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entitled: Emergency Services 2.0

Performed by: 6-year student, group STM17/M
speciality 073 “Management”
Victor Sarapin

Supervisor: Valentyna Zasadko

Reviewer: Roman Savchenko

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PROJECT OVERVIEW

The project describes considerations to create and operate emergency services that can cope with current and future demands, driven by population growth and city infrastructure lagging behind.

Current arrival time for medical emergency services should be under 10 minutes within city limit and under 20 minutes beyond city limit for emergency cases. Depending on meteorological conditions, road condition, season etc. it may be extended by additional 10 minutes[1]. Considering round-trip this means that for emergency case beyond city limit in case of extended timing 1-way reaction time is already 30 minutes and round-trip is 60 minutes - which is already an upper boundary for medical reaction time for emergency cases (should be under 60 minutes) - if this timing is exceeded, chances to get irreversible damage to patient health grow significantly[2].

Short-term results of the project is bringing real number of emergency calls to capacity of services, thus gaining reliable improvement of reaction time and provide case of success for regional healthcare services.

Long-term results of the project is have sustainable cost-effective emergency service with service level meeting or exceeding community expectations, with potential to be the growth point of low-infrastructure on-demand transportation system. My motivation for the project consists of several larger items: first was to dive into area way far from pure software engineering and deal with something that involves extensive hardware component. Second was to work in aerospace domain, which was an interest since while ago. Third was to deal with local healthcare infrastructure and get clearly visible improvement – and one of the most visible would be emergency services: o exist interviews in my company the most common case for leaving the company was relocation to another country, due to better healthcare for the person leaving the company and his or her kids, and better education system for the kids. Education is somewhat aside from my experience, but healthcare was exactly it – so I decided why not to do something about it. This project is already second initiative in this area.

PROJECT OBJECTIVES

It is clear from the very start that addressing the problem of regional emergency services is hardly the problem to be solved by a single company or individual, neither it affects only one stakeholder. So, to treat it seriously, a community of individuals and organizations need to be assembled, and to have it – there should be a common understanding of the situation (with respect of each participant’s perspective) and clear basis & means of communication. The objective of the project is to create such understanding and means, and outline possible options & constraints of the solutions, and options for each participant’s role and outcomes within these solution options. Also, project should have specific actionable items and constraints, that enable implementation of the project for participating organizations, individuals and other stakeholders. Let’s set outline it in measurable form:

1. Discover, formulate and validate specific factors that contribute to the current state of things in regional emergency services

2. Create viable business plan that will allow to implement next steps. It should include

- roadmap and key decision points with options
- business network structure
- financial plan

1. Reduce improper use of emergency services from 70% to 35% - this will reduce the load on existing emergency services by 1/3.

2. Reduce emergency reaction time to be under 10 minutes 90% of cases by researching emergency call patterns and correlations, and establishing routes and shifts so “next most probable call” will be reachable by ground means

3. Where there’s still need for medical transportation - provide it highly focused for specific need using automated (or semi-automated) electric aircraft. Such need may include

- blood or plasma delivery to the place of emergency
- medicine or medical device delivery to the place of emergency
- patient emergency delivery to point of care

CHAPTER 1. ANALYSIS

1.1. Market

In the draft of the State Budget of Ukraine for 2019, 6 billion UAH (~230M USD) allocated to finance the emergency medical care through the subvention mechanism. Statements of some deputies of Supreme Rada that the state budget provides for emergency medical care only in 5 oblasts and the city of Kiev, do not correspond to reality[11].

Emergency medical care system requires significant changes. The "fast" reform is one of the priorities of the Ministry of Health for 2019.

To make systemic changes to emergency medical care, it is intended: enhance emergency crew qualification level upgrading to the level of world standards for providing emergency medical care;
raising salaries for specialists who have been trained in modern life-saving methods;
new, modern transport, equipped with the necessary equipment;
modern dispatching services throughout Ukraine, united by a single electronic system.

Countrywide such changes will cost the Ukrainian budget an additional 10 billion USD. For these changes in the state budget-2019 allocated about 1 billion USD.

In 2019, the Ministry of Health of Ukraine starts the first stage of the reform of emergency medical care, which starts in Donetsk, Odesa, Ternopil, Poltava, Vinnytsia regions and Kyiv city. Changes will begin in areas with infrastructure, opportunities for re-training physicians and have demonstrated their managerial effectiveness in the reform of primary care. Here, an additional UAH 1 billion, set in the state budget for the next year, will provide significant changes while other areas are being prepared.

The health care system's transformation is being phased out: large-scale changes began in 2018 at the level of primary health care; in 2019, they will continue and cover already specialized and emergency medical care.

The Ministry of Health of Ukraine stresses that the use of doctors in political manipulation is unacceptable. Service traffic and emergency teams need to save people and not be participants in political shows.

To draw the line here, there’s considerable financing available to improve emergency services. Added with funds available from primary section of healthcare that creates a noticeable market for emergency services and accompanying infrastructure.

Emergency services market is regulated, by state licensing. Currently the market of emergency services consists of the following ways to deal with emergency:

1. State-owned emergency services. Most visible and known, and the one handling the majority of the calls. Also “owns” standard emergency numbers, (103 and 112), operating call/dispatch center that handles the calls from individuals. Transportation is provided by cars (purpose-configured vans), majority of them are in mediocre condition. This service handles both emergency services and generic medical transportation services. There are 4 stations distributed in the city, operating less than 100 cars. Formally call to state-owned emergency service is free-of-charge. Arrival time is 15 to 30 minutes.

2. Privately-held commercial emergency services. There are also commercial emergency services in Lviv – 5 organizations. Calls are handled by organization-specific call-center, number should be known in advance. Transportation is provided by cars (purpose-configured vans) – new or lightly used. Each organizations operate 2-3 cars. Services are commercial, prices vary from 1200 to 1600 UAH/arrival within city, and distance-dependent beyond city boundary. Privately-held emergency services also provide non-emergency service (should not be handled by state service) and medical transportation services. Arrival times are about 15 minutes (not very different from state owned)

3. Medical aviation. Currently exists only on paper. Procedurally even on paper it allows to shortcut allocation of medical specialists to complex medical cases, but actual logistics is provided by state-owned emergency services. Interestingly, that Lviv region have owned medical helicopter (Ka-226 – the only purpose-built medical helicopter in the country), but never used it since 2008, and even did not assembled it to ready state till 2017. Region suggested to transfer it to Dnipro military medical center, but deal broke, since Dnipro center was not financially able to operate helicopter. In August 2018 helicopter was transferred to Armed Forces of Ukraine as naval medevac helicopter. Statements of regional governor to purchase Airbus helicopters instead of russian-built Ka-226 also suitable for medical transportation did not turn into any action. There are also infrastructural restrictions on helicopter use – there's only one medical facility has helipad (hospital on Mykolajchuka) that requires maintenance, and military hospital helipad is still in design stage. Pricing and arrival time not applicable.
4. Taxi service or personal transport. Technically this is not an emergency service, but should be considered as a substitute. .They are operated as purely transportation means when no emergency service available or their arrival time is longer than a taxi/personal transportation. Arrival time is usually under 15 minutes, no traffic priority or life support means present. Usually medical specialists start to work with patient only when it arrives to ER – which is OK for majority of not-life-threatening cases.

It is worth noting that any of mentioned above services has 3 components:

- call/dispatch center that accepts and routes calls, provides initial assessment
- medical means and personnel
- transportation means and personnel

1.2. Stakeholders

Let’s consider the typical portraits of users and beneficiaries of the emergency services. This includes users, line employees and decision makers of organizations that provide, use or are involved in emergency services business.

1.3. Individuals

low income, low awareness user - majority of the load onto emergency services, usually state owned. Often call is related to alcohol intoxication or injury associated with alcohol abuse, and the majority of cases are not an emergency or life-threatening medical condition [7].

- upper middle income user - usually generates lower pressure onto emergency services, often uses private emergency services on commercial basis

1.4. Private emergency services

- executives - operate private emergency services. Looking towards improving variety and quality of services, while keeping costs under control.

1.5. State owned emergency services

- executives - maintain operations at current state. Often operate using established cliches of ”not enough resources”. Need to reduce load on scarce resources and reduce operational costs to improve working facilities

- staff - involved into day to day work. Overloaded schedule, and usually noticeable underpayment, poor working conditions. Need to reduce load to manageable level. Sometimes lack prescription drugs needed for emergency.

1.6. Blood centers

- Need to handle blood and blood products supply to the points in need - usually hospitals, sometimes accident locations, reduce blood waste due to not sufficient reach of transportation means - currently sent to location using emergency car or even normal car, even between cities.

With consideration of Market chapter it is worth noting that user segments and stakeholder segments has very little overlap – so do organizations that provide services for these segments, even if at first glance their service proposition looks nearly identical.

1.3. Cityscape overview

Lviv cityscape is similar to the cityscape of European medieval city, hardened by under-developed public transport and absence of underground means of transportation – this is

- a lot of activities happen in city center
- interconnection between distant city areas is via center
- streets in central part are narrow and crowded with traffic
- transportation conflicts with demand of having purely walking central part (touristic demand)
- in case of traffic accident larger cluster of streets are completely blocked by traffic
- on city periphery there is still a possibility to have wide street interconnect, in central this is hardly possible.
- morning/evening traffic when entering/exiting city boundary due to suburb demand for transportation

As a result, travel time from one city side from one side of the city to emergency hospital on another side and there's a traffic jam – that easily takes 30-40 minutes even having priority in traffic (due to congested streets priority is of little help in central part of the city)

There are no operational helipads in the city. There's also a lot of wires for various purposes run over the streets – especially in the city center.

1.4. Drone delivery in healthcare

According to [5] common drone applications in medicine include the provision disaster assessments when other means of access are severely restricted; delivering aid packages, medicines, vaccines, blood and other medical supplies to remote areas; providing safe transport of disease test samples and test kits in areas with high contagion; and potential for providing rapid access to automated external defibrillators for patients in cardiac arrest. Drones are also showing early potential to benefit geriatric medicine by providing mobility assistance to elderly populations using robot-like technology. Looking further to the future, drones with diagnostic imaging capabilities may have a role in assessing health in remote communities using telemedicine technology.

In Papua New Guinea, the organisation 'Doctors Without Borders' used drones to transport dummy tuberculosis (TB) test samples from a remote village to a large coastal city. This application of drones was significant because the country has a large TB burden with an increasing incidence of multidrug-resistant TB.

In Rwanda, Africa, drones were used to transport blood products and medicines to critical access hospitals and remote regions. The drones navigated using the Global Positioning System (GPS) and Rwanda's cellular network. Hospitals ordered blood and medicines via text messages and received the supplies within 30 minutes. The ability to transport blood is important; a single patient with massive bleeding can easily deplete the blood supply in medium-sized hospitals, and larger hospitals can run low on certain blood types. Several prior studies have demonstrated that drones are a safe method for transporting blood products, donated blood and vaccines using samples containing microbes.

In emergency medicine, studies have showed that the use of drones may prove to be safe and feasible for delivering an automated external defibrillator (AED) for out-of-hospital cardiac arrests (OHCA) in areas identified using GIS (Geographic Information System) models.18 The various methods of delivering an AED after arrival on-site while keeping the drones within the line of sight were further studied. This study showed that the use of an AED-equipped drone might have the potential to reduce the time to defibrillation for OHCA. A similar study conducted in the Netherlands considered the use of an ambulance drone designed to deliver an AED directly to heart attack victims. In this application, emergency services personnel provided instructions regarding AED use and cardiopulmonary resuscitation procedures to persons assisting on-site via livestream video and audio connections. The use of drones in this application has the potential to decrease response times and increase survival rates, especially for patients in cardiac arrest.

To summarize, there are next advantages and disadvantages of drone technology in medicine:

Pros	**Cons**
1. Saving human lives—drones can provide humanitarian aid and potentially life-saving treatments to areas affected by natural disasters and emergencies, leading to a quicker, more efficient response time. The provisions include medical supplies, antivenom and blood products	1. Regulatory limitations need to be addressed and updated before drones can be used in the medical field. These include legislations pertaining to predetermined flight corridors where drones need to fly 'in the line of sight'. In medical emergencies, the fastest route needs to be employed for ensuring life-saving therapy, including 'flying out of sight.' As such, any deviation from this might adversely impact the health and survival rate of a patient
2. Delivering laboratory samples or blood, as well as unique products brought to remote clinics or hospitals	2. The effectiveness of drones will depend on the individual aiming to deliver help to the emergency victim. This could be a layperson and not someone who can necessarily administer medical treatment. Such an arrangement might be a setback when compared with the more traditional medical transport methods and delivery of medical aid
3. Delivery of prescriptions and other supplies to hard-to-reach people including those at sea or at home	3. Storage and transportation of all drugs and specimens via drones needs to be carefully implemented and monitored. This includes temperature of storage and duration of transportation as these can affect drug efficacy and

Pros	**Cons**
	specimen data results. Any compromise on these parameters could lead to serious consequences to the health and well-being of a patient
4.Transportation of organs for transplantation 5. Potential to transport defibrillators to patients in cardiac arrest 6. Potential to deliver telemedicine and medical support including diagnostics, or even tools such as portable ultrasound to remote areas.	

There is a number of companies worldwide providing drone delivery services in healthcare, including cases of emergency delivery:

Company	**Healthcare items**	**Location of operations**
Matternet	Blood, medications	Haiti, Dominican Republic, Papua New Guinea, Switzerland
DHL Parcel	Blood, medications	Germany
Zipline	Vaccines, blood	Rwanda
Flirtey	Medications	Virginia, Nevada
Delft University	Defibrillators	Netherlands

Worth noting that only 4 locations from the list are “developed countries”, others are clearly fall into category of “under-developed countries” with poor economy and infrastructure. Their implementation have the following technical characteristics:

Company	Payload	Range	Speed
Matternet	2 kg	10 km	25 mph
DHL Parcel	2 kg	12 km	40+ mph
Zipline	3 lb	45 miles	90 mph
Flirtey	2 kg	20 miles	
Delft University	4 kg	12 km	60 mph

Launch, package delivery methods and landing technology is as follows:

Company	Lunchpad	Delivery method
Matternet	Automated ground station	Automated ground station
DHL Parcel	Automated skyport	Automated skyport
Zipline	Human operated skyport	Paper parachute
Flirtey	Airport	Dropped by rope
Delft University	???	Ground landing

In summary, drones are a rapidly developing technology with increasing worldwide applications. They have developed into a valuable tool in medicine by demonstrating their ability to address issues faced by both medical personnel and patients. Common drone applications in medicine include providing disaster assessments when other means of access are severely restricted; delivering aid packages, medicines, vaccines, blood and other medical supplies to remote areas; providing safe transport of disease test samples and test kits in areas with high contagion; and providing rapid access to AEDs for patients in cardiac arrest. Drones are showing significant potential for transforming healthcare and medicine in the 21st century.

1.6. Cost of the problem

With given load state emergency service handles from 360 to 500 calls a day. Considering each call cost being 800 UAH (commercial rates are 1200-1600 UAH per call) run rate for state service is ~15000 USD/day, 70% of which is waste. Achieving project objective #1 results in direct savings of 5250 USD/day only for state-owned emergency service only in Lviv. Monthly it gives ~150K USD of direct savings.

1.7. Problem statement

With respect to the analysis above, let’s formulate the problem to be solved:

Current emergency services can’t meet required reaction times due to the following reasons

- cityscape, road network & traffic
- poor utilization due to non-emergency cases
- poor condition of emergency services themselves, due to the list of reasons

Moreover, with given limitations of road network and growing load from personal & cargo transport it won’t be solved with extensive means (just adding more cars and people to emergency services)

Possible poor utilization may indicate that service is not used appropriately - it is perceived as a commodity rather than scarce valuable resource, and as a result - having little value to that user group.

In the next chapters I am going to investigate the statements above in more detail, validate them and suggest solution options for them, with respect to validation results and discovered contribution of each factor into problem composition.

CHAPTER 2. SUGGESTED SOLUTION

Create emergency service with the following characteristics:

- have 1-way reaction time under 10 minutes within Lviv boundary in 90% cases
- have roundtrip reaction time under 45 minutes within Lviv region in 90% cases
- operational costs less than with current emergency service.
- will be minimally limited by road network and growth of traffic.

This is expected to achieve by the following action items:

- reduce improper utilization - thus easing the need to actually involve emergency transportation and services,
- reduce reaction time by planning and prediction of emergency cases and
- improving transportation by using automated electric aircraft where appropriate.

2.1. Business model

For evaluation of decision options and their outcomes and for building plans one needs means of prediction – a business model. I am going to use Business Model Canvas by Alex Osterwalder [8, 9]. Other options were classical business plan and McKinsey 7s. Business Model Canvas was chosen due to comparable simplicity and comprehensiveness, strong enforcement of finding product-market fit (both separate canvas as a part of methodology and integral part of BMC itself) – which is critical for startup-like business, and still ability to provide actionable insights instead of prescriptions.

Key idea of BMC is to highlight insight of relation between value propositions and customer segments.

Business Model Canvas is composed of the following blocks:

Value propositions. This block outlines one or more specific value proposition that business is going to bring to customer segments.

Customer relationships. This block tells how we build our relations and interactions with customer.

Customer segments. This block outlines distinct customer segments that solution serves. It may be users, sponsors, other stakeholders

Key activities. This block outlines the main operational activities we are about to execute in order to create the value to our customers.

Key partnerships. This block provides an outline of the list of organizations or individuals we need to partner with in order to create value, promote it to customers or to perform key activities.

Key resources. This block outlines the resources we will require in order to generate value for our customers and to run operations (perform key activities).

Channels. This block lists the ways the created value is delivered or communicated to customer segments. It may be treated as a point or place of interaction.

Cost structure. This block outlines the cost structure of the business under discussion.

Revenues. This block outlines the key revenue streams that the business is expected to generate.

Items in the canvas can be formulated as facts or as hypothesis that need to be confirmed or denied – and results of such validation feed back into business model canvas during iterative revisions.

Key partners	Key activities	Value propositi	Customer relation	Customer segments
Taxi services	Call evaluation & scoring	Time reduction	Dispatch/all center	Private emergency services
Local authorities	ML models & software develo	Risk reduction		State emergency services
ATC services	Maps maintenance	Cost reduction		Blood centers
Primary physicians	Drone design			Individuals
Financial institutions (banks)	Advertisement & PR			Companies
Drone/Aircraft manufacturers	Area emergency forecast			
Software companies	blood/plasma delivery			
National call/dispatch service	Drug delivery			
	Critical resources		**Channels**	
	Historical list of emergencies		Dispatch/all center	
	HD maps with obstacles		Website	
	Wire & obstacle detection tech.		Press & publicity	
	The team		Local authorities	

Cost structure	Revenue streams
Dispatch/call center	Call scoring subscription
Software maintenance	Area emergency forecast subscription
Call processing software improvements	Blood & drug delivery subscription
Area emergency forecast improvements	Blood & drug delivery transactions
Maps update	Rental payments for aircraft
Aircraft maintenance	
Flight control center	

Now let's detail these blocks in the paragraphs below.

2.1.1. Value proposition

The essence of the value proposition is reduction of reaction time, reduction of unavailability risks and reduction of operational costs by making better use of limited valuable resources. Since for the largest group of users (low income, low awareness) there's little value in actually emergency – calls analysis reveals that actual need for this category is usually is the need for attention and significance, or the need for substance detoxification – such cases should be considered out of scope of emergency services, handled by different services with different SLA and reaction times. For those other customer segments time reduction and cost reduction are important. Scoring and appropriate routing of calls is done by call/dispatch service.

2.1.2. Customer segments

Described above in Stakeholders paragraph.

2.1.3. Customer relations

Customer relations are maintained via 2 key points:

- Call/Dispatch service: it is the first point of contact during an emergency. It drives the call through predefined protocol, collecting relevant info about case, provides scoring of the call based on location, previous calls history, patient health record (if available) and route to the most appropriate service to handle the case. It is expected that call/dispatch service is bound to standard emergency number, so people in emergency would use already established behavior.
- Local authorities: they establish policies and configuration for regional health organizations, responsible for budget allocations and handle licensing and regulated activities in certain business areas. Organizations in health and health emergency areas are directly affected by the actions and decisions of local authorities and individuals are affected indirectly – via resulting SLAs and quality of services that result from established policies and limitations.

2.1.4. Channels

Business model outlines the following channels that deliver or communicate value to the customers:

- Call/Dispatch service: it reduces reaction time for the caller by using IT systems and critical information resources. It also routes handling to the most appropriate (read: cost-efficient) service that can deal with the case – by doing so it also delivers cost saving value. Besides directly delivering value, it also is a way of communication, forming attitudes and social narratives about emergency services and their reputation.
- Website: communicates value to all customer segments, and serves ass public media. It is implied that “Website” channel also includes social media that also

are sued for public communications – contacts, achievements, announcements etc.

- Press & publicity: since a significant amount of users do not use the internet as primary media to get information, communication on “website” above should be complemented by normal media and, more importantly targeted interpretation of messages for target audiences. This also ensures visibility of the project to customer segments, as they will be more likely working with their “sources of truth” and perceive information from them with higher trust than from other sources.
- Local authorities: again, besides customer relation it is also a channel similar to media, that communicates value and ensures interaction of organizational customers in more formal and detailed way. It also may serve as a point of escalation in case any disputes surfaced during business operations.

2.1.5. Key activities

For key activities only those are stated that needed to run an established business operations. It is implied that certain amount of ramp-up activities is needed to establish those operations, and that these activities are addressed on earlier stages of the project, and that the economic burden of establishing operation is added to the lifetime cost of ongoing activity. Activities include:

- Call processing and scoring: operator activities to accept call, communicate with the person calling for an emergency, assess the situation in efficient and calming manner and collect as much relevant information as possible; using software assistance and scoring models evaluate most probable outcome of the situation, request assistance from most appropriate service and manage expectations for the calling person. After the situation – call back and asses the outcome of the emergency situation (needed for performance analysis and model truing). Operator also interacts with emergency crews that handles the situation, provides them with situational awareness and support and assists in handling additional requests.

- Development & maintenance of call scoring software and accompanying models: creating software with streamlined UX for operator assistance and support during call, collecting and cleansing historical data for the call scoring module, design and training of ML models for scoring. Maintenance and support activities. This also includes technical account management and collecting feedback from users of the call system and incorporating them into software as improvements. Software also provides situational awareness & support for emergency crew involved into case resolution – ideally provide them with all critical information that operator collected before arriving to the place of emergency.
- Providing area emergency reports (on a regular basis): calculate daily forecast for expected emergency calls and their expected nature with hours granularity and 3 minutes travel radius geospatial granularity for the area in control, coordinate positioning of participating emergency services appropriately. This should significantly cut the time to arrive for emergency, and decrease resource and crew effort waste.
- Maps maintenance: regular assessment of cityscape for changes – specifically wires, obstacles and changes to buildings or appearance of new construction site. Map also includes historical information about local wind and significant weather – needed for safe and predictable aircraft operation.
- Advertisement, PR, account management: communicating to stakeholders and users value, successes and needs of the project, monetization-related activities.
- Drone design: high-level design and cooperation with specialized units organizations about detailed design and production of specialized aircraft for the

task, in case commercially available off-the-shelf aircraft do not possess characteristics and properties to accomplish required tasks.

- Drug and blood delivery: operations of supply & flight control center that arranges supplies needed for immediate intervention to decrease urgency of emergency situation.

2.1.6. Key resources

Key resources needed to perform activities above are similar to resources of other business organizations involved in transportation business:

- The data – historical list of emergencies: this gives historical insights, trends, anomalies and allow to plan for demand and utilization of services, finances and allows to provide forecasts on what may be the flow of specific emergency case, based on similar historical cases.
- The data – cityscape map with obstacles: needed for operation of drone aircraft – if flown at the level of buildings, during takeoff and landing.
- Wire and obstacle detection technology: needed for operation of drone aircraft when wires are not completely mapped or map is outdated to avoid collision and crash that results in mission failure.
- The team: people who do the job – call center operators, drone operators, hardware engineers programmers, data engineers, devops specialists, PR & account managers, company management

2.1.7. The team – details

It is worth to dive deeper into team composition, units and organizational structure, since in research organization (startup is a research organization) human capital is the singular critical asset of the company. If you have it – you have finances, expertise, network, publicity and so on. If you do not – pack your bags: even if you have a good idea or invention, it is hardly possible to turn it into something usable and valuable without the team.

So, I expect to have the following team composition as a starting point:

Structural unit	**Role**	**Count**
Dispatch/call center	Operator	9
Dispatch/call center	Call center manager	1
Software engineering	Software engineer	3
Software engineering	QA specialist	1
Software engineering	Data Scientist/ML	1
Software engineering	DevOps	1
Business	Account manager	1
Business	Communication specialist	1
Business	CEO/Partner manager	1
Flight control	Drone pilot	2

Hierarchical version of organizational structure is expected to be as below:

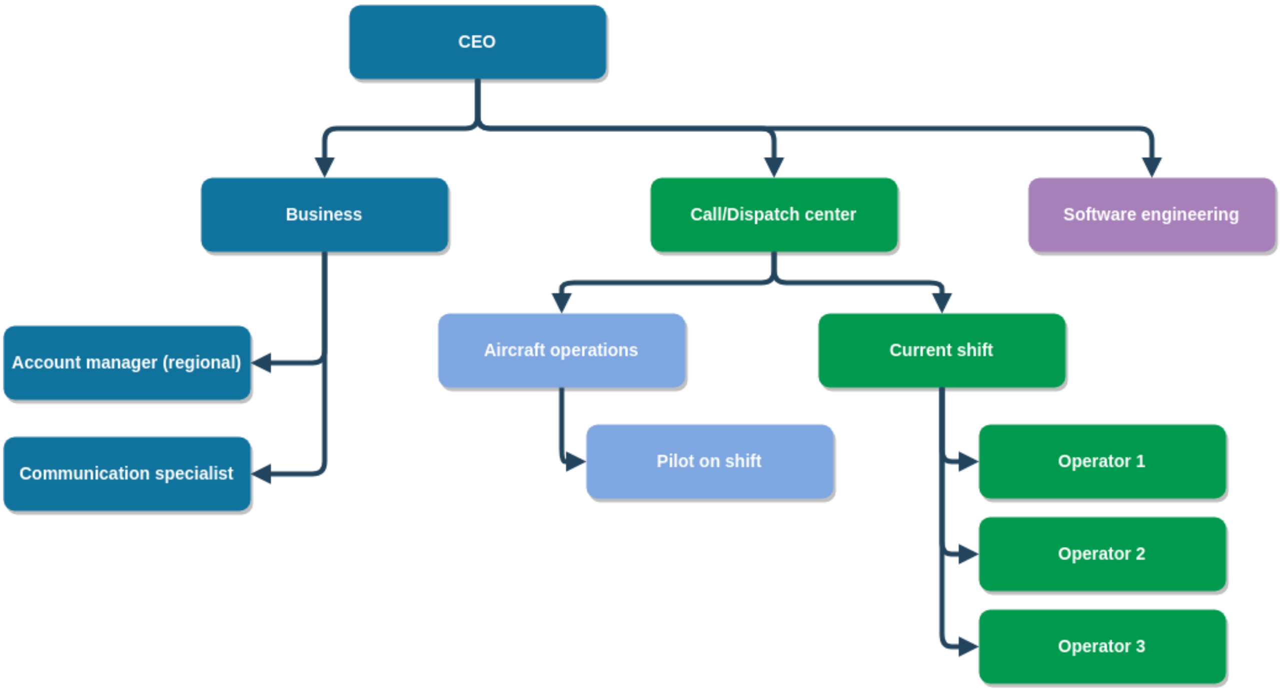

Figure 1: Organizational structure

If there is a need to scale onto regions other than Lviv, roles to be scaled are Account manager (responsible for accounts within certain region), operators (to scale call handling capacity) and pilots. Software engineering team intentionally not shown

– if works on iterative methodologies, then team considered to be single unit that allocates roles and responsibilities within itself. This is not the only one, and probably not the optimal way of representing the team involved, and more appropriate representations expected to be used for communication and interaction planning.

2.1.8. Key partners

As mentioned above, project objectives can't be achieved by the efforts of single organization – to provide full cycle of emergency services and not just rapid transportation, it involves organization providing implementation services, information, capital, medical assistance etc. List of partner organizations includes:

- Taxi services: special conditions for non-emergency medical assistance and prevention visits may be beneficial for general-purpose taxi service, and reduce cost of ownership for medical assistance facilities due to higher utilization of existing general purpose resource and less inappropriate use of scarce medical transportation facilities.
- Local authorities: provide mediation, policy definition and escalation of problems not being solved.
- ATC services: require coordination to provide safe operation of conventional aircraft (airline, general aviation, military) and drone aircraft operations. Also ATC is one of agents that confirms safe operation record as drone operations history builds up, which will be grounds for certification of subsequently higher degree of autonomy being used for drone operations.
- Primary physicians: this is important partnership for achieving 2 goals – first, prevention of emergency situations by acting proactively, as primary physician potentially has most complete information and context about health state of his patients and risks associated with their health state. And second is patient education - informing his patients about proper use of emergency services and bout consequences of improper use.

- Financial institutions: provide financial instruments and finances to pay for core technology infrastructure development.
- Software companies: provide additional software engineering and devops capacity for software aspects of the project. Benefit for them is yet another software project plus good publicity as result of participating in socially significant project.
- Drone aircraft manufacturers: provide commercial off-the-shelf or specially designed and built aircraft to perform drug delivery, blood delivery or emergency patient transportation.
- National call/dispatch service (103): needed in variety of roles – first as most common point of contact with emergency services, second as source of historical detailed data about emergencies and their outcomes, third – as point of access to patient charts in case of emergency via national e-Health platform (it is intended to keep extensive amount of patient health record for reason of reimbursements).

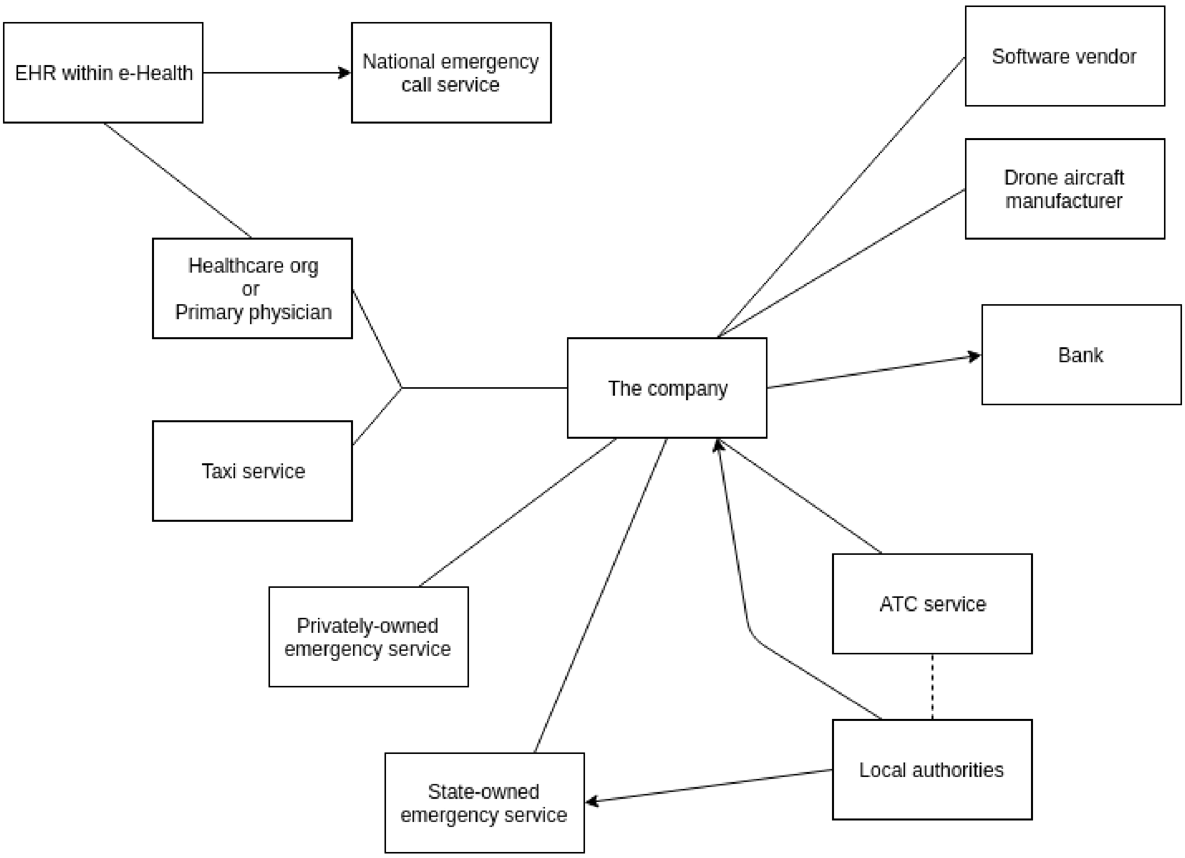

Figure 2: Partner network

2.1.9. Revenues & Pricing

I am going to use subscription model for call scoring services and area emergency forecast report, as it provides steady predictable cash-flow over a longer period of time, and is also easier financial load for the customer. Subscription is expected to be annual for emergency service operators – both state owned and privately owned. Pricing is built as partial payment from the problem solved – this should simplify sales negotiations by making clear translation from current cost of problem to financially measured value of suggested solution and by supporting clear and fair pay for it. With respect to pp. 1.6. "Cost of a problem" I assume 1/3 of problem costs to be initial price for each service. This should be treated as "always hypothesis" and checked for being an optimal price on regular bases. For the sake of simplicity each subscription is equally priced as 1/6 of total problem costs, but price checking they undergo separately.

For drugs & blood delivery different price formulation should be applied, as it is currently hard to predict actual use, and since most of costs happen during actual flights, I split pricing for the service in 2 parts – subscription that covers access to service and 3 deliveries per month included, and variable part, with payment per transaction. For the start of the project assume delivery transaction price to be 800 UAH per delivery – so it is still comparable to delivery by emergency vehicle (as it happens now) and being times less than commercial emergency operator and on par with state owned emergency operator. With such considerations subscription fee for blood and drug delivery would be 3000 UAH – that includes 3 deliveries plus payment for accessing the service (cash-flow from that part of payment should cover the costs of maintaining infrastructure in operational state when idle). Later as the more information will be collected and this segment of problem costs will be better understood the model may be switched also to "part of problem cost". Source of problem cost is regional delivery (both planned and emergency) that is done regularly on cars.

Rental payment from emergency services (presumably private ones) for by-case rental is expected when large VTOL aircraft will be available and is expected to be comparable to hourly rental of ultralight aircraft of general aviation – 200$/flight hour. Anticipated demand for such service in Lviv region is approximately 20 hours of service every month.

2.1.10. Costs

The largest contribution to costs is (expected) is software and data engineering services to design, implement and maintain it operational. Even considering ready-to-use commercial software for call center costs are significant. This is true in configuration when no extensive hardware design and development is done, and hardware and aircraft are ordered from partners/vendors as ready solutions. Dispatch/call center operations are not much smaller due to larger number of people involved and the need to have 3 shifts of operators to maintain 24/7 availability of call center. Maps update is provided as a guesstimate, based on topographic mapping services – the nature of mapping technology is way different, but for the purpose of evaluation this may be acceptable. There's also sharp peak in Flight control operations in last year of estimation – this stands for buying larger aircraft for regional services that are expected to become available by that moment.

2.2. Cash-flow estimation

The table below provides evaluation of cash-flow for 5-year period in case considerations above are correct. This should not be considered as accurate financial planning and used for rough estimation of financial outcomes of assumptions conditions and model (for example, assumption that "1/3 of the cost of problem solved" pricing already seems too optimistic and should be additionally verified as solution hypothesis)

	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Costs	$453,800	$474,080	$460,726	$463,230	$990,960	$2,842,796
Dispatch/call center	$120,000	$102,000	$102,000	$102,000	$102,000	$528,000
Software maintenance	$48,000	$48,000	$48,000	$48,000	$48,000	$240,000
Call processing software improvements	$90,000	$90,000	$54,000	$54,000	$54,000	$342,000
Area emergency forecast improvements	$114,000	$114,000	$120,000	$120,000	$120,000	$588,000
Maps update	$50,000	$50,000	$50,000	$50,000	$50,000	$250,000
Aircraft maintenance	$5,000	$5,000	$7,500	$7,500	$10,000	$35,000
Flight control operations	$22,000	$25,000	$32,000	$34,000	$546,000	$659,000
Taxes	$4,800	$40,080	$47,226	$47,730	$60,960	$200,796
Revenues	$323,280	$630,000	$649,200	$654,000	$1,242,000	$3,498,480
Call scoring subscription	$150,000	$300,000	$300,000	$300,000	$300,000	$1,350,000
Area emergency forecast subscription	$150,000	$300,000	$300,000	$300,000	$300,000	$1,350,000
Blood & drug delivery subscription	$6,000	$6,000	$6,000	$6,000	$6,000	$30,000
Blood & drug delivery transactions	$17,280	$24,000	$43,200	$48,000	$60,000	$192,480
Rental payments for aircraft	$0	$0	$0	$0	$576,000	$576,000

Form the evaluation above it looks that providing informational support to reduce emergency services problem is a viable business, and to operate drone delivery of blood and drugs is barely profitable (again, worth re-considering assumptions and dive deeper into this problem and with new information reconsider this evaluation). There's also a significant financial deficiency in year 1 – to address it, I suggest to move spending on aircraft operations infrastructure and personnel at least 1 year ahead, and look for grant-based financing from EU or government – in this case no dilution of equity happens. If this is unavailable – look for personal investments from local businesses and individuals: such initiative was discussed on latest board meeting of Lviv IT cluster.

2.3. Roadmap

Below goes anticipated roadmap to build sustainable business that achieves project objectives. Effectively it goes in 3 streams, as their operations, technology and staff is not heavily interrelated (also reflected in organizational chart) – one for call center/scoring and emergency forecast (this should decrease improper utilization and improve reaction time for incident by sending car in the trouble area in advance), second is establishment of light drone operations for drug and blood delivery, and the third is emergency delivery of patient by larger drone aircraft.

ID	Name	ETA	Expected results
1	Formulation of business model draft	01/07/2018	Initial business model formulated, initial hypothesis listed
2	Listing hypothesis	01/09/2019	Listed and formulated critical problem, customer and solution hypothesis
3	Validation of hypothesis complete	01/01/2020	Confirmed or denied high al high and medium problem, customer and solution hypothesis
4	Implementing MVP	01/01/2020	Collected data and drafted models to check for first actionable insights.

5	Research for large drone technology feasibility	01/02/2020	Listed all required technology components for solution. Confirmed or denied availability of every technology listed.
6	Business model revision	01/04/2020	Adjustment of business model based on the results of #3 and #4
7	Demo to initial customers	01/09/2020	Ensured commitment to buy after demo
8	Securing funding	01/11/2020	Funding for year 1 is secured
9	Assembling the team	01/12/2020	Core team is ready to work
10	Call evaluation done	01/03/2021	Software for call evaluation done
11	Area emergency forecast done	01/04/2021	Models, data and software for emergency forecast show relevant results
12	Dispatch/cal center operational	01/05/2021	Call center is staffed, trained and integrated in emergency call infrastructure
13	Drug & blood delivery started	01/06/2021	Regional delivery by small drones started
13	Project objectives achieved	01/06/2021	Confirmation of project objectives
14	First contracts renewal	01/08/2021	Provided value confirmed by customers renewing their service contracts
15	Business operates sustainably	01/12/2021	
16	Patient delivery by drone started	01/12/2025	First patient being delivered to the point of care using autonomous drone

2.4. Technology

Technology architecture consists of 2 larger parts: software and ML part that enables call evaluation & scoring and area emergency forecast with suggested actions, timing and routing, and second which supports physical intervention by delivering blood or plasma, drugs and medical devices to the place of emergency and in ultimate case - enable patient transportation.

2.4.1. Software

Software for call evaluation is based on decision trees - in case of any dispute there will be possibility to trace down the logic of decision making and avoid any accusation in discrimination. Many other AI approaches, neural network of any kind by its nature in particular are lacking this ability to explain decision that was made. Given current call rate it is easier to rely on history of emergency calls to have initial model configuration and then use new calls for truing and anomaly suggestion. Software also assists to operator during the call suggesting to ask specific questions to asses the situation and decide if it is really health threatening situation or it can be handled by other means. Another goal of call evaluation software is to keep and inform operator on “credibility score” - how likely is that this specific caller provides accurate information about the case and how likely that it is really an emergency - using similar techniques as in “proof of reputation” consensus algorithms [8] Call evaluation system together with properly trained operator is targeted to reduce improper use of emergency services and offloading emergency calls to more appropriate services - i.e. primary physicians.

Another software part is subsystem that provides area emergency forecast - geospatial and time-wise distribution of probability and severity of health-related situations that may be expected in next 24 hours - and plan actions and resources of emergency services accordingly, improving time to react. This subsystem is based on hypothesis that health-related situations and emergencies are not happening purely random, but have correlations with various factors, like historical emergencies, a noticeable number of people with high morbidity, serious chronic condition or other health complications in the area, specific of known health complications (can be derived from EHR currently being rolled out in the country), density of road accidents in the area, weather, time of day and others. This subsystem is suggested to implement using recurrent neural networks in combination with ensemble methods to compensate for errors of individual algorithms.

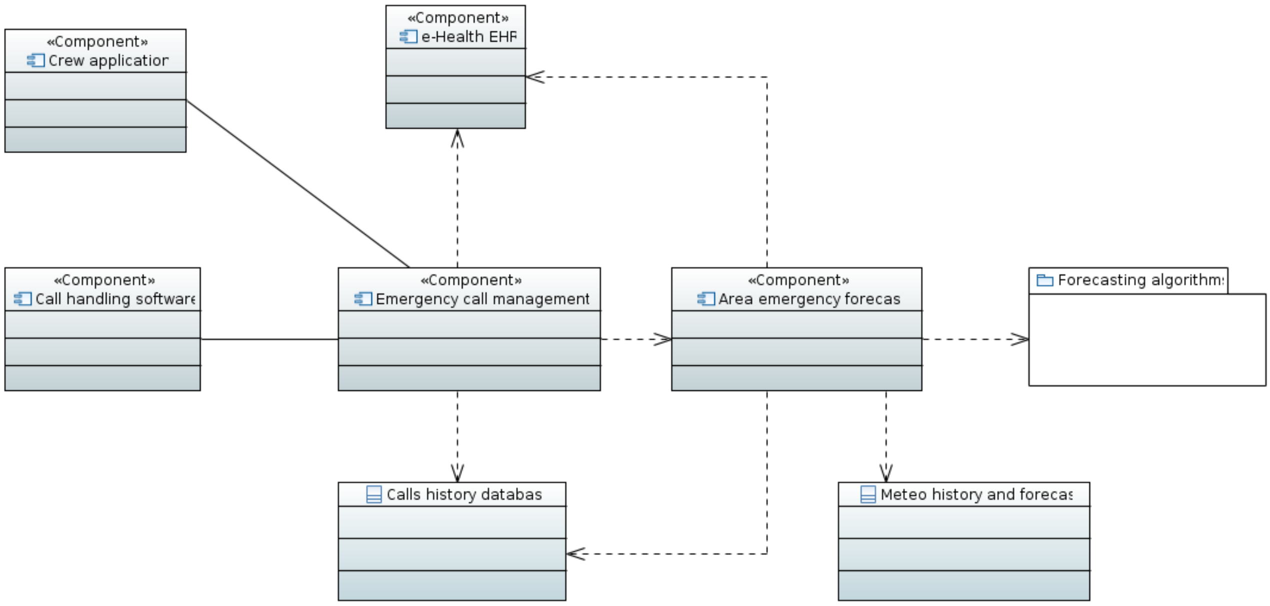

Figure 3: Component architecture of the software

I am going to use CRISP-DM[16] methodology for assessing, cleaning and preparation of data, building models and evaluating the quality of the model and of its predictions. CRISP-DM was introduced in 1997 by several companies, operating in different industries and dealing with growing data sets and growing need to derive meaningful actionable insights from these data. It was presented to the public in 1999. Currently CRISP-DM is heavily used by IBM, which recently provided extended and refined version of it. Currently CRISP-DM is the most widely used form of data-mining model because of its various advantages which solved the existing problems in the data mining industries. Methodology does not include project management activities – these should be handled separately by project management practice of choice. The fact behind the success of CRISP-DM is that it is industry, tool, and application neutral. Since the majority of data mining and data science projects deal with high degree of uncertainty, CRISP-DM is essentially and iterative approach, that proved to decrease risks and uncertainties in efficient and controllable way. The central part of it is array of data under investigation. Sequence of phases is not strictly defined and left to the choice of team, however moving back and forth between phases is heavily required for re-evaluation of results and making corrections to phases already visited. After each deployment there's a major re-evaluation of outcomes of every phase and overall results.

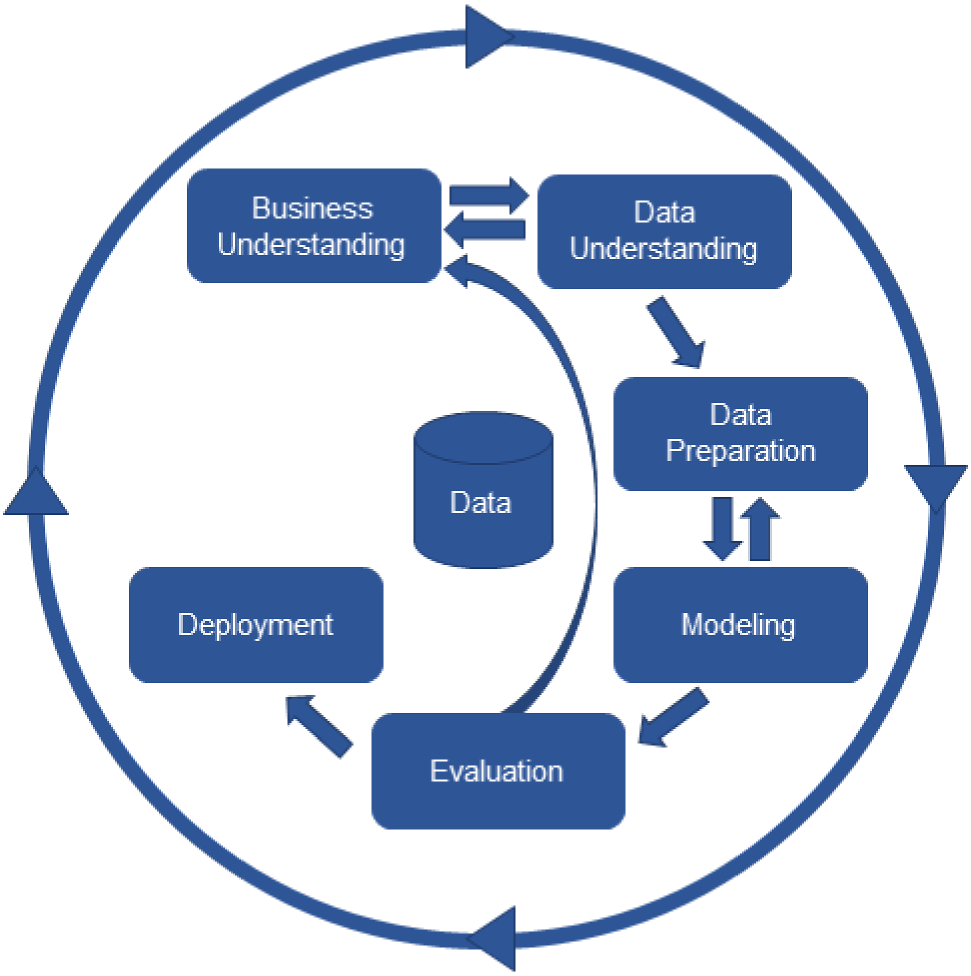

Figure 4: CRISP-DM iteration

2.4.2. Hardware

This section focuses on delivering physical intervention when it is needed, by using VTOL electric aircraft. Many considerations for using electric VTOL are already outlined in [3], so we take into consideration cases relevant to our use-cases. Main technology areas are batteries, noise reduction, and spatial navigation. Battery and charging technology currently is sufficient for operating small VTOL aircraft up to 200 km range, which is sufficient for the services considered. However, due to readiness considerations emergency services aircraft shall have option for replaceable battery additionally for standard charging, so it can be prepared back to ready state within minutes - even high-speed chargers currently won't allow to charge battery with required energy capacity in minutes. Another option is to make passenger/payload cabin replaceable - which allow interoperability of aircraft itself with other, non-emergency services (passenger transportation) when they appear.

Figure 5. Electric VTOL prototype by Airbus

Difference with described in[3] passenger transportation service is lack of open spaces in historical city center and significant number of wires over the streets (tram, trolley, power etc), rendering historical part of the city and most of adjacent areas inaccessible for larger aircraft without specially prepared landing pads - which puts under question patient transportation to/from city center under given project constraints. So, larger aircraft use is restricted only to transportation beyond historical city, or for transportation between prepared pads (hospitals and finite number of other suitable locations) Significant number of wires poses also a significant difficulty even for smaller aircraft (blood/drugs/ medical device delivery use-case). Currently it is suggested to build accurate map of city including wires and obstacles and use it for (semi)automatic operation, with constant improvement. Such map is a valuable asset by itself, providing additional ways of monetization. Until it's done, human-assisted piloting on lower altitudes with sensors helping to detect obstacles and wires is an option.

2.4.4. Why not helicopter?

According to [3], VTOL operations will involve the ability to take off with a rapid climb at a steep glide path angle to reach a cruising altitude up to a few thousand feet, then decelerate to land vertically at the end of the trip. There will likely be a limited need to hover for durations not exceeding one minute, with most vertical takeoff and landing transitions taking place in approximately 30 seconds.

Helicopters, on the other hand, are designed for military and multi-use roles that require sustained hovering for extended time (search and rescue, powerline inspection, takeoff and landing at unprepared locations, etc.). Hence helicopters are currently designed to optimize for hover efficiency, rather than for cruise. VTOLs will spend far more time in cruise which raises the question of how to optimize such a vehicle across short-term hover power versus long-term cruise energy. An airplane uses a wing and propeller for efficient cruise flight, while a helicopter uses rotor lift even during cruise with highly inefficient rotor edgewise forward flight. The design tradeoffs determining whether or not to use a wing or rotor depend primarily on speed, range, and hover requirements, as well as design constraints at the landing zone. As DEP VTOL designs mature, there is likely to be a continuum of approaches from fixed multirotor designs, through tilt-rotor to variants of blown-flap airplanes. Adding wings to enable high aerodynamic cruise efficiency combined with being able to tilt rotors or turn on/off different prop-rotors to provide lift or cruise power is a likely solution when biasing designs for cruise more than hover. These solutions, however, add weight, which increases power requirements for takeoff and landing due to the increased disc loading . This can also increase the noise and downwash in undesirable ways. Downwash concerns focus on the overall mass flow of the air being moved (not merely its velocity), which means that downwash for a small VTOL with disc loading of less than 50 lb/ft that only operate from concrete surfaces is likely not concerning. Few VTOL designs would consider disc loadings higher than this due to the extremely high power required, as shown in the prior downwash and downdraft figure with representative VTOL aircraft. Higher disc loadings can be beneficial, however. In our example commuter scenario—our most likely early use case—we are trading off increased power for a one-minute take-off and landing with acceleration to wing-borne flight for a 50-mile cruise that requires 15 to 20 minutes at significantly lower cruise power. The overall energy savings favorably impacts the economics of the flight and supports a rebalancing of design priorities from hover to cruise efficiency. Future versions of VTOLs may re-bias their designs for different infrastructures as well as primary use cases that may indicate more time needed to loiter, and shorter average distance trips. While many people associate electric aircraft with low speed, the NASA X-57 and Thin-Haul studies are showing that DEP powered-lift configurations favor high cruise speed solutions greater than 150 mph .

Current helicopter designs embody product solutions that capitalize on hover efficiency because their customers are accustomed to this capability. The high degree of operational flexibility that exists with helicopters is invaluable to many missions, but that flexibility comes at a steep price for noise, cost, and especially cruise efficiency. Using electrical propulsion instead of combustion engines and shafts also has reason - such approaches were attempted by many of the fixed-wing VTOL aircraft developed by NASA, the U.S. military, and numerous countries between 1950-1980 during the golden years of VTOL aircraft development when the U.S. developed many X-planes.

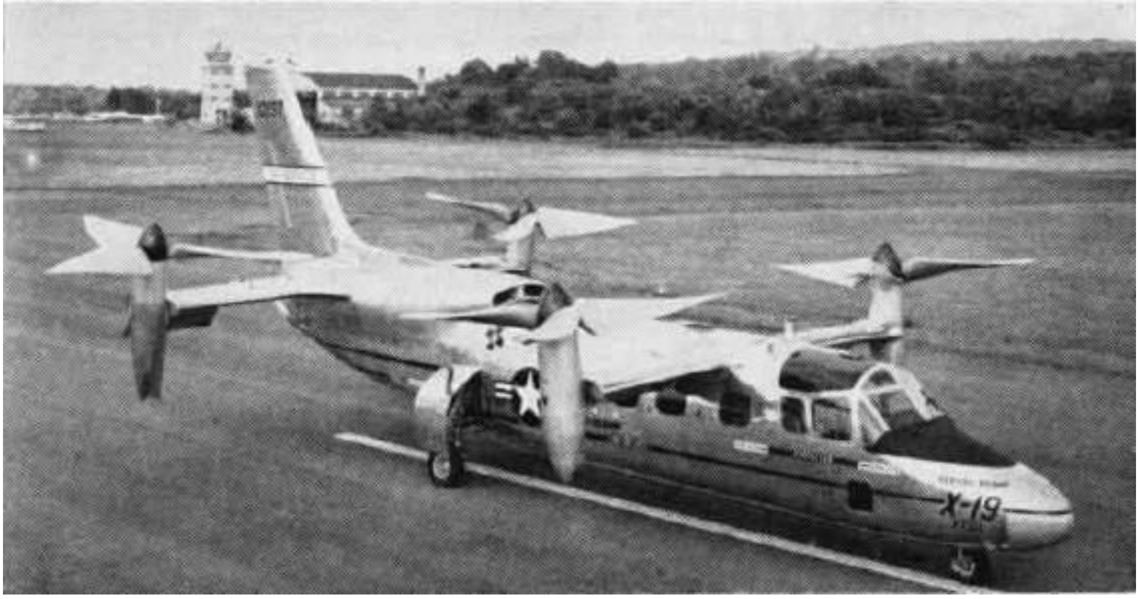

Figure 6: X-19 VTOL aircraft

The X-19 having 2 turboshaft engines, 8 gearboxes and 8 cross-shafts, is an example that showcases the extreme mechanical complexity that was required to achieve fixed-wing VTOL aircraft, which resulted in poor payload carrying capability, high expense and maintenance costs.

2.4.5. Wire detection

Wire detection is a key capability for safe navigation of autonomous aerial vehicles and is a challenging problem as wires are generally only a few pixels wide, can appear at any orientation and location, and are hard to distinguish from other similar looking lines and edges. There are advances from Carnegie Mellon research team [4] in utilizing computer vision and machine learning to detect wires, currently general purpose embeddable Nvidia TX2 platform, using software and later implemented in specialised hardware/firmware sensor, similar to commercial profile sensors (for example the ones at https://www.baumer.com). They continue to work on multi-view stereo methods to find distance of the wires and coming up with methods to avoid them robustly at high speeds. For improving the perception pipeline, we are looking into eliminating false positives and considering temporal information into account for consistent detection of wires.

Another approach is to tag wires with existing commercially available or RFID tags, or enhanced purpose-build RFID tags with additional range capability in the areas of most anticipated and frequent use of drone aircraft, and use RF sensors plus simplified algorithms for edge/wire detection on similar or even simpler embedded AI platform than mentioned above. Advantages of such approach is ability to “see” wire on a longer distance and higher speed, and to have all-weather detection capability of marked wires. Downsides are need to invest resources into infrastructure tagging and its maintenance, risk of unexpected or missed non-tagged wire, radio frequency pollution from aircraft sensor.

With advance of technology and appearance of affordable stereo multi-spectral cameras computer-vision approach is clearly more favorable, as it suggest more autonomy, less dependence on infrastructure awareness with comparable hardware/software complexity and and economics.

2.5. Time and resource restrictions

For this project we consider that road network in Lviv and region is constant - i.e. there won’t be any significant degradation, improvement in quality and no new backbone roads will appear in the next 5-7 years.

Lviv and region population remains considerably constant in next 5-7 years, with same demographics profile.

There can’t be denial of service in emergency state to any who authentically needs it or there were all reasons to think that the need is authentic.

Currency exchange rates, inflation & average salary remain within annual expected boundaries

There’s no breakthrough in battery & charging technology within the next 5 years, and battery technology progress remains as it is now.

Businesses for this project should be sustainable

Break-even period is up to 10 years

No significant restrictions imposed in drone industry and in emergency services regulations

2.6. Withdrawal conditions

Since things may go wrong, it is a good precaution to have measurable checkpoints along the way of the project so to know when to exit from the project or to close the project in order to minimize losses – financial, reputational etc. It is not always easy, especially for long-going projects that already consumed a significant amount of effort and resources. Let’s consider good options first – when the project is going fine, and one or more key participants decide to leave it and do something else. For this project the following successful options exists:

Condition	Action
Business is profitable, meets or exceeds plans and expectations of stakeholders and going to break even as planned or earlier. There’s intention of one of the partners (or investors, if there was a need for investment) to buy out	Sell my share of business and suggest to interested participants to do so
Business is profitable, meets or exceeds plans and expectations of stakeholders. No active intention from anyone to get into it.	Make it “cash cow” - find trustworthy person on the team who will run it for appropriate reward

Now consider what may go wrong, so we can stop burning time, effort and resources of everyone involved and apply to something more appropriate with better success. This should be complemented by regular risk management practice.

Condition	Action
No traction in 2 largest stakeholder groups in 6 months. No external obligations exist.	Close the business to minimize loss
No integration into emergency call system in 6 month.	Seek strategic partner that is capable of achieving that goal and selling him the business
MVP does not show anticipated results 3 iterations in a row. No external obligations exist.	Liquidate, close the business.
Regulatory changes make it legally impossible to provide drone aircraft services.	Liquidate drone part of business, continue with call center and emergency prediction services.
Larger aircraft technology not becoming available in anticipated timeframe.	Continue with call center and emergency prediction services.
No access to autopilot technology for BVR	Continue with call center and emergency prediction services.
Emergency forecast is technology not achieved or is not accurate enough	Discontinue emergency forecast reports, continue on call center operations and drone operations.
Conflict between founders that does not seem resolvable.	Sell own share , OR Announce exit and get minimal compensation required by law.

CHAPTER III. CONCLUSIONS

After working on this project, there is a need for re-evaluation of initial approach to the solution of emergency services, and even to the problem definition itself, and considerations for further steps and to the context of the project.

1. State-owned emergency service does not seem to be an emergency service, judging from the amount of improper utilization. Before spending any serious effort and resources to solving the issues of emergency services, it’s needed that it would be perceived as really an emergency service by users (at least most of them). This can be achieved by relaying costs of improper utilization on such misbehaving users, and communicating actual limitations and associated costs of it to the public. This approach clearly works for commercial emergency services, where improper utilization is seldom. Additionally, emergency services should be complemented by proper operation of other services that should be used instead – social assistance services (should ease the use of emergency services as a means of socialization and getting attention) and substance (alcohol & drug) abuse reduction.

2. The largest and the most problematic user group sees it as (free) commodity rather than valuable limited service. Already mentioned above, high improper use of emergency services is caused by the fact it is essentially perceived as free commodity thus having little to no cost associated with it, still having value. I don’t see the other way than to pass the cost of improper use to such users, complemented by the use of other more appropriate services. This creates both positive and negative stimuli for use emergency services for purpose (improper use simply becomes very expensive) and creating habit to use more appropriate services and means for non-emergency or even non-medical cases. Last, but not least would be to have sufficient compensation package and disciplinary policies for emergency crews, so it won’t be seductive enough to use the resources of emergency service for the sake of additional source of income. This is hardly a purely technology solution for these human problem.

3. Patient transportation by electric VTOL drone does not seem to be the right tool for the job of emergency transportation within the city - though larger electric VTOL aircraft may have other applications. There are several reasons for that: first, it won't influence improper use at all (which is the root cause of the problem), and for emergency transportation within the city there's structural limitation. Due to current cityscape currently there's no locations suitable for VTOL operations in almost all areas of the city, including both historical and newly build, and even if it there would be some – there's no way to have density for landing spots to be within 500m of reach from possible emergency points. While for personal and public transport that's a non-issue to have a short walk, transporting emergency patient for these distances by roller or otherwise is problematic and eats all the gain from the speed of aerial transportation. City is not even close to be ready for any means of aerial operations by larger aircraft due to lack of takeoff/landing pads and low altitude wiring in the street (even in newer areas of the city and wide enough streets there usually are trolley wires that prevent road to be used as landing spot), and if for emergency services it can be brought to demand by proper use and planning and allocation of reserved/priority routes, and properly securing them (by enforcing lane use and proper parking, which currently does not happen), but for even slight attempt to use air transportation may be impossible, and underground transportation in Lviv is questionable due to geological reasons. Not addressing city readiness for aerial transportation and not solving transportation issues may seriously impede the ability of the city to progress and worth addressing within city development strategy – so at least it will be possible to have some planned VTOL spots across the city in the future, and to address low altitude wire clogging, that prohibits the use of larger aircraft and impedes use of smaller drones in BVR and autonomous mode.

4. Blood & drugs delivery by smaller drones is still of questionable need & value here - too many unconfirmed assumptions & hypothesis for UA still, even having great example of ZipLine and its competitors. It still seems to be viable way of smaller package delivery within the city (with respect to unmarked wiring problem already

mentioned above) and has potential for saving on storage infrastructure for regional drug & blood delivery. If to stick to smaller drone aircraft with no plans to evolve technologies and know-how for larger VTOLs that are capable of taking 1-2 persons aboard, it would be preferable to establish a center of one of those services here, as it provides ready to use proven solution to smaller medical package delivery.

5. Problem as it is formulated can be solved or significantly eased using advanced software and proper management practices, without sophisticated hardware - good that it was discovered before any serious resources were commenced to drone-based solution, including hardware.

To draw the line here, decisions about the project are as follows:

1. "No go" for initial solution for the problem, as it is not appropriate
2. "Go" for solution of improper utilisation of emergency services via properly established dispatch/call center, relying on call scoring, relevant information information collection prior to arrival and proactive allocation of cars and crews to the area using area emergency forecast
3. Research further and reconsider use of small drone aircraft for drug and blood/blood products delivery, since competition shows it does have economical meaning, but current assessment was not able to surface it.
4. Re-formulate and re-target idea of larger autonomous aircraft into de-centralised aerial public transport, with respect to Uber Elevate whitepaper[3]. Since going from small to larger does not work for emergency services, let's go larger to small, applying technology to larger problem and then narrowing it down to emergency services use-cases.

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ANNEXES

1. List of Hypothesis

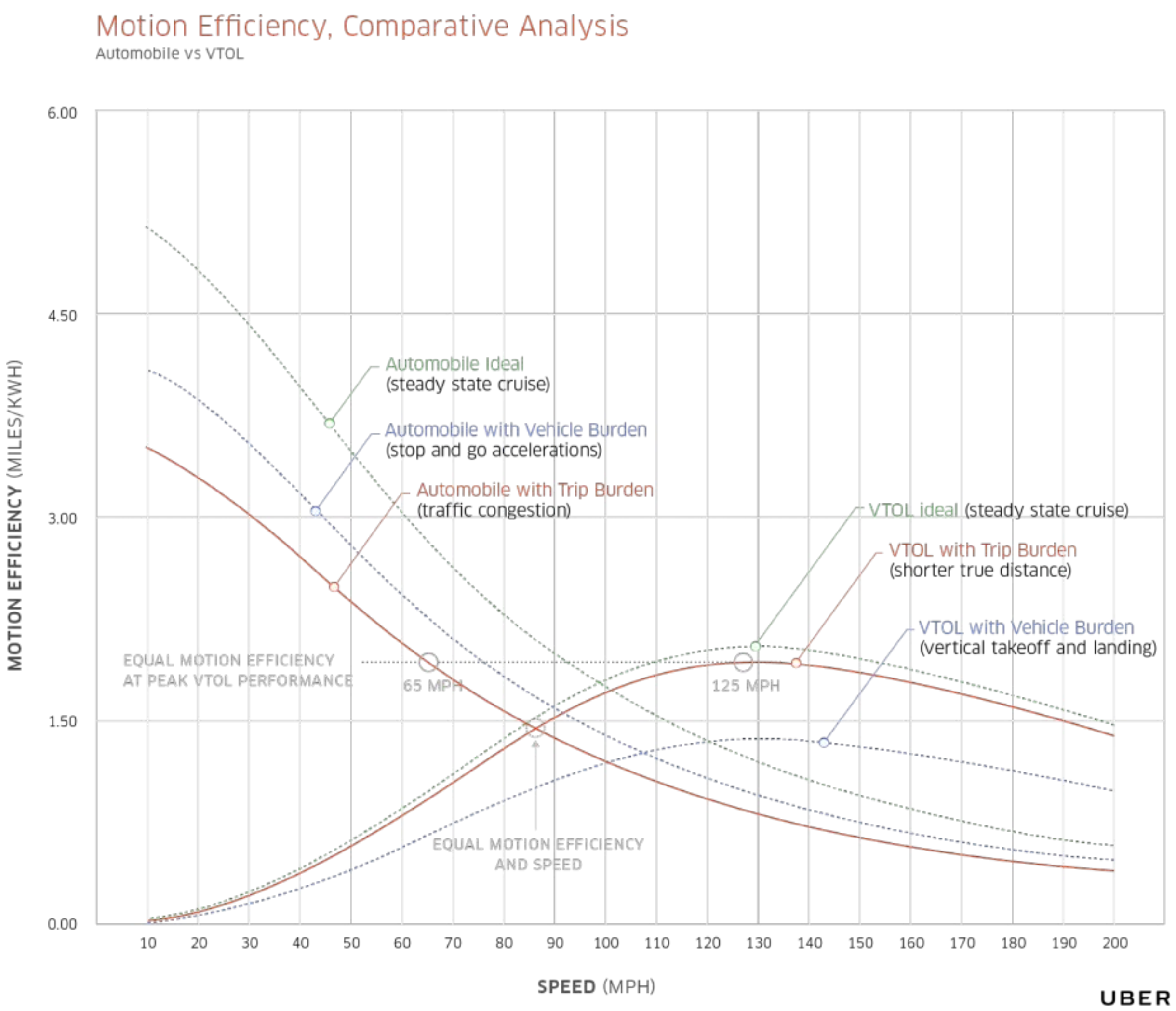
#	Name	Type	Priority	Status	Formulation	Experiment
1	There's overload of emergency services in Lviv	Problem	High	validated	Residents of the city believe that ambulance is overloaded and can not cope with the existing requirements.	Conducting a survey of Lviv residents, which at least twice a year called to an emergency service
2	Traffic significantly contributes to overload at #1	Problem	High	invalidated	I assume that riding an ambulance to a patient takes most of the time in process of request to the emergency service	analysis time was spent on the road
3	Majority of users value rapid emergency	Customer	High	in progress	I believe that the speed of transportation will increase the level of satisfaction	Conducting a survey of Lviv residents, which at least twice a

					of patients and may reduce mortality	year called to an emergency service	
4	There’s political resistance to improve emergency services in Lviv	Problem	Medium				
5	Users of commercial services will be also willing to pay for aerial transport	Customer	High	in progress	I believe that air transport can improve private emergency services. A partnership with private emergency services can reduce the burden on state institutions of emergency care	contact form for partnership on the landing page	
6	Aerial transport can access any part in the city with no prepared infrastructure	Solution	High	invalidated			

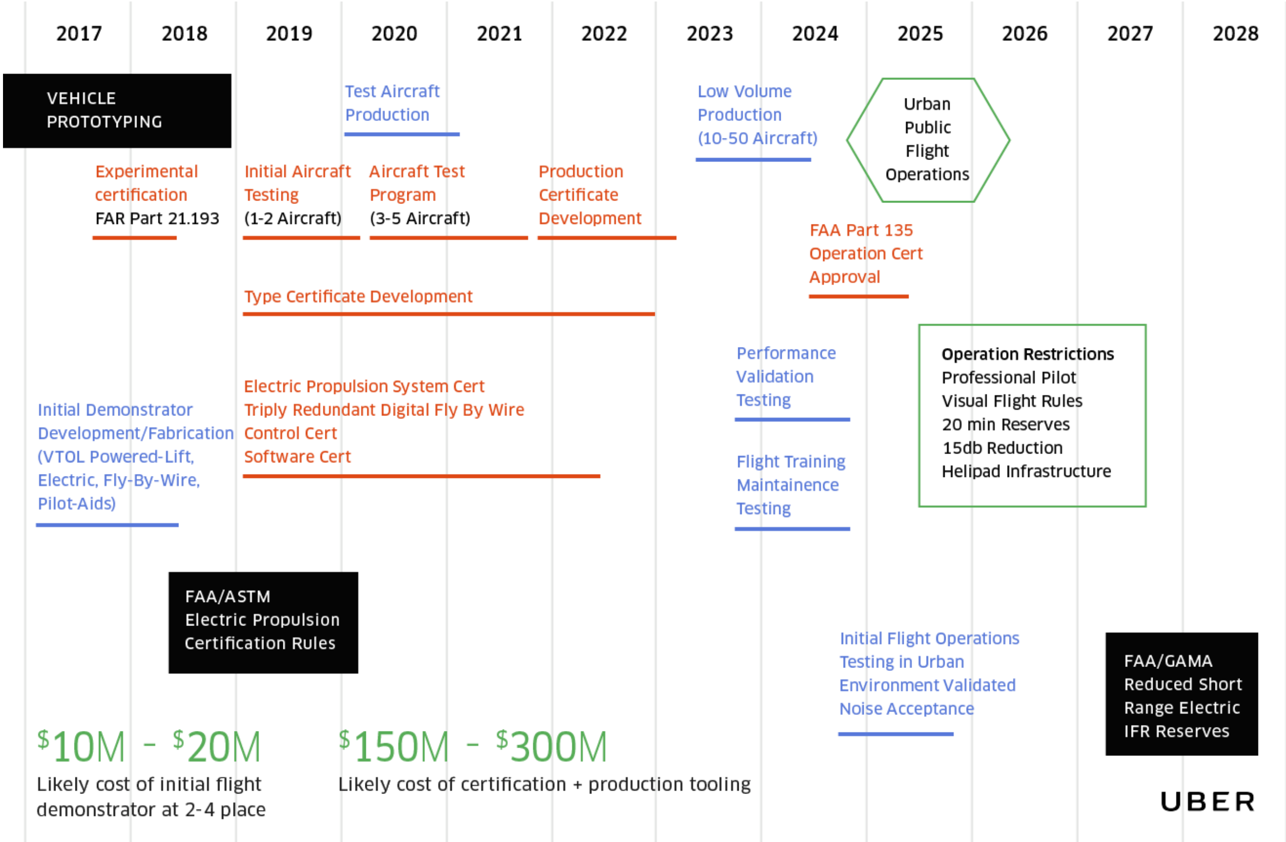
7	Emergency cases are concentrated in space and time	Problem	High	in progress	I believe that ambulance calls can be localized. I guess that in some places ambulance calls are more. If this hypothesis is confirmed, the software will predict the number and location of calls. Facts: the number of calls concentrates in time and date.	visualization all calls per day on the map. reporting analysis
8	Cargo traffic is significant part of overall traffic	Problem	Low	validated		counting vehicles
9	Wiring allows operation of small drone aircraft	Solution	High	in progress	the electricity grid may become a hindrance to the flight of	drone aircraft testing in Lviv and district

					small drone aircraft		
10	Wiring allows operation of larger drone aircraft/helicopter	Solution	High	invalidated			

2. Motion efficiency visualization by Uber



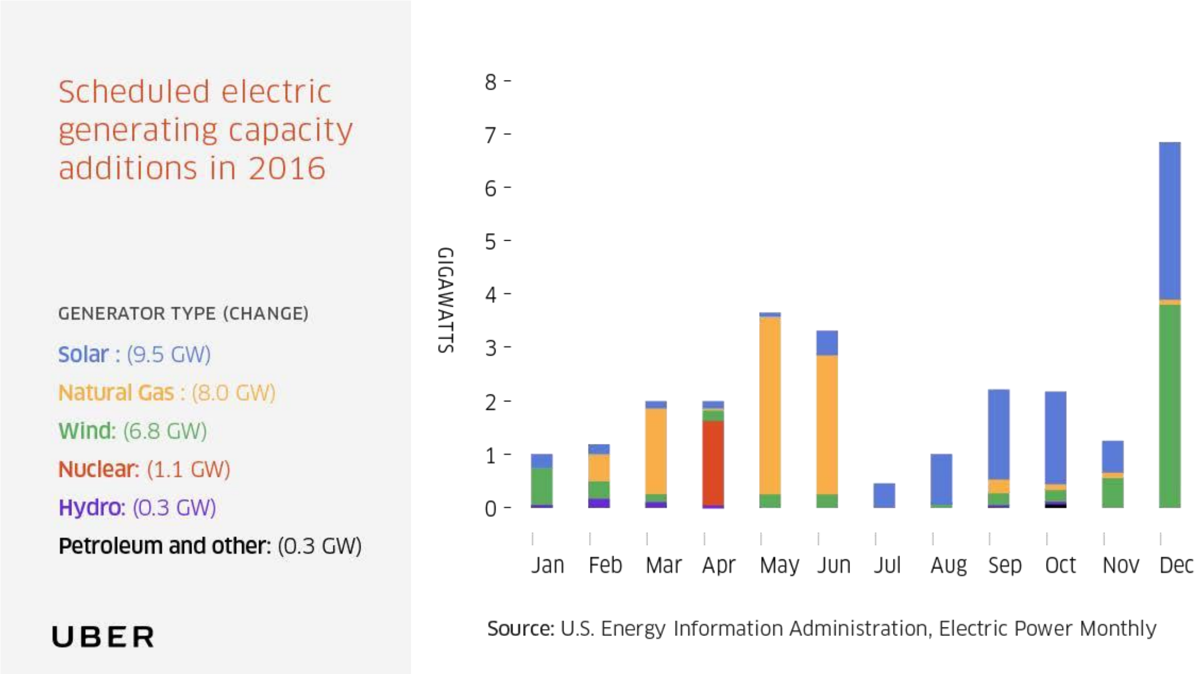
3. Autonomous aerial transport evolution by Uber



4. Autonomy levels

SAE level	Name	Narrative Definition	Execution of Steering and Acceleration/ Deceleration	*Monitoring* of Driving Environment	Fallback Performance of *Dynamic Driving Task*	System Capability *(Driving Modes)*
***Human driver* monitors the driving environment**						
0	No Automation	the full-time performance by the *human driver* of all aspects of the *dynamic driving task*, even when enhanced by warning or intervention systems	Human driver	Human driver	Human driver	n/a
1	Driver Assistance	the *driving mode*-specific execution by a driver assistance system of either steering or acceleration/deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	Human driver and system	Human driver	Human driver	Some driving modes
2	Partial Automation	the *driving mode*-specific execution by one or more driver assistance systems of both steering and acceleration/ deceleration using information about the driving environment and with the expectation that the *human driver* perform all remaining aspects of the *dynamic driving task*	**System**	Human driver	Human driver	Some driving modes
***Automated driving system* ("system") monitors the driving environment**						
3	Conditional Automation	the *driving mode*-specific performance by an *automated driving system* of all aspects of the dynamic driving task with the expectation that the *human driver* will respond appropriately to a *request to intervene*	System	**System**	Human driver	Some driving modes
4	High Automation	the *driving mode*-specific performance by an automated driving system of all aspects of the *dynamic driving task*, even if a *human driver* does not respond appropriately to a *request to intervene*	System	System	**System**	Some driving modes
5	Full Automation	the full-time performance by an *automated driving system* of all aspects of the *dynamic driving task* under all roadway and environmental conditions that can be managed by a *human driver*	System	System	System	**All driving modes**

5. Larger drone aircraft cost structure by Uber



6. Transportation safety assessment by Uber

Transportation Safety

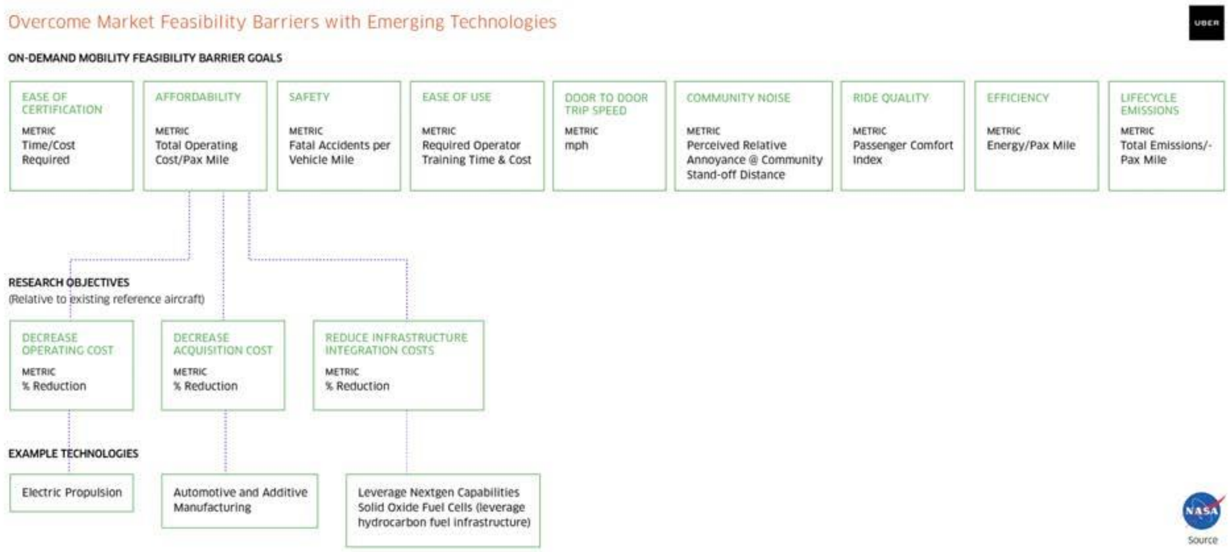
Fatalities by transportation method, normalized against passenger automobiles

VEHICLE TYPES	Annual Fleet Utilization: VEHICLE HOURS (1,000)	Annual Fleet Utilization: VEHICLE MILES (MILLION)	Annual Fleet Utilization: PASSENGER MILES (MILLION)	AVERAGE ANNUAL FATALITIES	Normalized Fatality Rates: PER 100,000 VEHICLE HOURS	Normalized Fatality Rates: PER 100M VEHICLE MILES	Normalized Fatality Rates: PER 100M PASSENGER MILES
PASSENGER CARS	50,300,000	1,510,000	2,340,000	14,701	1X (0.030)	1X (0.997)	1X (0.643)
PART 121 AIRLINES	18,600	7,891	579,000	16	2.9X	0.208X	0.004X
PART 135 AIR TAXI	2,100	375	1,500	18	29.3X	4.9X	1.9X
MOTORCYCLE	600,000	18,000	19,800	4,809	27.4X	27.4X	38.7X
GENERAL AVIATION	22,400	3,370	6,740	511	78.1X	15.6X	12.1X

+ Data is US only

UBER

7. Drone use feasibility barriers by Uber



8. Comparable travel timing in California by Uber