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A Method for Social Entrepreneurs to Develop Value Propositions for Sustainable Development

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ABSTRACT

We hypothesize that sustainable development is a wicked problem since it is virtually impossible to solve on account of incomplete, contradictory, and changing requirements. In this paper we introduce the Dilemma Triangle Method for social entrepreneurs to develop value propositions for sustainable development. The method is described and illustrated to further sustainable development of Kudagaon village, Odisha, India whose residents are at the bottom of the economic pyramid. The method is illustrated using the FOOD, ENERGY, and WATER Nexus construct. The method is applicable to framing wicked problems in general and identifying suitable value propositions. Our focus in this paper is on highlighting the method rather than the results.

1. INTRODUCTION

There are millions of people in developing countries who are living in extreme poverty. Poverty causes the scarcity of basic resources which further enforces poverty. Tackling such problems is a large task [1-3]. It takes time and money to address them all. Nonetheless, this also provides an opportunity for social entrepreneurs who strive to improve the quality of life of the developing communities.

It is important to understand the context of the problem before designing effective solutions. In the rural communities, at the bottom of the economic pyramid, FOOD, ENERGY and WATER (FEW) are the essential resources. Therefore, understanding the relationship and the nexus are critical. The FEW-Nexus plays a major role in the sustainable development. An increasing population in the world will lead to the increased demands for FEW. Hence, a strategy is needed to ensure sustainability of all three that takes into account three perspective, namely, the society (people), environment (planet) and economics (progress). These perspectives are interconnected, further complicating the problems, especially in the context of developing communities [4]. The nexus of FOOD, ENERGY and WATER and the perspectives – people, planet and progress are often in conflict and present decision makers with multiple dilemmas. We note that to have effective outcomes, apart from identifying various solutions, it is also important to assign appropriate priorities to them.

In this paper the Dilemma Triangle Method (DTM) is presented for framing wicked problems in general. For illustrating the efficacy of the DTM we use information from Kudagaon village in Odisha, India. We use the data that has been collected by SunMoksha for reconciling the points of view of various stakeholders and understanding the consequences of proposed solutions. This simplifies a social entrepreneur's decision-making process when designing sustainable value propositions for the developing communities. The DTM presented in this paper is generalizable and can be applied to other wicked problems.

In this paper, in Section 2, the DTM is presented. In Section 3, the DTM is illustrated using the data from Kudagaon an island village on the Mahanadi River Odisha located in Athmallik Tehsil, Angul District. It's population is 301 with 157/144 males/females and 47 children. The island is cut-off from the mainland for all infrastructure, especially energy services. Even though the village has access via a mud road through the riverbed, the path gets flooded and washed away every year during rains – grid electricity cannot reach there. Despite the availability of 400 acres of farmland, the villagers engage in agricultural activities only during the monsoon season, due to lack of irrigation.

The proposed DTM based on the FOOD, ENERGY and WATER Nexus is illustrated to develop a sustainable value proposition that satisfies multiple stakeholders (social entrepreneurs, villagers, and investors) [5]. Concluding remarks are in Section 4.

2. THE DILEMMA TRIANGLE METHOD

Sustainable development of a village ecosystem is seen as a wicked problem as it does not have a clear solution [6]. For example, in a village, a farmer may not have access to irrigation water for agriculture. To overcome this problem a social entrepreneur may provide the farmers with groundwater pumps. With reckless water consumption the farmers deplete groundwater which causes water scarcity as the amount of groundwater is finite or recharges slowly. This is a dilemma for a social entrepreneur: whether to provide groundwater pumps without considering the rate of groundwater depletion or not to provide anything to keep groundwater safe. To

address this dilemma, the social entrepreneur must find a sustainable solution that is safe for both people and the planet, thereby promoting agricultural progress. Therefore, to develop a sustainable value proposition, it is essential to identify and manage dilemmas before proposing a solution. The DTM is used to identify dilemmas in a system and find or manage solutions to resolve them.

The DTM is described in references [7-9] to frame a problem and to identify dilemmas within a sphere of sustainability, for example, ENERGY and the tensions are among issues affecting People (Social), Planet (Environment) and Profit (Economic). In these papers, the DTM was used to understand the dilemmas related to a single variable, namely, ENERGY [8].

In this paper, an expanded DTM to find value propositions for rural villages using three spheres of sustainability in the FEW Nexus with different focuses, is presented. This is a complicated problem and generates many dilemmas [9, 10]. Three spheres of sustainability are used as three perspectives of the Dilemma Triangle to develop a sustainable value proposition. The dilemmas that are identified within these perspectives are the gaps that social entrepreneurs need to fill. While framing the problem, 'tensions' and 'dependents' are identified amongst the drivers for particular focus areas. Thus, enabling the extended comparison among issues which affect multiple areas. In this way, a variety of dilemmas are identified [11].

Then each of three sub-triangles. In this case the FEW Nexus is anchored in people, planet and progress. This DTM is used to help understand the trade-offs among multiple stakeholders, for example, social entrepreneurs, villagers, and investors People explain their problems to social entrepreneurs and these social entrepreneurs identify sustainable value propositions which are opportunities for investment. To explore and understand the potential consequences of different value propositions, the dilemma triangle is implemented for the spheres of sustainability FEW. Note that the spheres are not independent of each other, however considering them independently can provide a better understanding of the potential difficulties and opportunities. These are further subdivided and focus areas of People, Planet and Progress, this results in 9 focus areas, Figures 1 and 2.

The DTM is particularly useful when framing a wicked problem, especially those in which a disruptive intervention is being considered. An investor, or other interested party can use multiple dilemma triangles to explore different alternative actions. Through the DTM undesirable consequences of the solutions can be identified in time and a better integrated solution can emerge. However, first it is necessary to identify a general objective or a solution for the wicked problem, in other words a desirable future state of the system. Then identify the solutions and see how their affect interacts with one another and the system as a whole. The keywords for the dilemma triangle method are:

The **Driver** "drives" the solution and helps to define scope of the problem that needs to be solved. For this paper the drivers are FOOD, ENERGY and WATER.

The **Perspective** is based on the problem context – in the case below, the focus is on sustainable progress and therefore the perspectives are based on People, Planet and Progress, in particular here the economic progress has a larger role. The perspectives must be the same for all of the drivers; the entire problem must be solved in a consistent context. These concepts are related to each other and are combined as shown in Figure 1.

The **Focus** is used to determine the problem boundary.

The **Issues** to be addressed are listed, especially those issues which will be affected by the intervention(s) under consideration.

The **Value Proposition** is based on the proposed disruptive intervention(s) under consideration.

Step 1 – Choose Drivers

A driver is an area that is used to identify a focus. In this paper the three drivers are FOOD, ENERGY and WATER. These drivers encourage the social entrepreneur to put the focus only on the individual areas, simultaneously. Each driver is placed at each corner of the dilemma triangle as shown in Figure 1.

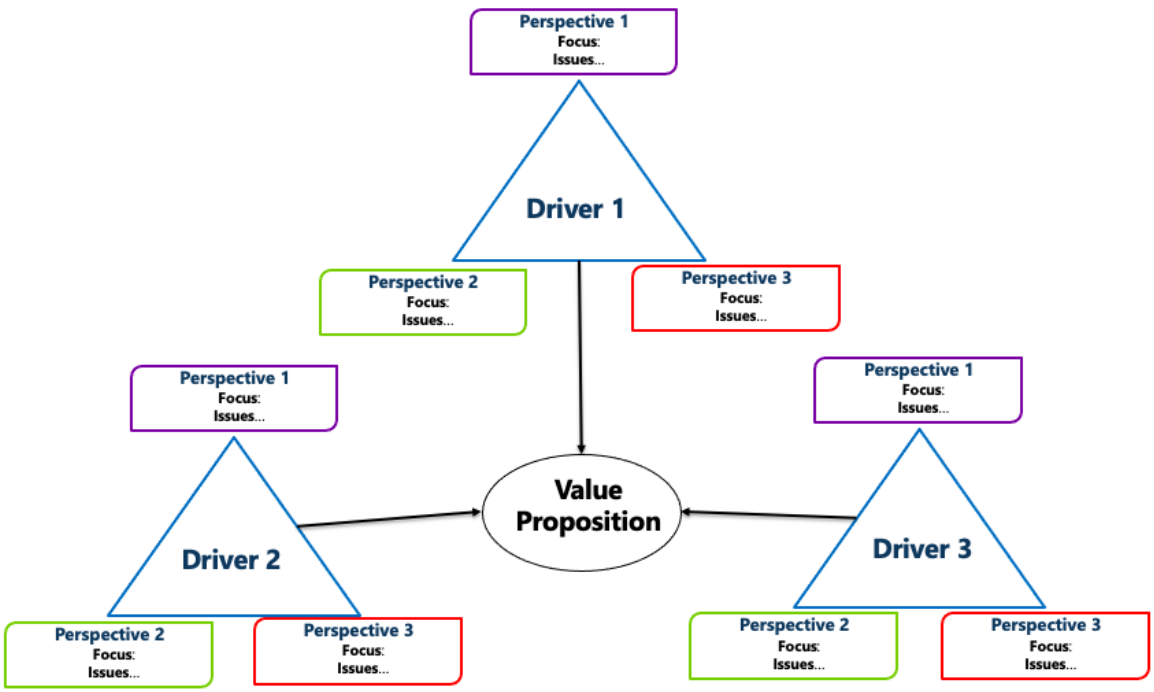

Figure 1. The arrangement of key concepts in a dilemma triangle

Step 2. Determine the Perspectives

The perspectives define the context in which the problem is placed. As mentioned above, the perspectives for this paper are people, planet and progress.

Step 3 – Fix Focus for Each Driver/Perspective Pair

For each driver/perspective pair, focuses must be determined. A focus is the aspect/goal related to each driver/perspective pair. This is determined based on the chosen problem. Hence, for each driver, all the perspectives are common but the focus areas change depending upon the problem and the social entrepreneur's possible interventions. Here, nine focus areas are used.

Step 4 – Collect Issues for Each Focus/Perspective Pair, Create Dilemma Triangles

In each of the perspective/focus areas, issues are identified. These issues are listed as words or verb-noun pairs. For example, increasing deforestation, lack of electricity, etc. In this section, for the example under consideration, a social entrepreneur should have identified most of the issues that are related to FOOD, ENERGY, and WATER combined with people, planet and progress. This results in 9 major sets of issues. These issues are further studied to identify dilemmas. Changes are made, as necessary, to resolve conflicts and the appropriate triangles are drawn, as in Figure 1.

Step 5 – Create Issue Matrix and Categorize Issues

In a wicked problem, issues are connected. This connection might be positive or negative. Five categories of relationships among issues have been identified:

1. Tensions
   When two issues conflict in such a way that, if we try to solve one issue, it affects the other issue negatively. These are called 'Tensions'.
2. Dependents
   This is similar to the Tensions in reverse. If we try to solve one problem, it affects the other issue positively. If we solve one issue, the other issue will be solved automatically due to their dependency. These are 'Dependents'.
3. Inter-Tensions
   If an issue from one driver (e.g., FOOD) conflicts with an issue from a different driver (e.g., WATER), then it is an 'Inter-Tension'.
4. Inter-Dependents
   If an issue from one driver depends upon another issue from a different driver, then it is an 'Inter-Dependent'.
5. Individual Issues
   These issues do not interfere with any other issues when they are solved. These issues are called 'Individual Issues'. They do not play an effective role in creating dilemmas.

A matrix is built for each Driver, Figure 2, with all the issues collected in a dilemma triangle. Each matrix cell represents two issues on the x and y axes, Figure 3. Then the issue matrices from all Drivers are compared to identify inter-dependents and inter-tensions among issues related to different Drivers. This allows a social entrepreneur to identify the relationships among five categories of issues. This matrix is explained with an example problem in Section 3.

Step 6 – Finding Dilemmas and Developing Value Propositions

Once Issues are categorized, group the issues that are related to each other. The groups can have a combination of different categories. Each group results in a dilemma. For each dilemma, a problem statement is developed keeping all the issues within the group in mind, Figure 3. The social entrepreneurs can then develop value propositions to address the problem as integrally as possible.

Implementing the Dilemma Triangle method is a time-consuming process. Constructing triangles and issue matrices for every driver/perspective is difficult. The DTM is illustrated using data from an island village, Kudagaon, with the help of an automated dashboard created in Excel.

		P-1			P-2		P-3			
	DRIVER 1	I-1	I-2	I-3	I-4	I-5	I-6	I-7	I-8	I-9
P-3	I-6									
	I-7									
	I-8									
	I-9									
P-2	I-4									
	I-5									
P-1	I-6									
	I-7									
	I-8									
	I-9									

Figure 2. An example of an issue matrix. P-1 … , P-3, are the Perspectives, I-1,…, I-9 are Issues

Related Tensions, Dependancies, Inter-Tensions and Inter-Dependencies to be Addressed	Dilemma	Value Proposition
T1, D2, IT2	Dilemma 1	Value Proposition 1
T2, D1, ID1	Dilemma 2	Value Proposition 2
…	…	…

Figure 3. Identifying dilemmas and developing value propositions

3. ILLUSTRATING THE DILEMMA TRIANGLE METHOD FOR A PROBLEM IN KUDAGAON VILLAGE

The dilemma triangle method is illustrated by applying it to Kudagaon, a small village in Odisha, India, Figure 4. Kudagaon, an island in Mahanadi River, is located in Athmallik Tehsil, Angul District, Odisha, India. As mentioned in Section 1, the village is cut-off from the mainland for all infrastructure, especially energy services. Even though the village has access via a mud-road through the riverbed, the path is flooded and washed away every year during rains. Moreover, despite the availability of 400 acres of farmland, the villagers engage in agricultural activities only during the monsoon season, due to lack of access to water for the irrigation system.

The steps for implementing the method described in Section 2 are as follows.

Step 1: Choose Drivers

FOOD, WATER and ENERGY are the key factors for the socio-economic development of the village, Figure 5.

Step 2: Determine the Perspectives

As we are interested in sustainability, discussed in Section 1, we have chosen PEOPLE, PLANET and PROGRESS as perspectives, Figure 5.

Step 3: Fix the Focus for Each Driver/Perspective Pair

For each driver, a focus to be achieved is decided. This process is repeated from each perspective (**PEOPLE,**

PLANET, PROGRESS) which results in 9 focuses as shown in Figures 6 and 7(a, b, c).

Step 4: Collect Issues for Each Focus in each Perspective and Create Dilemma Triangles for the issues FOOD, ENERGY, and WATER

In this example, the perspectives allow a social entrepreneur to study issues from 9 areas. This results in an improved understanding of issues affecting sustainable development. Among these issues, some issues will be in conflict, i.e., if the social entrepreneur tries to solve one issue, it may exacerbate some other issues; and some may resolve a few other issues. It is important to identify these types of issues to reach a satisfactory solution to the dilemma.

With every focus, related issues that prevent the realization of the focus area are identified. This results in 9 different types of issues as shown in Figure 7 (a, b, c). The issues affecting Kudagaon have been studied by our colleagues at SunMoksha to understand them.

The Dilemma triangles for FOOD, ENERGY and WATER are shown in Figure 6. This information was collected by SunMoksha personnel through interviews with the villagers and other stakeholders.

Figure 4. Kudagaon Island Village, Odisha, India

FOOD

Under the FOOD driver, for each perspective (PEOPLE, PLANET and PROGRESS) focus is determined and issues are collected as shown in Figure 6.

FOOD DRIVER/PERSPECTIVE PEOPLE

FOCUS: The focus of a social entrepreneur is to enable access to an adequate amount of nutritious food to everyone in the village.

ISSUES

Unreliable Water Resources

Water is essential for agriculture. Due to unreliable water resources, it is hard to achieve high food production.

Old Agricultural Techniques

Many technologies are introduced into agriculture which can enhance food production. Due to the practice of old techniques, the production is limited for the growing demand.

FOOD DRIVER/PERSPECTIVE PLANET

FOCUS: Here the focus is on conserving the fertility of the agricultural land to enable continuous crop growth.

ISSUES

Chemical Fertilizers

The use of chemical fertilizers often decreases the fertility of the soil.

Monocropping

Growing same type of crop every year is called monocropping. This enables the spread of pests and plant diseases which must be treated with more chemicals. Monocropping also reduces soil fertility.

FOOD DRIVER/PERSPECTIVE PROGRESS

FOCUS: The goal is to help to improve the farmers' income. These are some issues that impact this goal.

ISSUES

No Linkage to the Market

As Kudagaon is an island, the villagers must travel long distances to reach the market to sell their produce.

Poor Transportation

There is no source of transportation to deliver the crop to markets. Hence, the farmers are unable to sell a large quantity of their produce, which also results in higher waste of the harvest.

No Cash Crops

Since cash crops require a steady source of water, the villagers are unable to grow them in large quantities. This reduces their income.

Once a Year Farming

Lack of a steady supply of water prevents the villagers from practicing agriculture throughout the year. Instead, they depend on the monsoon season for a prosperous harvest. As Kudagaon has a monsoon only once a year, agriculture suffers for the remainder of the year. Moreover, the villagers are compelled to take up daily wages' jobs during the non-rainy seasons.

The preceding issues for each perspective are only from the driver: FOOD. This is one-third of the method. Similarly, this Dilemma Triangle is introduced for WATER and ENERGY as well.

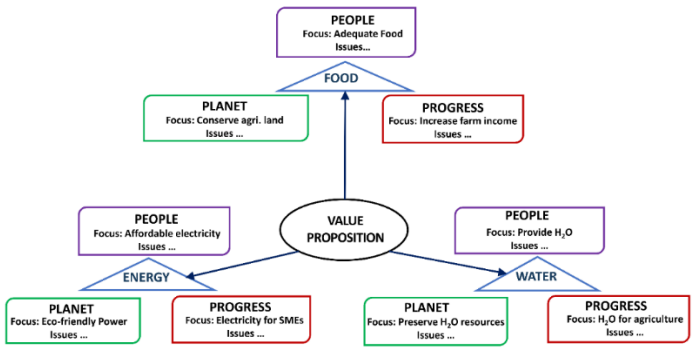

Figure 5. Dilemma Triangle of the FOOD, ENERGY and WATER Nexus. Note that this is an overarching dilemma triangle which is further divided into 3 dilemma triangles, one for each driver

WATER

For WATER the focuses are set for each of the perspectives (People, Planet and Progress) and issues are collected as shown in Figure 6.

WATER DRIVER/PERSPECTIVE People

FOCUS: For villages in extreme poverty, the main goal of a social entrepreneur is to provide access to water for both agriculture and household use.

ISSUES

Non-uniform Water Resource

Even though Kudagaon is an island, the availability of water is not consistent. During the rainy season the river water level comes close to the living area but when the dam gates are closed after the rainy season, the water level recedes to a narrow stream away from the island, making the access to water difficult for the villagers.

Unknown Water Table

As Kudagaon is a remote island village, where accessibility is an issue, there has been only a limited amount of testing and there is little knowledge about the water table. Without this knowledge, it is difficult to access underground water, even if it exists.

Difficult to Tap River Water

River water recedes during non-monsoon seasons, making it extremely difficult to access river water in those months.

WATER DRIVER/PERSPECTIVE PLANET

FOCUS: Here the focus is to preserve the available water resources for the future use.

ISSUES

Rapid Depletion of Water

Two water hand pumps have been installed by the government for domestic purposes. However, because of lack of knowledge of the water table, the villagers have suffered from the limited water supply from the pumps. In the beginning, the villagers used to pump large quantities of water, this has repeatedly resulted in the depletion of water such that people must wait for an hour or more before pumping water again.

WATER DRIVER/PERSPECTIVE PROGRESS

FOCUS: A social entrepreneur's focus is to bring substantial improvement in agricultural production through a steady and reliable source of water.

ISSUES

Limited Access to Water

Currently, there is no technology available in the village which makes it possible to access the available water resources in and around the village. This further results in limited access to water.

ENERGY

Similarly, for ENERGY, the focuses are determined, and issues are collected as shown in Figure 6.

ENERGY DRIVER/PERSPECTIVE PEOPLE

FOCUS: The focus is to provide reliable, sustainable and affordable electricity to Kudagaon. Some of the issues related to this are shown next.

ISSUES

No Access to the Mainland

This is a major issue for the energy crisis in the village. Usually, the government of India provides electricity through electric grid. Since it is hard to connect the grid to an island, Kudagaon is living in the dark.

Flooding

This is an issue in many aspects. Floods usually create property damage including the electric poles and wires. Flooded areas usually lose access to electricity until the infrastructure is restored.

ENERGY DRIVER/PERSPECTIVE PLANET

FOCUS: The focus is to generate eco-friendly power.

ISSUES

Capex and Opex are high

While renewable energy technologies such as windmills, solar-grid, hydroelectricity are environmentally friendly, they require large capital expenditure (Capex) and high operational expenditure (Opex).

Consuming Farmers' Land

Reliable and sustainable technology for electrical supply requires a relatively large area of land for the setup. However, as the farmlands are privately owned, this causes reduction of fertile farmland area which also results in lower income.

ENERGY DRIVER/PERSPECTIVE PROGRESS

FOCUS: The main focus is to promote productive loads.

ISSUES

Lack of Energy Infrastructure

As Kudagaon is an island village, it does not have any prior steady and a reliable source of power.

Lack of Electrical Appliances/Machines

Only providing electricity does not solve the problem. Efficient SMEs require technology and technical devices to run a business smoothly. For example, farmers need machines to process products or for cold storage to increase the life of the produce.

Lack of Entrepreneurial Skills

The lack of entrepreneurial skills is probably due to the lack of knowledge regarding businesses in general. Based on the village resources, small and micro-enterprises (SMEs) can be designed but due to lack of entrepreneurial skills, it is difficult to sustain these SMEs.

Step 5: Create Issue Matrix and Categorize Issues

In an Issue Matrix as shown in Figure 7. Each cell is checked to determine in which category the issues fall. Those categories are mentioned with the appropriate color and number. This is done for three drivers (FOOD, ENERGY, and WATER).

Please note that the relationship between the issues is considered from point of view of the issues in the rows, i.e., how resolving issues in rows affect the issues in the column. This applies to inter-tension and inter-dependent issues too.

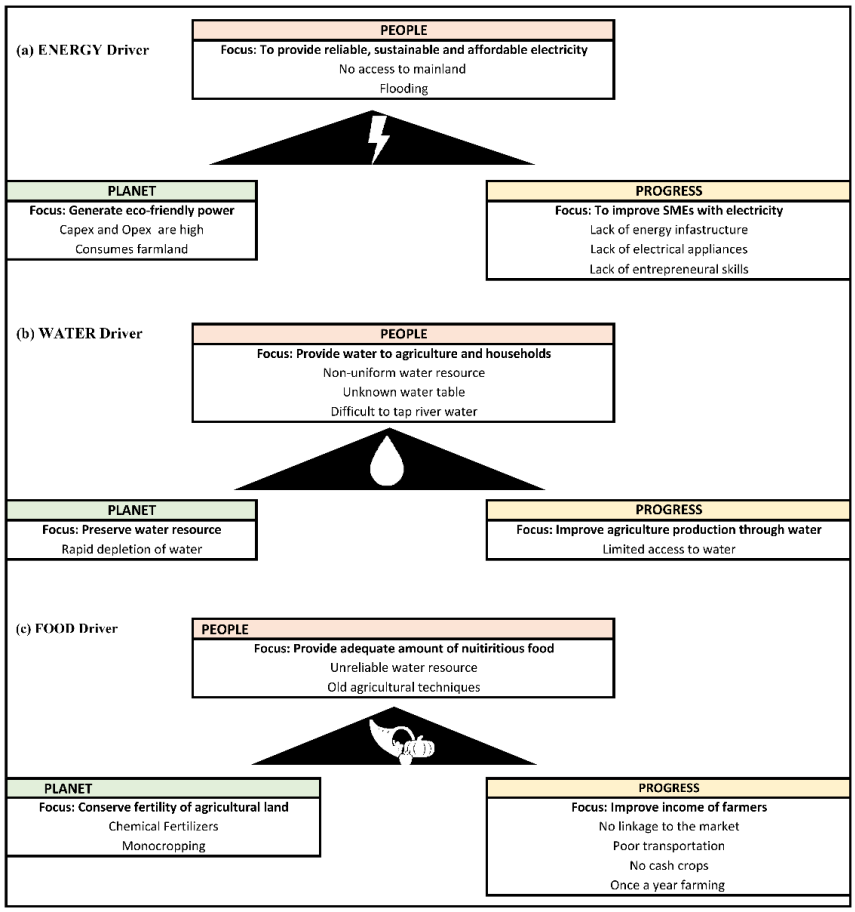

Figure 6. Dilemma triangles for the Drivers: (a) ENERGY, (b) WATER and (c) FOOD

FOOD	PEOPLE		PLANET		PROGRESS			
	Unreliable Water Resources	Old Agriculture Techniques	Chemical Feritilzers	Monocropping	No Market Linkage	Poor Transporation	No Cash Crops	Once a Year Farming
No Market Linkage			*Inter-Tension 1 with Energy	*Inter-Tension 2 with Energy				
Poor Transporation					Dependent 1			
No Cash Crops			Tension 1	Dependent 2				
Once a Year Farming			Tension 2				Dependent 3	
Chemical Fertilizers								
Monocropping								
Old Agriculture Techniques								
Unreliable Water Resources				Dependent 4			Dependent 5	

WATER	PEOPLE			PLANET	PROGRESS
	Difficult to Tap River Water	Unknown Water Table	Non-uniform Water Resource	Rapid Water Depletion	Limited Access
Limited Access	Inter-Dependent 1 with Food				
Rapid Water Depletion					
Difficult to Tap River Water			Dependent 6	Tension 3**	
Unknown Water Table			Dependent 7	Tension 4	Dependent 8
Non-uniform Water Resource					

Inter-Dependent 2 with Food

ENERGY	PEOPLE		PLANET		PROGRESS		
	Flooding	No Access to Mainland	Consuming Farmland	Capex and Opex are High	Lack of Entrepreneurial Skills	Lack of Electrical Appliances	Lack of Energy Infrastructure
Lack of Entrepreneurial Skills			Tension 5			Dependent 9***	
Lack of Electrical Appliances		Inter-Dependent 3 with Food		Tension 6			
Lack of Energy Infrastructure			Tension 7	Tension 8			
Consuming Farmland							
Capex and Opex are High							
Flooding				Dependent 10			
No Access to Mainland					Inter-Dependent 4 with Food		Dependent 11

*** We are considering that the markets will be established within the village**
**** River water runs thin during the non-rainy seasons**
***** Based on experience, with energy supply and development of entrepreneurial skills, villagers have acquired electrical devices for their enterprises.**

Figure 7. Issue matrixes for FOOD, ENERGY and WATER

Categorizing Issues in FOOD

Tension 1 – *No Cash Crops vs Chemical Fertilizers*

As more cash crops will be introduced in the farming practices, the farmers will continue to depend on the chemical fertilizers. Instead of the issue related to fertilizer getting resolved, it will either continue to exist or become worse.

Tension 2 - *Once a Year Farming vs Chemical Fertilizers*

When the issue related to once-a-year farming is resolved, i.e., when the farmers start their agriculture practices for more than one season, they will require more fertilizers for the yield. Therefore, the issue related with chemical fertilizer will get enhanced.

Dependent 1 – *Poor Transportation vs No Market Linkage*

As the facility for transportation is made available, the issue related to no market linkage will start to resolve.

Dependent 2 – *No Cash Crops and Monocropping*

As more and more cash crops are grown, the issue related to monocropping will be annihilated.

Dependent 3 – *Once a Year Farming vs No Cash Crops*

Once the farmers start to practice multi-season agriculture, they will be able to grow seasonal crops and primarily the cash crops of the season.

Dependent 4 – *Unreliable Water Sources vs Monocropping*

One of the major reasons for monocropping in Kudagaon is that the limited availability of water prevents the farmers to grow multiple crops. With a reliable source of water, the farmers can grow more crops, suited to the soil and area, instead of a single crop.

Dependent 5 – *Unreliable Water Sources vs No Cash Crops*

Cash crops require a reliable and adequate quantity of water to flourish. With a reliable water supply, the farmers will be able to grow cash crops.

Categorizing Issues in WATER

Tension 3 – *Difficult to Tap River Water vs Rapid Water Depletion*

While water is needed for prosperous agriculture practices, when the farmers are able to access river water in a reliable way, there is a threat that without any restrictions, they can cause depletion of water, especially in summers. The river water runs thin during non-rainy seasons.

Tension 4 – *Unknown Water Table vs Rapid Water Depletion*

When the water table is accessible, the chances of it being depleted increase as no means to monitor the water consumption exists.

Dependent 6 – *Difficult to Tap River Water vs Non-uniform Water Resource*

Once the option of tapping river water all year round is made available, the issue related to non-uniform water resource gets resolved.

Dependent 7 – *Unknown Water Table vs Non-uniform Water Resource*

Dependent 8 – *Unknown Water Table vs Limited Access to Water*

There is no information available about the water table in Kudagaon. This is an assumption that when the aquifers are identified, the issue of limited access to water will reduce.

Categorizing Issues in ENERGY

Tension 5 – *Lack of Entrepreneurial Skills vs Consuming Farmland*

As more entrepreneurial opportunities will emerge in the village, more farmland will be converted to enterprises. This will reduce the available farmlands in Kudagaon.

Tension 6 – *Lack of Electrical Applances vs Capex and Opex are high*

As the electrical appliances (domestic and commercial) will increase within the village, the size of the minigrid will increase. This is further imposed on the capital cost needed to expand the minigrid and hence, will have a higher operation cost too.

Tension 7 – *Lack of Energy Infrastructure vs Consuming Farmland*

As the infrastructure for minigrid increase, it will encroach into the farmlands for more land space. Therefore, while the issue related to energy infrastructure gets resolved, the issue related to consuming farmland will increase.

Tension 8 – *Lack of Energy Infrastructure vs Capex and Opex are High*

As the energy infrastructure increases the capex and opex related to them will also increase. Solving the issue on energy infrastructure will worsen the issue related to high capex and opex.

Dependent 9 – *Lack of Entrepreneurial Skills vs Lack of Electrical Appliances*

As the skills of the villagers improve in entrepreneurship, they will adapt to new technologies, which implies adaptation of electrical appliances for their enterprises.

Dependent 10 – *Flooding vs Capex and Opex are High*

When the issue related to flooding decreases in the village, the minigrid design and maintenance will not need to take this additional precaution. Hence, when the flooding issue goes down, capex and opex for the minigrid will also go down.

Dependent 11 – *No Access to the Mainland vs Lack of Energy Infrastructure*

Once a permanent and robust route is created that links the island village to the mainland, it can be used to bring in the traditional grid to Kudagaon, improving the energy infrastructure of the village.

Identifying Inter Tensions and Dependents

A pictorial representation of the Inter-Tensions and Inter-Dependents is complicated as they connect different matrices. Hence, these categories are directly mentioned below

Inter-Tensions 1 (FOOD vs. Energy)

No Market Linkage (FOOD) vs Consuming Farmland (Energy)

With better entrepreneurial opportunities such as food processing units within the village, the farmers will have within the village market linkage. However, food processing units will encroach the farmlands to build their infrastructure.

Inter-Tension 2 (FOOD vs. ENERGY)

No Market Linkage (FOOD) vs Capex and Opex are High (ENERGY)

Once again, if the market potential within the village increases, especially due to the entrepreneurial activities, this will also increase the capex and opex related to the energy infrastructure.

Inter-Dependent 1 (WATER and FOOD)

Limited Access (WATER) vs Unreliable Water Resources (FOOD)

Resolving the issue of limited access also resolves the problem of unreliable water resources.

Inter-Dependent 2 (WATER and FOOD)

Limited Access (WATER) vs No Cash Crops (FOOD)

Once there is an access to water, the farmers can grow multiple cash crops in their farmlands.

Inter-Dependent 3 (ENERGY and FOOD)

Lack of Electrical Appliances (ENERGY) and Old Agriculture Techniques (FOOD)

With an access to electrical appliances, farmers can adapt new technologies/techniques for agriculture.

Inter-Dependent 4 (ENERGY and FOOD)

No Access to Mainland (ENERGY) and No Market Linkage (FOOD)

Once there is an access to the mainland, the villagers will have better market linkage for their produces.

STEP 6: Identifying Dilemmas and Developing Value Propositions

Step 6a: Identifying Dilemmas

The issues developed in Step 5 (Tensions, Dependents, Inter-Tensions, Inter-Dependents) are grouped based on the problem.

Group 1 – Dilemma 1 – How to get water?

How can river water and groundwater be used to provide a continuous water supply so that the farmers grow multiple cash crops more than once a year without depleting the water sources? The issues related to this Dilemma are shown in Table 1.

Table 1. Considerations for dilemma 1 water related problems

D4	Unreliable Water Resources vs Monocropping
D5	Unreliable Water Resources vs No Cash Crop
ID1	Limited Access to Water vs Unreliable Water Resources
ID2	Limited Access to Water vs No Cash Crop
D6	Difficult to Tap River Water vs Non-Uniform Water Resources
T3	Difficult to Tap River Water vs Rapid Water Depletion
D7	Unknown Water Table vs Non-Uniform Water Resources
T4	Unknown Water Table vs Rapid Water Depletion
D8	Non-uniform Water Resources vs Limited Access

Group 2 – Dilemma 2 - How to improve agriculture production and also farmer's income?

The focus is to improve farmers' income. However, there are several issues related to the agriculture practices, water issues and poor market linkage. What value propositions can address the issues to achieve the objective? The related issues are in Table 2.

Table 2. Group 2 – Agriculture related problems

IT1	No Market Linkage vs Consuming Farmland
IT2	Linkage vs Capex and Opex are High
T1	No Cash Crop vs Chemical Fertilizer
D2	No Cash Crop vs Monocropping
T2	Once a Year Farming vs Chemical Fertilizer
D3	Once a Year Farming vs No Cash Crop
D4	Unreliable Water Resources vs Monocropping
ID3	Lack of Electrical Appliances vs Old Agriculture Techniques
ID4	No Access to Mainland vs No Market Linkage

Group 3 – Dilemma 3 - How to establish an energy source?

Problems are identified to establishing a source of electricity in the village. These issues are grouped, which leads to a dilemma as shown in Table 3. Where should a microgrid be installed concerning the growing demand?

Table 3. Group 3 – Electricity related problems

T7	Lack of Energy Infrastructure vs Consuming Farmland
T8	Lack of Energy Infrastructure vs Capex & Opex are High
D10	Flooding vs Capex & Opex are High
D11	No access to the Mainland vs Lack of Energy Infrastructure

Group 4 – Dilemma 4 - How to scale up Small and Micro Enterprises?

In extremely poor villages, establishing small and micro enterprises (SME) is challenging due to poor transportation, poor energy supply and poor marketing systems [12]. Hence the issues related to this are grouped as shown in Table 4. These issues affect both food production and handicrafts.

Table 4. Group 4 –Problems related to SMEs

T5	Lack of Entrepreneurial Skills vs Consuming Farmland
D9	Lack of Entrepreneurial Skills vs Lack of Electrical Appliances

Step 6b: Develop Value Propositions from Each Dilemma

Since dilemmas have been identified, value propositions can be developed to address them. These dilemmas serve as problem statements that provide hints for developing integral value propositions. Developing value propositions is not the primary focus of this work. Identifying dilemmas for the FOOD, ENERGY, WATER-Nexus is the most important objective. Once a social entrepreneur understands the dilemma, he/she and his/her team can find different ways to address those dilemmas. There are often many solutions to a problem. When a social entrepreneur identifies a dilemma, there is a high probability that the right solution for a particular problem can be found.

Value Proposition 1 (Dilemma 1: How to get water?)

The underground water table of Kudagaon is unknown. An intervention could be to place two surface pumps at different spots where the river water level is stable throughout the year. Water meters can be used to monitor water consumption. Furthermore, if the water supply is charged, the farmers will be cautious to not waste water during farming. This provides a sustainable and reliable water supply for agriculture and resolve the water related issues for farming.

Value Proposition 2 (Dilemma 2: How to improve agriculture production and also farmers' incomes?)

This should be considered when Dilemma 1 is addressed. With the steady supply of water throughout the year enables the farmers to move from monocropping to multiple cash crops. This transition ensures a significant growth in the agriculture produce and therefore, farmers' income. However, market linkage continues to be a problem for the selling the

harvest. In which case, dilemma 4 is also needed to be resolved to overcome the tensions within this dilemma.

Value Proposition 3 (Dilemma 3: How to set-up an energy source?)

A solar power plant with a battery backup is proposed as Kudagaon has plenty of sunlight [13]. The project was funded, wherein the capex was not a burden on the villagers. However, to resolve the issue related with opex, the electricity is sold at an affordable cost. The money collected is saved in the Village Energy Committee bank account. The saved amount is currently used for the local operator salary and all O&M costs. The installation of the plant is such that it will not be disturbed with the annual flooding of the island. Also, the owner of the farmland used for the power plant is given a compensation to cover the losses he would have incurred from not farming in the plot.

Value Proposition 4 (Dilemma 4: how to scale up Small and Micro Enterprises?)

Since market linkage is a large problem, cold storage can be provided to store their crops until they are sold. Moreover, processing units can also be setup to increase the life and quality of the produce. With such enterprises land owners can convert from being farmers to entrepreneurs and continue to have a steady source of income [14].

4. CLOSING REMARKS

In this paper, the Dilemma Triangle Method is introduced to manage dilemmas in decision making, especially for a social entrepreneur to develop sustainable value propositions. With the help of an automated dashboard, this method is illustrated using data from an island village, Kudagaon. It is used to is to understand the FOOD, ENERGY, and WATER Nexus and to help identify dilemmas that are essential in developing socio-technical value propositions. This DTM is illustrated for one village in India and it is generalizable for other applications. In order to apply this method, it is important to have basic knowledge of community problems to categorize the issues in the Issue Matrix.

The DTM is an attention directing tool. The efficacy of the DTM is dependent on the knowledge of the user and the ability of the user to frame the problem from a systems perspective. A further limitation is that only three drivers are compared at a time. In more complex cases, the most important drivers must be identified and the procedure repeated multiple times.

The process of categorizing issues is introduced and allows a social entrepreneur to identify four categories of issues that result in better understanding and framing of the problem. These categorized issues are grouped as shown in **Step 6a** from **Section 3** to form dilemmas. Since the purpose of this Dilemma triangle method is to identify dilemmas, a social entrepreneur explores most of the dilemmas using this method and decides what value proposition is needed to address these dilemmas.

A social entrepreneur can use the method to implement the dilemma triangle in the three important components (FOOD, ENERGY, and WATER) with multiple goals and issues. In each component, the three spheres of sustainability [15] are considered to be the three perspectives, that is, People (Social), Planet (Environmental) and Progress (Economic) that result in developing a sustainable value proposition. This method has allowed the personnel from SunMoksha to develop sustainable value propositions to address Sustainable Development Goal 11, sustainable cities and communities.

We foresee the automated Dilemma Triangle Dashboard being included as one of several tools embodied in a cloud-based computer platform. This platform would be accessible to any stakeholder from any location. This would enable multiple stakeholders to collaboratively develop value propositions to further development that is sustainable.

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REFERENCES

[1] Rittel, H.W.J., Webber, M.M. (1973). Dilemmas in a general theory of planning. Policy Sci., 4: 155-169. https://doi.org/10.1007/BF01405730

[2] Godfray, H., Beddington, J., Crute, I., Haddad, L., Lawrence, D., Muir, J, Toulmin, C. (2010). Food security: The challenge of feeding 9 billion people. Science, 327(5967): 812-818. https://doi.org/10.1126/science.1185385.

[3] World Commission on Environment and Development. (1987). Our Common Future, Oxford University Press.

[4] Flint, R.W. (2013). Practice of Sustainable Community Development. Springer. https://doi.org/10.1007/978-1-4614-5100-6

[5] Baldassarre, B., Calabretta, G., Bocken, N., Jaskiewicz, T. (2017). Bridging sustainable business model innovation and user-driven Innovation: a process for sustainable value proposition design. Journal of Cleaner Production, 147: 175-186. https://doi.org/10.1016/j.clepro.2017.01.081

[6] DeFries, R., Nagendra, H. (2017). Ecosystem management as a wicked problem. Science,356(6335): 265-270. https://doi.org/10.11126/science.aal1950

[7] Yadav, A., Das, A.K., Roy, R.B., Chatterjee, A., Allen, J.K, Mistree, F. (2017). Identifying and managing dilemmas for sustainable development of rural India. ASME Design Theory and Methodology Conference, Cleveland, OH. Paper Number DETC2017-67592. https://doi.org/10.1115/DETC2017-67592

[8] Ahmed, S., Xiao, M., Panchal, J.H., Allen, J.K., Mistree, F. (2012). Managing dilemmas embodied in 21st century engineering. ASME International Confeence on Design and Design Education, Chicago, IL. Paper Number DETC2012-71168. https://doi.org/10.1115/DETC2012-71168

[9] Kamala, V.V.R. (2020). A computational framework to foster sustainable development in Indian off-grid villages. MS Thesis, Industrial and Systems Engineering, University of Oklahoma, Norman, OK. https://shareok.org/handle/11244/324408, on accessed on Nov. 7, 2022.

[10] Munier, N. (2005) Introduction to sustainability: Road to

a better future. Springer. Dordrecht, The Netherlands. pp. 1, 5, 15, 20, 21, 24, 105, 121. https://doi.org/10.1007/1-4020-3558-6

[11] De Brucker, K., Macharis, C., Verbeke, A. (2013). Multi-criteria analysis and the resolution of sustainable development dilemmas: A stakeholder management approach. European Journal of Operational Research, 224(1): 122-131. https://doi.org/10.1016/j.ejor.2012.02.021

[12] Amiri, S., Naderi, N., Mohammadi Far, Y.Y. (2019). "Conceptualization of the challenges in home-based businesses in the villages of Kermanshah province. Journal of Rural Research, 10(2): 172-185. https://doi.org/10.22059/jrur.2019.276528.1333

[13] SunMoksha Pvt. Ltd, Bengaluru, India. https://sunmoksha.com/, accessed on Feb. 20, 2020.

[14] Budaev, D., Lada, A. Simonova, E., Skobelev, P., Travin, V., Voshchuk. G. (2018). Conceptual design of smart farming solution for precise agriculture. International Journal of Design and Nature and Ecodynamics, 13(3): 307-314. https://doi.org/10.2495/DNE-V13-N3-307-314.

[15] Hansmann, R., Mieg, H.A, Frischknecht, P. (2012). Principal sustainability components: empirical analysis of synergies between the three pillars of sustainability. International Journal of Sustainable Development and World Ecology, 19(5): 451-459. https://doi.org/10.1080/13504509.2012.696220