A comparison of MNP delivery models and factors for consideration in future MNP delivery

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Abstract

Background: Tackling micronutrient deficiencies in low- income/resource countries has been challenging. In the late 1990s, point-of-use fortification using micronutrient powders (MNPs) emerged as a viable option for combating nutritional anemia and retinol deficiency. However, there remains a substantial divide amongst program implementers, researchers, suppliers, and experts as to which MNP delivery model is most effective, especially in relation to its sustainability, demand creation, coverage, and adherence.

Objective: The objective was to conduct an in-depth review of free and fee based MNP delivery models, assess programmatic experience, costs, cost effectiveness and sustainability and provide insights on future MNP delivery.

Materials and Methods: We conducted a comprehensive literature review and key informant interviews with experts on MNP research, delivery, program implementation, monitoring and evaluation. The search was completed using 43 terms related to micronutrient powders and 26 key informant interviews were completed.

Results and Discussion: Delivery models reviewed included free, fee based (full-cost and subsidized) and hybrid models linked to existing infant and young child feeding (IYCF) programs and distributed through different channels. Delivery channels ranged from community health workers (CHWs) to direct retail sales agents. Challenges in coverage, use and adherence were significant irrespective of type of model. All three metrics improved in instances where significant investment was made in the delivery channel for e.g., CHWs providing one-on-one IYCF counseling and MNP use. A recommendation that continually emerged from the literature review and key informant interviews is for MNP delivery stakeholders and implementers to consider a hybrid model of either a full or subsidized cost model coupled with a free distribution model. Such a hybrid model would need to be contextualized for local implementation and linked to rigorous social and behavior change communication (SBCC) and training of implementers for IYCF messaging and use of MNPs. Critical considerations included the need for continued donor investment for startup costs and ancillary costs such as advocacy and regulatory guidance support, as well as, ensuring appropriate time allocations and workloads for workers, particularly health workers, if used as a delivery channel.

Conclusion: A hybrid MNP delivery model was identified as a promising potential future option for ensuring that children with micronutrient deficiencies in low-income/resource countries have access to micronutrients in a consistent and sustainable manner.

Key words: Micronutrient powders, delivery, coverage, delivery models

Introduction

Globally, micronutrient deficiencies, in particular iron, vitamin A, and zinc deficiencies, still affect more than two billion people (De-Regil, Suchdev, Vist, Walleser, & Pena-Rosas, 2011). Based on 257 population-representative data sources from 107 countries worldwide, in 2011 an estimated 496 million (95% CI 409-595 million) non-pregnant women, 32 million (28-36 million) pregnant women, and 273 million (242-304 million) children had anemia (Stevens GA et al., 2013). Tackling micronutrient deficiencies in low-income/resource countries has been challenging. In the late 1990s, point-of-use fortification through the use of micronutrient powders (MNPs) emerged as a viable option for combating nutritional anemia and retinol deficiency (Salam, MacPhail, Das, & Bhutta, 2013; Zlotkin, Arthur, Antwi, & Yeung, 2001). A MNP is a single dose sachet of a multiple micronutrient formulation that is mixed into food at the household level (De-Regil et al., 2011). In 2016, MNPs were recommended by the World Health Organization (WHO) as a strategy to reduce iron deficiency anemia in infants and children aged 6-23 months and 2-12 years in settings where anemia is a public-health problem[1]. The recommended consumption is 90 sachets of MNPs containing iron, zinc, and vitamin A over a six-month period (WHO, 2011). In 2019, the WHO added MNPs that contain iron, zinc, and vitamin A to the Model List of Essential Medicines (WHO, 2019).

Over the past two decades, extensive efforts have been put into the advancement of MNP interventions. Furthermore, considerable investment, emphasis and effort has been placed on the implementation and scale-up of MNP intervention programs. Significant emphasis has been placed on advocacy (global, regional, and national) along with donor support to individual countries. The support for implementation and scale-up has been in tandem with a multitude of efficacy studies, as well as, studies and efforts on formulations, powder composition, manufacturing, packaging, and labeling as MNPs have been found to reduce anemia in infants and young children aged 6 to 23 months (De-Regil et al., 2011; Oliveira, Sampaio, Muniz, Cardoso, & Group, 2016; Zlotkin et al., 2001; Zlotkin et al., 2003). Despite this, the effectiveness and scale-up of delivery, coverage and the long-term sustainability are still critical issues that need to be evaluated (Pelletier & DePee, 2019; Reerink et al., 2017; Zlotkin et al., 2001; Zlotkin et al., 2003). The outreach and scale-up of MNPs is evident from UNICEF statistics. In 2011, 36 countries had implemented MNP programs (national, sub-national, pilot, or emergency). As of 2017, 54 countries (27 at a national level, 10 at a subnational level, 13 with pilot studies, and 11 with emergency interventions) have implemented MNP interventions (UNICEF, 2017b).

One of the primary values of MNPs is that with an effective delivery system, these small sachets have the potential to reduce multiple micronutrient deficiencies. MNP delivery has occurred mostly via infant and young child feeding programs. MNPs have been delivered for free using existing Ministry of Health platforms (e.g., Nigeria) (Korenromp et al., 2016), subsidized using existing health services of Ministries of Health or NGOs as platforms (e.g., Vietnam, Bangladesh),(Afsana, Haque, Sobhan, & Shahin, 2014;

[1]Populations where the prevalence of anemia in children under two or under five years of age is 20% or higher

Nguyen, Poonawala, Leyvraz, Berger, Schofield, Nga, Van, Hoa do, et al., 2016), and as full-cost MNPs using commercial platforms (e.g., pilot conducted in Indonesia).

Critical for the success of an MNP intervention is a system that optimizes accessibility through the type of delivery model, platform and channel used coupled with social and behavioral change communication (SBCC) and sufficient training of implementers to support appropriate use and intake by the target population (Reerink et al., 2017). In addition to regulatory standards, policy support, and infrastructure, the delivery system impacts the availability, distribution, appropriate use, adherence, and coverage of MNPs, which in turn affect individual-level utilization and absorption. Specifically, with respect to the delivery model (e.g., free or fee-based), there remains a substantial divide amongst program implementers, researchers, suppliers, and experts as to which model is the most effective, especially in relation to its sustainability, demand creation, coverage, and adherence (Afsana et al., 2014; Nyhus Dhillon et al., 2017; Reerink et al., 2017; A. Tumilowicz, Schnefke, Neufeld, & Pelto, 2017; Vossenaar et al., 2017). Decreasing resources from donors along with barriers associated with distribution, adherence and coverage has led to a concern of the viability of free delivery models whereas fee-based models pose an opportunity to address the challenges of declining resources. Fee-based models have potential advantages of permitting sustainability in part through reducing or eliminating public-sector expenditures, and of increasing use by enhancing the perceived value among potential consumers who might question the value of free or public-sector-provided MNPs. Conversely, a fee-based structure may exclude individuals and/or households who cannot afford the MNP, which is problematic as these individuals and/or households may be at the most risk for micronutrient deficiencies. Therefore, optimizing accessibility must also aim to prioritize access for the individuals who need MNPs the most.

The overall objective of this study was to conduct an in-depth review of MNP delivery models, assess programmatic experience, costs, cost effectiveness and sustainability and provide insights on the potential factors to consider in future MNP delivery. The study aimed to conduct an in-depth review of MNP delivery models worldwide, particularly models that are overlaid on existing programs and platforms (e.g., infant and young child feeding programs) and understand how different types of models affect coverage, appropriate use and adherence, and demand for MNPs and identify factors for consideration in the design of future MNP delivery.

Materials and Methods

We used an approach that includes a comprehensive literature review coupled with key-informant interviews to assess stakeholders' perceptions and draw on their expertise. A theory-based organizing methodological framework was developed to guide the study, based, in part, on work undertaken by the Global Alliance for Improved Nutrition (GAIN) personnel and other experts in the field and on the foundations for analyzing demand and supply systems and how markets function in economics. A comprehensive literature search was completed using 43 terms related to MNPs (**Table 1).** The research team used PubMed and Google Scholar as online databases for collecting peer-reviewed literature. Additional literature, reports, publications, and manuals on

micronutrient powders were collected through non-governmental websites such as GAIN, World Health Organization, UNICEF, the Home Fortification Technical Advisory Group (HF-TAG), Helen Keller International (HKI), New York Academy of Sciences (NYAS), Scaling Up Nutrition (SUN), and the United States Agency for International Development (USAID) Strengthening Partnerships, Results and Innovations in Nutrition Globally (SPRING) project. Individuals who participated in the in-depth interviews also shared literature, particularly unpublished reports and articles, in-country reports, and white papers. A total of 99 peer-reviewed papers and 40 reports/papers in the grey literature were identified. Papers that focused on delivery, evaluation of delivery systems (specific emphasis on model and IYCF platform), sustainability, formative and process evaluation research linked to delivery models were retained in the review while papers that dealt with formulations and/or research papers or reviews of MNP use in pregnant and lactating women were not included.

We worked closely with GAIN to develop a sampling frame of experts within the area of MNP research and program implementation. From the sampling frame, 68 individuals were invited to participate, and 26 individuals completed interviews. Specific to the key informant interview component, IRB approval was obtained from the Tufts University Social, Behavioral and Educational Research Institutional Review Board and the GDPR committee. The University of Pennsylvania (UPenn) IRB provided concurrent exemption for the study. All interview participants were required to provide consent to participate per Tufts IRB guidelines. Interview participants located in the European Economic Area at the time of the interviews were required to provide written consent prior to their participation.

Key informants were based in various regions across the globe and their professional affiliations included governmental, international, and local non-governmental organizations, the UN, the private sector, and academia. Interviews lasted approximately 60 minutes and were conducted using an in-depth interview guide. Though the interview guide was used for the overall framework, each interview was tailored to the individual key informant's experience and expertise. Notes were taken during each interview and shared with the key informant after the interview. All key informants were asked to confirm the content of the notes to ensure accuracy of the responses. Each set of notes was reviewed by each co-author of this manuscript and confirmed. Information obtained from the 26 interviews was de-identified and all insights, recommendations, and perspectives from these interviews are cited as key informant (KI) to maintain the confidentiality of interview participants. The areas of inquiry used within the key informant interview are presented in **Table 2** and the characteristics of the key informants and their geographic region of expertise are provided in **Table 3**.

Results

We assessed the relative advantages and disadvantages of free, subsidized and fee-based models and examined factors that need to be considered in the design of future MNP delivery. We first outlined definitions and terminologies used in the review and then present the findings of this assessment in four distinct sections; "Programmatic

Experience around MNP Delivery Models", "Costs, Cost Effectiveness and Sustainability of Models", "Model Assessments: Country Examples" and "Factors to Consider in the Design of Future MNP Delivery".

I. Definitions and Terminologies

There is significant variation on terminology and definitions in the literature around MNP delivery. For instance, van Liere et al (2015) in their working paper on models for infant and young child feeding used the terms "market based" models (where there is full cost recovery), "social business" models (where there is partial recovery) and "public distribution models (where the product is provided for free) (M. J. van Liere, Frega, Tarlton, & Schofield, 2015). Typically, the first two models were supported through private investment and/or commercial loans while the third was supported through donor and/or governmental funding.

To set the stage for this review, firstly, we focus on the type of delivery model only and one type of platform, i.e., existing infant and young child feeding programs (IYCF). Secondly, while there are different definitions of the type of model itself, we utilize the terminology outlined in Reerink et al (Reerink et al., 2017) who referred to "*a delivery model*" as the cost of the MNP to the consumer and defined models as being free (no cost retrieved from the consumer), full cost (full cost retrieved from the consumer), subsidized (partial cost retrieval from consumer) and mixed or hybrid (price differentials co-existing as part of the same program)(Reerink et al., 2017). Within this context, we also note that full-cost and subsidized models can be referred to as "fee-based" models and utilize the approach of sub-categorizing full-cost and subsidized models under "fee-based" models.

Thirdly, given the nature of the review and significant variation in delivery platforms and channels, we focus on one type of "*delivery platform*". Through the literature, we found that the integration of MNP delivery into an existing IYCF program was the most common platform of delivery (Gibson, Kroeun, & Mundy, 2019; Leyvraz et al., 2017; L. M. Locks et al., 2018a). In 2018, over three-quarters of the more than fifty MNP programs reviewed were integrated into an IYCF program (L. M. Locks et al., 2018b). Using an existing IYCF platform was noted to have the potential to reduce start-up costs, target the appropriate population, and integrate SBCC via trained professionals alongside the MNP delivery. Finally, most of the literature we examined, conducts comparative analyses of different "*delivery channels*" using the same model and platform. For instance, a study in Uganda examined the free-based model delivered through an IYCF platform either via community outreach (channel) or through health facilities. We find very little in the literature where comparative assessments are made between different "*delivery model types*".

Coverage is a critical indicator of performance, and we find different definitions for coverage. For this review, "*coverage*" was the percentage of target population who have received/consumed or purchased an MNP in a specific time period, while "message coverage" was defined as having ever heard of the MNP; "contact coverage" as having ever consumed the MNP; "partial coverage" as having consumed at least one sachet in

the past week; and "*effective coverage"* as consumption of three or more sachets in the past week or 90 sachets over 6 months) by the target population (Nguyen, Poonawala, Leyvraz, Berger, Schofield, Nga, Van, Hoa do, et al., 2016). The definition of effective coverage was used as recommended by WHO and the Home Fortification Technical Advisory Group (HFTAG) (HFTAG, 2014; WHO, 2011).

II. Programmatic experience around MNP delivery models

Free Models

Free models involved distribution of MNPs for free and were often coupled with outreach linked to either the health or less often the non-health sector as a delivery channel (Reerink et al., 2017). The health sector, where IYCF services along with MNP delivery were delivered either through health facilities or through community outreach by community workers, was the most common channel. Reerink et al identified several advantages of adopting a free model of distribution including the ability to integrate with an existing platform (e.g., IYCF) and/or serving as motivation to conduct trainings around IYCF. Furthermore, they noted that free models had the potential for large-scale implementation especially if built into the national system. When integrated into the non-health sector (e.g., existing social protection programs), these models were likely to reach the most vulnerable households that were at most need of the intervention thus making scale-up more feasible (Reerink et al., 2017). Several KIs were strong advocates of the free delivery model. According to them, this was the only way to target individuals at the highest risk for micronutrient deficiencies. Even in settings where there were subsidized or full-cost models, they were often in conjunction with a free model where MNPs were distributed at no monetary cost to individuals who were enrolled in or accessed the existing platforms (e.g., IYCF programs). One KI likened the need to treat MNPs like vaccines, as an essential public good necessary for keeping the population safe. MNPs, like vaccines, should be given for free to protect the most vulnerable people (infants and young children) from preventable maladies. Another KI noted that the individuals and households most at risk of micronutrient deficiencies due to income-level or lack of access to systematic or community support and resources will never be able to afford MNPs at a monetary cost, let alone the food with which the MNP needs to be combined. According to the KI, this alone demonstrates the need for a free model.

Fee-based models

Fee-based models were either full cost or subsidized. A full-cost fee model was one in which a business (either multinational or small/medium enterprise) sold the MNPs as part of a group of health products (Reerink et al., 2017). Subsidized models were those where the consumer pays for the MNPs, but at a reduced cost. Like free models, fee-based models used different delivery channels. A direct retail channel (with social marketing) has been used by companies such as Ajinomoto in the delivery of KokoPlus (Aaron et al., 2016), while the Pushtikona channel links a producer with retail sales to an NGO for community-based sales or door-to-door sales (BRAC) that includes elements of service provision (GAIN). The advantages of a full-cost model include access to commercial funding, a lower likelihood of stockouts and access to retail channels that would allow for greater outreach (Reerink et al., 2017). A subsidized

delivery model was frequently seen in settings where CHWs sell MNPs as part of a social-marketing scheme (Afsana et al., 2014), but subsidized MNPs have also been delivered through retail settings (Ghana, Bangladesh, Laos, Madagascar, Somaliland) (GAIN; Reerink et al., 2017).

Hybrid Models

We also found models that are mixed or hybrid and that utilized a combination of a free and full-cost or a free and subsidized model. For example, where free distribution of MNPs targeted only young children aged 6-23 months, a subsidized model may be used to target older children aged 24-59 months, who may potentially benefit from MNPs, as well (HFTAG, 2014). Combining one or more delivery models within the same program has the potential to compensate for some of the challenges unique to each individual model by smoothing volatility of program delivery. The hybrid model allowed for recovery of some costs to expand to scale and reached both populations that need the product but are unable to pay for it and those that are willing and able to pay for the product. The underlying assumption of a hybrid model was that micronutrient needs exist across the spectrum of the population- from those who are the most vulnerable and cannot pay to those who are rich, upper middle-class or middle-class and can pay or are willing to pay for the health benefit that an MNP provides. A strong justification for using the hybrid model was provided by one of the key informants. The key informant noted that "*Creating an ecosystem that unites public and private sectors may be the best option to fulfill the needs of the beneficiary by providing convenience to purchase MNP when necessary and the ability to provide MNP at no monetary cost to those with the greatest need and an inability to pay*".

Advantages and Disadvantages by Model Type

Reerink et al analyzed, in depth, the comparative advantages and disadvantages of free, full cost, subsidized and hybrid models (Reerink et al., 2017), which are presented as an extracted table in **Table 4.** Several key informants indicated that a full-cost model was less likely to reach the poorest segment of the population, an observation that was also confirmed by Reerink et al (Reerink et al., 2017), as well as, in a cross-sectional study in Nepal that aimed to assess acceptability of purchasing MNPs and determine their prices. Gunnala et al found that while almost 80% of mothers found it acceptable to purchase an MNP and about 70% were willing to pay about 150 Nepali rupees ($1.5 USD) for 60 sachets (in surveys conducted at 3 months and 15 months of MNP delivery), acceptability for purchasing MNPs increased with increasing wealth quintile and increasing maternal education (Gunnala et al., 2017). Thus, those able to pay for MNP were those in higher wealth quintiles and may not have been those whose children were most at risk of micronutrient deficiencies. Several key informants made the argument that micronutrient deficiencies are high in most countries with MNP policies and that the need was across the economic spectrum. Furthermore, as found by van Liere et al., 2017, while free delivery offered equitable access to a public good, it often was being implemented via platforms and channels that are challenged with respect to capacity, capability, supply, and monitoring. On the other hand, the authors also found that many developing countries where the need for MNPs was the greatest, either lacked markets, particularly in remote rural areas, and/or had commercial retail

markets that were too immature for products like MNPs (Marti J. van Liere, Tarlton, Menon, Yellamanda, & Reerink, 2017).

Use, Adherence and Coverage by Model Type

The extent of coverage achieved greatly depended not only the delivery model but also the platform and the channel through which the MNP was delivered (Leyvraz et al., 2017). Using a robust platform (e.g., existing IYCF program) was more likely to lead to higher coverage due to the ability of that program to overcome supply and demand obstacles (Leyvraz et al., 2017).

Free models

In non-emergency contexts, MNP coverage in the free model can vary depending on the type of delivery platform and channel used, the extent of engagement with mothers and exposure to MNP messages. A pilot study in Nepal tested the potential for two different delivery channels, one whereby MNPs were delivered by community outreach through family care health volunteers (FCHV) and the other where MNPs were delivered through health facilities. Three months into the intervention, the study found, that while MNP distribution through community outreach channel was not significantly different from distribution through the health-facility channel, subsequent coverage was higher in the community outreach channel, in part influenced by mothers being reminded to use MNPs by the FCHV (Jefferds et al., 2015) likely through interpersonal communication (IPC). A subsequent post-pilot scale-up study in Nepal examined the predictors of MNP coverage, maternal knowledge of appropriate and consumption (n=2578 mother-child pairs representative of children 6-23 months) and found that while coverage (mothers who ever received a distribution) was 61%, repeat coverage (mothers who received a distribution twice or more times) was 46% (L. M. Locks et al., 2018a). Among those who received the MNP distribution, contact coverage (consumed MNP at least once) was 97%, with 39% of children who received the MNPs consuming more than 75% of the last distribution (each distribution was 60 sachets over 6 months – not 90 sachets over 6 months as recommended by WHO). Counseling on IYCF and MNP use was positively associated with knowledge, coverage, repeat coverage and high intake with the strongest association being with FCHV counseling, thus highlighting the potential role of IPC counseling (L. M. Locks et al., 2018a). Clearly the scale-up of free models using a community-based channel and IPC counseling approach would have significant resource implications both financial and human.

MNP delivery has also been examined within the context of emergencies as seen with the example of delivery of Pushtikona (a 15-micronutrient formulation) to pregnant and lactating women and infants and young children as part of the emergency response to Cyclone Sidr in Bangladesh in 2007. As part of the monitoring of MNP distribution, the World Food Program (WFP) found that 2 months post-distribution, awareness of Pushtikona was exceptionally high at 81% (n=610) with 87% of pregnant and lactating women (n=227) interviewed and 67% of children (n=258) reported consuming the recommended 40 and 20 sachets over 1.5 months respectively. Subsequent monitoring showed continued high frequency of consumption (WFP, 2008).

Fee-based models

Coverage was noted to be a significant issue when assessing the potential for fee-based models (whether full, subsidized, or hybrid) to go to scale. In Vietnam, Nguyen et al found effective coverage to be 11.5% among all surveyed caregivers and 27% in those who had visited health centers in the past month. The MNP purchase was positively correlated with the wealth quintile of the household. Critical to the success of the pilot also was access to IYCF counseling at health centers (Nguyen, Poonawala, Leyvraz, Berger, Schofield, Nga, Van, Hoa do, et al., 2016). A comprehensive review using FACT (the Fortification Assessment Coverage Toolkit) assessed three levels of coverage (message: awareness of the product; contact: use of the product at least one time; and effective: regular use aligned with program-specific goals) and barriers to coverage and factors that facilitated coverage in Ghana, Cote d'Ivoire, India, Bangladesh and Vietnam (Leyvraz et al., 2017). The products were fortified complementary foods in India and Cote D'Ivoire, MNPs in Bangladesh and Vietnam and a MNP with a soy-amino acid macronutrient component in Ghana (Aaron et al., 2016; Leyvraz et al., 2017). While they found coverage to be very variable, being as low as 0.8% effective coverage to as high as 99.7% of message coverage, a common theme identified in the analysis was that beyond creating awareness programs with high coverage were those with effective mechanisms in place to overcome barriers of both supply and demand (Leyvraz et al., 2017). Effective mechanisms included ensuring no gaps in the supply chain, implementing demand-creation activities, training sales agents, supporting a multi-component multi-channel communications strategy that includes community mobilization, sustained mass-media campaigns and regular and quality interpersonal communication to motivate and address individual barriers. Similarly, Reerink et al synopsized message, contact and effective coverage from surveys conducted in Bangladesh, Cote D'Ivoire, Ghana, India and Vietnam and reported effective coverage rates to be very low in Bangladesh (0.8-2.1%) and Cote d'Ivoire (4.6%) (Leyvraz et al., 2017). Leyraz et al also reported variability in message and contact coverage. In Bangladesh, for door-to-door sales of Pushtikona (an MNP), while message coverage was about 44%, contact coverage was low at 23%. In Cote d'Ivoire, while there was an 85% message coverage, effective coverage was only 4.6%. This indicated that while consumers were receiving the messages, the coverage that reflected the WHO guidance was low to non-existent.

There was variability in coverage based on the type of delivery channels used and the level of demand creation and behavioral-change communication. This was also documented by Aaron et al in Ghana that compared program coverage of two different delivery channels for the sales of KokoPlus, a complementary feeding supplement (Aaron et al., 2016; Leyvraz et al., 2017). Delivery channel 1 used a mixture of health-extension workers delivering behavioral-change messages and conducting demand-creation activities at the health centers and within the program-targeted communities along with petty traders that were part of a local microfinance initiative selling the supplement at market stalls and door-to-door. Delivery channel 2 used an approach that involved micro-retail sales (small shops and roadside stalls) with behavioral-change messages and demand creation led by a local social-marketing company. Channel 1 had high effective coverage of 88% and 83% at 2 months and 10 months respectively

but this fell to 62% at 14 months post-start of the project. The reduction in effective coverage was possibly due to the cessation of the demand-creation activities 3 months before the 14-month survey was conducted. Conversely the model that utilized channel 2 had a very low effective coverage rate (15.3%) at 2 months into the intervention initiation which dropped further to 9.4%, 11 months into the project (Aaron et al., 2016).

Another study focused on Pushtikona delivery (through sales) in Bangladesh found that in 50 sub-districts where intensive support on MNP use and IYCF counseling was provided (MNP-intensive areas), the mean adherence (defined as consuming one sachet per day within the past 60 days) was 70% in children aged 6-59 months and the mean adherence was even higher in children aged 6-23 months (Afsana et al., 2014; Angdembe, Choudhury, Haque, & Ahmed, 2015). Angdembe et al (2015) noted that adherence was high across all quintiles (70%) but was the highest among the poorest households at 78.4% followed by richest at 77%, richer at 71%, middle at 70% and finally poorer households at 55% (Angdembe et al., 2015). Mothers preferred giving MNP to their children daily rather than every other day. Another important finding was that 96% of mothers reported that a frontline worker called Shasthya Shebikas (SS) had provided information on anemia and/or MNP during their last visit and with every 1 unit increase in visits by a BRAC SS in the past 60 days, the odds of a higher adherence to MNP use by the child were over 50% higher than in those households not receiving visits. This was supported by findings from a process evaluation conducted by IFPRI in 2013 that also found that knowledge and purchasing patterns of mothers were better in the MNP-intensive subdistricts (Afsana et al., 2014; J. F. Hoddinott, Gillespie, & Yosef, 2015; Rawat et al., 2015). Afsana et al noted that the integration of the MNP with complementary feeding messages was key for this achievement. Increase in sales were also likely due to increased contacts between households and frontline workers and more comprehensive counseling, coaching and demonstration coupled with performance-based incentives for the SS (Afsana et al., 2014). This finding by Afsana et al, particularly emphasized the importance of interpersonal communication.

III. Cost, Cost Effectiveness and Sustainability of Models

We reviewed literature on costs, cost effectiveness and any assessments/reviews in the gray literature on sustainability. We found few studies that have explicitly assessed cost effectiveness particularly for a full-cost model. A recent study by Ahmed et al (2021) assessed the cost-effectiveness of the delivery of a full-cost MNP (Pushtikona-5) targeting children 6-59 months of age that was implemented in 164 sub-districts in Bangladesh through BRAC's community health worker program. The researchers found that the cost for every case of anemia averted was $22.2 while the cost of every DALY (Disability adjusted life years) averted was $159.3 (Ahmed et al., 2021). The authors note that the effect was higher in those children who consumed thirty or more sachets of MNP compared to overall consumption.

Schauer et al (2017) found that long-term costs of MNP interventions were not considered upfront and often funds were secured for pilot activities with the potential for future investments linked to success of the pilot. In full-cost models (which used pharmacies and other retailers as delivery channels) costs associated with advocacy,

regulation and training were often not accounted for in the product price. Furthermore, if the product was expensive, small retailers were less likely to stock it which led to consumer frustration and loss of interest. Lastly, limited demand and low profit margins were common risks that led to increased costs for social marketing and promotion. It was unclear to us from the literature if these costs were computed and if the impact of these added costs on the product price were estimated. With respect to free models particularly those through the health sector, Schauer et al (2017) noted that costs of MNP supply, project start-up, personnel for distribution and counseling, travel costs for outreach, other distribution monitoring costs along with the opportunity cost of the recipient's time and travel to the health facility for collection of MNP and counseling were needed to project the actual cost of MNP delivery. Finally, for subsidized models, in addition to supply and start-up costs, the fee charged to the paying consumer may not have been sufficient to support continued demand and market generation activities and thus motivate coverage. The role of subsidies in creating demand for essential health products has been examined (Dupas, 2014). Increasing coverage of already existing and proven health products and services was considered as low-hanging fruit for improving health outcomes. Based on econometric field experiments, products with large social benefits were likely to be most cost-effective as a strategy if distributed for free. If subsidies were provided, they would need to be heavy initially in order to drive demand (Dupas, 2014). Alternately, large initial subsidies may be viewed as endowment effects that are then hard to reduce without leading to decreases in demand (Kahneman & Egan, 2011).

Making the business case, ensuring cost recovery and profit margins along the entire MNP delivery chain through repeat sales and expanding the customer base are important for the sustainability of the full-cost model. While there is potential for the full-cost model to be more financially sustainable compared to the free model, there could still be implementation challenges on the production end (whether produced locally or internationally), the retailer end including the pharmacies that dispense the MNPs, or the distribution end with consistent staffing and staff time.

While solutions to manage cost issues and ensure sustainability were model-specific, we saw a common theme emerge in their analyses - donor support for start-up costs is needed to alleviate sustainability issues (Schauer et al., 2017). This issue was also raised by a key informant who noted that if one recovered all costs associated with delivering an MNP, the product price would be very high. According to the KI, it was important to identify alternate sales avenues such as incorporating sales of MNP within a basket of goods/services (e.g., counseling, spectacles, family planning products, essential drugs). This way, the cost of delivery would be spread across the basket of goods/services. However, in a related paper, Dupas noted very high prices even in the delivery of a basket of goods (Dupas, 2014). One of our KIs also noted that to reduce costs, it was critical to identify the correct distribution channel for each targeted subpopulation if a hybrid subsidized model was being considered.

In terms of free models, the Copenhagen consensus has reported free micronutrient interventions to be cost effective (Horton, Alderman, & Rivera, 2008) and estimated a

cost of $3.60 per year per child with additional costs for delivery doubling this amount to $7.20 per year per child for free delivery. A costing study in Kyrgyzstan for a free model estimated total costs at $8.16 per child for a 6-month period (Armstrong, 2009) and a commercial fee-based model estimated an out-of-pocket cost of about $6.60 per child per year (Bahl, Toro, Qureshi, & Shaw, 2013). Thus, depending on the model and context, costs varied greatly. The costs of demand creation were not estimated in any of these analyses. In addition to modeling costs per sachets and return on investments, we found reviews on the production cost of MNPs including costs associated with importing ingredients, equipment, electricity, construction and cost of packaging in fee-based models (Marti J. van Liere et al., 2017), as well as, a discussion and comparison of production costs between free and full-fee-based models (Schauer et al., 2017). We did not find a study that assessed the comparative cost effectiveness of delivery models and channels. One KI discussed a cost-effectiveness analysis of the two MNP delivery models implemented in Uganda (both free) and the findings are in the process of being published. This economic analysis, part of a pilot MNP project in Uganda, examined the cost effectiveness of delivering MNPs in a free model through health facilities versus community-based outreach. The analysis found that despite the higher cost of community outreach, this delivery channel was more cost effective than provision through health facilities. While the community-based outreach was more expensive, this arm delivered many more MNP sachets to children than were delivered at the facilities. While the facility delivery cost was lower $1,225,133 compared to community outreach ($1,797,517), the community outreach delivered 277,396 sachets compared to the facility which distributed 87,538 sachets leading to a unit cost of $0.22 per sachet in the community arm and $0.47 per sachet in the facility arm (Schott et al., 2021).

Finally, while we and several others have used the term free to describe the delivery model where the cost is not borne by the consumer, several KIs pointed out that the term free was misleading. Not only is there a cost to the program itself that is borne by a donor, but there was often a time or resource cost to the consumer that may not always be a monetary cost. As noted by one KI, even if a program delivered MNP to a community or a facility without charging a monetary value for the MNP sachets, there were opportunity costs associated with the consumer traveling to receive the MNP (monetary cost of the travel, time cost, etc.). Within this context, in the above-noted Uganda pilot, there were indications of opportunity costs such as distance and time taken to obtain MNPs from facilities, as well as, monetary costs around transportation for the caregiver as noted by D'Agostino et al (D'Agostino et al., 2019).

IV. Model Assessments: Country Examples

We conducted country case studies in Bangladesh, Ethiopia, Mozambique, Vietnam, and Indonesia (**Table 5**) to examine existing delivery models and identify challenges to implementation, as well as success stories. In this paper, we will provide a brief background on each of the five countries and then discuss more in-depth the MNP delivery models of Bangladesh, Indonesia, and Vietnam.

In Bangladesh, we found five ongoing national and sub-national MNP delivery programs targeting infants and children under the age of five years (HF-TAG, 2019). Of the five programs, two were full-cost delivery models and three were free-delivery models. Four of the products were under the “Monimix” product name while the fifth was a product developed by Renata and BRAC called “Pushtikona”. “Monimix”, was utilized by different organizations and was either sold or provided for free based on the program type. The MNPs available (e.g., Pushtikona or Monimix) through full cost or free delivery models that are endorsed by the Government of Bangladesh are composed of five micronutrients. The Government of Bangladesh has approved an MNP composed of 15 micronutrients (MixMe) for emergency-relief purposes only. This was first delivered through relief efforts during the 2007 cyclone season (WFP, 2009). While the government does not prevent sales of a 15 MNP sachets (e.g., Pushtikona sold through retail by Renata Ltd), it does not financially support or endorse the product.

In Ethiopia, while there are currently no national or sub-national distribution or sales of MNPs, several pilot projects and research studies have been conducted utilizing the free distribution model (Geletu, Lelisa, & Baye, 2019; Samuel et al., 2018; Alison Tumilowicz et al., 2019). We found two different MNP products, one called “MixMe®”, a low iron-dose MNP with 14 other vitamins and minerals (produced by DSM Nutritional products in South Africa) and the other called “Desta”, a locally branded MNP that was produced for the Government of Ethiopia by Hexagon, Ltd, India. Like “MixMe®” “Desta” was a low iron-dose MNP composed of 15 essential vitamins and minerals. Indonesia has one sub-national program that utilizes the free distribution model to deliver the MNP called “Taburia”. “Taburia” is composed of 14 micronutrients (HF-TAG, 2019) andwas developed in 2011 by the National Institute for Health Research and Development (NIHRD) of the Indonesian Ministry of Health (MOH). The term is derived from the Indonesian words for “to sprinkle” and “cheerful”. This was meant to emphasize the easy-to-use nature of the supplement and its benefits to children. The distribution of Taburia was set-up as a free model targeting low-income households with children aged 6-24 months via community health posts (Posyandu) across three provinces and 64 of 514 districts in Indonesia (Aang Sutrisna, Vossenaar, Izwardy, & Tumilowicz, 2017; A. Sutrisna et al., 2018). Prior to Taburia, Helen Keller International in partnership with Heinz ABC distributed MNPs for free to children aged 5-59 months affected by the 2004 tsunami and earthquake (de Pee et al., 2007).

In Mozambique, a fee-based model was implemented by the NGO PSI Mozambique. This program is no longer active due to lack of governmental support for commercial/full-cost delivery models, but MNP delivery and different model types have been piloted in Mozambique. For example, between 2015 and 2017, GAIN, in partnership with the Ministry of Health (Ministério da Saúde (MISAU)), Save the Children (SC), and PSI, with funding from the Government of the Netherlands implemented an MNP and SBCC program in three districts of Sofala province, targeting children aged 6-23 months.

In Vietnam, since 2013 GAIN has supported home fortification using MNP and a full-cost model, targeting infants and young children. Beginning in 2013, GAIN in

partnership with the National Institute of Nutrition (NIN), the Ministry of Health and Provinces, Institut de Recherche pour le Développement (IRD), Nielsen Company, Columbus Branding, Hanoi International Television Company, and Alive & Thrive Vietnam, implemented a six-month pilot program using a locally produced MNP called Bibomix. Bibomix was produced by NIN and made available for sale through public-health centers in four provinces of Vietnam (Leyvraz et al., 2017; Nguyen, Poonawala, Leyvraz, Berger, Schofield, Nga, Van, Hoa, et al., 2016; Tran, Spohrer, LE, Poonawala, & Monech-Pfanner, 2015).

Bangladesh: Scale up a Full-Cost Model

In 2010 in Bangladesh, Renata and BRAC, with support from GAIN, pushed the delivery of MNPs at scale and by 2014, BRAC was delivering 1.3 million sachets of MNP per month (Afsana et al., 2014). The delivery of Pushtikona was through CHWs called Shasthya Shebikas (SS). This model of selling products through a health worker required the health worker to purchase the commodities including micronutrient powders, health, and hygiene products (iodized salt, soap, contraceptives, etc.) from BRAC and then sell them to the community for a profit (Sarma, Uddin, Harbour, & Ahmed, 2016). In addition to selling MNP and other health goods, SS provided nutrition education and counseling to ensure compliance and appropriate use of the MNP. Pushtikona sachets were also available for retail purchase through pharmacies and Renata's network of doctors and sales representatives (Afsana et al., 2014). Over 49,0000 SSs sell MNPs under the BRAC umbrella across almost all districts in Bangladesh (Afsana et al., 2014; Marti J. van Liere et al., 2017). The SSs are considered as trusted reference points and in addition to selling a basket of health care products, they provided free health and counselling services. Despite the strength of the existing network, the BRAC pilot project found low uptake and effective use. This was likely due to an impact on revenues of the SSs and subsequent re-investment in MNP sachets for sales in the baskets. An assessment identified the need to address stock and supply issues but also to provide additional counseling skills and sales techniques to the SSs. In addition, BRAC identified a need to provide incentives to SSs to encourage repeat sales and adequate use. The other full-cost model in Bangladesh where retail distribution of MNPs was through pharmacies and physician offices by the Bangladeshi MNP producer (Renata Ltd) was not effective (Marti J. van Liere et al., 2017).

Overall, the delivery and scale-up of MNP use in Bangladesh revealed the need for significant efforts to be placed on evaluation and adaptation of approaches for MNP delivery whether through the SS model linked to an IYCF platform such as Alive and Thrive or through retail sales. Several caveats were revealed. This included the presence of two different forms of MNPs (a five-micronutrient and a 15-micronutrient formulation), both available through retail sales but only one endorsed by the Government. In addition, low governmental interest towards marketing MNPs, lack of national standards for procurement, different implementing programs with different regimens, guidelines and communication materials and rigidity of guidelines which led to reduced compliance and adherence were all factors that limited use and adherence to MNPs. A modification of the WHO guidelines led to improved compliance when the

90 sachets were spread out over the entire year with mothers being encouraged to provide 10 sachets of MNP per month all year round. Several KIs noted that the donor and private sector relationship in Bangladesh allows MNP to be available through various channels (ex., through SS, for sale in retail outlets, and through free distribution) and this makes MNPs accessible at multiple price tiers and to a greater audience, which can improve coverage and sustainability of the product. A KI noted the Government of Bangladesh would not be able to support free distribution at a national scale and thus the approach of a predominantly full-cost model with specific targeted free distribution was likely to be the most feasible option moving forward. Additionally, the same KI noted that the ability to maintain current levels of MNP coverage and adherence is linked to BRAC's outreach in nearly every district in Bangladesh. In addition, provision of nutrition counseling is also a critical factor for the success of MNP delivery. Such a delivery approach (i.e., at scale and with intensity) may not be possible in all settings and certainly not without continued funding from donors and private-sector actors. MNP delivery combined with IYCF counseling was highlighted as an essential element of the success.

Indonesia: Applying lessons learned to improve MNP use and adherence

In Indonesia, Taburia was found highly acceptable as a product among most caregivers during acceptability tests but during implementation there were issues as noted by Sutrisna et al (2018) linked to supplement distribution that may have led to low coverage and adherence (Alim A., Thaha R., & Citrakesumasari, 2011; A. Sutrisna et al., 2018). A particular issue in the Indonesia MNP delivery system was the workload of the front-line workers who delivered the supplement to the mothers (Alim A. et al., 2011). In addition to individual-level issues, the public distribution of Taburia was de-centralized with districts required to fund the activity from their budgetary allocations. According to GAIN, this made implementation less uniform across the country. There was very little marketing and demand creation to drive uptake and compliance (GAIN, 2019). Anecdotal reports, indicated concerns linked to the product altering the taste of the foods and/or perceived bad smell upon opening the sachet (Aang Sutrisna et al., 2017). However, a sensory evaluation that tested the acceptability of "Taburia" and a comparison MNP (MixMe™) in 232 children aged 6-24 months and their caregivers found "Taburia" enhanced texture, sweetness, saltiness, and umami taste[2] but there was also a perceived bitter taste. The overall taste of "Taburia" was preferred over MixMe™ (Aang Sutrisna et al., 2017). Caregivers' acceptability of the MNP was high and the changes in organoleptic properties generally did not discourage caregivers from using this MNP. A study examined the effect of re-designing the outer packaging of "Taburia" to include clearer information and educational messaging on knowledge and adherence to recommended MNP use (A. Sutrisna et al., 2018). In a community-based randomized control trial, it was found that improved packaging increased caregivers' knowledge of the recommended MNP use and increased their adherence to the MNP compared to caregivers who received the MNP with the original packaging while improved packaging with cooking demonstrations increased knowledge of the recommended MNP use, but not adherence (A. Sutrisna et al., 2018).

[2] Umami is a savory taste that is one of five basic tastes and is characteristic of broths and cooked meats

Using lessons learned from these studies and from the program evaluation of "Taburia," GAIN provided support to the Government of Indonesia to test a fee-based model for MNP distribution that was meant to start in December 2019 (KI 2, KI 20). The aim was to assess the potential of a social-marketing approach to promote and distribute MNP. The two-year project used an MOH-approved commercial version of "Taburia" that was locally produced and distributed through franchised midwives (about 900) who sold the MNP to caregivers of children aged 6-24 months. Sales through midwives were supported by a social-marketing company in selected parts of Indonesia. According to KI interviews, the GAIN pilot commercial MNP program was significantly delayed due to negotiations on the dosage of the MNP sachet. Thus, in Indonesia the conditions required for the implementation of a fee-based model linked to social marketing were being actively examined and tested. According to the research and KI interviews, the investments so far including improved outer MNP packaging have increased adherence, knowledge of appropriate MNP use, and have the potential to be transferred to other contexts.

Vietnam: Delivery of Bibomix through a full-cost model

In Vietnam, until the launch of BiboMix, MNP distribution occured only in specific humanitarian or emergency-response situations and/or to target very specific malnourished sub-populations (UNICEF, 2017a, 2018). To assess the potential for BiboMix (sold at $0.09 USD per sachet) to go to scale, a full-cost model pilot project was implemented with significant investment made in formative research and consumer testing to improve branding and packaging (Nguyen, Poonawala, Leyvraz, Berger, Schofield, Nga, Van, Hoa do, et al., 2016). Along with the sale of BiboMix, caregivers received counseling and education on product use, complementary feeding, and WASH practices from trained health workers. The pilot project routinely monitored sales. In 2014, five months after the start of the MNP distribution, a cross-sectional survey of caregivers and health staff found that the number of MNP sachets purchased by caregivers was positively associated with their wealth index. (Nguyen, Poonawala, Leyvraz, Berger, Schofield, Nga, Van, Hoa do, et al., 2016). As wealth increased, caregivers were more likely to buy a box of sachets with individual sachets being purchased at lower wealth quintiles (Nguyen, Poonawala, Leyvraz, Berger, Schofield, Nga, Van, Hoa do, et al., 2016). Several key informants in our assessment, as well as, in the study conducted by Reerink et al, perceived that the full-cost model was encumbered due to low consumer demand linked to affordability (Reerink et al., 2017).

With respect to coverage, of those who had heard about BiboMix, 74.8% had given it to their children at least once. Effective coverage (consumption of ≥ 3 sachets/child/week) was 27.3% among caregivers who had visited the health center within the past month, and 11.5% among all surveyed caregivers. These results reinforce the finding that initial uptake of a MNP with SBCC and education is high, but programming needs to focus on sustained use. Additionally, caregivers who accessed health facilities and heard about MNPs from health workers were more likely to have heard of and purchased MNPs. Message coverage increased from 30% (all caregivers) to over 50% in those who had visited health centers in the past 1-5 months. Similarly contact coverage went from 22% to over 40% while effective coverage went from 11.5% to between 23 and 27%. An

assessment of compliance in surveyed caregivers found high compliance irrespective of the type of compliance definition (Nguyen, Poonawala, Leyvraz, Berger, Schofield, Nga, Van, Hoa, et al., 2016). Most caregivers who gave BiboMix to their children adopted proper usage behaviors and more than 50% of caregivers were compliant with all steps of optimal usage recommendations. According to one KI, the high compliance was due to a combination of education received at the health centers and helpful pictograms on the outer packaging of the MNP sachet that showed how to correctly use the MNP.

KIs made several comments on lessons learned from the Vietnam pilot program including making the product available in different sachet amounts (i.e., boxes of 10, 20, 30 and 60 sachets) which was found to be effective in the promotion and uptake of the MNP (Nguyen, Poonawala, Leyvraz, Berger, Schofield, Nga, Van, Hoa do, et al., 2016). A KI noted that providing different options of number of sachets per box allowed for risk mitigation and caregivers were more likely to purchase boxes of ten sachets. The boxes of 30 sachets were sometimes cost prohibitive, so having lower-cost and lower-number options was a key achievement of the project that could be translated into future MNP programs. Another point noted by two KIs was that for sustainability of an MNP program in Vietnam, a hybrid model would be necessary. According to two key informants, having a full-cost model where the MNP is available only through sales is not sufficient; doing so effectively cuts-off access for the most marginalized and vulnerable populations. Conversely, a free model would not be sustainable due the cost associated with delivery particularly at scale-up. Both key informants supported a hybrid model that reduces the cost to extend coverage and targets populations at varying wealth indices.

V. Factors to consider in the design of future MNP delivery

We examined the perspectives on the future of the delivery models, the channels, as well as the actual product itself and found consensus around the need to consider modifications to existing models. Most key informants felt that a combination of a free and a fee-based model – thus, a hybrid model -- was the most appropriate approach. A free distribution model was considered volatile and subject to high risk of not being sustainable while a market-based or a full-cost system was very slow to grow and potentially excluded the households most at-risk of micronutrient deficiencies due to their income-level and lack of systematic resource support. Several key informants felt that dwindling donor support hampered efforts to ensure sustainability, as well. It was noted by a key informant, however, that the inclusion of MNPs on the WHO essential medicines list is likely to increase donor support towards MNP programming.

Despite the suggestion of a hybrid model, several KIs felt that the context or constraints would not change for people and households experiencing poverty and extreme poverty, and thus there was need to continue targeted free delivery model programs for these people. There was also clear consensus that the nature of the hybrid model would vary and would need to be contextualized to populations and countries. As noted by a key informant, in some instances, differences in delivery are required even within the same city. The need for contextualization of future MNP delivery methods and platforms is illustrated by differences in key informant responses.

Reerink et al (2017) have suggested that subsidizing the cost of the MNPs may be a more viable option (Reerink et al., 2017) than distributing the MNPs for free due to partial cost recovery (Bahl et al., 2013). Their study found that re-investment of profits earned from those who can pay to reach lower-income groups with additional distribution/promotional activities as seen in Vietnam as a possible option (Nguyen, Poonawala, Leyvraz, Berger, Schofield, Nga, Van, Hoa do, et al., 2016). In a program in Madagascar, urban consumers paid five times more than rural consumers with proceeds being utilized for promotional activities. Another form of a hybrid model was the presence of both a free and fee/full-cost model or alternatively delivery of MNPs for free to targeted populations coupled with MNP sales (through retail or community outreach). However, having access to both a free and a fee-based product could have had an impact on consumer perceptions and low consumer interest might have been a disincentive to the private sector. This was observed in Lao PDR where the same product available for free was perceived by the caregivers as being lower quality compared to the sachets that were available for a fee. Overall, it appears that coverage of a subsidized model was lower than a free model despite its potential to reach larger audiences. With respect to channels of delivery, two key informants suggested the use of non-health sector delivery linked to social marketing (e.g., micro-finance structures, women's groups) particularly to access rural populations, another key informant felt that the health sector was critical since this was the system that people trusted. One key informant suggested making changes to the incentive structure for health workers who sell MNPs (e.g., a flat-fee structure).

The role of SBCC, demand creation and interpersonal communication in MNP delivery

Irrespective of type of model or channel used, the importance of training, SBCC, demand creation and knowledge generation were highlighted as significant factors in the successful delivery of MNPs. Compliance, demand, adherence and addressing negative perceptions of product quality were issues that were strongly associated with sustained social and SBCC and consistent interactions with community health workers (or any frontline worker). One KI used the metaphor that even a big beverage company needs to continue advertising their products. Marketing of MNPs was similar – for sustained demand and adherence you need to constantly engage your target audience. One key informant noted that while it was fine to use the retail system to deliver the product, any messaging, training, and knowledge generation would need to be delivered separately from the retail delivery. Many KIs noted that adherence was greatly improved by frequent interactions with trained professionals such as CHWs. Interactions with health workers not only acted as a platform for nutritional SBCC, but these interactions provided opportunities for health workers to learn about programmatic issues through the perspective of the caregivers which they were able to relay back to the program implementers. It was also noted that future program designs need to extend outreach to targeted populations, especially vulnerable groups, and to focus on understanding health access barriers so that caregivers have more options for ways to learn about and obtain MNPs.

The importance of SBCC with a specific emphasis on interpersonal communication and counseling has been well illustrated by Hoddinott et al in two RCTs conducted in Bangladesh. The researchers found that mothers who received cash transfers accompanied by nutritional SBCC had significantly higher knowledge of iron deficiency, were more aware of the importance of the MNP, their children aged 6-59 months were more likely to have ever consumed MNP, and their children aged 6-59 months were more likely to have consumed MNP within the preceding week as compared to mothers who received cash alone, food and cash, or food alone (J. Hoddinott, Ahmed, & Roy, 2018).

In Bangladesh, in a full-cost delivery model, several KIs associated success of compliance and sustained demand due to involvement of BRAC SSs and their record keeping. The odds of having high adherence to MNP consumption increased by 55% for each visit by a BRAC SS (Angdembe et al., 2015). In Mali, Roschnik et al, who conducted a community-led free delivery MNP intervention targeting children 6-59 months, found the use of community pre-schools and multi-sectoral volunteers who offered a supporting environment (in addition to being the delivery mechanism) and who promoted good nutritional practices were critical for achieving the high adherence and acceptability observed in the study (Roschnik et al., 2019). Ford et al assessed predictors of MNP coverage and recent intake using cross-sectional survey data from the Amuria district in Uganda and found knowledge of correct MNP preparation and having heard about anemia were positively associated with MNP coverage while having heard about MNPs via radio, knowledge of correct MNP preparation and child not disliking MNPs were associated with recent intake. They concluded that increasing caregiver knowledge and skills was critical in improving MNP coverage and recent intake (Ford et al., 2019). In Ethiopia, a quantitative evaluation of a free-distribution program found that for each additional time a frontline worker met with a caregiver, within the three months preceding the survey, the caregivers were 13% more likely to have fed their children MNPs (Alison Tumilowicz et al., 2019). In Nepal, in a free-distribution model, counseling by community health volunteers on IYCF and use of MNPs was positively associated with knowledge, coverage, repeat coverage and high intake. Furthermore, health-center worker counseling was significantly associated with knowledge and coverage indicators while radio messages were associated with coverage indicators only (Lindsey M. Locks et al., 2019). In addition to supporting nutritional practices, interpersonal interactions provided the opportunity to address complaints or uncertainties with use of MNPs (e.g., black stool, diarrhea, constipation) and was noted by multiple KIs as another key factor in maintaining successful demand. Pelto et al., in Ethiopia found the need for stronger support systems for caregivers to manage negative child reactions as well as to manage mothers' reactions to any side effects (Pelto et al., 2019).

Procurement of MNPs

A very relevant issue that emerged was procurement. In most programs or studies, procurement of MNPs has been through international suppliers (Schauer et al., 2017) though we did find some countries who produced their own MNPs. In-country

production of the MNPs was linked to its own challenges with poor regulatory guidelines and quality assurance. In Cambodia, local production had such poor-quality assurance measure that it led to a loss of a large quantity of sachets. In addition, there was significant discoloration of the product which led to end-user refusal and subsequent governmental suspension of delivery (Schauer et al., 2017). In all instances, decisions around procurement were based on quality, cost and timing including times for production and shipping (Schauer et al., 2017). MNPs were often sourced as a fully imported product as this process allows for improved efficiencies, lower costs and better-quality control. However, reliance on imported MNPs was linked to long lead and delivery times, high import duties, logistical problems at points of entry or even prohibition of entry into the country.

Local context and changing demographics

One size will not fit all. This was a clear message from most of our key informants. While an illustrative model and platform is helpful for programming purposes, accounting for local context, ensuring governmental buy-in and ownership and modifying/adapting models based on cultural differences was a clear recommendation. Many key informants emphasized the importance of stakeholder engagement in determining model type, adapting models to account for country and local context but also to consider changing demographics in the areas of most need of micronutrient interventions. Governmental engagement is critical as governments are the custodians of any programmatic action. They are often aware that a free distribution system will not be sustainable. According to one of the key informants, many governments have bought into implementing the MNP intervention but have not received enough guidance and support to implement successfully.

The perceptions of key stakeholders drove the type of model being implemented while another KI indicated that cultural and socio-political differences including how a population responds or not to government-supported programs were critical in determining the success of one model over another. In addition to governmental stakeholders, civil society is often influential within a country and at least one key informant, at the country level, indicated that some civil society groups were not proponents of delivery of MNPs and were strong advocates of the food-based approach to alleviating micronutrient deficiencies. Finally changing demographics including the rapid urbanization seen in Asia and Sub-Saharan Africa were also raised by several key informants. Key informants in Bangladesh noted that as more products are being fortified and as more areas in Bangladesh are urbanizing, there will be an increase in use of fortified foods. Given this, it is quite possible that a product like Pushtikona would not be needed.

Innovation in Product Size, Product, Packaging and Delivery

There were several key informants who made suggestions to focus on innovation in the product itself and packaging itself. This ranged from making the product available in different sizes, being more environmentally friendly with respect to the packaging to re-useable packaging that might be an incentive for mothers to purchase/use the product to changing the product form itself.

In Vietnam, program implementers assessing the monitoring data found that making the product available in different volumes/amounts (i.e., boxes of 10, 20, 30 and 60 sachets) was very effective in the promotion and uptake of MNPs (Nguyen, Poonawala, Leyvraz, Berger, Schofield, Nga, Van, Hoa do, et al., 2016). Providing different options of number of sachets per box allowed for risk mitigation and led to more caregivers purchasing the product. Sachet sales in smaller quantities could lower cost and thus encourage uptake/purchases by caregivers in other contexts.

Exploring technological innovations in the product and in the packaging might make MNP delivery cheaper, which might prove to be a way forward particularly within the context of full-cost distribution. According to one key informant, this product has not changed in 20 years, but the consumer and the market has moved on. The KI also felt that the lack of innovation in developing MNPs into viable and aspirational products was as much a problem as low coverage and adherence of the existing product form. Further, even if these issues were addressed, making the business case to the private sector for MNPs was difficult, a task further compounded by environmental considerations on the use of aluminum foil packets. The KI did not seem optimistic about the potential of a sustainable market based on the current product form. One way, noted by the KI, of ensuring private sector engagement was through institutional markets (e.g., private sector supplying to UN agencies), which in turn translated into the requirement of donor support.

MNP Composition

A 2013 HF-TAG manual on MNP composition identified 30 different MNP formulations between 2003-2012 (2013). All formulations contained iron and the most common form of iron was ferrous fumarate (24/30). Twenty-nine of the 30 formulations were meant to target older infants and young children. An additional grey literature review found 28 different MNP formulations, most of which consisted of 12 or more micronutrients (HFTAG, 2013). HF-TAG has recommended that MNP formulations should be adjusted to meet the micronutrient needs of specific populations in each MNP program and provides dosage recommendations based on recommended nutrient intakes (RNIs) for 15 micronutrients for infants and young children and pregnant and lactating women (PLW). The 2016 WHO guidelines stated that MNPs can be used as a preventative implementation strategy at the population level without screening for any condition or disease (WHO, 2016); however, children diagnosed with a specific micronutrient deficiency should be treated appropriately. In malaria-endemic areas the WHO continues to recommend the use of MNPs, but programs should be implemented in conjunction with preventative, diagnostic, and treatment measures for malaria in that setting. However, in areas with vitamin A fortified foods, risk of inadequate and high intakes of vitamin A should be assessed before implementing any MNP program and vitamin A may be included or excluded from the MNP accordingly. In settings with high-dose vitamin A supplementation (VAS) MNPs can be combined as part of a national micronutrient strategy since VAS does not supply regular vitamin A to the diet. The WHO has based its recommendation of frequency (90 sachets/doses in a 12-month period) on two systematic reviews (De-Regil, Jefferds, & Peña-Rosas, 2017; De-Regil et

al., 2011). The number of sachets/doses can be adjusted dependent upon known micronutrient deficiencies at the population-level. At least one key informant indicated the need for future research and the need to pay attention to the inclusion and dosage of iron and zinc in MNPs.

The Role of Inflammation and MNP formulation

A systematic literature review in 2012 showed that in 17 studies, MNP, on average, reduced the prevalence of anemia by 34%, reduced iron deficiency anemia by 57%, and reduced retinol deficiency by 21% (Salam et al., 2013). However, the review concluded that while there are associations between MNP consumption and improvements in anemia and hemoglobin, the evidence also suggests an increase in diarrhea and a null impact on growth. This review cautioned that careful consideration and additional research should be in place before scaling-up of MNP delivery (Salam et al., 2013). This caution stemmed primarily from one cluster-randomized trial in Pakistan that also found an association between MNP consumption and reduced risk of iron-deficiency anemia, but also a significant increase in proportion of days with diarrhea and increased incidence of bloody diarrhea between six and 18 months (Soofi et al., 2013). This study also recommends a careful assessment of the potential risks and benefits from iron containing MNP interventions in populations with high diarrhea burdens and malnourished children. Additionally, according to one KI, concerns have been raised in Bangladesh where the iron content of water is high and serum ferritin levels are normal. The KI noted that within the country, questions have been raised especially by the government as to whether the iron content in MNP could be harmful to children.

According to a small 2019 controlled study in Kenya (n=28), iron-containing MNP delivered with antibiotics to children aged eight to ten months was associated with a decreased efficacy of the broad-spectrum antibiotic and increased risk for diarrhea (Paganini et al., 2019). The sample size for this study was small and for a particular context, however, so further research is needed on a larger scale and for different contexts to determine the interaction between concurrently delivered MNP and antibiotics. If the findings of this study were to be reproduced and confirmed in larger trials, delivery of MNPs might need to be temporarily suspended during antibiotic treatment of infants (Paganini et al., 2019). Environmental enteric dysfunction (EED) is a disorder in which the small bowel is inflamed. In low-resource settings, EED has been associated with growth faltering, immunity impairment, and micronutrient deficiencies (Long et al., 2019). Diagnosis of EED using noninvasive biomarkers is a significant challenge. According to a 2019 study in Bangladesh, zinc absorption from MNP is low in young children with evidence of EED (Long et al., 2019). In this study, children were given one of four dosages of zinc as part of an MNP, and multiple biomarkers of systematic and intestinal inflammation were collected. Irrespective of the zinc dosage, zinc absorption was low in children who exhibited strong evidence of EED, suggesting that further research is needed to determine the appropriate zinc dosage as part of an MNP in settings with high risk of EED.

Better characterization of micronutrient deficiencies in a population

An important point raised by a key informant was the need to assess the presence and extent of micronutrient deficiencies using both diet and biomarker data prior to any programming around micronutrients. There is need to go beyond the measurement of anemia, the common indicator used for measuring effectiveness of MNP delivery. There are few or no studies that have assessed impact of MNP consumption on micronutrient deficiencies other than iron deficiency anemia. There is need also to assess the prevalence of deficiencies within the context of infection and inflammation and genetics (particularly in South Asian populations) prior to deciding on the implementation of any MNP program (either national or sub-national). It is also critical to understand the cause of the deficiencies and explore what other interventions are being implemented. Several key informants felt that MNPs were not a silver bullet and that they were one of many available interventions that target micronutrient malnutrition. Thus, they should not stand alone but rather be incorporated into a wider strategy targeting micronutrient malnutrition. Several key informants believed there was need to consider other strategies of intervention such as fortification, bio-fortification and supplementation along with the promotion of diverse and quality diets.

To further this argument Neufeld and Cameron have pointed out that, “Relying solely on prevalence of deficiency identifies only those who have reached a state of insufficiency so as to alter biochemical or biological processes. Most biomarkers identify deficiency and cannot be used to assess whether intakes are optimized or whether there is a risk of excess intake” (Neufeld & Cameron, 2012). Complementary data are necessary to fully understand the cause and extent of micronutrient deficiency prevalence. KIs also emphasized that in addition to assessing prevalence, regular diet and biomarker assessments would prevent geographic mis-targeting and capture lack or excess of exposure to micronutrients in general. This was particularly an important consideration in the case of excess iron in infection-prone areas of the world. Solutions that are being developed include a tool called the MiniMod that would allow for a more comprehensive assessment of micronutrient deficiencies using both diet and biomarker data and to predict the effects of alternative micronutrient intervention programs (and combinations of them) on the intakes of key micronutrients. The researchers have also been working on developing a model that will allow them to predict the costs of implementation along with identifying the most cost-effective strategies to address micronutrient deficiencies over a 10-year period. Dietary data, biomarker data and predictive modeling may help to direct the policy discussions and prioritization around micronutrient interventions, but these data and approaches have their own limitations. For example, even where nationally-representative data exist for dietary intake, these data are often not sufficiently nuanced to account for variability by geographic, economic, or ethnic group (Neufeld & Cameron, 2012). Understanding additional factors such as the capacity of the governmental health system, existence of other nutrition-related interventions and programs, capacity for sustained MNP delivery, governmental and donor support would help to determine the potential need and success of MNP programs.

Discussion

Determining as good as possible models for delivery is critical for successful scale-up of proven interventions. The delivery of MNPs has been extensively studied, yet challenges linked to implementation and delivery model type persist. Our review focused primarily on understanding the MNP delivery models linked to existing IYCF programs and distributed through different channels. We found both global knowledge and country-specific knowledge to be extensive and recommendations included considering a hybrid model of MNP delivery with some support from the donor community, contextualized for local implementation in conjunction with continued support for SBCC and training for IYCF messaging and use of MNPs.

Many of our KIs recommended the use of hybrid or mixed models as a way forward. According to these key informants, hybrid models are the most likely delivery method to sustainably extend coverage to the most vulnerable while simultaneously reducing programmatic costs. The re-investment of profits earned from those who can pay to reach lower income groups (who pay for sachets at lower cost) has been an approach used in Vietnam. Another type of hybrid model is co-existence of full- and subsidized-cost models but there are caveats with respect to consumer perceptions, as well as perceived disincentives for private sector engagement. Providing multiple access points to MNP at tiered cost levels (either cost per packet or ability to choose boxes of different sachet quantities) is another recommended strategy. According to KIs, if demand is established, even the poorest families may choose to sometimes purchase MNPs if their cost is less than the time cost spent in obtaining MNPs for free. There was clear consensus across the interviews that the models should reach those that need it most. Full-cost models seemed unable to reach those most at need, particularly the poorest segment of the population. At an individual level, the acceptability to purchase an MNP decreases as wealth decreases. At a systemic level, while some countries might have well-developed markets, markets in remote and rural areas are considered too immature for a product like MNPs. These two issues would need to be addressed for a stand-alone full-cost model to work. Any efforts to support a full-cost model in such regions would require significant investment in local-market and supply-chain development.

There was significant variability in coverage, level of demand creation and behavioral change communication. Programs that were able to achieve a higher coverage, were those that created awareness as well ensured removal of any barriers in supply and in demand. Sustained use was one of the major challenges in all countries where coverage and adherence were measured. The case studies also revealed that the more often a health worker and or agent interacted with a caregiver, the more likely the caregiver was to correctly use and continue use of MNPs. This result is complemented by the finding that linking households to health services in general was positively associated with increased uptake of recommended health practices.

Thus, future MNP delivery must be linked to robust SBCC, counseling, demand creation and inter-personal communication. Sustained and consistent interactions were associated with increased demand, improved compliance, and adherence. Such

interactions were also important for minimizing any negative perceptions of the product itself or its quality. This was regardless of delivery model type making it essential for the success and sustainability of any MNP program, sub-national or national. In addition, irrespective of the model type, across most countries, frontline workers that were tapped for either free or fee-based delivery models were also the source of SBCC. These cadre of workers were found to be over-burdened and in need of training. Even well-trained workers had time constraints thus being unable to provide comprehensive support on IYCF. SBCC was most effective when health workers not only received frequent training but also received information on the management of MNP side effects.

Challenges in production, procurement and supply at the local level were systematic barriers to programmatic success, originating in some instances in poor or non-existent infrastructure. Some of the activities implemented as pilot programs were unable to troubleshoot supply-chain issues. Procurement was primarily through international suppliers and there was a clear consensus for localizing production and procurement and supporting the development and implementation of appropriate regulatory guidelines and quality assurance measures. Irrespective of model type, donor investments to manage startup costs linked to advocacy, guidance, regulation development and implementation, product supply, human resources and distribution are needed. In full-cost models, limited demand and low-profit margins are common risks that to lead to increased costs for social marketing and promotion.

A need for innovations across the delivery system (the product, the model, the platform and the channel) were noted. For instance, there is need to think of creative ways to bring MNPs to the markets and/or for sales in remote areas (e.g., as part of a basket of goods or services) such that the cost of delivery is spread across the basket. In order to reduce costs, it is important to identify the correct delivery model, platform and channel for each targeted sub-population. Furthermore, innovations of the product itself are needed. The lack of innovation in making MNPs a viable and aspirational product likely contributed to its low coverage and adherence. Innovation in packaging will also be critical for ensuring environmental sustainability but also possibly in providing incentives to mothers to continue use of the product (either from a cost or re-usability of the packaging perspective). Inputs are needed to understand and improve capacity while also potentially improving MNP packaging so that it has a longer shelf-life.

We found little literature that compared the different model types and, while there is emerging cost-effectiveness evidence, there is still a critical gap in our understanding of how delivery models would perform compared to each other thus preventing us from making a strong case of one model over the other. There was also very little comparative literature that examines coverage and subsequently improved outcomes using different model types. This is clearly an important research and programmatic need. We also noted the need to consider developing a wider strategy of micronutrient interventions and determining the unique position of MNPs. The assessments would also be helpful in ascertaining the changing demographics and changing micronutrient needs of any target population. And finally, linking policy and programs to science is critical and **r**esearch on the dosage of iron and zinc in MNP and the risk and benefits of

iron in MNPs in populations with high diarrhea burden particularly within the context of antibiotic delivery is needed.

Conclusion

This in-depth review was undertaken to bring together evidence (published and grey literature) and knowledge from key stakeholders involved in MNP delivery with experience either global or country specific with a focus on the type of delivery model implemented through existing IYCF platforms. Based on the review and interviews, the subsidized or hybrid model is a potential leading option for ensuring that children most at need are reached in a consistent and sustainable manner. In addition, we found a clear need for investments in production, procurement, innovations in the product itself as well as in the packaging. Despite the dwindling of donor support for free distribution, it was clear from our review and interviews that irrespective of the model chosen, donor investments would continue to be needed to cover start-up costs for supply, human resources, continued counseling and training, advocacy and support for guidance and regulation development and enforcement and training.

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Tables

Table 1: Literature Review inclusion criteria

Search Years	**Jan. 2009 – present**
Databases and Resources	• GAIN • PubMed • Google Scholar
Search Terms	
Micronutrient powder(s)	
AND	
1. Access	23. Policy
2. Branding	24. Price
3. Capacity	25. Private
4. Composition	26. Procurement
5. Cost	27. Public
6. Cost-effectiveness	28. Purchase/Purchasing
7. Coverage	29. Reach
8. Delivery	30. Retail
9. Demand/Demand Creation	31. Scale-Up
10. Distribution	32. Social behavior change
11. Donor/Donor Funding	33. Social-marketing
12. Effectiveness	34. Sprinkles
13. Effective Coverage	35. Stakeholders
14. Fee/Fee-based	36. Strategy/Strategies
15. Frequency	37. Subsidies
16. Government	38. Supplementation
17. Hybrid	39. Supply
18. Indicator	40. Supply chain
19. Intervention	41. Sustainability
20. Market/Marketing	42. Unit price
21. Monitoring	43. Voucher
22. Packaging	

Table 2: Areas of inquiry included in the key informant interview

Area	Types of Inquiry
General	Experience with systems that deliver micronutrient powders
	Countries of expertise
	Challenges in scale up of MNP delivery
Knowledge and Perceptions (Specific by Model Type)	
	Involvement and Engagement in implementation and/or research on specific model types
	Factors that led to the decision on choosing a specific model type
	Barriers and challenges encountered in implementation
	Type of coverage by model type
	Individual adherence by model type
	Misuse/inappropriate use of MNPs
	Considerations and challenges in ensuring sustainability
	Opinion on what an effective model would be
	Value of each of the models compared to one another
Stakeholder Perception (Specific by Model Type)	
	Government Stakeholders
	Non-Government stakeholders
	Private sector providers
For Program Implementers	
	Type of Model Implemented/tested
	Source of MNP for program/study
	Challenges around MNP delivery
	How was MNP delivery assessed
	Was there assessment of coverage, change in demand, acceptance, perceived value
	Perceptions of the value of each type of model (compared to the others)
Future of MNP delivery	
	Familiarity with unique models that combine existing approaches
	Success and replicability of such approaches
	Any program or non-program factors that affect MNP delivery (positive or negative)
	Recommendations for the future of MNP delivery
Other Questions	
	Literature (grey/published) that you would recommend
	Other experts that you would recommend

Table 3: Key Informant Characteristics and Region of expertise

Type of Affiliation	**Number of Key Informants**
Academic Institution	10
UN Agency	3
Private Sector	4
Non-Governmental Organization	7

Region	Number of Countries
Central Asia	1
East Asia	2
East Africa	4
Latin America and Caribbean	5
South Asia	2
South-East Asia	4
Southern Africa	3
West Africa	2

Table 4: Advantages and disadvantages by delivery model type

Model	Advantages	Disadvantages
Free	Cost sharing if high level of integration (both health and non-health sector), can be built into routine training for IYCF and will allow for linkages with IYCF information, services and referrals and has the possibility of being scaled-up into the national system. The free model is also likely to target more successfully vulnerable households and it might be more feasible to scale-up at a sub-population level.	Free models may rely on substantial external funding, IYCF programs may be weak, quality compromised at scale. Distribution might be variable particularly within a health system with weak supply management and reach may not be uniform, likely to overburden the national health system.
Full cost	It is commercially funded, lower likelihood of stock outs, potential easy access (e.g., retail channels) and can be taken to scale using a market-based platform.	Requires a well-developed commercial sector and substantial start-up investments. Linkages with IYCF information, services and referrals often lacking, training is likely to be limited and does not reach households in need that cannot pay.
Subsidized/Mixed	Potential to recover programmatic costs and expand scale- can reach population across the wealth spectrum. With respect to the mixed platform, likely to reach population sub-groups that are willing and able to pay a price that will support free distribution for those in need.	Relies on some level of external funding, requires specific sales training for MNP distributors. Specific to mixed models, free MNP could undercut commercial sales with leakage between MNP products at different prices.

44. Source: Extracted from Reerink et al 2017.

Table 5: Assessment of Delivery Models: Country Examples

Country	Program	Product Name	Implementation Partners	Scale	Primary Target Group: Children	Cost to Target Recipient
Bangladesh	Social Marketing of In-Home Fortification of Complementary Foods Using *MoniMix*	MoniMix	Social Marketing Company and USAID	National	6-59 months	Full cost
	Nutrition Recovery Response to Emergency (Cyclone Aila)	MoniMix	Shushilan - national NGO	Sub-national	6-23 months	Free
	Prevention and Control of Anemia in Children with MNP	MoniMix	Integrated Community Development Project, Chittagong Hill Tract (CHT) Development Board, Ministry of CHT Affairs	Sub-national	6-36 months	Free
	MNP Supplementation and IYCF Counseling for Children 6-23 Months	MoniMix	Directorate General of Family Planning, Ministry of Health and Family Welfare	Sub-national	6-23 months	Free
	Sprinkles Programme	Pushtikona	BRAC, GAIN, Renata	Sub-national	6-59 months	Full cost
Ethiopia	In Home Fortification Project in Amhara and Tigray Regions	Desta	GAIN, Concern Worldwide (CWW) and with funding from the Ministry of Foreign Affairs of the Netherlands, supported the Federal Ministry of Health (FMOH)	Sub-national	6-23 months	Free
Indonesia	Improved Nutrition through Fortification with Taburia MNP and Balanced Diet	Taburia	Ministry of Health	Sub-national	6-23 months	Free
Mozambique	Healthier Lives for Mozambique' Children, One Sprinkle at a Time	Super Bebé	PSI Mozambique	National	6-59 months	Full cost
Vietnam	Home Fortification Pilot Project	Bibomix	National Institute of Nutrition (NIN), the Ministry of Health and Provinces, Institut de Recherche pour le Développement (IRD), Nielsen Company, Columbus Branding, Hanoi International Television Company, and Alive & Thrive Vietnam	Sub-national	6-23 months	Full cost