2127 Brickell Av.
Miami, Florida
33129, USA

Tel. +52 728 287 7321
Cel. +52 55 2129 0567

http://www.riscmiami.com

Translation of Photogrammetry Article for Web-site www.riscmiami.com

V. Stewens 21.November 2018

Original document was edited in Spanish. Following translation was carried out with assistance of the Internet deep-l translator and reviewed afterwards by the author.

Introduction

RISC has had its first practical contact with digital photogrammetry in the case of a new toll road under construction in Mexico. This technology was already known in the areas of topography and cartography, however, in recent years, with the arrival of Unmanned Aerial Vehicles to various professional areas, there has been a wider dissemination of this technology and especially its related software. For those of us who have seen closely the practical application of the use of digital photogrammetry in risk inspections, it is difficult not to believe that in a few years this type of analysis will not be part of a global analysis of certain types of risks. The mining industry, construction of skyscrapers, construction and operation of toll roads in conflictive terrain are just a few examples in which we see the use of unmanned vehicle-assisted inspections in conjunction with digital photogrammetry as extremely useful for (re) insurers.

Background

The road that has been the object of our initiation to digital photogrammetry, is part of a project that started with its construction in 2012, and that had a number of impediments that considerably delayed its original construction program. It is important to note that the project is developed in an adverse geological environment, with a mountainous topography and strong slopes. The climatic environment is complex with recurrent heavy rainfall. In addition, the Government's original executive project presented certain inconsistencies and deficiencies that contributed to a number of incidents during the construction phase, which were partially recovered through insurance claims. A protracted work stoppage - due to a variety of reasons - resulted in a withdrawal of part of the project's reinsurers and the consequent entry of new markets. This circumstance implied the need to carry out a survey of the actual conditions of the motorway under construction, especially in order to delimit new events from those that had already occurred, all in the context of a "suspended project works" policy. These circumstances triggered an analysis of different assessment possibilities, also considering the not very gratifying antecedents with the work of adjusters who carried out a home office adjustment without fully inspecting the project. To be honest, it is worth mentioning that accessibility is complex in the area, not only because of the conditions of the access roads after cyclonic phenomena, but also because of the blockade of internal communication roads by relatively brave local community members.

Solutions

In principle, two possibilities of carrying out an "as is" survey of the section under construction were analyzed:

- Overflight with a helicopter / small plane and make a video to identify earth falls, landslides and embankment conditions.
- Overflight of the road leg with a drone equipped with a camera to make a detailed video of the stretch and its structures, which a video made from a helicopter would not have been able to show in such detail.

The first inquiries - which finally brought us closer to digital photogrammetry - revealed that, although a survey by means of a drone was going to give us a more precise and detailed result, a helicopter tour was economically more viable. On the other hand, with respect to digital photogrammetry, we should mention that, with the technological advances of recent years, it allows us to carry out volumetric measurement tasks similar to and superior to traditional topographic studies.

(Re) Insurance Needs

Before detailing further our experience with the drone assisted inspection, we dedicate a paragraph to analyze the needs of the (re) insurance industry, knowing that the interests between the insurer and the reinsurer are not always aligned.
Construction sites are dynamic projects whose exposures change over time. The variable component in a project is not only the constant increase in values, but also the stability of the structures, climatic variations, changes to the original project, etc., which make a construction project a job in continuous movement. Because of this, a project may be affected in the same season by several events of different nature, resulting in difficulties in assigning the total damage to the correct event, also due to slowness in the adjustment process: the "loss after a loss" effect has always been a complex issue for adjusters.

It is therefore important to have a survey of the actual conditions on a construction site, which may be simple for a compact project (a thermoelectric plant, an industrial plant, a cement factory) but more complex in a hydroelectric plant where the curtain may be at a great distance from the machinery house, or a road that has structures distributed over hundreds of kilometers.
Focusing on a road - which has been the reason why we got involved in the subject of digital photogrammetry - their exposures are multiple, as are their potentially exposed structures. An evaluation of insurance claims in road construction tells us that landslides of cuts, landslides of embankments, fall of beams, collapse of bridges, collapse of culverts are the most frequent events. The root cause of the most catastrophic disasters is rainfall, which has certainly increased in

intensity over the last decade in several regions of the world. On the other hand, the topographic, hydrological and geological environment is of basic importance for the risk exposure of a road under construction. In the case that the coverage includes ALoP, it is essential to have accurate information on the progress of the work and circumstances that could lead to a delay in the completion of the civil work.
A risk survey by the insurance company of this type of projects focuses largely on the above-mentioned aspects. To date, road inspections have been carried out in the traditional way: data collection, visual inspection of the road, photographic memory and writing of a report, more or less complete according to the inspector's experience. The limitations of this traditional procedure can be several:

- The length of the road does not allow for a detailed review of all the structures if the inspection timeframe is to be kept within a range acceptable also to the insured, whose primary job is to carry on with the work instead of attending to the insurer's personnel.
- There are structures that are difficult for an inspector to access, such as the bases of the piles of a bridge in a deep canyon, the drainage works in a very high cut or on the portals of a tunnel, the superior parts of the tunnel portals, the drainage works in deep canyons, as well as their protection works (spoilers, heads, channeling works).
- On long stretches affected by landslides - contrary to the work performed by an adjuster - the risk inspector cannot in a short time record all the exact locations of landslides, earth falls and major earth movements and data on the volumes involved.

On the other hand, an experienced inspector, despite the limitations described above, has so far been able to carry out his inspection, evaluating the construction site and detecting "hotspots", and inform the insurer by means of an inspection report of the risk conditions. This evaluation serves as the basis for underwriting decisions by the insurance industry.

Digital Photogrammetry

Conventional photogrammetry is a subject already known and used for many years especially in cartography and topography. The tours were carried out mainly in small planes. With the rise of unmanned aerial vehicles (drones), the miniaturization of the cameras used, and the always-higher capacity of data processing, digital photogrammetry becomes a very interesting solution to perform surveys of structures with the possibility of visualizing the object in its three axes from any angle. In the case of a road, a bridge or a tunnel, we can obtain three-dimensional images using specialized software, perform measurements of all types (length, height, thickness, distances, volumes and volumetric comparisons), make virtual tours (3D), obtain geo-locations of points of interest with an error of a few centimeters, all of the above duly documented with thousands of high-resolution images and with the possibility of updating if required. It is worth mentioning that digital photogrammetry does not only consist of the walkthrough and the taking of an endless number of

photographs: the important work consists of the composition of "three-dimensional models" and "super high-resolution orthophotos", which need to be processed afterwards. And here is a core aspect: the software used by the service provider. We found big differences in the resolution of the images, the quality of data processing and the speed of the data processing.
It is therefore important not only to distinguish between a digital photogrammetric survey and a video shot - the latter can give us a static visualization of the object, however it does not allow us the amount of measurements and evaluations that digital photogrammetry gives us - but also the software that is used for data processing.

Aircraft, Helicopter or Drone?

Our research - in the case we use as an example - led us to make decisions based on economic considerations and related to the readiness of the insurance industry to make investments in damage prevention without an immediate benefit. We are still in a soft market with technically insufficient premiums in which there is no ample margin for investment in prevention. There follows the eternal issue of who should supervise the level of damage prevention of the insured: is it the insurance company or is it the reinsurer? And the other question that remains unresolved: the investment in the cost of the inspection is still linked to the premium received (the classic 2.5% of the premium) rather than to the claim potential. Anyhow, it is a fact that when a major claim occurs, the (re) insurance industry's willingness to invest in the investigation of causes, to spend money in possibilities of reducing the indemnification is infinitely greater.

The use of small aircrafts and helicopters has two important conditioning factors: it requires an airport close to the construction site and that has facilities for civil aviation. Also, the service of video or photogrammetry must be contracted separately. On the other hand, it is extremely useful to have an airplane/helicopter rental service provider at the airport in question. We have found that costs increase significantly if the helicopter has to leave an air base far from the object to be inspected. With a cost of between 900 USD and 2,000 USD* per flight hour, the cost increases quickly just to bring the vehicle closer to the project area. To this investment must be added the cost of the service of a filming team that can make a video.
Companies that offer photogrammetry services with small planes charge about 400 USD* per kilometer of road. A photogrammetric sweep of a 100 km long road leads to an investment of USD 40,000*, which is not related to a road reinsurance premium, considering also that several inspections must be carried out throughout the construction period.

*All prices indicated are based on research conducted in Mexico in March/April 2018.

2127 Brickell Av. Miami, 33129, Florida, USA
Tel. 001 305 735-8257 +52 728 287-7321
Cel. +52 (1) 55 2129-0567 http://www.riscmiami.com

The Feasible Alternative: Digital Photogrammetric Evaluation (DPE)

In the course of our research, we have approached a specialized service provider that presented us with the benefits of digital photogrammetry based on practical cases, such as a slope collapse in a construction, a mining risk, and the erection of a tower next to condominiums.
In the case of our example, a digital photogrammetric survey would not only have revealed at first sight the "as is" conditions of the motorway in a general way, but would have given us more detailed information - with a bird's eye perspective - of the conditions of culverts on top of slopes that in a normal inspection can only be partially assessed, the conditions of culverts in deep canyons, the volumes of the earth falls and landslides in cuts and embankments as well as the length of the road surface affected by cracks and progressive earth movements of already constructed embankments. We should bear in mind that the road we were analyzing suffered considerable delays, and sections already completed were left at the mercy of inclement weather for a long time. The drone inspection, with considerably longer execution times, would make it possible to review sections that had not been reached previously due to the complexity of their access, also due to blockages by the local native residents with their range of "special demands".
We have already mentioned that the software/application would have enabled us, in the event of a new inspection, to highlight construction progress, or differences in the volume of earth falls or to detect new landslides and falls.

After an evaluation of the costs, the pros and cons of the different options at hand to carry out a survey of the "as is" conditions of the highway under construction, as well as the type of software used by the companies that offer this kind of services, it was decided to hire the service provider to carry out a survey of the section and to perform a digital photogrammetric survey of the project in its construction phase.

Preliminary Results

With the DPE (Digital Photogrammetry Evaluation) survey that we carried out, we can conclude that the results exceeded our expectations despite some details and opportunities for improving procedures in future inspections.

We can confirm that from our perspective the inspection, using the digital photogrammetric survey methodology, indeed shows advantages over the traditional inspection:

- A 3D mapping that gives us a comprehensive overview of the inspected risk with 3 visualization options: Three-dimensional model, high-resolution geo-referenced Orthophoto (.jpeg, .geoTiff) and a video of a virtual tour (through a separate process and application).

- Wide and complete aerial visualization that allows the observation of points that cannot be seen in a traditional route:

  - ✓ Visualization of difficult to access structures
  - ✓ Frontal visualization of structures such as geo-synthetic walls, retaining walls, drainage works in deep ravines and bridge piers, among others

  - ✓ Evaluation of canyons, measurement of their area (interesting for the evaluation of the hydraulic sections of culverts), evaluation of the topography and type of vegetation (debris and drag material).
  - ✓ Evaluation of drainage works (culverts) and their channeling works in very deep canyons.
  - ✓ Invasion of right-of-way by landslides (also relevant for civil liability in case of CECR)
  - ✓ Evaluation of businesses adjacent to the right-of-way in the case of urban motorways (civil liability)
  - ✓ Evaluation of the presence of proper drainage on the top of slopes and their maintenance conditions
  - ✓ Visualization of tunnel portals
  - ✓ Monitoring of neoprene pads' conditions in bridges

- Obtain high-resolution topographic data that allows calculation of distances, volumes and other characteristic dimensions (canyons, earth falls, landslides, slopes and its profiles, slope gradients, diameter of drainage works).
- Appraisal of quality characteristics of the motorway such as the condition of the rolling surface, cleanliness / clearing of the right-of-way, conditions of berms and slopes protected with sprayed concrete.
- Point-of-interest" signaling throughout the entire risk and its display as a PDF report
- Accurate walkthrough documentation with the ability to make comparisons of leg conditions over a period of time.

The above considerations may be valid in principle for the CAR and/or CECR policy of road projects. On the other hand, in the case of CAR it must be taken into account that access through secondary and temporary roads can cause considerable delays in digital photogrammetric surveying.
Where this tool is definitely - from our perspective - extremely useful, is the toll road already in operation and insured in an all-risk policy or CECR, not only because of the ease in accessing the road, which allows 3D mapping in a much shorter time than in the case of a motorway under construction. The monitoring and evaluation of maintenance aspects, neighborhoods (important in urban roads, beltways, bridges and overpasses in inhabited areas), evaluation of cut gradients, slope

angles, geological instabilities, puts the insurance industry in a position not only to assess in more detail the risk, but also in a position to have an "as is" of the stretch and then, in the event of a claim, to objectively appreciate volumes of earth falls and damaged areas, and in some cases to have a tool to determine the root cause of the event.

Deliverable

It has already been mentioned that the results of the DPE (Digital Photogrammetry Evaluation) are delivered by the supplier - in our case WD/360 - by means of a link in which the user can visualize in an online platform the inspected risk. The platform is user-friendly for risk visualization, but requires some training and routine to obtain measurements and volumetric calculations. A professional service provider can assist. It is important to note that there are differences in deliverables between the various providers that perform photogrammetric services. Some companies only provide a video of the current risk conditions, while in the case of others the inspection results are delivered in the "cloud", and all measurements can be performed at the user's own account. In the event of a re-inspection, the user himself can detect changes in highway conditions, i.e. new landslides, earth movements or construction progress. The platform makes it possible to accurately calculate volumes of concrete castings in bridge construction, progress in the road surface laying, progress in slope cutting or embankment construction, among others.

Based on our initial experience with the online platform - knowing that we are in an incipient learning phase - we dare to draw these first conclusions:
Reviewing in detail many kilometers of a road under construction at a rate of 10 meters - 30 meters on the computer screen is an activity that takes time. On the other hand, it is surprising that, for a risk inspector with experience in roads, there are many aspects that can be reviewed and the quality of the resolution of the images "invite" to observe in detail the different elements of the motorway:

- Geology in the cuts that present earth falls
- Draining ditches obstructed by drag-out material and debris
- Invasion of right-of-way by landslides & mudslides
- Gradient and angles of cuts and embankments
- Geological phenomena such as progressive embankment movements due to earth faults
- Cracks in the road surface etc.
- Drainage channeling works

With a little imagination it is not difficult to see that the insurance industry will soon be able to calculate the areas of the canyons and demonstrate the inadequacy of the hydraulic sections of the drainage works. This issue is very important for the stability of embankments and to prevent them from collapsing due to up-hill formation of water bodies caused by a drainage obstruction.

2127 Brickell Av. Miami, 33129, Florida, USA
Tel. 001 305 735-8257 +52 728 287-7321
Cel. +52 (1) 55 2129-0567 http://www.riscmiami.com

CECR - Motorways

Special mention should be made of the use of the DPE in the case of operating toll roads in Latin America that are covered by the Civil Engineering Completed Risk (CECR) policy. In several countries there are presently very aggressive construction programs with sometimes-limited resources. Damages occur normally within the first years of operation. Earth falls and landslides due to a very aggressive slope angle, insufficiency of the hydraulic section of culverts, lack of drainage ditches above the earth cuts, lack of channeling work for the drainage pipes, are examples of circumstances that lead to substantial claims. A more detailed monitoring of the maintenance conditions, of the topographic and geological environment, of eventual correction works in earth cuts, embankments, drainage works and reinforced walls, can prevent claims to the insurance company. Recurring digital photogrammetric inspections can help avoiding claims for progressive damage and/or damage due to obvious deficiencies in maintenance.
The aspect of exposure to TPL damage in the case of urban roads, overpasses and elevated beltways can be revealed by DPE. Lately we have travelled many sections of urban toll roads in operation, where commercial business adjacent to the highway "clashes" with the professional operation of a motorway.

Specifically for toll roads we summarize the advantages of a 3D Mapping with digital photogrammetry:

- 360º motorway survey with three-dimensional visualization possibilities
- Evaluation of hard-to-reach structures and components (bridge neoprene pads)
- Frontal visualization of structures such as geo-synthetic walls or other type of retaining walls, base of bridge piling etc.)
- Evaluation of canyons, measurement of their area (interesting for the evaluation of hydraulic sections of drainage works), evaluation of topography and type of vegetation (dragging material)
- Evaluation of culverts and their channeling works in very deep canyons
- Invasion of right-of-way by landslides (also interesting for third party liability)
- Assessment of establishments adjacent to the right-of-way in the case of urban motorways (third party liability)
- Verification of the existence of drainage ditches
- Maintenance of ditches and the right-of-way area in general

In addition to the aforementioned possibilities of parametric calculations (distances, volumes, slope gradients, diameter of drainage works, among others), the high resolution of the images will make it possible to appreciate certain quality characteristics of the motorway - which in many cases form part of the concession contract - such as the conditions of the road surface, settlements, cleaning and clearing of the right-of-way, conditions of berms and sprayed-concrete-protected slopes.

It is very important to point out that the entire DPE trail is digitally documented and based on the software used - it is possible to document the history of the conditions of the analyzed section. "Points of interest" for the insurer can be reviewed in future inspections.

Critical and Limiting Aspects

As in any new technology, we have also faced situations that teach us that there are still limitations when we use DPE.
An important aspect is the fact that the work rate of the technicians who carry out the photogrammetric route and that of the traditional Surveyor are totally different. While the traditional inspector carries out his route in an expeditious way, the photogrammetric route has definitely longer execution times.
On the other hand it must be considered that accessibility can significantly delay the progress of the inspection, especially in the case of a road under construction. In this context, the range of radio signal transmission should also be mentioned: 3D mapping in a mountainous environment requires more effort than in a flat terrain in which radio waves propagate without barriers.
It is also important to note that DPE technicians should have some experience not only in the type of risk being analyzed, but also in aspects relevant to the insurance industry, which ultimately focuses largely on loss prevention.
Weather conditions on the day of the inspection are also another issue: rain and visibility must be adequate in order to have clear, reproducible and actionable images.
We have also learned that in certain countries there are restrictions on the temporary entry of drones. In these cases it is necessary to comply with customs formalities that can take time.

Of course, it is important that drone operators have full knowledge of the capabilities of the drone used (flight times, ranges, interferences that could occur due to the topography and dominant winds) and the camera used. We can confirm that there are still enormous differences in the quality of the work delivered and not only with respect to image resolution.
As last aspects we do not want to leave aside some comments on the platform used and the software with which the data are processed. Processing more than 100,000 images, locating them geospatially, generating a "cloud of points", obtaining the desired resolution at critical points, allowing the export of the data obtained and documenting in a friendly way, in easily accessible files on any computer, make the "online platform" used a critical factor.

For additional technical details please contact
RISC: +52 (1) 55 2129 0567