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Design and Implementation of Public Bicycle Transportation System Using Public Big Data

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ABSTRACT

This paper designs and implements a database system for public bicycle transportation based on big data related to Seoul Bicycle Ttareungyi and provides the useful information for transportation linked with the subway. Through the database creation process utilizing public data, various methods are provided for database design, data collection, production and processing examples, and database utilization. With utilizing the database system in the daily life, the system can derive useful information that contributes to the current public bicycle environment in connection to the subway for transportation improvement in Seoul city.

Keywords: Ttareungyi, Public Bicycle, Database System, Public Transportation, Big Data

1. INTRODUCTION

The Seoul Metropolitan Government started the citizen unmanned rental system for the public bicycle, 'Seoul Bicycle Ttareungyi Project' in December 2015. 'The Seoul Bicycle Ttareungyi,' here in after referred to as 'Ttareungyi', was created with the motto of promoting citizens' health, alleviating traffic congestion, promoting low-carbon green growth, and aiming to create an unmanned rental system that can be easily and conveniently used by anyone, anytime, anywhere. At the beginning of the Ttareungyi introduction, it received a very favorable response to the citizens and quickly became known to the citizens and settled down in the lives of the citizens. Starting with 150 rental stations and 2,000 bicycles in five major regions (Yeouido, Sangam, Sinchon, the inside area of the Seoul Four Gates, and Sangsu) in October 2015, The Seoul Metropolitan Government has expanded its operations to about 20,000 units as of 2018 and plans to increase the unit number to 40,000 by 2020 with citizens' high response.[1]

However, as the operation scale of Ttareungyi expanded, the complaints about Ttareungyi began to increase. For example, there were complaints about the use of Ttareungyi, the system error of Ttareungyi, and the saturation of the users in the specific area due to erroneous infrastructure construction [1].

In order to reduce dissatisfaction of the residents with Ttareungyi, The Seoul Metropolitan Government should propose clear improvement plans. Utilizing the system, it is possible to suggest more effective improvement measures if we can acquire and process cumulative data related to Ttareungyi, and extract and utilize useful information based on the data [2, 3].

This research suggests methods to design and implement the database system that produces more useful information utilizing Ttareungyi than summarizing data. For the database system, the actual big data related to Ttareungyi are utilized such as 'Seoul Bicycle Rental Center Information' [4] and 'Ttareungyi User Usage Information' [5], and the actual big data related to public transportation are utilized as a connection with Ttareungyi such as 'Seoul Bicycle Road Location Information' [6] and 'Seoul Metro Station Location Information' [7].

This paper is organized as follows: Section 2 describes previous works related to this research. Section 3 describes database production processes such as E-R Model and processing data. And Section 4 provides representative examples of utilization plans. Finally, discussions and conclusions are described in Section 5.

2. RELATED STUDIES AND BIG DATA

2.1 Bicycles in the Public Transportation System

Schuijbroek et al. [8] dealt with the problem of setting up a relocation management zone under consideration of user service levels and resolving the path of a transportation vehicle for intra-zone bike relocation. Vogel et al. [9] analyzed the users' usage patterns and

visualized them utilizing the bicycle rental service in Austria together with the geographical information. Kaltenbrunner et al. [10] also conducted time and spatial analyses 'Bicing' in Barcelona like Vogel et al.[9] and predicted user demands by time of the day for each rental site.

Kim [1] proposed the factors influencing satisfaction of the use for the public bicycle information system, focusing on Seoul public bicycles and utilizing linkage between public bicycles and public transportation in order to improve quality of the citizen's public transportation system service. Yoon et al. [11] proposed the utilization and improvement plan for the public bicycle system "Tashu" in Daejeon city. In order to improve utilization of the public bicycle, they proposed the system operating in connection with public transportation such as bus and subway.

These studies suggest that public bicycles play a role of public transportation and are closely related to public transportation. It implies that it is valuable to link Ttareungyi to public transportation, and to generate various information through the linkage system.

2.2 Environmental Factors Affecting Satisfaction of the Bicycle Use

Won et al. [12] proposed that the quality of bicycle facilities and the bicycle road types have a great effect on the bicycle utilization rate. There are other various environmental factors that affect bicycle utilization, such as quality of bicycle roads, accessibility of major facilities, and diversity of street environments. They also proposed that the utilization of the bicycle is about 1.16% higher when the distance between residence and work place is within 100 meters.

Moon et al. [13] proposed that the bicycle roads of the physical environment affect bicycle utilization. As factors influencing the utilization rate of the bicycle they proposed the bicycle road slope, the road connectivity, the green area ratio, the bicycle road type, the paving type, the illegal parking rate, the road stripe, the speed limit and the traffic volume, etc. Especially, when the bicycle road slope was too steep, or the road connectivity is too low, the utilization rate of the bicycle road was decreased sharply.

Cho et al. [14] proposed that factors affecting satisfaction of the public bicycle use are accessibility to schools and companies, convenience of the kiosk use, connection with the public transportation, rationality of usage fee and cost reduction of the public transportation. They also suggested that these influential factors can be used as data for development of the public bicycle information system.

In addition to the factors presented in the study, there are a variety of factors that can affect satisfaction of the public bicycle use. If Ttareungyi utilization data are processed for the public satisfaction by the database system [15] and produces useful information, it can be also an important information resource for determining the development direction of the system.

2.3 Big Data from the Seoul Metropolitian Government for the Bicycle

Seoul Metropolitan Government provides big data for Ttareungyi User Usage Information, Seoul Bicycle Road Location Information and Seoul Subway Station Location Inquiry with Subway Code Number [5, 6, 7]. The research will use the big data for improvements and user satisfaction of the Bicycle Transportation Database System.

2.4 Related Database Design

Jang et al.[16] proposed a method of designing a database system using irregularization of a relational database, which enabled this research to design the generation of a flexible database system by omitting some of the normalization process of data with limited storage capacity.

3. ARCHITECTURE OF THE BICYCLE TRANSPORTATION DATABASE SYSTEM

3.1 Entity-Relationship Model

The system configuration of the database is as follows. For the Public Bicycle Transportation Database System an entity-relationship model (E-R model) is designed with seven tables: Borough, RentalCenter, RentalLog, TRI (Ttareungi), RentalType, Citizen_Satisfaction and BikeRoad as shown in Fig. 1.

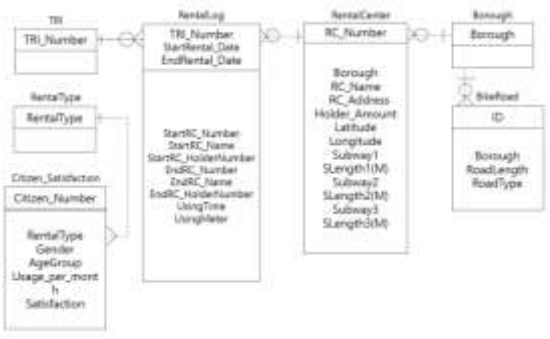

Fig. 1: E-R Modeling of the Bicycle Transportation Database System

The 'Borough' table contains boroughs of Seoul which has 25 districts, used in 'BikeRoad' and 'RentalCenter' tables.

The 'RentalCenter' table contains information about Ttareungyi Rental Center which keeps Ttareungyi. This table has location attributes such as a borough, rental center number and name, number of holders for keeping Ttareungyi (every rental center doesn't have the same number of holders), latitude and longitude, and 3 close subway names and the shortest direct distance between the center and the subway. This table can be used to get information of rental centers and rental logs. Plus, this table also provides 3 transferring subway stations where users can use after rent.

The 'RentalLog' table provides log attributes about the person who uses Ttareungyi, the starting place, the destination place, the rent time, length of the rent time. To serve these information, the RentalLog table contains many attributes, such as TRI_Number meaning the Ttareungyi number, StartRental_Date meaning the time when a user starts to rent, StartRC_Number meaning the identification number of the rental center which a user rents from, StartRC_Name meaning the name of the previous element, and StartRC_HolderNumber meaning which holder a user gets Ttareungyi on. And EndRental_Date, EndRC_Number, EndRC_Name, and EndRC_HolderNumber have the same mechanism as starting, but they mean the time and the place that the user returns. Finally, UsingTime and UsingMeter mean that how much time the user uses Ttareungyi and how many meters he/she moves with it. So, this table has overall information about rental like logs, which can be used on making statistics on Ttareungyi, such as total amount of usage, average usage of each Ttareungyi, which center has to be enlarged, and which center tends frequently to rent or return. This table involves valuable information to utilize and is connected with the TRI table and the RentalCenter table not to make log out of them and not to make errors on using them.

The 'TRI' table means Ttareungyi and collects all of Ttareungyi which are now running or fixing.

The 'RentalType' table collects all rental types which users can choose---for group, for 2 hours, for members only, for nonmembers, for games, and for games for 2 hours. The 'BikeRoad' table collects all bike roads of Seoul and classifies types of the bike road such as bike-only, human-bike or bike-car etc.

And the 'Citizen_Satisfaction' table is a relation, which is one of the core tables with the RentalLog table. This table has the user's information and the degree of satisfaction. Its attributes are Citizen_Number which means an identification number of a user, RentalType, Gender, AgeGroup to get information for preferences, Usage_per_month which means the user's average usage per month, and Satisfaction of the user ranging from 1 to 5.

3.2 Implemention of the Database System

Implementation of the system was performed by inserting instances of the public data into the designed E-R model in Fig. 1.

First, to insert the files as the RentalLog instances of the DBMS from the real big data, we split the csv file of the big data with over 780,000 lines during only the first quarter of 2018, which was split by the Java code. Then, we inserted 12 files for the RentalLog instances on DBMS and performed the validation test if cells have the integer data type.

Fig. 2: Java Code for adding Subway Information to the Original Rental Center

Second, we added subway information[7] to the original rental center csv file[4], public data, which is illustrated in Fig. 3 and Appendix 1. The original file didn't contain information of the subways close to the rental center as shown in Fig. 3 (a), and the file with the subway information after executing the Java code is shown in Fig 3 (b).

Third, by executing Java code we made virtual data about citizen information and satisfaction, based on the mean, the standard deviation and the number range of the public data. So, virtual data replaced real data in instances of citizen information and satisfaction since we can't access these data which only management can access.

Fourth, the TRI table has about 20,000 Ttareungyi. The exact number of Ttareungyi can be identified by management.

Finally, the BikeRoad table is based on the public data, but addresses of some roads are duplicated. So, for the address the surrogate key is introduced by ID.

The appropriate instances of these data have been inserted into DBMS, over 870,000 lines. These data will show how to manage the Bicycle Transportation Database System better and to make the database system support public transportation.

Borough	RC_Num	RC_Name	RC_Ad	Holder_	Latitude	Longitude
Gangnam	2301	HyundaiHighSc	Seoul	10	37.52407	127.0218
Gangnam	2302	GyoboTower	Seoul	10	37.50558	127.0243
Gangnam	2303	NonhyunStatio	Seoul	15	37.51152	127.0215
Gangnam	2304	ShinyoungRoya	Seoul	10	37.51253	127.0358
Gangnam	2305	MCM_MainOffi	Seoul	10	37.52064	127.0345
Gangnam	2306	ApgujeongStat	Seoul	30	37.52712	127.0287
Gangnam	2307	ApgujeongOrie	Seoul	10	37.52861	127.0386
Gangnam	2308	ApgujeongPoli	Seoul	14	37.5293	127.0356
Gangnam	2309	CheongdamSta	Seoul	10	37.5189	127.0494
Gangnam	2310	CheongdamMc	Seoul	10	37.52361	127.0402
Gangnam	2311	HakdongRoRar	Seoul	10	37.51777	127.043
Gangnam	2312	HakdongStatio	Seoul	10	37.52058	127.0563
Gangnam	2313	GeumwonBuild	Seoul	10	37.52512	127.0525

(a) before executing

Borough	RC_Nur	RC_Name	RC_Ad	Holder_	Latitude	Longitude	Subway1	SLength1	Subway2	SLength2	Subway3	SLength3
Gangna	2301	HyundaiH	Seoul M	10	37.52407	127.0218	Apgujeon	731	Sinsa	791	Nonhyun	1298
Gangna	2302	GyoboTow	Seoul M	10	37.50558	127.0243	SinNonhy	125	Nonhyun	621	Sapyung	912
Gangna	2303	NonhyunS	Seoul M	15	37.51152	127.0215	Nonhyun	42	Sinsa	500	SinNonhy	779
Gangna	2304	Shinyoung	Seoul M	10	37.51253	127.0358	Hakdong	451	Eonju	559	Gangnam	716
Gangna	2305	MCM_Mai	Seoul M	10	37.52064	127.0345	Hakdong	701	Gangnam	760	Apgujeon	832
Gangna	2306	Apgujeon	Seoul M	30	37.52712	127.0287	Apgujeon	26	ApguRode	1181	Hakdong	1322
Gangna	2307	Apgujeon	Seoul M	10	37.52861	127.0386	ApguRode	232	Apgujeon	1021	Gangnam	1174
Gangna	2308	Apgujeon	Seoul M	14	37.5293	127.0356	ApguRode	529	Apgujeon	747	Gangnam	1338
Gangna	2309	Cheongda	Seoul M	10	37.5189	127.0494	Cheongda	399	Samsung	706	Gangnam	828
Gangna	2310	Cheongda	Seoul M	10	37.52361	127.0402	ApguRode	378	Gangnam	652	Apgujeon	1221
Gangna	2311	HakdongR	Seoul M	10	37.51777	127.043	Gangnam	183	Sunjungre	681	ApguRode	992
Gangna	2312	HakdongS	Seoul M	10	37.52058	127.0563	Cheongda	321	Bongeuns	747	Samsung	815
Gangna	2313	Geumwon	Seoul M	10	37.52512	127.0525	Cheongda	581	Samsung	1213	ApguRode	1214

(b) after executing

Fig. 3: Adding Subway Information to the Original Rental Center

4. REPRESENTATIVE INFORMATION UTILIZING THE BICYCLE TRANSPORTATION DATABASE SYSTEM

The Public Bicycle Transportation Database System can be utilized in various ways from elementary to complicate ways. Utilizing big data, it is possible not only to provide the necessary items, but also to derive new information through linkage among each big data. There are some of useful information extracted from the system, as follows.

4.1 Nearby Subway Stations for Each Rental Center

The implemented database system shows the result of nearby subway station distances for each rental center.' In the example, we retrieved the rental center code number, rental center name, and three Seoul subway stations with distances nearest to the loan bicycle rental center. This useful information can be utilized to find subway stations in connection with the bicycle rental center for commuting and travelling.

4.2 Percentage of Bike-Only-Roads From Bike Roads

Fig. 4 is the pecentage of Bike-only-roads, an example of utilizing bicycle infrastructure data by region. Bicycle roads are one of the important factors in the bicycle usage rate [13], which should be watched in order to increase the utilization rate of the Ttareungyi. The proportion of Bike-only-roads exclusive for bicycle transportation is about 5% of all roads.

Fig. 4: Percentage of Bike-only-roads from Bike Roads

4.3 Percentage of Commute Time Usage of Bicycles

```
SELECT
COUNT
(CASE WHEN DATEPART(HH,StartRental_Date)>='06'
AND DATEPART(HH,StartRental_Date)<'09'
THEN 1 END)*100.0/COUNT(StartRental_Date)
AS [Rush_Hour_Usage(%)],
COUNT
(CASE WHEN DATEPART(HH,StartRental_Date)>='17'
AND DATEPART(HH,StartRental_Date)<'20'
THEN 1 END)*100.0/COUNT(StartRental_Date)
AS [Quitting_Time_Usage(%)],
COUNT
(CASE WHEN (DATEPART(HH,StartRental_Date)>='06'
```

```
AND DATEPART(HH,StartRental_Date)<'09') OR
(DATEPART(HH,StartRental_Date)>='17'
AND DATEPART(HH,StartRental_Date)<'20')
THEN 1 END)*100.0/COUNT(StartRental_Date)
AS [Commute_Time_Usage(%)]
FROM RentalLog;
```

	StartRC_Name	RC_Entropy
1	Yeouinaru Station Exit No. 1	138.2001
2	HongUniv Station Exit No. 2	113.9333
3	TtookIsland Station Exit No.1	97.4444
4	LotteWorldTower	83.6001
5	SungUniv Entrance Junction	71.1333
6	Gunja Station Exit No. 7	64.6667
7	Anam Rotary Junction	62.3556
8	BongramBridge Gyotong Island	61.6222
9	Daebang Station Exit No. 9	58.7556
10	DMC Station Exit No. 9	58.6667
11	ExpressBus Station Exit No. 8	57.9556
12	MapoGu Health Center	56.9778

Fig. 5: Daily Traffic Complexity of Each Rental Center for a Quarter of 2018

Fig. 5 is the result of daily traffic complexity of each rental center during the first quarter of 2018. We can see which region center has the highest utilization rate. In the example, Yeouinaru area using Ttareungyi for the purpose of leisure is the most used. This information will be helpful for relocation problems and infrastructure expansion of Ttareungyi as the example proposed by Schuijbroek et al. [8].

5. CONCLUSIONS

The research designs and implements a database system for bicycle transportation utilizing public big data related to Seoul Bicycle Ttareungyi, and provides the useful production using the system. Through the database creation process with public data, a variety of methods are provided for database design, data collection, production and processing examples, and database utilization.

The research has the meaning in that The Public Bicycle Transportation Database System makes it possible for the user to link riding of the public bicycle to the subway for transportation and using the system in the daily life produces useful information which can be used to improve the bicycle use environment and traffic environment of Seoul city. If we can utilize various public transportation data such as buses and taxis, we can generate useful information that can suggest the better development direction for Ttareungyi and alleviation of the congested traffic.

In the research, there is a limitation in obtaining transportation data, since the database system is constructed by using only data open to the public. And, when more big data is added to the system in the future, deterioration of data quality should be avoided, for which more sophisticated integrated model design and data refinement will be required [17, 18].

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Appendix 1. Java Code for Nearby Subway Stations for Each Rental Center

```
package data1;


import org.apache.poi.hssf.usermodel.*;

import java.io.*;

import java.util.HashMap;

import java.util.Iterator;


public class DataBase4 {

   public static void main(String[] args){

      long startMills = System.currentTimeMillis();

      DataBase4 dataBase4 = new DataBase4();


dataBase4.runCSVtoXLS("E:\\JAVA\\CSV\\RentalOriginal.
csv", "E:\\JAVA\\CSV\\Stations.csv",
"E:\\JAVA\\CSV\\RentalCenter.xls",3);

      dataBase4.printRuntime(startMills);

   }



   private void printRuntime(long startMills){

      System.out.println("\n[Runtime] :
"+((System.currentTimeMillis()-startMills)/1000.0)+" sec");

   }



   private void runCSVtoXLS(String input, String station,
String output, int repeatMax){

      int rowNum=0,cellNum=0; String
line,mapTempName,minStaticnName; String[] lineTemp;
```

```
        HashMap<String, double[]> tempMap,hashMap =
getStationsXY(station);

        double tempLength,minLength,tempX,tempY;

        double[] tempDoubles,minDoubles,mapTempDoubles;

        HSSFWorkbook workbook; HSSFSheet sheet;
HSSFRow row; HSSFCell cell;

        workbook = new HSSFWorkbook();

        sheet = workbook.createSheet("sheet1");

        try {

          BufferedReader br = new BufferedReader(new
InputStreamReader(new FileInputStream(input),"euc-kr"));

          lineTemp = br.readLine().split(",");

          row = sheet.createRow(rowNum++);

          for (int i=0;i<lineTemp.length;i++){//Create first line

            lineTemp[i] = lineTemp[i].replaceAll("'","");

            lineTemp[i] = lineTemp[i].replaceAll("\"","");

            cell = row.createCell(i);
cell.setCellValue(lineTemp[i]);

          }

          for (int repeat = 0; repeat<repeatMax;repeat++){

            cell = row.createCell(7+2*repeat);
cell.setCellValue("Subway"+(repeat+1));

            cell = row.createCell(8+2*repeat);
cell.setCellValue("SLength"+(repeat+1)+"(M)");

          }

          while ((line = br.readLine())!=null){

            lineTemp = line.split(",");

            row = sheet.createRow(rowNum++);

            setOriginContents(lineTemp,row);

            tempMap = new HashMap<>(hashMap);

            for (int repeat=0;repeat<repeatMax;repeat++){

              minLength = 99999; minStaticnName = "-";
minDoubles = null;

              Iterator<String> mapIterator =
tempMap.keySet().iterator();

              try{

                tempX = Double.parseDouble(lineTemp[5]);

                tempY = Double.parseDouble(lineTemp[6]);

                tempDoubles = new double[]{tempX,tempY};

              }catch (NumberFormatException nfe){

                throw new
NumberFormatException("!!NumberFormatException!! -
Go to <"+input+"> - "+(rowNum+1)+" lines  :
"+lineTemp[2]+" <"+lineTemp[5]+","+lineTemp[6]+">"

);

              }

              System.out.println("[Find near subway] ----- now
"+(repeat+1)+" times "+(rowNum+1)+" line"

);

              while (mapIterator.hasNext()){

                mapTempName = mapIterator.next();

                mapTempDoubles =
tempMap.get(mapTempName);

                tempLength =
getLengthOfDoubles(tempDoubles,mapTempDoubles);

                if (tempLength<minLength){ // if you find new
minimum length

                  minLength = tempLength; // get that length
as minLength

                  minStaticnName = mapTempName; // get
that station name as minStationName

                  minDoubles = tempDoubles; // get that
location coordinates as minDoubles

                }

              }

              if (minDoubles!=null){

                cell =
row.createCell(lineTemp.length+2*repeat);cell.setCellValue(
minStaticnName);

                cell =
row.createCell(lineTemp.length+1+2*repeat);cell.setCellVal
ue(getXYLengthtoMeter(minLength));

                tempMap.remove(minStaticnName);

                System.out.println("On tempMap, enter
<"+minStaticnName+"> and remove"

);

              }
```

```
            }

        }

        FileOutputStream fileOutputStream = new
FileOutputStream(output);

        workbook.write(fileOutputStream);

    }catch (Exception e){}

  }

  private void setOriginContents(String[]
lineTemp,HSSFRow row){

    HSSFCell cell;

    for (int i=0;i<lineTemp.length;i++){//Create original

      lineTemp[i] = lineTemp[i].replaceAll("'","");

      lineTemp[i] = lineTemp[i].replaceAll("\"","");

      cell = row.createCell(i);

      cell.setCellValue(lineTemp[i]);

    }

  }

  private int getXYLengthtoMeter(double lengthOfXY){

    return (int)(lengthOfXY*100000);

  }

  private HashMap<String,double[]> getStationsXY(String
station){

    HashMap<String,double[]> hashMap = new
HashMap<>();

    String line; String[] linetemp;

    try{

      BufferedReader br = new BufferedReader(new
InputStreamReader(new FileInputStream(station),"euc-
kr"));

      br.readLine();

      while ((line = br.readLine())!=null){

        linetemp = line.split(",");

        hashMap.put(linetemp[1],new
double[]{Double.parseDouble(linetemp[7]),Double.parseDou
ble(linetemp[8])});

        System.out.println("[HashMap] Station :
<"+linetemp[1]+">, Location
("+linetemp[7]+","+linetemp[8]+") is added"
);

      }

      System.out.println("\n[HashMap] the number of
stations : "

+hashMap.size());

    }catch (Exception e){}

    return hashMap;

  }

  private double getLengthOfDoubles(double[] origins,
double[] stations){

    double returnDouble = 0;

    returnDouble = Math.sqrt(Math.pow(origins[0]-
stations[0],2)+Math.pow(origins[1]-stations[1],2));

    return returnDouble;

  }
}
```