UNMANNED AERIAL VEHICLE IN LOGISTICS

A DHL perspective on implications and use cases for the logistics industry

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PREFACE

Flight of fancy or a fascinating new feature of modern living? Some doubt that our skies will ever be filled with pilot-less aerial devices. Others say that this future will be ours very soon. In different ways, both opinions are close to the truth.

This trend report takes a fully grounded look at the role of these devices in our near-future. It deals with current capabilities and circumstances, exploring the positive potential as well as the existing limitations of 'unmanned aerial vehicles' (UAVs), also known as drones – but this report deliberately avoids the name 'drones' as it has some profoundly negative connotations.

Today there is plenty of talk (and perhaps too much blue-sky thinking and hype) about civil applications for UAVs, but actual use cases are surprisingly thin on the ground.

Three impacts are at work here – technological capability, regulatory pressure, and public acceptance – and this report highlights the interplay between all three in current applications drawn from various sectors, including the logistics industry.

In exploring such an intriguing topic, this report is likely to raise issues and questions for many readers. Therefore DHL warmly invites you to visit the DHL Innovation Center in Germany which showcases proven UAV technologies. Please come and discuss your needs and joint development opportunities with us.

Yours sincerely,

Matthias Heutger

Dr. Markus Kückelhaus

1 UNDERSTANDING UAVs

Recent worldwide media attention has put unmanned aerial vehicles (UAVs) in the spotlight. Their many different applications make for great headlines – they are being used for military purposes in Pakistan (US Army), for development aid work in Africa (Matternet), and for parcel delivery in Germany (DHL Paket).

Some organizations are using UAVs specifically because of this high level of interest. Good examples are the world's largest online retailer, Amazon and the world´s largest logistics company DPDHL, which are testing UAV delivery. And countless start-ups have jumped on the bandwagon to gain publicity and boost sales (e.g., Zookal's stated intention to deliver textbooks via UAVs in Australia).[1]

However, for any emerging technology, it can be a double-edged sword to attract a lot of attention. There may be considerable benefits from all the limelight; for example, a new technology could stand more chance of receiving subsidies if considered 'of national importance'. But there is also the danger of creating false expectations – too much initial hype can leave people disillusioned and disappointed after the dust has settled – and there may be a public backlash against the perceived power of new technology to substantially influence and alter our everyday lives.

In addition to typical hype-cycle effects, there are two main drivers for the huge impact of UAVs:

1. The potential for actual disruption in specific industries (including security services, and in film and television) and

2. The emotional response to unmanned flying systems, caused largely by:

   a) Privacy concerns and the debate about how much technology should be included in our daily lives ("Do we want to crowd urban skies with UAVs capable of tracking and filming our daily routines?")
   b) Safety concerns

Perhaps the reality of UAV deployment is far less glamorous than the media hype suggests. The ideal mission for a UAV is described as one that is too "dull, dirty, and dangerous" for manned aircraft.

The purpose of this report is to provide an introduction to this exciting topic, present use cases from a broad variety of industries, and discuss potential applications in and for the logistics industry. We aim to review the hype and provide a realistic assessment of UAVs.

1.1 Scope

It is important to distinguish between military and non-military use of UAVs. Until recently, media coverage has focused mainly on military use, coining the term 'drone' and leaving many with negative attitudes towards this new technology. Michael Toscano, President of the Association for Unmanned Vehicle Systems International, is quoted in the Washington Times saying "The word [drone] instantly conjures up mental images of large predators firing missiles at hostile targets around the world".[2]

This report focuses solely on non-military applications. It is clear though, as with many other examples of technical development, that major advancements are likely to find their roots in military UAV usage and application.

In this report, we do not look into very long-distance (e.g., transatlantic) unmanned flight operations, because UAVs capable of performing these operations are likely to function in a comparable way to existing cargo airplanes (e.g., with horizontal take-off at airports). As such, they are not game-changing in the same way as are smaller UAVs designed to replace road delivery in megacities or overcome infrastructure challenges in Africa.

The scope of this report is also limited by timeframe. As technology and the regulatory environment are both subject to substantial change and development, the outlook in this report is restricted to the next ten years.

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[1] http://www.cnn.com/2013/10/18/tech/innovation/zookal-will-deliver-textbooks-using-drones/

[2] http://www.washingtontimes.com/news/2013/aug/14/drone-industry-journalists-dont-use-word-drones/

1.2 Regulation

The regulatory environment plays a crucial role in UAV adoption. Currently, there seems to be little common ground on designing effective rules across borders, let alone continents. Regulations vary widely from country to country. Major legislative changes could be realized over the coming years, particularly in the USA.
But regulators are constantly being criticized for moving too slowly on the matter. Mary Cummings, Director of the MIT Humans and Automation Laboratory, urges politicians to act in her Boston Globe article: "Congress needs to hold the FAA's feet to the fire before this technology takes flight and leaves the US commercial market behind."[3] She cites estimations of a USD 10bn yearly loss for the US economy caused by overly strict regulations. But regulating bodies believe they have solid arguments for taking their time. Amazon's plans to use UAVs for deliveries have been grounded for the time being, with the FAA declaring that they will not allow UAVs to be used for delivering packages to people for a fee.[4] Three major reasons explain why UAV regulation is a delicate matter:

Congested Airspace

For now, most UAVs operate outside controlled or restricted airspace, and this minimizes interference with other airspace users. But if UAV operations are to become widespread in logistics and other industries, integration will be essential. UAVs will be operating in all types of airspace and sharing this with airplanes, helicopters, and other flying systems. Airspace is already overcrowded in many regions, especially around major cities, and air traffic control operations typically work near to maximum capability (see Figure 1). An out-of-control UAV is a massive threat, capable of bringing down an airplane with several hundred passengers on board. In August 2013, an Alitalia pilot reported sighting a UAV as close as 200 feet to his plane during his final approach to JFK International Airport in New York, triggering investigations by the FBI and the FAA.[5]

Outside of extreme events and worst-case scenarios, it will still be a substantial challenge to regulate additional UAV traffic and integrate it into existing patterns.

Figure 1: Air traffic at 09:30 am in Western Europe; **Source:** Flightradar24

Inherent Risks

While trains, boats, and to a lesser extent cars follow restricted pathways, UAVs can move anywhere and everywhere. And because they are airborne, failure of a vital system (e.g., the engine or navigation system) could cause the UAV to fall from the sky at any time and place. However, the chance of a system crashing into pedestrians is highly unlikely, even with today's early UAV designs. In 2012, the US military drone safety record for the previous 12 months was better than for manned fighters and bombers.[6] Nevertheless, effective safety measures and operational procedures in case of engine failure or loss of navigation must be ensured, to guarantee previously defined safety levels that satisfy regulating authorities.

Public Concern

In addition to the tangible (and technically controllable) challenges of congested airspace and inherent risks, there is another, less-defined area of concern in the public domain. Regulators need to address the public's negative perception of UAVs – there is a general level of fear, and people seem to think UAVs pose some kind of threat. A large part of this fear is probably related to privacy issues: Cameras and other sensors (potentially invisible) attached to the flying system could be used for constant surveillance of every step one takes.

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[3] http://www.bostonglobe.com/opinion/2013/12/08/drones-and-and/MgLXPHtr0nvWqwkltSORYM/story.html

[4] http://www.independent.co.uk/life-style/gadgets-and-tech/amazons-drone-delivery-grounded-by-the-faa-9561807.html

[5] http://www.wired.com/threatlevel/2013/03/ufo-black-drone-fbi/

[6] http://www.bostonglobe.com/opinion/2013/12/08/drones-and-and/MgLXPHtr0nvWqwkltSORYM/story.html

Plans by the national German railway company, Deutsche Bahn, to use UAVs with attached infrared cameras to reduce graffiti attacks on its property[7] evoked a strong response with blog entries such as "This is the worst of dystopian science-fiction coming true. […] This sets the precedent for more of the same throughout the world. And it's not going to stop at spying on Graffiti Sprayers."[8]

When talking about the regulatory environment and the adoption of new technologies, it is worth considering the 'Law of Disruption' model. This describes an interesting pattern of how fast different types of change manifest themselves, and the model is very applicable to the current UAV situation. Technological advancements are rushing ahead of social and political change. That is exactly what we see happening with UAVs today.

From a technological perspective, various use cases are already feasible, but many of these are not accepted yet by the public. Social change is occurring at a substantially slower pace than this technological progress, and the last domain to react and adapt is the political one (see Figure 2). Following this model, we might anticipate regulatory barriers for UAVs to remain in effect for some time.

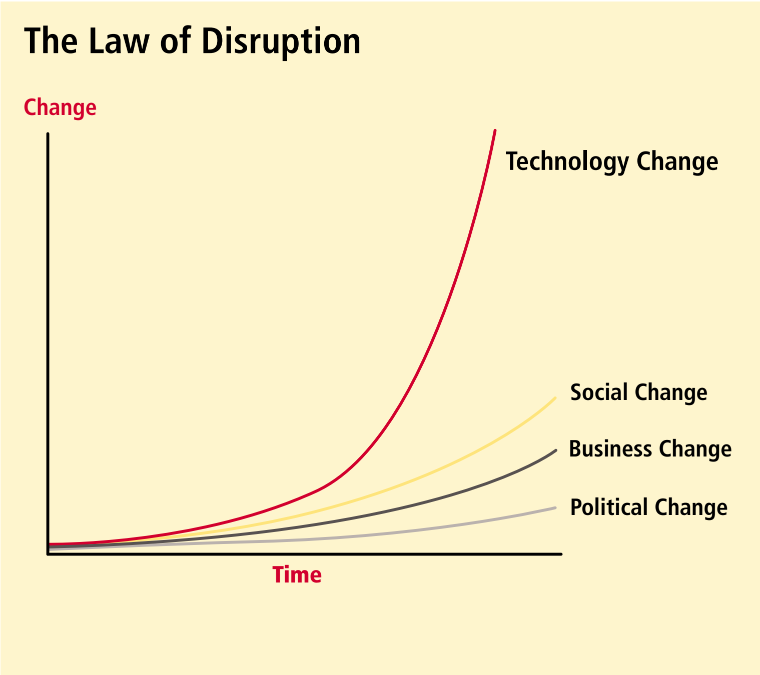

Figure 2: The Law of Disruption; **Source:** Larry Downes

[7] http://www.bbc.co.uk/news/world-europe-22678580

[8] http://www.abovetopsecret.com/forum/thread983050/pg1

1.3 Technology

The selection of available UAVs has greatly expanded over the last few years and it has become difficult to keep track of the entire range. The market offers diverse systems, and there is no universal classification. The US military uses a tier system with specific UAV requirements (e.g., they must offer particular levels of range or endurance).

In general, systems tend to be classified by measurements or specifications, which can relate not only to range and endurance but also to size, maximum take-off weight, service ceiling, and price. Other major distinctions are the build type and the engine used. The following table gives a brief overview of the advantages and disadvantages of different build types (see Figure 3).

Build Types

	Advantage	Disadvantage	Visual
Fixed-Wing	• Long range • Endurance	• Horizontal take-off, requiring substantial space (or support, e.g., catapult) • Inferior maneuverability compared to VTOL (Vertical Take-Off and Landing)	 **Source:** Indra Company
Tilt-Wing	• Combination of fixed-wing and VTOL advantages	• Technologically complex • Expensive	 **Source:** sUAS News
Unmanned Helicopter	• VTOL • Maneuverability • High payloads possible	• Expensive • Comparably high maintenance requirements	 **Source:** Swiss UAV
Multicopter	• Inexpensive • Easy to launch • Low weight	• Limited payloads • Susceptible to wind due to low weight	 **Source:** Microdrones

Figure 3: UAV build types

Figure 4: DHL-"Paketcopter"

The main types of engine used today in non-military UAVs are the electric engine and the internal-combustion engine. The electric engine is environmentally friendly and operates without much noise; these are important advantages especially in densely populated areas. It is relatively inexpensive to charge the battery, but battery weight is a drawback and UAV range can be limited by battery capacity.

Figure 5: Multicopter used for taking low altitude aerial photos; **Source:** Soliforum

A UAV powered by a comparable internal-combustion engine is likely to have superior range, due to the energy density advantages of fossil fuels and because range can be simply extended by adding fuel tanks. Hybrid systems are currently being developed, trying to combine the best of both worlds – the internal-combustion engine is used for longer distance flights, and the electric engine is used for take-off and landing in areas requiring quiet operation.

This report does not exclude any specific type, but its focus is rather on electrical engines and multicopters, because these appear to be the most promising choice for the logistics industry applications that are discussed in this report (see Figure 4 and 5). This reflects both cost and feasibility arguments: While long ranges and high payloads are technically feasible today, UAVs of this type tend to be expensive and may be a bad choice in densely populated environments such as cities, because of horizontal take-offs and noisy engines. This matters less outside urban areas, and in the following chapter we review the varied tasks being carried out by UAVs today.

2 INDUSTRY BEST PRACTICE

There is a broad range of possible applications and benefits for UAVs, which means that many different industries are interested in them. The following use cases give an overview of the broad usability of UAVs and can serve as an inspiration across industry boundaries.

2.1 Energy/Infrastructure

For big energy players, it is tedious and costly to constantly monitor their infrastructure. This can be due to the vast size of energy sites (mining), the scale of the infrastructure (power lines, pipelines), or the challenging environment (offshore wind parks).

UAVs can be operated more economically than manned helicopters; they are less limited by weather conditions (although this varies by model) and easier to deploy. They can be operated in extreme weather conditions and in geographically challenging locations without putting personnel at risk.

Another advantage is that UAVs can follow a pre-programmed flight path, and fly closer to both the infrastructure and the ground. This allows for highly detailed flight plans, higher measurement accuracy, and increased repeatability.

An example from the energy sector is the use of 'Swiss UAV' systems to inspect offshore wind power plants in the North Sea and in pipeline monitoring activities in Turkey (see Figure 6).[9]

Figure 6: Inspection of offshore wind power plants in the North Sea; **Source:** Blog Zeit

2.2 Agriculture and Forestry

Probably the agriculture and forestry industries don't spring to mind when considering potential applications for unmanned aerial systems. But in precision agriculture, UAVs are already playing a vital role today. They allow farmers to gather real-time data on crops, detect irregularities as early as possible, and take better decisions about using fertilizers, herbicides, and pesticides. In addition, animal tracking is another task well suited to the capabilities of UAVs.

In forestry, an example of how to use unmanned aerial systems is spotting and mapping forest fires (see Figure 7). The US Forest Service had plans to do this in 2013, but stopped because of the restrictive regulatory environment requiring each UAV to be in visual range of its pilot at all times.[10]

Figure 7: UAV application in forestry; **Source:** Avinc

[9] http://www.ila-berlin.de/ila2014/konferenzen2012/upload2012/04%20-%20SUAV-civil%20use1.pdf

[10] http://missoulian.com/news/state-and-regional/u-s-forest-service-drops-plans-to-use-drones-in/article_5d2a4c6e-c5b4-11e2-a357-001a4bcf887a.html

2.3 Site and Layout Planning; Construction Sector

Site and layout planning in the construction sector and in other industries can benefit in several ways from the use of unmanned aerial systems. The simplest application is analyzing a site from above, using live footage from a UAV (see Figure 8). This gives an overview of the site and indication of site specifics. Footage and data collected by a UAV can also be used in mapping (UAV-based data collection). And rapid improvements in user-friendliness mean that a wide user group can access the data collection tool: "Automation of aerial data collection makes this platform an attractive option for even those not versed in photogrammetric science."[11]

Figure 8: ANTEOS MINI during an acquisition in L'Aquila; **Source:** Int Arch

Using predefined flight paths is ideal for monitoring progress on construction sites with high accuracy and minimized effort. In addition to planned construction site applications, unmanned aerial systems are well-suited to support post-disaster investigation of damaged buildings. The Universities of Rome and L'Aquila published a paper on 'UAV Application in Post-Seismic Environment', which concludes that "Even if these [conventional surveying] techniques represent instruments of extreme operability there are still many evident limits on their use, especially regarding the survey of both the roofs and the facades of tall buildings or dangerous places, typical of post-earthquake situations. So using micro UAVs for surveying in such particular cases, many of these problems can be easily bypassed."[12]

In a more distant future, UAVs might carry out small maintenance and repair tasks in "difficult-to-reach or high-risk spaces".[13]

2.4 Environmental Protection

UAVs can play a vital role in environmental protection; for example, in the safeguarding of an endangered species. Already, conservation parks and private game reserves in South Africa are using unmanned flying systems to protect endangered rhinos from poachers (see Figure 9).[14]

The US- based environmental activist group 'Sea Shepherd Conservation Society' launches UAVs from its ships in the Antarctic ocean in the fight to protect whales.[15] In this application, a battery-powered 'Osprey' system is used; it is "comfortable in the wind and can handle 40 knots" explains Jimmy Prouty, representing the manufacturing company. "This unit is waterproofed and has multiple security backups so that, if it has problems or a low battery, it automatically returns to base." It is equipped with GPS systems and a camera that provides both videos and still images. The goal is to detect any movement of Japanese whaling ships as early as possible, enabling the Sea Shepherd fleet to intercept these vessels.

Paul Watson, founder of the conservation society, expects UAVs to be used in other environmentally sensitive areas as well; for example, in the highly protected Galapagos Islands.

Figure 9: Use of UAVs for environmental purposes; **Source:** Avinc

[11] http://www.sensysmag.com/spatialsustain/personal-uav-gains-an-audience.html

[12] http://www.int-arch-photogramm-remote-sens-spatial-inf-sci.net/XL-1-W2/21/2013/isprsarchives-XL-1-W2-21-2013.pdf

[13] http://enewsletters.constructionexec.com/techtrends/2013/07/drones-show-potential-to-aid-jobsite-safety-and-efficiency/

[14] http://www.cnn.com/2013/10/16/world/africa/helicopters-versus-drones-rhino/index.html?iref=allsearch

[15] http://www.seashepherd.org/news-and-media/2011/12/24/sea-shepherd-intercepts-the-japanese-whaling-fleet-with-drones-1299

2.5 Emergency Response and Police

A double blow of natural disasters hit Fukushima in 2011: The strongest earthquake in Japanese history followed by a tsunami which claimed the lives of more than 15,000 people and a whole region devastated. A big problem in the aftermath of natural disasters is that decision makers often lack information on which to base their decisions. In Fukushima, this was exacerbated by radioactivity leaking from damaged reactors, putting every human being who entered the power plant area at high risk of radioactive contamination. UAVs are ideal data-gathering machines in these circumstances. They are fully independent of the potentially demolished infrastructure, equipped with cameras and sensors, and controlled remotely. Their valuable contribution includes keeping humans out of danger zones or at least limiting their risk exposure.

This is precisely what happened in Fukushima. A Honeywell T-Hawk UAV was used to collect insights from the heart of the devastated plant. The T-Hawk is powered by a two-stroke gasoline engine and is capable of staying airborne for approximately 40 minutes before it requires refueling.[16] Not only carrying cameras but also rescuing people is the vision of the 'Rescue UAV' – a special version of the 'Volocopter', an electrically powered multicopter. It was developed by the German start-up e-volo and originally designed to carry two people, thereby excluding it from classification as an *unmanned* aerial vehicle.[17]

Researchers at Brigham Young University in Utah ran a pilot on using a UAV for search-and-rescue (SAR) missions. An operator was trained to use the system to spot lost hikers. A next step will be to develop an algorithm that can automatically detect a human being in collected footage.[18]

While these emergency response and SAR operations are likely to be hugely popular, there may be different public opinion about police use of UAVs. According to media reports, police departments in several countries, including Australia and the USA, are planning to use UAVs or already have UAVs in service (see Figure 10). The South Australian Minister for Police is quoted as saying:

Figure 10 a+b: Police applications of UAVs; **Sources:** Telegraph, Falcon-UAV

"UAVs represent a cost-effective solution for a range of policing operations, especially in situations when using conventional aircraft is too dangerous or costly, […] they can be fitted with a variety of cameras, can be deployed in minutes, and can fly at heights that effectively make them inaudible from the ground."[19]

One example of UAV usage comes from the Australian Queensland Police Service who is utilizing at least two UAVs for law enforcement. They are deploying them for "situational awareness" during sieges and other high-risk operations. Although they have been used in trials since early 2012, the continued usage of UAVs was only recently published in a federal report on drones and privacy.[20]

But this is exactly what worries civil liberty groups and the general public. People are uneasy about the scenario of an easily deployable, unrecognizable UAV that effectively spies on everyone unnoticed.

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[16] http://www.theatlantic.com/technology/archive/2011/04/inside-the-drone-missions-to-fukushima/237981/

[17] http://www.e-volo.com/information/what-is-a-volocopter

[18] http://www.homelandsecuritynewswire.com/uavs-perform-autonomous-search-and-rescue-operations

[19] http://www.theaustralian.com.au/news/sa-police-to-use-unmanned-drones-to-spy-on-criminals/story-e6frg6n6-1226671865697

[20] http://www.gizmodo.com.au/2014/03/queensland-police-now-flying-drones-around-crime-scenes/

2.6 Film and Photography

Aerial film and photography service providers are probably the heaviest commercial users of unmanned aerial systems today. The technical requirement is comparatively low – in many cases, off-the-shelf cameras are attached to the UAV with ready-made or makeshift mountings (see Figure 11). For a better focus and improved results, the camera and the UAV can be handled by different operators.

Significant cost savings can be achieved, and this results in a shift from more expensive options to UAVs, and opens up new customer segments. Film/photo missions that would previously have used a helicopter can now be executed at a fraction of the cost. In some instances, the UAV replaces expensive technology that is not even a flying device; for example, instead of using computer technology to create scenes, these can now be filmed by UAV. A Washington Post article lists many movies with UAV-filmed scenes, including some of the biggest blockbusters of recent years such as 'Skyfall', 'The Hunger Games' and 'The Dark Knight Rises'.[21]

In addition to technology shifts in established projects, new customers for aerial photography are entering the market; these customers would not have considered buying this type of service previously, because of prohibitive cost. For example, hotels and spas are now using aerial photography and video material for marketing purposes, especially on their websites. Real estate agents can now "show homes in context to neighbors, golf courses and other nearby landmarks"[22] – even though photographers in the USA are not yet allowed to charge for this service (FAA regulations restrict commercial use of this type of photography without permission; photographers are bypassing the law by charging only for editing).

In a non-commercial application, a young French start-up has taken the 'Instagram' idea to the skies: On dronestagr.am, visitors can upload their UAV-based aerial photographs and videos to "create a world map of our Earth with a bird's eye view".[23]

Figure 11: A UAV with an off-the-shelf camera attached; **Source:** Fast Company

2.7 Development Aid

"We will bring to the world its next-generation transportation system." This immodest statement is made on the homepage of Matternet, a California-based start-up that is seed-funded by investors such as Andreessen Horowitz (with previous interests in Skype and Groupon).

The organization intends to "create a network that is designed around human need, rather than the limitations of the antiquated technology that formed our current transportation system".[24] The basic idea is to use UAVs to leapfrog infrastructure developments. The envisaged network includes base stations in 10 km intervals, which will allow UAVs to recharge. The network should be capable of carrying relief shipments to hard-to-reach places and allow economical connection to rural populations (see Figure 12).

Figure 12: Matternet field test in Haiti; **Source:** SciDev.Net

[21] http://www.washingtonpost.com/blogs/the-switch/wp/2013/08/15/its-a-bird-its-a-plane-its-a-drone-that-makes-movies/

[22] http://finance-commerce.com/2014/01/drone-photography-catching-on-in-real-estate/

[23] http://www.dronestagr.am/about/

[24] http://matternet.us/matternet-manifesto/

3 IMPLICATIONS IN LOGISTICS

After taking a broad look at use cases from a range of different industries, this report now examines implications for the logistics industry. While many of the above applications are already common today, the use cases in and for logistics are still in its early stages. The use cases illustrated below must therefore be seen as visionary; the intention is to provide inspiration and trigger discussion. These logistics use cases are not intended as a precise prediction of future developments.

As previously mentioned, electrical multicopters (characterized by vertical take-off and landing) appear to be the most promising for the logistics industry. Accordingly we focus on use cases within short distances instead of considering long distance operations. DHL Trend Research divides logistics industry use cases into four categories: Urban First and Last-Mile, Rural Delivery, Surveillance of Infrastructure, and Intralogistics.

3.1 Urban First and Last Mile

Rapid urbanization is one of the megatrends of recent years and the near future, especially in emerging markets. The insurance company Swiss Re forecasts the global urban population will "grow by about 1.4 billion to 5 billion between 2011 and 2030, with 90% of the increase coming in the emerging markets".[25] Negative implications of this trend include congested roads, pollution, and decreased efficiency caused by delays in the flow of people and goods. It is often difficult for city planners to keep up with the pace of urbanization and population growth. In many cases, infrastructure projects can only provide temporary relief.

Part of the problem is urban first and last mile delivery, and demand for this is likely to increase as e-commerce volumes grow. China posted an impressive compound annual growth rate of 120% between 2003 and 2011 for its e-tailing market (consumer-facing e-commerce transactions excluding financial services, job search, and travel)[26] and, even if growth rates are likely to come down, future increases will still be substantial. UAVs could provide major relief for inner cities, taking traffic off the roads and into the skies. So far, payloads are limited but a network of UAVs could nevertheless support first and last-mile logistics networks.

Figure 13: Textbook delivery service via UAV; **Source:** Web2Carz

For instance, aerial delivery company Flirtey plans to introduce the worlds -first commercial UAVs for delivery. Student text book rental service Zookal will use Flirtey to deliver parcels directly to a customer. Customers will receive a smartphone notification that will enable them to track the parcel via GPS, and receive the parcel directly at an outdoor location. Once the UAV arrives at the outdoor delivery destination, it hovers and carefully lowers the parcel through a delivery mechanism that is attached to a retractable cord (see Figure 13). This aims to significantly reduce waiting times from two to three days, to as little as two to three minutes.[27]

An airborne first and last-mile network could look as follows: Shipments that arrive from outside the city limits are sorted at existing facilities (hubs, warehouses, cross-docking sites), and shipments meeting certain criteria are separated automatically. In addition to size, weight, and time criticalness, these criteria could also include dynamic metrics (e.g., current road conditions, air pollution, and network load). Each UAV automatically picks up assigned shipment(s) from a conveyer belt and takes off. On its way back to the hub, the UAV could carry out point-to-point deliveries that lie on its route.

[25] http://www.swissre.com/media/news_releases/nr_20131031_sigma_urbanisation.html

[26] "China's e-tail revolution: Online shopping as a catalyst for growth", McKinsey Global Institute, March 2013

[27] http://atp-innovations.com.au/flirtey/

Its routing decisions would always be dynamic, meaning an intelligent network would redistribute all resources in real-time, depending on the load and urgency of certain shipments. When an assignment for emergency transport comes in (e.g., time-critical delivery of blood from a blood bank), this is prioritized. End customers are equipped with an app that allows them to see nearby UAVs and order a dynamic pick-up – this system would use GPS data from the customer's smartphone to meet him or her wherever they are, even if they move to a different location after placing the order.

There would be the same flexibility for deliveries – as soon as the customer sends a notification, a UAV leaves the hub and makes delivery direct to the customer location or in case of returns, picks it up right from the first mile of the customer.

AMP Electric vehicles even plans to test the pairing of delivery trucks with UAVs that will deliver parcels that are outside of the main delivery route of the truck. The UAV would be positioned on top of a delivery truck, waiting for a parcel from the driver. When loaded, the UAV will scan the barcode on the parcel, schedule the route to the delivery point via GPS and take off to the destination. In the meantime, the truck will continue on its rounds. After a successful delivery, the UAV will fly back to the truck for its next delivery run, where it can also recharge its battery wirelessly. (see Figure 14).[28]

Figure 14: UAV teams up with AMP; **Source:** AMP Electric Vehicles

The first and last meters of the delivery process are likely to be the most technically challenging. If the customer is outdoors and moving, the UAV could meet them and 'hand-over' the delivery after identifying the customer via NFC or QR code on their smartphone. But if the customer is at home, things gets trickier. With a garden or balcony available, the UAV could drop the parcel onto this. With large buildings and skyscrapers, the UAV could land on the roof. The most problematic delivery would be to mid- sized buildings with pitched roofs – structures that are prevalent in European locations – necessitating an alternative delivery point, perhaps some sort of collection point. The existing DHL Packstation or Paketkasten net-work could be upgraded to handle shipments of this kind (see Figure 15).

Figure 15 a+b: Packstation and Paketkasten; **Sources:** Bitpage; Neuerdings

[28] http://www.wired.com/2014/06/the-next-big-thing-you-missed-delivery-drones-launched-from-trucks-are-the-future-of-shipping/?mbid=social_linkedin

Figure 16: Urban First and Last Mile

This urban first and last-mile use case is probably the most tangible and spectacular in the logistics industry. But it is also the application with perhaps the largest barriers, because privacy and safety concerns multiply in the densely populated urban environment. And it is the most challenging in terms of regulatory framework conditions and infrastructure – especially integration into existing urban infrastructures.

3.2 Rural Delivery

The potential of UAV technology is also evident in rural locations with poor infrastructure or challenging geographic conditions. George Barbastathis of the Harvard- MIT Division of Health Sciences and Technology initiated research into UAVs “to swiftly transport vaccines to rural locations and alleviate first and last-mile delivery problems and improve cost, quality, and coverage of vaccine supplies.”[29]
For the logistics industry, rural delivery by UAV is attractive not only in emergency applications because low-volume remote locations represent a costly part of standard networks. Furthermore, they typically require a non-standard infrastructure tailored to regional specifics (e.g., mountainous settings or island delivery).

For remote island locations, a conceivable use case is the delivery of parcels to near-shore islands, either replacing an existing (and complex) process involving cars, boats, and postal workers, or providing new, additional services. These could be off-peak delivery services originating from the mainland or specific express services (e.g., for pharmaceutical delivery).

[29] http://www.grandchallenges.org/Explorations/Pages/GrantsAwarded.aspx?Topic=Vaccines&Round=8&Phase=all

In recent news, Google has revealed its latest program called Project Wing to build autonomous delivery systems capable of bringing parcels to nearly every person within one to two minutes. Google has been working on Project Wing for more than two years and it is already currently testing UAVs for rural deliveries in Queensland, Australia (see Figure 17). However, Google recognizes that the project is far away from actually being ready for any sort of commercial or governmental use especially for UAV delivery in urban areas. "It's years from a product," explained Google Project Wing founder Nicholas Roy. "But it is sort of the first prototype we can stand upon."[30]

The obstacles Google will have to clear will go far beyond engineering. As previously mentioned rival Amazon floated its own aerial delivery service earlier this year and the UAV delivery project was quickly subdued in the US by the FAA.

Figure 17: Google's drone deliveries; **Source:** Engadget

To gain valuable insight into a comparable application, Deutsche Post DHL partnered with the UAV manufacturer Microdrones in December 2013 to deliver pharmaceuticals to employees at DHL's headquarters in Germany. This joint project took place in the city of Bonn, but the setting was comparable to a rural location as the UAV flew across the Rhine river – both the take-off and landing areas and the flight path were free of any buildings.

Figure 18: The DHL Paketcopter delivering a parcel in Bonn; **Source:** Wallstreet Journal

This is noteworthy as it substantially simplifies flight and delivery operations – buildings influence wind patterns and GPS signal strength and, most importantly, complicate delivery compared to the simple drop-off that's possible in rural settings.

A UAV called the DHL Paketkopter ("parcel-copter") was under the manual control of an operator at all times, to fulfill regulatory requirements (see Figure 18). But from a technical perspective, it could have operated with full autonomy by following GPS waypoints. This vehicle was equipped with a release mechanism allowing it to put down the parcel via remote control or pre-programmed instruction (scan Figure 19 to watch the video). Based on the test flights in December and depending on further regulatory developments DHL will continue to pursue this use case. This project clearly underlines the feasibility of UAV-based deliveries in a real-world setting. A wide-spread use, however, will still need time.

Figure 19: QR code video: Posttower

[30] http://www.cnet.com/news/google-announces-project-wing-for-drone-deliveries/

Figure 20: Rural Delivery

UAVs offer greatest advantage to infrastructures that are weak or almost non-existent. For example, in rural Europe aerial deliveries via a UAV network could speed up deliveries and raise service levels, but in rural Africa this could be a complete game changer. Remote communities in developing nations often lack access to proper roads and train lines. Connecting villages through UAV delivery networks could enable their participation in the global economy and more frequent supply of critical goods. This would, in turn, speed up economic development, as at some level the use of UAVs overcomes the expensive and time-consuming task of establishing infrastructure.

3.3 Surveillance of Infrastructure

As in other industries, organizations in the logistics industry must monitor their infrastructure. UAVs can help with security and safety surveillance in large-scale facilities such as warehouse sites, yards, docks and even pipelines. They can also help to guide various operations (e.g., the movement of trucks and forklifts on site). Probably the most promising application is using UAVs to provide customers with a value-added service (VAS); for example on oil fields. BP, British multinational oil and gas company, will routinely use UAVs to patrol their Alaskan oil fields which is the first authorized commercial UAV operation in the United States (see Figure 21). Their UAVs will be used to monitor specific maintenance activities on roads, oil pipelines, and other infrastructure in the vast and potentially dangerous artic environment of northern Alaska. It is estimated that BP ground crews spend up to a week checking a two mile section of pipeline, however, according to BP´s technology director Curt Smith, UAVs can scan a two mile section in 30 minutes.[31]

At a first level, surveillance of infrastructure involves the logistics company in monitoring its own sites and assets. This can ensure they are used to full capacity and are protected (e.g., theft reduction in warehouses containing items of particular value). The status of the infrastructure can be assessed from the air, and damage (e.g., on a warehouse roof) can be evaluated. At some future point in time, it may be possible for UAVs to carry out minor repairs on hard-to-reach parts of buildings and infrastructure.

[31] http://www.totallyunmanned.com/2014/06/20/bp-uav-makes-oil-production-safer-profitable/

Figure 21: BP using UAV; **Source:** Modelairplanenews

At a second level, surveillance of infrastructure involves the logistics company offering UAV services to its customers. Taking the example of an energy customer, their site may be of gigantic scale and their assets expensive and difficult to track. Losing the value of an asset, and hours invested searching for it, could be made even worse by customs fines for each imported item that is temporarily lost. Additionally, the energy customer is likely to be constantly challenged by issues of Health, Safety, Security, and the Environment (HSSE). It is not easy to keep perfect safety records in the harsh environment of oilfields and mining sites, and DHL already supports energy customers with asset tracking and HSSE record-keeping improvements.

To reach the next level of operational excellence, logistics companies and their customers may – at some point in the future – use UAVs to support tasks such as asset tracking, monitoring risk hotspots, and locating missing employees.

Figure 22: Surveillance of Infrastructure

3.4 Intralogistics

UAVs could play a vital role in intralogistics. Consider the automotive industry with its massive production sites, just-in-time processes, and mind-boggling cost of idle production lines: UAVs could support intra-plant transport as well as the supplier-to-plant emergency deliveries which are typically performed by helicopter today. Large-scale mining areas could also profit from the on-site express delivery of items that are crucial to maintaining operations (e.g., delivery of tools, machine parts, and lubricants).

UAVs are easy to deploy and can follow pre-defined flight paths, so there is no requirement for specially trained personnel to launch and fly them. As long as system operations are limited to private premises only, the organization has to deal with minimal regulatory boundaries and privacy concerns (issues that can be so detrimental that they render other use cases unfeasible). The most significant limitation for intralogistics is probably the payload issue. Smaller, affordable UAVs are still disappointingly expensive, and large unmanned helicopters almost rival their manned counterparts in terms of cost, maintenance, and infrastructure requirements, eliminating their major advantages.

Another imaginable intralogistics application is the use of UAVs inside the warehouse environment for more flexible and accessible high-bay storage.

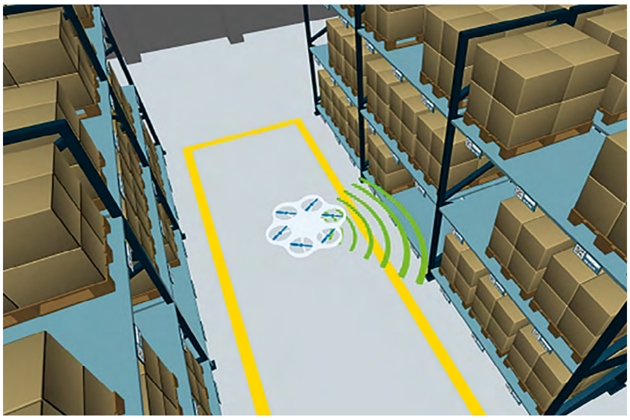

Figure 23: The Inventairy Research Project; **Source:** Autonomik 4.0

For example, a Fraunhofer IML research project investigates the use of a UAV platform for indoor and outdoor flights (see Figure 23). This concept is based on the Internet of Things, focusing on self-organization of machines and interaction among systems. The sensors allow the system to independently observe and analyze the surrounding environment so that the UAV is able to navigate through a warehouse, find logistical objects and carry out an inventory check. The information collected is also transmitted to third-party systems via intelligent interfaces and services. This allows the direct transfer of selected context-related information.[32]

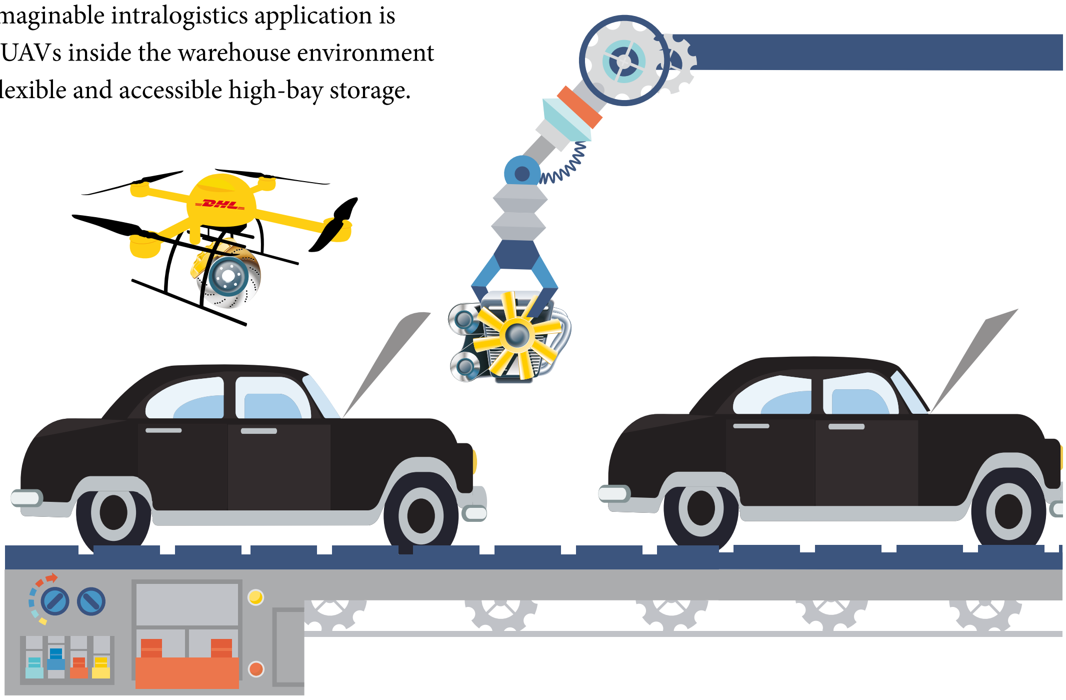

Figure 24: Intralogistics

[32] http://www.aibotix.com/research-project-inventairy.html

CONCLUSION AND OUTLOOK

It is clear that substantial challenges lie ahead for UAVs, particularly the regulatory environment, privacy concerns, and integration into existing networks. It is likely to take considerable time and effort to overcome these challenges and, in fact, many branches of the logistics industry may never develop regular use of UAVs at all.

However, this report has indicated specific applications in which UAVs are already succeeding today – applications that increase delivery speed and customer service levels, lower cost and, in some cases, save lives.

From today's perspective, the two most promising uses in the logistics industry regarding business potential are:

- Urgent express shipments in crowded megacities – improving the delivery speed, network flexibility, and potentially even the environmental record
- Rural deliveries in areas that lack adequate infrastructure (e.g., in Africa) – enabling people in remote locations to be connected to the global trade networks

This topic will continue to be of great interest over the next few years, particularly if technological developments and changes in legislation accelerate the dissemination of UAVs.

DHL Trend Research invites you to join this exciting journey to the future. Make sure you keep posted through our publications, visit us at the DHL Innovation Center (where you can see for yourself the DHL Paketkopter), and reach out to discuss your joint UAV project initiatives.

We look forward to hearing from you!

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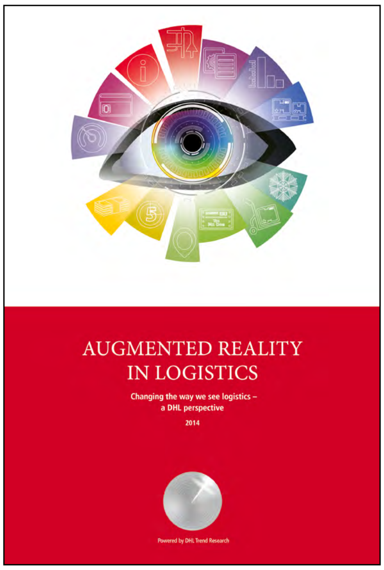

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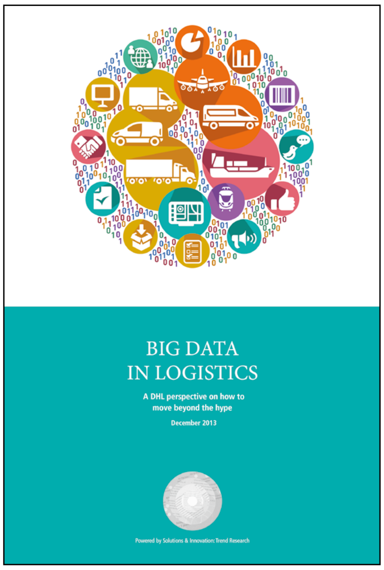

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