2.07
	Predominant	1.26	1.79
6-23 months	None	2.07	1.17

A long literature has documented the association of suboptimal breastfeeding and increased morbidity from acute respiratory infection and diarrhea. For children 0-6 months, the most recent authoritative review in the Lancet finds that predominantly breastfed infants have a relative risk of 1.26 for diarrhea morbidity and the risk triples for those not breastfeeding at all. For ARI the relative risk of morbidity is 1.79 for predominant breastfeeding while infants with no breastfeeding at all are twice likely to contract respiratory disease. Beyond exclusive breastfeeding for infants < 6 months of age, the Lancet also concluded that continued breastfeeding in the 6-24 month period also confers protection against these infections. Compared to children benefiting from continued breastfeeding, the risk of diarrhea episodes doubles for children who are not breastfed at all. The risk for ARI is more modest but still significant and can add to the national health care burden.

Suboptimal breastfeeding behaviors are widespread in Cambodia. The parameters included in this analysis are based on the latest data provided by the DHS 2010 includes:

- 74% of children of children <6 months of age are exclusively breastfed and 3.2% receive none. The remaining group is assumed to be equally divided between partial and predominant at rate of 11.7% each.
- For children 6-23 months we derive 25% non-continued breastfeeding behaviors based on a weighted average non-continued breastfeeding found in DHS of 6.2% for 6-11 months and 34% for 11-24 months.

DHS also provides the basic data to project the total burden of diarrhea and ARI cases with mothers' reporting 14.9% and 6.4% of children had diarrhea and ARI symptoms during the previous two weeks. This snapshot was annualized and corrected for seasonal variation to arrive at an estimate of 2.73 diarrhea cases and 1.24 ARI cases per child per year.[91] As shown in Table 30 this suggests nearly 3 million cases of diarrhea and more than 1 million cases of ARI annually in children < 24 months of age.

[90] Robert E Black, Cesar G Victora, Susan P Walker, Zulfiqar A Bhutta, Parul Christian, Mercedes de Onis, Majid Ezzati, Sally Grantham-McGrego, Joanne Katz, Reynaldo Martorell, Ricardo Uauy, and the Maternal and Child Nutrition Study Group Maternal and child undernutrition and overweight in low-income and middle-income countries The Lancet, June 6, 2013

[91] Data provided by UNICEF/MOH

Table 36: Estimated Annual Cases of Diarrhea and Respiratory Disease in Children < 24 months of Age

	Diarrhea	ARI
Reported in DHS for past 2 weeks	14.9%	6.4%
Annualized over 52 Weeks	3.87	1.66
Adjusted for Seasonal Bias (UNICEF/MOH)	2.73	1.24
Total Number of Estimated Cases < 6 months	530,801	241,096
Total Number of Estimated Cases 6-24 months	2,259,695	970,607

Table 33 below outlines the methodology to project excess cases of diarrhea and ARI specifically attributable to the current prevalence of non-exclusive in children <6 months. Based on the prevalence from DHS and distinct infection-specific risk from the literature for each of the 3 suboptimal breastfeeding behaviors (predominant, partial and none), 6 separate PARs are calculated – 3 each for diarrhea and ARI. These PARs are applied separately to the total burden of diarrhea and ARI to derive the number of cases attributable to each infection and each breastfeeding behavior. The sum of these 6 individual projections total ~139 thousand excess cases - 81 thousand diarrhea and 58 thousand ARI cases that may not have occurred with exclusive breastfeeding. A simpler calculation based on a single behavior, non-continued breastfeeding, shown in Table 34, is applied to the much larger 6-24 month cohort and suggest more than half a million excess cases preventable by improved breastfeeding practices. For the total <24 month cohort this suggests >650 thousand cases annually, or 16% of all cases of diarrhea and ARI could be avoided via optimal breastfeeding behaviors.

Table 37: Projected Cases Diarrhea and ARI Attributed to Suboptimal Breastfeeding Behaviors for Infant Age< 6 Months

RR of Diarrhea or ARI by Breastfeeding Behavior			% Suboptimal Breastfeeding Behavior (DHS2010)		Calculated PAR Infection		Total # Annual Cases Diarrhea and ARI		Cases Attributed to Suboptimal Breastfeeding
Diarrhea	None: 2.65	X	None: 3.2%	=	3%	X	530,801	=	15,605
	Partial: 1.68	X	Partial: 11.7%	=	7.34%	X		=	38,963
	Predom:1.26	X	Predom: 11.7%	=	5.015%	X		=	26,621
ARI	None:2.07	X	None: 3.2%	=	8%	X	241,096	=	20,319
	Partial: 2.48	X	Partial: 11.7%	=	11%	X		=	26,723
	Predom:1.79	X	Predom: 11.7%	=	5%	X		=	101,092

Table 38: Projected Cases Diarrhea and ARI Attributed to Suboptimal Breastfeeding Behaviors for Infant Age 6-24 months

RR of Diarrhea or ARI by Breastfeeding Behavior			% Suboptimal Breastfeeding Behavior(DHS2010)		Calculated PAR Infection		Total # Annual Cases Diarrhea and ARI		Cases Attributed to Suboptimal Breastfeeding
Diarrhea	2.07	X	25%	=	21%	X	2,259,695	=	472,876
ARI	1.17	X		=	4%	X	970,607	=	39,164

Establishing a financial cost for >650 thousand cases of diarrhea and ARI involves a number of parameters. To estimate the added burden to health care system and families for primary care visits, the following parameters are included:

- Not all cases result in seeking out health center or hospital care. According to DHS, only 59% of diarrhea and 64% of ARI are taken to health facilities.[92]
- Cost per visit is set at $1.33 based on a recently completed health system costing study done under the auspices of WHO/USAID.[93]
- Based on DHS survey of mothers, transport costs involved in visiting health facilities are higher than the health facility costs at $2.08.[94]
- A notional figure of $1 is applied to cases not seeking-out professional care to capture family purchases of Oral Rehydration Salts, antibiotics, bananas or traditional treatments and care.
- Lost productivity and opportunity costs involved in parents' time in extra child care and or travel to health facility as well as caring for sick child are not included.

As indicated in Table 35 below, more than 388 thousand cases seen at health facilities at an average cost of $3.41 indicates a cost of $1.32 million annually – with additional $260 thousand estimated for home treatments among those not seeking out professional care.

Table 39: Cost to Government and Families of Excess Diarrhea and ARI Attributed to Suboptimal Breastfeeding

		Diarrhea	ARI
Health Center	Average Cost/Case	$3.41	$3.41
	Cases Seen at HC	326,344	62,149
	Total Health Center Costs	$1,112,834	$211,929
Hospitalizations	Cohort Size Adjusted PAR < 6 months	1.53%	2.40%
	Cohort Size Adjusted PAR 6-24 months	6.28%	1.21%
	Attributed Hospital Costs	$153,628	$119,446
	Total Annual Cost of Hospitalization	$1,967,691	$3,305,234
Home Treatment Not in Health System @ $1/case		$227,721	$34,959
Cost Per Infection Pathway		$1,494,183	$366,334
Total Cost of Excess Cases due to Suboptimal Breastfeeding		$1,860,517	

In addition to primary care visits, a certain proportion of severe cases are admitted to secondary and even tertiary facilities. Two key data sources are used to estimate the contribution suboptimal breastfeeding to these higher level medical costs. First, MOH data from 2013 provides total number of hospital cases discharged for diarrhea and ARI cases by level of facility.[95] Second, the 2012 *Cambodia Hospital Costing & Financial Management Study* provides case costs by level of facility (CPA 1-3).[96] In the table below the total number of cases from taken MOH discharge records is applied to the cost per discharge from the *Hospital Costing and Financial Management Study* to estimate the cost of secondary and tertiary care for diarrhea and ARI cases among children <5 years, shown in Table 36 below. To estimate the share of these total costs of caring for diarrhea and ARI cases in children < 5 years age, the PARs for higher risks of infection found previously are adjusted to reflect the smaller cohort size relative to the much larger < 5 year cohort. The adjusted PARs of for diarrhea (1.5%-6%) and ARI (1-2%), as shown in Table 35 above, are applied to the total estimated costs suggesting more than half a million dollars of these

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[92] National Institute of Statistics, Directorate General for Health, and ICF Macro, 2011. *Cambodia Demographic and Health Survey 2010.*

[93] Steve Fabricant, Cost Analysis of Essential Health Services in Cambodia, MOH/WHO Health Sector Reform Phase III Project WHO/USAID/POPTECH, March 24, 2014

[94] National Institute of Statistics, Directorate General for Health, and ICF Macro, 2011. *Cambodia Demographic and Health Survey 2010.* Phnom Penh, Cambodia and Calverton, Maryland, USA: National Institute of Statistics, Directorate General for Health, and ICF Macro.

[95] Obtained by UNICEF from MOH Records for Jan-Oct, 2013

[96] Annette Martin, Cambodia Hospital Costing and Financial Management Study, Cambodia Ministry of Health (MOH) Department of Planning and Health Information (DPHI, Belgian Development Agency (BTC) and University Research Company (URC), September 3, 2012 (Final Draft)

hospital costs attributed to suboptimal breastfeeding. Total estimated cost of excess cases of diarrhea and ARI attributed to suboptimal breastfeeding behaviors in children < 24 months totals $1.86 million annually.

Table 40: Estimated Cost of Total Hospital Admissions for Diarrhea and ARI in Children < 5 yrs (Multiple Sources)

	Level of Hospitalization	Cases (From MOH)	Cost/Discharge (Cost Study)	Calculated Cost
ARI	Provincial/National (CPA1)	25,411	$101.00	$2,566,536
	District (CPA2)	7,536	$85.00	$640,581
	Lower Level (CPA3)	1,851	$53.00	$98,116
	Total			$3,305,234
Diarrhea	Provincial/National (CPA1)	15,861	$101.00	$1,601,986
	District (CPA2)	3,404	$85.00	$289,319
	Lower Level (CPA3)	1,441	$53.00	$76,386
	Total			$1,967,691

4.2. Excess Healthcare Costs Due to Zinc Deficiency

The literature on the association of zinc deficiency with diarrhea and ARI incidence is robust. Based on 17 intervention studies with all but 2 finding a significant protective of zinc, Black et al derive a pooled and prevalence adjusted RR 2.85 for diarrhea and RR 2.07 for ARI. Applying the RR 2.85 for diarrhea, to the Cambodian environment resulted in projection that seemed unreasonably high with a PAR of 50%. Therefore, we apply the low end of the confidence interval (CI) derived Black et al or RR 1.93 for diarrhea.[97]

Based on these coefficients of risk taken from the literature, the same approach used to estimate the excess health care costs associated suboptimal breastfeeding is applied to project excess cases of diarrhea and ARI emerging from zinc deficiency in children 6-59 months. As indicated in Table 37, while the methodology is the same and the relative risks comparable, the results derive a much higher PAR and indicate a much higher cost, about 4 times higher than the breastfeeding analysis for several reasons. First, while the baseline cases per child per year is the same as the breastfeeding analysis, the cohort is 2.5 times larger than the <24 month age group. Consequently the absolute number of cases rises to 5.7 million. Second, the estimated 52% prevalence of zinc deficiency, based on data from Vietnamese children, is more than double the rates of suboptimal breastfeeding. Consequently, excess healthcare costs projected for zinc deficiency are also higher, almost $7.5 million dollars annually in costs of caring for cases of diarrhea and ARI attributable to zinc deficiency.

Table 41: Excess Health Care Costs Attribute to Zinc Deficiency in Children 6-59 months

	Diarrhea	ARI
Cases of Disease		
Population at Risk 6-59 months	1,427,864	1,427,864
Annualized Cases per Child/Year	2.73	1.24
Total Projected Cases Diarrhea	3,898,069	1,770,552

[97] Supplement to: Robert E Black, Cesar G Victora, Susan P Walker, Zulfiqar A Bhutta, Parul Christian, Mercedes de Onis, Majid Ezzati, Sally Grantham-McGrego, Joanne Katz, Reynaldo Martorell, Ricardo Uauy, and the Maternal and Child Nutrition Study Group Maternal and child undernutrition and overweight in low-income and middle-income countries The Lancet, June 6, 2013

Cases Attributed Zinc Deficiency		
Prevalence Zinc Deficiency	52.0%	52.0%
RR of Disease with Zinc Deficiency	1.93	2.074
PAR of Disease with Zinc Deficiency	32.6%	35.8%
Calculated VAD/Zinc Attributed Cases	**1,270,630**	**634,476**
Utilization and Cost estimates		
Taken Facility %	59%	64%
Calculated Number of Excess Treatments		
Average Cost/Case	$3.41	$3.41
Cases taken to Health Primary Care Facility	748,401	406,064
Health Center Cost	$3,300,448	$1,790,744
Hospitalizations		
Total Annual Cost of Hospitalization	$1,967,691	$3,305,234
Cohort Size Adjusted PAR	29%	32%
Attributed Hospital Costs	$577,257	$1,065,985
Attributed Home Treatment Costs @ $1/case	**$522,229**	**$228,411**
Total	**$4,399,934**	**$3,085,140**

4.3. Excess Health Care Costs Attributed to Maternal Nutrition Status Resulting in Low Birth Weight

The previous mortality analysis (Section 2.1) found 31% of LBW cases associated with maternal nutrition status – low BMI, low height or anemia – 9,744 of 31,887 annual cases. As in the previous mortality analysis these 9,744 cases are segmented into 8,608 moderate and 611 severe cases weighing < 2000 grams. The 2012 *Cambodia Hospital Costing and Financial Management Study* finds an average pediatric case cost (among the 3 levels of health care facilities) of $86.[98] For the 54% of deliveries in a health facility, we apply this average cost of $86 to the less severe cases weight 2000-2499 and 150% of the average to the 611 more severe cases. To each case we add 4 days of caretaker supplements and referral/travel costs as defined in the national Standard Benefit Package and Provides Payment Mechanism for Health Equity of Riel 5,000/day.[99] Based on these parameters, shown in Table 38 below, we project $582 thousand annually in costs of treating LBW birth cases attributed to maternal nutrition status.

Table 42: Costs of Caring for LBW Attributed to Maternal Nutrition

Health Background Data	
LBW Babies	31,887
PAR Maternal Conditions	31%
Nutrition Attributed Cases	9,744
Cases 2000-2500g	8,608
Cases <2000g	1,136
% in Facility	53.8%
Cases 2000-2500g	4,631
Cases <2000g	611

98 Annette Martin, Cambodia Hospital Costing and Financial Management Study, Cambodia Ministry of Health (MOH) Department of Planning and Health Information (DPHI, Belgian Development Agency (BTC) and University Research Company (URC), September 3, 2012 (Final Draft)

99 Standard Benefit Package and Provides Payment Mechanism for Health Equity, MOH, June 2012

Costs Units	
2000-2499 g: Average Cost Per Pediatric Discharge:	86.00
< 2000 g: 150% Average Cost Per Pediatric Discharge	129.00
Referral Transport	$15.00
Caretaker Supplement 4 days	$5.00
Cost/Cases 2000-2500	$490,886
Cost Cases < 2000	$91,039
Total Costs	**581,926**

5. Summary: National Economic Consequences of Child Malnutrition

The impact of the indicators of malnutrition analyzed in the report represent a burden to the national economy of Cambodia estimated at more than $400 million annually - 2.5% of GDP. This figure is comprised of qualitatively different kinds of loss as measured via 4 pathways.

- **Pathway #1:** NPV of the lost workforce resulting from more than 6000 annual childhood deaths totals $89 million or 21% of the total burden.
- **Pathway #2:** NPV of lost future productivity potential due to cognitive and other deficits from childhood anemia and stunting total $182 million or 43% of the total burden.
- **Pathway #3:** Current annual losses due to work performance deficits among anemic adults engaged the manual labor sector total $138 million annually.
- **Pathway #4:** Expenses incurred in treating excess cases of diarrhea, respiratory disease and low birth weight attributed to zinc deficiency, suboptimal breastfeeding behaviors and maternal malnutrition cost government and families > $10 million annually.

Table 43: Summary Economic Consequences for All Indicators NPV @ 3% (Adjusted for Multiple Risks)

	NPV Lost Workforce	NPV Lost Child Productivity	Current Lost Productivity	Current Health Costs	Total	
	000,000/yr	000,000/yr	000,000/yr	000,000/yr	000,000/yr	%
Maternal Nutrition	$9.7			$0.6	$10.2	2.4%
Suboptimal Breastfeeding	$21.7			$1.9	$23.6	5.6%
Wasting (WHZ)	$18.8				$18.8	4.5%
Stunting (HAZ)		$128.3			$128.3	30.6%
Underweight (WAZ)	$22.3				$22.3	5.3%
Zinc Deficiency	$5.7			$7.5	$13.2	3.2%
Vitamin A Deficiency	$4.6				$4.6	1.1%
Childhood Anemia		$52.7			$52.7	12.6%
Birth Defects	$5.9	$0.78		$0.03	$6.7	1.6%
IDA in Adults			$138.3		$138.3	33.0%
Annual Total	**$88.7**	**$181.7**	**$138.3**	**$10.0**	**$419**	100%
	21%	***43%***	***33%***	***2%***	**% of GDP**	**2.64%**

Nearly two-thirds of this projected burden is based on the NPV of the work force lost to child mortality and productivity lost to childhood stunting and anemia. From economic perspective, the value of a child's life and future earnings potential is very sensitive to the interest rate used to calculate the NPV. The base analysis reported above uses a 3% discount rate to develop the NPV, as recommended by the World Bank's World Development Report. As indicated in Table 40 below, applying a higher 7% discount rate shrinks the value of child survival and future productivity from $270 million to about $100 million per year –and consequently the projected annual burden to the Cambodian economy drops to about $250 million annually, 1.5% of GDP.

Table 44: Summary Economic Consequences for All Indicators NPV at 7% (Adjusted for Multiple Risks)

	NPV Lost Workforce	NPV Lost Child Productivity	Current Lost Productivity	Current Health Costs	Total	
	(000,000/yr)	(000,000/yr)	(000,000/yr)	(000,000/yr)	(000,000/yr)	(%)
Maternal Nutrition	$3.4			$0.6	$4.0	1.6%
Suboptimal Breastfeeding	$7.6			$1.9	$9.5	3.8%
Wasting (WHZ)	$6.7				$6.7	2.7%
Stunting (HAZ)		$47.4			$47.4	19.2%
Underweight (WAZ)	$8.0				$8.0	3.2%
Zinc Deficiency	$2.0			$7.5	$9.5	3.9%
Vitamin A Deficiency	$1.7				$1.7	0.7%
Childhood Anemia		$19.7			$19.7	8.0%
Birth Defects	$2.1	$0.27		$0.03	$2.4	1.0%
IDA in Adults			$138.3		$138.3	56.0%
Annual Total	**$31.5**	**$67.4**	**$138.3**	**$10.0**	**$247**	100%
	13%	***27%***	***56%***	***4%***	**% of GDP**	**1.56%**

As illustrated in the figure, the changing interest rate used to derive the NPV does not affect the $148 million in losses from adult work performance deficits in agriculture and industry and from health care costs to treat nutrition-attributable cases of diarrhea and ARI. However, as a higher interest rate of 7% is used for the NPV, a lower value is placed on child survival and productivity. Therefore, the non-discounted burden from the share of the burden represented by current losses health care costs and adult productivity deficits rises from 35% at the lower discount rate to 60%. Commensurately, the share of losses from child mortality and lost future productivity decreases from 64% to 40%.

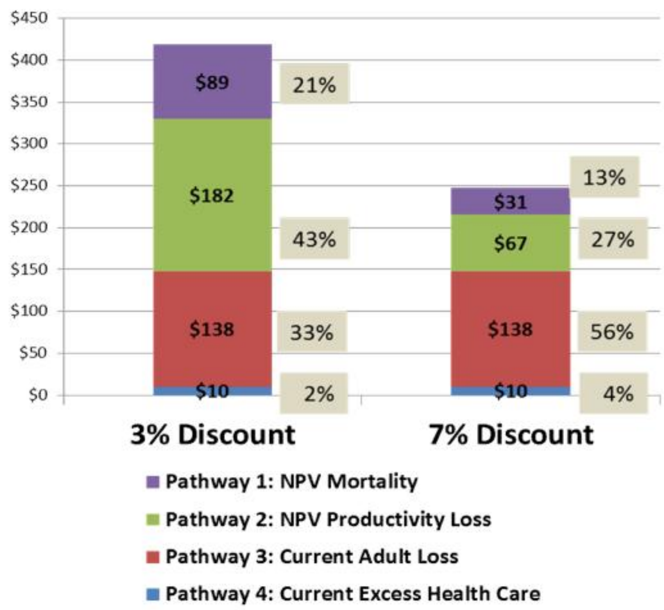

Figure 3: Impact of Discounting on Economic Burden

Considering the share of various indicators of malnutrition and their contribution to the over-all burden, provides an economic perspective or criteria for developing and prioritizing interventions. For example, as shown in Table 41, 57% of the losses emerge from indicators measured in children, while 43% of losses are from indicators independent of childhood measurements - indicators of maternal behavior along with well as maternal and adult nutrition. Since nearly half the losses are determined prior to the birth of the child, this has implications for targeting and timing of programs. While all programs to improve child nutrition target both mothers and their young children, this indicates a large burden and consequent need to intervene with women independently - during pregnancy and pre-pregnancy periods, including taking advantage of opportunities to intervene during secondary school.

Table 45: Share of Losses Across the Life Cycle: Pre-Maternity and Pregnancy versus Motherhood and Infancy

Intervention Target	Indicators	% Economic Loss @3%
Adult, Pre-Maternity women & Mothers	Anemia in Adults	33%
	Maternal Nutrition	2%
	Suboptimal Breastfeeding	6%
	FAD Birth Defects	2%
	Losses from Pregnancy, Pre-Pregnancy & Adult Indicators	**43%**
Mother& Child	Stunting	31%
	Underweight	5%
	Wasting	4%
	Zinc Deficiency	3%
	Vitamin A Deficiency	1%
	Child Anemia	13%
	Losses from Childhood Nutrition Indicators	**57%**

Table 42 below considers losses segmented by their origin in behavior, quality of diet or quantity of food along with the appropriate and strategic program response. This perspective indicates:

- Breastfeeding behaviors account for 6% of the burden - or $10 million annually. Addressing this loss requires targeted behavior change intervention – face-to-face, peer-group counseling along with community and national breast feeding promotions and appropriate national regulatory changes.
- A second set of indicators including mainly micronutrient deficiencies (anemia, folic acid, vitamin A and zinc deficiency) suggest deficits in the quality of the diet - representing a national burden of more than $200 million annually. This dietary quality is associated both with access to the right foods as well as knowledge and behaviors that optimize nutrition from available foods and take advantage of appropriate pharmaceutical products like supplements including iron, zinc and vitamin A as well as multiple micronutrient powders.
- A third set of indicators, representing 43% of the burden, includes maternal nutrition and child anthropometric indicators. IN addition to maternal behavior and the quality food, these indicators are also influenced by deficits in the quantity of food, consistent and high quality calories. This suggests that in addition to behavior change and providing opportunities to improve the quality of the diet, investment to improve access to food, including targeted distribution of food supplements, may be part of an effective intervention mix.

Table 46: Share of Losses Segmented by Possible Causes and Interventions

Intervention Content	Nutrition Indicators	% Economic Loss @3%
Sub Optimal Behaviors Requiring Education	Sub Optimal Breastfeeding	6%
Quality of Food and Behaviors Requiring Intervention with Micronutrient Supplement along with Nutrition Education and Behavior Change	FAD Birth Defects	2%
	Zinc Deficiency	3%
	Vitamin A Deficiency	1%
	Child Anemia	13%
	Anemia in Adults	33%
	Subtotal	51%
Quality & Quantity of Food Plus Behaviors Requiring Intervention with Food Supplement along with Nutrition Education and Micronutrient Supplement	Wasting	4%
	Maternal Nutrition	2%
	Stunting	31%
	Underweight	5%
	Subtotal	43%

The economic perspective outlined in this report suggests that strategic planning for effective nutrition intervention recognize that:

- More than half the losses attributed to malnutrition are associated with feeding behavior and food quality rather than simply access to sufficient quantity of food.
- Nearly half the losses attributed to malnutrition in this report emerge from maternal, adult and inter-generational factors. While these factors have an overwhelming impact on child nutrition status, the point of intervention may be independent of the child.

This report describes the magnitude losses from malnutrition in order to enable policy discussion and ultimately secure investment in programs on a scale appropriate to the extent of the burden malnutrition. The $250-$400 million in projected losses describes the scale of economic benefits that might be secured by investment in effective and affordable interventions to lower prevalence of these specific indicators of malnutrition. Given the low cost of interventions and the high baseline losses, investment in nutrition programs in Cambodia is likely to offer high returns and attractive benefit cost ratios.

Over the next decades, a growing Cambodian economy will doubtless lower the $250-400 million annual burden on national economic activity. However, nutrition status responds relatively slowly to economic growth. A recent World Bank analysis from 79 countries concluded "that income growth can play an important role in malnutrition reduction, but it is not enough. Increases in the number and effectiveness of direct nutrition interventions have a crucial role to play if nutrition goals are to be met."[100] Moreover, investments to reduce malnutrition do not only serve nutrition goals. If malnutrition continues to depress economic activity at 1.5-2.5% of GDP, Cambodia's ambitious national objective of 7% annual GDP growth will be more difficult to achieve and sustain. Investment in nutrition is an investment in achieving that national economic development goal.

[100] Harold Alderman, Simon Appleton, Lawrence Haddad, Lina Song and Yisehac Yohannes Reducing Child Malnutrition: How Far Does Income Growth Take Us? Centre for Research in Economic Development and International Trade, University of Nottingham