Toward a Market-Based Lean Startup Product Design Method for the Developing World

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TOWARD A MARKET-BASED LEAN STARTUP PRODUCT DESIGN METHOD FOR THE DEVELOPING WORLD

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ABSTRACT
The question of how to effectively design products for consumers in the developing world has been widely debated. Several methodologies have been developed to address this issue focusing on human centered and community centered methods, but few methods are rooted in market-centered approaches. Recent advances in market-centered design from lean startup methodologies hold promise for the development of new methods that allow effective product design for consumers in the developing world. This paper contributes a method from which consumer level products can be designed to effectively supply the under-served markets of the developing world with innovative and sustainable solutions. Utilizing an iterative method based on three fundamental hypotheses, the Lean Design for Developing World Method (LDW) seeks to provide products that are economically viable, have strong market growth potential, and have a net positive impact on the customers and their communities.

1 INTRODUCTION
The topic of design for the developing world is one full of complex interdisciplinary challenges. Solutions to the challenges of designing for the developing world require an interdisciplinary approach [1]. The motivation for the research presented in this paper is to develop a method for consumer product design that is applicable to the needs and challenges of the developing world. We present the Lean Design for Developing World (LDW) method, which brings together ideas from Human Centered Design (HCD), traditional product design methods, and the lean startup methodology. LDW provides an iterative design approach that is targeted for use by businesses, NGOs, and entrepreneurs interested in developing consumer products for the developing world that have long-term economic viability for both the designers and the customers, strong market growth potential, and have net positive impact on the customers and their communities. Up-front investment of time and capital is significantly reduced, and data limitations are addressed with LDW through the shortening of the product ideation phase and via learning about the customer through quick product iterations.

The LDW method is based in the idea that using sales data, customer feedback, and distributor feedback creates aggregate customer needs (ACN) that can aid in the rapid understanding of a target market. The LDW method leverages ACN data to allow design teams to put aside preconceived notions and assumptions and focus only on the pursuit of finding accurate needs for their target market. The LDW method leverages the unforgiving nature of the market to keep engineers disciplined in testing the value of a product.

Existing methods such as Human Centered Design (HCD), Engineering and Sustainable Community Development, and traditional engineering product design do not fully address all the challenges currently experienced in designing consumer products for the developing world. A method that can created viable products sold at unsubsidized market prices, and lower expenses for the customer and make profits for the business is necessary to make economically sustainable product solutions.

This work was inspired by companies such as D-Rev, Nokero, and others who are working to use the market in order to make life-changing products for millions of customers in the developing world. These companies have been using cutting-edge techniques as well as homegrown trial and error methods in order to create products. Therefore a rigorous and formalized method is needed in order to start treating people in the developing world as customers instead of charitable cases.

This paper contributes a method that adapts and repurposes the lean startup methodology for the design of products for the developing world. The motivation of this research is to help create products that are profitable for the business producing the product and of value and impact for the end user. The LDW method aims to better allocate time spent by a design team to reduce waste in time and financial resources on unviable

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products. LDW also works to bring ideas from various areas of research into focus with the end goal of making valuable and impactful products designed specifically for the developing world.

2 BACKGROUND

The LDW method builds on topics from a variety of fields. This section reviews topics to provide the necessary general background for understanding the methodology of the LDW. The first topic reviewed is the design for the developing world. Next, Human Centered Design (HCD) is highlighted to show how many design teams approach challenges present in developing world design. A brief overview of a traditional product design method is provided to give an overall view of how products design is completed from a high level perspective. Finally, the basics and key terms for the Lean Startup Method are explained.

2.1 The Developing World

The term "developing" has several different definitions in the international development literature that depend greatly on the context of the end goal and type of development being examined [2]. Development can refer to social, human, and/or economic development. It is often difficult to address all aspects of development when categorizing nations [3]. Developing nations can be described as nations where people live on less than $2 USD per day, which represents a population with approximately $5 trillion USD in purchasing power parity [4, 2].

The term "design for the developing world" in this paper refers to what Polak calls the "other 90%" [5]. In his book, "Out of Poverty," Polak writes how a major problem is that 90 percent of the designers in the world spend their time working on solutions to problems for the richest 10 percent of the world's customers. Therefore design for the developing world refers to the targeted development of products for the developing world consumers who are traditionally ignored by the majority of the world's designers [5].

2.2 Human Centered Design

To achieve a better understanding of customer needs, design engineers often use the HCD methodology as defined by IDEO. In the HCD toolkit, co-developed by iDE and IDEO, HCD is defined as a "process and set of techniques used to create new solutions for the world. Solutions include products, services, environments, organizations, and modes of interaction" [6].

The first broad step in the HCD process is the Hear section. The Hear section works to identify a design challenge and gather qualitative data directly from users utilizing a variety of methods; most of which require significant field work. Observations and information gathered in this phase is used to identify areas of opportunity for new product development or the improvement of existing products. The second step is the Create section. The Create section translates what was learned in the field and proposes concrete solutions to select opportunities identified in the first phase. Lastly the Deliver section moves the solutions and plans into implementation in the field. The Deliver section then allows for the creation of a plan to measure and learn from the implemented designs [6].

Some weaknesses of the HCD method have been examined in the literature [7]. First, HCD requires large upfront investments by a design team in the form of both time and financial resources in an effort to better understand potential customers. Other representative methods used in design for the developing world such as co-design, implementation of philanthropic resources, and appropriate technology methods also require large upfront investment in time and energy before the first product is released [8, 9, 10, 11, 12, 13, 14, 15, 16, 1]. Second, the HCD method can produce limited results as people may be unaware of their needs, unwilling to speak about their needs, or unable to effectively articulate their needs with a design team [17]. Third, design teams can be prejudiced about a users' needs when they become too involved in the design process. Fourth, the design team may over-emphasize the findings from a relatively small number of users, which could lead to an over-customized product [18]. HCD provides a method from which to understand how complex and intricate design for the developing world can be, and how there is no one answer to solve all the challenges present.

2.3 Traditional Design Methods

Traditional engineering product design is efficient in designing robust, innovative, market defining products [19]. Engineering product design follows a linear progression from project definition to product definition to conceptual design to product development and finally to product support. The project definition phase works to create a business framework and model that is driven by technology developments, market direction, or product changes. These drivers push design teams to identify and choose products to develop in the product development phase. The next step is the development of a conceptual design which then is refined into a physical product in the product development step. After the product has been released, the project goes into the product support phase [20]. Numerous methods exist in the literature and are used in industry. Two methods are briefly reviewed here including Society, Technology, Economy, Environment, and Politics (STEEP) analysis and the International Council on System Engineering (INCOSE) Systems Engineering formal stakeholder needs analysis method [21, 22].

STEEP analysis attempts to derive opportunities and hidden needs by identifying broad trends in the areas that STEEP focuses upon [22]. The STEEP technique assumes the availability of data that can be difficult to attain in developing markets. Difficulty in gathering data in developing markets can lead to lengthy delays or broad assumptions in the product development cycle, cost overruns, and increases the likelihood of project failure.

Formal stakeholder needs analysis as defined by the INCOSE, and described in depth by Blanchard and Fabrycky [23], focuses on surveying key stakeholders to elicit formal requirements. This technique assumes a stakeholder that is well-informed and able to articulate stakeholder needs in appropriate, often technical language. Many developing world stakeholders do not have the technical background necessary to

effectively communicate with engineering design teams adhering to the methods advocated by INCOSE [21].

Traditional engineering product design techniques can be challenging to implement in developing markets where information is limited and the key stakeholders may not be able to clearly articulate their desires using technical language. These limitations lead to challenges with applying common engineering product design approaches.

2.4 The Lean Startup

In the developed world, companies and design teams of all sizes and across a wide variety of industries have adopted lean startup methods. Lean startup methodology, as described by Ries in "The Lean Startup," presents many ideas that have been used in startups in the United States over the past decade [24].

Ries defines a startup as "an organization that rapidly turns ideas into products." In the context of the research presented in this paper, the term "startup" will be replaced with "design team." Thinking of a design team as a startup fits the definition set forth by Ries, yet narrows the scope to engineering design teams rather than entire corporations or organizations. The design team uses the products generated from ideas and quickly places them in the hands of customer in order to generate useful data including customer feedback indicating what people like and dislike about a given product, and market and sales data that identifies product value. The market and sales data explains potential market demand between varying demographics and regions [24].

2.5 Value and Growth Hypotheses

Two initial hypotheses are required in the lean startup method and were originally conceptualized in the field of customer development [25]. They are the value and growth hypotheses.

Value hypothesis: The value hypothesis tests whether a product delivers value to customers or markets when they are using the product. It is typically a measurable, market-based metric for the design team to gauge if the product is addressing a market need through the affirmation of profitable sales and positive customer use feedback.

Growth hypothesis: The growth hypothesis tests how new customers discover a product or service. The design team uses the growth hypothesis to determine if a product is experiencing a sustainable adoption rate, sales growth, and retaining customers. It is confirmed through long-term sales growth and distributor feedback.

2.6 Minimum Viable Product

After the growth and value hypothesis are defined, the next goal is to bring a product to market in order to test these hypotheses. The tool to facilitate this testing is the minimum viable product (MVP) [26]. A MVP contains a "minimum feature set" necessary to have an economically viable product and facilitates the learning process [25]. The key to developing a MVP is to not focus on the least expensive or most simple product design, but rather focus on the minimum product feature set required to enable testing of the value and growth hypotheses. The MVP will inevitably lack many features that may later prove essential or include features that are later deemed unnecessary; however the rapid testing of the value and growth hypotheses will enable the design team to identify what is vital and what is unnecessary to the product [24].

Upon the release of a MVP, the design team will review information generated by product sales and customer feedback using pre-defined metrics and a technique called Innovation Accounting. The initial feedback from the MVP is used to prove or disprove the original value and growth hypotheses. The innovative accounting method is used to parse the gathered information in quantitative and qualitative approach that allows startups to better define the value and growth hypotheses, and subsequently the market needs [27].

2.7 Pivot and Persevere

A "Pivot" is defined as a rejection of the original value and growth hypotheses. Pivots require that the design team rethink both the value and growth hypothesis, and reflect this change in the form of a new product [24]. "Persevere" is defined as a refinement of the original value and growth hypothesis. When Persevering, the design team has found that the original growth and value hypothesis were largely accurate however slight adjustments are needed to either hypotheses, or additional optimization is needed on the product in order to better serve the customer [25].

Following a Pivot or Perseverance, the design team has completed one iterative cycle of the lean startup method. After the decision to Pivot or Persevere is made, the team returns to the first stage to either Persevere by refining an existing product changed slightly from the original MVP or Pivot by redefining the value and growth hypotheses. If after a few Pivot iterations, the original design idea is still not finding a market, Canceling the Product is the last option for the design team [24].

While the lean startup method has worked well for software companies in the developed world and is starting to see use elsewhere, it is not well-suited to applications in the developing world.

Having reviewed design for developing world, Human Centered Design, Traditional Design, and lean startup methods, it is apparent that an opportunity exists to develop a new method that helps address some of the weaknesses outlined framework above. The Lean Design in Developing World (LDW) method seeks to address the need for a method that allows design teams focused on the developing world to succeed. By eliminating the need for large up-front investment, the iterative method by which LDW operates allows for portions of the lean startup method to be applied in the developing world. Placing an emphasis on learning and iteration based upon market based feedback, the LDW method seeks to deliver consumer level products to the developing world that have strong value propositions to consumers, are profitable and have long-term viability for companies, and provide net positive impact on communities.

3 METHOD

The Lean Design in Developing World (LDW) method proposes a new, iterative design method which can be used by

businesses interested in entering developing world markets, NGOs that want to develop self-sustaining products, and other organizations and entrepreneurs who wish to design products for the developing world. The resulting products are economically viable both for customers and the businesses that produce the products, have strong market growth potential, and have net positive impact on the customers and their communities. LDW attempts to shorten up-front investments of time and capital, and address data limitation issues when designing products for the developing world. Emphasis is placed on a shortened product ideation phase and on learning about the customer from a shortened product iteration process. Learning about the customer is derived from lean startup methodologies. The LDW iterative design process can produce both quantitative and qualitative data to use in making choices on how design iterations will be conducted. The LDW parallels the tasks of understanding the customer and developing the engineering design of the product which results in a shortened design cycle. The LDW allows businesses, NGOs, and entrepreneurs to attain long-term profitability while also reducing customer expenditures on essential goods and services, and ensuring a net positive impact on the customers and their communities.

3.1 Lean Design in the Developing World Methodological Framework

At the heart of the LDW method is the idea that the market can best identify product value. The notion of product value must always remain the focus of the designer who implements market based approaches to design. The LDW method presented in this paper borrows from traditional product design methods, design for the developing world methodologies, and the lean startup method. By pulling together three diverse areas of design methodology, a novel approach to designing products for the developing world is proposed.

The LDW method has three overarching steps including: 1) Product Concept and Deployment 2) Validated Learning, and 3) Decision Making. The three steps are iterative in nature and have a decision point where one of three decision choices is made including 1) Pivot, 2) Persevere, or 3) Cancel the Product, as adopted from the lean startup literature [24]. A diagram showing how the three overarching steps interact with one another and how iteration in the LDW method is performed is shown in Figure 1.

Step 1: Product Concept and Deployment

The Product Concept and Deployment stage of the LDW is a rapid formulation of a product idea and the creation of a plan to generate value and growth hypotheses, as defined in the lean startup methodology [24], and an impact hypothesis that is not

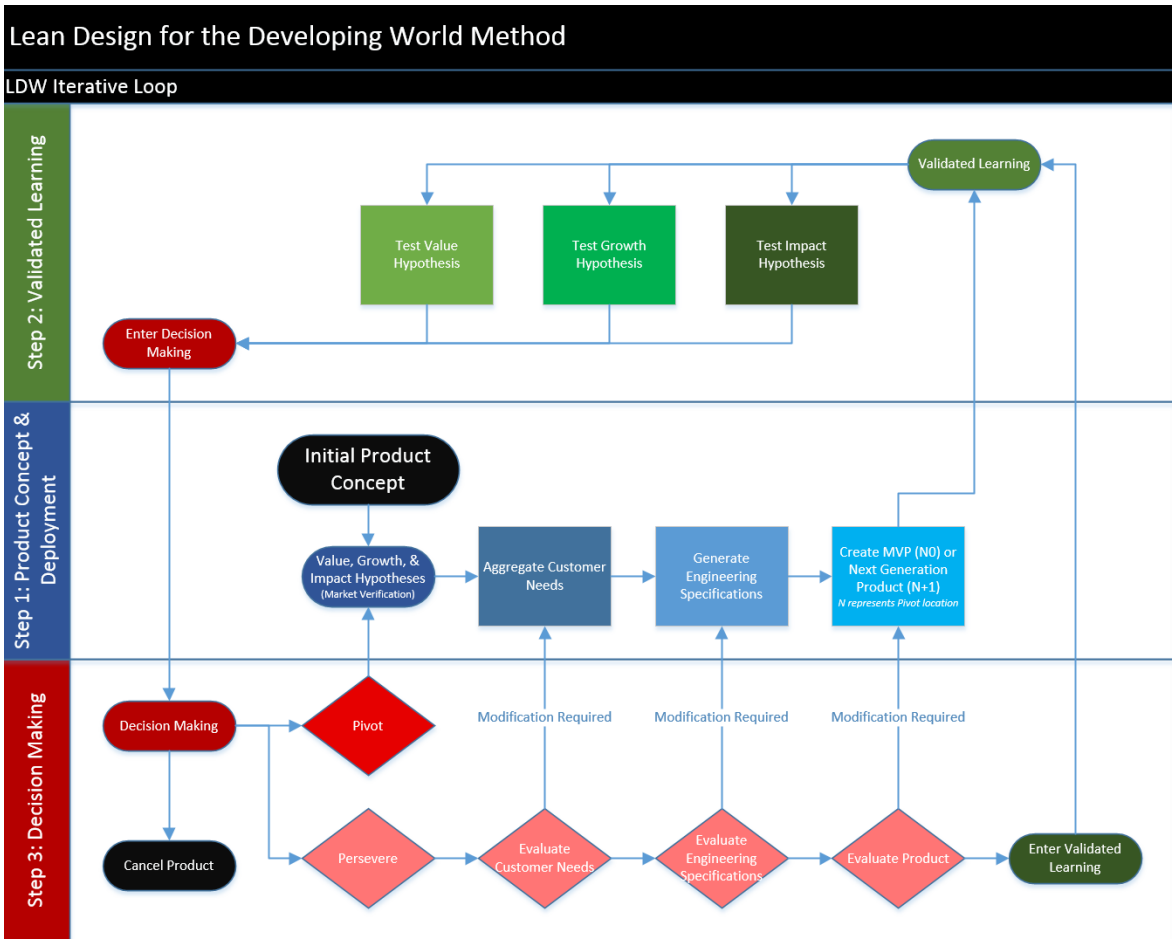

Figure 1: Lean Design for the Developing World (LDW) Flowchart

included in the lean startup methods. One starting action and four additional actions are taken by the design team in Step 1 of the LDW including initial product concepts; value, growth and impact hypotheses; aggregate customer needs; generate engineering specifications; and create MVP or next generation product. Each action is detailed below.

Initial Product Concepts:

The generation of an initial product concept is developed through an analysis of how customers spend their money. Through research in existing data repositories such as those kept by the UN, academic publications, and NGOs, a design team can begin to identify the areas of consumer budgets where the highest portions of income are spent [28, 1, 29, 30]. These areas are then targeted for intervention by the design team.

First-hand experience by the design team through field research and testing is sometimes required prior to the generation of initial product concepts and strategies. The level to which a design team would need to gather first-hand experience in the field is largely product dependent. At a minimum a local contact with knowledge specific to a target market region would be required before the generation of initial hypotheses for the LDW method.

Value, Growth, & Impact Hypotheses:

The design team then works to develop an initial value hypothesis based upon projected savings provided to the customer following the purchase of a product. Using this approach to product concept generation greatly limits the up-front time required by methods such as HCD's deep-dive and in-depth market research used in classical product design methodologies. The three hypotheses, value, growth, and impact, are used as a basis for product design requirements. Design and initial deployment of the product is handled using standard product design methods.

The value hypothesis, adopted from the lean startup method, tests if a product delivers value to customers [24]. A product that provides customers a net Return on Investment (ROI) of 100 percent within one year of purchase and 300 percent ROI by the product's end of life is identified by Polack as delivering value [5]. We believe that the ROI measures advocated by Polack [5] are a reasonable starting point for design teams using the LDW method but that the ROI measures should be adjusted to fit specific product development situations. The value hypothesis is validated in Step 2 of the LDW method through the collection and analysis of quantitative sales data and qualitatively through the collection of customer feedback.

In the context of the LDW, the growth hypothesis has been modified from the lean startup method to test market share growth of a product in a community, region, or the entire developing world. This hypothesis is vital to the long-term success and viability of a product in the developing world. It should be noted that the design team must also take into account the economic viability of fielding the product for the design firm. A capacity for scaling the business or product to reach millions of customers across many different regions and provide strong ROI is necessary to further reduce cost, thus allowing for a larger market to access the product, and to aid in the success of the third hypothesis. The growth hypothesis is validated in Step 2 of the LDW method through the collection and analysis of quantitative sales data and qualitatively through the collection of local distributor feedback.

The impact hypothesis for the LDW method is novel to LDW and does not appear in lean startup methodologies. This hypothesis measures the net impact upon individual consumers, their communities, and their regions. One unified method of assessing product impact on individual consumers, their communities, and their regions in the developing world currently does not exist. However, depending upon the product being developed, several different methods of evaluating the impact hypothesis are available such as the EU Emissions Transfer System. One notable example is the Poverty Reduction through Irrigation and Smallholder Markets (PRISM) Programs method developed by iDE. The PRISM framework is a value-chain analysis tool used by iDE, in the areas they work, to assess needs before an intervention and track changes after the intervention as well. More work is needed in this area [31].

A framework to measure impact is presented in Lucena et. al.'s Engineering and Sustainable Community Development (ESCD) text [32]. ESCD advocates for the use of several effective listening methods [33, 34, 35, 36, 37]. ESCD also suggests measuring local economic diversity, environmental sustainability, and social justice [32]. Bridger and Luloff add that self-reliance and energy use should also be measured [38].

While difficult to quantify, we believe it is important for engineers designing for the developing world to measure societal impacts of their products and retain a code of ethics even if the target market lacks the governance to require an ethical standard through legislation. It is important to understand that even if a lack of governance creates a unique market, the exploitation of this circumstance is unethical. Therefore it is vital that the impact hypothesis is considered equal to the value and growth hypotheses.

Aggregate Customer Needs:

Aggregate Customer Needs (ACN) are needs generated from a combination of sales data with customer and distributor feedback. ACN seeks to leverage both quantitative sales and qualitative feedback data are utilized to aid in the generation of a product able to test the original three hypotheses. Customer feedback is gathered and analyzed using tools from methods such as those provided in the HCD Toolkit [6] but while minimizing the investment of time and resources to collect this information. Additionally a prioritized customer needs list can be generated through methods such as the questionnaire method, cluster analysis method, and the articulation method. This data then can be assimilated into customer use patterns for the generation of a prioritized list of customer needs [39, 40, 20].

Generate Engineering Specifications:

Several methods are available to develop engineering specifications including engineering product development methods based on House of Quality and system engineering

methods advocated by INCOSE [23, 21, 19]. It is important to match engineering specifications with ACNs to ensure that the product meets the expectations of the market and will validate the three hypotheses.

Create MVP or Next Generation Product:

Following the generation of the hypotheses, existing engineering product design methods are used to develop engineering and customer specifications and requirements. After specifications and requirements are developed, the creation of a Minimum Viable Product (MVP) can begin.

The product is designed using the MVP method as described in the lean startup literature. The MVP method focuses the design team on the minimum set of features needed for a successful product which shortens the development of the product, reduces product cost, and allows for future testing of the three hypotheses in Step 2 of the LDW iterative loop. It should be noted that the MVP method does not reduce product quality or reliability [24].

To aid in the understanding of the LDW method, a fictional, idealized case study is provided in the form of a renewable source of light for regions in sub-Saharan Africa that traditionally have relied on kerosene fuels for lighting their homes. The product, named the Sol-D, was created to address customers who spend up to 30% of their income on kerosene fuels to light their homes. From this initial data, the design team can develop the initial value and growth hypotheses.

Value Hypothesis: Customers will eliminate the need to purchase kerosene for lamps by utilizing a renewable source of energy for lighting. The product will remain at a price point where the customer will see a ROI for the product within the first 6 months of use and a 300% ROI will be achieved before end of life.

Growth Hypothesis: Product demand will be generated organically through word of mouth after initial introduction to a limited set of local distributors.

Impact Hypothesis: The product will provide a safe and renewable source of light eliminating harmful pollutants generated from the burning of fossil fuel lanterns [41].

The next step for the design team is the development of the MVP to begin the iterative process. The design team uses existing methods to generate metrics and specifications in order to best serve the three hypotheses. After an MVP product is produced, the design team enters Step 2 of the LDW method.

Step 2: Validated Learning

The Validated Learning step follows each successive product release, as shown in Figure 1. The purpose of this step is to learn from the product design and deployment cycle that occurred in Step 1 in order to make a decision on the next phase of the product lifecycle. The information gathered and analyzed in this step is fed into the decision-making process of the LDW Step 3.

In order to validate the three hypotheses developed in Step 1 of the LDW, the validated learning technique is borrowed and adapted from the lean startup methodology. Validated learning in the context of LDW is a process of demonstrating empirically that a design team has found valuable truths about a product's present and future prospects in the market. Validating the three hypotheses provides valuable insight for decision-makers on the course that product development should take.

The first stage of validated learning is to collect and prepare data including sales figures, customer feedback, distributer feedback, manufacturing information, and other relevant data sets. The three hypotheses utilize the data in different ways and require different analyses. Additionally, comparisons between iterations of the product are made in order to track progress toward validating the hypotheses. Each of the three hypotheses has quantitative goals such as achieving ROI within one year and 300% ROI by the end of the product's lifecycle. As the lean startup method has demonstrated, it is rare that all three hypotheses will be validated on the first iteration of a product [24].

Analyzing sales data and customer feedback tests the value hypothesis. Sales data is broken down into institutional purchases (e.g.: NGOs, governments, etc.) and distributor purchases, and is also discretized by location. Customer feedback is gathered and analyzed using tools such as those provided in the HCD Toolkit [6] but while minimizing the investment of time and resources to collect this information.

Analyzing sales data and distributer feedback tests the growth hypothesis. Sales data breakdowns used in the value hypothesis are also used in the growth hypothesis. Distributor feedback is used to understand the reasons behind local sales growth or contraction. Feedback from distributors is gathered in the same manner as customer feedback.

The impact hypothesis is tested by using the method of assessing product impact that the design team chose in Step 1 of the LDW. While it can be difficult for engineers to understand and utilize available impact measurement tools, it is important that the impact hypothesis is tested. Engineers have an obligation to uphold ethical standards embodied in the LDW impact hypothesis.

Returning to the fictional Sol-D product case, the design team now has 6 months of sales data, customer feedback, and distributor feedback. With this data, the team can now test the three hypotheses.

Value Hypothesis: The team found that sales have been fairly strong which contributes to an affirmation of the original value hypothesis. The customer feedback however has lead the design team to understand that the price point is too high and feature set greater than demanded. The Sol-D team decides the market demands an additional product with a lower entry price point.

Growth Hypothesis: The sales data has seen steady yet limited growth as time progressed. The distributors noted that the customers have been hesitant to purchase the product due to its cost, however more customers have been inquiring about the product as word spreads of the potential savings over time from eliminating the need for kerosene fuels.

Impact Hypothesis: The team has had their original hypothesis confirmed by customers and distributors that reducing the reliance on fossil fuels has improved the health of the users. An additional unrealized benefit is the reliability of the lights as compared to the irregular access to kerosene fuels.

Following the generation and analysis of hypothesis data, the design team next enters Step 3 of the LDW method.

Step 3: Decision Making

The final step of the LDW method is to make a decision to either 1) Pivot, 2) Persevere, or 3) Cancel the Product. The decision is made using the information derived from Step 2 of the LDW. The three decision choices are adopted from the lean startup method.

The data collected and analyzed in Step 2 of the LDW is used to determine if the three hypotheses developed in Step 1 either 1) have been met and are an accurate representation of the target market or require minimal refining (Persevere), 2) require a complete redefinition of the three hypotheses (Pivot), or 3) indicate the product should be abandoned altogether (Cancel the Product). It should be noted that the design team has the option of choosing to both Pivot and Persevere. If the combined option is chosen, the original product is continued on down the Persevere path while a new iteration of the product is created through the Pivot path.

A design team choosing to Pivot will return to Step 1 at the point of defining the three hypotheses. New information collected in Step 2 of the LDW provides the design team with relevant information to significantly change the three hypotheses to more accurately represent the market. The design team then continues through Step 1 and the rest of the LDW iteration cycle.

Choosing to Persevere requires the design team to determine what, if any, portions of Step 1 need to be modified. The design team can reenter Step 1 at either the aggregate customer needs, generate engineering specifications, set specification targets, or create MVP stage of Step 1. Alternatively, the design team may find that none of the stages of Step 1 need to be revisited instead the design team will reenter Step 2 after a length of time sufficient to collect new data that indicates a reanalysis of the data should be conducted, as shown in Figure 1. It is important to pay close attention to where reentry into Step 1 occurs or if reentry into Step 2 is appropriate. Needlessly revisiting stages of Step 1 uses valuable time and resources that could otherwise go toward releasing the next iteration of the product. Skipping stages of Step 1 and directly reentering Step 2 without careful analysis of the data can lead to a delay in design changes that could benefit validation of the three hypotheses.

Canceling the Product terminates the LDW for the product entirely and the product is discontinued. This option can be chosen for a variety of reasons such as there being no viable market for the product or any derivation of the product. While canceling a product is never ideal, an advantage to the LDW method is the reduced upfront investment makes the design team more willing to Cancel the Product when necessary.

Both Pivoting and Persevering can occur when the design team determines that both options are appropriate. This means that there is a viable market for both the original product and a derivative product. Pivoting and Persevering is analogous to the creation of product families in product design and systems engineering methods.

The fictional Sol-D team has finished testing the hypotheses in Step 2 of the LDW. With the information gathered and analyzed in Step 2, the design team enters Step 3 where they decide to Pivot to a lower price point product while also Persevering the original Sol-D because the sales data and customer and distributor feedback show continued and increasing market growth of the original product while a second market for a lower price point product exists. Thus the Sol-D design team reenters Step 1 of the LDW.

Following the completion of Step 1 of the LDW, six months of sales of both the original Sol-D and the derivative product, now called the Sol-Delight, have concluded. The team enters Step 2 of the LDW to collect analyze the data needed to enter Step 3.

As seen in Figure 2, the Sol-Delight quickly caught on with customers and sales increased significantly. Concurrently, the Sol-D saw a slight drop in sales following the release of the Sol-D but remained a viable product. This data indicates that the design team made a valid decision to Pivot to a less expensive price point with the Sol-Delight and Persevere with the Sol-D, as evidenced by the robust sales of the Sol-Delight and the continued viability of the Sol-D. The design team decides to Persevere both the Sol-D and the Sol-Delight through another iteration of the LDW.

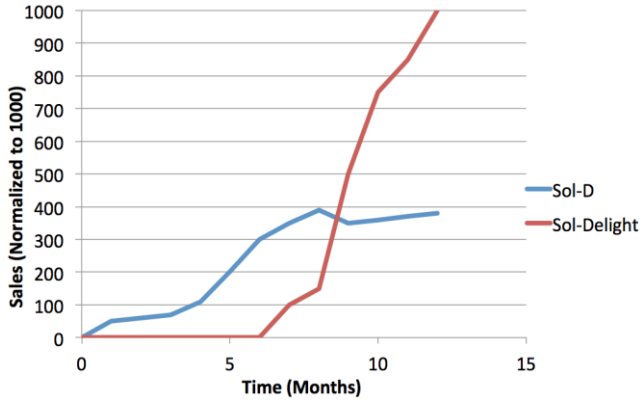

Figure 2: Sales Data of the Fictional Case Study on Sol-D Bulbs

Six months later, the Sol-D team has collected and analyzed enough data in Step 2 of the LDW to enter Step 3 where they decide to Persevere the Sol-Delight and Pivot the Sol-D into a higher price point product that allows for cell phone charging from built-in solar-charged batteries. This feature was requested from the distributors as a means to create an additional revenue stream in their shops by allowing customers to charge their phones during the day for a fee.

As can be seen by this fictional case study the portfolio of products developed through Pivots can quickly become difficult to track. To aid in tracking product development and branching, nomenclature for recordkeeping in the LDW method has been developed following the IDEF0 nomenclature approach. Part of the IDEF family of modeling languages, IDEF0 is built upon the functional modeling language Structured Analysis and Design Technique (SADT) [42, 43]. An example of a LIF flowchart with multiple products can be seen in Figure 3.

A product with the designation A represents the original product. Each increase in letter from A through B, C, D, etc., represents a Pivot away from the original A product. A number following the product letter designation represents each Perseverance made in a product line. Finally, when a product is canceled, it is indicated with an X in the place of the Perseverance placeholder. An example of a LDW product tree based upon the fictional Sol-D product family is shown in Figure 4.

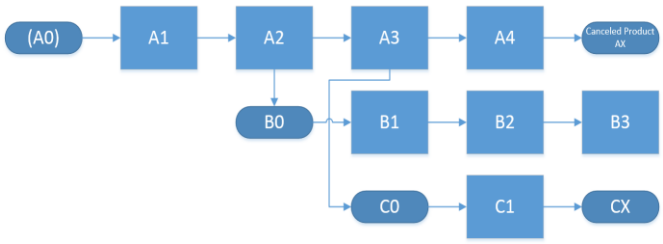

Figure 3: Lean Iterative Framework (LIF) Flowchart

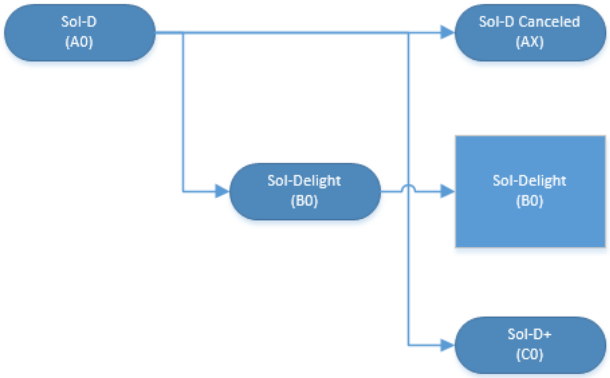

Figure 4: Lean Iterative Framework (LIF) Flowchart for Sol-D Fictional Case

3.2 Methodology Summary

The LDW method seeks to reduce the upfront investment required by design teams when entering the developing world, shorten design cycle iterations, provide compelling ROI cases for customers that frees up portions of their incomes for other uses, and create products that have positive impacts on the consumers, their communities, and their regions. Entrepreneurs, businesses, and NGOs will benefit from the LDW by developing products that in addition to providing value to customers, having long-term growth potential, and having positive impacts, also are profitable. Utilizing an iterative approach, the LDW method stresses leveraging sales data, customer feedback, and distributor feedback to evaluate and refine the three hypotheses of 1) value, 2) growth, and 3) impact. To accomplish this, the LDW uses three overarching steps:

Step 1: Product Concept and Deployment
Step 2: Validated Learning
Step 3: Decision-Making

4 CASE STUDY

Several companies are currently implementing methods analogous to the LDW and have served as inspiration for development of the LDW. The case study presented below is used as both validations of the LDW method and a tool to highlight the strengths of the method. A short discussion of D-Rev and an in-depth analysis of Nokero USA, LLC are presented.

D-Rev is a small nonprofit that designs medical equipment for developing countries and licenses the designs to for-profit distributors in the developing world. D-Rev relies on markets-based revenue streams rather than donations or grants for growth. D-Rev is an example of a nonprofit that designs products for the developing world and that is reliant on revenue generated from product sales for its continued existence.

An in depth case on Nokero is presented next. The Nokero case study provides a unique perspective on designing for the developing world. Nokero allows for the application of the LDW method to several years of product iteration as well as providing examples of Pivots into a variety of markets discovered during the numerous product iterations the company has performed since 2010.

4.1 Nokero Background

Nokero designs, manufactures and distributes solar-based light bulbs and chargers. The name Nokero is a portmanteau of "no kerosene," a common fuel used in lanterns in the developing world. The technologies that Nokero develops are effective at eliminating the need for harmful and polluting kerosene and other fossil fuels in both the developing and developed world. The Nokero product lineup has been designed for the large market of people without reliable access to electricity. This market contains an estimated 4 billion people [2]. In many cases, people without access to reliable electricity spend up to 30% of their incomes on kerosene lamp fuel [41]. Eliminating the need for kerosene by using solar lanterns eliminates the ongoing expense of kerosene. The Nokero product lineup can see a complete ROI for the consumer in six months [41].

The flagship product from Nokero is the N200 solar light bulb. This light bulb comes with a replaceable, rechargeable AA sized battery. The bulb's relatively inexpensive price and simplicity was not a product of luck; it took many years and iterations to achieve commercial success. Nokero provides an instructive case study that demonstrates that even with well-defined underserved markets, creating a product that provides value and growth prospects is no easy task. Nokero has defined a market and the market's needs to great success. The company delivers impactful products to the hands of consumers who can most benefit while proving to be a profitable and viable business.

4.2 Nokero and the LDW Method

The value hypothesis developed by Nokero was that in creating a renewable source of light for developing world markets that lack access to reliable electricity will eliminate the need for lamp fuel. These markets are forced to use fossil fuel based lamps that can require the use of up to 30% of wages in order to buy fuel. By providing a light source that eliminates the need for fuel, Nokero believed it could create a product that would be both profitable for the business and save the customer money while providing a rapid ROI for the customer. The growth hypothesis was to utilize local distributor channels and word-of-mouth advertising for sales growth. The impact hypothesis was that by eliminating the need to burn kerosene fuels, the health and wellbeing of the customer would be improved.

To test these original hypotheses, Nokero released the N100. From initial customer feedback, the Nokero team was able to identify where the original hypotheses were invalid. For example, the N100 was designed with panels located on the sides of the bulb and contained four separate panels that all faced in directions 90 degrees apart from one another, as shown in Figure 5. This orientation of panels prevented the panels from absorbing the maximum amount of energy available to the bulb due to the angle of the sun with respect to all four panels. The assumption by the design team was that the user would be willing to sacrifice a complete charge in order to eliminate the need to manually adjust the orientation of the panel during the day. Nokero Pivoted the N100 in order to enable a complete charge and released N200, with a single solar panel located on the top of the bulb housing, as shown in Figure 5. This single panel had greater efficiency and reduced the complexity of the design in addition to allowing for a longer charge when the user took the time to readjust the angle of the panel to maximize solar energy collection [44].

Figure 6: Nokero N100 (Left) and Nokero N200 (Right) Visual Comparison

Despite the shortcomings of the N100, its rapid release was vital to enabling Nokero to test its value hypotheses. While the N100 lacked many of the features that were present on later, more successful iterations, it was vital in confirming some assumptions while dismissing others that Nokero initially viewed as vital to commercial success. Nokero was able to create a product that more accurately matched the market needs at a rapid pace due to the feedback gained from the N100 [45]. Figure 6 shows how the Nokero development process looked over time, using a LIF flowchart, when looking at the N100, N200, and N180.

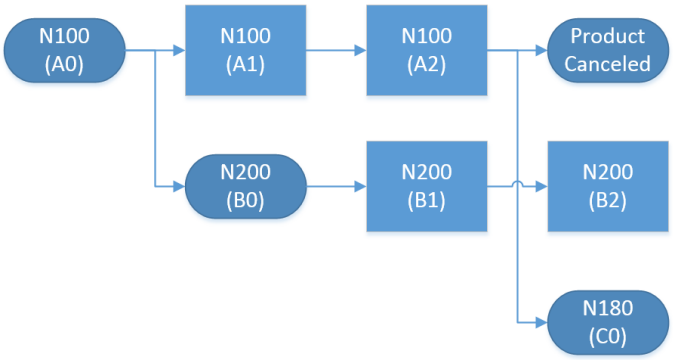

Figure 5: Nokero Lean Iterative Framework (LIF) Flowchart

Figure 7 shows comparative sales data between the N100 and N200. The sales data in the figure were normalized to retain confidentiality; additionally the figure compares the two sets of data on a log base 5 scale to highlight trends present in the sales data. This figure shows how both Pivoting and Persevering a product can directly impact sales. It can be seen that after the first month of release, the N200 rapidly overtook the N100 in overall sales despite its higher price point. The decision to increase the effectiveness of the bulb and negate preconceived notions on what the market was willing to pay enabled Nokero to rapidly expand its business [46].

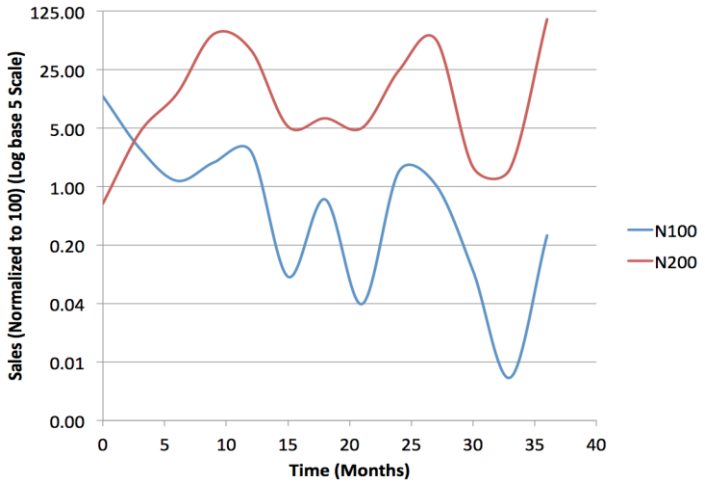

Figure 7: Nokero N100 vs. N200 Sales Comparison (Normalized for Confidentiality)

Since the N200's release, half a dozen LDW Persevere iterations have been completed to further refine the N200. In addition, a number of Pivots into additional product lines have been made with products such as the N180, N220, and an array of solar phone chargers such as the P101 and P102.

5 DISCUSSION

The LDW method is designed to provide additional design tools for the developing world. A key difference between the LDW method and HCD is the initial project definition stage. In HCD, the design team is tasked to generate a design challenge and tasked with creating a product that can solve a challenge present in the target market. In contrast, the LDW method generates value, growth, and impact hypotheses that focus on value creation for both the end user and the business producing the product, market growth of the product for long-term commercial viability, and positive impact on the customers. Because of this focus on value, growth, and impact, the design team is able to leverage market data to a greater extent, as the product does not rely on outside resources to be financially viable. Many of the case studies in research that champion product success in the developing world have not come from commercial business interests but instead originate with nonprofit or charitable organizations [5]. Businesses have the potential to earn profits while making a huge positive impact towards the goal of ending poverty, but thinking must change in how resource-poor customers are viewed.

Paul Polak states in *Out of Poverty* that there are six basic principles required to create economically sustainable, profitable, and positive impacting products including:

1) Products need to serve customers who live on less than 1 USD per day.
2) Products should be designed to be affordable to the customers who live on less than 1 USD per day at unsubsidized fair market prices.
3) Products should be income-generating and capable of at least paying for themselves within the first year.
4) The business model for the design team must be capable of reaching bottom-line profitability rapid enough to satisfy investors who fund the business.
5) Positive impacts on poverty must be measurable.
6) Growth and scaling capacity must be an essential component of the method.

The LDW method has been shown to address each of these principles through the case study provided as well as through its unique combination of different research disciplines. Nokero has seen success in the areas that Polak views as vital to serve: those making less than $1 USD per day [5]. To that point, Nokero recently released the N180 bulb, a Pivot from the N200, to better serve this particular market. The lower cost N180 bulb was created to address feedback received from the data gathered by Nokero since the N100 was released [46].

LDW is a method that provides a way to create products that meet all six of the principles defined by Polak. Principle 1 is addressed through the value hypothesis component of the LDW method. During the Product Concept and Deployment stage, methods for identifying customer expenditures are analyzed for potential areas to create value for the even the most resource poor populations. Principle 2 is also addressed in the same manner as principle 1; the Product Concept stage identifies value-adding products for those living under $1 USD per day. Principle 3 is addressed in the value hypothesis of the LDW method. The value hypothesis is used to create products that can provide at minimum a 100% ROI within the first year and 300% before product end of life. When this metric for value is not met, a new value hypothesis is required and a Pivot is necessary. Principle 4 focusing on the creation of a profitable business model is addressed through the Product Concept and Deployment step of the LDW method. By focusing on the generation of value for both the business in the form of profit and value for the customer in the form of ROI, LDW is built to iterate toward maximizing the profit-generating potential of a product, which will lead to a product that can generate value for investors and shareholders. Principle 5 is addressed through the LDW impact hypothesis and the constant monitoring and improvement of the impact hypothesis that products have on the end user and surrounding community. Lastly, principle 6 is addressed through the inclusion and constant testing and refinement of the LDW growth hypothesis.

The time frame for iterations within the LDW will depend greatly on the type of product being produced and the target market for the product. For Sol-D and Nokero an iteration time frame of around 6 months can be expected. Some products may require more or less time for iteration. Additionally at times when substantial Pivot's are required the time frame may become greater than if a product is to simply undergo a Perseverence.

6 FUTURE WORK

The LDW method will require further refinement and validation through further investigation of a few key areas. These areas are highlighted as topics that will require both investigation and validation. The first of these areas in need of further investigation is the need for additional case studies.

6.1 Additional Case Studies

While Nokero provides a representative case study of success through the use of LDW techniques, further case studies and collaborations with industry and NGO partners will help to refine the LDW method to aid others in achieving similar success. Much like LDW itself, this research is the MVP of a larger process that will iterate the initial hypotheses made in the early phases of the research. A few additional companies that are known to employ lean methods were highlighted; however Nokero is the only company at this time that has generously provided the detailed and expansive data necessary to help affirm the validity of the LDW methods.

6.2 Impact Hypothesis

As a novel method unique to the LDW, the impact hypothesis will require further testing and confirmation. While the adaptation of well-established and effective methods and frameworks such as ESCD that have proven useful in combination with other methods, it is still not clear how these methods will fair in the rapid iteration process proposed by the LDW.

6.3 Metric Creation for the Design Team

While sales data coupled with both customer and distributor feedback can create insights for the design team act upon in the Decision Making step of the LDW, there remains a need for concrete metrics from which a design team can

analyze. It may be possible for a design team to speed up the rate at which iteration can take place if there were more quantitative metrics from which a Pivot could be derived [44].

7 CONCLUSION

The developing world has many challenges and pitfalls not present in the develop world, but at the same time it also possesses unique opportunities. Adding to the great work being done using HCD, the lean startup-derived method, and others, the Lean Design for Developing World (LDW) method presented in this paper provides a method for a market-based approach to design for the developing world. Through the combination of approaches in the LDW method, design teams can more easily identify areas of great opportunities while rapidly identifying and avoiding pitfalls before large investments of capital and time are placed into a product. The combination of value, growth, and impact hypotheses in the LDW method rapidly creates products that are economically viable for both customers and the businesses that produce the products, have strong market growth potential, and have a net positive impact on the customers and their surrounding community.

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