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# APPLICATION OF SMART CELLS TO SPATIAL PLANS

KRIHS Korea Research Institute for Human Settlements

## APPLICATION OF SMART CELLS TO SPATIAL PLANS

The study aims to devise ways of applying smart cell to spatial policies. Smart cell, mobile phone big data, is the minimum unit in which individual spatial information is identifiable in real time.

Developing countries can use smart cells to build social statistical databases, as such nations tend to lack basic statistical data on their populations and economically active people due to underdeveloped social institutions and budget constraints. Furthermore, smart cells can be incorporated into emergency prevention and response systems. Mobile big data is an automatic data collection system based on mobile phones that enables constant monitoring of how many people in a given area are at risk from natural and social disasters.

*This report referred to the materials of the e-learning and the workshop under the project performed by the Korea Research Institute for Human Settlements and financed by the World Bank Group Open Learning Campus (World Bank Group Open Leaning Campus. 2016. 2016 KRIHS-WBG/OLC Blended Learning Workshop on Sustainable Urban Land Use Planning and Management).*

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# APPLICATION OF SMART CELLS TO SPATIAL PLANS

KOREA RESEARCH INSTITUTE FOR HUMAN SETTLEMENTS SPECIAL REPORT 2016

KRIHS

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- Logistics System Development Strategies for Cambodia, 2016, MOSF
- Comprehensive National Road Plan, 2016, MOLIT
- The Application to Smart cell to Disaster Management, 2015, KRIHS
- The Application to Smart cell to Space Policy, 2014, KRIHS
- Transport Investment Policy by Comparison with Transport Cost of Each Scenario, 2013, KRIHS
- The Increasing Effectiveness of Legal Transportation Planning System in Seoul Metropolitan Area, 2013, KRIHS
- The Reduction Effect of Air Pollution by Promoting Green Transport Mode, 2009, KRIHS
- Feasibility Study on Honam Express Railway Construction, 2005, MOLIT
- Effects of Transport Environment Improvement by Integrating BRT and Road Pricing Measures, 2004, KRIHS

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# Summary

The operational definition of a smart cell and the process of producing information about smart cells can be understood as follows for the purposes of this study. A smart cell is the minimum unit of territory in which individual spatial information (e.g., personal characteristics and location) is identifiable in real time.

Smart cells can track the behavior of individuals through space by means of lines (representing movement) and dots (representing individuals), which can be seen moving in and out of smart cells. Data for this purpose are collected by mobile phone base stations and processed by wireless service carriers.

Smart cells have a number of applications in transportation and spatial planning policy, as data from smart cells are scalable and can thus be extrapolated to different spatial hierarchy levels such as towns and regions.

This research sought to analyze activity in the Seoul metropolitan area along gender and age lines at different times of the day. The central focus of activity in the city was found to shift over the course of a day, from Seoul's south side at 7 a.m. to north side by noon, and back south again by 6 p.m.

On the demographic distribution for age groups, the analysis showed greater activity in southern Seoul among men, whereas women were more active in the city center.

This study tracked human activity in real time in Gangnam-gu (ward), an upscale and busy area in southern Seoul, using mobile big data generated by smart cells. Human activity, the survey found, was highly concentrated near subway stations, especially Gangnam and Yeoksam. Weekend activity was also monitored in and around Seoul Land, one of the capital region's most popular amusement parks, and parking lots saw peak levels of congestion Saturdays between noon and 3 p.m.

Smart cells are likely to prove extremely helpful in the event of a natural disaster or other emergency thanks to its ability to provide real-time information on human activity in a specific location, including the number of people and their precise coordinates. This study evaluated the utility of smart cells in a hypothetical disaster scenario in which an extreme heat wave hits Jongno-gu, an administrative ward in central Seoul. In the event of a predictable, slow-occurring disaster such as extreme heat wave, smart cells have applications in three stages: the advance warning stage, in which authorities issue an excessive heat advisory and urge appropriate precautions; the emergency stage, in which they prepare to evacuate people in high-risk areas; and the evacuation stage.

The scenario analysis demonstrates that smart cells can be used in developing countries in the following four ways:

First, smart cells can help build statistical databases for the purpose of better understanding population trends and the habits of the economically active population. Developing countries tend to lack basic statistical data on such matters because of budget constraints and underdeveloped social institutions. As this study shows, wireless carriers' databases and mobile big data can possess significant information about human activity in any country with a high rate of mobile phone penetration. By using smart cells to gather basic social statistics that could otherwise be obtained only through surveys, developing countries stand to save significant time and costs.

Smart cells also enable spatial planners to implement policies at different levels within the spatial hierarchy (e.g., nation, region or city). National territorial policy transcends boundaries such as those between new and old city centers. Smart cells can help achieve policy objectives at different levels in the spatial hierarchy; it commands high value for macro spaces such as countries and regions, as well as micro spaces such as towns and districts.

Smart cells also have business applications. Merchants who wish to start small businesses can preemptively use the data to reduce their risk of failure. Equipped with a clearer understanding of trends in human activity in a given area, entrepreneurs can be better prepared to serve their potential markets. In developing countries, many new entrepreneurs have recently moved to large cities and lack knowledge about their respective markets. Information obtained through smart cells can prove indispensable for such a purpose.

Furthermore, smart cells can be incorporated into disaster prevention and response systems. Mobile big data is a mobile phone-based system of automatic data collection that enables constant monitoring of the number of people in a given area who are especially vulnerable to a natural or social disaster. Continuous monitoring is an effective tool for disaster prevention in regions at high risk of natural or social disaster. Developing countries with insufficient databases for basic statistics can use smart cells in the event of a disaster to forecast the number of casualties and devise effective responses. In the event of a disaster, this technology can send to emergency response teams highly reliable information in a timely fashion to expedite the decision-making process and minimize casualties.

CHAPTER 1.

# Overview of Research

## 1. Background and Objectives

In 2013, Korea's rate of mobile phone penetration was 1.07 devices per capita. Smartphones accounted for 69 percent of the mobile phone market, greatly outpacing feature phones (31 percent). The number of smartphone subscribers reached 35.56 million, indicating that the country could soon reach its long-awaited milestone of one smartphone for every person. In 2013, the volume of all mobile phone data traffic skyrocketed 210 percent year on year to 73,000 terabytes per day,[01] thanks to greater market penetration of smartphones, devices that offer a variety of mobile apps in addition to voice calls. The resulting convergence between the IT and human spheres has enabled the production of dynamic information about static territory. Dynamic spatial information, deliverable by smart cells, encompasses human activity in a specific area on a given day of the week at a given hour of day, thereby adding diversity to the tools available to spatial planners. Such information also allows change in the existing top-down policy model for construction of neighborhood infrastructure in favor of a more innovative model in which people take the initiative.

01. A terabyte is a measure of computer storage capacity of approximately 1,000 gigabytes.

As shown in this study, population-level big data acquired through smart cells, by matching spatial information with that of mobile phones, marks the starting point toward real-time tracking of national territory. Due to limitations in capturing the daily lifecycles of individuals, formulation of spatial policies that connect with the people has proven difficult. Yet at a time when almost everyone in Korea has a mobile phone, phone-based big data can be instrumental in identifying demographic movement and daily life cycles and capable of doing so in real time. By identifying the real-time spatial distribution of mobile phone users, this information solves significant problems for spatial planners and is truly a high value-added product.

In addition, systematic approaches are needed to develop a new concept of spatial planning policy in this age of sensible space. New approaches require the creative analysis of new forms of information, in this case, the convergence of information on individual behavior and space generated by information and communications technology (ICT).

## 2. Research Objective

The study seeks to devise ways of applying smart cell-based mobile phone big data to spatial policies created by social nexuses. To this end, we looked at the smart cell concept and reviewed related data, analyzed the dynamic distribution and changes in population active in a given area, and suggested a direction for the development of spatial planning policy based on smart cells.

## 3. Research Data

**02.** SK Telecom
**03.** 890,000 cells x seven days/week x 24 hours/day = 14,952

The spatial scope of analysis is the Seoul metropolitan area, which has large economically and socially active populations and can thus be expected to undergo dynamic changes in patterns of human activity. Such patterns vary according to day of the week and time of day. Leveraging the advantage of smart cells that are scalable and accordingly lend themselves both to micro and macro analyses, the study looked at different levels of the spatial hierarchy: the Seoul metropolitan region, other cities, counties (*gun*) and wards (*gu*), and individual facilities. SK Telecom collected the big data used in this research[02] from 890,000 cells in the Seoul area in November 2013. The big data file consists of 150 million data points occupying 10 gigabytes of space.[03] The analysis sought to determine the characteristics of people active in a given cell area over the course of a week and that of a day. Cell data refers to location information and human activity patterns for each day of the week and each hour of the day in the form of geographic information system (GIS) data.

**Figure 1. Seoul Metropolitan Area (887,323 smart cells)**

CHAPTER II.

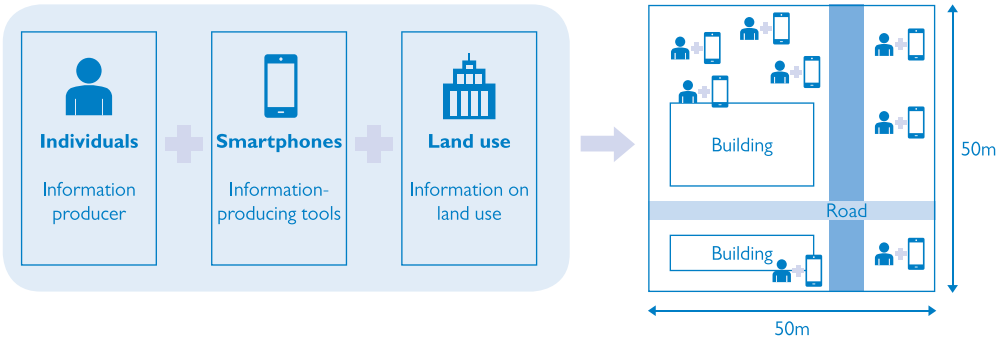
# Smart Cell Concept

## 1. What Is a Smart Cell?

A smart cell is defined as the minimum unit of territory in which it is possible to determine the number of people active in a given location. For instance, the Seoul metropolitan region comprises 890,000 smart cells, each measuring 50 square meters.[04] Smart cell data encompasses demographic structure (age and gender ratio), location (coordinates) and spatial information (e.g., administrative hierarchy); these are generated by the activities of mobile phone users such as voice calls, data transmission, text messaging and physical movement.

**04.** Spatial scope of data provided by SK Telecom

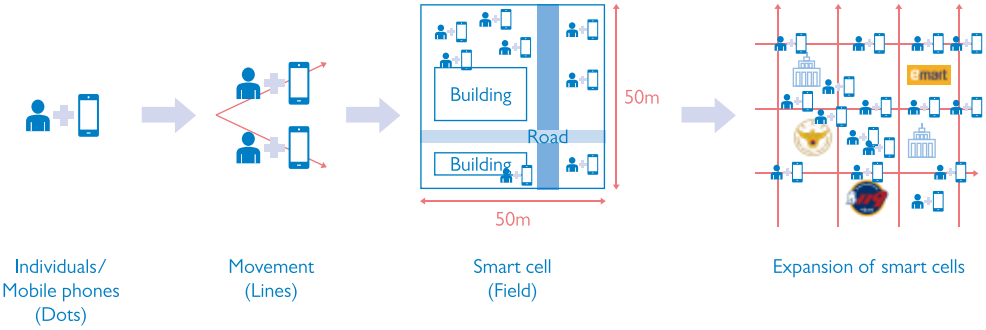
**Figure 2. Conception of Smart Cell**




Source: Jonghak Kim, et al. (2014).

**Figure 3. Information Production Process of Smart Cells**

Source: Jonghak Kim, et al. (2014).

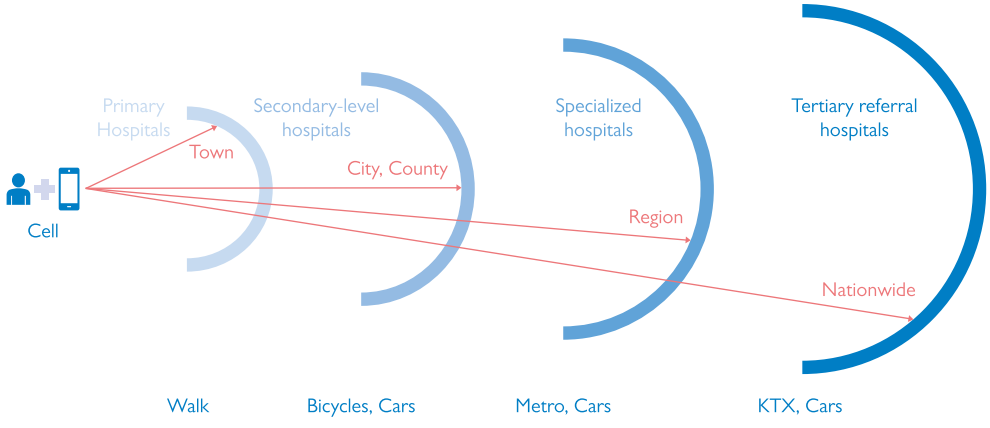



Smart cell information can be classified as static or dynamic. Static information includes smart cell locations and use of the surrounding land, whereas dynamic information includes the incoming and outgoing movement of individuals active in a given area and their gender and age characteristics.

The smart cell concept is spatially scalable; it can be extrapolated to micro spaces such as parking lots and also to macro spaces such as counties, cities and regions. This scalability makes it possible to apply consistent data when formulating spatial planning policy.

**Figure 4. Scalability of Smart Cell Concept**

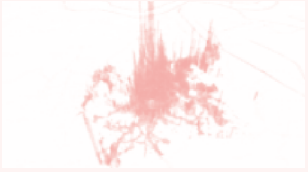
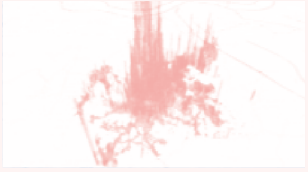
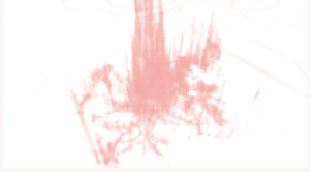
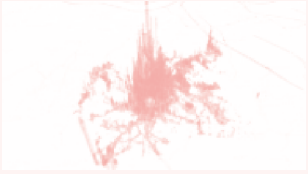
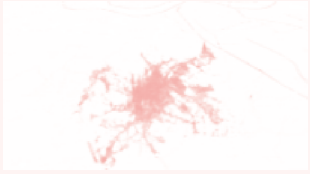
Source: Jonghak Kim, et al. (2014).



## 2. Setup of Mobile Big Data

This research sourced data sanitized to mask personal information from the wireless carrier SK Telecom and aligned the data with geographic information. Data from a wireless carrier originates from a grid of base stations. Raw data from mobile phones can produce processed data in 15-minute increments. This research has set up a dataset for analysis by structuring existing information on geography and disasters in a way that aligns raw big data provided by SK with geographic information. The data structuring process is done through coordinate system alignment and spatial joint that matches mobile big data to locations of a given facility.

**Table 1. Mobile Big Data: Case Study of Gwacheon**

| Time | Active population by hour of day | |
|---|---|---|
| **Morning** |  06:00 |  09:00 |
| **Afternoon** |  Noon |  17:00 |
| |  21:00 |  21:00 |

# 3. Characteristics of Mobile Big Data

## 3.1 Applicability to Diverse Levels in Spatial Hierarchy (Spatial High Resolution)

Smart cells are distinguishable by its applicability to diverse levels in a spatial hierarchy. Cell-based data is applicable regardless of whether the spatial unit is an apartment complex or vast region within a country. Accordingly, applications can vary from small-scale events such as a leak of toxic substances at a chemical plant to large-scale events such as a radioactive leak at a nuclear power plant.

## 3.2 Real-time Information Building (Temporal High Resolution)

Smart cells enable the collection and storage of information in real time, as data production corresponds to mobile phone use. Statistical data represents information specific to a given period, whereas mobile big data is fluid; thanks to an automatic data collection system, it can be broken down for analysis according to season, month, day of the week and time of day. This sort of real-time information building enables timely responses to emergencies.

## 3.3 Resident vs. Dynamic Populations

Smart cells provide insight into human activity in a given area. Mobile phone big data can generate demographic information such as the number of people active in a certain area, their gender and age distributions, and where they live and work. Should a contagious disease break out such as severe acute respiratory syndrome (SARS), Middle East respiratory syndrome (MERS) or a livestock disease, its spread can be tracked through space by looking at the movements of people (or animals) active in the affected areas and identifying their places of residence.

CHAPTER III.

# Spatial Distribution of Human Activity Centers

## 1. Human Activity in Seoul Metropolitan Area: Shifting Centers of Gravity

This study tracked the busiest centers of activity in the Seoul metropolitan area, measuring which areas saw the greatest levels of human activity at different times of the day using mobile information from the area's 890,000 smart cells. Centers of activity are distinct from those of population in that the underlying data pertains to mobile phone use rather than resident populations. The central points of activity were calculated on the basis of the following formula, and those in the Seoul metropolitan area differed on weekdays and weekends and also according to time of the day.

$$\overline{X_K} = \frac{\sum_{i=1}^{n} p_{iK} x_i}{\sum_{i=1}^{n} x_i} \qquad \overline{Y_K} = \frac{\sum_{i=1}^{n} p_{iK} y_i}{\sum_{i=1}^{n} y_i}$$

Note:
*i*: Total no. of smart cells (890,000)
*k*: Time range of activities (00:00-23:00)
*pix*: Active population
$x_i$: *i* Smart-cell coordinate *x*-value
$y_i$: *i* Smart-cell coordinate *y*-value

Microsoft Power Map was used to assign coordinate values (geocoding) and track changes in locations in real time. This study used smart cell data to analyze how the central points changed, depending on the day of the week and time of the day.

## 1.1 Human Activity in Seoul Metropolitan Area: Changes in Entire Region

This study reviewed changes in the central points of activity for different times of the day and different days of the week, and found that the central points of activity shifted along the north-south axis rather than the east-west axis. The average travel distance was 2.1 kilometers north along the north-south axis, far higher than 0.5 kilometer west along the east-west axis.

The shift of activity from south to north in the Seoul area corresponded to the northward movement of commuters living in densely populated southern suburbs such as Seongnam, Anyang, Suwon, Yongin and Hwaseong. In addition, the northern part of the capital saw less human activity than the southern part, resulting in a south-to-north shift in demographic movement.

From noon to 8 p.m., a time range of the main business hours, the central point of activity was near Haengrim Elementary School in the Sadang-dong neighborhood of Seoul. Activities centered on workplaces during business hours, resulting in marginal changes in the central points of activity compared with other time ranges.

The central point of activity moved north at 8 p.m. and stayed there until midnight before moving south again. People were active primarily in the northern part of the capital area after typical office hours and then moved south to suburban residential areas.

Centers of activity for different time ranges differed on weekends and weekdays. Weekday activity was concentrated between 10 a.m. and 9 p.m., reflecting peak times for work activities, whereas people were most active between 8 a.m. and 6 p.m. on weekends.

**Figure 5. Changes in Central Points of Activities by Hour of Day: Weekdays vs. Weekends**

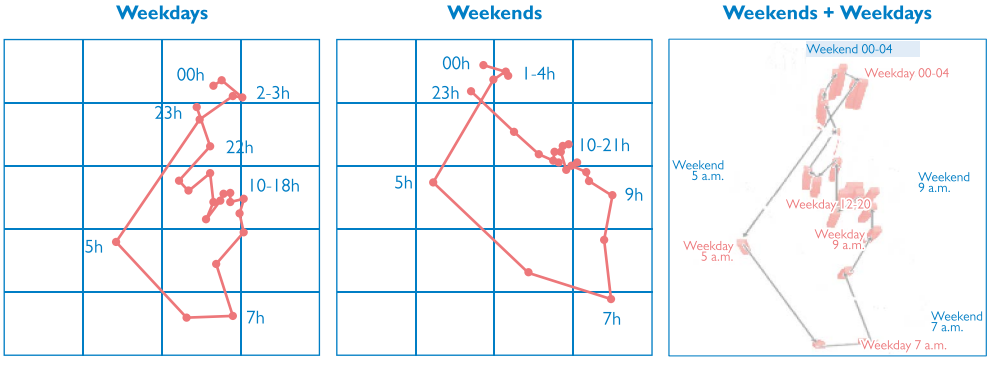
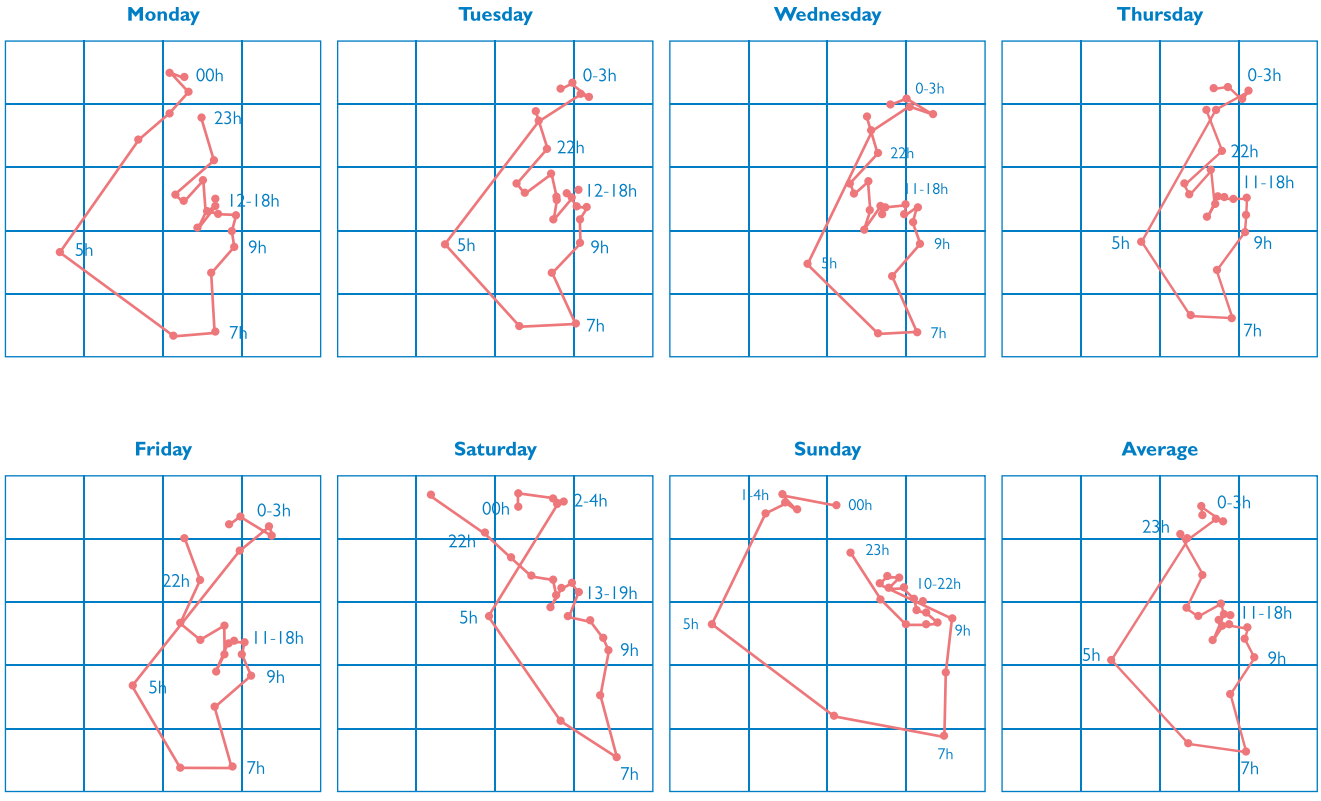


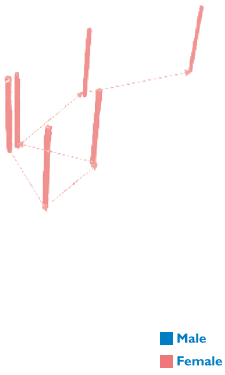
**Figure 6. Changes in Central Points of Activities by Hour of Day: Day of Week**




## 1.2 Central Points of Activity in Seoul Capital Area: Gender and Age Breakdown

This study analyzed demographic activity trends during weekdays along gender and age lines. For people in their 20s through to 50s, the central points of activity in the Seoul metropolitan area showed a visible north-south divide between men and women, with women being more active in the north and men in the south. The central points of activity for teenagers of both genders overlapped with those for 40-something women, most likely reflecting similar spatial patterns for stay-at-home mothers and middle and high school students. In addition, the central point of activity for men in their 50s corresponded with that of women in their 20s.

**Figure 7. Changes in Central Points of Activities by Hour of Day: Gender and Age Group**




## 2. Distribution of Active Population in Gangnam-gu: Place of Residence

This study looked at the distribution of mobile phone subscribers active in Gangnam-gu, one of the best known districts in Seoul, by place of residence. The analytical data consisted of SK Telecom customers' billing addresses[05] and travel distance from Gangnam-gu to their cities, counties (*gun*), or wards (*gu*) of residence based on traffic demand analysis.

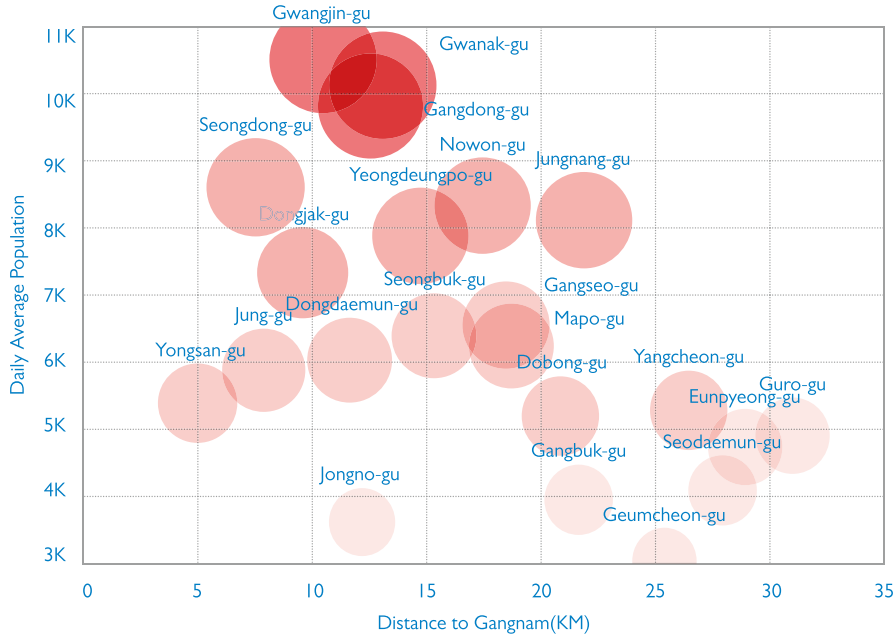
Given the massive inflow of people into Seoul, this study divided mobile phone subscribers active in Gangnam-gu into four groups according to place of residence: Seoul, Gyeonggi Province, Incheon and other regions. According to the analysis, Seoul ranked the highest at 57.2 percent, followed by Gyeonggi (25.5 percent), other regions (14.2 percent) and Incheon (3.1 percent). That is, of 10 people active in Gangnam-gu, 8.6 resided in the Seoul metropolitan area and 1.4 in other regions.

**05.** Billing addresses identifiable only at city, country (*gun*) and ward (*gu*) levels.

### 2.1 Distribution by Place of Residence Seoul

This study looked at the residency status of people who lived in Seoul and were active in Gangnam-gu. The three most represented districts in Seoul, accounting for 53 percent of human activity in Gangnam-gu, were Gangnam-gu, Seocho-gu and Songpa-gu, followed by other districts in close proximity to Gangnam-gu. Downtown districts such as Jung-gu and Jongno-gu, despite their proximity to Gangnam-gu, were underrepresented due to their small populations.

**Figure 8. Distribution of Population Active in Gangnam-gu: Seoul Residents by District**




Note: Excluding Gangnam-gu, Seocho-gu and Songpa-gu

## 2.2 Distribution by Place of Residence: Gyeonggi Province and Incheon

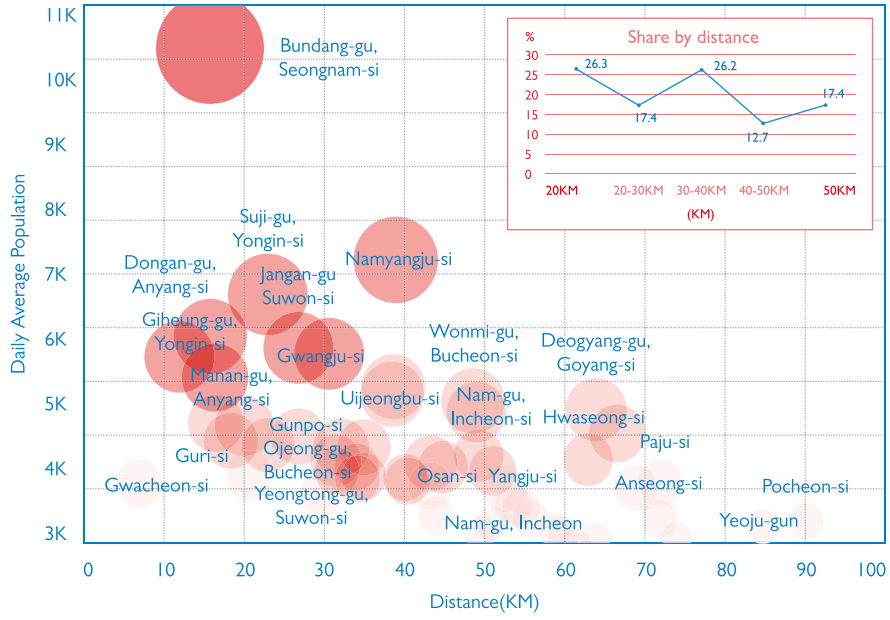
We then looked at human activity in Gangnam-gu to see what proportions of its active population came from different parts of Gyeonggi Province and nearby Incheon. The ward of Bundang-gu in Seongnam ranked highest at 9.7 percent, followed by the city of Namyangju at 5.6 percent and the ward of Suji-gu in Yongin at 4.9 percent. That is, for every ten Gyeonggi residents active in Gangnam-gu, one was visiting from Bundang-gu.

For intercity transportation, this study categorized the proportion of people active in Gangnam-gu but living in Gyeonggi or Incheon according to travel distance to their places of residence. Residents of areas in Gyeonggi and within 20 kilometers of Gangnam-gu—for instance, Gwacheon, Bundang-gu (in Seongnam), and Dongan-gu (in Anyang)—comprised 26.3 percent of the total. Those from areas 20-30 kilometers away—for example, the cities of Gunpo, Uiwang and Yongin—accounted for 17.4 percent. Residents of areas 20-30 kilometers away from Gangnam-gu—for example, the cities of Ansan, Suwon and Namyangju—made up 26.2 percent. The proportion of people coming to Gangnam-gu from cities situated more than 40 kilometers away such as Siheung, Osan, Gimpo, Incheon and Pyeongtaek was a relatively high 30.1 percent.

Intercity transportation in Gangnam-gu was characterized by even distribution of transportation volume across routes of varying distances. Transportation volume was higher closer to Gangnam-gu, creating traffic congestion. Non-Gangnam-gu residents active there were almost evenly split into two groups: those traveling less than 30 kilometers (50.4 percent) and those traveling more than 30 kilometers (49.6 percent).

In areas such as Gangnam-gu—where traffic volume is evenly distributed across short-, medium- and long-distance routes—improvement of access via public transportation was needed. For example, the number of buses operating on the Namyangju-Seoul route was 396, more than three times that (107) on the Seongnam-Gangnam route that runs parallel to the subway tracks. This demonstrated the need to enhance subway networks in eastern Seoul to divert demand from buses to subways.

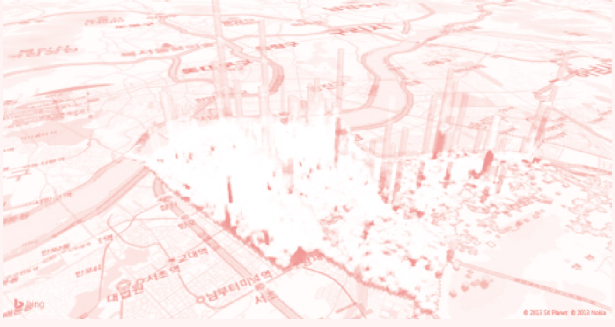
**Figure 9. Distribution of Population Active in Gangnam-gu: Gyeonggi Province and Incheon**




The number of people active in Gangnam-gu peaked at 1.25 million at 5 p.m. weekdays, 2.2 times higher than the number of district residents (570,000). The smart cell with the largest active population in the district was located at Exit 3 of Gangnam Station on the Shinbundang Line (DX Line) in Yeoksam 1-dong. This cell recorded the presence of 2,570 people per hour during morning commuting hours.

During weekdays, the active population in Gangnam-gu tended to be concentrated near subway stations such as Gangnam and Yeoksam.

Among smart cells in Gangnam-gu, the active population peaked at Exit 3 of Shinbundang Line, Yeoksam 1-dong, Gangnam-daero 84-gil.

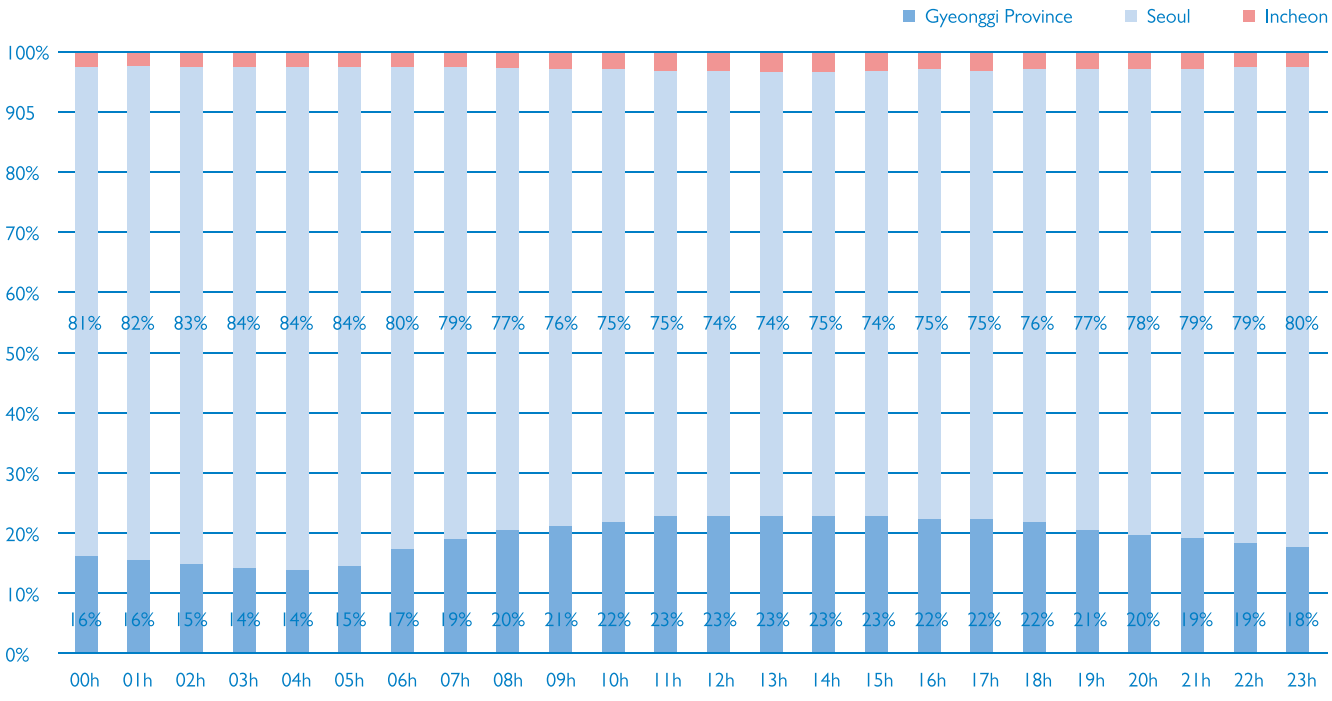


Comparison of active population by hour of day: 09:00 (Red), 17:00 (Blue)

• Of people active in Gangnam-gu, 78.2 percent resided in Seoul, 19.4 percent in Gyeonggi Province and 2.4 percent in Incheon.

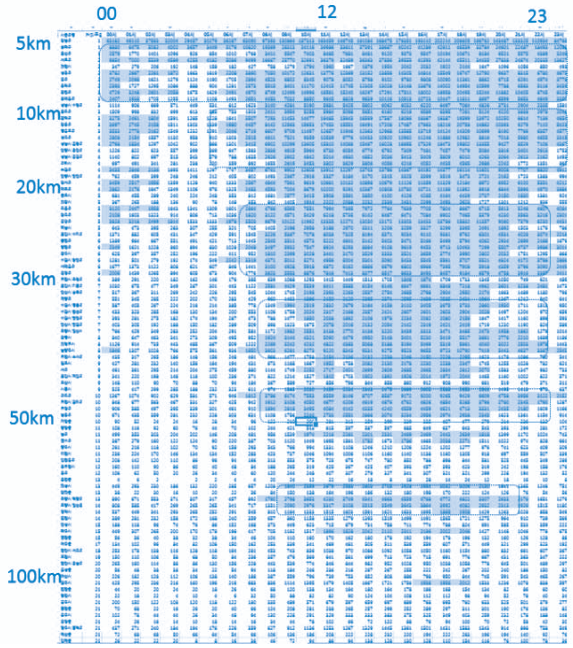
- The proportion of people active in Gangnam-gu and residing in Gyeonggi Province ranged from 14 to 23 percent. That is, about a fifth people active in Gangnam-gu resided in Gyeonggi.

**Figure 10. Distribution of Population Active in Gangnam-gu by Place of Residence: Seoul, Gyeonggi Province and Incheon**




Residents of Bundang-gu in Seongnam, Suseong-gu in Namyangju, Dongan-gu in Anyang, and the cities of Yongin, Gwangmyeong and Goyang were each within the top 10 percent of Gyeonggi residents active in Gangnam-gu. The period of activity was longest for those from Bundang-gu, which is close to Gangnam-gu, lasting from 8 a.m. to 10 p.m. Residents of Goyang and Uijeongbu were most active in Gangnam-gu during afternoon hours.

**Figure 11. Period of Activity in Gangnam-gu by Place of Residence (or Traveling Distance)**




# 3. Changing Centers of Activity in Neighborhood Facilities

## 3.1 Overview

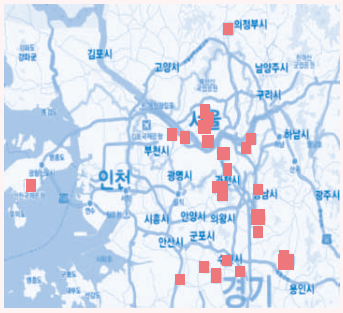
Existing spatial data are structured according to administrative hierarchies. Consequently, surveys until recently were the only way to measure human activity in individual neighborhood facilities. But the smart cells discussed in this research can use micro data to shed light on human activity even in individual facilities.

Neighborhood facilities can be classified into various groups. This study tracked changes in human activity in neighborhood facilities where such activity played a significant role, including transportation, leisure and shopping centers.

This study tested the applicability of smart cell data to user patterns in neighborhood facilities. We selected facilities geographically diverse and representative of the Seoul metropolitan area. Part of this analysis looked at human activity in Seoul Grand Park, one of the area's major amusement parks, with a focus on facilities such as parking lots as well as Seoul Grand Park Zoo. Furthermore, the data visualization method was used to track dynamic hourly changes in the areas surrounding Gangnam Station, the single busiest site in the Seoul metropolitan area.

## Table 2. Changes in Active Population: Neighborhood Facilities

| Type | Facility |
|---|---|
| Leisure facilities | Gyeongbok Palace, Seoul Grand Park, Everland, Yangjae Citizens Forest, Bundang Central Park |
| Transportation facilities | Gangnam Station, Seoul Station, Suwon Station, Uijeongbu Station, Incheon International Airport |
| Shopping facilities | Myeong-dong Lotte Dept. Store, Emart (West Suwon), Seongnam Moran Market |
| University hospitals | Seoul Asan Medical Center, Seoul National University Bundang Hospital |
| Others | National Assembly in Yeouido |




## Table 3. Smart Cell Size by Neighborhood Facility

| Location | No. of smart cells |
|---|---|
| Gangnam Station | 311 |
| Seoul Station | 309 |
| Suwon Station | 309 |
| Uijeongbu Station | 315 |
| Incheon Airport | 183 |
| Gyeongbok Palace | 149 |
| National Museum of Korea | 111 |
| Seoul Grand Park | 414 |
| Yangjae Citizens' Forest | 65 |
| Everland | 501 |
| Lotte Dept. Store (Sogong-dong) | 34 |
| Seongnam Moran Market | 16 |
| Emart West Suwon | 35 |
| Seoul Asan Medical Center | 57 |
| Bundang Central Park | 119 |
| National Assembly in Yeouido | 131 |

Smart cell by facility (part)

Everland



Seoul Grand Park

Seoul Asan Medical Center

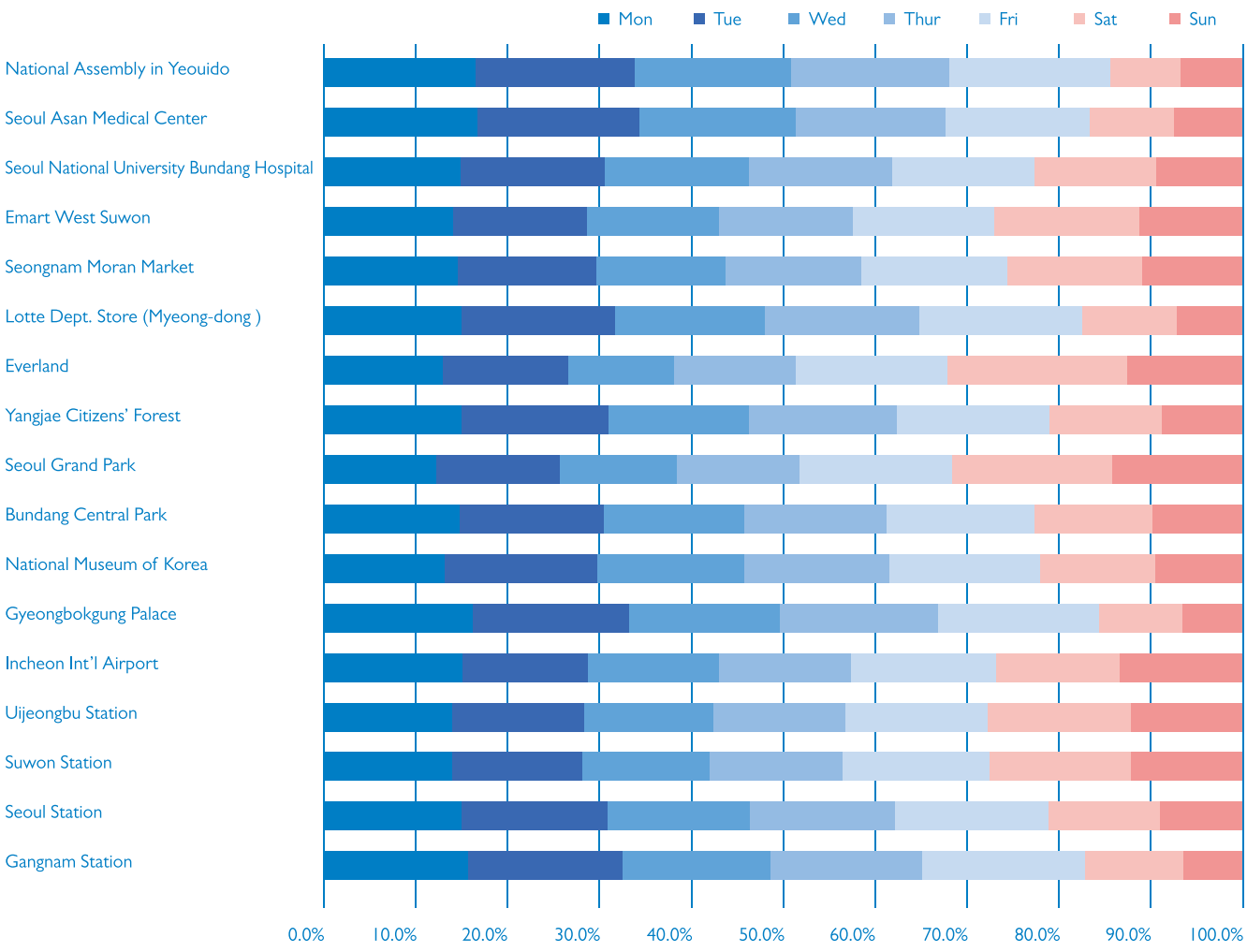
## 3.2 Patterns of Human Activity in Facilities on Different Days of Week

In most facilities, human activity was at its highest level Fridays, followed by Tuesdays. Gangnam Station accounted for the highest proportion of human activity Fridays at 17.7 percent. That is, for every 100 people active in the Seoul metropolitan area on a Friday, 17.7 were near Gangnam Station. In contrast, university hospitals, which see patients only on weekdays, recorded the most activity Tuesdays and Wednesdays. The National Assembly and vicinity accounted for a high proportion of human activity Tuesdays and Fridays. The data suggests that university hospitals had a large number of outpatients Tuesdays and Wednesdays and the National Assembly had many visitors Tuesdays and Fridays. The proportion of all human activity at amusement parks peaked Saturdays, recording 17.4 percent for Seoul Grand Park and 19.5 percent for Everland. Relative to all activity conducted Saturdays, Everland accounted for 36 percent, whereas the corresponding figure for Seoul Land was only 22 percent.

**Table 4. Share of Active Population in Facilities by Day of Week**

| Type of facility | Location | Mon. | Tue. | Wed. | Thur. | Fri. | Sat. | Sun. | Total |
|---|---|---|---|---|---|---|---|---|---|
| Transportation facilities | Gangnam Station | 15.7% | 16.8% | 16.2% | 16.5% | 17.7% | 10.8% | 6.4% | 100% |
| | Seoul Station | 15.1% | 15.8% | 15.6% | 15.7% | 16.8% | 12.0% | 9.0% | 100% |
| | Suwon Station | 13.9% | 14.3% | 13.9% | 14.4% | 16.0% | 15.4% | 12.1% | 100% |
| | Uijeongbu Station | 13.9% | 14.5% | 14.1% | 14.3% | 15.7% | 15.6% | 12.1% | 100% |
| | Incheon Int'l Airport | 15.1% | 13.4% | 14.4% | 14.4% | 15.8% | 13.4% | 13.3% | 100% |
| Leisure facilities | Bundang Central Park | 14.8% | 15.8% | 15.3% | 15.5% | 16.2% | 12.7% | 9.8% | 100% |
| | Seoul Grand Park | 12.3% | 13.6% | 12.7% | 13.2% | 16.6% | 17.4% | 14.2% | 100% |
| | Yangjae Citizens' Forest | 14.9% | 16.1% | 15.4% | 16.0% | 16.8% | 12.1% | 8.8% | 100% |
| | Everland | 13.1% | 13.5% | 11.7% | 13.0% | 16.6% | 19.5% | 12.6% | 100% |
| Shopping facilities | Lotte Dept. Store (Myeong-dong ) | 15.0% | 16.7% | 16.4% | 16.7% | 17.6% | 10.5% | 7.1% | 100% |
| | Seongnam Moran Market | 14.6% | 15.1% | 14.0% | 14.8% | 15.9% | 14.7% | 10.8% | 100% |
| | Emart West Suwon | 14.0% | 14.6% | 14.4% | 14.5% | 15.5% | 15.8% | 11.1% | 100% |
| Hospitals | Seoul National University Bundang Hospital | 14.9% | 15.7% | 15.8% | 15.5% | 15.6% | 13.2% | 9.4% | 100% |
| | Seoul Asan Medical Center | 17.1% | 17.4% | 17.0% | 16.2% | 15.7% | 9.1% | 7.5% | 100% |
| Politics | National Assembly in Yeouido | 16.3% | 17.6% | 17.1% | 17.2% | 17.6% | 7.5% | 6.7% | 100% |

**Figure 12. Share of Active Population in Facilities by Day of Week**




This study applied Power Map's data visualization function to analyze activity patterns for different times of day based on data from smart cells in the area surrounding Gangnam Station. A visual analysis of such patterns was done within a 500-meter radius of the station in every direction (Figure 12). Activity levels fluctuated marginally in the direction of Seocho-gu in the area near the Woosung Apartment complex and Seocho Elementary School, but more significantly near Samsung Building. In the direction of Sinnonhyeon Station, activity levels fluctuated a great deal near Kumkang Shoes and Lotte Cinema, and considerably at Daewoo DiosVil, the Yeoksam Tax Office in the direction of Yeoksam Station, as well as at Exit 3 on the Shinbundang Line in the direction of Yangjae Station.

The visualization of big data is useful given the high level of efficiency and timeliness it offers in identifying temporal and spatial changes in the subject of analysis.

## Figure 13. Changes in Active Population: Smart Cells at Gangnam Station and Vicinity

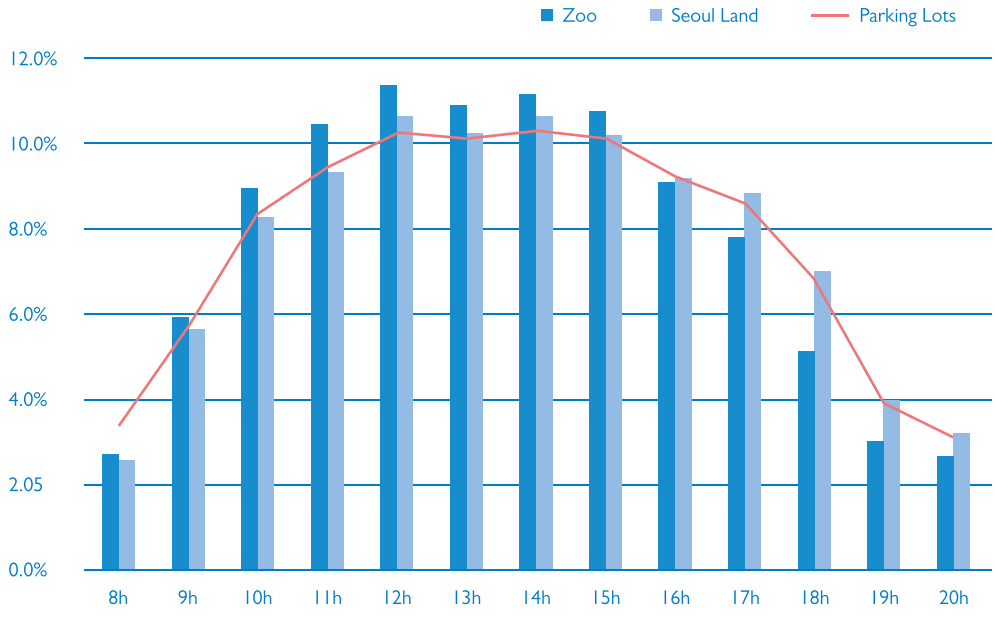
**Active population by time of day**

## 3.3 Distribution of Activity Levels at Seoul Grand Park

This study examined the distribution of activity levels in Seoul Grand Park at different times of day Saturdays, which sees greater activity than other days, and found the largest concentration of human activity and highest levels of congestion between noon and 3 p.m. Over that time period, the concentration ratio of the active population was 44.3 percent at the zoo, 41.9 percent at Seoul Land and 41.1 percent at parking lots.

For the three aforementioned facilities at Seoul Grand Park, human activity levels peaked at noon Saturdays. The concentration ratio of the active population was 11.4 percent at the zoo, 10.4 percent at Seoul Land and 10.3 percent at parking lots. The zoo recorded a high concentration of activity until 3 p.m., after which Seoul Land was busier due to its longer operating hours.

**Figure 14. Share of Active Population at Seoul Grand Park by Time Range and Facility**

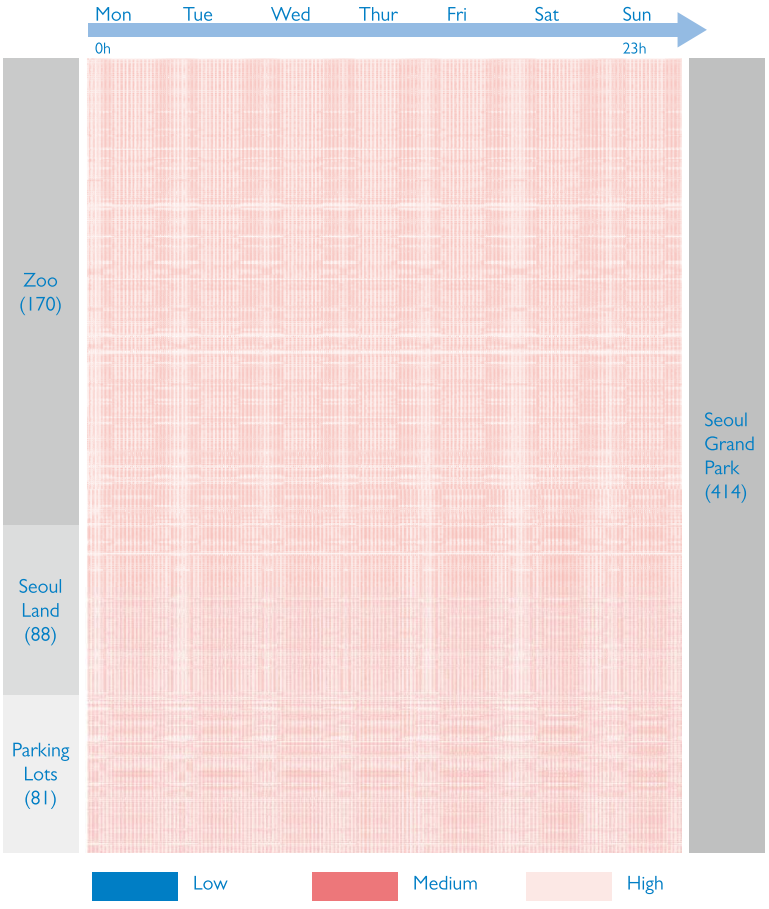



An analysis of activity levels for individual facilities at Seoul Grand Park indicates that smart cell data sheds light on user patterns of activity, and thus gives information on user distribution. A study of seasonal data can be expected to provide real-time information on levels of congestion at individual facilities and can be used to improve convenience by reducing waiting times.

This study tracked the distribution of people active at Seoul Grand Park's three key facilities -- parking lots, Seoul Land and the zoo—for different times of day and days of the week by analyzing heat maps (69,552 units). The parking lots had the densest concentration of visitors, followed by Seoul Land and the zoo. This study compared the active population density in smart cells at the park's three major facilities. The zoo was assigned an active population density level of 1, and researchers estimated

the corresponding figures at 3.1 for Seoul Land and 3.9 for the parking lots. Figure 15 illustrates human activity in smart cells at Seoul Grand Park measuring 50 meters by 50 meters each. Low density regions appear in blue, those of medium density in red and those of high density in pink. As seen in Figure 15, blue prevails at night, whereas red and pink dominate during daytime hours. Seoul Grand Park is mostly rendered red, indicating medium population density, due to its vast area. In contrast, Seoul Land and the parking lots are pink because they are heavily trafficked areas. The presence of red is limited in the zoo, which closes at 6 p.m., but extensive in Seoul Land and the parking lots, which close after 9 p.m.

**Figure 15. Distribution of Active Population at Seoul Grand Park by Time Range**

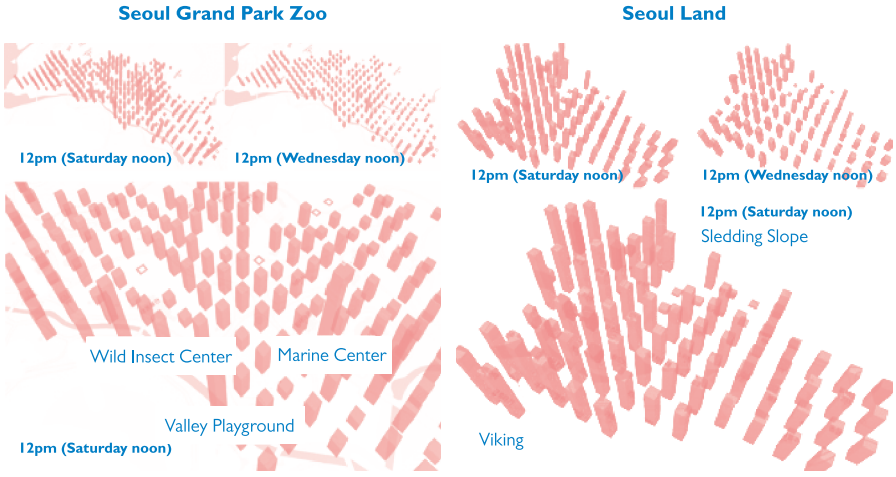


## 3.3 Activity Levels in Seoul Grand Park Zoo and Seoul Land: Distribution of Activity at Various Facilities

Figure 16 compares noontime activity levels at the zoo and Seoul Land Saturdays and Wednesdays. Saturdays saw higher levels of activity than Wednesdays.

With the application of the Power Map tool, smart cell data consisting of geodetic longitude and latitude were processed to produce video images for different times of day and highlight the facilities with the highest levels of activity. Highly trafficked facilities included the Wild Insect Center, Marine Center, and Valley Playground at Seoul Grand Park. At Seoul Land, non-child-centered facilities such as the Viking attracted more activity than children's facilities.

**Figure 16. Active Population in Seoul Grand Park by Key Facility**



CHAPTER IV.

# Use of Smart Cells in Emergency Planning

According to the *Regional Safety Index* released by the Ministry of Public Safety and Security, Jongno-gu earned a Grade 4 assessment in fire safety, indicating a high level of risk. The high daytime concentration of elderly people in the Jongmyo neighborhood suggested that many senior citizens are vulnerable in the event of an emergency. For this reason, this study analyzed dynamic changes in human activity, broken down according to age group, using mobile big data for Jongno-gu.

This study conducted a field study and statistically verified the active population (mobile big data). We also verified differences in the age and time distributions of activity levels using the two-way ANOVA (Analysis Of Variance) method to ensure that the age distribution was statistically significant among the elderly. In addition, this study envisioned a hypothetical disaster in the form of an extreme heat event in Jongno-gu, which has a high concentration of senior citizens who are especially vulnerable to rapid temperature change.

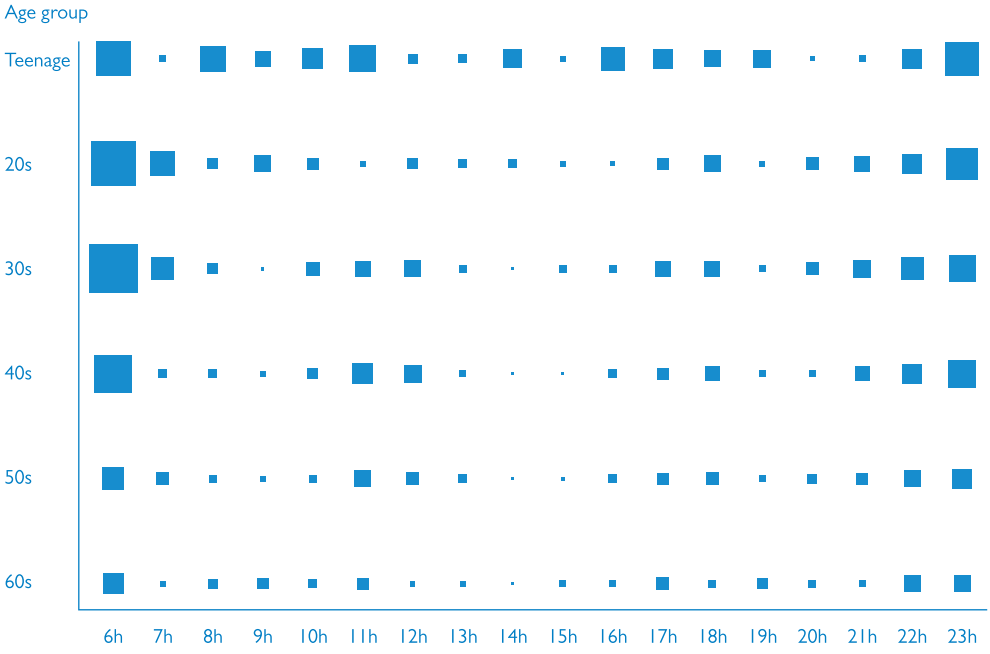
This study analyzed the distribution of human activity levels in Jongno-gu for the aforementioned reasons.

## 1. Central Points of Activity: Age and Time Distribution

This study tracked changes in the central points of activity from one time range to another along age lines, and found that the changes coincided with daily life cycles. Activity rose during the morning hours, slowed later in the day and rebounded in the evening. The findings demonstrate a daily life cycle pattern that evolves from morning hours, when people are waking up, to daytime when day-to-day functions are taken care of, and to night hours, around bed time, through mobile big data.

After examining the age distribution, we found that changes in activity levels were most significant among teens (2.4) and least significant among those in their 60s (0.7). In relative terms, changes in activity levels among people age 60 and older were 29 percent of what we observed among teens. In other words, the mobile big data illustrated a pattern of more varied daily routines among younger people and more static routines among older people. This suggests that emergency facilities at fixed locations can accommodate the elderly as part of disaster response plans.

**Figure 17. Changes in Activity of Population Active in Jongno-gu by Age Group and Time Range**




## 2. Spatial Distribution for Different Age Groups

This study examined the demographic distribution of Jongno-gu to identify the spatial distribution of human activity in the event of a disaster. If pinpointing the distribution of people active in the area at different times of the day was possible, this would ensure greater safety for the elderly and other vulnerable individuals.

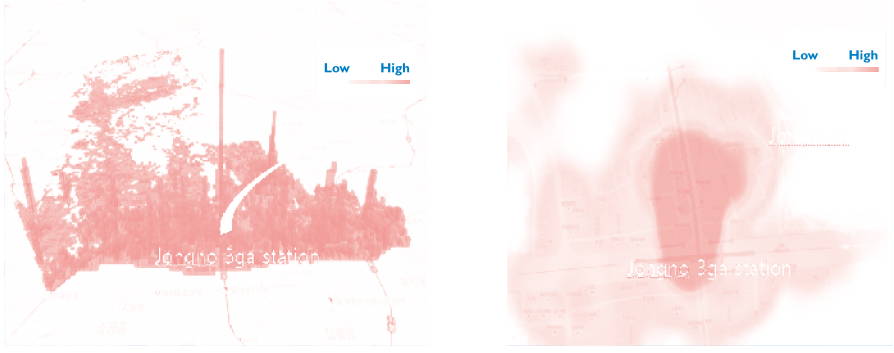
Figure 18 shows the spatial distribution of hotspots that represent activity among different age groups at 3 p.m. on a given weekday. In spatial distribution, teen activity was concentrated in the Gahoe-dong neighborhood, which has many middle and high schools. Activity among people in their 20s and 30s was concentrated in Jongno 5-ga, the 30-40 age group at Jonggak Station, and the 60s age group in Jongno 3-ga, where Jongmyo is located. In a hypothetical family, the average 60-something man might be found in Jongno 3-ga while his son was at Jonggak and his grandson in Jongno 5-ga.

**Figure 18. Distribution of Active Population in Jongno-gu by Age Group: 15:00 on Wednesday**

This research looked at areas with high concentrations of people age 60 or older, who are more vulnerable in emergencies than other age groups. The popular perception is that the elderly is concentrated in areas surrounding Jongmyo during the afternoon, but data has not yet verified this.

This study found a high concentration of elderly at Jongno 3-ga Station (at the exits for the Nos. 1 and 3 lines) on the basis of data. The data confirms the general perception of a high elderly population active in Jongno 3-ga.

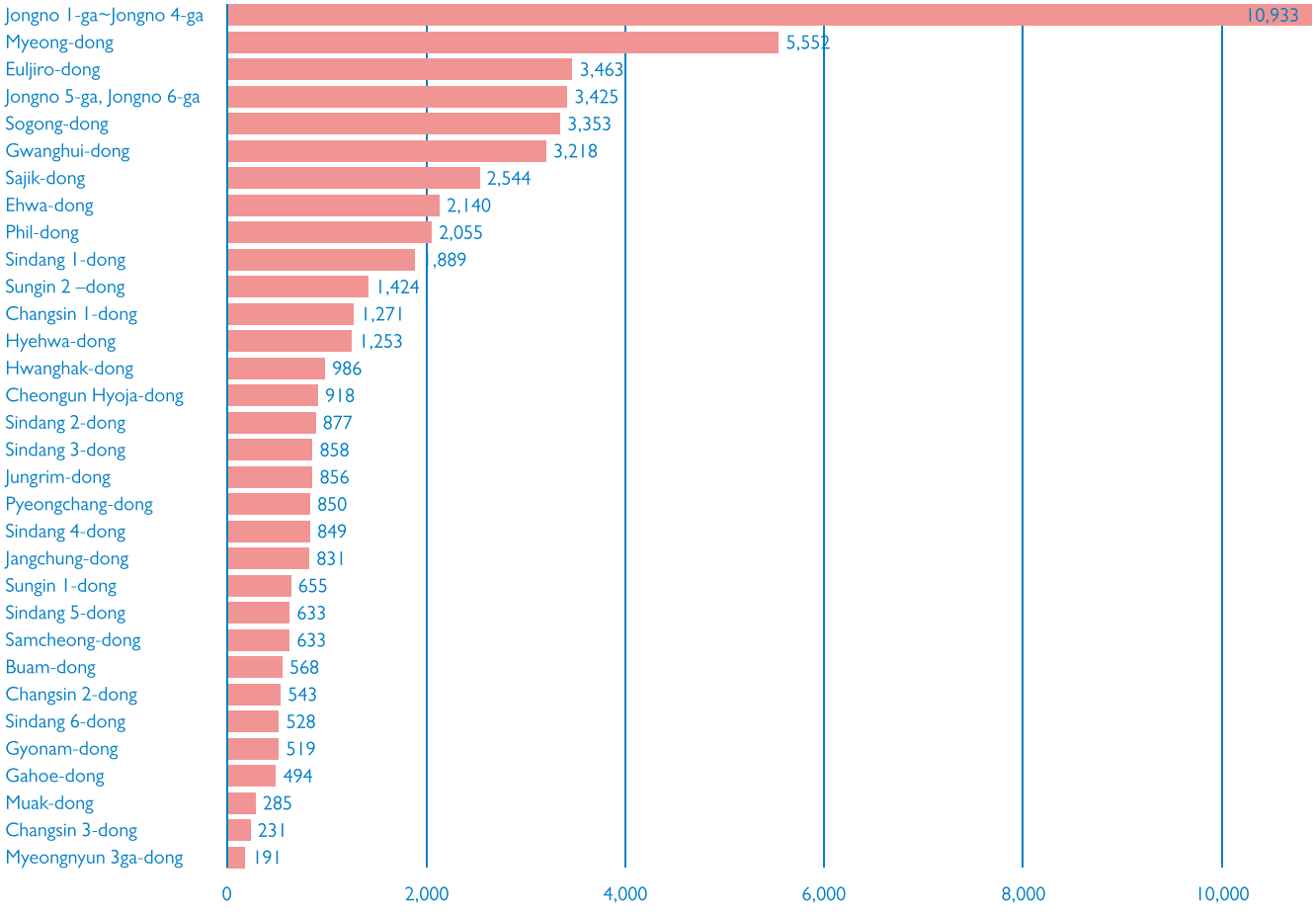
**Figure 19. Distribution of Active Population Age 60 or Older: 15:00 on Wednesday**



This study analyzed the distribution of activity levels among people age 60 or older in 32 legal *dong* (neighborhoods) in Jongno-gu and Jung-gu on the basis of mobile big data.

According to the analysis, human activity stood at 11,000 people per hour in Jongno-gu (i.e., Jongno 1-ga, Jongno 2-ga, Jongno 3-ga and Jongno 4-ga), twice the level seen in Jung-gu (i.e., Myeong-dong). The analysis confirms a high concentration of elderly active in and around Jongno 3-ga.

**Figure 20. Distribution of Active Population: 60-plus Age Group**

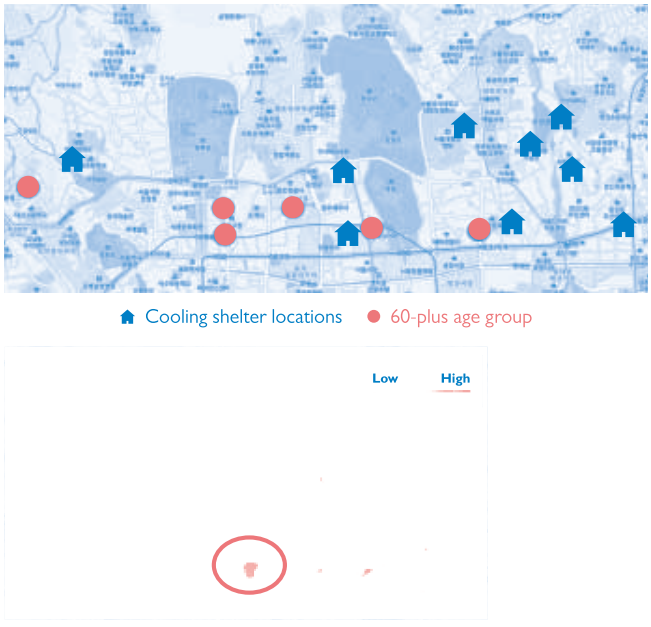


## 3. Distribution of Emergency Shelters in Jongno-gu

As the frequency of extreme heat warnings being issued has risen due to climate change, this study looked at the distribution of senior citizens centers that also serve as cooling shelters in Jongno-gu. As such shelters are located within existing centers, the distribution of their locations does not fully correspond with the distribution of people age 60 and over who are active in the area.

Jongno-gu and the surrounding areas have a number of emergency centers, called 119 centers because 119 is the number to dial in Korea in case of emergency. Centers in areas with a significant elderly population as well as that of other vulnerable people should be better equipped to help them in the event of disaster. Other needs include evacuation, 119 response and hospital ER routes; designation of senior safety zones; enhancement of safety facilities in surrounding areas; and installation of CPR kits.

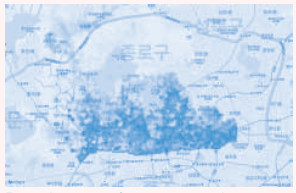
**Figure 21. Distribution of Disaster Shelters and 60-plus Age Group**

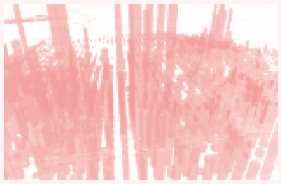


## 4. Analysis of Extreme Heat Scenario

The study examined the use of mobile big data in the event of power outages in Jongno-gu in combination with an extreme heat wave, an increasingly likely scenario given the progression of climate change.

**Table 5. Analysis of Excessive Heat Wave Scenario**

| Timeline | Situation | Prevention & Response | Monitoring of mobile big data | Distribution of active population in Jongno-gu by situation | |
|---|---|---|---|---|---|
| Aug. 2, 2015 | Excessive heat watch issued, when temperature exceeds 33.5C for 2 consecutive days | CBS issues excessive heat alert, sends SMS to encourage elderly to stay indoors | Nat'l Emergency Management Agency (NEMA) asks monitoring of active population in Jongno-gu |  Extraction of cells in Jongno-gu | |
| Aug. 3, 2015 | Excessive heat watch maintained, as temperature stays at 35.1C | - SMS message issued advising against outdoor activities<br>- Excessive heat warning ready for release<br>- Jongno-gu Office makes person-to-person contact to encourage elderly to stay indoors (morning) | Intensive monitoring of areas with high concentration of active population |  Distribution of active population across Jongno-gu | Concentration of active population |
| Aug. 4, 2015 12:31 | Excessive heat warning issued, when temperature exceeds 33.5C for two consecutive days | CBS issues excessive heat alert, sending SMS to encourage elderly to stay indoors (morning) | Monitoring of areas densely populated with elderly & vulnerable |  Concentration of teenage group (Hyehwa Station) |  Population of 60-plus age group active in Jongno 3-ga |

| Timeline | Situation | Prevention & Response | Monitoring of mobile big data | Distribution of active population |
|---|---|---|---|---|
| 14:00 | - Power supply to Jongno 3-ga suspended due to breakdown of power substation in Jongno-gu<br>- Air-conditioning service stops at subway station & buildings | - 119 centers ready for dispatch.<br>- Situation alerted to related organizations<br>- Evacuation orders issued | - Monitoring of changes in population active in Jongno at 5-minute interval<br>- 4,000 people aged 60 or older estimated to be active in Jongno 1-ga to Jongno 4-ga | <br>50,000 people active in Jongno 3-ga at 14:00<br>  <br>35,000 people active in Jongno 3-ga at 14:10<br><br>20,000 people active in Jongno 3-ga at 14:20<br><br>4,000 people aged 60 or older active in Jongno 3-ga at 14:20 |
| 14:30 | Continuation of situation | - Evacuation order issued to areas with high concentration of active population<br>- Mobile big data employed to designate high-priority evacuation areas, reflecting elderly & vulnerable groups | Identify size of active population & age-group distribution by cell at 14:30 in Jongno-gu | <br>Jongno 3-ga with high density of elderly population designated as first evacuation area |
| 15:00 | Three elderly heatstroke cases reported at Jongno 3-ga Station | - Dispatch of 119<br>- Priority-based provision of human resource & supplies | Monitoring of changes in active population in high-priority areas at 15:00 | <br>Monitoring of evacuation status by priority area: Decline in active population confirmed |
| 15:30<br>-<br>16:29 | Forty elderly heatstroke cases reported at Jongmyo | - Provision of human resources & supplies at Jongmyo<br>- Support of 119 centers in surrounding areas | Monitoring of evacuation situation | <br>Estimating remaining evacuees |
| 16:30<br>-<br>17:30 | - Recovery of power substation in Jongno-gu<br>- Restart of air-conditioning system in Jongno-gu | - Transfer to air-conditioned facilities<br>- End of situation | | <br>Recovery to normal state |

CHAPTER V.

# Implications for Developing Countries

Developing countries can use smart cells to build social statistical databases, as such nations tend to lack basic statistical data on their populations and economically active people due to underdeveloped social institutions and budget constraints. Accordingly, smart cell-based data on active populations, as shown in this study, are identifiable in wireless carriers' databases and can be useful for any country with a high rate of mobile phone penetration. By obviating the need for surveys this way, smart cells can result in significant savings of time and cost.

Furthermore, smart cells enable the implementation of spatial policies at different levels within a spatial hierarchy (e.g. nation, region or city). National territorial policy knows no boundaries, such as those between old and new city centers. Smart cells can be used to achieve policy goals at different levels within a spatial hierarchy—macro spaces such as countries and regions and micro spaces such as towns and districts.

In developing countries, smart cells can also help small merchants to start new businesses and preemptively reduce the risk of failure. In such nations, many new entrepreneurs move to large cities from other regions and lack proper knowledge of urban markets. If they have objective information on human activity in a given area, they can create a more solid foundation from which to build on.

Lastly, smart cells can be incorporated into emergency prevention and response systems. Mobile big data is an automatic data collection system based on mobile phones that enables constant monitoring of how many people in a given area are at risk from natural and social disasters. Continuous monitoring is an effective tool for disaster prevention in regions in great danger of natural or social disasters. Developing countries, even if lacking in basic statistical databases, can use smart cells in the event of a disaster to forecast the number of casualties and devise response. When a disaster hits, such technology can provide emergency responders with highly reliable information in a timely fashion to facilitate the decision-making process and minimize human casualties.

## References


Kim Jonghak, Yongseok Goh, Jungi Kim, and Donghan Kim. 2014. *Application of Smart Cell-based Active Population to Spatial Policy*. Gyeonggi Province: Korea Research Institute for Human Settlements.

Kim, Jinyun. "Effects of Satellite City Development on Urban Spatial Structure: Focus on Effects on Demographic and Employment Distribution of Phase I Satellite Cities in the Seoul Capital Area." *The Korea Spatial Planning Review* 64 (2010): 185–201.

Korea Communications Commission. 2014. *2013 Survey of User Behavior of Media*

SKT Geovision. 2012. *Data Pack Introduction*

http://www.youtube.com (Introduction on Power Map)

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