Abstract

Background/Objectives: This research aims to find methods of digitally registering and managing graphical cadastral areas and to prove their feasibility by conducting experiments and verification procedures on a selected region.

Methods/Statistical Analysis: We established methods of digital registration by applying a way of determining graphical survey results based on actual surveys. We selected experiment areas to which the methods were applied and conducted analysis on a total of 41 land parcels.

Findings: It turned out that we can digitally register more than 50% of land parcels (25 out of 41) including those up for revision of land registration items.

Improvements/Applications: It is expected to contribute to digitizing graphical cadastres in connection with a cadastral resurvey project if we can confirm the validity of the research methods through an experiment on a wide range of regions.

Key Words: Graphical Cadastre, Numerical Cadastre, Digital Registration, Cadastral Resurvey.
1 Introduction

Korea’s registration and management system of land boundaries is operated based on cadastral paper maps devised by graphical survey in a land survey project or a forestry survey project, or on graphical cadastres (management of cadastral paper maps) based on a forestry map. Unlike digital maps managing land boundaries with X and Y coordinates, a graphical cadastral map causes cadastral non-coincidences between occupational land boundaries and those on the maps due to shrinkage/stretching or damage. A numerical cadastre system was introduced in the cadastral field in 1975 and cadastral records called numerical terriers were established in an effort to resolve the problems arising from graphical cadastres. Afterwards, the numerical terrier was renamed to land boundary coordinate register and has been in operation ever since.

Regions managed by numerical cadastre are those registered and managed in the land boundary coordinate register resulting from confirmation survey in the urban development project and numerical survey in the land consolidation project. It has been nearly 40 years since the introduction of the numerical terrier system, but few land parcels are in the numerical cadastre.

The Korean government has implemented a cadastral resurvey project from 2012 to 2030 with the purpose of resolving cadastral non-coincidences and converting the graphical cadastrre to a digital one, and in 2016 the fifth-year project is in operation (Notification No. 2013-122, Primary Plans of Cadastral Resurvey Project, Ministry of Land, Infrastructure and Transport) \(^1\). At the early stage of the implementation it was expected the project would go smoothly, but in fact it has been delayed to due to liquidation money expended for digitally establishing and confirming new boundaries.

Therefore, additional methods of digital registration are needed in addition to an urban development project, a land consolidation project, and the cadastral resurvey project to promote digital registration of graphical cadastral regions (areas in the graphical cadastre).

We reviewed main precedent studies in relation to the subject of our research. First of all, as for cadastral confirmation surveying, a lot of research on how to convert the existing system has been conducted due to the introduction of a global coordinate system for the
As for the cadastral resurvey, numerous studies were conducted on improvement of systems and policies for the cadastral resurvey and on problems arising from its implementation and its solutions. As this shows, there is no sufficient research on methods of digitally registering graphical cadastral regions aside from the methods of cadastral confirmation surveying and cadastral resurvey.

This research aims to find methods of digitally registering graphical cadastral regions and to prove their feasibility by conducting application and verification procedures on the said areas.

2 Graphical Cadastre and Numerical Cadastre

A graphical cadastre manages land boundaries based on cadastral paper maps. A numerical cadastre registers and manages land boundaries by measuring them with numerical coordinates. The biggest characteristic of both graphical cadastre and numerical cadastre is how they manage surveying results. The cadastral map widely used in Korea is based on the paper map devised by the land survey project conducted during Japanese imperial rule. At that time or for a considerable amount of time afterwards, relatively accurate measurements of the land boundaries were made, reasoning that there were no changes in the initially registered occupational boundaries and that the maps were still intact.

However, as Korea was liberated from imperial rule in 1945 and entered the Korean War soon after in 1950, the accurate cadastral control points were lost and cadastral records were damaged. Moreover, the subsequent industrialization and urbanization prevented the relevant officials from conducting accurate cadastral organization procedures. Also, as the use of the paper maps for a long time resulted in shrinkage/stretching and damage to the paper, there were discrepancies between the occupational boundaries and those on the maps. Graphical cadastral regions in Korea, which are managed by the graphical paper maps and subject to graphical surveying, account for more than 90% of all cases.

As for numerical cadastral regions, based on a survey theory, surveying the distance from the starting point to the control point is...
conducted to establish the land boundary and then measurement of the boundary is made. In other words, after going through cadastral triangulation points, cadastral complementary triangulation points, cadastral topographic control points, and cadastral detail surveying (land parcel surveying), the location of a land parcel is defined on the 1:1 X and Y coordinates without a map scale. To place it on the X and Y coordinates there should be an observation of azimuth and distance at each stage. As for observation equipment, GPS is used to survey control points (triangulation/complementary triangulation) and a total station for cadastral topographic control points. As for cadastral detail survey, plane table surveying was utilized in the past and now electronic plane table surveying is widely used.\textsuperscript{10,11,12}

A cadastral control point is established for each stage and equipment is set up on this cadastral control point. The location of the control points of the land parcels is determined after measuring azimuth and distance with accurate numbers; thus, there is rarely any difference in surveying results regardless of the surveyor (within a margin of error). This method is applied to numerical cadastral areas (where the land boundary coordinate register is used) with coordinates used.

3 Current Status of Digital Registration of Graphical Cadastre and Relevant Problems

It has been nearly 40 years since a numerical cadastre was introduced to Korea. As of 2014, the registered area of the entire land is 100,266.2 km\textsuperscript{2} and the number of registered land parcels is 37,925,210. In terms of graphical cadastral and numerical cadastral areas, the region for graphical cadastre is 95,555.3 km\textsuperscript{2} and that for numerical cadastre is 4,710.9 km\textsuperscript{2}. As for land parcels, there are 35,684,943 for the graphical cadastre areas and 2,240,267 for numerical cadastral areas.\textsuperscript{13} As these figures show, the numerical cadastre accounts for about 4.6% in terms of the land and approximately 5.9% in terms of land parcels, the conversion rate to the numerical cadastre system is considerably low.
As for the average annual rate of increase from the graphical cadastre areas to the numerical cadastre areas from 2005 to 2014, it is 2.58% in terms of land parcels in the numerical cadastre areas and 3.88% for land area as shown in Figure 1, which is terribly low. The Korean government has tried to convert the graphic cadastral system to a numerical one by expanding cadastral confirmation surveying in the urban development project in an effort to raise the conversion rate of numerical cadastre areas but lack of awareness of project actors and relevant costs hindered the effort.

![Figure 1: Average Annual Rate of Increase of the Numerical Cadastre Areas](image)

The government has been implementing digital registration by cadastral confirmation survey and the cadastral resurvey project in an attempt to promote digital registration of the graphical cadastral areas. However, even the cadastral resurvey project has not been carried out as smoothly as expected. To be specific, in 2012 the cadastral resurvey project was implemented across the country but even in January 2014 there were many unfinished areas. Progress remained nearly unchanged until 2015. According to the progress rate of the 2012 cadastral resurvey project collected by the Ministry of Land, Infrastructure and Transport in January 2014, it is 68.4% on average across the nation. The reasons for the delay are adjustment of boundaries and confirmation, not measurement of land parcels.

Moreover, these statistics were calculated based on the project being considered finished once the boundaries were defined; thus, the schedule for paying liquidation money was not included in this data. In other words, projects were reported as finished once the boundaries were defined, but the payment stage for the liquidation money settlement or objection prevented the project from actually
being finished. Consequently, the fact that the project, which was expected to be finished in a year, is still not finished after more than two years shows the gravity of the issue.

Therefore, the government should seek new ways to have the graphical cadastral areas registered and converted to numerical cadastral areas with the cadastral resurvey project. Brand-new methods should be sought other than converting the graphical cadastral areas to numerical cadastral areas through calculation of liquidation money as applied to the cadastral resurvey project.

4 Experiment and Analysis

4.1 How to Conduct the Experiment

In this research we sought prior basic ways to propose how to conduct digital registration of the graphical cadastral areas. We sought methods using determination of graphical survey results based on the actual measurements. We surveyed the cadastral control points on the areas subject to digital registration, and based on these cadastral control points we conducted a precise survey. We overlapped the cadastral map with one based on the precise survey and moved the existing cadastral map side to side, up and down, and even rotated it with the precisely surveyed map as the standard to produce an adjusted map.

Through this process we analyzed the location and variation of the land and registered the land parcels which fall into a margin of error to the numerical cadastre. We registered those in excess of the margin of error to the digital registration after revising the land registration items and conducting the cadastral resurvey project. We performed the actual measurements using a reference boundary line, which is a graphical surveying result on the current graphical cadastre, and we applied this method to the design of the precisely adjusted map. Figure 2 below shows the methods and procedures of the digital registration of graphical cadastral areas.

<table>
<thead>
<tr>
<th>Selection of area</th>
<th>Graphical cadastral land</th>
</tr>
</thead>
<tbody>
<tr>
<td>Observation of cadastral control points and burial</td>
<td>Observation of surrounding cadastral control points (cadastral complementury triangulation points and topographic control points)</td>
</tr>
<tr>
<td>- If control points are not available</td>
<td>- Additional points</td>
</tr>
</tbody>
</table>
4.2 Experiment

We selected an area in Jucheon-ri, Jucheon-myeon, Yeongwol-gun, Gangwondo for the experiment. This area is managed with a 1/1,000-scale graphical cadastre from the land consolidation project in 1977 and some of it is managed with a 1/1,000-scale graphical cadastre from the revision of scale in 1998.

We chose this area because the graphical land consolidation was conducted a long time ago, which enabled us to review the consistency/inconsistency of the old record and the currently measured one due to changes in terrain and graphical boundaries of land parcels. In terms of appropriateness it shows a high rate of consistency between the actual boundaries and those on the map, which makes it easier to convert to a numerical cadastre. Also, there are surrounding areas determined by graphical surveying results using unorthodox methods of graphical cadastre around the regions, which enables us to apply various digital registration methods. The land parcels subject to the experiment is total 41 and the area as described in the land record is 37,909 m$^2$. Figure 3 and Figure 4 below show an aerial photograph and cadastral map of the experiment areas.
Upon selection of the research area we conducted a field survey. We performed the survey on cadastral complementary triangulation points and cadastral topographic control points surrounding the experiment area. It was carried out for a week from the 17th to the 21st of August 2014, and for the area requiring the supplementary survey we conducted the further field survey afterwards.

We used GRX-2, which is GNSS (Global Navigation Satellite
System), for surveying the control points and SET230R, which is total station equipment, for surveying the boundaries of the land parcels. Figure 5 shows the overlapped image of the actual measurement map and the existing cadastral map of the experiment area.

![Figure 5: Overlapped Image of the Actually Measured Map and Existing Cadastral Map (Legend, Actual measurement boundaries, Boundaries on the cadastral map)](image)

### 4.3 Analysis

We compared the survey results and the coordinates of the existing cadastral map to assess the possibility of digital registration of the actual measurement of the experiment area. We analyzed a total of 133 land boundaries which can be commonly compared. As for the analysis method, we calculated the difference between the existing coordinates and actual measurement coordinates and conducted RMSE analysis on them. We also compared the calculated results with the permitted margin of error (10 cm) as stated in the relevant regulations.
As for a total of 133 land boundaries of the parcels, we compared the existing coordinates and actual measurement coordinates. The results show that the RMSE for the X-coordinate is ±1.25 m; that of the Y-coordinate is ±2.84 m; and the RMSE for connection error is ±3.10 m as shown in Figure 6. It far exceeds 10 cm, the permitted margin of error. Therefore, in digitally registering the area with the actual survey results, there is a limit considering the current graphical cadastral areas.

![Figure 6: Comparison of the Coordinates of the Existing Graphical Cadastral Map and Those of the Actual Survey Results](image)

In this research we devised the adjusted map by moving it in a block unit with a reference boundary line as a standard, deciding on a graphical survey result to match the existing cadastral map with the current status in an attempt to draw land parcels subject to the registration by actual survey. To be specific, we divided the existing cadastral map into blocks and moved it side-to-side or up-and-down or rotated it on land parcels in each block to devise a map which is consistent with the actual survey results. Through this process, if land boundaries show a margin of error within 10 cm and they do not exceed the permitted margin of error for the land, these land parcels are qualified to be digitally registered.

As a result of analysis, Land Parcels 15, 16, and 17 are qualified to be digitally registered, as their margin of error for land boundaries falls into less than 10 cm. A total of 17 land parcels (Land Parcels 13 and 14, and 18 through 26) can be digitally registered if the items for the land boundaries are revised. In other words, if agreement between land owners is made these land parcels can be digitally registered without changes to the land.

On the other hand, a total of 16 (Land Parcels 1 through 12) land parcels are not qualified to be digitally registered even with
adjustment on the grounds that cadastral non-coincidences irregularly occur. There seems no other way for these land parcels to be digitally registered than to conduct a cadastral resurvey of them (Figure 7).

Figure 7: Classification Results of Land Parcels Qualified / Unqualified to be Digitally Registered with the Research Method Applied

The areas which can be digitally registered through revision of the land registration items are those whose current status has changed due to additional reclamation (outskirts), road construction in a village, damaged embankment, or ditch reconstruction. It seems that land owners are likely to agree to revised boundaries in these areas. Therefore, these areas can be digitally registered once the land boundaries are revised with agreement between stakeholders, though it is hard to digitally register them through the actual survey immediately.

5 Conclusion

This research aims to develop methods for digitally registering graphical cadastral areas and to prove their feasibility through application and analysis of the cases. The results are described below.
We sought how to use determination of the graphical survey results based on actual survey. We applied this method to the selected area and analyzed the results. There were a total of 41 land parcels, and the land area in the land register was 37,909 m².

As a result of applying the method using the actual survey to the selected area, land parcels to be digitally registered (those up for revision of land registration items included) are 25 out of 41 in total, more than 50%. To be specific, 8 land parcels can be digitally registered immediately; 17 can be digitally registered after revising land registration items; and 16 are up for cadastral resurvey. Based on the research findings, if the methods described in this research are applied to nationwide cadastral surveys, many land parcels can be digitally registered and managed accordingly.

Last, experiment and verification procedures should be conducted on a wide range of areas to validate this research. Once it is validated, it is expected to be used in converting graphical cadastral lands into digital registration along with the cadastral resurvey project.

References


