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IDB Lab

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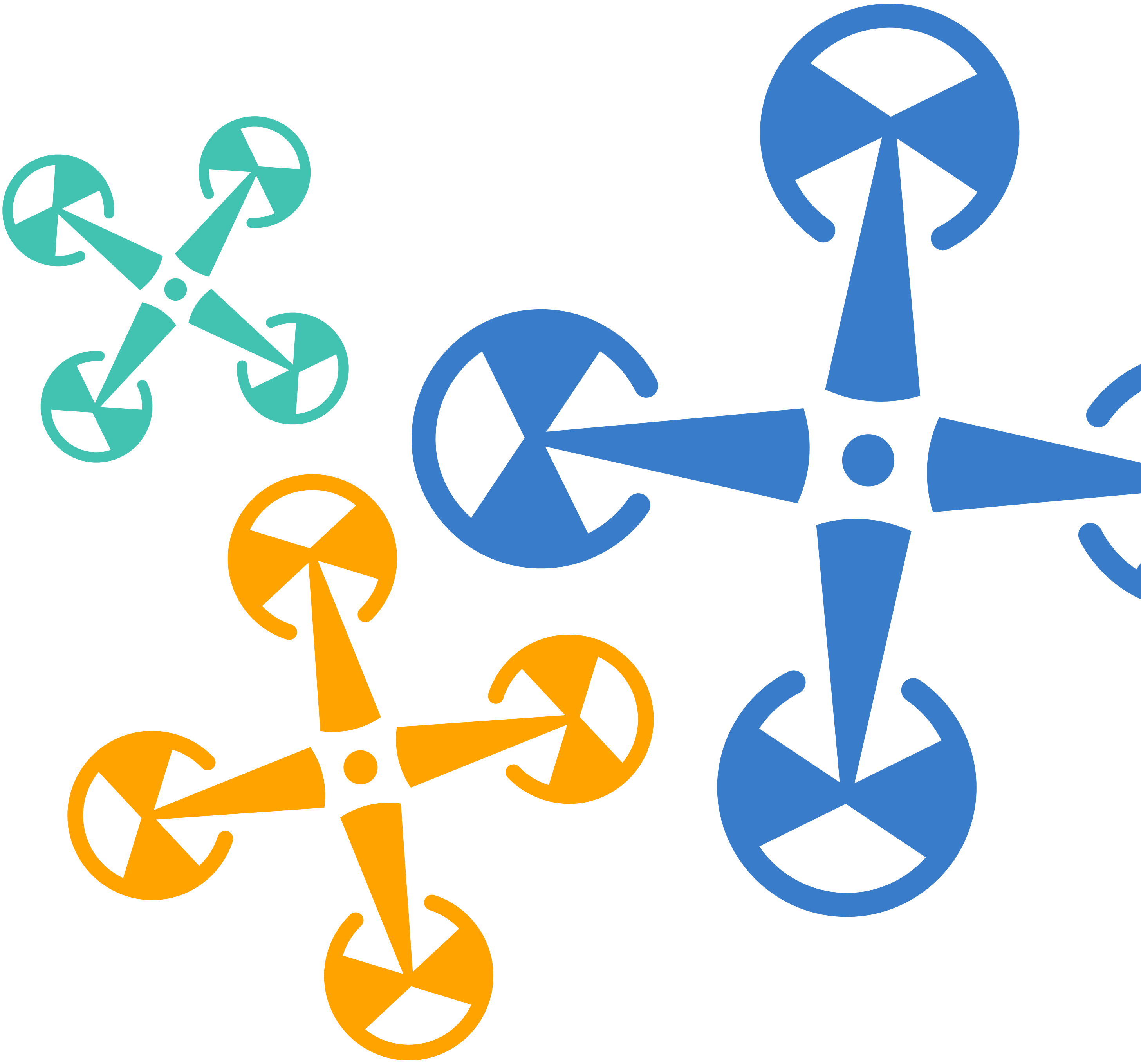
MEDICAL CARGO DRONES IN RURAL DOMINICAN REPUBLIC



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INTRODUCTION

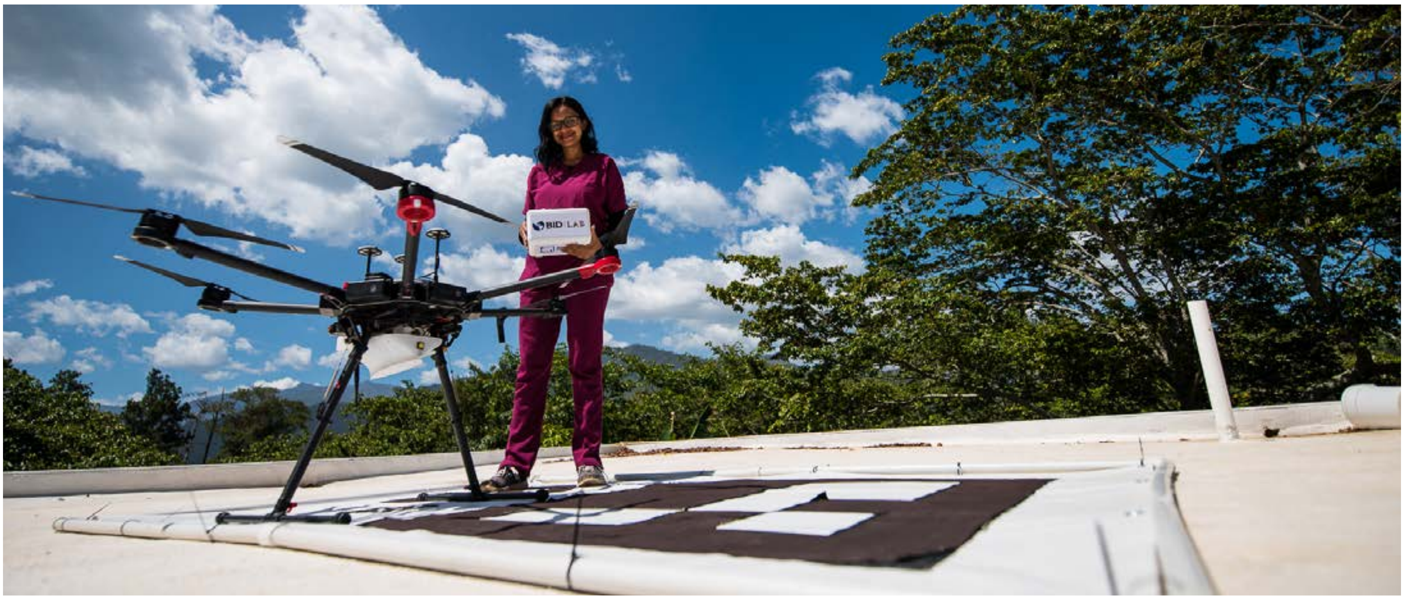
INTRODUCTION

Unmanned aerial vehicles (UAV) or drones, similar to many other interventions such as the internet, GPS and nuclear energy, derived from applications designed for military purposes.

In the 21st century drone technology advanced due to a reduction of production costs of smaller electro-mechanical systems such as gyroscopes and accelerometers that were critical components of mobile technology and smartphones. The lower production costs for these parts opened the door for multiple applications in agriculture, security, health, logistics, sports and humanitarian aid. Many of these applications have the potential to increase business productivity and improve access to services for the broader population.

This report examines one area of drone application with the greatest potential impact, health. This report presents results from an evaluation of the versatility of drone operations within the health sector, and the associated costs of operating drones in a region where access to basic health services is limited due to the topography of the land. This evaluation is informed by data collected on more than 150 flights made over a period of two years, between primary care centers and hospitals in the province of San Juan de la Maguana in the Dominican Republic.

Of particular interest, the results provide useful information regarding when the use of drones makes the most practical and economic sense depending on projected costs. By comparing the costs of the



traditional transport method (motor vehicle) to drones, we provide a reference framework to support public and private sector decision makers considering using this type of technology.

The report relies heavily on the Drone Evidence Generation Toolkit, developed by VillageReach in coordination with the Interagency Supply Chain Group (ISG) as well as an Excel-based tool developed by InSupply, JSI and LLamasoft to compare drone transportation costs to existing ground transport by road. The Drone Evidence Generation Toolkit provides a standardized set of indicators and tools that can be adapted to generate evidence around any drone project implementation as well as the costs associated with the use of drones for the transportation of medical supplies.

We hope that the findings of this report can support public and private sector stakeholders when making decisions regarding the use of this technology to complement integrated health service networks and to improve the provision of basic health services in hard-to-reach areas.

150
FLIGHTS

2
YEARS

PRIMARY CARE CENTERS AND HOSPITALS IN SAN JUAN PROVINCE

EXECUTIVE SUMMARY

EXECUTIVE SUMMARY

With support from the Inter-American Development Bank (IDB), through its Innovation Lab (IDB Lab), the Drone Innovation Center demonstrated the feasibility of safe, repeated deliveries of medical commodities by drones in San Juan Province, Dominican Republic.

From 2016 to 2019, the Drone Innovation Center conducted a total of 157 test flights, and generated evidence around the extent to which the local political, regulatory, and social context is conducive to the use of drones, as well as the potential benefits and costs of introducing drones into the medical commodity transport system.

This use case analysis applied the framework and tools presented in the Drone Evidence Generation Toolkit, developed by VillageReach in coordination with the Interagency Supply Chain Group (ISG). This toolkit provides a standardized set of indicators and tools that can be adapted to generate evidence around any drone project implementation.

Evidence was generated around three deliverables:

↘ **DELIVERABLE 1.1:**
Permission secured to import and use drones

↘ **DELIVERABLE 1.2:**
Feasibility of introducing drones is evaluated

↘ **DELIVERABLE 1.3:**
Safe and locally reliable technology is tested

This evidence was used to develop key recommendations for next steps in the Dominican Republic, including:

1
Engage a multi-sectoral group of government decision-makers around the political, regulatory, human resource, financial, and health implications and requirements of introducing drones for medical commodity delivery

2
The government, implementers and technology partners flying drones in the Dominican Republic should conduct multi-method, comprehensive community outreach before initiating drone flights

3
Prioritize the use of drones to deliver products which have the potential to be lifesaving if available urgently, are cost-efficient, or require cold chain or special handling

4
Prioritize geographic locations for delivery of health products and services by drone that are hard-to-reach or not reached by other services

5
Compile and collect the data needed to optimize the transport system with drones

6
Explore the use of drones beyond public health and develop public-private partnerships both within public health and across sectors to begin to identify sufficient financial resources for the ongoing use of drones

7
Develop and implement a capacity-building plan to ensure ongoing maintenance and operations of drones in country

BACKGROUND

BACKGROUND

Effective and efficient medical commodity delivery is essential to ensuring quality health care provision for all people, but unreliable or nonexistent infrastructure prevents products from reaching those who need them in low-resource environments, as in many rural areas of the Dominican Republic.

Governments have begun to investigate the potential of drones as an integrated component of a responsive and resilient transportation network to resolve these supply chain challenges.

With support from the Inter-American Development Bank (IDB), through its Innovation Lab (IDB Lab), the Drone Innovation Center demonstrated the feasibility of safe, repeated deliveries of medical commodities by drones in San Juan Province, Dominican Republic.

From 2016 to 2019, the Drone Innovation Center conducted a total of 157 test flights, and generated evidence around the extent to which the local political, regulatory, and social context is conducive to the use of drones, as well as the potential benefits and costs of introducing drones into the medical commodity transport system.

The Drone Innovation Center contracted VillageReach to:

- ↘ **Provide insights into the efficiency of the drone transportation model, including costs and benefits, such as reduction in transport time**
- ↘ **Provide a case study with recommendations for a model to integrate drones into the current transport system, taking into consideration the challenges, community acceptance, available and reliable technology, compliance with aviation regulatory guidelines, associated costs, and flight safety**

To achieve these objectives, VillageReach conducted a desk review of existing reports and available data, led primary data collection in San Juan Province from May to July 2019, and conducted secondary analyses and modeling exercises. This report presents the combined findings as well as recommendations for the next steps to integrate drones into public health supply chains in the Dominican Republic.

1. Objectives

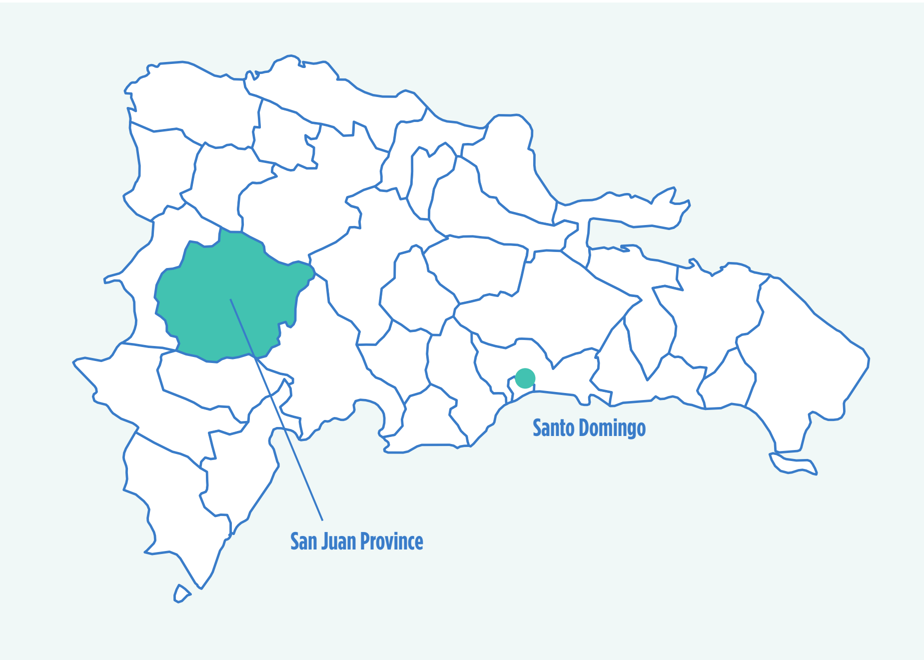
The objectives of this use case analysis were:

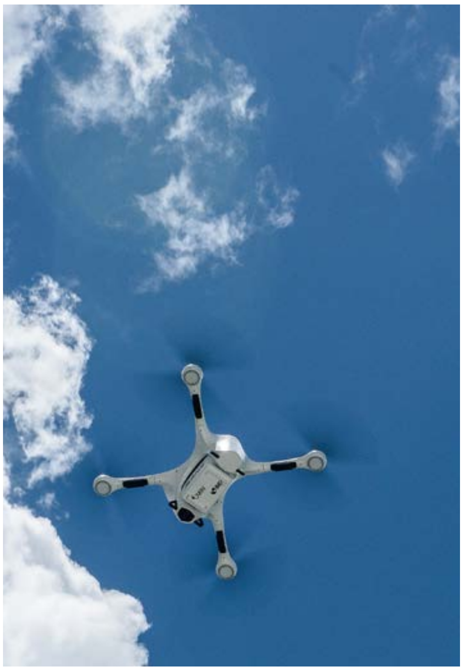
- **Evaluate stakeholder and community acceptance of using drones to transport public health products or services in San Juan Province, Dominican Republic**
- **Identify key cost drivers in the current ground transport system in San Juan Province and a potential drone transport system**
- **Identify scenarios in which cost savings could potentially be realized by introducing drone transport**
- **Explore the potential benefit of introducing drone transport on transport distance and time**
- **Compile existing operational data from prior drone test flights in San Juan Province, beginning in 2017, and collect operational data on 2019 drone test flights**
- **Provide recommendations for next steps in optimizing the public health supply chain through the introduction of drones**

2. Methods

In 2016, San Juan Province was selected for the drone test flights, in coordination with government stakeholders, based on the following criteria:

1. LARGEST PROVINCE IN THE COUNTRY, SUGGESTING THAT SCALE-UP MIGHT EFFICIENTLY REACH A LARGE AREA
2. PRIMARILY RURAL, AND THEREFORE HEALTH FACILITIES SERVE WIDE GEOGRAPHIC AREAS
3. INFRASTRUCTURE WAS INSUFFICIENT TO REACH ALL HEALTH FACILITIES IN THE PROVINCE IN A TIMELY MANNER





This use case analysis applied the framework and tools presented in the Drone Evidence Generation Toolkit, developed by VillageReach in coordination with the Interagency Supply Chain Group (ISG). This toolkit provides a standardized set of indicators and tools that can be adapted to generate evidence around any drone project implementation. Government stakeholders and other implementers can use this evidence to inform decision-making around next steps in the Dominican Republic. In addition, evidence can be shared more broadly to support the advancement of the sector globally.

The framework used to prioritize evidence generated around this project is presented in Figure 1. See Appendix A for a full list of indicators and methods used.

RESULT	DELIVERABLE	INDICATOR
1: AN ENABLING ENVIRONMENT FOR THE USE OF DRONES TO TRANSPORT MEDICAL COMMODITIES IS ESTABLISHED.	1.1: PERMISSION SECURED TO IMPORT AND USE DRONES	1.1.1 FLIGHT PERMISSION TYPE
	1.2: FEASIBILITY OF INTRODUCING DRONES IS EVALUATED	1.2.1 LEVEL OF STAKEHOLDER ENGAGEMENT 1.2.2 COST DRIVERS IDENTIFIED 1.2.3 BENEFITS IDENTIFIED
	1.3: SAFE AND LOCALLY RELIABLE TECHNOLOGY IS TESTED	1.3.1 # OF FLIGHTS COMPLETED 1.3.2 MAXIMUM DISTANCE 1.3.3 MAXIMUM PAYLOAD

TABLE 1: Project evidence generation framework

↘ DELIVERABLE 1.1:
PERMISSION SECURED TO IMPORT AND USE DRONES

Written, signed documentation of flight permission received from the Dominican Institute of Civil Aviation (Instituto Dominicano de Aviación Civil) was reviewed and categorized as follows:

1. What type of flight was permitted?
This describes whether the drone can be flown within the sight of the operator or can be flown beyond the sight of the operator

2. How long is drone flight permitted?
Permission may be granted for a one-time flight, a limited duration, or without limit

3. Where is drone flight permitted?
The geographic range of flight may or may not be specified

↘ DELIVERABLE 1.2:
FEASIBILITY OF INTRODUCING DRONES IS EVALUATED

The feasibility or potential of introducing drones for medical commodity delivery, including objective assessment of the costs and benefits of the approach, must be evaluated before it can be recommended to government decision-makers. This use case analysis looked at three components:

↘ Community and stakeholder acceptance

↘ Costs associated

↘ Potential benefit for transport time

Community and stakeholder acceptance

To evaluate the extent to which stakeholders and community would accept the use of drones to transport health commodities beyond the test flights, focus group discussions (FGDs) were conducted with general community members residing within close proximity to the take-off and landing sites in May 2019. FGDs were facilitated by three university-educated consultants from the University of Santo Domingo and the Drones Innovation Center. Health workers were asked to support recruitment of FGD participants. FGDs lasted approximately 30 minutes and were conducted in Spanish. Participation in FGDs was voluntary, and groups were divided into men's and women's groups to support an open dialogue.

Key informant interviews (KIIs) were conducted with community leaders and health workers (see Appendix B for the data collection tool). Health center management was asked to help recruit KII participants. Each KII lasted between 30-60 minutes and was conducted in Spanish. FGDs and KIIs collected feedback on the use of drones to transport health commodities and can inform future community outreach strategies.

Costs associated study

A costs associated exercise aimed to provide insights into the costs of using drones to transport medical commodities between the San Juan Provincial Warehouse and primary health care facilities in San Juan Province. The full list of facilities included in this analysis can be found in Appendix C.

An Excel-based tool developed by InSupply, JSI and LLamasoft was used to compare drone transportation costs to existing ground transport by road. This tool allows the user to select pre-filled data compiled from publicly available sources and previous projects or to input their own data based on their context of interest. This tool was selected because it rapidly estimates high-level supply chain costs based on available data and does not require an extensive data-collection process.

The Excel-based tool requires three types of inputs: **geographic inputs, product inputs,** and **transport inputs**. In this exercise, we collected data to populate the geographic

inputs and transport inputs, and we used the pre-filled data for product inputs. Input data for geographic and transport inputs was collected through online search of publicly available resources and key informant interviews with WeRobotics (the drone supplier) and provincial logistics managers. See Appendices D and E for guiding questions used and Appendix F for a list of individuals participating in key informant interviews. Pre-filled input data on products were used to rapidly compare the drone and land transport systems across multiple product categories, including diagnostic specimens; reproductive, maternal, neonatal and child health (RMNCH) products; and essential medicines. Appendix G provides full details on the inputs used for the analysis.

Transport time comparison

In addition to studying the costs associated with introducing drones, it is also important to consider the relevant benefits, including the ability to rapidly reach health facilities and the potential to save lives that might otherwise be lost without quick and reliable transportation of medical commodities. GPS points for the San Juan Provincial Warehouse and health facilities in the province were collected. GPS points were available for 60 of the 69 health facilities in the province and were input into Google Maps to estimate the transport distance in kilometers and transport time in minutes both by ground and aerial transport.

↘ DELIVERABLE 1.3: SAFE AND LOCALLY RELIABLE TECHNOLOGY IS TESTED

Operational data from test flights conducted in August 2017, December 2017, and June-August 2019 were consolidated and analyzed. For the August 2017 test flights, conducted by Matternet, data was collected on the origin, destination, and departure and arrival times. For the December 2017 test flights, conducted by WeRobotics, comprehensive data was collected on the status of the drone equipment at take-off and landing as well as the details of origin, destination and departure and arrival times. The same data was collected for the June-August 2019 flights, as well as detailed data on the payloads transported.

Qualitative data was collected alongside test flights to complement the quantitative operational data. Four KIIs were conducted with health workers working at health facilities participating in the drone test flights and four observations of test flights were conducted. See Appendix H for KII tool for health workers and Appendix I for drone test flight observation tool.

3. Results

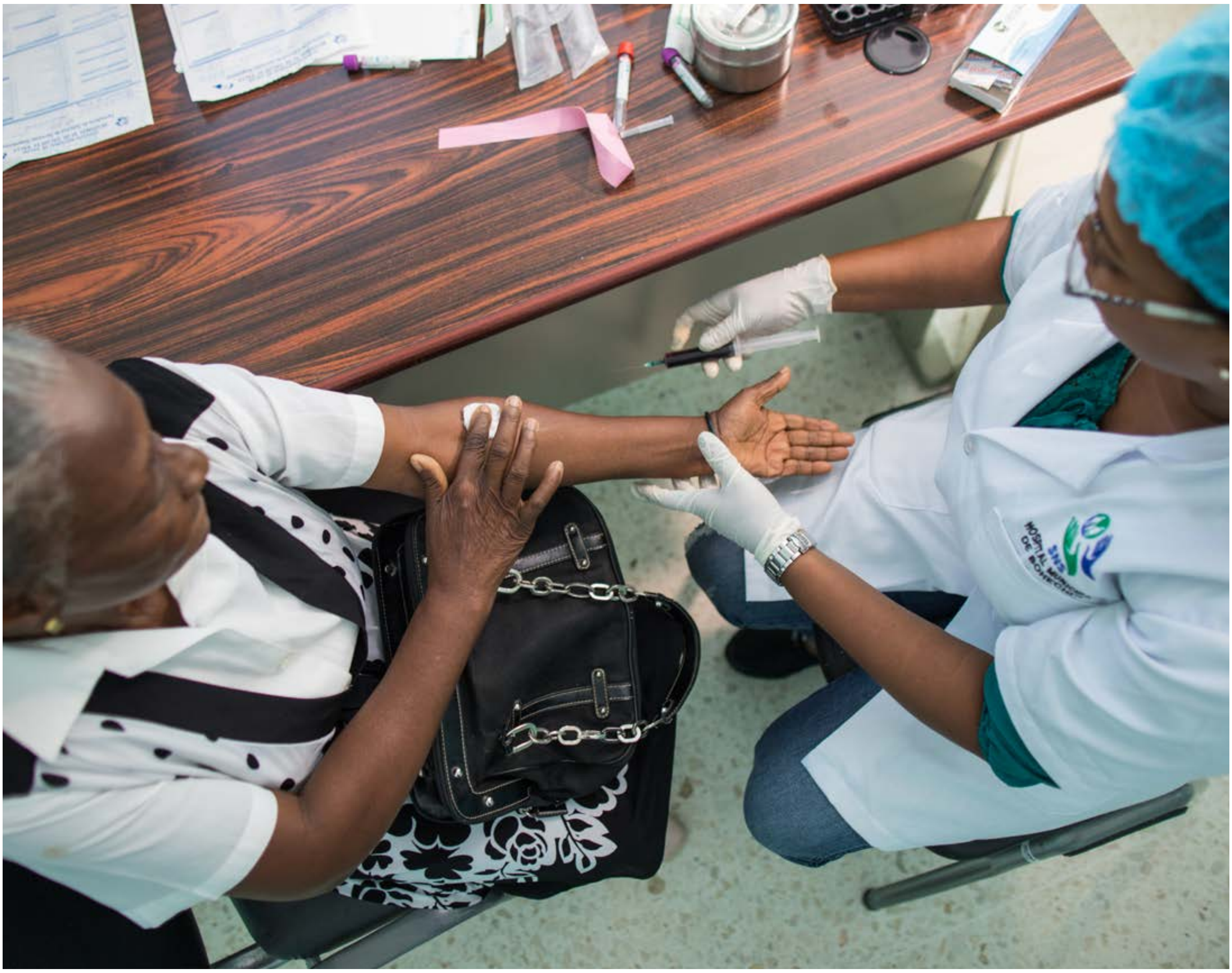
↘ DELIVERABLE 1.1:
PERMISSION SECURED TO IMPORT AND USE DRONES

In the absence of formal regulations governing the use of drones to transport medical commodities in the Dominican Republic, the Drone Innovation Center received special permission from the Dominican Institute of Civil Aviation (Instituto Dominicano de Aviación Civil) to fly drones in San Juan de la Maguana Province (Indicator 1.1.1: Flight permission type). This permission allowed beyond-visual-line-of-sight (BVLoS) flight for a limited duration between specified sites.

↘ DELIVERABLE 1.2:
FEASIBILITY OF INTRODUCING DRONES IS EVALUATED

Community and stakeholder acceptance

A total of 108 people participated in FGDs or KIIs on community and stakeholder acceptance of the use of drones to transport public health products and services.



SITE	FGD					
	MEN		WOMEN		TOTAL	
	# OF GROUPS	# OF RESPONDENTS	# OF GROUPS	# OF RESPONDENTS	# OF GROUPS	# OF RESPONDENTS
BOHECHÍO	0	0	1	8	1	8
DERRUMBADERO	1	9	1	8	2	18
EL CERCADO	1	7	1	10	2	17
EL COCO	1	6	1	8	2	14
JUAN DE HERRARA	1	8	0	0	1	8
LA JAGUA	2	17	1	6	3	23
TOTAL	**6**	**47**	**5**	**40**	**11**	**87**

TABLE 2: Summary of FGD respondents

SITE	KII RESPONDENTS						
	MEN			WOMEN			TOTAL
	# OF HEALTH WORKERS	# OF COMMUNITY LEADERS	# TOTAL	# OF COMMUNITY LEADERS	# OF COMMUNITY LEADERS	# TOTAL	
BOHECHÍO	0	1	1	0	2	2	3
DERRUMBADERO	0	1	1	0	2	2	3
EL CERCADO	0	0	0	0	2	2	2
EL COCO	1	1	2	0	1	1	2
JUAN DE HERRARA	3	0	3	0	3	3	6
LA JAGUA	0	0	0	0	1	1	1
MONTECITOS	0	0	0	0	1	1	1
SAN JUAN	2	0	2	0	0	0	2
TOTAL	**6**	**3**	**9**	**0**	**12**	**12**	**21**

TABLE 3: Summary of KII respondents

A total of 11 FGDs were conducted with 87 participants, 47% of whom were women, across six locations, both at the municipal hospital and primary health center level. KIIs were conducted with 21 respondents, 57% of whom were women, including respondents at the regional, municipal, and primary health center level. In three of the 11 FGDs, respondents had witnessed either the August 2017, December 2017, or May 2019 drone flights, while respondents in two of the remaining FGDs were mixed in their prior exposure to the project's drone flights, and respondents in the remaining six FGDs had not seen the project's drone flights.

Benefits of drones

FGD and KII respondents expressed a general familiarity with drones, although some of those who had witnessed the project's drone flights recalled surprise or fear when they first saw drones flying in their community. Overall, respondents agreed that drones were a sign of development, with many potential benefits, including saving lives, saving the patient time and money in accessing products or services further away, ensuring quality of items transported, and providing better security for products. Respondents identified multiple health-related uses of drones, including transporting pints of blood or lab samples to remote sites. In addition to uses of drones related to health, respondents felt that drones could be used to put out forest fires, record video, support agricultural delivers, or increase security.

Risks of drones

In addition to these potential benefits of drones, respondents also agreed that there were some risks. Drones have the potential to crash, whether due to wind, darkness, or an operator with insufficient training, and could cause harm to people, the environment, or the payload. One respondent expressed

concern that drones could be used by untrustworthy operators. Additionally, some respondents felt that investment in drones might not be seen as positive if the cost-effectiveness is not clear in comparison to other initiatives that can improve health outcomes. For example, a health worker identified a need for an increase in human resources, expansion of laboratory services, and procurement of medicines. Since 2016, when this project began, the province of San Juan de la Maguana has received significant investment in infrastructure, and may not be a geographic priority for the introduction of drones.

Who, where and when to fly

Respondents agreed that operators should be trained, from a trusted organization, over the age of 18, and from the community where the drone will be used. One group proposed the establishment of a community committee to monitor the operations and use of drones based on the local context. Another group highlighted the importance of not relying solely on health center staff to operate and use drones, due to turnover.

Respondents felt that drones were not suited to use at the border, in known drug trafficking areas, or near the national park to avoid being confused with illicit activity. In addition, drones should not be used where they may be confused with military activity.

Respondents highlighted the importance of educating the community about the use and purpose of drones, so that people are not surprised or scared by their use. Some respondents advised that drones shouldn't be flown at night, potentially because night time is quiet and people may want to be home as well as superstitions surrounding night time. In certain areas (El Cercado and Juan de Herrara), respondents advised that drones shouldn't be flown in the strong afternoon winds to avoid the risk of crash.

Communication strategy

Respondents who had observed the project's drone flights reported that they consulted neighbors or health workers when they wanted more information about the drone flights. Health workers, however, reported that they wanted more information to be able to provide community members. Respondents agreed that information should be widely disseminated through established community groups, radio, television, announcements by megaphone, and through workshops held in and near health centers. Communication should focus on how to handle adverse events, and the drones should have clear instructions in simple language or pictures on what to do in an emergency, with instructions for who to call for help.

Costs associated study

The costs associated study identified key cost drivers in both the existing land-based transport system and a potential drone transport system. The land-based transport system included three Toyota Hilux trucks, and the drone-based transport system included DJI M600 drones. The land-based transport system had a high capacity of 1,000 kg and 3,000 L per trip, so could serve all assigned facilities within one day. With a much lower capacity of 2 kg and 5 L per trip, drones would be required to make multiple trips to maintain supply at the health facility. The costs associated exercise compared the cost of operating a drone-based system focused on three different types of products, one with low weight and volume requirements (diagnostic specimens), one with high weight and volume requirements (essential medicines), and one in between (RMNCH products). Key cost drivers are presented below in Table 4.

The largest cost driver in the land-based transport system was the salary of the drivers for the three vehicles (46% of the

GROUND TRANSPORT		DRONE TRANSPORT			
COST DRIVER	% CONTRIBUTION	COST DRIVER	% CONTRIBUTION		
			DIAGNOSTIC SPECIMENS	RMNCH PRODUCTS	ESSENTIAL MEDICINES
1. DRIVER SALARY	46%	1. OPERATOR SALARY	87%	45%	42%
2. VEHICLE MAINTENANCE	23%	2. BATTERY COST	6%	26%	27%
3. VEHICLE COST	14%	3. DRONE FUSELAGE & AVIONICS COST	4%	15%	17%
4. FUEL COSTS	11%	4. DRONE MAINTENANCE	3%	12%	13%

TABLE 4: Comparison of key cost drivers, land vs. drone transport

total cost per kilometer), followed by vehicle maintenance (23%), vehicle cost (13%), and fuel cost (11%). In all three product scenarios, the largest cost driver in the hypothetical drone transport system is the operator's salary, although the proportion varies based on weight and volume requirements due to the number of flights needed. Operator salary contributes 87% of the cost per flight to the diagnostic specimen scenario, and is as low as 42% of the cost per flight in the essential medicine scenario. Variation in the percent contribution of cost drivers by product category is due to the number of trips the drone would need to make based on product volume and weight. For example, the tool assumes that each facility requires 32.5 kg and 100 L of diagnostic specimens annually, whereas the tool assumes that each facility requires 1,625 kg and 6,500 L of essential medicines annually. This means that a single drone may be able to fully meet the weight and volume required per facility for diagnostic specimens by making monthly flights between the warehouse and each health facility, whereas at least three drones would be needed to meet the weight and volume required per facility for essential medicines. For additional tables and figures and the underlying assumptions, please see Appendix J.

The cost per kilometer for the current land transport system is estimated at **$1.11** per kilometer. In the three product scenarios for drones, the total cost per kilometer of transporting diagnostic specimens is estimated at **$1.47 per kilometer**, while when transporting larger quantities and volumes of RMNCH products or essential medicines (thus requiring a much greater number of flights) the cost per kilometer is reduced to **less than $0.36 per kilometer**. Therefore, in comparison to the land transport system, drone transport may yield cost savings when the quantity and volume required is sufficient to require daily use of drones. A cost savings per kilometer of up to 69% may be achieved. The table below summarizes this comparison.

PRODUCT CATEGORY	WEIGHT AND VOLUME REQUIREMENTS	COST PER KM, LAN TRANSPORT	COST PER KM, DRONE TRANSPORT	POTENTIAL COST PER KM IMPACT OF DRONE TRANSPORT
DIAGNOSTIC SPECIMENS	LOW	$ 1.11	$ 1.47	INCREASE BY 32%
RMNCH PRODUCTS	MEDIUM	$ 1.11	$ 0.36	DECREASE BY 68%
ESSENTIAL MEDICINES	HIGH	$ 1.11	$ 0.34	DECREASE BY 69%

TABLE 5: Cost per kilometer traveled, land vs. drone transport, by product category

For the three product categories considered, drone transport of RMNCH products and essential medicines may have potential cost savings per kilometer over the existing land transport system. Even though the use of drones to transport medical commodities in low demand may increase the cost per kilometer, as estimated for diagnostic specimens here, decision-makers should still consider whether the potential benefits of providing routine service to areas not currently reached might outweigh these increased financial costs. This analysis looks at a primary product to deliver by drone, but low demand products may be transported along with products in higher demand when products in low demand are urgently needed or are out of stock.

Transport time comparison

On average, transport by drone has the potential to decrease transport distance from the provincial warehouse to the health facility by an average of 30%, from an average of 28.6 kilometers to 19.9 kilometers, and to decrease transport time by an average of 38%, from an average of 37.9 minutes to 23.5 minutes. See Annex J for a full list of results.

↘ DELIVERABLE 1.3: SAFE AND LOCALLY RELIABLE TECHNOLOGY IS TESTED

A total of 157 test flights were conducted, beginning in 2017. From August 14-18, 2017, 26 test flights were successfully completed, in partnership with Matternet.

These flights were conducted between Bohechío Municipal Hospital and El Coco health facility, located 13 kilometers and 30 minutes away by ground, and between Bohechío Municipal Hospital and Montacitos health facility, located 20 kilometers and 50 minutes away by ground. Drone flights were able to reduce transport time from the municipal hospital to the health facility to 10 minutes.

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	TOTAL
2 FLIGHTS AUG 14	10 FLIGHT AUG 15	5 FLIGHTS AUG 16	2 FLIGHTS AUG 17	7 FLIGHTS AUG 18	**26 FLIGHTS**

TABLE 6: Drone test flights per day, August 2017

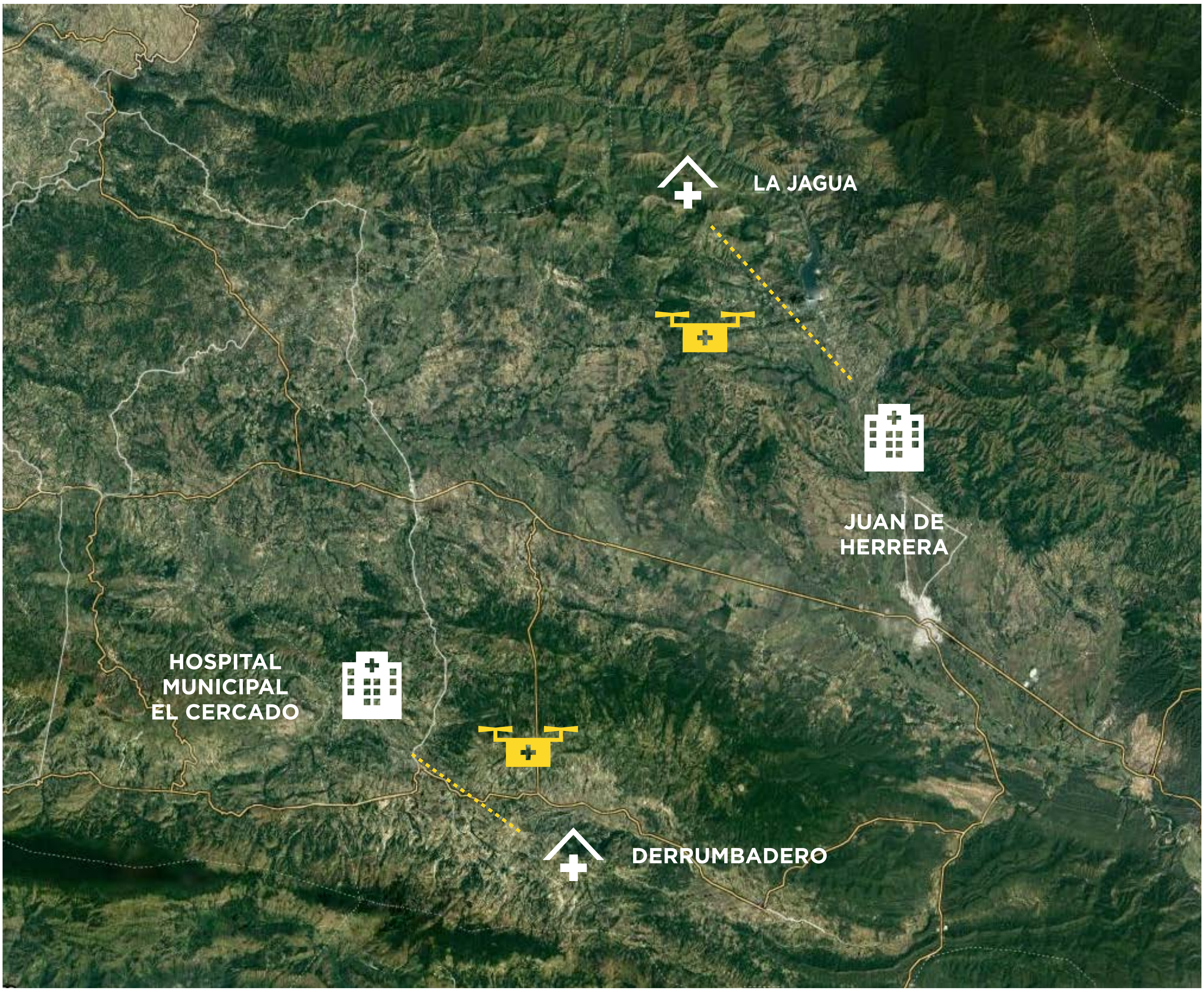
From December 4-12, 2017, 30 test flights were conducted in partnership with WeRobotics. WeRobotics tested the feasibility of two drone models in the local context: the DJI M600 (14 test flights) and the DeltaQuad (16 test flights).

Of the 30 test flights, 19 were conducted between El Cercado Municipal Hospital and Colonia health facilities, a ground distance of approximately 10 kilometers estimated to take 20 minutes by ground transport. Nine test flights were conducted between El Cercado Municipal Hospital and Derrumbadero, a similar ground distance. Drone transport was able to cut travel time in half, to as little as 10 minutes. Three additional test flights were conducted between Juan de Herrera Municipal Hospital and Jagua health facility, a further distance of 20 kilometers estimated to take 35 minutes by ground transport. Drone transport was able to cut travel time by two-thirds, to as little as 10 minutes. During these test flights, WeRobotics was able to demonstrate the payload capabilities of the M600 and the DeltaQuad. Twelve of the 30 test flights transported non-medical sample payloads to test the functionality of the technology while carrying a payload up to 1 kilogram.

MAP 1: Drone test flights, August 2017

SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	TOTAL
2 FLIGHTS DEC 3	9 FLIGHTS DEC 4	4 FLIGHTS DEC 5	5 FLIGHTS DEC 6	1 FLIGHT DEC 7	6 FLIGHTS DEC 8	27 FLIGHTS
DEC 10	DEC 11	3 FLIGHTS DEC 12	DEC 13	DEC 14	DEC 15	3 FLIGHTS
					TOTAL	30 FLIGHTS

TABLE 7: Drone test flights per day, December 2017



MAP 2: Drone test flights, December 2017

In May 2019, 6 local operators from the Dominican Red Cross and the National Emergency System were trained on the setup and operations of the M600 and received hands-on experience flying the drones in San Juan Province. From June 26-August 1, 2019, these trained local operators completed 101 flights to demonstrate how the transport system could operate, with 40 of these flights carrying medical commodities requested by health workers to health facilities where they could be immediately used by patients.

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	TOTAL PER WEEK
JUN 24	JUN 25	3 FLIGHTS JUN 26	6 FLIGHTS JUN 27	8 FLIGHTS JUN 28	**17 FLIGHTS**
JUL 1	JUL 2	JUL 3	6 FLIGHTS JUL 4	JUL 5	**6 FLIGHTS**
JUL 8	4 FLIGHTS (1 WITH CARGO) JUL 9	10 FLIGHTS (5 WITH CARGO) JUL 10	10 FLIGHTS (7 WITH CARGO) JUL 11	JUL 12	**24 FLIGHTS (13 WITH CARGO)**
JUL 15	2 FLIGHTS JUL 16	10 FLIGHTS (4 WITH CARGO) JUL 17	8 FLIGHTS (4 WITH CARGO) JUL 18	JUL 19	**20 FLIGHTS (8 WITH CARGO)**
JUL 22	8 FLIGHTS (7 WITH CARGO) JUL 23	6 FLIGHTS (4 WITH CARGO) JUL 24	8 FLIGHTS (8 WITH CARGO) JUL 25	JUL 26	**22 FLIGHTS (19 WITH CARGO)**
JUL 29	JU 30	6 FLIGHTS JUL 31	6 FLIGHTS AUG 1	AUG 2	**12 FLIGHTS**
				TOTAL	**101 FLIGHTS (40 WITH CARGO)**

TABLE 8: Drone demonstration flights per day, June-August 2019

The maximum payload weight transported was 1 kilogram, with an average of 530 grams per cargo flight. Example payloads included:

CEFALEXINA
AN ANTIBIOTIC USED TO TREAT INFECTIONS OF THE EAR, SKIN, AND URINARY TRACT

1

CIPROFLOXINA
AN ANTIBIOTIC USED TO TREAT INFECTIONS OF THE RESPIRATORY TRACT AND STOMACH

2

FLUIMUCIL
USED TO RESOLVE COUGHING

3

NISTATINA
AN ANTIFUNGAL SKIN CREAM MEDICATION

4

METRONIDAZOL
AN ANTIBIOTIC USED TO TREAT STOMACH AND GENITAL INFECTIONS

5

DOLORGESIC
A PAIN RELIEVER

6

DIAGNOSTIC BLOOD AND URINE TESTS
FOR GLUCOSE, HIV, CHOLESTEROL, AND HEPATITIS B TESTING

7

Health workers participating in KIIs agreed that their responsibilities in loading or unloading the drone at the health facility does not interfere with their existing responsibilities and takes only approximately 15 minutes. All four respondents expressed interest in more training to learn more about how drones could benefit their communities and how to support the operations of the drones. Two respondents expressed concern that the drone might not be able to transport all of the products that they need.

Test flight observations reported that the local drone operators demonstrated a high capability to operate the drones. Operators were able to maintain communications with the receiving team by telephone, and all flights observed were conducted as expected.

4. Recommendations and Conclusions

↘ **RECOMMENDATION 1:**
ENGAGE A MULTI-SECTORAL GROUP OF GOVERNMENT DECISION-MAKERS AROUND THE POLITICAL, REGULATORY, HUMAN RESOURCE, FINANCIAL, AND HEALTH IMPLICATIONS AND REQUIREMENTS OF INTRODUCING DRONES FOR MEDICAL COMMODITY DELIVERY

The next step to introduce the use of drones to transport medical commodities in the Dominican Republic is to bring together a multi-sectoral group of government decision-makers, from civil aviation, public health, and other interested ministries, to discuss the findings of this project and evaluate its potential strategic alignment with the priorities of the government.

↘ **RECOMMENDATION 2:**
IMPLEMENTERS AND TECHNOLOGY PARTNERS FLYING DRONES IN THE DOMINICAN REPUBLIC SHOULD CONDUCT MULTI-METHOD, COMPREHENSIVE COMMUNITY OUTREACH BEFORE INITIATING DRONE FLIGHTS

The community assessment results described in this study should be used to finalize outreach strategies that address any misconceptions or negative traditional beliefs, orient community leaders and members on the purpose and scope of all drone flights, and provide instructions on the appropriate safety measures to be taken in case of adverse events. The community outreach based on these assessments should be interactive, including seeing and touching the UAV to build familiarity with the new technology. Outreach should target all levels of the community including schools and universities, not just health workers directly involved in operation of the drone transport system, and should use multiple methods including radio, television, and in-person participatory activities to reach as much of the population as possible.

↘ RECOMMENDATION 3:
PRIORITIZE THE USE OF DRONES TO DELIVER PRODUCTS WHICH HAVE THE POTENTIAL TO BE LIFESAVING IF AVAILABLE URGENTLY, COST-EFFICIENT, OR REQUIRE COLD CHAIN OR SPECIAL HANDLING

Global best practice suggests that drones should only be used to address existing transport issues. They should be used as a way to augment, not replace, the existing system. It is not cost-efficient to use UAVs to transport medical cargo to sites that can be accessed reliably through existing methods of transport, which are not frequently stocked-out, or which are not in high enough demand to justify the cost. The use of drones to transport products and services that require cold chain or other special handling (and therefore are vulnerable to contamination during long, unstable transit by ground) or are time sensitive, has the potential to have a significant impact on the potency or quality of health products, for example, blood and laboratory samples. Determining the highest priority uses of drones would require establishing a baseline for demand. This would require a long-term study to analyze potential health impact, including lives saved, and supply chain impact, which may include costs saved, in comparison to the current transportation system. Such a long-term study would enable analysis based on real-world data, rather than assumptions, as in this study's cost associated exercise.

↘ RECOMMENDATION 4: PRIORITIZE GEOGRAPHIC LOCATIONS FOR DELIVERY OF HEALTH PRODUCTS AND SERVICES BY DRONE WHICH ARE HARD-TO-REACH OR NOT REACHED BY OTHER SERVICES

Global best practice indicates that the critical geographic use cases for drones include areas that are hard-to-reach, whether seasonally or due to their proximity to lakes, plateaus, or forests. Even if not geographically distant from the site where a health product or service is available, some urban areas may be hard to reach due to traffic. This becomes a particularly critical issue when the product or service is lifesaving and urgently needed, as in the case of blood or certain lifesaving medications. Geographies might include those that are hard to reach from the designated district hospital or laboratory but are faster to reach by air from a different district. Any system that incorporated these optimizations would require further policy and financing discussions.

Distribution sites should also be selected from amongst those with the capacity to administer the targeted product. For example, blood should only be distributed to district hospitals or high-volume health centers that have an operating theater.

↘ RECOMMENDATION 5: COMPILE AND COLLECT THE DATA NEEDED TO OPTIMIZE THE TRANSPORT SYSTEM WITH DRONES

Because cost-efficiency is greatest when drones are used to serve hard-to-reach areas, which also have a high demand for the targeted products, it is necessary to ensure the availability of accurate and updated health burden data as well as GPS locations for all health facilities, municipal hospitals, and provincial warehouse. Where this data is not available, partners should be mobilized to collect this data. Demand data should be overlaid on maps of prioritized geographies, and complementary uses of drones for transport should be identified.

↘ RECOMMENDATION 6:

EXPLORE THE USE OF DRONES BEYOND PUBLIC HEALTH AND DEVELOP PUBLIC-PRIVATE PARTNERSHIPS BOTH WITHIN PUBLIC HEALTH AND ACROSS SECTORS TO BEGIN TO IDENTIFY SUFFICIENT FINANCIAL RESOURCES FOR THE ONGOING USE OF DRONES

Partners should identify other government agencies and private sector actors with potential interest in the functionality of drones, whether for transport or other purposes.

Drone manufacturers will need to ensure that payload compartments can safely and securely accommodate multiple uses. The private sector is critical to the financial sustainability of drones to transport medical commodities. Public-private partnerships that benefit all partners should be pursued. These may include pharmaceutical companies whose products could be delivered to new markets by drones or who could financially support drone operations as part of their corporate social responsibility program. Another potential use case for public-private partnerships is a drone that can deliver health products as well as provide mapping services.

↘ **RECOMMENDATION 7:** DEVELOP AND IMPLEMENT A CAPACITY-BUILDING PLAN TO ENSURE ONGOING MAINTENANCE AND OPERATIONS OF DRONES IN COUNTRY

Partners should develop and implement a capacity-building plan, including specifying any new job functions which need to be created to coordinate and operate drones as part of the public health supply chain. The capacity-building plan should identify existing personnel at the health facility, which may include hospital attendants, laboratory technicians, or other cadres of health staff, and the roles and responsibilities that they could be assigned within a drone transport system. The plan should include short-term as well as longer-term activities, beginning with identifying the knowledge and skills needed to initiate repeated deliveries within the current organizational structure. These may include:

- ↘ **Receiving drones, unloading payload, delivering payload to relevant staff, re-loading payload, communicating with other drone team members, sending back the drone, and recording data about the performance of the drone**
- ↘ **Recognizing the need for repair or maintenance of the drone and its related hardware**
- ↘ **Adhering to safety protocols, including understanding weather patterns and determining whether it is safe to launch the drone**
- ↘ **Liaising with relevant civil aviation authorities to ensure regulations are adhered to**

The Drone Innovation Center and WeRobotics have already begun the process of identifying individuals in-country who could take on day-to-day operations of the drone transport system, and partners should be engaged to expand this pool of operators further and ensure that all knowledge and skills needed are built locally.

APPENDIX A

PROJECT DATA COLLECTION PLAN

Adapted from
Drone Evidence Generation Toolkit

#	INDICATOR	DEFINITION	USE OF DATA	METHOD	DATA COLLECTION TOOL	TIMING OF DATA COLLECTION
PHASE 1: SAFETY & FEASIBILITY TESTING						
DELIVERABLE 1.1: PERMISSION SECURED TO IMPORT AND USE DRONES IN-COUNTRY						
1.1.1	TYPE OF DRONE FLIGHT PERMISSION RECEIVED	TYPE OF FLIGHT PERMISSION RECEIVED, REFLECTIVE OF STATUS OF REGULATIONS IN THE COUNTRY. INCLUDES TYPE OF FLIGHT APPROVED AS WELL AS DURATION AND LOCATION OF FLIGHT PERMISSION	TRACK MATURITY OF REGULATIONS IN THE COUNTRY AND INFORM OTHER IMPLEMENTERS ABOUT REGULATORY MATURITY WITHIN EACH COUNTRY	REVIEW OF DOCUMENTATION OF PERMISSION RECEIVED	REGULATION CHECKLIST DEFINING TYPE OF PERMISSION RECEIVED	END OF PROJECT
DELIVERABLE 1.2: FEASIBILITY OF INTRODUCING DRONE USE CASE IS EVALUATED						
1.2.1	STAKEHOLDER AND COMMUNITY ACCEPTANCE OF DRONES (QUALITATIVE)	THE EXTENT TO WHICH STAKEHOLDERS AT ALL LEVELS ARE AWARE OR HAVE CONCERNS ABOUT THE USE OF DRONES TO TRANSPORT MEDICAL COMMODITIES, AND IDENTIFICATION OF ANY TRADITIONAL BELIEFS OR LOCAL PREFERENCES.	QUALITATIVE RESULTS ARE USED TO INFORM DEMONSTRATION FLIGHT DESIGN AND OUTREACH STRATEGY CONTENT AND AUDIENCES.	FOCUS GROUP DISCUSSIONS (FGDS) AND KEY INFORMANT INTERVIEWS (KIIS) WITH DISTRICT AND COMMUNITY LEVEL AT TAKE-OFF AND LANDING SITES	FGD & KII TOOL FOR STAKEHOLDER AND COMMUNITY ACCEPTANCE	BEFORE 2019 FLIGHTS

#	INDICATOR	DEFINITION	USE OF DATA	METHOD	DATA COLLECTION TOOL	TIMING OF DATA COLLECTION
PHASE 1: SAFETY & FEASIBILITY TESTING						
DELIVERABLE 1.2: FEASIBILITY OF INTRODUCING DRONE USE CASE IS EVALUATED						
1.2.2	**COST DRIVERS IDENTIFIED FOR DRONES IN COMPARISON TO CURRENT OR IDEAL TRANSPORT**	IDENTIFY KEY COST DRIVERS THAT MIGHT HAVE A SIGNIFICANT IMPACT ON THE COST-EFFECTIVENESS OF INTRODUCING DRONES	TO SHARE WITH MINISTRY OF HEALTH AND OTHER IMPLEMENTERS CONSIDERING TRANSPORTING THE SAME PRODUCTS OR IN THE SAME GEOGRAPHY AND TO INFORM A POTENTIAL EXPECTED BENEFIT OF DRONES	COLLECTION OF AVERAGE COST DATA FOR KEY SYSTEM COST INPUTS FOR DRONES AND CURRENT OR IDEAL TRANSPORT	JSI COST SIMULATION TOOL	ALONGSIDE 2019 FLIGHTS
1.2.3	**TRANSPORT TIME FOR DRONES IN COMPARISON TO GROUND TRANSPORT**	COMPARISON OF AVERAGE TRANSPORT TIME NEEDED FOR DRONES TO TRAVEL A GIVEN ROUTE IN COMPARISON TO GROUND TRANSPORT	TO SHARE WITH MINISTRY OF HEALTH AND OTHER IMPLEMENTERS CONSIDERING TRANSPORTING THE SAME PRODUCTS OR IN THE SAME GEOGRAPHY AND TO INFORM A POTENTIAL EXPECTED BENEFIT OF DRONES	ESTIMATION OF GROUND TRANSPORT AND AERIAL TRANSPORT DISTANCES AND TRANSPORT TIME USING GPS POINTS	COMPILED DATA FROM GOOGLE MAPS IN A TRANSPORT TIME COMPARISON DATABASE	ALONGSIDE 2019 FLIGHTS
DELIVERABLE 1.3: SAFE AND LOCALLY RELIABLE TECHNOLOGY IS TESTED						
1.3.1	**NUMBER OF SUCCESSFUL FLIGHTS CONDUCTED**	THE TOTAL NUMBER OF FLIGHTS CONDUCTED WITH SUCCESSFUL TAKE-OFF AND LANDING	TO SHARE WITH GOVERNMENT, OTHER IMPLEMENTERS AND TECHNOLOGY PARTNERS, AND DONORS TO AID IN COMPARISON ACROSS IMPLEMENTATIONS	REVIEW OF OPERATIONAL CHECKLISTS COMPLETED BEFORE AND AFTER EACH FLIGHT	PRE- AND POST-FLIGHT CHECKLISTS	CONSOLIDATION AT THE END OF DEMONSTRATION FLIGHTS
1.3.2	**MAXIMUM DISTANCE ACHIEVED WITHOUT STOPPING, IN KILOMETERS**	THE MAXIMUM DISTANCE REACHED BY THE DRONE WITH SUCCESSFUL TAKE-OFF AND LANDING, WITHOUT NEEDING TO RECHARGE BATTERIES OR RE-FUEL	TO SHARE WITH GOVERNMENT, OTHER IMPLEMENTERS AND TECHNOLOGY PARTNERS, AND DONORS TO AID IN COMPARISON ACROSS IMPLEMENTATIONS	REVIEW OF OPERATIONAL CHECKLISTS COMPLETED BEFORE AND AFTER EACH FLIGHT	PRE- AND POST-FLIGHT CHECKLISTS	CONSOLIDATION AT THE END OF DEMONSTRATION FLIGHTS
1.3.3	**MAXIMUM PAYLOAD CARRIED PER FLIGHT, IN KILOGRAMS**	THE MAXIMUM WEIGHT OF PAYLOAD TRANSPORTED BY THE DRONE WITH SUCCESSFUL TAKE-OFF AND LANDING	TO SHARE WITH GOVERNMENT, OTHER IMPLEMENTERS AND TECHNOLOGY PARTNERS, AND DONORS TO AID IN COMPARISON ACROSS IMPLEMENTATIONS	REVIEW OF OPERATIONAL CHECKLISTS COMPLETED BEFORE AND AFTER EACH FLIGHT	PRE- AND POST-FLIGHT CHECKLISTS	CONSOLIDATION AT THE END OF DEMONSTRATION FLIGHTS

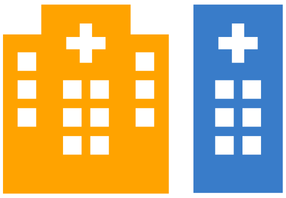
APPENDIX B

STAKEHOLDER AND COMMUNITY ACCEPTANCE INTERVIEW TOOLS

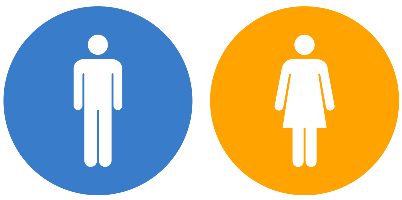
Recruitment

Conduct FGD/Key informant interview near **[THE HOSPITAL NAME]**

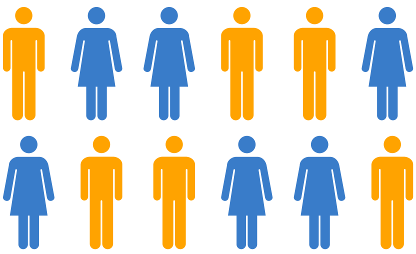
And near the health clinics **[CLINIC NAME]**



Focus group discussions (FGDS) **will be held separately with men and with women from the community.**



Each FGD should consist of approximately 10 people **(8 at minimum, 12 at maximum).**

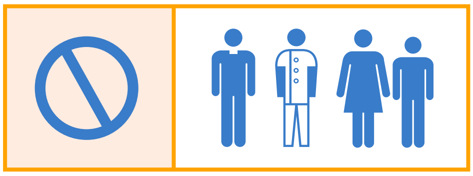


Participants in the FGD for community members should not be:

Health workers

Religious, political or other leaders

Members of the same family



This tool should be used when the participants have seen the WeRobotics flights.

DESCRIBE THE PURPOSE OF THE INTERVIEW AND EXPLAIN THAT THEIR PARTICIPATION IS VOLUNTARY

IF SOMEONE DOESN'T WANT TO PARTICIPATE, THANK THEM FOR THEIR TIME AND CONTINUE WITH THE FOCUS GROUP WITHOUT THEM

After informed consent has been completed for each participant, ask the questions below.
Encourage all participants to respond to all questions to the best of their ability, but it is ok if participants choose not to answer all questions.

When interviewing use the following probes to get meaningful responses from interviewees:

What do you mean by...?

Can you tell me more about...?

Can you give me an example of...?

When...?

Where...?

Introduction (to be read by facilitator):

Center for Drone Innovation is an organization which is working with the Ministry of Public Health to help improve the transportation of medical products to rural health facilities. In this assessment, we want to find out how a technology called drones could deliver health products or lab specimens.

(Show the photographs of drones, and pass them around.)

I would like to ask your thoughts on this technology. Any information you share here is confidential and will not be associated with you. Your participation is voluntary, and you can stop participating at any time. There is no penalty or benefit for participating. You don't have to answer any of the questions if you don't want to.

FGD only:

NUMBER OF PARTICIPANTS IN THE FGD:	
SEX OF PARTICIPANTS:	

KII ONLY:

TITLE OF KII RESPONDENT:	
SEX OF RESPONDENT:	

?

INFORMATION SHARED BEFORE THE TEST FLIGHTS

1. How did you first find out that the drone test flights were going to happen in the site where you saw them?

---

2. What information did you find out?

---

3. Was this enough information for you?
    a. If no, Is there anything else you would have liked to know? If yes, what else would you have liked to know?
    b. If yes, what was particularly helpful about this information?

BENEFITS OF DRONES

1. What did you think about the drone that was flying overhead during the test flights?

---

2. Was there anything about it that interested or excited you?

---

3. Do you think there are any benefits to using drones to carry medicines?
    a. If yes, what?

4. Are there other health products that you think drones could be used to transport?
    a. Any other health related uses for drones?
    b. For each product/service mentioned – probe on why they think they could be used

5. Are there any other ways that you think drones could be used in the DR, other than transporting health products?

RISKS OF DRONES

1. Was there anything about it that worried you?
2. Do you think there are any risks to using drones to carry vaccines? If yes, what?
3. Thinking about the concerns you have identified, do you think any of these are very serious? If yes, which ones?
4. Did you know what to do if there was a problem, such as if the drone made an unplanned landing? What would you have done?

WHAT TO TRANSPORT, WHEN, AND WHERE

1. If you or a family member were to go to the health center to receive treatment, and the treatment had been delivered by drone, would you have any concerns? If yes, what?
    a. Why or why not?

2. Are there any items that you do NOT think drones should be used to transport?
    a. Why should they not be used for those items?
    b. Why or why not?

3. Are there times of day or days of the week when a drone should not fly in the community?
    a. If yes, why?

4. Are there places in the community where people might feel uncomfortable seeing drones flying overhead?
    a. If yes, why?

5. In general, would you recommend that the DR Ministry of Health use drones to transport medicines from the hospital to health centers?
    a. Why or why not?

COMMUNICATION STRATEGIES FOR DRONES

1. Are there any groups of people or individuals that you think would be particularly interested in the drone flights? Why?

2. Are there any groups of people or individuals that you think would be particularly concerned about, afraid of, or confused about drone flights? Why?

3. Before we test the use of drones in your community, who should we share information with? What information should we share to help them understand?

4. How should we share information with your community about drones?

    a. Allow the group to respond, then ask: Do you think that if we show videos, photos, or demonstrate how the vehicle flies, this will help people understand the technology?

5. Is there a particular person or group in your community that you can trust to share information like this with the rest of the community?

APPENDIX C

LIST OF HEALTH FACILITIES IN SAN JUAN PROVINCE

HEALTH FACILITY	ONE-WAY DISTANCE AND TRANSPORT TIME FROM HEALTH FACILITY TO PROVINCIAL WAREHOUSE					
	GROUND DISTANCE (KM)	AERIAL DISTANCE (KM)	% OF DISTANCE SAVED	GROUND TIME (MINS)	AERIAL TIME (MINS)	% OF TIME SAVED
ZONE VII						
1. ARROYO CANO	38.0	22.6	40%	51	27	47%
2. BOHECHÍO	43.8	24.9	43%	60	30	50%
3. EL COCO	30.4	16.6	45%	37	20	46%
4. GUANITO	19.5	16.2	17%	23	19	15%
5. LA GUAMA	35.3	19.5	45%	47	23	50%
6. LOS BANCOS	24.7	22.2	10%	25	27	-7%
7. LOS FRIOS	57.0	26.4	54%	76	32	58%
8. LOS MONTACITOS	58.0	25.4	56%	79	30	61%
9. SABANA ALTA	18.8	15.0	20%	22	18	18%
ZONE VIII						
10. CAPULÍN	34.1	20.2	41%	40	24	39%
11. CARDON	14.1	11.8	17%	19	14	26%
12. EL BATEY	10.2	8.2	20%	15	10	34%
13. EL CACHEO	16.1	11.0	31%	22	13	40%
14. EL ROSARIO	9.0	7.4	18%	13	9	32%
15. LA FLORIDA	N/A	N/A	N/A	N/A	N/A	N/A
16. LAS CHARCAS DE GARABITO	13.7	7.6	45%	17	9	47%
17. LAS ZANJAS	13.2	9.4	29%	16	11	29%
18-19. LOS TRANSFORMADORES I-II	1.5	1.4	10%	7	2	77%
20. MANOGUAYABO	N/A	N/A	N/A	N/A	N/A	N/A
21. MOGOLLÓN	8.4	4.0	52%	19	5	75%
22. VALLEJUELO	33.7	21.0	38%	40	25	37%
ZONE IX						
23. HATO NUEVO	18.4	16.3	12%	26	20	25%
24. HIGUERITO	1.9	1.2	39%	5	1	72%
25. JINOVA	6.1	5.2	16%	12	6	49%
26. JUAN DE HERRERA	8.4	7.3	13%	13	9	32%
27. LA JAGUA	29.4	19.1	35%	47	23	51%
28. LA MAGUANA	15.2	13.3	13%	21	16	24%
29. MIRADOR NORTE	2.2	1.4	37%	6	2	72%
30. SABANETA	21.7	19.4	11%	33	23	30%
31-34. VILLA LIBERACIÓN I-IV	3.1	2.2	29%	8	3	67%

HEALTH FACILITY	ONE-WAY DISTANCE AND TRANSPORT TIME FROM HEALTH FACILITY TO PROVINCIAL WAREHOUSE					
	GROUND DISTANCE (KM)	AERIAL DISTANCE (KM)	% OF DISTANCE SAVED	GROUND TIME (MINS)	AERIAL TIME (MINS)	% OF TIME SAVED
ZONE X						
35. BARRANCA	12.0	10.1	16%	21	12	42%
36. CORBANO NORTE	3.3	2.5	26%	10	3	71%
37-39. CORBANO SUR I-III	3.5	2.7	24%	11	3	71%
40. GUACHUPITA	N/A	N/A	N/A	N/A	N/A	N/A
41. HATO DEL PADRE	8.4	6.5	23%	19	8	59%
42. LAS CHARCAS DE MARI NOVA	19.8	17.4	12%	28	21	25%
43. PEDRO CORTO	20.7	20.2	3%	25	24	3%
44. PERPETUO SOCORRO	4.7	4.1	12%	12	5	59%
45. PUNTA CANA	21.7	15.7	28%	28	19	33%
46. QUIJÁ QUIETA	N/A	N/A	N/A	N/A	N/A	N/A
ZONE XI						
47. CARRERA DE YEGUA	45.6	34.0	31%	59	41	26%
48. EL HOYO	40.0	37.0	8%	48	44	8%
49. EL NARANJO	43.0	35.9	19%	53	43	17%
50. LOS CARTONES	33.1	31.2	1%	38	37	6%
51. LOS COPEYES	45.0	30.9	5%	39	37	31%
52. LOS GRINGOS	34.7	31.5	10%	42	38	9%
53. LOS JOBOS	46.2	40.9	6%	52	49	12%
54. MATAYAYA	41.0	39.2	0%	47	47	4%
55. POZO HONDO	50.4	34.3	40%	69	41	32%
56. VILLA CARMEN	N/A	N/A	N/A	N/A	N/A	N/A
57. VILLA ESPERANZA	33.5	31.4	6%	40	38	6%
58. YABONICO	40.9	26.2	38%	51	31	36%

HEALTH FACILITY	ONE-WAY DISTANCE AND TRANSPORT TIME FROM HEALTH FACILITY TO PROVINCIAL WAREHOUSE					
	GROUND DISTANCE (KM)	AERIAL DISTANCE (KM)	% OF DISTANCE SAVED	GROUND TIME (MINS)	AERIAL TIME (MINS)	% OF TIME SAVED
ZONE XII						
59. BATISTA	45.7	27.8	39%	67	33	50%
60. DERRUMBADERO	49.8	29.9	40%	77	36	53%
61. EL JOVITO	52.8	31.5	40%	70	38	46%
62. JORGILLO	45.6	24.1	47%	55	29	47%
63. JUAN SANTIAGO	61.8	40.1	35%	92	48	48%
64. LA COLONIA	56.3	36.3	35%	50	44	13%
65. LA ESTANCIA	38.7	31.2	19%	47	37	20%
66. LA NAVAJA	55.4	34.6	37%	75	42	45%
67. LA RANCHA	43.5	29.8	32%	54	36	34%
68. RANCHO LA GUARDIA	71.3	47.1	34%	112	57	50%
69. VALLECITO	52.1	29.0	44%	63	35	45%

APPENDIX D

GUIDING QUESTIONS FOR INSUPPLY EXCEL-BASED TOOL (DRONE TRANSPORT)

DOMINICAN REPUBLIC, THE DRONES INNOVATION CENTER

1. What is the cost to purchase the drone? (Broken down as below)

    a. What is the cost of the **fuselage** (or body of the drone)?
    b. What is the cost of the **battery**?
    (Price per battery and number of batteries required)
    c. What is the cost of the **software** or any other electronics needed for the drone to fly?

---

2. What is the life cycle of the drone? (Broken down as below)

    a. How many flights can we assume the drone can fly before the **fuselage** needs to be replaced?
    b. How many flights can we assume the drone can fly before the **batteries** need to be replaced?
    c. What is the battery pack size (in KWh)?
    d. How many flights can we assume the drone can fly before the **software** or electronics need to be replaced?

---

3. What is the range of the drone under local conditions?
Under ideal conditions?

---

4. What is the maximum weight (in kg) of payload under local conditions?
Under ideal conditions?

---

5. What is the maximum volume (in L) of payload under local conditions?
Under ideal conditions?

?

6. What personnel would be needed on the ground to operate the drone, in addition to existing health workers?
    a. How many drones could an operator (based at a central location serving multiple sites) manage at a time?
    b. Would the operator need ground staff to support loading and unloading? If yes, how many?

APPENDIX E

GUIDING QUESTIONS FOR INSUPPLY EXCEL-BASED TOOL (LAND TRANSPORT)

Dominican Republic, The Drone Innovation Center

Assumptions:

Medicines and other health supplies that health facilities need are warehoused and dispatched from one warehouse in San Juan Province.

The province is divided into 2-4 areas, each managed by an area manager.

Vehicles used to transport products are purchased tax-exempt, so no customs fees, tariffs or taxes are added on top of the purchase price.

Drivers and any other staff who travel with the products to the health facilities do not receive per diem in addition to their salary or day rate.

NAME OF PERSON INTERVIEWED:	

TITLE OF PERSON INTERVIEWED:	

?

1. Can you provide a list of health facilities in each area? Can you provide GPS coordinates for each health facility, including the provincial warehouse?
   a. If it is not possible to provide GPS coordinates for each health facility, what is the **longest** distance between the warehouse and health facilities (in kilometers and hours traveled)?
   b. What is the **typical** distance between the warehouse and health facilities (in kilometers and hours traveled)?
   c. Approximately how many people are served by each health facility? (If unknown, we can use population data.)

?

2. Are there any health facilities which are difficult to reach at any time of the year, for any reason? Which ones? Why?

3. What type of transport or vehicle is used to transport products from the warehouse to the health facilities (pickup, SUV, motorcycle, by foot)? Does this type of transport serve all health facilities in the province, or are multiple types of transport used? Please list all, including make and model of any vehicles.

TYPE OF TRANSPORT	MAKE	MODEL	APPROXIMATE PURCHASE PRICE (NEW) IF OWNED, OR DAY RATE IF RENTED

4. How many of each vehicle does the warehouse use to transport products to health facilities?

5. How often is each vehicle used to transport products to health facilities (how many days per month per vehicle)?

6. During these trips, is the vehicle only used to transport products, or also for some other purpose? Would these trips still occur, without the need to transport products? Why or why not?

7. Who travels with the vehicle to the health facilities (driver, logistician, anyone else)? What is the typical salary of everyone who travels with the vehicle?

	% OF MONTH SPENT ON TRANSPORTING PRODUCTS (100% IF FULL-TIME DRIVER FOR TRANSPORTING PRODUCTS)	SALARY OR DAY RATE ($ OR PESOS, INCLUDE UNITS – FOR EXAMPLE, $10,000 PER YEAR OR $50 PER DAY)	NOTES
DRIVER			

8. Can you share the transport log from the last 3 months, so that we can learn about the type and quantity of payload transported and the routes taken?

   If not available or incomplete:

   a. Please describe the route taken from the warehouse to each area, including the number of health facilities visited per day and number of kilometers traveled per day for each area and each vehicle.
   b. What products are transported? Please give as complete of a list as possible, including name of item and number of items transported.
   c. On an average trip, how much cargo is transported?
   Consider the number of cartons or boxes transported, and provide the number of kilograms and liters transported per trip, including all products.

d. How much cargo does each health facility receive, in kilograms and liters? Does each health facility receive the same quantity at each delivery, or does it vary?

e. On an average trip, is the vehicle always full when it leaves the warehouse, or is there space remaining? If space remaining, please estimate what proportion of the capacity of the vehicle is typically available?

APPENDIX F

KEY INFORMANT INTERVIEW RESPONDENTS

Drone Transport Inputs

CAMERON DOWD
UAV Project Engineer, WeRobotics

YOANN LAPIJOVER
Junior Engineer, WeRobotics

PATRICK MEIER
Executive Director, WeRobotics

Land Transport Inputs

JAQUELINE CORCINO
Strategic Director, San Juan Province

JOSÉ MATOS
Director of Medicines and Regional Supplies, Province of San Juan

BOLÍVAR MATOS
Regional Director

IRENA MORA
Area II Manager

APPENDIX G

DETAILED LIST OF INPUTS USED FOR COSTS ASSOCIATED ANALYSIS

Geographic Inputs

Geographic inputs needed in the Excel-based tool, including geographic area and population of the province, were collected from publicly available demographic data and GPS locations for each health facility were collected from the provincial warehouse manager in San Juan. These inputs included:

ASSUMPTION	ACTUAL	INPUT
FACILITY DENSITY	69 PER 3,569 KM^2	193 PER 10,000 KM^2
AVERAGE NUMBER OF PEOPLE SERVED PER FACILITY	317,293 PEOPLE PER 69 FACILITIES	4,598 PEOPLE PER FACILITY
ROAD CIRCUITY FACTOR (AVERAGE ROAD DISTANCE/ AVERAGE STRAIGHT LINE)	28.92 KM/20.20 KM	1.43

TABLE G1: Geographic input data

Product Inputs

Pre-filled product inputs were used to rapidly compare drone transport to land transport for multiple product categories, one with low weight and volume requirements (diagnostic specimens), one with high weight and volume requirements (essential medicines), and one in between (RMNCH products). Demand variability of all three was assumed to be 30% weekly.
Inputs included:

PRODUCT CATEGORY	WEIGHT AND VOLUME REQUIREMENTS	WEIGHT PER FACILITY ANNUALLY (KG)	VOLUME PER FACILITY ANNUALLY (L)
DIAGNOSTIC SPECIMENS	LOW	32.5	100
RMNCH PRODUCTS	MEDIUM	500	2,000
ESSENTIAL MEDICINES	HIGH	1,625	6,500

TABLE G2: Product input data

Transport Inputs

The current ground-based transport system in San Juan Province transports medical commodities once a month, using three Toyota Hilux pickup trucks to reach 69 health facilities. Each of the three Toyota Hilux trucks can transport up to 1,000 kg or 3,000 L per trip, which means that many health facilities can be served in one trip from the warehouse, even if the full capacity is not utilized. Each vehicle is able to reach its assigned health facilities within one day, therefore, per diem is not provided for drivers. Although each truck is only used for one or two days per month to transport medical commodities to health facilities, the full purchase and maintenance cost of the vehicle is included in the estimate because the purchase of the truck is necessary for operation of the ground-based transport system.

ASSUMPTION	PER VEHICLE	TOTAL FLEET (3 VEHICLES)
PURCHASE PRICE		
VEHICLE PURCHASE	$15,000	$45,000
MAINTENANCE		
MAINTENANCE AND INSURANCE	$1,950	$5,850
REPLACEMENT FREQUENCY		
ASSUMPTION FOR KM OF USEFUL LIFE	100,000	300,000
ASSUMPTION FOR KM PER YEAR	6,000	18,000
EXPECTED VEHICLE LIFETIME IN YEARS	5.6	
PAYLOAD CAPACITY		
WEIGHT CAPACITY IN KG	1,000	3,000
VOLUME CAPACITY IN L	3,000	9,000
OPERATIONS		
DRIVER SALARIES	$3,060	$9,180
FUEL CONSUMPTION IN KM/L	9.35	
FUEL PRICE IN USD/L	$1.16	

TABLE G3: Land transport input data

Between 2016 and 2019, the Drone Innovation Center tested the use of three drone models: Matternet's M2 model, as well as the Vertical Technologies' DeltaQuad and the DJI M600 drones adapted by WeRobotics. This costing exercise used the DJI M600 drone, which was used to complete 101 successful flights in 2019. All drone transport inputs were provided by WeRobotics, except where noted under the table below. One drone is assumed to be able to carry out 6-8 flights per day, 5 days per week, for 52 weeks per year, or 1,560-2,080 flights per year. In comparison to the Toyota Hilux pickup trucks, each M600 drone has a much lower payload of 2 kg or 5 L per flight, which means that the drone would be able to serve one health facility per trip whereas the trucks can serve multiple health facilities per trip.

The number of trips that the drone would need to make would vary based on the weight and volume of each type of product required per facility. For example, the tool assumes that each facility requires 32.5 kg and 100 L of diagnostic specimens annually, whereas the tool assumes that each facility requires 1,625 kg and 6,500 L of essential medicines annually. This means that a single drone may be able to fully meet the weight and volume required per facility for diagnostic specimens by making monthly flights between the warehouse and each health facility, whereas at least three drones would be needed to meet the weight and volume required per facility for essential medicines. Inputs included:

ASSUMPTION	PER DRONE OR FLEET OF 1 DRONE	FLEET OF 3 DRONES
PURCHASE PRICE		
FUSELAGE	$4,446	$13,338
BATTERY SET (6 PER DRONE)	$1,254	$3,762
AVIONICS	$300	$900
MAINTENANCE		
PER FLIGHT	$0.60	$1.80
REPLACEMENT FREQUENCY (IN NUMBER OF FLIGHTS)		
FUSELAGE	10,000	30,000
BATTERY SET (6 PER DRONE)	1,000	3,000
AVIONICS	1,000	3,000
DRONE RANGE		
RANGE IN KM	15	
PROPORTION OF RANGE PER AVERAGE TRIP	90%	

PAYLOAD CAPACITY		
WEIGHT CAPACITY IN KG	2	6
VOLUME CAPACITY IN L	5	15
OPERATIONS		
NUMBER OF OPERATORS	1	3
OPERATOR SALARIES*	$3,060	$9,180
BATTERY PACK SIZE IN KWH	0.594	1.782
ENERGY PRICE PER KWH**	$0.10	

TABLE G4: Drone transport input data

* Salary per operator based on current salary for vehicle drivers in San Juan Province
** Energy price per KWh based on globalpetrolprices.com

Medical commodities are transported by land monthly, whereas we assume that transport by drone would be available more frequently on a weekly or monthly basis per facility, depending on the level of demand.

APPENDIX H

KEY INFORMANT INTERVIEW TOOL FOR HEALTH WORKERS

Purpose

This interview tool will be used to collect operator and health worker perceptions of the UAV flights that have occurred over the past month.

Product Inputs

Participants: The tool should be used to collect data from operators and health workers who have been trained and have been loading, operating, sending, or receiving the UAV. Interviews should only be conducted with health workers who have been directly involved in the UAV flights.

Introduction

Introduction: Introduce yourself to the respondent and explain that we are interested in their experience with the UAV flights and their recommendations for the government around the use of UAVs in the future.

Name of interviewer:

Date of interview:

Name of health facility or other location:

Location of health facility:

Name of person interviewed:

Title of person interviewed:

1. What do you think about the UAV test flights that have occurred the last few weeks?

2. Can you describe your role in sending, receiving, or otherwise operating the UAVs?

    a. How much time does this role take per flight?
    b. Is this role in addition to another role you have, such as health worker? If so, what is your other role?
    c. If you have another role also, does your role with the UAVs interfere? Why or why not?

3. What training or support did you receive to carry out this role? Who provided this training or support? How many hours or days of training or support was provided?

4. Do you feel like you have the knowledge, skills, and equipment needed to carry out your role in sending, receiving, or otherwise operating UAVs? Why or why not?

    a. If you feel like you need additional knowledge, skills or equipment, what are these?

5. If the UAV didn't function as you expected or you had problem with sending the UAV, what would you do? Would you be able to resolve all issues yourself, or is there someone you would contact?

6. Do you have any concerns about sending, receiving, or otherwise operating the UAVs? If yes, what are these?

?

7. What products have you sent or received by UAV? Can you give some examples?
    a. Why were these products selected to transport by UAV?
    b. If these products were not sent by UAV, how would you have received them?
    c. Are there any challenges with the current way that you would receive these products?
    d. Which of these products do you think has been most urgently needed by patients? Why?
    e. Do you think there are other products that should be sent by UAV? What?

8. If UAVs were an option for health centers to receive products, how would this effect your work? Can you think of any benefits to the health centers' ability to serve patients? Any disadvantages?

9. In general, do you think that the government should continue to use UAVs to transport health products? Why or why not?

10. Do you have any other comments or suggestions share about the UAV flights or the use of UAVs in the Dominican Republic?

APPENDIX I

DRONE TEST FLIGHT OBSERVATION TOOL

Intended user:

Non-technical staff who are not directly involved in the operations of the drones, which can include government officials, implementers, or researchers. The user should not interfere with the drone operations in any way.

Purpose:

Generate qualitative observational data about the drone flights, in addition to the technical quantitative data that is generated during each flight by the drone operators. This qualitative data will be used to triangulate the quantitative data.

When:

This tool can be completed upon take-off or receiving the drone. The tool should be completed whether or not the drone behaves as expected (for example, if the drone does not take off, the tool can still be completed.)

Sample Size:

It is recommended that an equal number of observations are made upon take-off and landing, but the observational tool is not recommended for use at every demonstration flight, if flights will take place over a long period of time.

Users should consider using the observational checklist at 10%, 25%, or 50% of flights (depending on the total number of flights expected) or identifying strata for analysis (for example, 2 observations for each drone operations team or 3 observations for for each province.)

Name of person completing the checklist:

Date:

Time:

Location:

1. Is this observation checklist completed at take-off only, landing only, or a combined take-off and landing?

2. What is the payload (type of product and quantity)?

3. How would you describe the weather?

4. How many people are involved in sending or receiving the drone, and what is their affiliation (government agency, drone company, health worker)? Specify the number of people present from outside the country and those from the country. If applicable, specify the job title or department.

AFFILIATION OR JOB TITLE	# PRESENT	LOCAL OR EXTERNAL?

5. Of those listed above, who seems to be in charge of the flight? Why do you say this person? For example, is one person directly touching the drone most of the time, or is one person answering questions for everyone else?

6. How would you describe the attitude of those operating the drone? (Calm, frantic, worried, confused, capable?)

?

7. Are there others observing the sending or receiving of the drone, other than the people directly involved in sending or receiving the drone?
   If yes, please describe.

8. Is there any interaction between the drone operators and those observing the drone? If yes, what?

9. Is there a separation between the two groups? If yes, what?

10. How would you describe the attitude and interest of those observing the drone operations? (Interested, disinterested, worried, etc.?)

11. Do they observe the entire process? Why or why not?

12. If appropriate, please approach someone who is observing the drone operations. Introduce yourself and ask what they think of the drone flights. Do they have any questions or concerns?

13. Do you observe the drone operators communicate with the sending or receiving team, either where the drone has come from or where it is going? If yes, do there appear to be any communication challenges?

14. Are the operators able to resolve any maintenance or issue with the drone in order for it to fly, at least initially? If no, why not?
   Are the drone operators able to fully complete their mission, either to send, receive, or both receive and then send back the drone as intended?
   If no, what happened?

APPENDIX J

SUPPLEMENTARY TABLES AND FIGURES FROM COSTS ASSOCIATED STUDY AND ASSUMPTIONS

COST CATEGORY	COST PER KM
VEHICLE COST	$0.15
MAINTENANCE	$0.25
INSURANCE	$0.08
FUEL COST	$0.12
DRIVER SALARY	$0.51
TOTAL	**$1.11**

TABLE J1: Cost components per kilometer, land-based transport

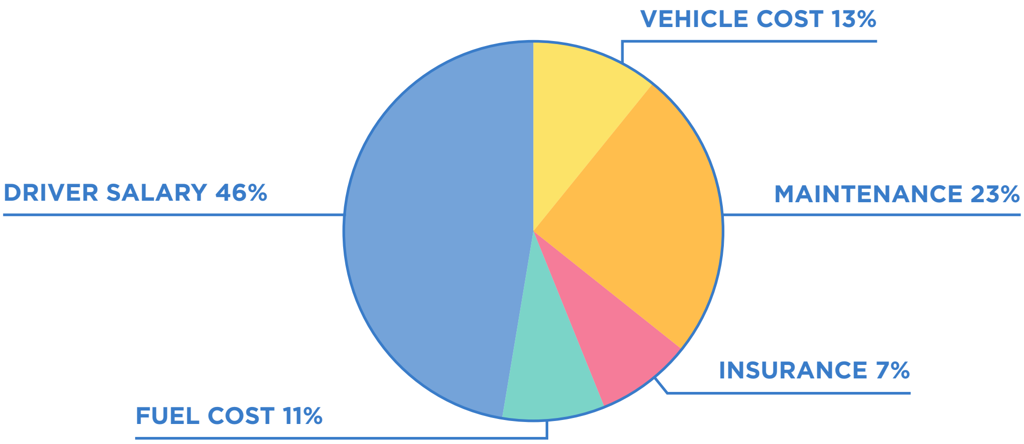


FIGURE J1: Cost drivers of land-based transport in San Juan Province

COST CATEGORY	DIAGNOSTIC SPECIMENS (LOW WEIGHT AND VOLUME REQUIREMENTS)	RMNCH PRODUCTS (MEDIUM WEIGHT AND VOLUME REQUIREMENTS)	ESSENTIAL MEDICINES (HIGH WEIGHT AND VOLUME REQUIREMENTS)
NUMBER OF FLIGHTS PER YEAR	178	1,421	4,796
NUMBER OF KM TRAVELED PER YEAR	2,398	19,185	64,748
NUMBER OF DRONES REQUIRED	1	1	3
VARIABLE COSTS			
FUSELAGE COST	$0.44	$0.44	$0.44
BATTERY COST	$1.25	$1.25	$1.25
AVIONICS COST	$0.30	$0.30	$0.30
MAINTENANCE	$0.60	$0.60	$0.60
ENERGY COST	$0.06	$0.06	$0.06
FIXED COSTS			
OPERATOR SALARY	$17.23	$2.15	$1.91
COST PER FLIGHT	**$19.88**	**$4.81**	**$4.57**
COST PER KM	**$1.47**	**$0.36**	**$0.34**

TABLE J2: Cost components per kilometer, drone-based transport

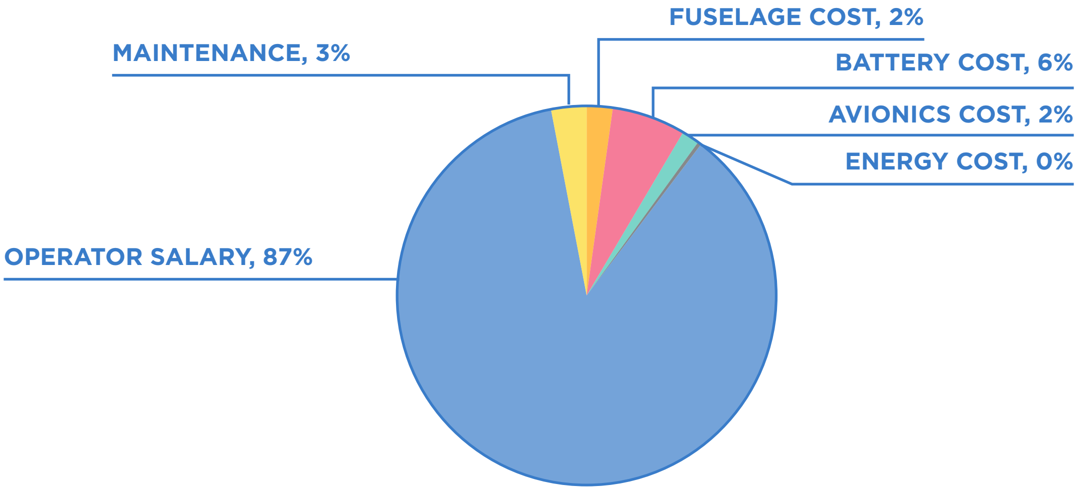


FIGURE J2A: Cost drivers of drone-based transport in San Juan Province - diagnostic specimens

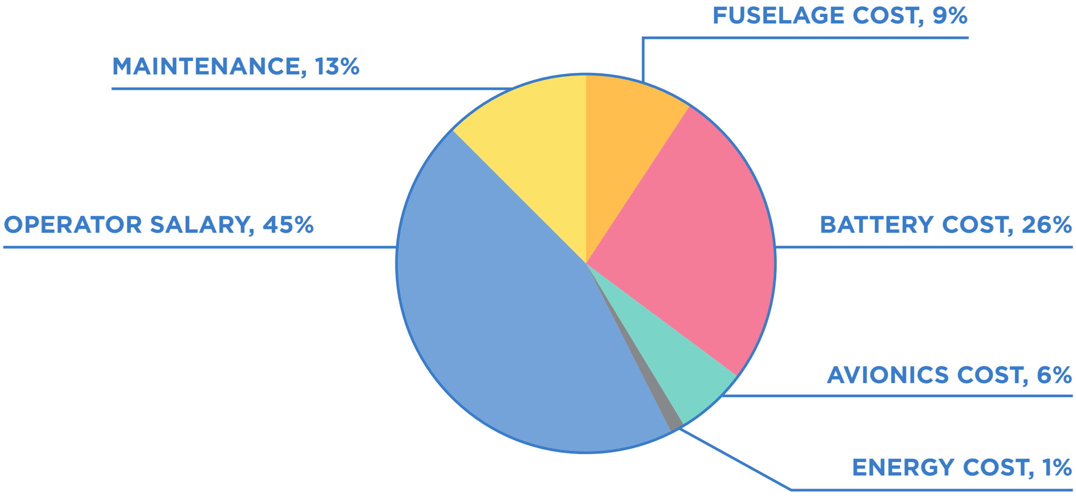


FIGURE J2B: Cost drivers of drone-based transport in San Juan Province - RMNCH products

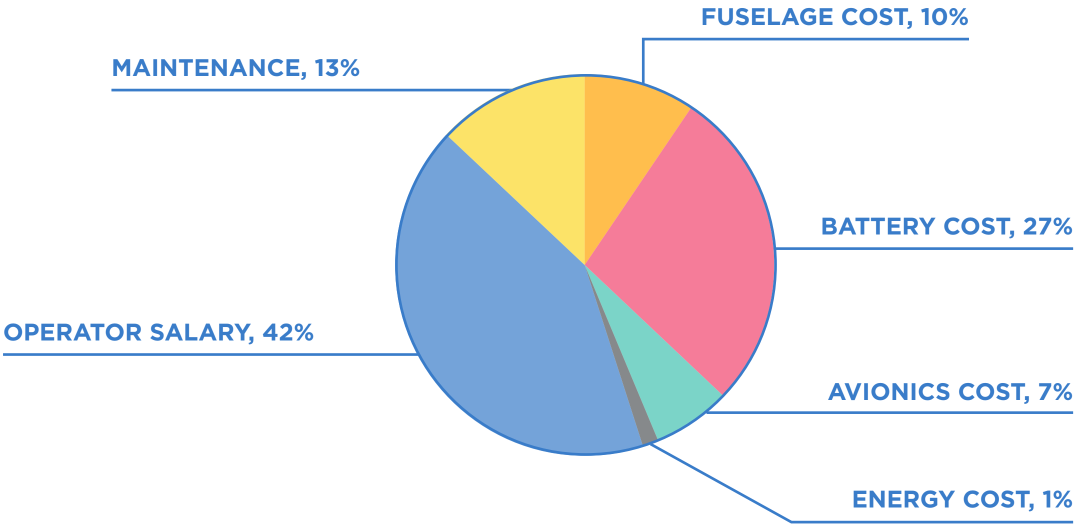


FIGURE J2C: Cost drivers of land-based transport in San Juan Province - essential medicines

Assumptions

This analysis assumed that the ground transport driver salary needed to be paid and considered as a fully allocated cost to the ground transport system, regardless of whether the driver delivered medical commodities every day. If the provincial warehouse is able to cover this cost of this salary through other means, such as cost-sharing with another department, this cost driver would be reduced.

The analysis also assumes that the drone operator would be paid at a similar rate as the ground transport driver, but because the drone delivery system does not exist in the Dominican Republic, this assumption would need to be validated based on the technical requirements of the position. The drone operator's salary contribution to the total cost of the drone transport system relies on the number of flights annually; as the number of flights increases, the proportion of the total cost that the operator's salary contributes is reduced.

At the same time that the number of drone flights increases, the number of kilometers traveled would increase in scenarios of medium and high weight and volume requirements in comparison to products in low demand, which would likely lead to differences in actual maintenance costs related to more frequent use. In addition, maintenance costs were assumed to be 10% of the total cost of the Toyota Hilux and the drone, and this assumption would need to be validated through actual operation in the field.

The cost of drone batteries is linked to the expected useful life and capacity of the batteries, assumed to be 1,000 flights. If this expected life could be extended or more efficient batteries used, this cost could be reduced, impacting the overall cost per kilometer traveled.