Implementing a revised standard for wheat flour fortification in Indonesia: A Benefit-Cost Analysis

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Acronym List

Acronym	Full form
APTINDO	Asosiasi Produsen Tepung Indonesia
ARI	Acute Respiratory Infections
B	Billion
BC	Benefit-Cost
BCA	Benefit-Cost Analysis
BPS	Badan Pusat Statistik
BRINDA	Biomarkers Reflecting Inflammation and Nutritional Determinants of Anemia
CI	Confidence Intervals
DHS	Demographic and Health Surveys
DRI	Daily Nutrition Requirement
EDTA	Ferric sodium ethylenediaminetetraacetate
ES	Executive Summary
FA	Folic Acid
FAO	Food and Agriculture Organization of the United Nations
FD	Folate Deficiency
FE	Iron
FOB	Free on Board
GDP	Gross Domestic Product
g/day	Gram per Day
HR	Hazard Ratio
ID	Iron Deficiency
IDA	Iron Deficiency Anaemia
IFLS	The Indonesian Family Life Survey
IQ	Intelligence Quotient
M	Million
MMT	Million Metric Tons
MN	Micronutrient
MND	Micronutrient Deficiency
MOH	Ministry of Health
MT	Metric Tons
NPV	Net Present Value
NTD	Neural Tube Defects
OR	Odds Ratio
PAR	Population Attributable Risks
RISKESDAS	Indonesian basic health research
RR	Relative Risk
SD	Standard Deviation
SGA	Small for Gestational Age
SKRT	National Household Health Survey
SNI	Indonesian National Standard
STH	Soil Transmitted Helminth
TDS	Total Diet Study (2014)
UNDP	United Nations Development Programme
UNICEF	United Nations Children's Fund

Acronym	Full form
US	United States
USDA	United States Department of Agriculture
WB	World Bank
WFF	Wheat Flour Fortification
WHO	World Health Organization
ZD	Zinc Deficiency
$	US dollars

Executive Summary

IMPLEMENTING A REVISED STANDARD FOR WHEAT FLOUR FORTIFICATION IN INDONESIA: A BENEFIT-COST ANALYSIS

Micronutrient deficiencies (MND) are a serious public health threat in Indonesia. For several decades, national and regional surveys have continued to indicate MND are widespread throughout the population and represent a serious threat to public health and national development. These deficiencies can cause anaemia, with iron deficiency being a major cause of anaemia globally. To address the widespread burden of anaemia and other vitamin and mineral deficits, the Government of Indonesia has adopted a range of policies and programs, including supplementation, fortification and nutrition education. Food fortification has been widely identified as a cost-effective strategy for addressing micronutrient malnutrition at scale. As such, Indonesia launched the Wheat Flour Food Fortification Program in 2002, which mandated that wheat flour should be fortified with iron, zinc, folic acid, and vitamins B1 and B2 (SNI 3751:2001). However, the national standard did not specify the type of iron compound to be used for fortification which led millers to fortify wheat flour with elemental/electrolytic iron that was not in line with the World Health Organization (WHO) guidelines.

In 2018, the government revised the legislation and the national standard (SNI 3751:2018) to specify the use of more bioavailable iron compounds, including ferrous fumarate, ferrous sulphate and sodium iron EDTA (ferric sodium ethylenediaminetetraacetate), as recommended by the WHO. This standard was made mandatory in 2021.

In 2022 Nutrition International conducted an economic analysis of wheat flour fortification (WFF) to understand the potential impact of the revised standards. The analysis generated an up-to-date estimates of the possible health effects of the population and economic benefits for the country. Based on the revised fortification standards, this paper aims to project the potential reduced national prevalence of MND, estimate the associated health and productivity benefits, and develop a benefit-cost ratio for flour fortification in Indonesia.

The analysis quantified the economic consequences of not addressing the current high prevalence of iron deficiency anaemia (IDA), folate deficiency (FD) and zinc deficiency (ZD) in Indonesia over the next 10 years (from 2023–2032). A benefit-cost ratio was developed and the analysis:

1. Estimates the health and productivity benefits of WFF in reducing the current levels of IDA, FD and ZD.
2. Calculates the magnitude of costs involved in implementing the revised WFF standard in Indonesia over 10 years.
3. Calculates a benefit-cost ratio for WFF.

The Benefit-Cost Analysis (BCA) begins with an economic damage assessment, a “consequence model” that describes the productivity losses associated with the status quo, and the current prevalence of IDA, ZD and FD.[1] For each of these three MND, the scientific literature has developed substantial evidence defining higher risks of mortality and morbidity, quantifying deficiencies in child development that lead to future productivity deficits, and measuring lower on-the-job productivity among adults. The BCA is based on economic losses associated with eight specific negative economic impacts of IDA, ZD and FD, which are grouped into four distinct economic pathways:

- **Pathway #1**: Net present value (NPV) of mortality associated with IDA, ZD and FD in children. (Lost Workforce)

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[1] Folate and folic acid are two forms of vitamin B9. Folate is the naturally occurring form while folic acid is synthesized. Either can play a crucial role in the production and maintenance of healthy cells, particularly during fetal development and infancy. However, folic acid is more stable and has a longer shelf life, making it a more practical option for use in fortified foods. In this paper the micronutrient deficiency will be referred to as Folate Deficiency (FD) and the term “folic acid” will be used when referring to the fortificant in flour.

- **Pathway #2**: NPV of lost productivity due to anaemia-associated cognitive deficit in children and FD-associated birth defects and disability. (Lost Future Productivity)
- **Pathway #3**: Current value of lost productivity of adults with IDA working in jobs that require manual labour and physical strength. (Lost Current Labour Productivity)
- **Pathway #4**: Current value of avoidable healthcare and welfare services required to address the added burden of FD-related birth defects, as well as to address cases of diarrhoea and acute respiratory infections associated with ZD. (Current Healthcare Costs)

Results

COST OF INACTION

The annual economic cost of doing nothing to address the burden of IDA, ZD and FD is estimated at $2.79 billion, which is approximately 0.22% of national Gross Domestic Product (GDP) (see Table ES 1). About 70% of this lost national economic activity represents current losses from lower adult productivity, while 20% represents the NPV of lost workforce and future productivity and the remaining 10% represents excess healthcare costs. Taking account projections for relatively flat population growth and declining birth rates, 10-year losses are estimated at $28.56 billion. The micronutrient deficiency with the most acute economic burden is IDA, with 87% of total economic consequences.

ES Table 1: Summary Economic Consequences for All Indicators

	NPV Lost Workforce	**NPV Lost Future Productivity**	**Lost Current Labour Productivity**	**Current Healthcare Costs**	**Total**	
	$ M/year	$ M/year	$ M/year	$ M/year	$ M/year	%
Iron Deficiency Anaemia	130.8	293.06	2,001.1		2,424.96	87%
Folate Deficiency	77.6	7.4		3.66	88.66	3%
Zinc Deficiency	65.5			210.9	276.40	10%
Total	**273.9**	**300.5**	**2,001.1**	**214.5**	**2,790.00**	100 %
	9.8%	**10.8%**	**71.7%**	**7.7%**		

Discounting for the NPV applied in Pathways #1 and #2 to derive the value of child survival and development deficits represents a major bias and shortcoming of an economic analysis. The NPV is sensitive to the discount rate applied. Therefore, in addition to the base 5% discount rate used in the body of the analysis, a sensitivity analysis is run at 3% and 7% (see Table ES 2). At the 3% rate, the share of losses from child mortality and impaired cognitive development rose from 20% to 30% of the total. Conversely, at 7% discount rate, the NPV of lost life and impaired cognitive development drops to 14%.

ES Table 2: Sensitivity Analysis: Economic Consequences Using Three Discount Rates ($ Millions)					
	NPV Lost Workforce	**NPV Lost Future Productivity**	**Lost Current Labour Productivity**	**Current Healthcare Costs**	**Total**
NPV @ 3%	469.88	466.29	2,001.05	214.55	3,151.77
Pathway % of Total	**15%**	**15%**	**63%**	**7%**	
Base NPV @ 5%	273.87	300.48	2,001.05	214.55	2,789.95
Pathway % of Total	**9.8%**	**10.8%**	**71.7%**	**7.7%**	
NPV @ 7%	166.10	203.47	2,001.05	214.55	2,585.17
Pathway % of Total	**6%**	**8%**	**77%**	**8%**	

HEALTH IMPACT, COST OF FORTIFICATION AND BENEFIT-COST ANALYSIS

How much of the 10-year $28.5 billion loss can be prevented by flour fortification with iron, zinc and folic acid? Estimating the extent to which these baseline losses can be prevented by wheat flour fortification defines the potential economic benefits of the national program. Defining the baseline economic losses emerging from the current prevalence of iron, zinc and folate deficiencies is the first step in the analysis aiming to estimate the economic benefits of flour fortification. The key parameters of coverage and efficacy of flour fortification, representing the effectiveness of the program, are applied separately for each of the indicators of loss.

The analysis estimates for flour consumption are built on reports from the national milling association, APTINDO, indicating flour milling increased from 4.66 million metric tons (MMT) in 2012 to 6.96 MMT in 2021, an average annual increase of 5.2%. Adjusting for exports and imports of flour and flour products, this average 10-year growth rate suggests national flour consumption reached 7.136 MMT in 2022. Distributing this national flour supply among 282 million Indonesians yields a national average consumption of approximately 71g/day, below the 75 g/day the threshold for average consumption established by the WHO Recommendations for Flour Fortification.

Based on the 10-year efficacy projections developed in the paper and the 10-year coverage projections, Table ES 3 summarizes logic and calculations for potential reductions in prevalence of IDA, ZD and FD. As coverage expands and consumption rises over the years 2023–2032 reductions in prevalence rise year by year as national coverage expands and as average consumption continues to rise, increasing delivery of micronutrients and improving the efficacy of fortification. The coverage of flour fortification is projected to increase from 41% to 49% over 10 years (see Table ES 3). As a result, the IDA prevalence is expected to be reduced by 7%–10% (percentage points) and the prevalence of ZD is expected to be reduced by 16%–22% (percentage points) compared to baseline. This lowered national prevalence suggests a reduced national caseload of about 45 million prevented IDA and ZD cases. Since the BCA only addresses IDA and not overall iron deficiency in the population, the 10-year reduction in IDA caseload could well be 60–80 million (details in Annex XV) . As indicated in the table below, FD-associated birth defects are expected to decrease 18–24% (percentage points) compared to baseline.

ES Table 3: Reduced National Prevalence

A		B		A X B
Coverage of Flour Fortification	X	Projected Efficacy of Fortification	=	Projected Effectiveness: % Reduction in Prevalence
41% in 2023 to 49% in 2032		IDA: 17.5% (2023) to 20% (2032)		IDA: 7.2% (2023) - 9.9% (2032)
		ZD: 38% (2023) to 44% (2032)		ZD: 15.6% (2023) – 21.6% (2032)
		FD: 43% (2023) to 49% (2032)		FD: 17.7% (2023) – 24.4% (2032)[2]

The logic model applies the effectiveness parameters for lower prevalence of iron, zinc and folate deficiencies developed in the study to the economic losses attributed to these three MND. The summary of the logic model above suggests flour fortification may reduce status quo 10-year losses of $28.6 billion by approximately $3 billion (see Table ES 4).

ES Table 4: Logic Model Projecting 10-Year Economic Benefit Attributed to Flour Fortification (in $ Millions)

Projected 10-Year Attributed Economic Loss from 3 MND	**X**	**Projected 10-Year Effectiveness:** **% Reduction in Prevalence**	**=**	**Projected 10-Year Economic** **Benefits of Flour Fortification**
IDA: 24,954.9		7.2% (2023) - 9.9% (2032)		IDA: 2,124.9
ZD: 2,747.40		15.6% (2023) - 21.6% (2032)		ZD: 506.30
FD: 860.00		17.7% (2023) - 24.4% (2032)		FD: 370.90
Total: 28,563				Total: 3,002.2

Cost for the Indonesian National Standard (SNI)-mandated premix including ferrous fumarate, virtually universally applied by the Indonesian milling industry ranges between Free On Board (FOB) 7–8 $/kilogram (kg). Taking an average $7.50 per kg cost at the specified dosage rate of 230 parts per million (ppm) indicates a premix cost of $1.73 per metric ton fortified flour. Currently reported industry cost structure suggests raw materials input represents approximately 84% of total processing costs. Presuming premix cost is representative of other raw inputs this indicates an overall fortification cost—including storage, administration, quality assurance and equipment amortization—of $2.05 per MT flour. Annual fortification costs will rise from about $14.6 million to $21.9 million between 2023 to 2032 as milling volumes increase at the projected 5.2% annually. For consumers, this suggests an invisible daily cost of approximately $0.10 per person, per year.

Table ES 5 shows that over 10 years, an investment of $181 million in fortifying flour at Indonesia's mills will return about $3 billion in prevented losses and increased national economic activity. For every $1 in projected fortification costs, a value of approximately $14.6 (at 5% discount rate) will be returned to the national economy as:

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[2] Prevalence reduction refers not to biochemical deficiency as is the case with IDA and ZN but directly to reductions in incidence of deliveries of infants suffering neural tube defects.

- NPV $576.3 million arising from child mortality and resulting lost workforce.
- NPV $263 million from reduced future loss from current child disability and cognitive deficit
- Reduced productivity deficits of adults working manual labour valued at $1769.9 million.
- Saved healthcare and welfare expenditures of $393.5 million.

ES Table 5: 10-Year Overview of the Economic Analysis Process to Derive Benefit-Cost Ratio ($ Million)

10-Year Baseline Economic Loss	X	Projected Coverage	X	Projected Efficacy of Fortification	=	Projected Improvement or Benefit	/	10-Year Cost of Fortification	=	Benefit-Cost Ratio
IDA: $24,954		41.1% 2023 To 49.4% 2032		17%- 20%		IDA: $2,124		$181		14.6
ZD: $2,747				38%-44%		ZD: $506.3				
FD: $860				43%-49%		FD: $370.9				
$28,563						**$3,002.2**				

Note: (at 5% discount rate)

Conclusion

There are clear health and economic arguments for continued investment in implementing and improving WFF in Indonesia.

Key Messages:

1. For the year 2023, the economic cost of inaction in addressing the burden of IDA, ZD and FD is an estimated $2.79B, which is approximately 0.2% of the national GDP. The projected losses over 10 years are an estimated $28.6B.
2. The current prevalence of MND is associated with the deaths of nearly 20,000 children annually. Iron deficiency anaemia represents Indonesia's most acute economic burden constituting 87% of total economic consequences.
3. As the consumption of wheat flour products continues to increase, fortification is expected to benefit approximately half of the population by 2032. Wheat flour fortification is projected to decrease the national prevalence of IDA by 7.2–9.9% and ZD by 15.6–21.6% annually in children and adults between 2023–2032. Over the next decade, a total of 45M cases of IDA and ZD could be prevented in Indonesia through WFF. Additionally, national rates of folate-associated birth defects are predicted to decrease by approximately 25%.
4. As national consumption continues to increase, annual fortification costs are projected to rise from $14.7M in 2023 to $21.9M in 2032. The increased cost of fortification borne by mills is projected at $2.05 per MT flour. For consumers, this suggests an invisible daily cost of approximately $0.10 per person, per year.
5. Of the $28.6B economic losses over the course of 10 years, WFF may prevent $3.0B in the form of NPV of reduced mortality and improved future productivity. An estimated 10-year investment of $181M in fortifying wheat flour for a benefit of $3.0B indicates that every $1 invested in WFF will bring a return of $14.6 in increased economic activity over the next 10 years (2023–2032).

Implementing a revised standard for wheat flour fortification in Indonesia: A Benefit-Cost Analysis

1. BACKGROUND AND RATIONALE

Micronutrient malnutrition erodes the foundation of national economic growth by impacting people's strength and energy and hampering their creative and analytical capacity, initiative and entrepreneurial drive. The inadequate intake and absorption of vitamins and minerals is a serious public health threat in Indonesia. For several decades, national and regional surveys have continued to indicate vitamin and mineral deficiencies are widespread throughout the population and represent a serious threat to public health and national development (Annex I). Anaemia is estimated to impact the health and productivity of approximately 70 million Indonesian children and working age adults (Table 1).

Table 1: Anaemia Prevalence in Key Risk Groups, RISKESDAS 2018

Risk Group	%	# millions
Children (age < 15 year)	30.6%	21.7
Women (age 15-65 year)	27.2%	26.2
Men (age 15-65 year)	20.3%	19.2
Pregnant women	48.9%	2.3

To address the widespread burden of anaemia and other vitamin and mineral deficits, the Government of Indonesia has adopted a range of policies and programs providing micronutrient supplementation and nutrition education. In 2002 the Ministry of Health and Ministry of Industry mandated that millers fortify wheat flour with five micronutrients: vitamin B1, vitamin B2, zinc, folic acid and iron to reduce the prevalence of anaemia, zinc, folate and other micronutrient deficiencies. Indonesia's milling industry has the capacity to fortify and comply with the mandate. However, national surveys over the past two decades found the prevalence of anaemia have not fallen as expected, particularly in pregnant women. In response, the Indonesia National Standard (SNI 3751:2018) was adopted in 2018 to specify the use of more bioavailable iron (ferrous fumarate, ferrous sulphate, or NaFeEdta), as recommended by the World Health Organization (WHO). The government made this standard mandatory in 2021.

Based on these adjusted fortification standards, this paper aims to project the potential reduced national prevalence of micronutrient deficiencies (MND), estimate the associated health and productivity benefits, and develop a benefit-cost ratio for flour fortification in Indonesia. The general logic model of the Benefit-Cost Analysis (BCA) and bottom-line results over a 10-year period is summarized in Table 2, suggests that for every dollar invested in fortification, 14.6 dollars are returned in the form of increased economic gains.

Table 2: 10-Year Overview of the Economic Analysis Process to Derive Benefit-Cost Ratio

10 Year Baseline Economic Loss	X	Projected Coverage	X	Projected Efficacy of Fortification	=	10 Year Projected Improvement or Benefit	/	10 Year Cost of Fortification	=	Benefit-Cost Ratio
$28.56 billion		41.1%- 49.4%		17.5%- 49.2%		$3.002 billion		$181 million		14.6

2. METHODOLOGY: QUANTIFYING THE ECONOMIC CONSEQUENCES OF MICRONUTRIENT DEFICIENCIES

The Benefit-Cost Analysis (BCA) begins with an economic damage assessment, a “consequence model,” describing the productivity losses associated with the status quo, the current prevalence of three micronutrient deficiencies: iron deficiency anaemia (IDA); zinc deficiency (ZD) and folate deficiency (FD)[3]. For each of these three MND, the scientific literature has developed substantial evidence defining higher risks of mortality and morbidity; quantifying deficiencies in child development that lead to future productivity deficits; and measuring lower on-the-job productivity among adults. The BCA is based on economic losses associated with eight specific negative economic impacts of IDA, ZD and FD, which are documented in the global literature quantified as a relative risk (RR) or proportional deficit (%) and grouped into four distinct economic pathways:

- **Pathway #1**: Net present value (NPV) of mortality associated with IDA, ZD and FD in children. (Lost Workforce)
- **Pathway #2**: NPV of lost productivity due to anaemia-associated cognitive deficit in children and FD-associated birth defects and disability. (Lost Future Productivity)
- **Pathway #3**: Current value of lost productivity of adults with IDA working in jobs that require manual labour and physical strength. (Lost Current Labour Productivity)
- **Pathway #4**: Current value of avoidable healthcare and welfare services required to address the added burden of FD-related birth defects, as well as to address cases of diarrhoea and acute respiratory infections associated with ZD. (Current Healthcare Costs)

The coefficients of risk or deficits associated with eight negative economic impacts described above are defined in the global literature reflect universal biological processes. However, the determinants of economic impact are local: national prevalence of MND, demography and the national economic context determine the actual scale of economic consequences. Key national economic parameters used in the BCA include[4]:

- Average Wages, all Employment Sectors: $2,430/y
- Average Wage, Adults Manual Labour: $2,034/y
- Labour Participation Rate: 70.2% including 84% male and 56% female
- Average Duration of Working Life: 47.8 years
- Discount rate for NPV of future economic activity: 5% (See Annex III)

PARAMETERS FOR PREVALENCE OF MICRONUTRIENT DEFICIENCIES

It should be noted that data for prevalence of MND is not optimal. RISKESDAS provides comprehensive and credible national data for anaemia based on hemoglobin, a single indicator for all anaemia emerging from multiple causes. However, only anaemia caused by iron deficiency (IDA) will respond to supplemented iron nutrition via flour fortification. In the absence of national data for the proportion of anaemia emerging from iron deficiency, the BCA estimates for prevalence of IDA are based on a review of localized surveys along with global and regional literature (See Annex IV).

Two recent publications compiling data from 10 countries provide an approach to distinguishing nutritional causes of anaemia versus inflammation, parasitic and other causes[i]. These suggest that in countries with a relatively medium to low burden of infection like Indonesia, 30%–50% of anaemic children and 65%–71% of anaemic women suffer from iron

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[3] Folate and folic acid are two forms of vitamin B9. Folate is the naturally occurring form while folic acid is synthesized. Either can play a crucial role in the production and maintenance of healthy cells, particularly during fetal development and infancy. However, folic acid is more stable and has a longer shelf life, making it a more practical option for use in fortified foods. In this paper the micronutrient deficiency will be referred to as Folate Deficiency (FD) and the term “folic acid” will be used when referring to the fortificant in flour.

[4] See Annex II for full list and discussion of economic parameters.

deficiency. The BCA selects the mid-point of the range for women and children with resulting assumptions for the prevalence of IDA shown in Table 3.

Table 3: Anaemia and IDA Prevalence in Key Risk Groups, Based on Wirth/Engle-Stone and RISKESDAS 2018

Risk Group	Anaemia% RISKESDAS	Parameter for IDA % Wirth/Engle-Stone	Anaemia from Iron Deficiency
Children (age < 15 year)	30.6%	40%	12.2%
Women (age 15-65 year)	27.2%	68%	18.5%
Men (age 15-65 year)	20.3%		13.8%
Pregnant women	48.9%		33.3%

While small scale studies in Indonesia have found widespread ZD—in some cases up to 75% of young children with low serum zinc—there is no national or regional data. Therefore, a literature review was undertaken to define a reasonable and conservative parameter to apply in the BCA (see Annex V). The BCA adopts an estimate of 25% ZD for children younger than 5 years of age based on well-established correlations of low serum zinc with dietary intake, stunting and other health factors as elaborated in Wessels et al[ii]. As a point of reference, a 25% prevalence is significantly lower than found in recent national nutrition surveys in The Philippines and Vietnam. Finally, there is no serum data on FD in the population. The BCA measures the impact of FD via regional estimates for incidence of Neural Tube Defects (NTD)[iii].

Table 4 shows an expanded logic model used in the BCA to estimate economic damage along with other key economic parameters used to value impact. This was adapted and run separately for each of the eight negative outcomes associated with IDA, ZD and FD.

Table 4: Logic Model and Parameters to Project Economic Losses from Individual Indicators

Number Affected	**X**	**Coefficient of Risk/ Deficit**	**X**	**Labour Participation**	**X**	**Average Wage**	**X**	**Average Work-Life**	➡	**Apply NPV (children)**	**=**	**Losses to Economy**
Prevalence % X Risk Group #		RR or % Deficit		70% Working 56%F 84%M		$2,034-$2,430/ year		15 years - 62.8 years = 47.8 years		Future earning children		**$/year**
RISKESDAS & WB Population		Global Literature		BPS[5]		BPS		Healthy Life Expectancy 62.8 years UNDP		World Bank and U.S. Public Health Service		

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[5] BPS refers to Badan Pusat Statistik, which is a census conducted by Statistics Indonesia.

3. RESULTS: COST OF INACTION

3.1 PATHWAY #1 MORTALITY ASSOCIATED WITH IDA, ZD AND FD.

BCA modeling estimates the proportion of child mortality associated with three micronutrient deficiencies (IDA, ZD and FD). Table 5 displays the general logic model.

Table 5: Projection of Methodology for Projecting Mortality from Malnutrition Indicators

Prevalence of Indicator	X	Relative Risk of Mortality	=	PAR: Population Attributable Risk[6]	X	Mortality in Risk Group Affected	=	# Deaths/year Attributed to Indicator
National Surveys		RR Global Literature		Fraction (%) of Risk Group Affected		# Deaths/Year National Data		

Mortality of Children less than One Year Attributed to Maternal Anaemia

The nutrition status of pregnant women is a powerful predictor of birth outcomes, including survival over the first 12 months of life. Perhaps the strongest evidence associates maternal nutrition with likelihood of babies who are small for gestational age (SGA), who face much higher risks of mortality than normal weight babies during their first year of life. A meta-analysis of 11 iron supplementation trials identified 20% reduction in risk of SGA babies associated with maternal iron status[iv]. Large scale data sets from Indonesia indicate maternal supplementation with iron folic acid tablets provide strong evidence linking maternal anaemia and child mortality. Using national survey data on 52,917 live births and 1,525 deaths of children younger than five years of age, Dibley et al. (2012) concluded, "After adjustment for potential confounders, risk of death of children was reduced significantly by 34% if the mother consumed any iron-folic acid supplements"[v].

Based on the protective effect reported by Dibley et al. (2012), a Hazard Ratio (HR) of 0.69 for neonatal mortality and HR of 0.74 for post-neonatal deaths is used , the BCA estimates a linked higher risk, RR 1.45 for neonatal mortality and RR 1.35 for deaths among children between the ages of one and 11 months. The BCA runs two parallel calculations, to suggest maternal anaemia is associated with approximately 11,500 annual deaths of children <1 year of age (Table 6).

Table 6: Projection of Deaths Children of 6–59 months Attributed to Maternal IDA

Prevalence of Condition	X	Relative Risk of Mortality	=	Population Attributable Risk	X	Annual Deaths Neonatal Deaths	=	Annual Deaths Attributed
33.3%		<1m: RR 1.45		<1m: 13%		<1m: 57,383		<1m: 7,458
		1-11m: RR 1.35		1-11m: 10.5%		1-11m: 38,256		1-11m: 4,004

Mortality Attributed to Zinc Deficiency in Children younger than five years of age.

The association of ZD with higher morbidity and mortality due to infectious disease has been widely observed[vi]. A recent review of randomized control zinc supplementation trials showed a significant 18% reduction in all-cause mortality in children between the ages of one to four years[vii]. In 2008, Yakoob et al. reviewed the effects of zinc supplementation on child mortality

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[6] 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 as: (Prevalence*(RR-1))/(1+(Prev*(RR-1))).

in eight trials—five of which provided data sufficient to derive cause-specific mortality from diarrhoea and mortality from Acute Respiratory Infections (ARI)—concluding that zinc supplements for children <5 years are associated with a reduction in diarrhoea mortality of 13% and ARI of 15%[viii]. Based on these findings of the protective effects of zinc supplementation, Black et al (2013) and The Maternal and Child Study Group derive an adjusted RR of mortality from diarrhoea of RR 2.01 and pneumonia RR 1.96[ix]. The BCA model applies the coefficients derived by Black et al. (2013) to the 25% prevalence of ZD to develop Population Attributable Risks (PAR) of 19.4% for ARI and 20% for diarrhoea. These PAR are applied to the estimated deaths of Indonesian children under five years of age from diarrhoea and ARI to project approximately 5,000 annual deaths attributable to ZD (Table 7).

Table 7: Projection of Deaths Children of 6–59 Months of Age Attributed to ZD

Prevalence of Condition	X	Relative Risk Mortality	=	Population Attributable Risk (PAR)	X	Annual Deaths Children <5 year 109,985	=	Annual Deaths Attributed
25% ZD		ARI: RR 1.96		19.4%		ARI: 17%/ 18.6k[x]		3,619
		Diarrhoea: RR 2.01		20%		Diarrhoea: 6%/6.6k[xi]		1,330

Mortality Attributed to Folate-Related Neural Birth Defects

Neural Tube Defects (NTD), including spina bifida and anencephaly, are a significant cause of death and disability throughout the world. A 2008 review calculated that more than 200,000 NTD deaths are likely preventable with additional folic acid[xii]. A 2016 analysis estimated 260,100 birth outcomes affected by NTD, with 75% resulting in death[xiii].

There is very little data on the incidence of NTD in Indonesia as well as the outcome and cost of these NTD cases. Therefore, the BCA analysis is based on findings from other countries and is conceptual and notional. In 2015, Zaganjor et al. developed a regional estimate of 15.8 cases of NTD per 100,000 births for Southeast Asia based on reports from Thailand, Vietnam, Malaysia and Singapore[xiv]. Applying Indonesia's birth rate to this finding suggests 7,555 NTD cases annually. While most births in Indonesia are attended by skilled personnel, access to surgery required to address serious defects like spina bifida and anencephaly is considered rare[xv]. Blencowe et al. estimated that, when access to appropriate surgery is not available, the NTD mortality rate rises to 95–100%. Reflecting on the Indonesian context and Blencowe's finding, the BCA model applies a fatality rate of 90% indicating 6,800 deaths, mostly likely in the first year of life.

SUMMARY: MORTALITY IN CHILDREN ATTRIBUTED TO IRON DEFICIENCY ANAEMIA, ZINC DEFICIENCY AND FOLATE DEFICIENCY

The individual analysis above totals approximately 23,000 annual deaths or about 21% of child mortality attributed to three micronutrient deficiencies in the study period (Table 8). However, these risks overlap in the <1 year age group. In an effort to at least theoretically correct for "double counting," a hybrid PAR of 21% was developed and applied to estimate about 95,000 annual deaths prior to age one, lowering the total to 19% of under-five mortality[7].

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[7] Deaths of children <1 year based on rates reported in UNICEF State of Children, 2021

Table 8: Adjusting Individual Mortality Analysis (in Numbers)

	Individual Unadjusted	Adjusted Mortality
<1 Year Mortality Attributed to Maternal IDA	11,460	9,983
<5 Year Mortality Attributed to Maternal FD	6,800	6,038
<5 Year Mortality Attributed to ZD	4,949	4,395
Total < 5 Year Mortality	23,210	20,416
% U5 Mortality	21%	19%

Estimating the Value of Workforce Lost to Child Mortality

While the value of a lost life is immeasurable, from an economic perspective this tragedy is represented simply as the discounted future value (NPV) of a lost worker. The calculation, shown in Table 9 below, indicates the economic value of 20,400 deaths of children annually totals $273.9 million annually—which breaks down to approximately 13,000 per child. Clearly, an economic analysis is insufficient and paints a very incomplete picture.

Table 9: Model for Calculating Value of Future Workforce Lost to Child Mortality

# Deaths		Labour Participation		Average Wage		Average Work Life	➡	Apply NPV		Losses to Economy $ M
IDA: 9,983 <1 year	X	70%	X	$2,430/ year	X	47.8 years		@ 5% Avg. 15 year delay	=	**130.1**
ZD: 4,395 <5 years								@ 5% Avg. 12.5 year delay		**77.6**
FD: 6,038 <1 year								@ 5% Avg. 15 year delay		**65.5**
20,416										**273.9**

3.2 PATHWAY #2: COGNITIVE LOSS AND FUTURE PRODUCTIVITY

Attributed to Childhood Iron Status

Evidence for economic losses linked to poor iron status in children <15 years of age is based on two streams of research: first, quantifying the impact of anaemia and iron deficiency on cognitive development and learning; and second, linking cognitive deficits in childhood to lower earnings and productivity as adults (See Annex VI & Annex VII).

A range of evidence gathered over decades links anaemia and iron deficiency in young children to cognitive and development delays. A 2001 Journal of Nutrition review observed a positive impact of iron interventions on cognitive scores, generally ranging from 0.5 to 1 Standard Deviation (SD) and concluded “that iron deficiency causes cognitive deficits and developmental delays”[xvi]. A 2007 Lancet review found “outcome in formerly iron deficient anemic or chronically iron-deficient individuals including long term effects on IQ, lower motor scores, more grade repetition"[xvii]. A 2010 Nutrition Journal review by Falkingham et al. cites 14 trials evaluating the effects of iron supplementation on cognitive performance in school children concluding that improved iron status increased IQ by 2.5 points[xviii]. A 2017 paper by Larson et al. found a cognitive benefit of iron supplements on school-age children of 4.55 IQ points[xix].

Second, the literature from child psychology and economic science links childhood developmental deficits with lower earnings as adults. A review by Galal et al. concluded that a "0.25 SD increase in IQ would lead to a 5%–10% increase in wages"[xx]. A 2003 review in *Food Policy* by Horton et al. projects a 4% drop in adult earnings associated with iron deficiency and anaemia-related cognitive deficits[xxi]. Horton et al. note that cognitive improvements achieved via iron supplementation to young children were sustained into adolescence with a correlation coefficient 0.62[xxii]. Applying this correlation coefficient to findings of 4% earnings deficit, suggests deficit coefficient of 2.5% in lower future earnings and productivity as a consequence of childhood anaemia and iron deficiency[xxiii]. Based on an estimated 12% of children <15 years of age with IDA, Table 10 shows a logic model for projecting annual losses valued at NPV $293.1 million annually.

Table 10: Logic Model for Calculating Net Present Value of = Productivity Loss Attributed to Childhood IDA

Number Affected	X	Average Earnings	X	Labor Force Participation	X	Coefficient Deficit	X	Average Work-Life	→	Apply NPV	=	Economic Losses
8.8M		$2430		70.2%		2.5%		47.8year		5% 7.5year		NPV $293M/year

Depressed Productivity of Disabled NTD Survivors

The BCA model notionally assumes half the survivors of serious folate related birth defects live with severe disabilities and are essentially lost to the work force, while the remaining cases suffer a moderate disability reducing their productive potential 50%. Table 11 shows separate calculations for notional severe and moderate disabilities totaling $7.4 million annually.

Table 11: Lost Lifetime Product Associated with Disability of NTD Survivors

Prevalence of Condition	X	Productivity Deficit	X	Labor Participation	X	Average Wage	X	Average Work Life		NPV	=	NPV of Lost Productivity
Moderate: 378		50%		70.2%		$2,430/year		47.8	→	5% 15/year		$2.5 M/year
Severe: 378		100%										$4.9 M/year

3.3 PATHWAY #3: PRODUCTIVITY LOSS AMONG ANEMIC WORK ADULTS

Weakness, fatigue and lethargy from anaemia result in measurable productivity deficits among adults, particularly in physically demanding work (see Annex VII). In 1979, Basta et al. found that the output of Indonesian rubber tree tappers who supplemented with iron was 17% higher than coworkers who did not supplement with iron[xxiv]. A series of studies in cotton mills, jute mills and cigarette rolling factories in China and Indonesia all found a roughly 5% improvement in work output after correction of anaemia via iron supplementation[xxv]. Based on this research, a 1998 review concluded anaemia results in a 5% deficit in all blue collar workers (manual labourers) and an additional 12% loss for more physically demanding tasks[xxvi]. More recently, an extensive trial on a tea estate in West Bengal published in 2020 by Blakstad et al. confirm earlier findings[xxvii]. Blakstad et al. found anaemia predicted 9.1% less productivity in physically demanding tasks and 7.6% for less strenuous work, findings falling well into the 5–17% range of earlier studies[xxviii].

The BCA applies lower deficit coefficient of 7.6% from Blakstad et al. to adult men and women suffering from IDA who are considered to be engaged in manual work. The BPS data for February 2022 provides parameters for the total number of Indonesian workers segmented into 17 employment sectors, suggesting that the blue collar workforce represents about 61% of all employment (See Annex VIII). Based on these parameters, the BCA model estimates a loss of $2 billion annually due to anaemia among adult women and men employed in manual labour (Table 12).

Table 12: Annual Losses Attributed to IDA Among Manual Labourers

Anaemic Workers		Average Earnings		Labour Participation		Coefficient Deficit		**Annual Loss**
Female: 18.5% 33.6M	**X**	Female: $1994[8]	**X**	Female: 56%	**X**	7.6%	**=**	$943.7 M/Year
Male: 13.8% 49.5M		Male: $2034		Male: 84%				$1060 M/year

3.4 PATHWAY #4: EXCESS HEALTH AND WELFARE COSTS ATTRIBUTED TO ZINC AND FOLATE STATUS

Micronutrient malnutrition in children impairs immunity; leads to more frequent infection and disease; and increased utilization of both formal medical and traditional health services.

Cost of Treating Cases of Diarrhoea and Respiratory Disease Attributed to Zinc Deficiency

Diarrhoea and ARI represent a significant morbidity burden among children <5 years of age. Indonesia's Demographic and Health Survey (DHS) 2017 suggests 106 million cases annually of Diarrhoea and ARI [xxix]. A range of studies associate these cases with significantly higher incidence of diarrhoea and ARI. Drawing on 16 studies, Black et al. (2013) calculated a pooled RR of 2.85 (CI (Confidence Intervals) RR: 1.93 – 4.2) for incidence of diarrhoea and RR of 2.074 (CI RR: 1.394-3.05) ARI[xxx]. The BCA applies the lower end of the confidence intervals calculated by Black et al. (2013) to the burden of diarrhoea and ARI in Indonesia: RR 1.93 for diarrhoea and RR 1.394. Based on prevalence of 25% ZD, disease-specific PAR is calculated and applied to the number of cases estimated from DHS to project 2.15 million annual cases of ARI and 15.9 million annual cases of diarrhoea attributable to ZD, approximately 18 million cases added to the national burden of childhood infection (Table 13).

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[8] Female wages have been slightly adjusted to reflect the World Bank finding that female wages are approximately 98% of wages paid to their male counterparts.

Table 13: Cases of Child Diarrhoea and ARI Attributed to Zinc Deficiency

Prevalence ZD	x	Relative Risk Disease	=	Population Attributable Risk	x	Annual Cases (DHS 2017)	=	Attributed Annual Visits to Facilities
25%		ARI: RR 1.394		9%		ARI: 23.9 M		ARI: 2.15M
		Diarrhoea: RR 1.93		18%		Diarrhoea: 84M		Diarrhoea: 15.9M

Not all zinc-attributed cases access the healthcare system. A 2018 survey of Indonesian mothers and health facilities by Siregar et al. found that mothers seek out treatment for their child's diarrhoea or ARI about half the time, suggesting zinc deficiency results in approximately nine million cases consulting the health system and another nine million treated at home[xxxi]. Based on estimates for disease-specific unit costs and segmented by level of health facility accessed, the BCA projects the economic burden of zinc-attributed cases: a financial burden of more than $100 million annually[xxxii] (Table 14 and Annex IX).

Table 14: Outpatient Costs for Treatment of Zinc Attributed Diarrhoea and ARI Cases ($)

	Diarrhoea		ARI		Total Costs
	Unit Cost[xxxiii]	Annual Cost	Unit Cost/Case	Annual Cost	
	$/Case	$ M	$/Case	$ M	$ M
Public Hospital	41.33	9.82	45.62	1.32	11.14
Private Hospital	21.39	5.93	20.24	0.30	6.23
Puskesmas	2.84	4.45	3.33	0.92	5.37
Posyandu	1.39	0.25	2.24	0.03	0.28
Others	11.51	64.12	10.56	8.59	72.71
Not Treated (Notional Cost)[9]	1.00	8.11	1.00	1.00	9.11
Total		94.32		12.38	106.70

There are additional costs to the outpatient treatments shown in the table above. Siregar et al. found that 0.5% of diarrhoea cases and 0.32% of ARI cases are referred for hospitalization, indicating an added cost of $11.3 million annually for in-patient services[xxxiv]. Moreover, while most costs are covered by public institutions and private insurance, families face additional out-of-pocket costs including access fees, lab and drug costs, meal expenses, and transportation and lodging away from home. Siregar et al. calculated the average out-of-pocket cost per case for various levels of health services enabling a BCA projection for the cost of zinc-attributed cases at an additional $93 million annually[xxxv]. The total projection for

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[9] BCA adds notional cost of $1.00/case for those not accessing healthcare, but caretakers may still purchase special foods for remedies.

annual healthcare costs for zinc attributed cases of diarrhoea and ARI in children will reach $210.9 million annually (See Annex IX).

Health and Welfare Services for Survivors of Folate Related NTD

There is an economic cost for those who survive infancy with birth defects like NTD. While there is no data available for initial cost of surgeries, ongoing rehabilitation and other healthcare services, notional annual costs for 378 moderately disabled NTD survivors and 378 severely disabled NTD survivors are roughly projected at $3.66 million as follows:

- BCA speculates—of the 31% of children born in hospital—about one-tenth[xxxvi] of infants have access to life-saving and advanced pediatric surgical care in the days after birth. Assuming a cost of $10,000 per surgery, the suggested annual cost totals $2.4 million.
- The cost of ongoing rehabilitation and health services for surviving NTD cases who suffer moderate and severe disability are notionally estimated at $1,000/year and $2,000/year respectively, suggesting an annual cost of $944,400.
- A notional cost of $500 that provides a minimal social safety net, welfare and other special government, religious or philanthropic programs implies a cost of $315600 annually.

3.5 SUMMARY OF COST OF INACTION

The annual economic cost of doing nothing to address the burden of IDA, ZD and FD is estimated at $2.79 billion, which is about 0.22% of the national GDP[10]. About 80% of this lost national economic activity represents current losses from lower adult productivity and excess healthcare costs while the remaining 20% represents the NPV of lost future productivity (Table 15).

Table 15: Summary Economic Consequences for All Indicators ($ M/ year)

	NPV Lost Workforce [11]	**NPV Lost Future Productivity**	**Current Labour Productivity**	**Current Healthcare Costs**	**Total**	
Iron Deficiency Anaemia	130.8	293.06	2,001.1		2,424.96	87%
Folate Deficiency	77.6	7.4		3.66	88.66	3%
Zinc Deficiency	65.5			210.9	276.40	10%
Total	**273.9**	**300.5**	**2,001.1**	**214.5**	**2,790.00**	100%
	9.8%	**10.8%**	**71.7%**	**7.7%**		

Taking account projections for relatively flat population growth and declining birth rates, the 10-year losses are estimated at $28.563 billion (See Annex X for indicator-by-indicator and year-by-year analysis)[12]. IDA represents the most acute economic burden, with 87% of total economic consequences.

Discounting for the NPV applied in Pathways #1 and #2 to derive the value of child survival and development deficits represents a major bias and illustrates the shortcomings of a purely

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[10] According to the website Trading Economics, Indonesia's GDP is $1319.10 billion in 2022.

[11] Adjusted for overlapping risk.

[12] Inflation is not factored into the 10-year period due to difficulty in speculating movements in this parameter over 10 years. Furthermore, we assume inflation in wages, medical costs or other factors will be balanced by equal inflation in the mill costs of fortification.

economic analysis. The NPV is very sensitive to the discount rate applied. Therefore, in addition to the base 5% discount rate used in the body of the analysis, a sensitivity analysis is run at 3% and 7% (Table 16). At the 3% discount rate, the share of losses from child mortality and impaired cognitive development rose from 20% to 30% of the total. Conversely, at 7% discount rate, the NPV of lost life and impaired cognitive development dropped to 14%.

Table 16: Sensitivity Analysis: Economic Consequences Using Three Discount Rates ($ Millions)

	NPV Lost Workforce Mortality	**NPV Lost Future Productivity**	**Current Productivity Lost**	**Current Healthcare Costs**	**Total**
NPV @ 3%	469.88	466.29	2,001.05	214.55	3,151.77
Pathway % of Total	**15%**	**15%**	**63%**	**7%**	
Base NPV @ 5%	273.87	300.48	2,001.05	214.55	2,789.95
Pathway % of Total	**9.8%**	**10.8%**	**71.7%**	**7.7%**	
NPV @ 7%	166.10	203.47	2,001.05	214.55	2,585.17
Pathway % of Total	**6%**	**8%**	**77%**	**8%**	

COMPARISON OF CURRENT BCA WITH FINDINGS OF 2010 BCA

Table 17: Summary 2010 BCA Paper: Projected 10-Year Losses from IDA and Folate Associated NTD ($M)

NPV of	NPV of	Adult	Total	NTD	Total Losses from
Perinatal Mortality	Child IDA	IDA	Anaemia	Losses	NTD and IDA
$602.67	$1,941.02	$6,786.60	$9,330.29	$316.26	$9,646.55
6%	20%	70%	97%	3%	

The BCA written in 2010[xxxvii] identified 10-year losses of $9.65 billion (Table 17).

While some demographic data—like length of work life or labour participation rates—remained relatively stable, overall population applied in the BCA rose approximately 20% between the 2010 BCA and the 2022 BCA.

The methodology used to measure loss is heavily influenced by average wages. Estimated annual earnings—which were set at $2,430/year for all sectors and $2,034 in manual labour—were much lower in the 2010 BCA, at $1,049/year.

Anaemia rates and estimated conversion parameters to IDA are significantly different. Prevalence applied in the 2010 BCA—which was drawn from RISKEDAS (2007) and (SKRT 2001, 2004)—was generally lower than RISKESDAS 2018.

Further, in 2010, estimates for IDA share of anaemia was based on prevalence of microcytic anaemia, which was thought to be an indicator of iron deficiency. In 2022, anaemia prevalence was taken from RISKESDAS 2018 with adjustments for iron deficiency share based on findings of Wirth and Engle-Stone[xxxviii]. As shown in Table 18, estimated IDA rates in 2010 were between 56–71% less for adults and pregnant women although higher for children.

Table 18: Comparing Anaemia Rates Applied in 2010 versus 2022

	2022 Anaemia & IDA Prevalence		2010 Anaemia & IDA Prevalence		Difference
	Anaemia % from RISKESDAS	Estimated IDA % based on Wirth et al.	Anaemia % from SKRT & RISKESDAS	% IDA Based on Microcytic Anaemia	2010 as % of 2022
Pregnant Women	48.9%	33.3%	40.10%	23.66%	71%
Women	27.2%	18.5%	27.90%	16.46%	89%
Men	20.3%	13.8%	13.10%	7.73%	56%
Children	30.6%	12.2%	24%	16.82%	137%

Finally, additional indicators of loss were developed for the 2022 BCA based on a literature review from the previous decade during which research developed, expanded and refined evidence of the negative impacts of micronutrient deficiencies (See Annex VII).

Based on new findings over the past decade, indicators were added to quantify the impact of ZD on child mortality as well as incidence of diarrhoea and ARI. Zinc deficiency accounts for one-tenth of the economic damage estimated in the 2022 BCA.

- New evidence from Indonesia for all-cause mortality in children younger than one year was substituted for the more general and theoretical link of maternal anaemia to perinatal mortality.
- Based on research published in 2020, a new coefficient of deficit for productivity loss among manual labourers contributed to the differences between the 2010 assessment and the 2022 assessment.

4. RESULTS: HEALTH IMPACT ANALYSIS OF SCALING FORTIFICATION

Logic Model for Projecting Potential Benefits of Flour Fortification

How much of the 10-year $28.5 billion loss can be prevented by fortifying flour with iron, zinc and folic acid? Estimating the extent to which these baseline losses can be prevented by flour fortification defines the potential economic benefits of the national program. As illustrated in the Table 19 below, defining the baseline economic losses emerging from the current prevalence of iron, zinc and folate deficiencies is the first step in a three-step analysis aimed to estimate the economic benefits of flour fortification. The key parameters of coverage and efficacy of flour fortification, representing the effectiveness of the program, are applied separately for each of the eight indicators of loss. The logic model is shown in Table 19.

Table 19: Logic Model for Calculating Savings or Prevented Losses

Baseline Economic Loss from Iron, Zinc and Folate Deficiencies	X	Projected Effective Coverage of Regular Flour Fortification	X	Projected Protection of Fortified Flour Consumers[13]	=	Savings: Estimated Prevented Losses $/year
$28.5 Billion over 10 Years		% Consuming and expected to benefit		% Protected		
From Cost of Doing Nothing		Industry and Market Analysis		Global Literature for Each Micronutrient		

Estimating Coverage of Flour Fortification

Absent comprehensive and credible consumption surveys, the BCA requires reviewing flour milling and market data and making estimates and assumptions about daily intake and the distribution of flour consumption. The BCA estimates for flour consumption are derived from reports from the national milling association, APTINDO, indicating flour milling increased from 4.66 million metric tons (MMT) in 2012 to 6.96 MMT in 2021, an average annual increase of 5.2%. Adjusting for exports and imports of flour and flour products, this average 10-year growth rate suggests national flour consumption reached 7.136 MMT in 2022. Distributing this national flour supply among 282 million Indonesians yields a national average consumption of approximately 71g/day, which falls below the 75 g/day threshold for average consumption established by the WHO *Recommendations for Flour Fortification*. However, in Indonesia where rice, not flour, remains the primary national staple cereal grain, the distribution of consumption may be very skewed—and averages very deceiving.

National food frequency data gathered by RISKESDAS enables consumer segmentation to better understand how the flour supply is distributed[xxxix]. Based on RISKESDAS, low, mid and high consumption segments can be characterized as follows:

- **Low Consumption Group**: 33.8% of the population consume flour products less than three times per month, which is not enough to provide protection. Many consume no flour at all. It's reasonable to project this segment will not benefit from flour fortification.
- **High Consumption Group***:* 7.8% of Indonesians consume flour products more than once a day. This suggests a minimum of 80g/day[14]. Flour fortification will likely offer efficacious protection for this relatively small consumer segment.
- **Mid Consumption Group***:* By far the largest segment, 58.5% of Indonesians consume flour products between one and six times per week, a wide range of consumption that covers near-daily intake to relatively insignificant intake. With no additional clarifying data, the BCA makes several assumptions about the proportion of consumers with efficacious coverage within this segment, venturing that 55% of the Mid Consumption Group will enjoy some level of protection from fortified flour—representing about 32% of all Indonesian consumers (See Annex XI).

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[13] This model assumes that the micronutrient deficiencies in the covered population is parallel to the national population.

[14] This calculation is based on the conversion using 80g as size of average noodle package.

As shown in Table 20, based on the above RISKESDAS data and consumer segmentation, the BCA assumes that currently 40% of Indonesian may benefit from fortified flour. Presuming the national flour market continues to expand at the average growth rate of 5.2% annually over 10 years, this projected coverage is expected to expand to 41% by 2023 and beyond.

Table 20: Consumer Segmentation and Coverage Based on RISKESDAS Food Frequency Data

Frequency Fortified Flour Consumption	% Population by FF Segment (RISKESDAS)	Assume % Protected	Assume % w/ Some Protection
>1/day	7.8%	100%	7.8%
1-6/week	58.5%	55%	32.2%
<= 3/month	33.8%	0%	0%

Based on projected population growth, estimated milling growth and increased national flour consumption, the BCA makes a series of calculations to project expanded coverage from 41.1% in 2023 to 49.36% in 2032, rising from 115 million to 150 million consumers (See Annex XI)[15].

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[15] With surveys showing consumption among all gender and age groups as well as wide distribution in both urban and rural areas, the BCA assumes that the national prevalence of micronutrient deficiencies applies to these 115–150 million consumers.

ESTIMATING AVERAGE ADDED DAILY DELIVERY OF IRON, ZINC AND FOLIC ACID

The BCA model requires a parameter for average daily flour consumption among consumers considered to be covered with some level of protection in order to make projections for efficacy of flour fortification. To estimate daily flour intake among consumers, the BCA estimates that 85% of the national flour supply goes to the High Consumption and Mid Consumption segments, where some impact is expected, and 15% to the Low Consumption population where little impact is expected (See Annex XII). Based on the parameters defined for number of consumers (Annex XI) as well as daily flour intake per capita among those consumers (Annex XII), Table 21 shows the calculation estimating average per capita daily flour consumption among the High Consumption and Mid Consumption segments. The year-by-year projection estimates that the 10-year average per capita flour consumption will rise from 140 g/day in 2023 to 161 g/day by 2032. This falls comfortably within WHO guidelines for countries with average consumption of >75g and <150g, and the positive impact of fortification can be reasonably expected.

Table 21: Estimated Average Daily Flour Consumption Among Covered Population

	Domestic Flour Consumption	Supply to 85% Covered Consumers	Covered Population	Average Flour Consumption In Covered Population	
	MT/Year	MT/Year	# 000	kg/year	g/day
2023	7,136,247	6,083,500	115,855	51.0	140
2024	7,518,447	6,409,317	119,155	52.3	143
2025	7,848,859	6,690,986	122,572	53.0	145
2026	8,195,748	6,986,702	126,109	53.8	147
2027	8,559,986	7,297,207	129,772	54.6	150
2028	8,942,464	7,623,262	133,563	55.4	152
2029	9,344,156	7,965,695	137,489	56.2	154
2030	9,766,088	8,325,383	141,554	57.1	156
2031	10,209,382	8,703,282	145,765	57.9	159
2032	10,675,192	9,100,375	150,124	58.8	161

Based on average daily consumption shown expanding 140-161 g/day between 2023–2032, Table 22 indicates significant average levels of Dietary Reference Intake (DRI) (based on standards developed for women of reproductive age) delivered to covered consumers.

Table 22: Estimated Nutrition Protection Delivered at Average Flour Consumption of High & Mid Consumer Segments

	Fe Dose[16]	Protection	Zinc Dose	Protection	Folic Acid 90%	Protection
	FE mg/day	% DRI 18mg	mg/day	DRI 8 mg/day	FA Dose	DRI 400 ug/day
2023	7.0	38.8%	4.19	52.4%	279.58	70%
2024	7.2	39.8%	4.30	53.7%	286.34	72%
2025	7.3	40.4%	4.36	54.5%	290.54	73%
2026	7.4	40.9%	4.42	55.3%	294.81	74%
2027	7.5	41.6%	4.49	56.1%	299.17	75%
2028	7.6	42.2%	4.55	56.9%	303.61	76%
2029	7.7	42.8%	4.62	57.8%	308.13	77%
2030	7.8	43.4%	4.69	58.6%	312.74	78%
2031	7.9	44.1%	4.76	59.5%	317.43	79%
2032	8.1	44.8%	4.83	60.4%	322.23	81%

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[16] While losses of added vitamins are expected during storage and processing, minerals like iron and zinc are expected to be extremely stable in the 94–100% range. See Annex XVIII for references.

Sensitivity Analysis

COMPARING AND RECONCILING BCA PARAMETERS FOR COVERAGE, CONSUMPTION AND NUTRITION PROTECTION WITH INDONESIA TOTAL DIET STUDY 2014[xl]

Annual milling volume reports from APTINDO, the national milling organization, along with the RISKESDAS 2013 consumer segmentation are the key sources used in this BCA to estimate coverage and intake of fortified flour. This, in turn, enables the calculations of nutrition protection for iron, zinc and folic acid shown in Table 22 above. This approach locks both the cost of fortified flour supply from the milling industry and the benefits of consumer intake of fortified flour into a single consistent equation. It keeps the BCA honest because changes in the level of nutrition protection are linked to parallel changes in the cost of fortification. Still, while APTINDO and RISKESDAS are very credible sources, this approach includes a number of assumptions and begs the question: are BCA parameters consistent with traditional consumption surveys? Consequently, the BCA ran an analysis based on the Individual Food Consumption Survey: Total Diet Study (TDS), published by the Ministry of Health's Health Research and Development Agency in 2014.

Drawing on a sample of 162,044 individuals, TDS provides the relatively recent comprehensive national survey of individual wheat flour consumption. The analysis in Annex XIII compares TDS results with parameters used in the BCA parameters for national coverage and total national supply. The resulting parameters are very much in line with those used in the BCA.

- TDS results suggest 38.8% coverage of flour products in 2013-2014. Adjusting this baseline coverage to the year 2023 using the same parameters for expanded coverage shown in Annex XI indicates 42.5% coverage for 2023, within about 3% of the 41.1% parameter applied in the BCA.
- TDS found a national average consumption of wheat flour products at 51.6 g/day per capita[xli]. Based on Indonesia's 2014 population of 256 million[xlii] this suggests national flour supply of 4.8 million metric tons for the year, compared to 5.09 million metric tons from APTINDO reporting used in the BCA, within approximately 5%
- TDS found a national average consumption of flour products at 51.6 g/day per capita. With a significant portion of Indonesians reporting no flour consumption, the average significantly underestimates intake among actual flour consumers. Correcting for coverage as reported by TDS, average daily consumption among consumers is about 133 g/day, which is very much in line with the BCA estimate of 140 grams per day in 2023 (See Annex XIII).

Potential Impact of Fortified Flour among Children <12 Years of Age

In addition to the general validation of BCA coverage and consumption estimates, TDS 2014 offers some insight into potential impact of flour fortification among children. The TDS consumption data from approximately 21,000 children between the ages of 0–12 years of age indicates average flour intake of 40.8 grams/day among children younger than five years and 66.5 grams day among children between the ages of five and 12 years of age. As indicated in Table 23, after correcting for the large proportion of the population that does not consume any flour products, this suggests fortified flour may deliver on as much as one-half to two-thirds of DRI to these two key vulnerable groups (See Annex XIII).

Table 23 Nutrition Protection Provided by Fortified Flour Intake at Average Consumption Corrected for Proportion Consuming Flour Products, Reported by TDS 2014

Iron	g/day	mg/day	DRI 8mg/10mg
0-59 months	84.8	4.2	53%
5-12 years	129.9	6.5	65%
Zinc			DRI 4mg/7mg
0-59 months		2.5	64%
5-12 years		3.9	56%

EFFICACY ASSUMPTIONS AND PROJECTIONS

The logic model and algorithm for estimating efficacy is presented in Table 24, which form the basis for the estimations that are further discussed in this section.

Table 24 Logic Model & Algorithm for Efficacy Estimates: Projected % Reduced Prevalence in Covered Consumers

A: (%)	B: (mg or ug/day)	C: (g/day fortified flour)	D: (%)	E: (%)
Literature Review		From Section 4	Calculated: C / B	Calculated: D X A
Expected % Reduced Prevalence of Iron, Zinc and Folate Deficiency	Threshold Daily Dose Delivered to Achieve Expected % Reduction	Estimates for Average Units of Delivered Via Flour Fortification	% Threshold Dose Achieved	Efficacy: Projected % Reduced in Prevalence of Iron, Zinc and Folate Deficiency

Reduced Prevalence of IDA Among Flour Consumers

The literature on efficacy of iron fortification is extensive and several streams of evidence are considered (Annex XIV).

- WHO Recommendations for Flour Fortification state that programs should decrease the prevalence of iron deficiency "to levels reported in industrialized countries" or less than 5% IDA[xliii]. The WHO study group recommendations established intake of an additional 7.1mg iron/day via fortified flour as a threshold where efficacy can be expected.
- A 2018 meta-analysis by Sadighi et al. that included 94 fortification trials provide a review of efficacy segmented iron compound, showing superior performance of ferrous salts with improvements ranging from 11% to 27%[17].
- Evaluation of two national fortification programs fully based on WHO recommended levels and iron compounds found reduced prevalence between 45%–48% in adult women, and between 32%–79% in children[xliv].
- Reviews published by American Journal of Clinical Nutrition, Cochrane Reviews and the Food Fortification Initiative point a range of potential reductions in prevalence IDA from

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[17] Discounting the 11% decrease in the before/after trials that counterintuitively find high effectiveness on anaemia than the more specific indicators of iron status.

21% to 52%. For a number of reasons, the error bands are wide, and the authors usually concede that the strength of the evidence is less than optimal (Annex XIV).

BCA modeling for efficacy of fortification with iron is based on the following assumptions:

- Average reduced prevalence found by Sadighi et al. for ferrous salts, suggesting a potential decrease of 17.8%.
- A notional threshold when the 17.8% decrease in prevalence is achieved set at 7.1mg/day of iron from Hurrell et al. (Sadighi and other sources provide no data on dosage).

The efficacy algorithm developed in Table 24 is applied in Table 25 as follows: the proportion of the 7.1mg/day of added iron (from ferrous fumarate) achieved via flour fortification defines the proportion of the 17.8% prevalence reduction achieved. Based on the 50mg/kg mandated in Indonesian flour standards and 140g/day to 160g/day consumption, BCA projection for the average added intake among regular flour consumers rises from 7mg/day in 2023 to 7.9mg/day, which represents between 98%–113% of the 7.1mg/day dose threshold. Consequently, the BCA model projects a decrease in IDA prevalence rising from approximately 17.5% in the early years to 20.1% by 2032.

Table 25 Projection for % Decrease in Prevalence of IDA Among High and Mid Consumers

	Fe Dose	% of Threshold Dose to Achieve Estimated Reduction 17.8%	Projected Decrease Prevalence Among High/Mid Consumers
	FE mg/day	% 7.1mg	% of 17.8%
2023	7.0	98.4%	17.5%
2024	7.2	100.8%	17.9%
2025	7.3	102.3%	18.2%
2026	7.4	103.8%	18.4%
2027	7.5	105.3%	18.7%
2028	7.6	106.9%	19.0%
2029	7.7	108.5%	19.3%
2030	7.8	110.1%	19.5%
2031	7.9	111.8%	19.8%
2032	8.1	113.5%	20.1%

Reduced Prevalence of ZD Among Fortified Flour Consumers

At the time of the original BCA in 2010, zinc was not a commonly used fortificant and evidence of efficacy for zinc fortification was scarce. By 2016, a Cochrane Review of zinc fortification that included eight trials concluded that foods “fortified with zinc increased the serum or plasma zinc levels in comparison to foods without added zinc”[xlv]. A 2021 review by Tsang et al. synthesized a much more robust evidence base on trials 59 studies concluding “food fortification with zinc, given alone or with other micronutrients, increased plasma/serum zinc concentrations, with a corresponding 24% and 55% decrease in prevalence of zinc deficiency in efficacy and effectiveness studies, respectively”[xlvi]. The average zinc dose provided in the 59 studies included in the meta-analysis was 4.37mg/day[xlvii]. (See Annex XIV)

BCA modeling for efficacy of fortification with zinc makes the following assumptions:

- Averaging Tsang's findings for efficacy and effectiveness studies, BCA adopts an average of 39.5% for reduction in prevalence achieved.
- A notional threshold when 39.5% prevalence reduction is achieved set at an average added intake 4.37mg/day added zinc.

The efficacy algorithm developed above is applied in Table 26 as follows: the proportion of the 4.37mg/day added zinc achieved via flour fortification defines the proportion of the 39.5% prevalence reduction achieved. Based on the 50mg/kg mandated in Indonesian flour standards and 140 –160g/day consumption, the BCA projection for the average added zinc intake among regular flour consumers rises from 4.19mg/day in 2023 to 4.83mg/day. This represents 96%–110.6% of the 4.37mg/day dose threshold. Consequently, the BCA model projects decreases in the prevalence of zinc deficiency among regular consumers of fortified flour rising from about 38% in the early years to 44% by 2032.

Table 26: Projection for % Decreased Prevalence of Zinc Deficiency among High and Mid Consumers

	Zinc Dose	% of Threshold Dose to Achieve Estimated Reduction 39.5%	Projected Decrease Prevalence Among High Consumers
	mg/day	% 4.37mg/day	% of 39.5%
2023	4.19	96.0%	37.9%
2024	4.30	98.3%	38.8%
2025	4.36	99.7%	39.4%
2026	4.42	101.2%	40.0%
2027	4.49	102.7%	40.6%
2028	4.55	104.2%	41.2%
2029	4.62	105.8%	41.8%
2030	4.69	107.3%	42.4%
2031	4.76	109.0%	43.0%
2032	4.83	110.6%	43.7%

Reduced Prevalence of Folic Acid (FA)/NTD among Fortified Flour Consumers

A significant reduction in NTD including spina bifida, anencephaly and other birth defects has been consistently demonstrated via flour fortification with folic acid. Twenty longitudinal studies from 12 different countries showed an average of 41% reduction in the incidence of NTD, with individual studies finding improvements ranging from 19%–60% (See Annex XIV). No information for average dose was identified.

With no dosing data available, the BCA makes a notional assumption that delivery of two-thirds of added DRI (267ug/day of DRI 400ug/day) for folic acid will achieve for 41% reduction in NTD. As consumption increases over the 10-year period from 140g–161g per day, the average added intake of folic acid delivered to covered Indonesians will rise from 280ug to 322ug/day. This represents 105% to 121% of the 267ug/day threshold notionally established to achieve a 41% decrease (See Annex XIV). This suggests that among women regularly consuming fortified flour, incidence of NTD among infants will drop by 43% in the initial years attaining a decrease of nearly 50% within 10 years (Table 27).

Table 27: Projection for % Decreased Incidence of NTD among High and Mid Consumers

	Folic Acid Dose	% of Threshold Dose to Achieve Estimated Reduction 41%	Projected Decrease Prevalence Among High Consumers
	ug/day	% 266.7ug/day Consumption	% of 41% Reduction
2023	279.58	105%	43.0%
2024	286.34	107%	44.0%
2025	290.54	109%	44.7%
2026	294.81	111%	45.3%
2027	299.17	112%	46.0%
2028	303.61	114%	46.7%
2029	308.13	116%	47.4%
2030	312.74	117%	48.1%
2031	317.43	119%	48.8%
2032	322.23	121%	49.5%

Effectiveness of Flour Fortification

Based on the 10-year efficacy projections and the 10-year coverage projections developed in Section 4, Table 28 summarizes the logic and calculations for potential reductions in prevalence of IDA, ZD and FD. As coverage expands and consumption rises over the years 2023–2032, reductions in prevalence will rise year by year as national coverage expands and as average consumption continues to rise, which will increase delivery of micronutrients and improve the efficacy of fortification. The coverage of flour fortification is projected to increase from 41% to 49% over 10 years (Table 28). As a result, the IDA prevalence is expected to be reduced by 7%–10% (percentage points) and the prevalence of ZD is expected to be reduced by 16%–22% (percentage points) compared to baseline. This lowered national prevalence suggests a reduced national caseload of approximately 45 million prevented IDA and ZD cases (see Annexes XV and XVI). Since the BCA only addresses IDA and not overall iron deficiency in the population, the 10-year reduction in caseload may well be 60–80 million of IDA (details in Annex XV). As indicated in Table 28, FD-associated birth defects are expected to decrease by 18%–24% (percentage points) compared to baseline.

Table 28: Reduced National Prevalence and Parameters for Reduced National Economic Losses

A		B		A X B
FF Coverage	X	Projected Efficacy of FF	=	Projected Effectiveness: % Reduction in Prevalence
41% in 2023 to 49% in 2032		IDA: 17.5% (2023) to 20% (2032)		IDA: 7.2% (2023) – 9.9% (2032)
		ZD: 38% (2023) to 44% (2032)		ZD: 15.6% (2023) – 21.6% (2032)
		FD: 43% (2023) to 49% (2032)		FD: 17.7% (2023) – 24.4% (2032)[18]

5. RESULTS: COSTING AND BENEFIT-COST ANALYSIS OF FORTIFICATION

5.1 THE COST OF FORTIFICATION

Cost for the SNI mandated premix including ferrous fumarate, virtually universally applied by the Indonesian milling industry ranges FOB $7–$8/kg[19]. Taking an average of $7.50 per kg cost at the specified dosage rate of 230ppm indicates a premix cost of $1.73 per metric ton of fortified flour.

Currently reported industry cost structure suggests raw materials input represents about 84% of total processing costs. Presuming premix cost is representative of other raw inputs, this indicates an overall fortification cost including storage, administration, quality assurance and equipment amortization of $2.05 per MT flour. Annual fortification costs will rise from about $14.6 million to $21.9 million between 2023 and 2032 as milling volumes increase at the projected 5.2% annually (Table 29 and details in Annex XVII)

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[18] Prevalence reduction refers not to biochemical deficiency as is the case with IDA and ZN but directly to reductions in incidence of deliveries of infants suffering NTD.

[19] FOB costs reported by APTINDO and confirmed by premix suppliers.

Table 29: Annual Projected Cost of Fortification

	Domestic Consumption @ 5.2% Annual Increase[20]	Estimated Cost to Fortify @ $2.05/MT
	MT/y	$ ‘000
2023	7,136	$14,655
2024	7,518	$15,440
2025	7,849	$16,118
2026	8,196	$16,831
2027	8,560	$17,579
2028	8,942	$18,364
2029	9,344	$19,189
2030	9,766	$20,055
2031	10,209	$20,966
2032	10,675	$21,922

5.2 THE BENEFIT-COST ANALYSIS OF FORTIFICATION

Table 30: Summary Logic Model Projecting 10-Year Reduced Economic Loss (or Benefit) Attributed to Flour Fortification (in Millions)

Projected 10-Year Attributed Economic Loss from 3 MND	X	Projected 10-Year Effectiveness: % Reduction in Prevalence	=	Projected 10-Year Prevented Losses Benefits of Flour Fortification
IDA: $24,954.9		7.2% (2023) – 9.9% (2032)		IDA: $2,124.9
ZD: $2,747.40		15.6% (2023) – 21.6% (2032) (2032)		ZD: $506.30
FD: $860.00		17.7% (2023) – 24.4% (2032)		FD: $370.90
Total: $28,563				Total: $3,002.2

The logic model shown above in Table 30 applies the effectiveness parameters for lower prevalence of iron, zinc and folate deficiencies developed in Table 28, to the economic losses attributed to these three micronutrient deficiencies, as summarized in Table 15. The summary logic model above suggests flour fortification may reduce status quo 10-year losses of $28.6 billion by about $3 billion. Table 28 summarizes a more granular analysis; this calculation of potential flour fortification program benefits is based on a year-by-year and indicator-by-indicator analysis, which is shown in Table 31.

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[20] Note that these figures include an estimate for imported flour products which are presumably fortified but not by national millers. This is included in the effort to reflect the full consumer cost of fortification in the BCA.

Table 31: Estimated Losses & Projected Prevention/Benefit from Flour Fortification 2023-2032: Year by Year & Indicator By Indicator (in $ Millions)

	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	Total
Iron Deficiency Anaemia											
Mortality: <1Year											
Losses	130.8	129.4	128.0	127.5	127.0	126.4	125.8	125.2	124.5	123.8	1,268
Prevented	9.4	9.7	9.9	10.2	10.5	10.9	11.2	11.6	11.9	12.3	107.6
Productivity Deficit Child <15year											
Losses	293.1	286.9	2,912.4	457.6	456.6	453.9	451.1	449.0	447.8	446.4	4,532
Prevented	21.1	28.5	247.3	36.7	37.9	39.0	40.2	41.5	42.9	44.4	384.9
IDA Labour Deficits Adults											
Losses	2,001	2,018	2,035	2,052	2,070	2,088	2,105	2,121	2,134	2,146	20,774
Prevented	143.7	151.2	157.8	164.6	171.8	179.5	187.5	195.9	204.5	213.4	1,769
Zinc Deficiency											
Mortality Child <5Year											
Losses	65.6	65.8	65.7	65.9	65.7	65.3	64.9	64.6	64.5	64.3	652.4
Prevented	10.2	10.7	11.1	11.5	11.8	12.2	12.5	12.9	13.4	13.9	120.2
Morbidity Health Cost											
Losses	210.9	211.4	211.2	211.6	211.1	209.9	208.6	207.6	207.0	206.4	2,095
Prevented	32.9	34.4	35.5	36.8	38.0	39.1	40.3	41.6	43.0	44.5	386.1

Table 31: Estimated Losses & Projected Prevention/Benefit from Flour Fortification 2023-2032: Year by Year & Indicator By Indicator (in $ Millions)

Folate Deficiency										
NTD Mortality										
Losses	77.6	76.8	75.9	75.7	75.4	75.0	74.7	74.3	73.8	73.4	752.5
Prevented	33.3	33.8	33.9	34.3	34.7	35.0	35.4	35.7	36.0	36.4	348.5
Health Welfare Costs										
Losses	3.7	3.6	3.6	3.6	3.6	3.5	3.5	3.5	3.5	3.5	35.5
Prevented	0.6	0.7	0.7	0.7	0.7	0.7	0.8	0.8	0.8	0.8	7.4
Disability Earnings Loss										
Losses	7.4	7.3	7.3	7.2	7.2	7.2	7.1	7.1	7.1	7.0	72.0
Prevented	1.3	1.4	1.4	1.4	1.5	1.5	1.6	1.6	1.7	1.7	15.0
Total Loss	**2,790**	**2,806**	**2,821**	**2,838**	**2,853**	**2,867**	**2,880**	**2,891**	**2,902**	**2,912**	**28,563**
Total Prevented Losses	**252.6**	**263.8**	**273.0**	**283.1**	**293.4**	**304.1**	**315.1**	**326.7**	**338.9**	**351.5**	**3,002.2**

The logic model introduced in Section 1 is shown in Table 32 with additional detail of parameters applied in the BCA modeling. Over 10 years, an investment of $181 million to fortify flour at Indonesia's mills will return approximately $3 billion in prevented losses and increased national economic activity. For every $1 in projected fortification costs, a value of approximately $14.6 (at 5% discount rate) will be returned to the national economy as:

- NPV $576.3 million arising from child mortality and resulting lost workforce
- NPV $263 million from reduced future loss from current child disability and cognitive deficit
- Reduced productivity deficits of adults working manual labour valued at $1,769.9 million
- Saved healthcare and welfare expenditures of $393.5 million

Table 32: 10-Year Overview of the Economic Analysis Process to Derive Simple Benefit-Cost Ratio (in Million)

10-Year Baseline Economic Loss	X	Projected Coverage	X	Projected Efficacy of Fortification	=	Projected Improvement or Benefit	/	10-Year Cost of Fortification	=	**Benefit - Cost Ratio**
IDA: $24,954		41.1% 2023 To 49.4% 2032		17%- 20%		IDA: $2,124		$181M		14.6
ZD: $2,747				38%-44%		ZD: $506.3				
FD: $860				43%-49%		FD: $370.9				
$28,563						**$3,002.2**				

Note: (at 5% discount rate)

Table 33 shows this year-by-year benefit-cost perspective, with benefits rising from $253 million in year 2024 to $339 million in year 2023 and a summary benefit-cost ratio of 14.6.

Unlike high dose supplements or vaccines that begin providing benefits in the very short term, protection from fortification builds up slowly with the small added daily doses of micronutrient. Therefore, the year-by-year calculation for benefit-cost ratio below shown in Table 33 accounts for costs in the year they are incurred but assumes benefits in healthier pregnancies, improved child health and development, increased productivity of adults working in manual labour jobs, and reduced health and welfare expenditures will be delayed by one year. Table 33 calculates the benefit-cost ratio according to a stricter accounting methodology which includes estimates for the benefits and costs . Consequently, the benefit-cost ratio calculation includes 10 years of costs but only nine years of benefit are achieved within the 10-year time frame of the analysis.

Table 33: Annual and 10-Year Benefit-Cost Ratio

	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	Total
Benefit (in $ M)		$253	$264	$273	$283	$293	$304	$315	$327	$339	$2,651
Cost (in $ M)	$14.7	$15.4	$16.1	$16.8	$17.6	$18.4	$19.2	$20.1	$21.0	$21.9	$181
Benefit-Cost Ratio	-	18.0	17.7	17.6	17.4	17.3	17.2	17.0	16.9	16.8	14.6

Note: (at 5% discount rate)

While annual benefits rise along with increasing coverage and efficacy, the cost-benefit ratio drops slightly every year. This is due to rising costs of fortification as milling volumes increase an average of 5.2% per year and baseline losses remain stagnant or even decline slightly as the birth rate and population of key risk groups decline somewhat over the next 10 years.

6. CONCLUSION AND KEY MESSAGES

There are clear health and economic arguments for continued investment in implementing and improving WFF in Indonesia.

Key Messages:

1. For the year 2023, the economic cost of inaction in addressing the burden of IDA, ZD and FD is an estimated $2.79B, which is approximately 0.2% of the national GDP. The projected losses over 10 years are an estimated $28.6B.
2. The current prevalence of MND is associated with the deaths of nearly 20,000 children annually. Iron deficiency anaemia represents Indonesia's most acute economic burden constituting 87% of total economic consequences.
3. As the consumption of wheat flour products continues to expand, fortification is expected to benefit approximately half of the population by 2032. Wheat flour fortification is projected to decrease the national prevalence of IDA by 7.2–9.9% and ZD by 15.6–21.6% annually in children and adults between 2023–2032. Over the next decade, a total of 45M cases of IDA and ZD could be prevented in Indonesia through WFF. Additionally, national rates of folate-associated birth defects are predicted to decrease by approximately 25%.
4. As national consumption continues to increase, annual fortification costs are projected to rise from $14.7M in 2023 to $21.9M in 2032. The increased cost of fortification borne by mills is projected at $2.05 per MT flour. For consumers, this suggests an invisible daily cost of approximately $0.10 per person, per year.
5. Of the $28.6B economic losses over the course of 10 years, WFF may prevent $3.0B in the form of NPV of reduced mortality and improved future productivity. An estimated 10-year investment of $181M in fortifying wheat flour for a benefit of $3.0B indicates that every $1 invested in WFF will bring a return of $14.6 in increased economic activity over the next 10 years (2023–2032).

Annexes

ANNEX I: NATIONAL ANAEMIA SURVEYS: 2001–2018

Risk Group	% Anaemia	Source
Children <5 Year	28.0%	RISKESDAS 2013
	27.7%	RISKESDAS 2007
	48.1%	SKRT 2001
	39.0%	SKRT 2004
Children <15 year	24.0%	SKRT 2004
	29.4%	RISKESDAS 2007
	27.4%	RISKESDAS 2013
Women	27.9%	SKRT 2001
	19.7%	RISKESDAS 2007
	23.0%	RISKESDAS 2013
Pregnant Women	37.0%	RISKESDAS 2013
	49%	RISKESDAS 2018
	40.0%	SKRT 2001

ANNEX II: PARAMETERS FOR POTENTIAL ANNUAL EARNINGS, ECONOMIC AND DEMOGRAPHIC STATISTICS

Demographics	#	Source/Comments
Total Population	281,844,000	Population estimates and projections - World Bank Databank https://databank.worldbank
Population Working Age Adults 15-65	190,986,000	Population estimates and projections - World Bank Databank https://databank.worldbank
Population Working Age Male Adults 15-65	94,572,000	Population estimates and projections - World Bank Databank https://databank.worldbank
Population Working Age Female Adults 15-65	96,414,000	Population estimates and projections - World Bank Databank https://databank.worldbank
Population Children < 5 years	71,010,000	Population estimates and projections - World Bank Databank https://databank.worldbank
Population Children <5 years	23,048,000	Population estimates and projections - World Bank Databank https://databank.worldbank
Population 6-59 months	20,657,023	<5-(annual births *50%)

Demographics	#	Source/Comments
Population 6 months to 15 years	68,619,023	<15 - 50% annual births
Birth Rate	16.97	UNICEF
Annual Live Births	4,781,953	Calculated
Mortality Rates		UNICEF State of Children 2021
Under 5 Mortality/1,000	23	
Infant Mortality/1,000	20	
Neonatal < 1 month/1,000	12	
Maternal Mortality/100,000	305	
Adult Labour Participation Rate (Male and Female Combined)	70.2%	https://data.worldbank.org/indicator/SL.TLF.ACTI.ZS?end=2021&locations=ID&start=1990&view=chart
Adult Male Labour Participation Rate	84.0%	
Adult Female Labour Participation rate	56.0%	
Economically Active Adults	135,611,895	BPS, Feb. 2022
Healthy Life Expectancy	62.8	https://apps.who.int/gho/data/node.main.688
Median Age of Birth Mother	29	https://population.un.org/dataportal/data/indicators/18/locations/360/start/2022/end/2032/table/pivotbylocation
Average Work Life of Mother After Childbirth	34	Healthy Life Expectancy-Median Birth Age
Average Age at Workforce Entry	15	Assumption
Female Work Life	28.6	Calculated
Male Work Life		Calculated
Work Life Average (Male and Female)	47.8	Calculated
Female Manual Wage as % Male Manual Wage	98%	World Bank
Discount Rate	5%	World Bank Human Development Report, Investing in Health, 1993

ANNEX III DISCOUNT RATE FOR NPV

Valuing the future productivity of children is complex. For a child born in 2015, the earnings "stream" may not begin until the child enters the work force in 14–25 years, and those earnings stretch another 32–50 years into the future. The literature from psychology and economics agrees that people place higher value on the present than in the future—and the further off in the future, the lower the perceived value. The Net Present Value (NPV) is a subjective factor used to define that future value in current currency by applying an interest or discount rate, which effectively discounts the value of the future. This enables a lifetime of future earnings to be expressed as a current annualized economic loss. This "social discount rate" is not related to inflation or bank interest charges but merely reflects the subjective preference for current over future consumption or savings[xlviii].

For this analysis, a 5% discount rate is used to calculate NPV of lost future earnings due to child mortality or growth deficits in childhood. The choice of a discount rate of 3% or 5% is established as a standard in global health, notably through the recommendations of the Panels on Cost-Effectiveness in Health and Medicine[xlix]. The practice on discounting in economic evaluations in global health overwhelmingly is aligned with the recommendation of applying a discount rate of 5% to both costs and health outcomes. In the effort to produce a conservative and credible BCA, in the current atmosphere of rising interest rates and inflation, this paper also applies 3% and 7% discount rate to calculate the NPV.

ANNEX IV: ETIOLOGY OF ANAEMIA: WHAT PORTION IS ASSOCIATED WITH IRON DEFICIENCY.

The prevalence of anaemia from RISKESDAS is shown in the table below. This annex reviews the evidence for the proportion of this anaemia prevalence that represents IDA. .

Prevalence of Anaemia Among Key Risk Groups in Indonesia		
Children <15 years	30.6%	Calculated from RISKESDAS 2018 (see below)
Pregnant Women	48.9%	RISKESDAS 2018
Adult Women	27.2%	RISKESDAS 2018
Adult Men	20.3%	RISKESDAS 2018

RISKESDAS did not report for three segments of children under 18 years of age. The 27.4% prevalence for children under 15 years was derived from a population-weighted average from RISKESDAS shown in the table below.

	Average Male/Female Prevalence	
Under 5 years	28.1%	5 years
5-12 years	29.4%	8 years
13-18 year	17.55%	2 years
<15 years weighted	27.4%	15 years

Alternative Causes of Anaemia:

Causes of anaemia fall into three broad categories: iron deficiency, infections (such as hookworm and malaria) and hereditary blood disorders. Only anaemia from iron deficiency (IDA) and iron deficiency are responsive to iron nutrition interventions such as flour fortification. However, national anaemia prevalence data for Indonesia is based on a simple indicator of anaemia—hemoglobin—and therefore does not clarify the share of anaemia prevalence that can be addressed by iron nutrition intervention like supplementation, nutrition education or fortification. In the absence of national data for this crucial parameter, a number of pathways were explored to define ways to conservatively estimate the portion of anaemia reported in RISKESDAS that is caused by poor iron nutrition.

The impact of non-nutritional factors on anaemia prevalence in Indonesia is considered insignificant:

- National prevalence of thalassemia, which is considered the most prevalent anaemia-associated blood disorder, was reported at 1.5% in 2007 in the national RISKESDAS survey. Eight provinces had higher prevalence than national average ranging from 3% to 13%[l].

- The impact of malaria, globally considered a major cause of anaemia, particularly in rural areas, is insignificant. In 2009 the Ministry of Health Republic of Indonesia announced a plan to reach the pre-elimination stage by 2020 and to be free of malaria transmission by 2030. The World Bank reports annual incidence of malaria between 0.2%–0.3% for the years 2018–2020[li].

- The share of anaemia associated with soil-transmitted-helminths like hookworm may be significant. While acknowledging scant recent data, a 2019 literature review published in the *Korean Journal of Parasitology* cites a survey carried out in 2008 that reported a regional (or endemic) prevalence of soil transmitted helminth (STH) infection of up to 61% and an average prevalence of STH infection in school-age children between 2002 and 2009 was reported to be 12%–32%[lii].

The citations above suggest roughly 15%–40% of anaemia may emerge from causes unrelated to nutrition.

Small or Localized Studies and Spot Estimates Specific to Indonesia

Based on six studies that provided data on both anaemia and IDA prevalence among adolescents in Indonesia, Kesso et al. (2021) found that iron deficiency shares of anaemia prevalence ranged among 27%–86%, concluding that, on average, 53% to 58% of anaemia cases could be explained by iron deficiency[liii] (also see Annex IV). An average of data gleaned from 10 studies from the Kesso et al. in 2021 as well as six other relatively small surveys shown in the table below indicate a gross average of 58% of anaemia is associated with iron deficiency.

Study	Anaemia	IDA	IDA% Anaemia	ID	ID+IDA	As % Anaemia
Angeles[liv]			68%			
Andriastuti[lv]	14%	5.80%	41%	18.40%	24.20%	173%
Sumarlan[lvi]	31%	13.50%	44%	17.20%	30.70%	99.6%
Widjaja[lvii]	29.5%	29.40%	99.7%			
Sanjaya[lviii]	11.70%	5.30%	45%			
Markara[lix]	19.60%	13.50%	69%	17.20%	30.70%	157%
Dillon 1[lx]	54.00%	15.00%	28%	21%	36.00%	67%
Dillon 2[lxi]	45.00%	25.00%	56%	25%	50.00%	111%
Dillon 3[lxii]	100.00%	56.00%	56%			
Kurniawan[lxiii]			55%			112%
Htet[lxiv]			86%			
Average			59%			152%

In addition to the IDA share of overall anaemia, six studies in the table above also report prevalence of iron deficiency without anaemia—low iron status regardless of anaemia. In all but one study, the prevalence of low iron status was as high or higher than the prevalence of anaemia. As a gross unadjusted average, the prevalence of low iron status is 1.5 times higher than anaemia. This reflects an oft-repeated rule of thumb that, for every case of anaemia there is a case of iron deficiency, with or without anaemia.

GLOBAL AND REGIONAL ESTIMATES OF IRON DEFICIENCY SHARE OF ANAEMIA PREVALENCE

In absence of national data, global regional averages and estimates can be useful. In 1985, WHO estimated that about half of the global anaemia burden was caused by ID[lxv]. Five additional meta-analyses concurred that about 50% of anaemia is iron-related[lxvi]. In 2011, a WHO review on impacts of iron supplementation calculated that shifts in hemoglobin concentration imply that approximately 41% in children and 54% in non-pregnant women could be eliminated by iron supplementation[lxvii]. As part of the Global Burden of Disease project—also using cause-specific shifts in hemoglobin after iron-fortification interventions—Kassebaum et al. estimated about 60%–80% of anaemia in young children is associated with ID[lxviii]. In a supplement to their Lancet article of 2013, Black et al. (2013) estimate anaemia prevalence for Southeastern Asia at 33.9% and Iron Deficiency anaemia at 20.8%, suggesting IDA represents a 61% share of anaemia[lxix]. In the same supplement, Black et al. (2013) estimate that in Southeast Asia, the prevalence of anaemia and IDA in pregnant women at 30.2% and IDA at 16.9%, suggesting IDA with a 56% share of all anaemia[lxx].

A 2016 review by Petri et al., which includes most of the above publications, makes the commonsense conclusion that “the proportion of the population with anaemia attributable to ID changes with varying epidemiologic characteristics. In high burden countries, where anaemia prevalence is >40%, the prevalence of infectious diseases such as malaria, schistosomiasis, and HIV is also high, and consequently the relative contribution of IDA to total anaemia prevalence is comparably lower[lxxi].” For countries like Indonesia with improving economies, better living conditions, healthier environments there is a relatively lower burden of malaria, thalassemia and STH when compared with countries in African, South and Southeast Asia. Furthermore, prevalence of anaemia is generally <40%, the proportion of anaemia due to iron deficiency may well be increasingly significant—tending towards the 60%–80% found by Kassebaum et al. and Black et al. (2013) , rather than the roughly 50% emerging from the global meta-analysis.

Two companion publications from the BRINDA Project (Biomarkers Reflecting Inflammation and Nutritional Determinants of Anemia) compiling data from 10 countries provide an approach to distinguishing poor iron nutrition as cause of anaemia versus inflammation, parasitic and other causes[lxxii].

The 10 countries (Cameroon, Colombia, Côte d’Ivoire, Georgia, Indonesia, Laos, Liberia, Mexico, Papua New Guinea and United States) are segmented into low, medium and high based on the national burden of infection and the associated prevalence of non-nutritional anaemia. Based on the 10 countries, the BCA notionally categorizes Indonesia as somewhere between the low and medium infection burden categories. The BRINDA publications suggest that in countries with medium to low burden of infection, the proportion of IDA ranges 30%–50% for anaemic children and 65–71% for anaemic women. The BCA selects the mid-point of this range with the resulting assumptions for the prevalence of IDA as shown in the table below.

CONCLUSION AND BCA PARAMETERS

In absence of national data on proportion of anaemia prevalence from iron deficiency, the rough analysis above provides background to establish parameters to refine the anaemia prevalence reported by RISKEDAS and to focus on the portion that can be impacted by flour fortification. The BCA will adopt an average of findings from the BRINDA Project for countries with lower-to-moderate burden of infection and other non-nutritional causes.

- For children: average 30% low infection and 50% medium infection countries, or 40%

- For adults: average 65% low infection and 71% medium infection countries, or 68%

Prevalence of Anaemia Among Key Risk Groups in Indonesia			
Risk Segment	Anaemia (RISKESDAS)	% IDA	'% population with IDA'
Children <15 years	30.6%	40%	12.2%
Pregnant Women	48.9%	68%	33.3%
Adult Women	27.2%		18.5%
Adult Men	20.3%		13.8%

ANNEX V: ZINC DEFICIENCY PREVALENCE

There are no national or even large regional surveys for zinc deficiency in Indonesia. Therefore, projections for the benefits of flour fortification including zinc deficiency are relatively speculative and rely on local data and theoretical projections.

- **Small Studies**. A small study in Lampung province in 2019 found average zinc levels well below the WHO threshold with 75% of toddlers having low zinc levels[lxxiii]. Another recent study in the Makassar area found all women in the study sample had serum zinc less than 66mcg/dL and the associated dietary survey found all the women had low zinc intake, mainly from plant sources with low bioavailability[lxxiv].
- **Theoretical Approach**. Using a theoretical approach by applying well established correlations low serum zinc with zinc intake, stunting[21], and other factors, Wessels et al. projected categories of prevalence of zinc deficiency of >25% in Indonesia[lxxv].
- **National Data from Neighbouring Countries with Similar Nutrition Profiles**. The most recent National Nutrition Survey in Vietnam found zinc deficiency in 67% of adult women and 52% of children[lxxvi]. A national survey in The Philippines measured a national rate of 30% including 22% of children five years of age[lxxvii].
- **Correlation with Iron Deficiency and Anaemia**. Zinc is the co-factor of several enzymes and plays a role in iron metabolism, so zinc deficiency is associated with IDA[lxxviii]. Zinc deficiency is expected to co-exist with iron deficiency in low- and middle-income countries because of an overlap of food sources and dietary factors inhibiting or facilitating the absorption of the two nutrients[lxxix]. A recent study among young children found the odds of being anaemic were 3.4 times higher among the infants and toddlers who were zinc deficient. Indicators of iron deficiency and zinc deficiency overlapped in 54%–81% of the children[lxxx].

ANNEX VI: ADDRESSING MIXED FINDINGS OF ANAEMIA LINKED COGNITIVE DEFICIT IN YOUNGER CHILDREN

Among the youngest children, especially those under two years of age, the more recent reviews are more ambiguous, which is not unexpected given the difficulties of measuring cognition among very young children. Among preschool-aged children, particularly those younger than two years of age, Larson et al., "showed mixed results for visual, cognitive, and psychomotor development, with some studies demonstrating small benefits"[lxxxi]. Likewise, a 2013 Cochrane review of iron supplementation trials found "no convincing evidence that iron treatment of young children with IDA has an effect on psychomotor development or cognitive function within 30 days after commencement of therapy. The effect of longer-term treatment remains unclear"[lxxxii]. For several reasons, these findings might be questioned. First, the main findings in the Cochrane review are based on 30 days of iron supplementation, which is not a

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[21] Note from Gupta et al. "Because stunting is also caused by factors other than zinc deficiency, it is therefore assumed to overestimate the zinc deficiency prevalence. However, an assessment of zinc deficiency based on PZC (plasma zinc concentrations) from 19 national-level surveys and its comparison with stunting and FBS (food balance sheet) methods concluded that the stunting prevalence is a better proxy because the two indicators (i.e., plasma zinc and stunting) resulted in similar categorization of countries into high versus low-risk groups, with a few exceptions, whereas the FBS underestimated the prevalence."

sufficient time frame to fully correct anaemia and iron deficiency, let alone secure any functional benefits—and certainly not reflective of a long-term sustained input like flour fortification. On the other hand, Cochrane findings for longer term interventions included just two studies, with one of the two finding a significant positive impact of supplementation.

Second, while the Larson et al. review of impact on preschool-aged children includes 17 studies, IQ measurements are analyzed largely without reference to baseline anaemia or iron status. In 10 of these studies "baseline anaemia and iron deficiency status" is classified as "unselected," "unknown," "non-anaemic" or "iron replete." Cognitive improvement is not expected among the iron replete—and in the majority of cases, the preschoolers in the Larson meta-sample were either non-anaemic or their iron status was unknown. The rationale for iron interventions is not that supplementation or added iron nutrition directly improves cognition, but rather that improvement in iron status improves cognition. The Falkingham study finds clear cognitive improvements among supplemented anaemic schoolchildren, "although it had no effect in non-anaemic individuals"[lxxxiii]. The benefit is specific to the children with poor iron status. In fact, when Larson et al. does segment results for the older children by iron status, they found that, while "there was no overall benefit from iron supplements in IQ in primary school children although among anemic children, iron supplements did improve IQ"[lxxxiv]. Measured benefits emerged only after segmentation by iron status.

While the findings of the Cochrane Review and Larson et al. do not fully support applying the 2.5% coefficient of deficit, given the potential flaws in the recent literature discussed above, the 2022 update will continue to apply the 2.5% coefficient of deficit defined by Horton et al. Also note that the "mixed" findings for preschool-aged children—mainly for children <2 years of age—only affect about 10–15% of the population between the ages of six months and <15 years to whom the 2.5% coefficient is applied.

ANNEX VII: LITERATURE REVIEW OF EVIDENCE FOR COEFFICIENTS OF RISK OR DEFICIT USED IN 2020 BENEFIT-COST ANALYSIS

The key coefficients of risk or deficit that drove the computer modeling for *Economic Analysis of Flour Fortification in Indonesia: Applying Global Evidence to the National Environment (2010)* was completed in 2008. Since that time, evidence for the impact of micronutrient deficiencies on morbidity, mortality and productivity has been developed and refined, pathways to economic loss have been increasingly specified, and risks have been more precisely quantified. Therefore, updating the 2010 BCA requires a review of more recent literature to update the relative risks and other coefficients that underly the modeling. The following notes describe more recent literature along with proposed adjustments and updates to the coefficients used in the analysis.

Cognitive loss associated with anaemia in children

The original computer model and analysis on the economic consequences of iron deficiency and anaemia in children applied an average 2.5% future productivity loss for current cohort of anaemic children between the ages of six months and 15 years of age[22]. The 2010 analysis cited two streams of evidence.

First, as reported in the Journal of Nutrition, "available evidence satisfies all of the conditions needed to conclude that iron deficiency causes cognitive deficits and developmental delays"[lxxxv]. The literature includes a range of observational studies indicating anaemic children score 0.5 to 1.5 SD lower on intelligence tests[lxxxvi]. Further, the robust literature documents the positive impact of iron interventions on cognitive scores, generally ranging from 0.5 to 1 SD[23]. Second, literature finds a direct link of anaemia-related cognitive deficits

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[22] Note the studies below apply to iron deficiency as well as anaemia and, further, the cited iron supplementation trials, by definition, apply to correcting deficits in iron intake (and therefore apply to iron deficiency). The evidence suggests these deficits are widespread among children with iron deficiency but not anaemia as well as with IDA. Limited data from the region and from Indonesia suggest that the total IDA and iron deficiency without anaemia is in all probability greater than the prevalence of anaemia from all causes. However, the BCA will take a conservative approach and attribute cognitive deficits only to children presumed to suffer from IDA.

[23] Annex VI provides descriptions and sources for a number of individual studies.

with future earnings. A review of the global evidence by Galal et al. quantified the link between cognitive test scores and earnings concluding that a “0.25 SD increase in IQ… would lead to a 5%–10% increase in wages”[lxxxvii].

In 2003, a review in Food Policy by Horton et al. found iron deficiency related deficits in children young than 15 years old was associated with a 4% drop in earnings[lxxxviii]. Citing a range of studies suggesting cognitive improvements in young children achieved via iron interventions, Horton et al. concluded that cognitive improvements are largely sustained through secondary school and adulthood with a correlation coefficient of 0.62, indicating a 2.5% decrease in future earning for children younger than 15 years of age.

The evidence base applied in 2010 is largely supported by later evidence. In a 2010, Falkingham et al. cite 14 trials evaluating the effects of iron supplementation on cognitive performance in schoolchildren, concluding that improved iron status increased IQ by 2.5 points[lxxxix]. A 2017 paper by Larson et al. in the Annals of Nutrition Metabolism review the impact of iron supplementation separately for preschool, primary and secondary school children, concluding there is clear evidence of cognitive benefits of iron treatment on children school-age children, with mean difference of 4.55 IQ points[xc].

Economic impact of anaemia in adult workers

In *Applying Global Evidence to the National Environment (2010),* the analysis on the economic consequences of anaemia in adults applied a 5% work performance deficit to anaemic adults working in manual labour and added 12% to the portion of the workforce considered to work in heavy manual labour where impacts of anaemia on strength and energy are more severe.

The 2010 paper cited a substantial literature showing the negative impact of anaemia on indicators of physical performance. Ability to sustain moderate-to-heavy physical labour involving strength, endurance and aerobic capacity is compromised by 10%–75% times[xci]. Workplace studies find these laboratory physiological deficits translate into performance deficits. In blue collar manufacturing jobs, three studies measuring productivity of supplemented female cotton mill workers in China as well as jute mill workers and cigarette rollers in Indonesia all found a roughly 5% improvement in work output after iron supplementation[xcii, xciii]. The output of iron supplemented rubber tree tappers in Indonesia involved in heavy manual labour was 17% higher than their non-supplemented coworkers[xciv].

Based on these two studies, the 2010 analysis applied a 5% productivity deficit to the workforce involved in manual labour, mainly concentrated in Indonesia’s agriculture, extraction, manufacturing and electricity sectors. An additional 12% was applied to a portion of the manual labour force estimated to be engaged in more physically demanding or heavy labour, to match the 17% deficit measured in anaemic rubber tappers.

A recent study published in 2020 by Blakstad et al. generally confirms these earlier findings[xcv]. At commercial tea estates in West Bengal, tea pickers were paid a base wage to meet a quota of 25kg/day and additional wages for excess production. This work environment offered an opportunity to compare both productivity and wages of anaemic versus iron replete workers, both directly from volume of tea picked by each worker as well as actual wages earned. The workplace study found significant productivity deficits among workers with anaemia:

- Overall, anaemia predicted an average 2.02kg tea plucked or a 9.1% productivity deficit.
- During less physically demanding work, productivity deficit for anaemic workers was 7.6%.

- An increase of 1.0g/L in hemoglobin concentration predicts 0.71kg (3.3%) more tea plucked.

Given the rigor, specificity and clarity of these findings, for the 2020 update of Economic Analysis, it may be appropriate to apply this 9.1% coefficient of deficit to all anaemic manual labourers. This is both simpler and more understandable that the two-tier workplace segmentation into “manual” and “heavy manual” labour, that requires numerous assumptions to apply to the specific national environment.

Perinatal deaths associated with anaemia in pregnancy

Based on Stoltzfus et al. in Global Burden of Disease (2004), *Economic Analysis of Flour Fortification in Indonesia (2010)* attributed about 7,000 perinatal deaths to maternal anaemia In Indonesia, based on an algorithm used by Stoltzfus et al. that associated a 16% decrease in perinatal mortality for every 1 gram per deciliter increase in maternal hemoglobin, equivalent to a relative risk (RR) of 0.84[xcvi]. However, definitions of “perinatal” vary and national data is often inconsistent. In Indonesia and other countries where this model was applied, applying this perinatal mortality indicator led to discussions on the validity of the data, the appropriateness of this parameter and sometimes detracted from stakeholder focus on the economic consequences of anaemia in pregnancy.

On the other hand, neonatal mortality, partially included in perinatal mortality, measures a similar risk of anaemia in pregnancy. Neonatal mortality is a more transparent indicator and the evidence associating maternal anaemia with neonatal mortality reported by Black et al. (2013) is at least as robust as the association with perinatal mortality—if not more[xcvii]. The Lancet review by Black and the Maternal and Child Study Group reviewed a number of studies including Dibley et al. (2012) who compiled demographic and health surveys in Indonesia indicating the risk of death for children <5 years of age was reduced 34% among mothers consuming any iron-folic acid supplements. This analysis found a protective effect of odds ratio (OR) 0.69 for neonatal deaths and OR 0.74 for post-neonatal deaths[xcviii]. In the 2020 update, these parameters for neonatal mortality associated with maternal anaemia will substitute for the perinatal mortality analysis done in the 2010 paper.

Zinc attributed mortality and morbidity in children associated with diarrhoea and ari

When *Economic Analysis of Flour Fortification in Indonesia* (2010) was undertaken, the initial evidence for the impact of zinc deficiency on child health and survival was not fully recognized. In 2004, a WHO-conducted Quantification of Health Risks noted the association of zinc deficiency with higher morbidity and mortality due to infectious disease has been widely observed[xcix]. However, the pathways and risks had not been fully developed and quantified.

Over the past decade, a number of intervention trials and reviews have clarified the pathways and quantified the risks of child morbidity and mortality via diarrhoea and ARI. In 2009, Brown et al. published randomized case control zinc intervention trials showing a significant 18% reduction (RR 0.82) in all-cause mortality in children aged 1–4 years[c]. In 2011, Yakoob et al. reviewed three trials demonstrating significant infection-specific impacts via lower incidence of diarrhoea, ranging from RR 0.22 to RR 0.89, and pneumonia ranging from 0.36 to 0.9[ci]. Based on these findings of protective effect, Black et al. (2013) derive a summary prevalence adjusted RR of mortality from diarrhoea of RR 2.01 and pneumonia of RR 1.96[cii]. Based on these two summary coefficients of risk, it is proposed that the 2022 update of *Economic Analysis of Flour Fortification in Indonesia* apply these more recent findings to project child mortality associated with maternal zinc deficiency.

The association of zinc deficiency with incidence of diarrhoea and ARI in children 6–59 months is equally robust. A 2014 Cochrane Review including 80 randomized controlled trials concluded that zinc supplementation reduced diarrhoea morbidity with protective effect of RR 0.87[ciii]. For zinc deficient children, this suggests an RR 1.15 for increased risk of disease RR. A 2016 Cochrane Review including six studies involving 5193 subjects showed that zinc supplementation reduced the incidence of pneumonia by 13% (RR 0.87) and prevalence of pneumonia by 41% (RR 0.59)[civ]. For zinc deficient children, this suggests RR 1.15-1.69 for increased risk of disease. Based on 17 intervention studies showing the positive effect of zinc supplementation, Black et al. (2013) and the Maternal and Child Nutrition Study Group derive RR 2.85 for incidence of diarrhoea and RR 2.07 for incidence of ARI for children with zinc deficiency[cv]. It is proposed to apply the findings of the Maternal and Child Study group published in the Lancet or an average of the Lancet and Cochrane findings, RR 2.0 diarrhoea and RR1.61 for ARI.

Maternal Mortality Associated with Anaemia in Pregnancy

During pregnancy, iron requirements rise significantly and so does the prevalence of anaemia, threatening the health and survival of mother and child. This association of maternal anaemia and death in childbirth is well accepted and the evidence is specific and quantified in the 2013 Lancet report from the Maternal and Child Study Group[cvi]. However, while maternal mortality from anaemia is a significant factor in the overall burden of micronutrient deficiencies, it is increasingly recognized that the very high iron requirements of pregnant women cannot be significantly addressed by levels of iron added to fortified flour, levels that are more appropriate for a safe and effective intervention targeting the general population, including women of reproductive age. For these reasons, while maternal deaths due to anaemia were calculated in the 2010 analysis, the results were not included in the report. It is proposed that the 2020 update also does not include maternal mortality.

Mortality and Healthcare Costs from NTD (Folate Deficiency)

Neural Tube Defects (NTD), spina bifida and anencephaly, are a significant cause of death and disability throughout the world. The March of Dimes Global Burden of Birth Defects estimated almost 324,000 yearly NTD births worldwide. A recent review calculated that more than 200,000 are likely preventable with additional folic acid in the diets of women[cvii]. There is very little data on the incidence of NTD in Indonesia as well as the outcome and cost of these cases. Therefore, *Economic Analysis of Flour Fortification in Indonesia (2010)* is conceptual and speculative. However, folic acid fortification to reduce birth defects is a powerful advocacy message and folic acid included in the premix represents a cost to the program. Therefore, it is proposed that the national cost of NTD be updated for 2020.

ANNEX VIII: MANUAL LABOUR ESTIMATES

No	**Main Sector**	**February 2022**		
		Population	**Est % Manual**	**Est # Manual**
1	Agriculture, Forestry and Fisheries	40,635,997	100%	40,635,997
2	Mining and Quarrying	1,587,978	100%	1,587,978
3	Processing industry	18,671,926	100%	18,671,926
4	Procurement of Electricity, Gas, Steam/Hot Water and Cold Air	309,484	100%	309,484
5	Water Supply, Waste Management and Recycling, Waste and Garbage Disposal and Cleaning	534,247	100%	534,247
6	Construction	8,188,425	100%	8,188,425
7	Wholesale and Retail Trade; Car and Motorcycle Repair and Maintenance	25,800,553	66%	17,028,365
8	Transportation and Warehousing	5,710,510	66%	3,768,937
9	Provision of Accommodation and Provision of Food and Drink	9,635,433	25%	2,408,858
10	Information and Communication	1,097,558		-
11	Financial Services and Insurance	1,512,007		-
12	Real Estate	450,519		-
13	Company Services	1,940,203		-
14	Public Administration and Defense; Compulsory Social Security	4,633,405		-
15	Education Services	6,626,638		-
16	Health Services and Social Activities	2,384,745		-
17	Other Services	5,892,267		-
	Total	**135,611,895**	Total # Manual	93,134,217
			% Total Manual	68.68%

ANNEX IX: COST OF TREATING ZINC ATTRIBUTED CASES OF DIARRHOEA AND RESPIRATORY DISEASE

A major cause of child mortality, diarrhoea and ARI constitutes a significant morbidity[cviii] burden among children in Indonesia. Indonesia's DHS 2017 reports that in the two weeks prior to the survey 14% of children <5 years of age suffered from diarrhoea and 4% had ARI symptoms. Cumulatively, over the course of 52 weeks, this suggests an average of 1.1 cases of ARI/child/year or approximately 23 million cases and 3.7 cases of diarrhoea/child/year or >84 million annual cases.

Cost Estimates			
Health System Utilization	Diarrhoea	ARI	Total
Total Attributed Cases in Health System	2,086,700	737,125	2,823,824
Total Attributed Cases Hospitalized	0.50%	0.32%	
% Cases in Public Hospitals	46.13%	66.5%	
% Cases in Private Hospitals	54%	33.5%	
Average Cost Per Public Hospital Inpatient	$362.80	$366.82	
Average Cost Private Hospital Inpatient	$146.11	$433.44	
Cost Public Hospitals/y	$1,751,250	$576,306	$2,327,556
Cost Private Hospitals/y	$823,574	$343,039	$1,166,614
Total Annual Hospitalization Costs	$2,574,825	$919,346	$3,494,171

A range of studies associated zinc deficiency in children <5 years of age with significantly higher incidence of diarrhoea and ARI, and supplementation trials have demonstrated that providing additional zinc can lower diarrhoea and ARI morbidity:

- A 2014 Cochrane review including 26 studies concluded that zinc supplementation reduced diarrhoea morbidity, including the incidence of all-cause diarrhoea with RR 0.87[cix].
- A 2016 review of six studies by Lassi et al. concluded zinc supplementation reduced the prevalence of pneumonia by 41%[cx].
- Drawing on 13 studies with zinc deficient children, Black et al. (2013) and the Maternal and Child Nutrition Study Group derived a pooled RR of 2.85 for incidence of diarrhoea with Confidence Intervals ranging from RR 1.93 to 4.2[cxi]. Based on three studies with zinc deficient children, the same Lancet meta-analysis by Black et al. (2013) derived an increased risk RR of 2.074 for incidence of pneumonia with Confidence Interval ranging from 1.394 to 3.05[cxii].

The BCA applies the lower end of the of range of RR calculated by Black et al. (2013) to the burden of diarrhoea and ARI in Indonesia, RR 1.93 for diarrhoea and RR 1.394 for respiratory disease. These disease-specific RR are applied to an assumed prevalence of 25% zinc deficiency to develop a Population Attributable Risk (PAR) of 6% for ARI and 18% for diarrhoea. As shown in the table below, these PAR are applied to the number of annual cases estimated from DHS 2017 to project 2.15 million annual cases of ARI and 15.9 million annual cases of diarrhoea attributable to ZD—18 million cases added to the national burden of childhood infection and disease.

Projection of Deaths Children of 6-59 Months Attributed to Zinc Deficiency

Prevalence of Condition	X	Relative Risk Disease	=	Population Attributable Risk	X	Annual Cases	=	Zinc Attributed Cases
25%		ARI: RR 1.394		9%		ARI: 23.9M		ARI: 2.15M
		Diarrhoea: RR 1.93		18%		Diarrhoea: 84M		Diarrhoea: 15.9M

Not all of these 18 million zinc-attributed cases result in visits to a healthcare provider and therefore a cost to the health system. In DHS 2017, mothers report "seeking advice or treatment" for 92% of ARI cases and 80% of diarrhoea cases, suggesting about 95 million visits to a range of formal and informal health providers and facilities. A recent 2018 study by Siregar et al. focusing specifically on mother's health-seeking behaviours for children with diarrhoea and ARI in Indonesia found a lower utilization of services, finding about half of all the cases seeking treatment at public or private hospitals, Puskesmas, Posyandu, or other formal or traditional providers, which suggests about 50 million cases annually[cxiii]. The BCA applies the lower estimates from Siregar et al., which are also segmented by type of health facility, to estimate demands made on the healthcare system by the 18 million zinc-attributed cases. The table below suggests nearly nine million cases annually seeking healthcare services from hospitals, Puskesmas, Posyandu, and other health or traditional providers.

Estimated Zinc Attributed Cases Seeking Health Services: Total and Segmented by Type of Health Facility

	Zinc Attributed Diarrhoea Cases		Zinc Attributed ARI Cases		Total
Type of Health Facility/Service	% Utilization	#000 Cases	% Utilization	#000 Cases	#000 Cases
		15,939		2,149	18,088
Public Hospital	1.49%	237	1.35%	29	267
Private Hospital	1.74%	277	0.68%	15	292
Puskesmas	9.83%	1,567	12.84%	276	1,843
Posyandu	1.12%	179	0.68%	15	193
Others[24]	34.95%	5,571	37.84%	813	6,384
Total Cases Seeking Healthcare	50.13%	7,831	46.61%	1,148	8,978
Not Treated/Home Treated	49.87%	8,108	53.39%	1,002	9,110

About eight million diarrhoea cases and one million ARI cases incur a cost for facilities and services outside the home. Based on a survey of both families and facilities, Siregar et al. estimate the average cost per case incurred at the various facilities[cxiv]. As shown in the table below, these unit costs enable calculating the segmented cost of the zinc-attributed cases of

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[24] The "others" category developed by Siregar et al consists of a range of facilities not grouped within the other five types of facilities. For these, "we used the treatment cost of the most similar of the five types of institutions from our survey data.

ARI and diarrhoea totaling $32 million annually. This figure includes a notional cost of $1.00 per case for about half the cases that do not access formal healthcare but still may purchase special foods or home remedies. Further analysis and segmentation of data provided in Siregar et al. suggests that 0.5% of diarrhoea cases and 0.32% of ARI cases are referred for hospitalization.

Outpatient Costs for Treatment of Zinc Attributed Diarrhoea and ARI Cases

	Diarrhoea		ARI		Total Costs
	Unit Cost	Annual Cost	Unit Cost/Case	Annual Cost	
	$/Case	$ M	$/Case	$ M	$ M
Public Hospital	$41.33	$9.82	$45.62	$1.32	$11.14
Private Hospital	$21.39	$5.93	$20.24	$0.30	$6.23
Puskesmas	$2.84	$4.45	$3.33	$0.92	$5.37
Posyandu	$1.39	$0.25	$2.24	$0.03	$0.28
Others	$11.51	$64.12	$10.56	$8.59	$72.71
Not Treated (Notional Cost)	$1.00	$8.11	$1.00	$1.00	$9.11
Total		$94.32		$12.38	$106.70

While facility costs and many drug costs are covered by public institutions and private insurance, families often face added out-of-pocket costs of accessing healthcare facilities. This includes various access fees, added lab fees and drug costs, transportation and meal expenses, and sometimes lodging away from home. Based on extensive patient interviews, Siregar et al. developed average out-of-pocket cost per case for the various levels of health services, to which we apply to number of zinc-attributed cases to project a >$28 million burden on families who seek health provider assistance[cxv].

Patient Financed Costs for Accessing Healthcare Facilities and Non-Covered Costs			
Facility Segment	Segmented Cost	Cases Per Segment	Segmented Out-of-Pocket Costs
	$/Case		$ M
Public Hospital	$19.78	266,507	$5.27
Private Hospital	$22.68	291,954	$6.62
Puskesmas	$2.63	1,842,780	$4.85
Posyandu	$1.97	193,133	$0.38
Others	$11.87	6,383,995	$75.78
		8,978,369	$92.90

Total projection for annual healthcare costs for cases of diarrhoea and ARI attributed to zinc deficiency in children reach $210.9 million annually.

ANNEX X: 10-YEAR LOSS PROJECTIONS FOR EIGHT NEGATIVE OUTCOMES

10-Year Loss Projections for Eight Negative Outcomes (at 5% discount rate)

	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	10 Year Loss
Zinc < 5year											
Mortality #	4,311	4,323	4,317	4,326	4,316	4,291	4,264	4,244	4,233	4,220	42,846
Mortality NPV	65.6	65.8	65.7	65.9	65.7	65.3	64.9	64.6	64.5	64.3	$652.37
Risk Group % Growth		0.26%	-0.13%	0.20%	-0.22%	-0.58%	-0.63%	-0.47%	-0.27%	-0.31%	
FE <1year											
Mortality #	9983	9,879	9,770	9,735	9,697	9,654	9,608	9,557	9,503	9,449	96,835
Mortality NPV	131	129	128	128	127	126	126	125	124	124	1268
Risk Group % Growth		-1.04%	-1.11%	-0.35%	-0.40%	-0.44%	-0.48%	-0.52%	-0.57%	-0.57%	
NTD Births											
Mortality #	5924	5,862	5,797	5,776	5,753	5,728	5,701	5,671	5,638	5,606	57,456.46
Mortality NPV	$77.5	76.7	75.92	75.65	75.35	75.02	74.66	74.27	73.85	73.43	$ 752.52
Risk Group % Growth		-1.04%	-1.11%	-0.35%	-0.40%	-0.44%	-0.48%	-0.52%	-0.57%	-0.57%	
Future Earnings Child <15y											

10-Year Loss Projections for Eight Negative Outcomes (at 5% discount rate)										
NPV Loss	$456	$457	$457	$458	$457	$454	$451	$449	$448	$446	$4,532
Risk Group % Growth		0.26%	-0.13%	0.20%	-0.22%	-0.58%	-0.63%	0.47%	-0.27%	-0.31%	
Current Earnings Adults											
Earnings Loss	$2,001	$2,018	$2,036	$2,053	$2,070	$2,088	$2,105	$2,121	$2,135	$2,147	$20,774
Risk Group % Growth		0.85%	0.89%	0.82%	0.86%	0.87%	0.82%	0.74%	0.64%	0.58%	
NTD Disability	7.42	7.34	7.26	7.24	7.21	7.18	7.14	7.10	7.06	7.02	64.57
Risk Group % Growth		-1.04%	-1.11%	-0.35%	-0.40%	-0.44%	-0.48%	-0.52%	-0.57%	-0.57%	
NTD Medical											
Medic/Welfare	$3.66	3.63	3.59	3.57	3.56	3.54	3.53	3.51	3.49	3.47	$35.54
Risk Group % Growth		-1.04%	-1.11%	-0.35%	-0.40%	-0.44%	-0.48%	-0.52%	-0.57%	-0.57%	
Zinc Med Cost											
ARI/DRI Costs	$210.88	211.43	211.17	211.58	211.12	209.90	208.58	207.61	207.05	206.42	$2,095.73
Risk Group % Growth		0.26%	-0.13%	0.20%	-0.22%	-0.58%	-0.63%	-0.47%	-0.27%	-0.31%	
	$2,953.08	$2,969.65	$2,984.26	$3,001.66	$3,016.89	$3,029.72	$3,041.23	$3,052.24	$3,062.65	$3,071.66	$30,183

ANNEX XI: COVERAGE

Coverage of Flour Fortification

While consumption of wheat products has expanded dramatically in Indonesia over the past two decades, consumption patterns and consumer profiles have not been credibly or comprehensively detailed and quantified. National data and estimates published by FAO, USDA and others suggest average annual consumption has grown to about 30 kg/year or 80 grams per day, or more[cxvi]. However, none of these estimates consider the wide variation in individual flour intake in Indonesia where flour represents a secondary staple food and rice remains the predominant cereal grain staple. The national average does little to clarify the extent flour fortification can cover the population with an efficacious dose of micronutrient protection. Consequently, the BCA will require reviewing flour milling and market data, referring to food frequency surveys and making educated assumptions about the daily intake and the distribution of flour consumption.

Indonesia's large, modern and sophisticated milling industry provides precise data for overall national milling and consumption trends. Annual reporting from APTINDO, the national industry association, indicates flour milling for national consumption increased from 4.66 million metric tons (MMT) to 6.96 MMT between 2012–2021, an average annual increase of 5.2%. After adjusting for exports and imports of flour and flour products, this suggests national flour consumption reaching 7.136 MMT in 2022. Distributed among 282 million Indonesians, this indicates a national average consumption of approximately 71g/day, which is less than the 75 g/day threshold for average consumption established by the WHO Recommendations for flour fortification. WHO states that "per capita consumption of <75 g/day does "not allow for addition of sufficient level of fortificant to cover micronutrient needs for women of childbearing age"[cxvii]. However, averages are deceiving, particularly when flour does not represent the primary national staple and the distribution of consumption may be very skewed.

	APTINDO 2012-2021 Annual Flour Milling (000 MMT/Year)										
Year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Increase
000 MT	4,662	5,089	5,431	5,455	5,841	6,275	6,519	6,843	6,700	6,960	
Change/ year	13%	8%	6%	0%	7%	7%	4%	5%	-2%	4%	Av/5.2%

National food frequency data gathered by RISKEDAS and published in 2019 enables consumer segmentation and illuminates how the national flour supply is distributed among the population[cxviii]. Low, Mid and High consumption segments are characterized as follows:

- **Low Consumption Group**: BPS and IFLS data suggest that 80–90% or more of Indonesians consume at least some flour products. However, these surveys are binary and don't clarify how often or how much. RISKESDAS survey finds 33.8% of the population consumes flour only products <3 times per month. Presumably, based on BPS and IFLS data, 10%–20% of this group consume no flour at all. Moreover, even consuming noodles two to three times per month is not sufficient for the safe and low fortification dose to provide protection. Therefore, it's reasonable to project that even though flour is consumed, this low consumption segment will not benefit from flour fortification.
- **High Consumption Group**: RISKESDAS reports that 7.8% of Indonesians consume flour products more than once per day. This indicates a minimum of 80g/day (average noodle package) and suggests fortification levels recommended by WHO and implemented in Indonesia will offer efficacious protection for this consumer segment.
- **Mid Consumption Group**: RISKEDAS reports 58.5% of Indonesians consume flour products between one and six times weekly, suggesting a wide range of consumption among most of the population, from near-daily consumption to relatively insignificant amounts of fortified flour. With no additional data, the BCA

undertakes additional segmentation and makes several assumptions about the proportion of efficacious coverage within this segment.

- One or two portions per week provide an average of 3%–11% of Daily Nutrition Requirement (DRI), probably not sufficient for significant nutrition protection.
- Two to four portions per week provide an average of 9.5%–17% of DRI for the three micronutrients, possibly offering some level of protection.
- Five or six portions provide 16%–34% of DRI for the three micronutrients, probably offering a modest level of efficacy.

Presuming that a) each segment above represents one-third of the Mid Consumption Group and b) that at the lower end of the distribution, between 34–46 grams per day of flour consumption provides an added 10% DRI, represents a threshold for some level of efficacy. The BCA model will assume that more than half–say 55% of this Mid Consumption Group–will enjoy some level of protection from their consumption of fortified flour.

Conceptual Scenario: What Proportion of those Consuming Flour 1-6 Times Weekly May be Protected?

Consumption		Iron Protection		Zinc Protection		Folic Acid Protection	
Portions/ Week	g/day @ 80g/ portion	Added Fe mg/day	% DRI	Added Zn mg/day	% DRI	Added FA Ug/day	% DRI
1	11	0.6	3.2%	0.34	4%	23	6%
2	23	1.1	6.3%	0.69	8.6%	46	**11%**
3	**34**	1.7	**9.52%**	1.03	**12.9%**	69	**17%**
4	**46**	2.3	**12.7%**	1.37	**17%**	91	**23%**
5	57	2.9	**15.9%**	1.71	**21%**	114	**29%**
6	69	3.4	**19.0%**	2.06	**26%**	137	**34%**

As summarized in the table below, the consumer segmentation and assumptions above suggest that with current distribution of flour consumption across the population 40% of Indonesians may benefit from fortified flour. Presuming the national flour market continues to expand at the average growth rate of 5.2% over 10 years, this projected coverage is expected to expand to 41% by 2023.

RISKESDAS 2018 Consumer Segmentation

Frequency Fortification Consumption:	% Population by Fortification Segment (RISKESDAS)	Assume % Protected	Assume % w/ Some Protection
>1/day	7.8%	100%	7.8%
1-6/week	58.5%	55%	32.2%
<= 3/month	33.8%	0%	0%

Given modest projected population growth, 0.72%–0.096% growth annually over the next 10 years will be necessary to simply sustain the current 40% consumer coverage. At 5.2% average annual growth, the remaining 4.24%–4.49% represents an expansion of the flour market beyond population growth. Not all this growth will represent additional and efficacious coverage of consumers; some growth will be attributed to those currently covered who simply consume more flour and some is consumed by an expanding population that is consuming more flour, but not at sufficient level to enjoy protection. The BCA model will assume two-thirds of market growth represents an expanding proportion of consumers with flour intake in sufficient amounts to enjoy some level of nutrition protection. Based on these assumptions, the table below shows a 10-year expansion of the flour market and expansion of coverage at roughly 2.9% annually. Over 10 years, the BCA model assumes efficacious coverage of flour fortification may rise from 41.1% to 49.36%, from 115 million to 150 million consumers.

Growth in Population Considered Covered 2023-2032

	Population Growth %	Milling Growth Above Population	Annual Growth Coverage @ 2/3rd Milling Growth	Assumed/Modeled Coverage	
				%	#000
2023	0.96%	4.24%	2.83%	41.11%	115,855
2024	0.93%	4.27%	2.85%	41.87%	119,155
2025	0.90%	4.30%	2.87%	42.68%	122,572
2026	0.88%	4.33%	2.89%	43.52%	126,109
2027	0.85%	4.36%	2.90%	44.39%	129,772
2028	0.82%	4.38%	2.92%	45.30%	133,563
2029	0.80%	4.41%	2.94%	46.25%	137,489
2030	0.77%	4.44%	2.96%	47.25%	141,554
2031	0.74%	4.46%	2.97%	48.28%	145,765
2032	0.72%	4.49%	2.99%	49.36%	150,124

ANNEX XII: AVERAGE CONSUMPTION AND PROTECTION

The BCA requires a parameter for average daily flour consumption among covered consumers in order to make projections for efficacy. The consumer segmentation into covered and non-covered suggests a parallel segmentation of the flour supply: one supply to consumers where some impact is expected and another supply destined for the low consumption segment where little impact is expected. The BCA based on the RISKEDAS food frequency data and the consumer segmentation the table below outlines a thought experiment and a series of assumptions including:

- Within the protected population, assume 7.8% high consumer segment (>1 portion/day) at average 1.25 portions/day; and the covered 37.175% Mid Consumer (55% of the segment) consumes (4–6 portions/week), an average of five portions per month.
- Within the population where no impact is expected, assume 26.325% Mid Consumer segment (1–3 portion/week) on an average two portions per week, and the 33.8% Low Consumer segment (<3 portions/month) at an average 1.5 portions a week.
- After converting the various denominators to portion per year, the portions are summed, and a percentage is derived for each of these four consumer segments.
- Summing the two protected segments suggests 85% of flour consumers by the 39% of covered consumers and the remaining 15% by consumers with low or no consumption.
- The BCA model assumes that this 85%/15% segmentation reflects the distribution of the national flour supply among covered and non-covered consumers.

Conceptual Scenario: Portions Consumed by Protected vs Unprotected Populations			
Consumer Segments	Average Portions	Total Portion/year	% Total Portions
Protected Population			
7.8% @ >1 day	1.25/day	445	53.8%
32.175% @ 1-6 week	5/W	260	31.4%
			85.2%
Unprotected Population			
26.325% @ 1-6 week	2/W	104	12.6%
33.8% @ < 3/month	1.5/M	18.0	2.2%
		827	**14.8%**

The segmentation of both consumers and flour supply into covered and non-covered segments enables a projection of average per capita flour consumption specifically among higher volume or covered consumers. Calculations for average consumption among consumers considered covered by flour fortification rises from 140g/day in 2023 to 161 g/day by 2032. This average consumption falls comfortably within WHO guidelines for countries with average consumption of >75g and <150g and positive impact of fortification can be reasonably expected. The table below is based on BCA parameters for growth of both national population and national flour consumption and includes the assumption that 85% of the flour supply is consumed by 41% to 49% of the population with intake sufficient to be considered covered by fortified flour.

Estimated Average Daily Flour Consumption Among Covered Population					
	Domestic Flour Consumption	Supply to 85% Covered Consumers	Covered Population	Average Flour Consumption In Covered Population	
	MT/Y	MT/Y	# 000	kg/year	g/day
2023	7,136,247	6,083,500	115,855	51.0	140
2024	7,518,447	6,409,317	119,155	52.3	143
2025	7,848,859	6,690,986	122,572	53.0	145
2026	8,195,748	6,986,702	126,109	53.8	147
2027	8,559,986	7,297,207	129,772	54.6	150
2028	8,942,464	7,623,262	133,563	55.4	152
2029	9,344,156	7,965,695	137,489	56.2	154
2030	9,766,088	8,325,383	141,554	57.1	156
2031	10,209,382	8,703,282	145,765	57.9	159
2032	10,675,192	9,100,375	150,124	58.8	161

Based on average daily consumption shown 140–161 g/day for the 10-year period, the calculations below for average daily protection indicate significant average levels of DRI delivered to covered consumers including: 39%–45% of DRI for iron, 51%–60% of DRI for zinc and 70%–81% of DRI for folic acid.

	Fe Dose	Protection	Zinc Dose	Protection	Folic Acid 90%	Protection
	FE mg/day	% DRI 18mg	mg/day	DRI 8 mg/day	FA Dose	DRI 400 ug/day
2023	7.0	38.8%	4.19	52.4%	279.58	70%
2024	7.2	39.8%	4.30	53.7%	286.34	72%
2025	7.3	40.4%	4.36	54.5%	290.54	73%
2026	7.4	40.9%	4.42	55.3%	294.81	74%
2027	7.5	41.6%	4.49	56.1%	299.17	75%
2028	7.6	42.2%	4.55	56.9%	303.61	76%
2029	7.7	42.8%	4.62	57.8%	308.13	77%

2030	7.8	43.4%	4.69	58.6%	312.74	78%
2031	7.9	44.1%	4.76	59.5%	317.43	79%
2032	8.1	44.8%	4.83	60.4%	322.23	81%

ANNEX XIII: COMPARING AND RECONCILING BCA DATA AND ASSUMPTIONS TOTAL DIET STUDY 2014[cxix]

In the flour fortification benefit-cost methodology, the level of benefit from added micronutrient intake is determined by the grams per day of individual flour intake. On the other hand, the cost is determined by the millions of metric tons fortified by the milling industry. In this assessment, both these parameters are based on the same key sources:

- Cost of fortification is based on commercial fortificant prices reported by millers along with the total volume of national flour milling as reported by APTINDO, the national flour industry organization (adjusted for imports and exports).
- Average per capita consumption can be calculated simply by distributing the millions of tons annually reported by APTINDO among the national population as projected by the World Bank. However, most Indonesian consumers do not regularly consume flour products and a national average figure seriously underestimates actual intake among actual consumers.
- Estimates for actual levels of individual daily fortified flour intake are derived by applying the consumer segmentation developed by RISKESDAS 2013 (along with some assumptions).

This methodology is based on industry reports, not food consumption surveys, consumer recall or household inspections. Reporting from an organized, modern and sophisticated milling industry as is the case in Indonesia might be considered more reliable than individual consumer recall on which surveys are based. Perhaps more important, leaving aside questions of which approach might be more reliable, the BCA approach of deriving individual intake from national production statistics links both cost of supply from industry and the benefits of demand from consumer into a single, consistent equation. It keeps the BCA honest because changes in the level of projected benefit are linked to the cost of fortification. Still, the BCA analysis via the RISKESDAS consumer segmentation includes a number of assumptions and begs the question: are BCA parameters consistent with traditional national consumption surveys?

Drawing on a sample of 162,044 individuals, the *Individual Food Consumption Survey: Total Diet Study of 2014 (TDS)*, which was published by the Ministry of Health's Health Research and Development Agency, provides the only comprehensive national survey of individual consumption wheat flour consumption. This annex compares BCA and TDS results for national coverage and total national supply and individual consumption. The following analysis is mainly based on two key tables in TDS: "Average consumption of cereals and processed products per person per day by age group (Table 3.2.1)" and "Proportion of population consuming cereals and their processed produce by age group (Table 3.2.1)."

Coverage

TDS Table 3.2.2 shows proportion of population consuming seven forms of cereals and cereal products. The table reports that wheat is consumed by 30.2% of all Indonesians, processed wheat products by 19.5% and noodles by 23%. The distinction amongst these categories is unclear except that all would be fortified. These are not unique segments that can be summed to arrive at estimate for coverage of flour fortification.

Projected Coverage of Fortified Flour Based on TDS Consumer Segments		
	Assumed Unique Consumers	All Ages
Wheat	100%	30.2%
Processed Wheat	20%	19.5%
Noodles	20%	23.4%
Processed Wheat:		30%
Wheat		4%
Noodles		5%
Total Consuming Flour		38.8%

A significant proportion of Indonesians may well consume more than one of these three wheat products, and therefore these figures cannot simply be summed to 73% coverage. In order to project a single parameter for the percentage of the population consuming fortified flour, the BCA assumes the following:

- The largest segment of consumption, 30.2% consuming processed wheat, represents the minimum percent consuming wheat flour products. TDS 2014 does not define to what extent the other two categories represent unique consumers and therefore additional coverage.
- For the sake of making a conservative estimate, the BCA assumes 20% of the consumers in wheat and noodles categories represent coverage added to the minimum defined by the processed wheat category—consumers who are not included in the 30.2%.
- As shown in the attached table, BCA adjusts the categories for the assumed unique consumers and sums the 3 categories to arrive at a coverage estimate of 38.8%. Adding 9 percentage points to the minimum defined by the wheat category seems conservative.

Adjusting Coverage 2013-2023 @ 0.92%/year			
2013[25]	38.8%	2019	41.0%
2014	39.1%	2020	41.3%
2015	39.5%	2021	41.7%
2016	39.9%	2022	42.1%
2017	40.2%	2023	**42.5%**
2018	40.6%	2023 in BCA	**41.1%**
		Difference	96.8%

In Annex XI, the BCA projects annual increased coverage from 41.1% in 2023 to 49.36% in 2032—an average annual increase of 0.92%. Using the same parameter for average annual increase in coverage, 38.8% for 2013 is adjusted to 42.5% for 2023, within about 3% of the coverage figure derived from APTINDO reporting.

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[25] This 38.8% coverage is based on survey data gathered in 2013.

National Supply

Comparing APTINDO Report for National Milling for 2013 with Implied National Consumption from TDS 2014

Average Per Capita Consumption TDS 2013	51.6 g/day or 18.83 kg/y
Population 2013 WB	256,229,761[cxx]
Implied MT Milling	4,825,831
APTINDO Reporting 2013 Used in BCA	5,089,000
% Difference	105%

TDS found national average consumption of wheat flour products at 51.6 grams per capita[cxxi]. Based on Indonesia's 2014 population of 256 million, this suggests national flour supply of 4.8 million metric tons for the year, compared to 5.09 million metric tons from APTINDO reporting used in the BCA. The TDS 2014 findings for both national supplies are within 5% of supply reported by APTINDO.

Potential Impact Among Children

For a number of reasons—including lack of granularity in efficacy evidence—the BCA makes no distinction among risk groups when developing parameters for efficacy and effectiveness of flour fortification. However, because of young children's lower food consumption and higher nutritional requirements (relative to weight and gastric capacity) the issue arises: will flour fortification supply sufficient added nutrition protection for this key vulnerable group? The TDS provides flour consumption data segmented by age group and provides some of the necessary granularity to assess this question.

Flour Consumption Among Children <12 Years of Age from Table 3.2.1, TDS 2014

Age Group/ Wheat Product Segment	Wheat g/day	Processed Wheat Flour g/day	Noodles g/day	Total Flour Consumption g/day
0-59 months	5.7	15.2	19.9	40.8
5-12 years	9.2	6.9	50.4	66.5

TDS Table 3.2.1 indicates total consumption of wheat, processed wheat flour and noodle averaged 40.8 grams per day for children aged 0–59 months and 66.5 grams per day for older children between 5–12 years. The addition of 50 mg/kg iron to this indicated average daily consumption provides an added ~2 mg/day iron for 0–59-month-old children and an added 3.3 mg/day iron for a 5–12-year-old. This represents significant added iron nutrition protection, about one-quarter of DRI for children under five and about one-third DRI for 5-12 years[26]. Zinc fortification at 30 mg/kg offers an added 1.2mg/day for children under five and 2mg/day for the older children, roughly the same magnitude of additional nutrition protection. However, given the large proportion not consuming any flour, this average protection is an underestimate.

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[26] Age groups used by Institute of Medicine in developing age specific DRI do not match age segments surveyed in TDS. The table approximately compensate for this age mismatch.

Nutrition Protection Provided by Fortified Flour Intake at Average Consumption Reported by TDS 2014			
Iron	**g/day**	**mg/day**	**DRI 8mg/10mg**
0-59 months	40.8	2.0	26%
5-12 years	66.5	3.3	37%
Zinc			**DRI 4mg/7mg**
0-59 months		1.2	31%
5-12 years		2.0	29%

TDS Table 3.2.2 reports proportion of children consuming three forms of flour: wheat, processed wheat and noodles, ranging from 21.3%–39.4% for the younger cohort and 31.4%–37.6% for the older children. As noted earlier, calculating coverage is complicated by the fact that TDS does not define to what extent the three reported categories of flour consumption are unique versus overlapping. The analysis applied to average national consumer above is applied specifically to children in the table below, suggesting 48% coverage of 0–59-month-olds and 51% coverage among 5–12-year-olds.

Assumptions and Calculations for Total % Children Consuming Flour based on TDS	**% Assumed Unique Consumers**	**% Consuming by Age Segment**	
		0-59 months	**5-12 years**
Processed Wheat: (Minimum)	100%	39.4%	37.6%
Wheat	20%	22%	31.40%
Noodles	20%	21%	36.60%
Processed Wheat: (Minimum)		39%	38%
Wheat		4%	6%
Noodles		4%	7%
Estimate Total Consuming Flour Products		48%	51%

Using the coverage estimates above, the average daily flour consumption for children from TDS Table 3.2.1 can be adjusted to reflect the distribution of actual flour consumption. As shown in the table below, with about half the population projected not covered by fortified flour, the average.

Age Group	Iron DRI	Age Group Total Diet Study	Adjusted Iron Requirements
1-3 years	7 mg/day	0-5 year	8 mg/day
4-8 years	10 mg/ day	5-12 year	10mg/day
9-13 years	8 mg/day		
Age Group	**Zinc DRI**	**Age Group Total Diet Study**	**Adjusted Zinc Requirements**
1-3 years	3 mg/day	0-5 year	4 mg/day
4-8 years	5 mg/day	5-12 year	7 mg/day
9-13 years	8 mg/day		

protection figures based on average consumption adjust upwards by about 100%, with fortified flour offering children half to two thirds of DRI. While methodologies used in the BCA (based on RISKESDAS and APTINDO) and TDS may not by totally parallel, the brief and general analysis suggests significant nutrition protection offered by flour fortification to children <5 years of age and older.

Nutrition Protection Provided by Fortified Flour Intake at Average Consumption Corrected for Proportion Consuming Flour Products, Reported by TDS 2014			
Iron	g/day	mg/day	DRI 8mg/10mg
0-59 months	84.8	4.2	53%
5-12 years	129.9	6.5	65%
Zinc			DRI 4mg/7mg
0-59 months		2.5	64%
5-12 years		3.9	56%

ANNEX XIV: PROTECTION AND EFFICACIOUSNESS OF FLOUR FORTIFICATION

ANAEMIA AND IRON DEFICIENCY

WHO Recommendation

WHO Recommendations for Flour Fortification suggest that a well implemented national program following WHO technical guidelines should "decrease the prevalence of iron deficiency in the target at-risk populations to levels reported in industrialized countries" or <5% iron-deficiency anaemia. For Indonesia, this suggests declines in prevalence of anaemia in the order of 80% from current estimated levels of anaemia among consumers of fortified flour[cxxii]. The WHO projection may be over-ambitious for Indonesia where flour is a growing but still secondary staple and wide segments of the population do not consume a significant proportion of calories and carbohydrates from flour.

The Reviews and Meta-Analysis

A large number of studies, trials and program evaluations have documented the impact of flour fortification with iron. Many have been included in comprehensive and robust reviews and meta-analysis published over the past decade.

- Drawing on 60 trials, a review published in the *American Journal of Clinical Nutrition* showed that iron fortification of a variety of foods resulted in 41% population-wide reduction in the risks of anaemia and a 52% reduction in iron deficiency[cxxiii].

- A Cochrane review of randomized control trials comparing consumption of fortified wheat flour to non-fortified wheat concludes fortification "may reduce anaemia by 27%"[cxxiv].

- A compilation of 12 field trials and program evaluations from 10 countries by the Food Fortification Initiative of Emory University Rollins School of Public Health indicated an average anaemia reduction of 35–37%[cxxv].

The conclusions point to a range of potential reductions in prevalence from 27%–41% for anaemia and 21%–52% for IDA. These synthetic reviews mask a range of factors influencing the impact of fortification on anaemia including: prevalence of non-nutritional causes of anaemia; intakes of iron absorption inhibitors; various outcome indicators (anaemia, iron deficiency and IDA) which are often not clearly distinguished; fortification across a range of addition levels and iron compounds; sample sizes ranging from a few dozen to regional and national evaluations; and duration of interventions from a few weeks to several years. As a consequence, the predominantly positive findings mask a wide range of results, including negative outcomes. Consequently, the error bands are wide and the authors usually concede that the strength of the evidence is less than optimal.

Review of Two Key National Program Evaluations

The metanalysis does include two rigorously implemented and fully national evaluations of fortification programs based on WHO recommended levels and iron compounds. These two programs showed results significantly higher than the pooled meta-analysis.

- The evaluation of the Costa Rica nation fortification program published by Martorell et al. in the *American Journal of Clinical Nutrition*, found 45% decrease in prevalence of anaemia among adult woman of reproductive age and 79% decrease among children[cxxvi].
- The evaluation of the Fiji national flour fortification program by the Fiji Ministry of Health (MOH) Food & Nutrition Institute (supported by WHO and UNICEF) found a 32% decrease in prevalence of anaemia and 48% decrease in iron deficiency among women of childbearing age[cxxvii].

These national evaluations, which measure the impact of regular and small doses of added vitamins and minerals as recommended by WHO and over a long-term multi-year frame, may provide the best picture of what a well-designed fortification program might achieve.

Review Studies by Iron Compound

A 2018 meta-analysis by Sadighi et al. including 94 fortification studies and trials found iron-fortified flour led to significant increases of mean hemoglobin, mean ferritin and parallel decreases in prevalence of anaemia and IDA. Sadighi et al. provides the only review that segments results by iron compound, enabling a comparison of iron powders like electrolytic reduced iron (the highest quality iron powder) and hydrogen reduced iron (widely used under Indonesia's original fortification standards). Results for the iron powders are marginal to negative. The results clearly indicate the performance of ferrous fumarate is consistently superior to the iron powders—by several orders of magnitude. Sadighi et al. suggest ferrous fumarate may achieve 13%–14% reduction in prevalence of anaemia and 17%–22% reduction for ID and IDA[27]. A limitation of the Sadighi analysis is that no information for iron dose was provided.

	Studies	Electrolytic FE	Hydrogen Reduced FE	Ferrous Fumarate
Before/After Trials	#	Prevalence Point Estimate		
Anaemia Prevalence	40	-.048	-.001	-.132
ID Prevalence	30	+.005	-.085	-.114
Controlled Trials				
Anaemia Prevalence	19	-.03	-.022	-138
ID Prevalence	14	+.033	+.020	-.223
IDA Prevalence	6	-.138		-.165

Conclusions and Parameters used in BCA Modeling

The literature suggests a range of possible outcomes.

- WHO recommendations imply possibly 80% reduction in prevalence for delivery of 7.1mg/day added iron.
- The best-done national evaluations from Fiji and Costa Rica suggest 32%–79% decrease.
- The four meta-analyses suggest reductions in the range of 27%–52%
- Studies specifically with ferrous fumarate, mainly in shorter term studies, suggest anaemia prevalence reduced 13%–14%, ID prevalence reduced 11%–22% and IDA prevalence reduced 11%–27%.

Effectiveness Parameters	
From Sadighi et al.: Range of Reduction in Prevalence for IDA & ID Reduction with Ferrous	
Average Low End of Range	11%
Average High End of Range	24.5%
Average of Averages	17.8%
WHO Recommendations/Hurrell	
Fe dose for moderate efficacy:	7.1 mg/day

The projections for efficacy of fortification will be based on two of the data points above. First, averaging the range of lower prevalence of IDA and iron deficiency found by Sadighi et al. for studies with ferrous salts. The average of averages suggests a potential decrease of 17.8%. However, Sadighi provides no data on the dose of iron provided by fortified flour. Therefore, the BCA takes the 7.1. mg/day iron necessary for efficacy described by Hurrel et al. and expert study group developing the WHO Recommendations for Flour Fortification as a notional threshold when the 17.8% decrease in prevalence is achieved. For the BCA analysis, the

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[27] Discounting the 11% decrease in the before/after trials that counterintuitively find higher effectiveness with anaemia than the more specific indicators of iron status.

proportion of the 7.1mg/day achieved via flour fortification will define the proportion of the 17.8% prevalence reduction achieved.

The efficacy algorithm developed above is applied in the table below. As consumption increases over the 10-year period from 140–161 grams a day, the average added intake of iron nutrition to covered Indonesians rises from 7mg/day to 7.9mg/day, which is 98% to 113% of the 7.1 mg/day dose threshold drawn from Sadighi et al. The model projects annual decreases in prevalence of IDA among consumers rising from 17% in the initial years to 20% in 2032.

Efficacy Projections: Iron			
	Fe Dose	Projected Decrease Prevalence Among Hi Consumers	
	FE mg/day	% 7.1mg	% of 17.8%
2023	7.0	98.4%	17.5%
2024	7.2	100.8%	17.9%
2025	7.3	102.3%	18.2%
2026	7.4	103.8%	18.4%
2027	7.5	105.3%	18.7%
2028	7.6	106.9%	19.0%
2029	7.7	108.5%	19.3%
2030	7.8	110.1%	19.5%
2031	7.9	111.8%	19.8%
2032	8.1	113.5%	20.1%

Zinc Fortification

At the time of the original BCA in 2010, zinc was not a commonly used fortificant and evidence of efficacy for zinc fortification was scarce. By 2016 a Cochrane Review of zinc fortification included eight trials, lasting between one and nine months and including 709 participants from seven countries. Although characterizing the strength of evidence as low, the authors concluded that foods “fortified with zinc increased the serum or plasma zinc levels in comparison to foods without added zinc”[cxxviii]. The authors made no finding on the impact of fortification on prevalence of zinc deficiency and drew a curious conclusion that “If zinc is added to food in combination with other micronutrients, it may make little or no difference to the serum zinc status…Fortification of foods with zinc may improve the serum zinc status of populations if zinc is the only micronutrient used for fortification”[cxxix].

Noting that the Cochrane review may have “excluded a large body of literature relevant to the “real world” context of large-scale food fortification,” a 2021 review by Tsang et al. synthesizes data from 59 studies which assessed biochemical and health outcomes after the provision of a zinc-fortified food or beverage, 33 specifically cereal grains[cxxx]. These studies included a wide range in zinc doses, from 0.7 mg/day to 54.4 mg/day, with a median of 4.37 mg/day provided by fortification. Contrary to the Cochrane review, the 2021 analysis found that “food fortification with zinc, given alone or with other micronutrients, increased plasma/serum zinc concentrations, with a corresponding 24% and 55% decrease in prevalence of zinc deficiency in efficacy and effectiveness studies, respectively”[cxxxi].

Conclusions and Parameters used in BCA Modeling

The BCA modeling is based on the meta-analysis by Tsang et al. which found prevalence reductions with an average zinc dose of 4.37 mg/day. Given the curious finding of superior efficacy in effectiveness versus efficacy trial, the BCA modeling will adopt an average of 39.5% for reduction in prevalence achieved an average 4.37mg/day added zinc. For the BCA analysis, the proportion of the 4.32 mg/day achieved via flour fortification will define the proportion of the 39.5% prevalence reduction achieved.

The efficacy algorithm developed above is applied in the table below. As consumption increases over the 10-year period from 140–161 grams a day, average added intake of zinc nutrition delivered to covered Indonesians rises from 4.2mg/day to 4.8mg/day, representing 96% to 111% of the average 4.37% threshold dose drawn from Sadighi et al. The model projects annual decreases in prevalence of IDA among consumers rising from 17% in the initial years to 20% in 2032. The model projects a decrease in prevalence of zinc deficiency among consumers of fortified flour rising from 38% in the first years of fortification to 34% in Year 10.

Efficacy Projections: Zinc			
	Zinc Dose	Projected Decrease Prevalence Among High Consumers	
	mg/day	% 4.37 mg/day	% of 39.5%
2022	4.19	96.0%	37.9%
2023	4.30	98.3%	38.8%
2024	4.36	99.7%	39.4%
2025	4.42	101.2%	40.0%
2026	4.49	102.7%	40.6%
2027	4.55	104.2%	41.2%
2028	4.62	105.8%	41.8%
2029	4.69	107.3%	42.4%
2030	4.76	109.0%	43.0%
2031	4.83	110.6%	43.7%

Folate Deficiency (FD) Incidence of Neural Tube Defects (NTD)

A significant reduction in NTD including spina bifida, anencephaly and other birth defects has been consistently demonstrated via flour fortification with folic acid. Twenty longitudinal studies from 12 different countries showed an average of 41% reduction in the incidence of NTD, with individual studies finding improvements ranging from 19%–60%. No information for average dose was identified, however we presume that average added folic acid via fortification is less than 100% of DRI.

NTD Reduction Pre- and Post-Fortification: 20 Studies in 12 Countries

Country	Study	Pre-Fortification NTD/10,000	Post-Fortification NTD/10,000	Difference from Pre- to Post-Fortification	% Reduction in NTD Prevalence
Argentina	Calvo 2008	321	176	145	45%
Brazil	Silva 2009	7.2	5.1	2.1	29%
Chile	Castilla 2003	24.2	14	10.2	42%
Chile	Cortes 2012	17.1	8.6	8.5	50%
Costa Rica	Tacsan 2004	9.7	6.3	3.4	35%
Costa Rica	Arguello 2011	11.97	7.32	4.65	39%
Peru	Sanabria 2013	13.6	8.7	4.9	36%
Canada	De Wals 2007	15.8	8.6	7.2	46%
Canada (Alberta)	Botto 2006	9.65	6.81	2.84	29%
Canada (Newfoundland)	Liu 2004	43.6	9.6	34	78%
Canada (Nova Scotia)	Persad 2002	25.8	11.7	14.1	55%
Canada (Ontario)	Ray 2002	11.3	5.8	5.5	49%
Canada (Ontario)	Gucciardi 2002	10.3	5.3	5	49%
Canada (Quebec)	De Wals 2003	18.9	12.8	6.1	32%
Iran	Abdollahi 2011	31.6	21.9	9.7	31%
Jordan	Amarin 2010	18.5	10.7	7.8	42%
Saudi Arabia	Safdar 2007	19	7.6	11.4	60%
South Africa	Sayed 2008	14.1	9.8	4.3	30%
USA	Honein 2001	3.78	3.05	0.73	19%
USA (Atlanta)	Botto 2006	11.53	7.5	4.03	35%
USA (Texas)	Botto 2006	9.13	7.07	2.06	23%
Average Reduction					**41%**

Conclusions and Parameters used in BCA Modeling

With no dosing data available, the BCA makes a notional assumption that delivery of a full two-thirds of added DRI for folic acid will achieve a 41% reduction in NTD.

The efficacy algorithm developed above is applied in the table below. As consumption increases over the 10-year period from 140–161 grams a day, average added intake of folic acid delivered to covered Indonesians rises from 280ug/day to 322ug/day. This represents 70%–81% of DRI and 105% to 121% of the 267ug/day threshold notionally established by the BCA model. This suggests that among women consuming fortified flour, incidence of NTD will drop 43% in the initial years rising to nearly 50% within 10 years.

Efficacy Projections: Folic Acid			
	Folic Acid Dose	Projected Decrease Prevalence Among High Consumers	
		% 266.7ug/day Consumption	% of 41% Reduction
2022	279.58	105%	43.0%
2023	286.34	107%	44.0%
2024	290.54	109%	44.7%
2025	294.81	111%	45.3%
2026	299.17	112%	46.0%
2027	303.61	114%	46.7%
2028	308.13	116%	47.4%
2029	312.74	117%	48.1%
2030	317.43	119%	48.8%
2031	322.23	121%	49.5%

ANNEX XV: STATUS QUO PREVALENCE CASES AND PROJECTED LOWERED CASELOAD VIA FORTIFICATION

Summary 10-Year Cases ZD and IDA Prevented			
Total Cases IDA	405,688,506		
Prevented	34,540,082	8.51%	
Total Cases ZD	57,455,750		
Prevented	10,587,924	18.43%	
Total MND Cases	463,144,256		
Total IDA & ZD Cases Prevented	45,128,006	9.7%	
Total Cases Assuming 1 Case ID for Every Case IDA	79,668,088		

Cost Framings			
10 Year Program Cost	$181,117,951		
Cost/Case Prevented (Including ID)	$2.27		
Cost/Case Prevented (No ID)	$4.01		
Loss/Case			
Total Annual Loss	Loss	Cases	Loss/Case
IDA Adults: Total Average Economic Loss/Case	$20,774	181,428,004	$114.50
IDA <15ys: Total Average Economic Loss/Case	$2,912.38	138,381,787	$21.05
ZD <5 years.: Total Average Economic Loss/Case	$2,748.11	85,878,715	$32.00
Average Loss all ZD and IDA Cases		405,688,506	$65.16

Calculations for Projected Lowered Caseload 2023-2032										
	2023	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**
Effectiveness										
Iron	7.2%	7.5%	7.7%	8.0%	8.3%	8.6%	8.9%	9.2%	9.6%	9.9%
Zinc	15.6%	16.3%	16.8%	17.4%	18.0%	18.6%	19.3%	20.0%	20.8%	21.6%
Prevented Cases: IDA										
Population Aged 15-64, Female (in thousand)	94,572	95,349	96,171	96,948	97,769	98,602	99,388	100,091	100,722	101,292
IDA Cases/Y @ 18.5%	17,492,037	17,635,751	17,787,788	17,931,502	18,083,354	18,237,426	18,382,804	18,512,831	18,629,541	18,734,968
Prevented Cases	1,256,430	1,321,618	1,378,481	1,437,763	1,500,945	1,567,764	1,637,476	1,709,594	1,784,402	1,862,229
Population Aged 15-64, Male (in thousand)	96,414	97,269	98,176	99,007	99,889	100,790	101,652	102,439	103,110	103,730
IDA Cases/Y @13.8%	13,308,989	13,427,013	13,552,215	13,666,926	13,788,678	13,913,052	14,032,042	14,140,680	14,233,304	14,318,889
Prevented Cases: IDA	955,967	1,006,216	1,050,241	1,095,826	1,144,480	1,196,023	1,249,925	1,305,842	1,363,315	1,423,277
Population <15y	71,010,000	71,047,000	70,894,000	70,763,000	70,459,000	70,035,000	69,605,000	69,231,000	69,231,000	69,231,000
IDA Cases/Y @ 12.2%	8,693,080	8,697,609	8,678,879	8,662,842	8,625,626	8,573,720	8,521,079	8,475,294	8,475,294	8,475,294
Prevented Cases	624,413	651,796	672,578	694,594	715,939	737,032	759,028	782,663	811,793	842,432
Status Quo: Projected Cases	39,494,105	39,760,373	40,018,882	40,261,270	40,497,658	40,724,197	40,935,925	41,128,805	41,338,139	41,529,151
Estimated Prevented Cases	2,836,810	2,979,630	3,101,300	3,228,183	3,361,364	3,500,820	3,646,428	3,798,099	3,959,510	4,127,938

Calculations for Projected Lowered Caseload 2023-2032										
	2023	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**
Prevented Cases: ZD										
Population <5 y	23,048,000	23,079,000	23,139,000	23,110,000	23,156,000	23,105,000	22,972,000	22,829,000	22,723,000	22,662,000
IDA Cases/Y @ 25%	5,762,000	5,769,750	5,784,750	5,777,500	5,789,000	5,776,250	5,743,000	5,707,250	5,680,750	5,665,500
Prevented Cases	897,838	937,985	972,502	1,004,934	1,042,356	1,077,184	1,109,759	1,143,336	1,180,383	1,221,646

ANNEX XVI: EFFECTIVENESS PARAMETERS

Flour Fortification Effectiveness: Coverage X Efficacy = Effectiveness										
	2023	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**
Coverage	41.11%	41.9%	42.7%	43.5%	44.4%	45.3%	46.3%	47.2%	48.3%	49.4%
Efficacy Parameters										
Iron	17.5%	17.9%	18.2%	18.4%	18.7%	19.0%	19.3%	19.5%	19.8%	20.1%
Zinc	37.9%	39%	39%	40%	41%	41.2%	42%	42%	43%	44%
Folic Acid	43.0%	44.0%	44.7%	45.3%	46.0%	46.7%	47.4%	48.1%	48.8%	49.5%
Effectiveness: Lowered Prevalence										
Iron	7.2%	7.5%	7.7%	8.0%	8.3%	8.6%	8.9%	9.2%	9.6%	9.9%
Zinc	15.6%	16.3%	16.8%	17.4%	18.0%	18.6%	19.3%	20.0%	20.8%	21.6%
Folic Acid	17.7%	18.4%	19.1%	19.7%	20.4%	21.1%	21.9%	22.7%	23.6%	24.4%

Based on coverage and effectiveness parameters developed earlier, the table above shows 10-year projections for reduction in prevalence of IDA, ZD and FD. The effectiveness parameters are applied to the 10-year loss analysis for each of the indicator

Total Estimated Losses and Projected Loss Prevention/Benefit via Prevalence Reductions Achieved from Flour Fortification over 10 Years

	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	Total
Iron Deficiency Anaemia	$ M	$ M	$ M	$ M	$ M	$ M	$ M	$ M	$ M	$ M	$ M
Mortality: <1Y											
Losses	$130.8	$129.4	$128.0	$127.5	$127.0	$126.4	$125.8	$125.2	$124.5	$123.8	$1,268.3
Prevented Losses	$9.4	$9.7	$9.9	$10.2	$10.5	$10.9	$11.2	$11.6	$11.9	$12.3	$107.6
Productivity Deficit Child <15Y											
Losses	$456.1	$457.3	$456.7	$457.6	$456.6	$453.9	$451.1	$449.0	$447.8	$446.4	$4,532.4
Prevented Losses	$32.8	$34.3	$35.4	$36.7	$37.9	$39.0	$40.2	$41.5	$42.9	$44.4	$384.9
IDA Labour Deficits Adults											
Losses	$2,001.1	$2,018.0	$2,035.9	$2,052.7	$2,070.4	$2,088.4	$2,105.5	$2,121.0	$2,134.5	$2,146.9	$20,774.2
Prevented Losses	$143.7	$151.2	$157.8	$164.6	$171.8	$179.5	$187.5	$195.9	$204.5	$213.4	$1,769.9
Zinc Deficiency											
Mortality Child <5Y											
Losses	$65.6	$65.8	$65.7	$65.9	$65.7	$65.3	$64.9	$64.6	$64.5	$64.3	$652.4
Prevented Losses	$10.2	$10.7	$11.1	$11.5	$11.8	$12.2	$12.5	$12.9	$13.4	$13.9	$120.2
Morbidity Health Costs											
Losses	$210.9	$211.4	$211.2	$211.6	$211.1	$209.9	$208.6	$207.6	$207.0	$206.4	$2,095.7
Prevented Losses	$32.9	$34.4	$35.5	$36.8	$38.0	$39.1	$40.3	$41.6	$43.0	$44.5	$386.1

Total Estimated Losses and Projected Loss Prevention/Benefit via Prevalence Reductions Achieved from Flour Fortification over 10 Years

	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	Total
Folate Deficiency											
NTD Mortality											
Losses	$77.6	$76.8	$75.9	$75.7	$75.4	$75.0	$74.7	$74.3	$73.8	$73.4	$752.5
Prevented Losses	$33.3	$33.8	$33.9	$34.3	$34.7	$35.0	$35.4	$35.7	$36.0	$36.4	$348.5
NTD Health Welfare Costs											
Losses	$3.7	$3.6	$3.6	$3.6	$3.6	$3.5	$3.5	$3.5	$3.5	$3.5	$35.5
Prevented Losses	$0.6	$0.7	$0.7	$0.7	$0.7	$0.7	$0.8	$0.8	$0.8	$0.8	$7.4
Productivity Loss											
Losses	$7.4	$7.3	$7.3	$7.2	$7.2	$7.2	$7.1	$7.1	$7.1	$7.0	$72.0
Prevented Losses	$1.3	$1.4	$1.4	$1.4	$1.5	$1.5	$1.6	$1.6	$1.7	$1.7	$15.0
Losses	**$2,953.1**	**$2,969.6**	**$2,984.3**	**$3,001.7**	**$3,016.9**	**$3,029.7**	**$3,041.2**	**$3,052.2**	**$3,062.6**	**$3,071.7**	**$30,183.0**
Prevented Losses	**$264.3**	**$276.1**	**$285.6**	**$296.2**	**$307.0**	**$318.0**	**$329.5**	**$341.5**	**$354.2**	**$367.4**	**$3,139.8**

Based on average consumption figures for the 47%–55% of Indonesians who consume sufficient flour-based products to achieve protection, the calculations in the table above suggest fortification can deliver significant levels of nutrition protection. Using DRI standards developed for woman of reproductive age, fortification is projected to deliver:

- 31% of DRI for iron in 2022 rising to 39% in 10 years
- 42% of DRI for zinc in 2022 rising to 53% in 10 years
- 50% of DRI for folic acid rising to 63% in 10 years

Parameters for Iron Effectiveness:

In developing WHO recommendations for flour fortification, the study group led by Richard Hurrel set a dose of 7.1 mg/day added iron from fortification as “efficacious.” The projected added iron intake for an Indonesian consumer rises from 5.7mg/day to 7.0mg/day threshold in 2030. The minor shortfall is associated with the SNI-mandated 50ppm addition level for ferrous fumarate, slightly less than the WHO recommended 60ppm. Nevertheless, the dose represents a significant level of DRI. Based on the parameters reviewed in the literature (Annex VII), the BCA effectiveness parameters for those in the high consumption group are 12% per year, rising in equal increments to 33% in Year 10.

Parameters for Zinc Effectiveness:

The Tsang et al. meta-analysis finding that fortification with zinc achieves a 55% decrease in prevalence of zinc deficiency was based on 54 trials that delivered an average dose of 4.4mg/day additional zinc via fortified food. This threshold is barely achieved in Year 10 of the analysis, with average delivery of 4.31 mg/day added. Therefore, a 55% reduction may be overly optimistic. We propose to apply a 50% reduction by Year 10 as an effectiveness parameter for consumers in the high-volume segment. For the preceding nine years when flour fortification is delivering significant dose of DRI, but not above 4mg/day, we propose applying 25% reduction in Year 1 (when delivering 43% of DRI) rising in equal increments, along with higher levels of added zinc protection, to 50% in Year 10.

Parameters for Folic Acid Protection

Given the high levels of DRI delivered, beginning at 52% of DRI in Year 1, based on our literature and averaging results of multiple national programs, we apply a parameter of 41% reduction in the incidence of births with NTD.

	Iron Effectiveness Parameter	Zinc Effectiveness Parameter	Folic Acid Effectiveness Parameter
2022	12%	25%	41%
2023	14%	27.8%	41%
2024	17%	30.6%	41%
2025	19%	33.3%	41%
2026	21%	36.1%	41%
2027	24%	38.9%	41%
2028	26%	41.7%	41%
2029	28%	44.4%	41%
2030	31%	47.2%	41%
2031	33%	50.0%	41%

ANNEX XVII: ANNUAL VOLUME MILLING AND FLOUR FORTIFICATION COST

Annual Flour Milling (‘000 MT) 2011-2011 (Aptindo) Year on Year % Change with 10 Year Average 5.2% Annual Increase											
	2011	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
Milling ‘000MT	4,041	4,662	5,089	5,431	5,455	5,841	6,275	6,519	6,843	6,700	6,960
% Increase		13%	8%	6%	0%	7%	7%	4%	5%	-2%	4%

APTINDO reports average milling volume in Indonesia’s approximately 30 mills increased to nearly 7MMT in 2021 with average year-on-year increases of 5.2% over the past 10 years (this includes one year of no growth and a COVID-19 year of negative growth). Presuming the average for the past 10 years reflected the next 10 years, projections for milling volume for 2022–2032 are shown in the table below.

The total domestic milling is adjusted on the margins to reflect national flour consumption. In 2020–2021, about 350 thousand MT of domestic milling went to exports of wheat-based products[cxxxii]. The reported increase from 2020–2021 increase of 2.3% crispy savory products, wafers, instant noodles, and pasta is applied across a 10-year period and subtracted from the national milling total. On the other hand, USDA reports 73.3 MT imports of wheat flour and wheat-based products in 2021, an increase of 11% over the previous year[cxxxiii]. Assuming this growth rate is not sustained, we apply a notional figure of 5% year-on-year increase over the course of the 10-year period of the BCA analysis and add this to the supply over 10 years. This rough analysis indicates net domestic consumption of flour products will rise from a baseline of about 7.3 million MT in 2022 to 10.8 MT million over the 10-year period.

Cost Structure of Indonesia Milling Industry	
Raw Materials	83.71%
Manpower	3.09%
Gas/Electric	1.90%
Buildings/Machinery/Equipment	0.10%
Other	11.20%

Cost for the SNI-mandated premix including ferrous fumarate, the option that virtually all of the Indonesian milling industry applies, ranges from \$7–\$8/kg[28]. Taking a simple average \$7.50 cost at the specified dosage rate of 230ppm, this suggests a premix cost of \$1.73 per metric ton of fortified flour. Based on the current cost structure reported by Indonesian milling industry and BPS, raw materials input represents approximately 84% of total processing costs as indicated in the table below. Classifying premix as a raw material input to the milling process, this indicates an overall cost of \$2.05 per MT flour. This estimate may be a bit high (and therefore, conservative for the BCA) as estimates in many countries suggest premix represents >90% of fortification costs. Applying the incremental fortification cost of \$2.05 to all domestic consumption of flour products, whether domestically milled or imported, suggests fortification costs of about \$15 million in 2023 rising along with increasing consumption to \$22 million in 2032. While the cost to the national milling industry is slightly less, the BCA will assume all imported flour products are fortified as mandated.

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[28] FOB costs reported by APTINDO and confirmed by premix suppliers.

Cost of Fortifying 100% Domestic Milling or 100% Domestic Flour Product Consumption @ $2.05/MT					
	Total Domestic Milling	**Domestic Milled Fortified Flour**[29]	**Total Domestic Flour Consumption**	**Fortification Cost** **All Domestic Flour Consumption**[30]	**Fortification Cost Domestic Milling Only**
	000 MT Flour	000 MT Flour	000 MT Flour	@ $2.05/ MT $ 000	
2023	7,322	7,063	7,136	$14,655	$14,505
2024	7,703	7,442	7,518	$15,440	$15,282
2025	8,033	7,768	7,849	$16,118	$15,953
2026	8,378	8,111	8,196	$16,831	$16,657
2027	8,741	8,471	8,560	$17,579	$17,396
2028	9,122	8,849	8,942	$18,364	$18,173
2029	9,521	9,246	9,344	$19,189	$18,988
2030	9,941	9,663	9,766	$20,055	$19,844
2031	10,382	10,102	10,209	$20,966	$20,744
2032	10,845	10,562	10,675	$21,922	$21,690

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[29] Domestic milling minus projected exports as per 2021 MOT@350,000 MT plus 1%/y increase

[30] Domestic milling for national market plus imported flour products @ 73,000 MT plus 5%/y increase

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