Pictometry: Potentials for Land Administration [1]

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SUMMARY

The Netherlands' Cadastre, Land Registry and Mapping Agency (Kadaster) performed a research to the potentials of the Pictometry technology for cadastral purposes in close co-operation with the GeoTexs company from Delft, The Netherlands and Blom Info, Copenhagen, Denmark, part of the Blom Group. Blom Group has an exclusive license to apply Pictometry technology in Europe. Data capturing with this technology will be executed for all 50.000+ inhabitants cities in Europe. The patented technology allows users to easily and efficiently view and measure in ortho images and oblique images and enables creation of a much richer database of the real world while the images can be processed in existing GIS environments. In the research Pictometry images were used captured in 2006 and covering the entire territory of Apeldoorn municipality, The Netherlands. The map data consists of: (1) boundary lines of objects of Top10Vector and Top25 Raster, (2) feature lines of the Large Scale Base Map of the Netherlands (GBKN) and (3) cadastral map. Our tests reveal that the accuracy of taking location measurements in ortho-images is 19cm and in ortho-images 86cm, expressed in terms of root mean square error. The accuracy of the elevation component depends on the accuracy of the underlying DEM. Although Pictometry technology has been announced as a visualisation tool, not as a surveying tool, the above measures demonstrate that photogrammetric surveying accuracy can be achieved. Within a cadastral context Pictometry may serve as aid in splitting parcels and carry out parcel formation. Furthermore, it appears to be a suitable tool for (1) preliminary boundary determination via notary, (2) building registration and (3) communication from government to citizen.

1. INTRODUCTION

Pictometry is an aerial image acquisition and data processing technology developed and patented by US-based Pictometry International Corp, headquartered in Rochester, New York. The essential difference with conventional airborne photogrammetry is that in addition to vertical also oblique images are taken, which is enabled by a sensor system consisting of five cameras, one directed nadir (image plane approximately parallel to terrain), the others viewing forward, backward, left and right (Figure 1). The viewing angle for all sideward looking cameras is approximately 40 degrees off-nadir (Figure 2). The (mutual) geometry of the five cameras is accurately calibrated, potentially providing, in conjunction with today's advanced computer technology many new application prospects. The dynamic range of the grey values is 12 bits enabling to carry out surveys under unfavourable light conditions. The

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present standard approach stems from US homeland security purposes and includes a flying height for neighbouring images of 3,000 feet (1,000m) and for community images 6,000 feet (2,000m) and pixel size 6 inches (15cm) and 1 foot (30cm), respectively. In oblique images the pixel size varies from 10cm at the bottom to 18cm at the top of the image. The standard products acquired by Blom Group of Europe are usually neighbourhood images. Up to 16 square kilometre can be acquired per hour and every 1.5 seconds photos are taken. Each image consists of 6MB of data while each square kilometre is covered by around 50 views, that is around 310mb of data. Each point on the ground is visible in up to 18 oblique images, provided absence of occlusion (point is not visible because it is concealed by another object in the line of view). Direct geo-referencing is enabled through the onboard, integrated GPS and Inertial Navigations Systems (Applanix, a subsidiary of Trimble).

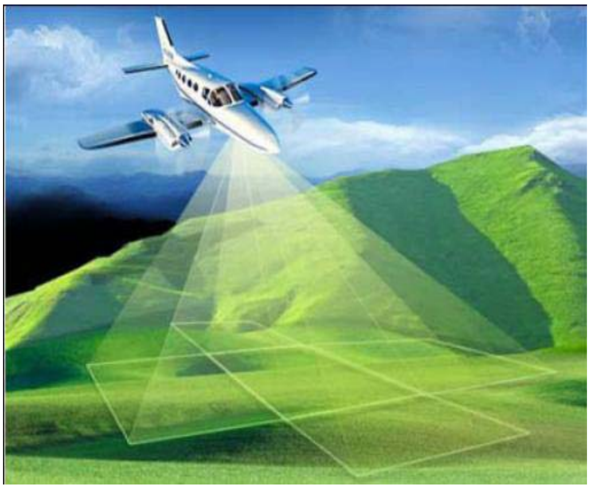

Figure 1, The Pictometry camera sensor systems consists of five cameras, one directed nadir, the others viewing forward, backward, left and right (Image Courtesy: Blom Group).

In the standard approach, vertical images have a 30% along track overlap. This is sufficient to ensure that no gaps occur due to unplanned movements of the airplane but not enough to allow stereo-viewing and mapping. As from October 2006 onwards, Blom Group has modified the standard approach to 60% along track overlap, which allows for stereo viewing. To create orthoimages from non-stereo vertical views a Digital Elevation Model (DEM) is required. In the Netherlands the existing AHN (Actuele Hoogtebestand Nederland) is used. In the case of stereo-images, DEMs can be semi-automatically extracted from the overlapping images, using image matching techniques. Pictometry images are provided as an integrated library to be used with the Electronic Field Study (EFS), which is software to view and measure both ortho and oblique images and to navigate and find a required location.

The ongoing Pictometry project, currently the largest image-acquisition project in Europe, aims at creating a standard database of oblique and ortho-aerial imagery covering every town in Europe with more than 50,000 inhabitants, a total of over nine hundred towns, the first and main customer is Microsoft. By the end of September tens of cities in the Netherlands are already available (http://maps.live.com; http://local.live.com). An interesting feature of the business model is that, anticipating growing interest in geo-information on the part of non-conventional users and partly induced by the success of Google Earth, Blom first acquires the images and then approaches potential customers. Anyone can then take out a licence to use the standard image library for a price per square kilometre. The standard list price is presently Euro 250/km^2 annually but depends on, amongst others, volume ordered and time span of subscription. Image acquisition without ordering at forehand is a business model gaining popularity; for example, Cyclomedia, which captures terrestrial photographs from a car platform, has also adopted this capture-prior-to-order model. And of course, this model already exists for decades for Earth observation from satellites.

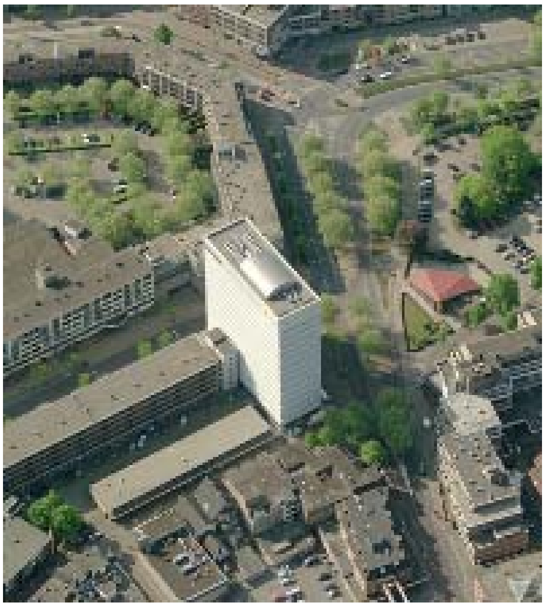

Figure 2, Oblique view from the North on main building of Kadaster in Apeldoorn.

Cadastral Applications in Europe

Although a recent technology, Pictometry has already attracted the attention of several cadastral institutes in Europe. The Spanish cadastre has started a project in which they use Pictometry ortho images for detecting illegal buildings along the Mediterranean coast as an aid to monitoring urban growth. Spain has a good mapping record: 40% of urban areas are on scale 1:1,000. No use is made of a standard product, but the images are acquired in dedicated surveys. The ortho images have a Ground Sampling Distance (GSD) of 10cm. Also the Danish Cadastre (KMS) has shown interest in Pictometry. IGN France and Ordnance Survey in England are resellers of the product.

Aim of the Research

The research aimed at investigating whether and if yes, how, Kadaster might benefit from the Pictometry technology within the framework of its ambitions and vision on the future. The following questions have been addressed:

1. Achievable accuracy
2. Information content
3. Addition of geo-referenced oblique images to conventional airborne photogrammetry
4. Possibilities to support the definition of preliminary cadastral boundaries and measuring newly created cadastral boundaries
5. Costs

2. CHARACTERISTICS OF PICTOMETRY

One may ask what does Pictometry technology add to traditional aerial photogrammetry? In principle just oblique images are added, and there is nothing new about that. In the past the process of extracting accurate geometric information from aerial images was restricted technologically and could only be done on a production scale by using vertical images. Much emphasis was on using vertical images measuring stereoscopically and the whole image acquisition and measuring process was adapted to this. Compared to carry out measurements in mono nadir images, measuring in stereo images brings the following advantages: (1) acquisition of 3D coordinates without support of a Digital Elevation Model, (2) better interpretation, (3) higher precision is achievable because points can be better identified. Today the geometry of the sensors can be calibrated accurately, direct geo-referencing can be done through GPS and inertial navigation systems while complex geometric transformations can be carried by computer and additional information sources, in particular high resolution, accurate DEMs, can be easily incorporated by computational means. As a result, extraction of relatively accurate geometric information from oblique images is now possible. The biggest advantage of oblique images compared to vertical images is better and more intuitive interpretation. Interpretation of vertical images requires training and craftsmanship while the interpretation and taking measurements in oblique images can be done after a short training. This statement has been confirmed in our tests. Oblique images make aerial information thus accessible to a large, non-professional user group, such as officers at municipalities to support their actual tasks. Measurements which can be carried out on the oblique images include height, distance, area, location and elevation. Volume of, for example, buildings although in principle possible, can not yet be determined by the EFS software. Both the ability to observe the environment from an oblique viewpoint and the ability to take measurements provides many new applications for a variety of user groups. Table 1 provides a non-limited list of possible applications within the context of Kadaster.

Support for orientation purposes - pda, data acquisition by citizens
Overlays with (add on's to) Top10Vector/NL, CadMap, Large Scale Topographic Map and Address Co-ordinates
Building registration, including additional measurements such as stock counts, extraction of building height
Extracting cadastral boundaries
Mapping (updating with GPS)
Disaster management
Urban planning
Cadastral map quality improvement (map renovation)
Fast acquisition of boundary vertices
Updating of the topographic map TOP10 Vector/NL
Updating of the GBKN
Cadastral geometric data acquisition and support in legal/administrative data acquisition in developing countries - also slums and customary area's
Communicating cadastral information to citizens in the framework of the cadastral website www.vindjeeigenhuis.nl

Table 1. Possible applications of Pictometry

Pictometry versus Microsoft's local.live.com

What does a license for using Pictometry products, which is rather expensive, add to using the same images available at Microsoft's local.live.com website for free? Actually, the two scenarios are not comparable at all. First of all, the availability of images and areas are completely determined by Microsoft; images may be available but not yet included on the website. Furthermore, and more importantly only the oblique images are available, not the ortho-images with as consequence that no stereo-images will be available. Another major drawback is that users are not enabled to carry out measures on the images and to use them as a navigation tool for example to access other data sets. In short: Microsoft's website local.live.com enables just viewing of weakly geo-referenced oblique images.

3. TESTING AND RESULTS

A laboratory environment was created, including a stand along computer on which all data and the pictometry software (EFS) was installed. Furthermore, two regular computers with internet connection were available. In addition to Pictometry images of Apeldoorn digital maps were installed on the stand alone computer; all maps were transformed to WGS84. All map data contained geometry of objects; the attribute data were removed to ease testing. The map data included:

- Boundary lines of objects of Top10Vector and Top25Raster
- Feature lines of the Large Scale Base Map of the Netherlands (GBKN)
- Cadastral map.

Figure 3, Cadastral map (black lines) superimposed on Pictometry ortho-image.

Accuracy Assessment

To answer research question 1 (estimation of the accuracy) a comprehensive test was conducted by creating a test field of single points around the Kadaster building of which the x,y coordinates were determined by high-end GPS measurements. Well-identifiable points in particular corners of white roads signs which contrast much with the dark colour of the street asphalt were selected. As a measure of accuracy the root mean square error (RMSE) of the x and y coordinates were determined (Table 1).

	$RMSE_x$	$RMSE_y$	$RMSE$
Ortho	17cm	8cm	19cm
Oblique	62cm	60cm	86cm

Table 1, Accuracy assessment of Ortho- and Oblique images.

To determine the variability of measuring in different oblique images, all GPS points visible in all oblique images were measured; one to six measurements of the same point were carried out, depending on the visibility and identifiably of the points in the diverse oblique images. For 31 points two or more measurements could be carried out; the average values and other statistics are shown in Table 2.

Oblique	Mean	Minimum	Maximum	Median
σ_x	72cm	17cm	185cm	55cm
σ_y	86cm	12cm	300cm	59cm
$\sqrt{\sigma_x^2 + \sigma_y^2}$	112cm			

Table 2, Statistics of measuring identical points in different oblique images.

The achievable accuracy of the elevation component (elevation; research question 2) depends on the accuracy of the underlying DEM.

Information Content

Are Pictometry images suited as an aid for updating large scale topographic maps? An experienced operator was invited to work for two days with the Pictometry technology. He received the explicit tasks to confront the information contents and functionality of Pictometry technology with the work procedures he was used to update topographic maps at TD Kadaster, the following advantages were found:

- With 15cm GSD the resolution of pictometry images is more than twice as high as the images used by TD (36cm), the better sharpness improves interpretation
- Oblique images enable to look “underneath” objects which improves the quality of attribute assignment (Figures 4)
- The height measuring tool improves attribute assignment
- Operating EFS software is easy and intuitive
- Having available the topographic map on screen improves the work process because of the better orientation capability
- Colour information adds value during attribute assignment

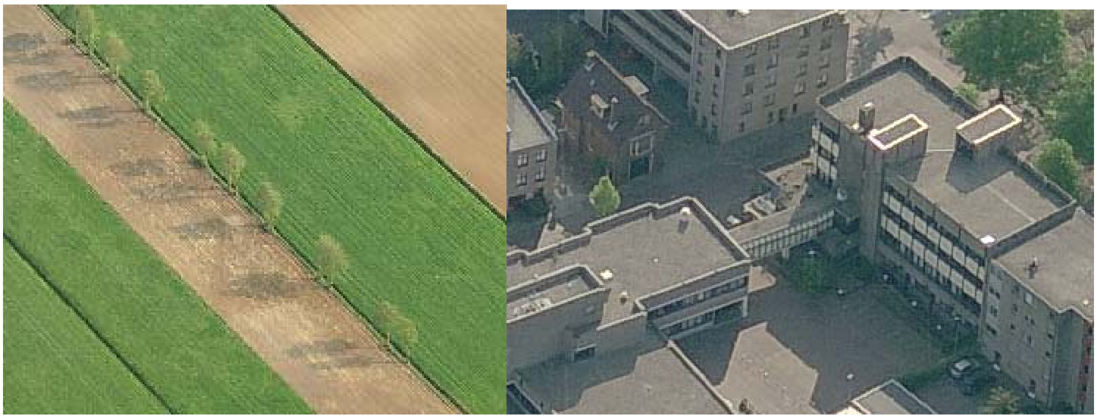

Figure 4, Left, Oblique image enables to recognize that the trees are located at the left side of the ditch. Right, Oblique image showing a corridor connecting two buildings, hanging free in space.

Shortcomings are related to viewing images in mono-mode and include:

- Reconstruction of the footprint of buildings is very difficult; only the edges of roofs are visible. In some practical situations the footprint and "roofprint" are different
- Discontinuities are difficult to recognize in mono-images, although an impression of height differences can be obtained by using several oblique images, but this is time-consuming
- In general mono images lose an important visual clue (depth) compared to stereo images. Absence of the stereo component is, as earlier stated, not a characteristic of the Pictometry technology itself, but of the standard products delivered.

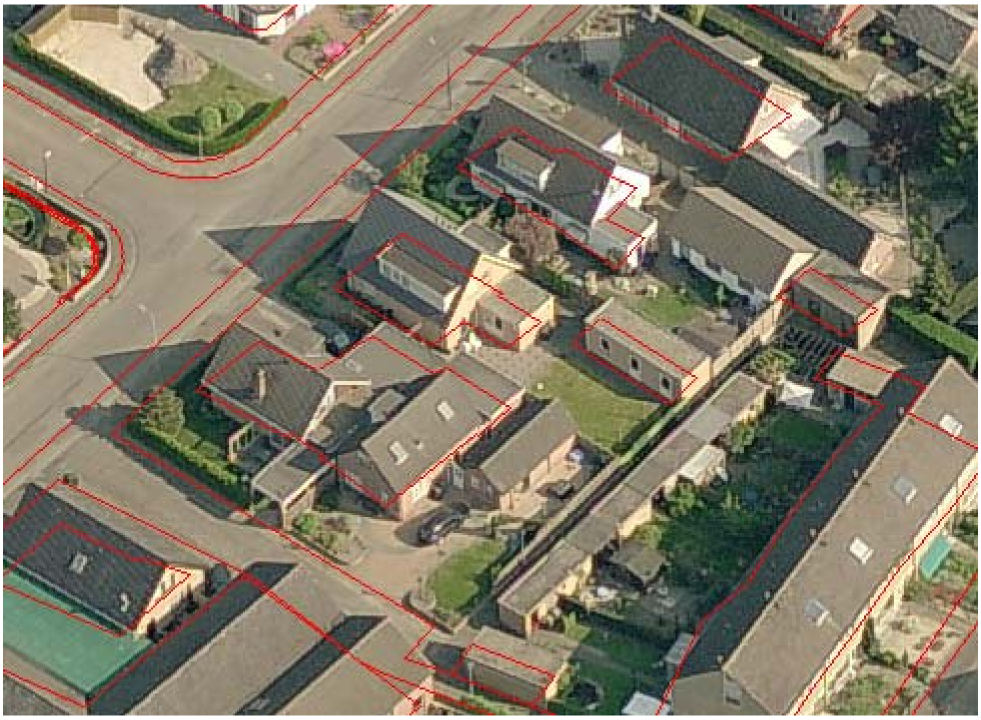

Figure 5, Projection of GBKN lines into oblique image.

The functionality of the EFS software is compared to digital photogrammetric workstation software rather modest:

- No possibility to extract polygons, an important feature for topographic map updating
- When switching from the one oblique image to the other often requires scrolling to get the concerning object in centric screen view; this is time consuming and labour intensive
- The ability to project the digital topographic map into oblique images is in general not of much use because the correspondence between both may be weak as a result of occlusion of the ground area by mainly buildings, which leads to a confusing view (Figure 5)
- Direct mapping of features and their attributes on colour images is not feasible, because attributes are assigned to features in the form of colour codes which are difficult to observe on colour images. Furthermore, black/white images do have a better contrast.

Parts of the above shortcomings in functionality may be resolved by plugging EFS into GIS packages such as Geomedia and ArcGIS, for which plug-ins have been developed. Such plugs-in were not used in our tests.

GBKN Use

In the GBKN context, Pictometry technology could be used for:

- Checking, editing and completion of the automated created polygons in the process to enhance the GBKN from a line-oriented data base to an area-oriented database. This can be done manually by superimposing the GBKN on the ortho-images, while keeping the oblique images at hand in the form of thumbnails as an additional interpretation aid
- As source to add manually object codes to the polygons
- As an additional information for the surveyor while being in the terrain for retrieving the location of pipelines, sewerages, telephone line and other utilities. Using the ortho images as a backdrop, the GBKN and the utility map can be superimposed on the images. Since the different data sets can be merged with high accuracy, measures can be derived such as the distance from a road edge visible on the ortho image and an utility line element visible in the map.

Cadastral Use

When a party buys a part of an existing cadastral parcel, the parcel has to be split into two entities and the boundary between these entities measured. How can Pictometry technology support this process? After signing the transaction act at the notary, the splitting of parcels is usually down in two stages. First the buyer and seller carry out boundary addressing in the presence of a cadastral land surveyor. Next the surveyor measures the boundary in the terrain. Sometimes both actions are carried out simultaneously; immediately after boundary addressing the surveyor measures the boundary, but there might also be a (large) time delay between both. Furthermore, boundary addressing is usually not carried out immediately after signing of the transaction act at the notary, there is a time delay which may appear too long for some parties. Therefore, these parties will carry out boundary splitting prior to going to the notary. In 2006 the cadastre processed 85,000 transaction acts in which a part of a parcel was delivered to a buyer, thus requiring parcel splitting; 25,000 of these were split prior to establishing the notary act; that means about 30% of splitting is subject to prior land surveying of the boundary. The situation in The Netherlands is quite exceptional. In the most countries splitting of the parcel has to take place before the transaction act.

The measurement and registration of cadastral boundaries serves two tasks

- to enable splitting so that new parcels can be created and registered in the archives of Kadaster. Not only the measurement values are stored but the new boundary is also drawn on the cadastral map which serves as an index entry to the registers
- Reconstruction of the boundaries between properties sufficiently accurate, sufficient often meaning in practice at the centimetre level. Given the accuracy level determined within the accuracy tests described above, Pictometry technology will be unable to serve that aim.

Although Pictometry technology is not suited for the last task, it may serve the first task as an aid in splitting parcels and parcel formation by preliminary boundary determination. The reason for prior splitting is usually not to arrive at an accurate boundary description, but to establish the new parcels immediately after passing the notary act. So, the time delay between passing of the transaction act and parcel formation is crucial because it is often undesirable. Furthermore, the separation of boundary addressing and actual boundary measurement is experienced by many as annoying. Given the above practices it would be beneficial when a system would be at hand which enables to carry out boundary addressing and subsequent parcel formation directly at the notary during and as an integral part of the transaction ceremony. Our tests demonstrate that such a procedure could be based on Pictometry technology (Figure 6).

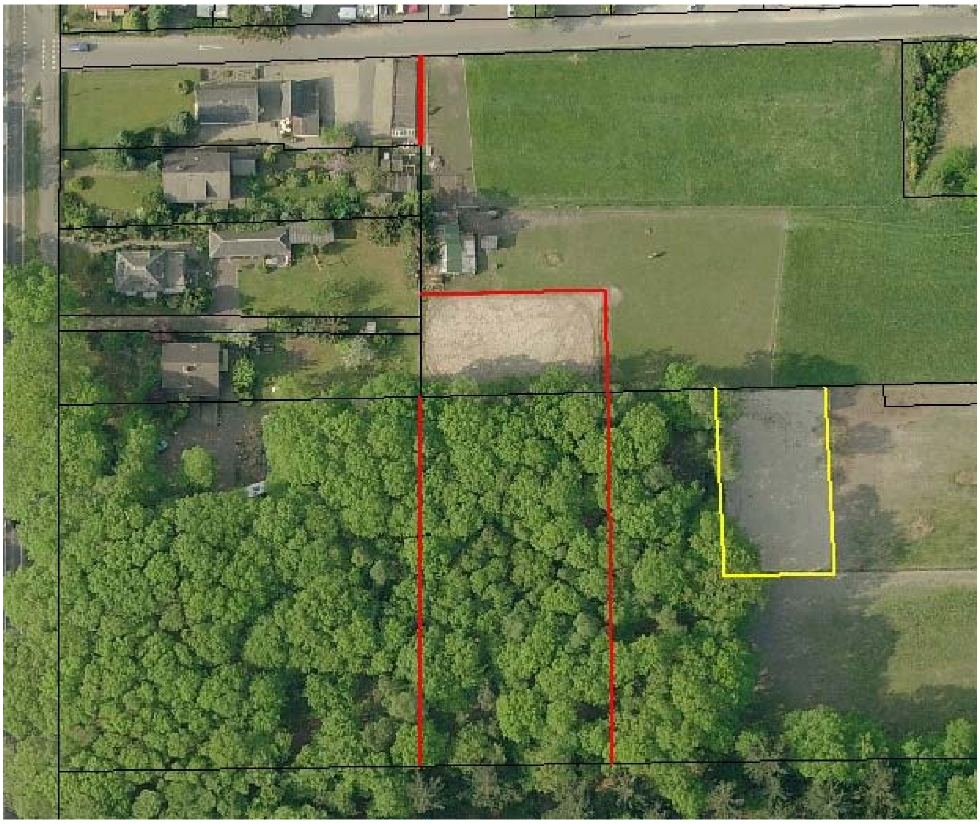

Figure 6, Identification of preliminary boundaries (red and yellow) in Pictometry ortho-image.

3. COST CONSIDERATIONS

The cost considerations are of a general nature, because the research did not intend to incorporate Pictometry technology as a replacement in an existing production process. Suppose for comparison purposes that the whole of the Netherlands would be flown once in every two years, which is presently the standard schedule for updating TOP10 by TD Kadaster and that the standard list price has to be paid to acquire the images: 250 euro per square kilometre per annum. The land area of the Netherlands is around 35,000 square kilometres. So, the entire territory of the Netherlands can be captured for a cost of Euro 8.75 million per annum. When we restrict cost calculations to the major cities (50,000+ inhabitants), which is the present standard approach, just 4,300 square kilometres have to be captured resulting in a total investment of around Euro 1 Million per annum.

The Topographic Survey out-sources the aerial surveys necessary to capture the entire territory of the Netherlands by photographs for Topographic Map updating. The costs are around Euro one million for capturing the whole territory of the Netherlands at a resolution which is, more than two times less than Pictometry images (36cm versus 15cm), while the flying height is three times less (3km versus 1km). For that amount the Topographic survey receives stereo film images (black/white or colour) at scale 1:18,000 which are scanned with a GSD of 36cm. In recent contracts the images may also be acquired directly in digital format in colour with a GSD of 27cm.

4. CONCLUSIONS & RECOMMENDATIONS

Pictometry technology is a very promising technology when viewed from the broader perspective of the ambitions of Kadaster. The costs of Pictometry technology for covering the urban areas in the Netherlands (50,000+ inhabitants) is Euro 1Million on an annual basis. As a result Pictometry technology can be beneficially and cost-effectively applied when it serves several (future) tasks of Kadaster and in a broader perspective the geo-information needs of the whole of the Netherlands. More importantly, Pictometry technology might serve as an engine and catalyser to fulfil the ambitions of Kadaster to become the principal supplier of real estate and geo-information within the Netherlands. The opportunities offered by this emerging technology should be particularly valued from that perspective.

A better understanding of all possibilities and opportunities of Pictometry technology in the context of the present and future tasks of Kadaster, requires further study. From the list of many possible applications, the Board of Kadaster has selected three pilot studies:

1. Identifying preliminary boundaries via notary
2. Building registration
3. Communication citizens and government

They have been chosen because they are new or rather new for Kadaster, while they fit within the ambitions of Kadaster and have a high degree of actuality. The anticipated results of the first pilot are: (1) better spatial orientation for all parties during transaction, including buyer, seller and notary, (2) in many cases – say 50% - no identification in the field will be required anymore, releasing buyer, seller and surveyor, (3) the splitting and creation of the new parcels can be realized immediately after passing of the act, (4), the cadastral map and graphical indication of the new boundary superimposed on the Pictometry image forms a new template for the surveyor, which can be used prior to and during measurement in the terrain, and (5) an overview of cost savings to be gained. The anticipated results of the second pilot – building registration – include: (1) understanding of the information required in the building register, (2) insight in which of the required information can be extracted from Pictometry technology, (3) development of a prototype to use Pictometry technology as a navigation tool to access other (geo-spatial) databases, (4) definition of the concerning work processes and (5) an overview of the costs involved. The anticipated results of the third pilot include: (1) easier access to data, such as BAG and WOZ data, over the internet, (2) level of appreciation by customers, (3) overview of potential products to be delivered over the internet and applications.

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BIOGRAPHICAL NOTES

Mathias Lemmens Dr. Mathias Lemmens holds a post at Delft University of Technology, The Netherlands and operates, being principal of the firm GeoTexs, as an international consultant and technical advisor specially focused on emerging and developing countries and specialised in the fields of remote sensing, photogrammetry, Lidar and GIS. Geodesist by training, he has over twenty-five year's research, lecturing and advisory experience. He has published over 300 articles and a state-of-the-art book on Geoinformation Technology. He also serves as editor-in-chief of GIM International.

Christiaan Lemmen, geodesist, graduated at the Delft university of technology. He spent the 25 years before joining Kadaster International in 2002 in information system design and development for cadastral mapping, topographic mapping and land development. He is part time associate professor at the International Institute of Geoinformation Science and Earth Observation (ITC). Within FIG he holds the position of chairman of a working group on pro poor land management. He is a contributing editor of GIM International.

Martin Wubbe is within Kadaster International responsible for the region Central and Latin America. He is a Delft-university graduated geodesist who has about 25 years experience in managing substantial projects for cadastral mapping, topographic mapping and land development. He spent quite some years as project manager in the America's. The last ten years, before joining Kadaster International in 2004 as a full staff member, he was responsible for land development projects in the whole western part of the country.

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