



Evaluating Business Criteria for Scaling Stock of Malaria Rapid Diagnostics

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Background & Motivation

In spring 2015, researchers in the Comprehensive Initiative on Technology Evaluation (CITE) at MIT developed a study to better understand the scalability of malaria rapid diagnostic tests (mRDTs) in Uganda. mRDTs offer a fast and accurate means of diagnosing malaria in settings where microscopy is unavailable or unreliable. The diagnostic tests are promising for the private sector because they require no fixed asset investment or electricity, are easy to interpret, and entail relatively little training.

In much of the developing world, feverish patients are diagnosed with malaria without confirmation by mRDT or microscopy.¹ Diagnosing malaria by clinical symptoms alone is very challenging because many malaria symptoms are nonspecific and overlap with other indications. One study found that 74% of patients with fevers in Uganda were given antimalarial medication but only 35% of the patients actually had a positive mRDT result.² Over-diagnosis of malaria is common not only in Uganda, but across sub-Saharan Africa.^{3,4,5}

Accurate diagnosis is important, since non-discriminatory treatment could lead to widespread resistance to artemisinin, the base compound for artemisinin-based combination

therapies (ACTs). This could incite a global public health crisis, as “no other antimalarial medicines are available that offer the same level of efficacy and tolerability as ACTs, and few promising alternatives are available in the immediate research and development pipeline.”⁶

The private sector uptake for mRDTs is especially critical in countries like Uganda where the majority of patients first seek care from private clinics, pharmacies, and drug shops.^{7,8} However, in only 3 of 10 countries recently surveyed did private-for-profit sector availability exceed 20%; one of these countries was Uganda.⁹ Higher stock levels in the private sector supply chain are critical for increasing access and use of the devices in many countries.

Most mRDT studies have focused on factors that influence patient decisions, with some study of retailer decisions, and no study of their upstream supplier decisions.^{10,11,12} A study in Uganda found significant heterogeneity in retailer adoption of mRDTs, but the reasons were unclear; the authors offered one consideration (minimum order quantity from wholesalers) and called for further research on adoption decisions.¹³ This study fills a gap in understanding the mRDT decision making

Key Recommendations

The results of this study indicate that private sector preferences and priorities vary by agent role in the supply chain, and include a wide range of factors that influence the decision to stock mRDTs. Two recommendations emerge from this study:

1. For retailers, **malaria diagnosis should be framed as a service** to be provided rather than a product to be sold.
2. Business objectives and risks vary among agents in the supply chain, indicating an **opportunity to design business models and risk sharing contracts** that are better aligned with incentives.

criteria for retailers and their suppliers. It explicitly considers the preferences and priorities of private sector agents across the supply chain when deciding whether or not to include mRDTs in their offerings, and if so, how much to stock.

Context & Methodology

The limited penetration of mRDTs in the private sector means that only a small number of suppliers have made decisions regarding the product. Moreover, we wanted to explore various criteria that could influence decisions, such as related services. As a result, we conducted an in-depth study of the complete supply chain for a pilot, facilitated by Malaria Consortium, that introduced an “enhanced malaria RDT bundle” in the heavily populated Wakiso district in Uganda. The bundled service included training to retailers, biohazard disposal, marketing, and barcoding of devices. Following an open invitation, Malaria Consortium selected for the pilot two manufacturers that make devices approved by the World Health Organization (WHO) and that would make provision for the bundled services through in-country distribution partners.

The pilot involved one first-line buyer (FLB) for each manufacturer that was able to import the devices and three distributors that replenished retailer stocks and provided retailer training. Malaria Consortium provided technical assistance, training and supervision, and performance-based incentives along the supply chain but did not interfere with business activities. The pilot reached around 180 private sector clinics, drug shops, and pharmacies across the Wakiso district.

The research team conducted focus group discussions and interviews with agents at several stages in the pilot supply chain: both first-line buyers, all three distributors (though one distributor opted out of some questions and the incomplete data were not used for analysis), and 28 retailers. Note that while the number of upstream actors in the sample was low, the data collection included the full population of such actors exposed to this bundled service option. Multi-criteria decision analysis (MCDA)¹⁴ was used to elicit (i) which criteria are important in making decisions regarding how many, if any, mRDTs to keep in stock, (ii) the relative importance (weights) of the criteria, and (iii) the level of performance that agents seek for each criterion. This study adapted MCDA elicitation protocols to be applicable in the Ugandan context and understandable to the agents who participated in the study.

Key results of the multi-criteria analysis are presented here with some discussion. For further reading, please refer to “Using



CITE Researcher and MIT Graduate Student Corinne Carland leads a focus group discussion on malaria rapid diagnostic tests.

Multi-Criteria Decision Analysis to Assess Private Sector Agents’ Preferences and Priorities in Stocking Malaria Rapid Diagnostic Test Kits in Uganda.”¹⁵

Decision Criteria & Weights

Through a literature review, interviews, and focus group discussions with respondents, researchers identified 17 criteria as factors that agents in the supply chain considered when making decisions about stocking mRDTs (Table 1). Most criteria were determined in advance through expert interviews and literature, though some emergent criteria raised by respondents during interviews and focus groups were also included.

To elicit the weights, the focus group leader asked each individual to weigh each criterion using range of 0-100 and to set the most valuable criterion with a score of 100. The weights in Table 1 are based on the median values for the retailers and actual values for each of the individual distributors and FLBs; all criteria are normalized to a sum of 100. Blanks in the table represent criteria that were not expressed as relevant or important to that particular agent. Note that profit is included as a criterion in addition to cost and price in order to reflect respondents’ preferred responses.

Overall, there is a variation in the spread of weights between the supply chain agents. Retailers have a narrow range, from 7.4 to 10.8, while the FLBs have a wide range from less than 5 to over 20. This may indicate cognitive biases, which could be explored through future work.¹⁶ Some criteria, such as cross sales of other products like malaria treatments, are critical for all agents. Other criteria vary by role in the supply chain. For example, training is relatively important for the retailers providing the patient service; only the cost of training is relatively important for the distributors who provide this service. The relative weights for each agent reveal the most salient aspects in their business decisions.

Table 1: Decision criteria and normalized weights for supply chain agents (all weights normalized to 100)

Criterion	Retailers (based on median value, n=28)	Distributor 1	Distributor 2	First Line Buyer 1	First Line Buyer 2
Training	10.8				
Time per sale	10.5				
Awareness/ads	9.6				
Customer satisfaction	9.6				
Time to delivery	9.6				
Quality	9.0			20.9	19.8
Price of device	9.0			23.3	15.4
Cost of device	8.4	16.5	14.6	7.0	22.0
Sales of other products	8.4	11.6	13.0		17.6
Other opportunities	7.8				
Volume	7.4	16.5	16.3		
Expiration date		14.9	15.4		
Efficiency of distribution		14.9	14.6		
Profit		14.0	13.0	4.6	11.0
Cost of training		11.6	14.6		
Relationship w/ NGO				23.3	12.1
Administrative time				20.9	2.2

Note: Cost is defined as the amount paid by the agenda to procure the device and price is the amount received by the agent upon sale.

Value Functions

In addition to the relative importance across criteria revealed by the weights, it is important to consider the level of performance that agents seek for each criterion. Such preferences are revealed by eliciting a value function for each criterion, where value represents the satisfaction that an agent derives from various levels of criterion performance. In this study, the primary method employed was direct rating, which requires respondents to apply a score to various points of the criterion. Respondents provided a numerical value for points on a continuum between the upper and lower performance bounds, which were assigned the highest value (5) and lowest value (1) respectively. Piecewise linear interpolation was used to create a continuous value function.

The value functions reveal the range of performance that is desired by agents and also the marginal gain in value with increases in performance, which is not always constant. For example, consider Figure 1 where value is plotted as a function

of the profit margin for first line buyers. Clearly, a profit margin of 0% has minimal value, but the range varies by agent: FLB 1 gives a maximal value at 50% margin while FLB 2 seeks 100%. The marginal increase for both is greater on the low end, with the marginal value dropping notably at 10% margin for FLB 1 and dropping slightly at 30% margin for FLB 2.

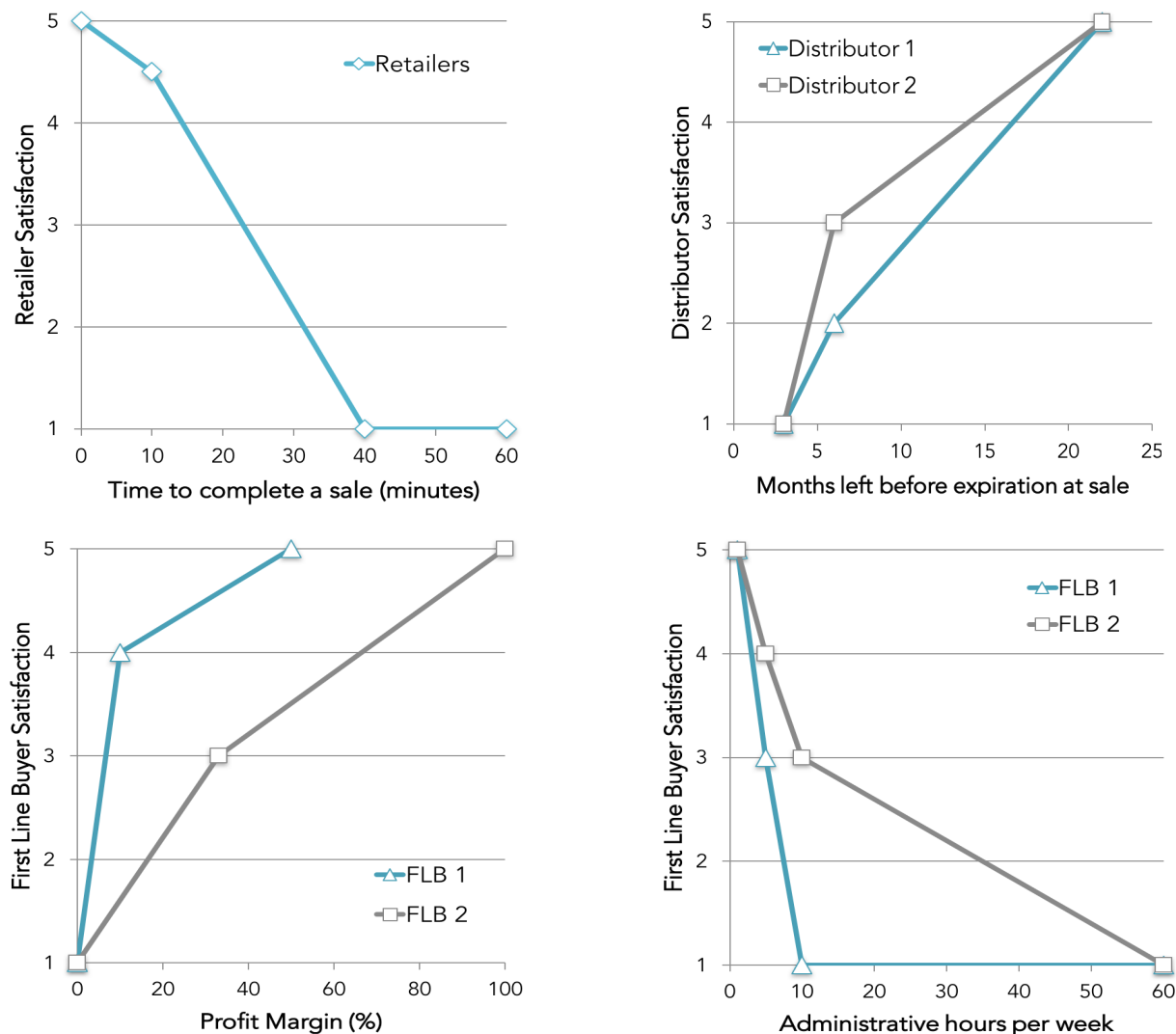
Findings

Considering the criteria weights and value functions together, several insights for the various agents emerge. In addition, the direct combination of weights and values enable evaluation of overall bundled service options.

Retailers value training and are most concerned about time to complete a sale

The highest weighted criterion for retailers was training on how to administer the devices. This sentiment was echoed in conversations where retailers expressed appreciation in learning about the importance of diagnosis and how to offer another

Figure 1: Value functions for various agents and criteria



service to customers. It is not surprising that training is ranked highest since it is a fundamental requirement enabling retailers to offer diagnostic services.

Interestingly, this study discovered that the next most important criterion for retailers was the amount of time required to complete a sale, with a relative weight greater than typical business objectives of profits or sales volume. The sales transaction is not simple since the retailer needs to explain the importance of diagnosis, administer the mRDT, wait for the results, and then provide appropriate treatment (either an antimalarial or other medicine); this process can take up to 60 minutes. In the meantime, other sales may be lost if customers enter and find the retailer occupied. Value functions show that retailers were generally fine spending up to 10 minutes with a

customer; they were completely dissatisfied with sales taking 40 minutes. The relative importance of this criterion reveals that retailers fundamentally view the mRDT as a service, with time associated, rather than a product with a simple sales transaction.

Distributors bear most of the stock risk

The criteria weights reveal the risk structure of this supply chain. In the Malaria Consortium pilot, the distributors owned most of the stock and, thus, faced the greatest losses for unsold products that expire. For them, expiration date and sales volume were weighed among the most important criteria. The value function shows that products with three months of shelf life have minimal value for distributors and the value only increases slightly with six months.

The retailers were able to place small orders from the distributors to avoid expiration risk; as a result, expiration date was not even considered a concern for retailers and sales volume received the lowest weight among criteria considered. The first line buyers consider neither expiration date nor sales volume since they did not bear financial risk once the sales transaction to distributors was completed.

First line buyers have different business strategies

Criteria weights show that relative priorities between the first line buyers differ, which may point to distinct business strategies. FLB 1 puts much higher weights on NGO relationships and administrative time, and is unwilling to invest more than 10 hours per week on managing mRDTs. In contrast, FLB 2 puts more weight on profits and cross sales, with a value function indicating a desire for much higher profit margins; yet FLB 2 is willing to invest more time in achieving these financial results. Agents playing the same role as the supply chain may have different preferences that may be important to consider when designing business models.

Evaluating bundled service options

The value of various bundled service options can be determined for each agent in the private sector supply chain using a direct combination of weights and values. The study evaluates four options: (1) sell WHO-approved mRDTs with no bundled services, (2) sell WHO-approved mRDTs using Malaria Consortium's bundled service, (3) sell mRDTs that are not approved by the WHO, and (4) not stocking mRDTs at all. For each option, performance levels for all criteria are determined, from which values can be calculated based on the function for each agent; the overall score for an option is a weighted sum of these values using the agent's criteria weights. Table 2 shows the overall value, based on value functions and weights, for the different agents.

These results show that the highest value option for one agent



A one-step malaria rapid diagnostic test. Credit: Corinne Carland

was not necessarily the best for another. First-line buyers and retailers prefer a bundled service of mRDTs. A key factor for retailers may be the high value that they placed on training, which was a key component in the bundled service. In contrast, distributors would prefer selling mRDTs outside of the bundled service, perhaps due to the cost of training and the financial risk from stock expiration. Modifying aspects of the bundled service could serve to better align incentives across the supply chain and drive higher sales volumes.

Recommendations

The results of this study indicate that the private sector preferences and priorities vary by agent role in the supply chain and include a wide range of factors that influence the decision on whether or not to stock mRDTs. Two recommendations emerge from this study:

1. For retailers, malaria diagnosis should be framed as a service to be provided rather than a product to be sold.

Results show that retailers' decisions consider the time to complete a sale and appropriate training as more important than profits or sales volume from the product. This indicates that retailers fundamentally view the mRDT as a service, with

Table 2: Overall value for supply chain agents on a scale of 1 (low) to 5 (high)

Option	First Line Buyers	Distributors	Retailers
Sell WHO approved mRDTs	2.86	2.63	2.74
Sell WHO approved mRDTs through bundle	3.39	2.02	3.78
Sell non-WHO approved devices	2.29	2.56	1.85
Do not sell mRDTs	1.84	1.83	1.57

Note: The two distributors' and first line buyers' results are averaged.



Women and children in rural Uganda look on as the service provider from a nearby health center provides malaria tests for communities on the lake's edge. Credit: Kim Burns Case

important time associated, rather than a product with a simple sales transaction. Framing the business opportunity as a service rather than a product may be critical for increasing mRDT availability.

This shift in emphasis is in line with recent thinking in the development space. A Roll Back Malaria working group noted the distinction between campaigns to increase access to artemisinin combination therapies (ACTs) and interventions to ensure diagnosis before treatment. That discussion recognized that, in addition to ensuring access to affordable devices, malaria diagnosis should be supported by training, quality-assurance, demand generation, a referral system, and safe disposal of biohazard waste.¹¹ These results from Uganda indicate that retailers place high value on these supporting aspects and a service model that bundles them. Reframing diagnosis of malaria as a service may also pave the way for initiatives that further bundle diagnosis and treatment into one package with one price. Such a package could be priced and marketed so that both patients and retailers prefer the package that includes diagnosis

and appropriate treatment to the sale of treatment alone.

2. Business objectives and risks vary among agents in the supply chain, indicating an opportunity to design business models and risk sharing contracts that are better aligned with incentives.

The study found that agents in the mRDT private sector supply chain preferred different business model options. The criteria weights and value functions point to different business strategies and incentives across supply chain roles and also among agents playing the same role. This result points to the importance of understanding decision-maker preferences and evaluating the options that produce the relative highest value. Such information enables design of programs and business models that align incentives and maximize value across the supply chain.

In addition, the weights and value functions clearly exposed the issue of concentrating the product expiration risk with one agent in the supply chain. Mechanisms to share risk across agents may relieve pressure on the distributors and encourage greater buy-in and collaboration among all the agents. There is potential in further study of risk sharing contracts for mRDT supply chains.

This study fills an important gap in understanding the decision criteria of various actors across the supply chain for malaria rapid diagnostics. More generally, it demonstrates the potential for employing multi-criteria decision analysis as a tool for evaluating multi-actor supply chains in such contexts (see text box). One limitation of the study is the small sample of actors exposed to mRDTs and related services. Further research is needed to confirm and extrapolate the insights drawn from this in-depth study of decision criteria in Uganda. Hopefully this study contributes to an expanded evidence base by helping to scale up private sector stock of rapid diagnostics among populations at risk for malaria.

SPOTLIGHT: MULTI-CRITERIA DECISION ANALYSIS

Multi-criteria decision analysis (MCDA) was chosen as a methodology for this study because of the complexity of stocking decisions and the multiplicity of agents. The agents involved in the supply chain – manufacturers, first line buyers, distributors, and retailers – each make their own decision, but their respective decisions influence and shape other agents' decisions. Further, there is a collaborative component; the devices cannot reach the end user without some sort of agreement between the agents. Finally, each agent was faced with a variety of criteria – and tradeoffs among these criteria – that may be considered in reaching a decision. MCDA¹⁷ is a methodology that draws from decision sciences, operations research, and economics; it is most useful for complex decision problems where there are multiple objectives and no clear optimal decision. MCDA methodologies have been employed in a wide range of settings, including public health,^{18, 19, 20} finance,²¹ sustainable energy,²² national resource management,²³ and more. MCDA has particular potential in the developing world context.²⁴

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Cover photo: A health worker in Kalangala District, Uganda, tests a client for malaria using a Rapid Diagnostic Test. Credit: Ritah Mwangale

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