Developing a Water Pipe Management System in Seoul

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Introduction

- Running water shortage compared to water supply (99.9%) in Seoul
  - Bursts in water mains and feed pipes
  - Inefficiency in design and maintenance
- Replacing old pipes leads to failure of water supply for a long period
- To minimize the effects of water cut-off or to maintain stable supply, alternative mains are necessary

Block-based Management System

- Block-based management system in Shizuku City, Japan after 1964 earthquake to maintain the distributing pipes
- Devised for construction of water network, proven to be efficient in water management
- Seoul City employed the Shinzuku's block system dividing the whole city into 39 reservoir-based blocks and again into 1st, 2nd and 3rd blocks summed to 2,037 small blocks.
- Maintain the distribution and control the water supply based on the blocks' demands
- Beginning from the water use in each parcel, smallest blocks were created where the total use each becomes 1000~2000 tons per a day

Block Design

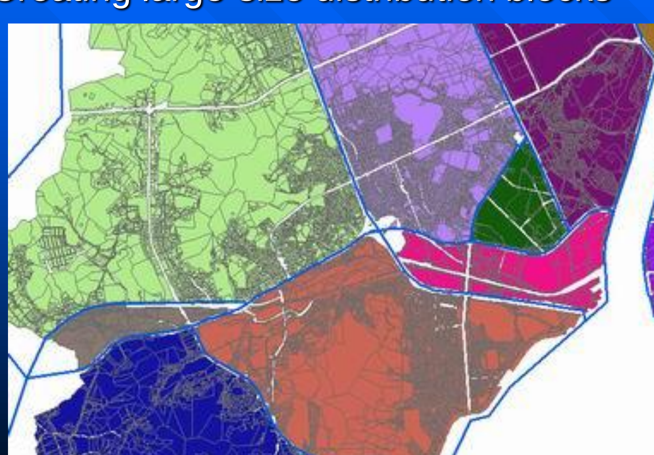
- We used different schemes to design blocks
- Used street network's hierarchical structure in Korea
  - small roads(level 1), main roads(level 2), inter-districts(level 3) and highways(level 4)
- Level 2 road networks was first used in creating major blocks and then level 1 was used in dividing the major blocks into mid-sized blocks.
- Used GIS maps to automate the process
- Test area : Guro and Yangchun Wards, Seoul

Block Design

- Removing roads from the parcel map

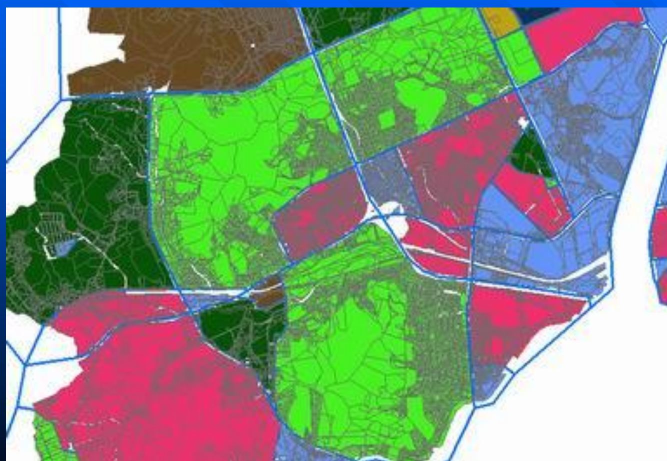
Block Design

- Creating large-size distribution blocks



Block Design

- Creating mid-size distribution blocks



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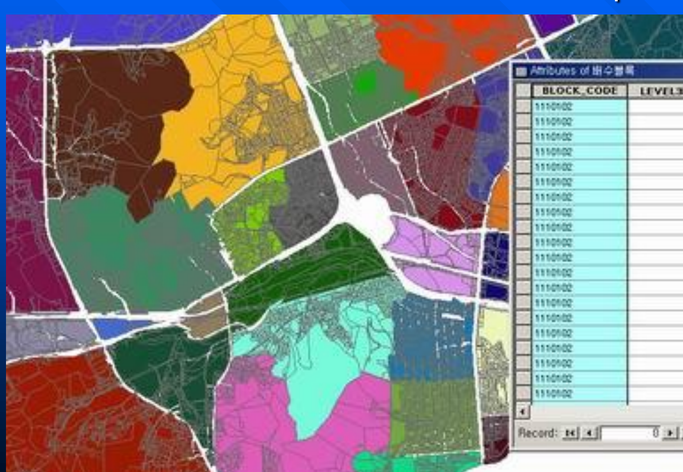
Block Design

- Distribution blocks based on water consumptions



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Pipe Superannuation

- We simplified the modelling processes by using some representative values
  - The year pipe installed, material, length, diameter, elevation of distribution reservoir and the average elevation of the block

$$S_i = \frac{YP - YI_i}{D_i} \qquad (1)$$

- S_i : superannuation of pipe *i*
- YP : present year
- YI_i : the year installed of pipe *i*
- D_i : the durability of pipe *i*

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Pipe Superannuation

- Considering the length of the pipe compared to the aggregate length in a block and the weight value, the eq. (1) is defined as

$$S_i = \frac{YP - YI_i}{D_i} \times \frac{L_i}{TL} \times P_i \qquad (2)$$

- L_i : the length of pipe
- TL : the aggregate length of all pipes in a block
- P_i : the weight value assigned to pipe *i*

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Pipe Superannuation

- Duration of pipe materials

Code No.	Material	Duration(years)
001	Cast iron	30
003	Zinc	10
004	Softened vinyl	15
005	Polyethylene	15
006	Stainless	30
007	Copper	25
010	Plastered cast iron	20
019	Fabric-covered steel	40
028	Fabric-lined polyethylene	30
040	Impact-resisting	30
999	Others	

Pipe Superannuation

- Diameters of pipes and their weight values

Diameter (millimetres)	Weight value
< 30	1
30-100	2
100-200	3
200-300	4
> 300	5

Pipe Superannuation

- Calculating pipe ages taking into account water pressure between a distribution reservoir and a block

ER – EB – MHL (3)

- *ER* : Elevation of the reservoir
- *EB* : Average elevation of the block
- *MHL* : Mean head loss

- Darcy-Weisbach Headloss

$$H_l = \lambda \times \frac{l}{D} \times \frac{v^2}{2g} \quad (4)$$

- H_l : head loss
- λ : coefficient of friction
- l : pipe length
- D : diameter
- v : velocity of water current
- g : acceleration of gravity

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Optimal Path Between Reservoirs

- Optimal path problem is finding the minimum-cost path from a node to the other in a network.
- We find an optimal path between two points or distribution reservoirs using *Dijkstra's* algorithm and calculates the construction cost based on the found optimal route.

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Optimal Path Between Reservoirs

Algorithm *Dijkstra*;
$O = N; C = \emptyset;$
$d(i) = \infty$ for each node $i \in N$;
$d(s) = 0$ and pred(s) = 0;
while ($O \neq \emptyset$)
{
    let $i \in$ be a node for which $d(i) = \min\{d(i) : i \in O\}$;
    $O = O - \{i\}$
    $C = C \cup \{i\}$
    for each $(i,j) \in A(i)$
        if $d(j) > d(i) + c(ij)$ **then** $d(j) = d(i) + c(ij)$ and pred(j) = i;
}

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Optimal Path Between Reservoirs

- We used two types of cost;
  - i) the length of links as in traditional Dijkstra's algorithm
  - Ii) the aggregate distance between a link and all small blocks included in a large-sized reservoir block
- To use the second method, each segment of the street is first assigned the aggregate length from the all small blocks in a reservoir block to the link segment.
- Then, the same Dijkstra's algorithm is applied using the aggregate block length as the cost, resulting in a path of optimal distance to the small blocks.
  - It turns out that the second method prevents a path from being biased to one side in a reservoir block.

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Construction Cost

- Calculated the construction cost along the path using the equations as;
  - Cost of buried unit pipe

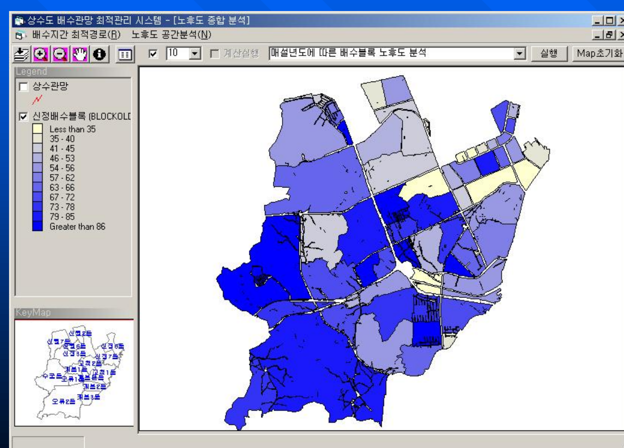
Diameter (mm)	Cost of buried unit pipe (Won/m)	R^2	MAE (%)
Φ75 – 350	$e = 19904+19.659 \times d^{1.40}$	0.9995	0.9
> Φ400	$e = 41685+1.3302 \times d^{1.80}$	0.9973	0.3

System Development

- Two management systems — the pipe monitoring system and the optimal path system — were integrated in a user interface.
  - used .NET and ESRI's MapObject
  - Zooming and panning and many sub functions
  - Block design function: instead of using the traditional blocks which have been used so far, the system allows the user to create different blocks based on the current street network and water consumption of each parcel.
  - Optimal path between two user-provided points

System Development

- Pipe superannuation monitoring system



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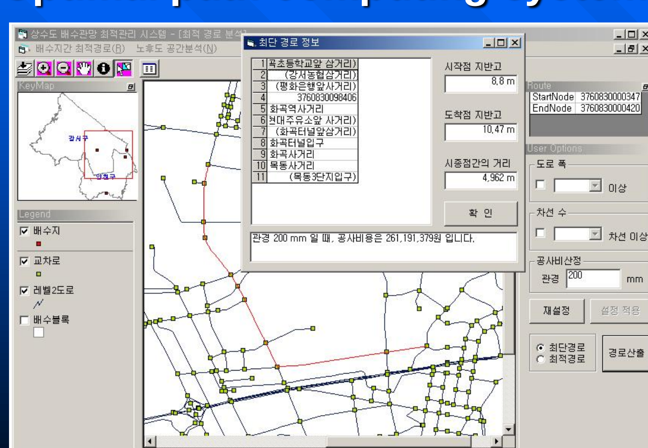
System Development

- Optimal path computing system



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Concluding Remarks

- Since construction for water pipes usually requires time and money on a large scale, the decision should be made based on proper estimation and analysis.
- We developed a prototype system that can help in two areas;
  - block designing and pipe monitoring
  - optimal path simulation between major reservoirs

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Concluding Remarks

- Block-designing can be made more practical by incorporating up-to-date street network and water consumption.
- The pipe management module also helps the decision makers by allowing them to use various factors affecting the superannuation.
- Alternative pipe routes can be created by simple user operations on the screen showing existing reservoirs and pipe network.
- Further refinements:
  - calculate superannuation and the pipe route considering the elevation differences
  - also, other functions such as water-leak monitoring can be integrated into the system to help comparison of logical superannuation with field values

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Thank You!

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