UAVs in Supply Chains:

Thinking about UAVs as a transport mode

Sidharth Rupani
LLamasoft, Inc.
Global Impact Team
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Let’s start off by looking at transport modes broadly
Globally, how do transport modes compare on cost?
Is cost the only criterion?
How do shippers choose the ‘right’ mode?

Characteristics of Transport Mode

Match

Characteristics of Shipment to be Transported
How do shippers choose the ‘right’ mode?

**Characteristics of Transport Mode**
- Availability
- Capacity
- Cost
  - Fixed Cost
  - Variable Cost
  - Other systemic non-transport costs
- Performance
  - Speed
  - Flexibility
  - Reliability

**Characteristics of Shipment to be Transported**
- Physical Characteristics - weight and volume
- Need for transport conditions (e.g. cold chain)
- Value
- Distance
- Urgency of Demand
- Frequency of Demand
- Unpredictability of Demand
- Seasonality (non-levelness) of Demand

**Match**
Mode Performance – Match with Value and Urgency of Demand

Value per Ton by Commodity Group

- Pharmaceutical products
- Electronic, electrical, and office equipment
- Transportation equipment, n.e.c.
- Precision instruments and apparatus
- Tobacco products
- Textiles, leather, and products
- Machinery
- Motorized and other vehicles and parts
- Miscellaneous manufactured products
- Furniture, mattresses and lighting products


Examining costs further: Fixed vs Variable Costs

Fixed vs Variable Costs – Match with Distance to be Transported

Comparing Avg. Shipment Distance by Mode

Mode Capacity and Costs – Match with Volume and Weight to be Transported

Mode Speed – Match with Demand Volatility

Relation: Transport time lag – volatility of demand?

Fast transport provide firms with a real option to smooth demand volatility

- “Firms employ air shipments is increasing in the volatility of demand they face.”
- A one standard deviation increase in the past demand volatility raises the option value of air transport by about 17.1 percent.
- The rapid decline in air transport costs associated with the introduction of jet engines increased the option value 31-fold for US imports and 100-fold for US exports.”

“…both importers and exporters use more air shipping...when there is a positive sales surprise.”

Source: Jian-yu Ke, “Transport Modal Selection and Inventory Levels in the Context of Global Supply Chains”, Ph.D. Dissertation, (2012), University of Maryland
What do we know about the characteristics of this new transport mode – UAVs?

**Characteristics of Transport Mode**

- Availability
- Capacity
- Cost
  - Fixed Cost
  - Variable Cost
  - Other systemic non-transport costs
- Performance
  - Speed
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  - Flexibility
# UAV Configuration Types

### Lighter than Air

- **Balloon**
- **Blimp**

### Heavier than Air

- **Fixed Wing**
  - Small UAV
  - VTOL fixed wing
  - MALE
  - HALE
- **Hybrid**
  - Tilt wing
  - Tilt engine
  - Tilt platform
- **Multi-rotor**
  - Tri-copter
  - Quad-copter
  - Hexa-copter
  - Octo-copter
  - Nano
  - Flettner
- **Single-rotor**
  - Conventional
  - Coaxial

Source: Drone Industry Insights
[www.droneii.com](http://www.droneii.com), June 2016
UAVs have a very wide range of characteristics, capabilities, and costs.

Example Landscape: Payload and Distance

Source: VillageReach, Modified from Wings for Aid slide
Focusing in on the option we typically have available for last mile delivery: road and comparing UAVs to it.
The cost of using trucks in for last mile deliveries in global health depends on a number of factors:

- What size truck?
- What utilization?
- What region, road conditions, usage, fuel prices?
- Are you doing multi-stop routes or single-deliveries?

Source: LLamasoft Global Health projects across Africa
Using average figures –
Comparing land transport options with UAVs on a Cost per ton-km basis

Source: Public data estimates and LLamasoft projects across Africa
Using average figures – Comparing land transport options with UAVs on a Cost per ton-km basis

Logarithmic - Cost per ton-km by Mode (Air and Land in Public Health)

Source: Public data estimates and LLamasoft projects across Africa
UAVs appear expensive

But...

What about performance benefits?
What about other system cost benefits?
Design is the art of intelligent tradeoffs
Cost
Transport Cost
Inventory Holding Cost
Facility Operations Cost

Responsiveness

Availability

Unexpected consequences: Behavior/Complexity
To examine tradeoffs

let’s look at the global health context
Match to Shipment Characteristics in Public Health Supply Chains?
Requires demand analysis for specific products and contexts

**Characteristics of Transport Mode**
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  - Transportation Fixed Cost
  - Transportation Variable Cost
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Match

Demand Analysis
An Example Case for Analysis

- Dodoma, Tanzania
- 157 health facilities
Different Product Types have different Shipment Characteristics

- Blood
- Rabies PEP + Immunoglobulin
- Vaccines + supporting products
- Prioritized Program and Essential Medicines
<table>
<thead>
<tr>
<th>Product Type</th>
<th>Frequency</th>
<th>Urgency</th>
<th>Difficulty to store at end point</th>
<th>Weight and Volume of each shipment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blood</td>
<td>Daily (or multiple times per day)</td>
<td>Very High (minutes matter)</td>
<td></td>
<td>low (3 units = ~ 1.5kg)</td>
</tr>
<tr>
<td>Rabies PEP</td>
<td>Very sporadic (each facility 2-3 times/quarter)</td>
<td></td>
<td></td>
<td>very low (&lt;1 kg)</td>
</tr>
<tr>
<td>Vaccines</td>
<td>can choose</td>
<td></td>
<td>high, cold chain required (fridge capacity)</td>
<td>low (each facility 10-20 Liters per month)</td>
</tr>
<tr>
<td>Essential Medicines</td>
<td>can choose</td>
<td>low</td>
<td>none</td>
<td>high (~100 kgs a month per facility)</td>
</tr>
</tbody>
</table>
Does the mode apply to all product types? Can we choose a different demand response model for each type?

**Blood**
- **Frequency:** Daily (or multiple times per day)
- **Urgency:** Very High (minutes matter)
- **Difficulty to store at end point**
- **Weight and Volume of each shipment:** low (3 units = ~1.5kg)

**Rabies PEP**
- **Frequency:** Very sporadic (each facility 2-3 times/quarter)
- **Weight and Volume of each shipment:** very low (<1 kg)

**Vaccines**
- **Frequency:** can choose
- **Difficulty to store at end point:** high, cold chain required (fridge capacity)
- **Value:** Very high
- **Weight and Volume:** low (each facility 10-20 Liters per month)

**Essential Medicines**
- **Frequency:** can choose
- **Urgency:** low
- **Difficulty to store at end point:** none
- **Value:** Medium
- **Weight and Volume of each shipment:** high (~100 kgs a month per facility)

Immediate Response for Delivery on Demand

Response to critical stock levels or stockouts
Beyond transport costs, costs can be reduced in other parts of the system by reducing inventory holding costs and capacity needs

- Across facilities at current delivery frequency (usually monthly) by trucks
  - Cycle Stock - 1 month of quantity delivered in each cycle, average cycle stock 2 weeks
  - Safety Stock - 6 weeks of inventory quite standard
- Vaccines are a high value product
- One health facility could easily hold >$1000 worth of vaccine inventory at any given time
- Inventory holding cost has a few components
  - Cost of Capital: 10%-20% (Central bank rate)
  - Storage Cost: 4%-6% (electricity and equipment)
  - Wastage: 12%+ (starting assumption, 1% chance of temperature exclusion or expiry each month)
- All-in inventory holding cost rate >30%

Image Source: John Snow Inc., The Pump Cold Chain Policy vs Cold Hard Reality, Nov 3, 2015
Beyond transport costs, costs can be reduced in other parts of the system by reducing inventory holding costs and capacity needs.

- Smaller, higher frequency deliveries (which could be enabled by UAVs) lead to lower:
  - Cycle Stock
  - Safety Stock
- If inventory holding reduces from 8 weeks to 4 weeks, then on the total inventory value, there could be substantial savings, which could offset transport costs.
- Higher frequency deliveries would also mean less cold-chain storage needed at the facility level, and delay the need to add cold-chain capacity.

### Emergency System for Vaccine Delivery

<table>
<thead>
<tr>
<th>Cost and Savings in USD</th>
<th>Increased Transport Cost</th>
<th>Reduced Inventory Cost of Capital</th>
<th>Reduced Inventory Storage Cost</th>
<th>Reduced Expiry and Temp Exclusions</th>
<th>Net Cost</th>
</tr>
</thead>
</table>

![Diagram showing cost and savings in USD for emergency system for vaccine delivery.](image-url)
Other performance improvements include speed/responsiveness – illustrated by the case of blood

- Currently each health facility/hospital likely to send a van back and forth to central city blood bank to fetch blood
- Method is slow and expensive
- Long average travel response time (return) >2 hrs
- Slow transport leads to poor health outcomes for patients
- Transport for blood alone has high hidden costs – personnel time and transport
- Using UAVs could greatly reduce travel time and could also reduce cost (as drone could be appropriately sized to transport 2-3 units of blood)
Additional benefits of on-demand response model include increasing availability for sporadic demand products

- Health facilities often don’t have stock of Rabies PEP, because it is an unpredictable infrequent-use medicine with <1 bite/month per facility.
- Currently there is rarely stocking of rabies medication at health facility level, as tracking inventory and ordering for such sporadic demand product is low priority.
- Many patients have to make multiple trips to multiple facilities to obtain treatment, at high personal cost, and often obtain very delayed treatment or no treatment as a result.
- In the coverage area of 157 facilities, on average there are ~1700 bites per year (Source: Ifakara Health Institute data).
UAVs could increase availability by responding on an on-demand basis

- Using UAVs, a central store of Rabies PEP can be provided to the health facility on an “as-needed” basis
- Storing centrally and providing on demand would alleviate need to hold and track inventory at the health facility level
- Can reliably treat 1700 people with bites using Rabies PEP
- If these people did not receive treatment otherwise, 1700 bites could translate to ~100 lives
- The cost to provide this treatment reliably to all facilities using UAVs is $X per year
- Comparatively, if facility used land transport (most facilities don’t even have vehicles, so this is not an option) to travel to center to respond on demand, cost could be $2X-3X per year
How are these tradeoffs going to evolve over time?

How can we improve these tradeoffs with system design innovation with current technology?
UAV characteristics are not going to stay fixed over time – they will change **rapidly** – look at historical air freight rates.

As rates reduce, share of transport increases rapidly

One key component – Batteries, are improving steadily in cost and performance. This could lead to increases in payload, range, and system costs.
Batteries are showing 10%-15% learning curve with increasing volumes in production.

http://rameznaam.com/2015/10/14/how-cheap-can-energy-storage-get/
Innovations in systems design – such as intelligently pairing land transport with UAVs could increase benefits and applicability

- Analogous to “Mobile Warehousing” concept used in many countries, including Tanzania
- Concept can now be extended to include UAVs!
- Cost and Benefit improvements provided by such pairings need to be analyzed and quantified

See full video:  https://vimeo.com/181793867

Lessons

Mix and match modes to serve your needs – the tradeoffs are going to be positive only in particular niches

Match to shipment characteristics
  • Match to regions (accessibility and distance)
  • Match to product (weight and volume)
  • Match to product value and urgency of demand need
  • ...many more

Which part of your supply chain makes sense to serve using UAV?
How can we use innovative system design to increase applicability and benefit?
What will be the right mode mix as mode characteristics change over time?

This is a design problem – today and tomorrow
THANK YOU!

Please reach out to us

sid.rupani@llamasoft.com
globalimpact@llamasoft.com