經營科學
第21卷 第3號
2004年 11月

소포 집배송 서비스를 위한 GIS, GPS 및 최적화 기술의 통합

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Integrating GIS, GPS, and Optimization Technologies for Pick-up/Delivery Service

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■ Abstract ■

In this paper, we describe an intelligent monitoring and control system for pick-up/delivery service. This system applies geographical information system(GIS), global positioning system(GPS) and wireless communication technologies for managing pick-up/delivery operations more effectively. It consists of three subsystems, pick-up/delivery sequence planning system, pick-up/delivery monitoring system, and PDA execution system. Pick-up/delivery sequence planning system generates routes and schedules for pick-up/delivery using GIS and optimization techniques. Pick-up/delivery monitoring system monitors current positions of vehicles and actual pick-up/delivery results as compared with planned routes and visit times, while PDA execution system transmits information for vehicles positions and actual pick-up/delivery results using GPS and wireless communication technologies. The intelligent monitoring and control system is currently being used for the pick-up parcel service in a local post office of Korea Post.

Keyword : Pick-up, Delivery, Monitoring, Scheduling

논문접수일 : 2004년 7월 31일 논문게재확정일 : 2004년 10월 15일
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1. 서 론

Door-to-Door parcel delivery service can be defined as the transmission of items(i.e., parcels) from senders' locations to receivers' locations using delivery vehicles such as trucks, bans and auto cycles. There are many delivery service providers who offer various kinds of delivery services. UPS, FedEx and TNT are the most famous private delivery service providers, while USPS (United States Postal Service), DPWN (Deutsche Post World Net) and CPC (Canada Post Corporation) are the largest national postal operators that provide parcel delivery service. Demand on the parcel delivery is rapidly increased and competition in the parcel delivery business is more intensified.

Demand increase of parcel delivery is associated with the growth of electronic business based on the Internet. B2C (Business-to-Customer) type of electronic business is the main source of new demands on the parcel delivery. For example, Web-based Internet shopping malls, which conduct their business over the Internet, take customers' orders on the Web and place delivery requests to delivery service providers. Gartner Group estimates the size of electronic business as $446 billion in 2006. As the size of Web-based electronic business grows, sellers (Businesses) and buyers (Customers) expect various kinds of delivery services ever before. Scheduled pick-up, delivery confirmation and collect on delivery(COD) are those kinds of special delivery services.

As an environment of domestic logistics business in Korea, home delivery market is growing over 30% every year due to the expansion of home shopping and e-business, but there is an intense competition between major companies and smaller business struggling for getting a prior occupation in markets rather than profitability. In 2002, sales of domestic home delivery market were about 1350 billions dollars, and we expect 20% increase in 2003. Five major home delivery business operators in Korea occupy half of entire market, and Korea Post has 9.9% market share. Korea Post is currently trying to jump to the integrated logistics enterprise through consolidating logistics businesses, and also trying to construct the logistics hub in Northeast Asia. Korea Post is advancing from postal parcel(C2C) to delivery service including B2C and to 3PL logistics(B2B) services. Korea Post will also change the business structure. In 2002, letter and logistics had the ratio of 80 to 20, but they will be changed as the ratio of 50 to 50 in 2007.

In general, door-to-door parcel delivery is conducted with five basic operations : (1) Collection (pick-up) ; (2) Outbound Sorting ; (3) Switching ; (4) Inbound Sorting ; and (5) Delivery. Collection and Delivery are the processes of pick-up/delivery of parcels from senders and to receivers, respectively. On the other hand, Sorting is the sortation process of parcels conducted by automated sorting facilities at sorting centers. A sorting center typically covers some regional areas for Inbound and Outbound Sorting. Collected parcels from senders' locations within some regional areas are sent to the specified sorting center for Outbound Sorting, while parcels transmitted from(Outbound) sorting centers are sorted for delivering parcels to receivers' locations through Inbound Sorting. Switching is the exchange process for consolidating parcels with the same destination(sorting center).

Sorting and Switching are capital-intensive operations performed with automated mechanical facilities, while Pick-up/delivery is labor-intensive operations performed manually. Pick-up/delivery is called as the first and last mile operations, respectively, since those are the starting and finishing points of parcel delivery service. Costs for pick-up/delivery operations form more than 40 percent of total delivery service cost. In addition, the pick-up/delivery operations are two contacting points of customers where most of service quality is measured and experienced. Therefore, it is very important to manage effectively the first and last mile operations for competitive advantage. Major delivery service providers and postal operators have made efforts to develop monitoring and control systems for process improvement in those two important operations.

In this research, we develop an intelligent monitoring and control system for pick-up/delivery service, especially for managing pick-up/delivery operations more effectively. The system developed in this paper applies geographical information system (GIS), global positioning system (GPS) and wireless communication technologies to monitor and control pick-up/delivery operations. The system consists of three subsystems, pick-up/delivery sequence planning system, pick-up/delivery monitoring system, and PDA execution system for generating routes and schedules for pick-up/delivery, monitoring current positions of vehicles and actual pick-up/delivery results, and transmitting information for vehicles positions and actual pick-up/delivery results, respectively.

There are a few research results related to the monitoring and control system for parcel delivery. Zito et al. [10]. considered the use of GPS for obtaining information on the position, speed and direction of travel of vehicles, while Hafberg. [4] described the concepts and techniques combining GIS, GPS, and digital communication technologies to measure the position and velocity of a vehicle and transmit this information to a central monitoring system. Weigel and Cao [9] and Derekenaris et al. [3]. combined GIS, GPS and optimization techniques to solve home-delivery problems and ambulances routing problems, respectively. Derekenaris et al. [3]. was the most similar research, in which a monitoring and control system was developed applying GIS, GPS and GSM technologies for the effective management of ambulances. Dao, Rizos and Wang [2] provided some background to the technology underlying location-based services (LBS) using GIS, GPS and mobile communications, and some issues in developing and launching LBS.

The remainder of this paper is organized as follows. First of all, we analyze practical pick-up/delivery processes to identify possible opportunities that can be used to improve the productivity of pick-up/delivery operations. Also, functional requirements are defined based on the results of the process analysis. In the next section, we describe overall system configuration for the intelligent monitoring and control system. We then explain details of three subsystems of the system, followed by reporting of the system implementation results. Finally, we make concluding remarks and comment on future research areas.

2. Process Analysis of Pick-up/Delivery Operations

In this research, we analyzed pick-up/delivery operations performed at a local post office of Korea Post to identify possible opportunities for process improvement. In the following, we present details of the pick-up/delivery operations and results of the process analysis.

2.1 Analysis of Pick-up Operations

Pick-up process of each pick-up postman has three-level hierarchy. Level-1 process (Pick-up) is divided into three level-2 processes (Preparation, Execution, Finish). Also, each level-2 process consists of several level-3 processes. The hierarchy is briefly given below.

(1) Preparation
- Confirm pick-up requests
- Determine pick-up sequence
- Make pick-up list

(2) Execution
- Move to pick-up location
- Measure size and weight of parcel
- Attach the label to parcel
- Determine payment method and charge a fee

(3) Finish
- Arrange parcels collected
- Input pick-up results and address information for collected parcels to computer system

Preparation and Finish processes are performed by postman at a local post office, while Execution process is done outside the local post office. Normally, Preparation process starts at 8 : 00 A.M. and Execution process is continued from 9 : 00 A.M. to 6 : 00 P.M. During Preparation process, postman manually decides a sequence of visits for pick-up requests (not yet completed) from senders based on his past experiences and knowledge. After Execution process, on the other hand, postman manually keys in results of pick-up. Pick-up process is repeated on a daily basis.

There are several factors that cause the inefficiency in pick-up operations. First, there may be much difference in quality among visiting sequences decided by postmen according to their lengths of service. Especially, a novice whose length of service is less than six months has limited capability in deciding good visiting sequence due to the lack of geographical information. Also, it is difficult to manage newly generated pick-up requests during Execution process since actual pick-up results and current position of postman are not monitored. In addition, it is hardly to give answers for customers' inquires about estimated visit time of postman to pick-up parcels. Finally, there exist (non- value added) duplicated manual operations such as Make pick-up list and Input pick-up results, which can be eliminated if appropriate information system is used in those operations.

2.2 Analysis of Delivery Operations

Like pick-up process, delivery process of each delivery postman has three-level hierarchy. Level-1 process (Delivery) is divided into three level-2 processes (Preparation, Execution, Finish). Also, each level-2 process consists of several level-3 processes. The hierarchy is given below.

(1) Preparation

- Sort parcels
- Determine delivery sequence
- Make delivery list
- Load parcels to delivery vehicle

(2) Execution

- Move to delivery location
- Deliver parcel and take a signature
- Charge a fee

(3) Finish

- Input delivery results to computer system
- Arrange returned and undelivered parcels

Preparation process of Delivery is the same as Pick-up except that actual parcels are sorted and loaded in Delivery. Also, returned and undelivered parcels are arranged in Finish process of Delivery instead of collected parcels in case of Finish process of Pick-up. Taking signature is another important process in Execution process of Delivery. The signature is used as proof-of-delivery for a parcel. Preparation process of Delivery starts at 7:00 A.M. earlier than Pick-up since actual parcels should be sorted manually by postmen for delivery. Normally, Execution process is continued from 9:00 A.M. to 5:00 P.M. During Preparation process, postman manually decides a delivery sequence of parcels based on his past experiences and knowledge. After Execution process, postman manually keys in results of delivery that include whether a parcel is delivered or not and the reasons why some parcels are not delivered. Delivery process is repeated on a daily basis.

Factors caused the inefficiency in delivery operations are : plan quality for delivery sequence by postmen like pick-up operations ; difficulties in responding to customers' inquiry about delivery results (e.g. delivery confirm) ; duplicated manual operations. Note that delivery confirm is very important if the sender is a business based on the Web like Internet shopping mall since the sender can start its payment process only after delivery confirmation.

2.3 Possible Opportunities for Process Improvement

As mentioned in previous subsections, there exist several factors that cause the inefficiency in pick-up/delivery operations. In this subsection, we summarize possible opportunities that can be used to improve the productivity of pick-up/delivery operations. Those opportunities can be realized using innovative information technology such as GIS, GPS and wireless communication technologies. Details on how to realize those opportunities are described in the next section.

(1) Adjustment of parcels for pick-up/delivery

Postman can cover wider pick-up/delivery area than before by adjusting parcels to be picked-up/delivered among postmen using parcel information displayed on electronic map. This will result the reduction of resources and equipment.

(2) Address Correction

Address information can be corrected at the receipt stage of pick-up requests utilizing the address correction system. The correction system will allow a postal export to add an address correction rule for the original address to the system.

(3) Quality in Pick-up/delivery Sequences

GIS and optimization techniques can be used to generate feasible routes and schedules with good quality. The problem of deciding pick-up/delivery sequences of each postman is the traveling salesman problem with time windows (TSPTW), well-known in combinatorial optimization areas. Also, geographical information of GIS can be used to compute distances and travel times between any two visiting locations, which are basic input of the TSPTW, and generate paths between visiting customers.

(4) New Pick-up Requests

GIS, GPS and mobile communication technologies together with optimization techniques can be used to handle new pick-up requests during pick-up Execution. Real-time reservation for new pick-up request can be realized by monitoring vehicles positions and actual pick-up results since GIS-based optimization algorithm may decide best-suited postman and estimated visit time for new pick-up request if those information are monitored.

(5) Response to Customers' Inquires

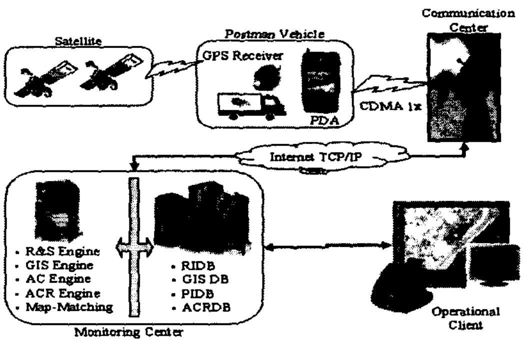
Estimated visiting time and delivery confirm are the most frequently asked inquiries from customers. The former can be obtained by solving the TSPTW based on GIS and optimization techniques, while the latter can be handled using mobile device and communication technologies.

(6) Non-value added Manual Operations

Non-value added manual operations can be reduced using mobile device and customized software applications.

3. The Overall System

In this section, we describe an overall system configuration of intelligent monitoring and control system in which possible opportunities identified in previous section are realized using GIS, GPS and wireless communication technologies together with optimization techniques. <Figure 1> presents the overall system configuration. As shown in this figure, there are five system units for pick-up/delivery service; Monitoring Center, Operational Client, Communication Center, Vehicle units for pick-up/delivery, and Satellite System. Monitoring Center has (1) GIS engine to display address information on the electronic map using GIS DB and parcel information DB(PIDB), (2) address correction engine(AC Engine) to perform address correction, (3) address correction rule engine (ACR Engine) to apply or add correction rule, and (4) routing & scheduling engine(R&S Engine) to generate routes and schedules using routing information DB (RIDB). Operational Client is used by users to generate routes and schedules, and to monitor vehicles positions and real-time re-



〈Figure 1〉 The overall system configuration sults for pick-up/delivery. Vehicle units send vehicle positions and results of pick-up/delivery through Communication Center, while GPS Receiver of Vehicle units detects positions of vehicles through Satellite System.

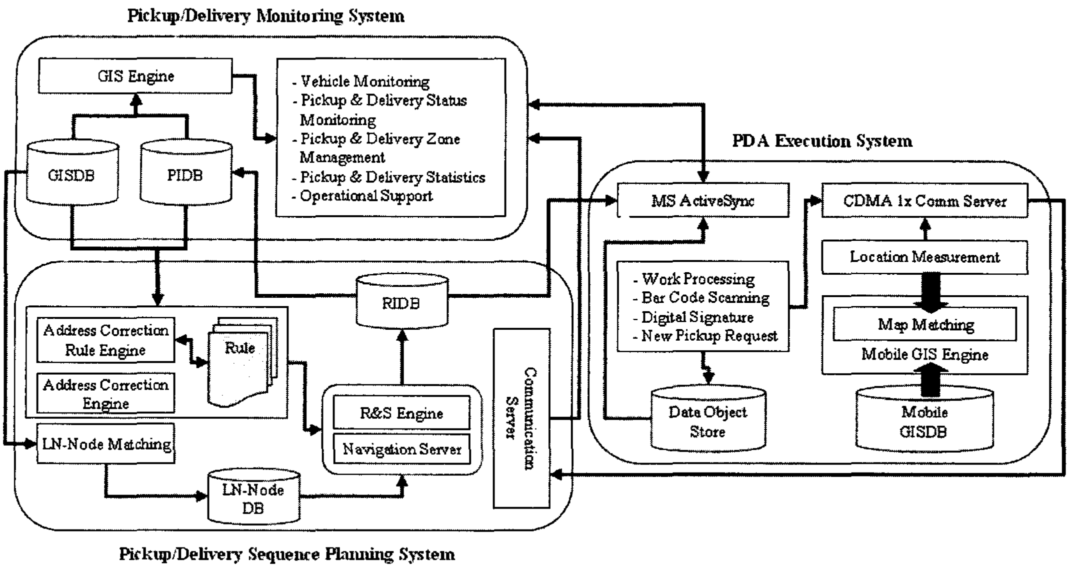
The followings are the main functions of intelligent monitoring and control system.

- Address correction for visiting place : Address for pick-up/delivery is corrected by AC Engine. Also, address correction rule is applied to the address which is not found in the GIS DB or is added for original address to the system.
- Scheduling and modification for pick-up/delivery : Sequences of the visiting locations for pick-up/delivery are created and modified on the electronic map. Also, pick-up/ delivery areas are adjusted for all postmen daily using electronic map according to parcel volume to be picked-up and delivered.
- Parcel sorting by sequence : Pick-up/delivery sequence number is displayed in the PDA by scanning the barcode of parcel, and therefore parcels are loaded according to the pick-up/delivery order in the vehicle.
- Mobile pick-up/delivery operations using PDA : Postman performs pick-up/delivery service using PDA with information of visiting locations, barcode scanning, SMS transmission & telephone call, and electronic signature for delivery confirmation.
- Tracing of vehicle : GPS and CDMA 1x are applied to verify the trace and position of vehicle on the electronic map.
- Verification of real time pick-up/delivery status : Postman transmits the pick-up/delivery results to the control center in real time using PDA built-in CDMA.
- Verification of next pick-up/delivery location : PDA displays next visiting address automatically, and electronic map is used to verify buildings and roads of the visiting locations.
- Navigation : Current position and visiting place are displayed with routing information in PDA.
- Real time transmission of new pick-up request : New pick-up request information is transmitted to PDA in real time during pick-up service.

4. The System Architecture

This section discusses details of system architecture for intelligent monitoring and control system. The architecture is depicted in <Figure 2> Main functions of the intelligent monitoring and control system are realized by three subsystems, pick-up/delivery sequence planning system, pick-up/delivery monitoring system, and PDA execution system.

Pick-up/delivery sequence planning system corrects various non-standard postal addresses among parcel information to the ones used by GIS, and then creates the optimized routes based on the parcel information with consideration of visiting request time of customer, lunch time of postman, and priority between contract customer and individual customer. Pick-up/delivery monitoring system monitors current positions of vehicles and actual pick-up/delivery results displayed on the electronic map, and manages various statistics for pick-up/delivery results. In PDA execution system, new pick-up request in



〈Figure 2〉 The system architecture

formation is received from Operational Client, and information for vehicles positions and actual pick-up/delivery results are transmits to Monitoring Center.

4.1 Pick-up/Delivery Sequence Planning System

In Pick-up/delivery Sequence Planning System, four databases (GIS DB, PIDB, Lot Number-Node DB (LN-Node DB), and RIDB) and three sub modules (Address Correction Rule, LN-Node Matching, and R&S Engine) are used to generate the optimized route for the pick-up/delivery of parcels.

The functions of ACR Engine are correction of non-standard address and assignment of near delivery point about pick-up/delivery address. Since the addresses provided by postal customers usually do not directly match the ones stored in GIS, it is necessary to transform or sometimes correct the original addresses so that they can be found in GIS DB. For each non-standard address pattern, one or more rules have been defined to do the required transformation or correction. If the corrected address still cannot be found in the GIS address database, the address correction system allows a postal expert to add an address correction rule for the original address to the system. The address correction and mapping with GIS DB are performed automatically by making out rule script document and using added knowledge.

PIDB includes information about sender and receiver of parcel such as postal address, requested time, name, and phone number while GIS DB includes geographical information of whole pick-up/delivery area such as postal addresses and its coordinates values, and road and building information. In GIS DB, each intersection on physical road is represented as one node. Also, all postal addresses in GIS DB are matched to corresponding nodes. Matching between a postal address and a node is performed by LN-Node Matching module. Note that there exist one-to-many relations between a node of GIS DB and postal addresses. Corresponding node for a postal address is determined as the nearest intersection on physical road to the address. In addition, travel times and lengths of shortest path between all of node pairs in GIS DB are stored in LN-Node DB. Here, a path is a consecutive nodes linked between two nodes of LN-Node DB. The shortest path between any two nodes is obtained using well-known Dijkstra's algorithm.

R&S Engine of PDPS uses data of PIDB and LN-Node DB to run optimization algorithm for pick-up/delivery service. Results of R&S Engine, routes and schedules for pick-up/delivery, are stored in RIDB. The problem of pick-up/delivery of each postman considered here is a kind of the TSPTW. The objective of the TSPTW is to find an optimal tour where a single vehicle is required to visit each of a given set of customers exactly once and then return to its starting location. The vehicle visits each customer within a specified time window, defined by an earliest service start time and latest service start time. The vehicle conducts its service for a known period of time and departs for the next scheduled customer. The objective of the problem considered here is to minimize the total duration times and total travel times of all routes. Visiting request time of customer, lunch time of postman, and priority between contract customer and individual customer are considered.

A tabu search algorithm is used to solve the pick-up/delivery problem considered here. The tabu search moves from the current solution to its best neighbor at each iteration, not necessarily less than the cost(travel time or length of tour in our problem) of the current solution, until a stopping criterion is satisfied. In order to prevent cycling, solutions that have been examined before are forbidden and inserted in a tabu list. The tabu search algorithm which we propose is initialized with the heuristic solution obtained with the nearest neighbor heuristic. The nearest neighbor procedure is one of the fastest heuristics to construct an approximate TSP tour. Starting with an arbitrary node as the beginning of a path, a node closest to the last node added to the path is found and added to the path. This procedure is repeated until a TSP tour is obtained. The tabu search uses the neighborhood structure to develop new solutions(tours) that are related to the current solution. In this algorithm, we use simple neighborhoods based on insertion, swap-exchange and two-opt. Note that a node used in tabu search algorithm is corresponded to a postal address in PIDB and its corresponding node of LN-Node DB. See Carton and Barnes [1], Knox [5], Laporte [6], Ong and Huang [7], and Voudouris and Tsang [8] for more details on tabu search algorithm for traveling salesman problem.

4.2 PDA Execution System

PDA execution system consists of industrial PDA based on Microsoft Windows CE 3.0 Handheld PC with CDMA 1x, vehicle cradle with GPS module, and cradle for performing the data communication as Operational Client.

PDA execution system downloads (1) sequence and estimated visiting time from RIDB generated by pick-up/delivery sequence planning system and (2) parcel information of PIDB using Microsoft ActiveSync 3.6 of Operational Client and Message-Driven Architecture of MS

Windows CE when Operational Client is synchronized with PDA. Postman performs pick-up/delivery operations, and transmits pick-up/delivery results to Communication Center through CDMA wireless communication in real time. These results are then sent to Monitoring Center via LAN and used to monitor the current status in real time. Data Object Store of PDA is used to store the data at the same time. The data transmitted to Communication Center and the electronic signature files used for delivery verification are stored in Data Object Store. During pick-up operation, postman can confirm and conduct new pick-up request information transmitted from Operational Client through CDMA wireless communication in real time. These data are uploaded to PIDB of pick-up/delivery monitoring system through ActiveSync, and the pick-up/delivery results of Data Object Store are used for data verification after postman returns from visiting locations.

To detect and transmit the vehicle position, Location Measurement module in PDA execution system calculates longitude and latitude coordinates of current position, moving direction, and speed through the communication (NMEA 0183 V2.2 I/F) with GPS receiver. Also, trace information is transmitted to pick-up/delivery monitoring system according to the trace transmission interval using CDMA wireless communication.

Map Matching and map display operation are conducted to display the current position to PDA based on Mobile GIS Engine and map information of Mobile GISDB produced for mobile. Coordinates obtained from GPS receiver may occur the error according to the surrounding situation. Map Matching is the work to correct the error and to adjust the coordinates about the current position. Also, navigation function displays routes on electronic map of PDA after computing the shortest route from the current position to the next visiting position using position data received from GPS. The current position and the next position data are transmitted to navigation engine of monitoring system via CDMA wireless communication, and then navigation server computes the optimal route and transmits the results to the navigation module of PDA. The navigation module displays the optimal route on the electronic map of PDA using the results.

4.3 Pick-up/Delivery Monitoring System

Monitoring Center and Operational Client in pick-up/delivery monitoring system monitor vehicle position and real-time status of pick-up/delivery operations using (1) visiting sequence and estimated visiting time of RIDB generated from pick-up/delivery sequence planning system and (2) current status of pick-up/delivery of PIDB. Also, pick-up/delivery service time and results are verified using PIDB with the present status of pick-up/delivery from PDA execution system. In addition, pick-up/delivery monitoring system displays visiting sequence, estimated visiting time, and route generated by pick-up/delivery sequence planning system on electronic map through GIS Engine. By using the real time pick-up/delivery status, the planned sequence and the vehicle route can be compared with the actual trace of postman transmitted from PDA execution system.

Since pick-up/delivery monitoring system has Web environment based on GIS component, it is easy to manage map information, version upgrade of GIS engine, and maintenance and repair. GIS Engine used here is open GIS component which meets the requirements of Open GIS International Catalog Specification. GIS Engine provider offers COM-based Object and standard interface, and it is possible to make access and joint ownership about spatial information in distributed environment. GIS Engine also provides attribute operation and spatial operation for zoom in, zoom out, area magnification, and movement as basic functions. It consists of GIS Query Processing Engine (GIS/QPE), GIS API Processing Engine (GIS/GAPE), and GIS Client. Spatial database management system based on R-Tree and R*-Tree is implemented for storage and access of spatial information.

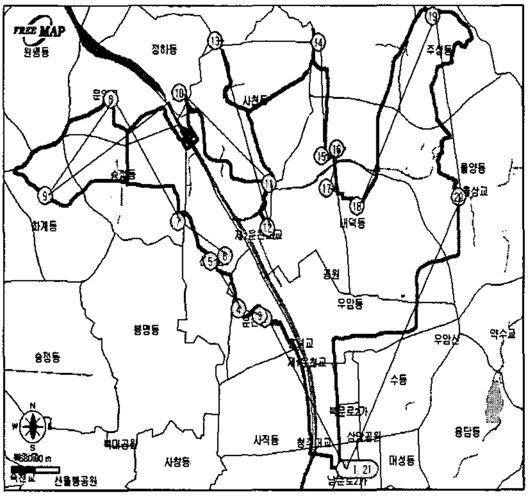
5. Implementation of the intelligent monitoring and control system

We implemented the system for a local post office of Korea Post. The local post office covers a city with population of six hundreds thousands and 180,000 different postal addresses. The city area is divided into 18 sub areas for parcel delivery where each sub area is covered by one postman. On the other hand, there are five sub areas for parcel pick-up, which are more aggregated since the amount of pick-up is less than that of delivery. As a result, there are 5 postmen for pick-up and 18 postmen for delivery who cover their own separated sub areas of the city. On average, 1500 parcels are delivered and 150 pick-up requests are handled per day. Note that collected parcels are more than 150 since there are many business customers who send several parcels simultaneously at a time.

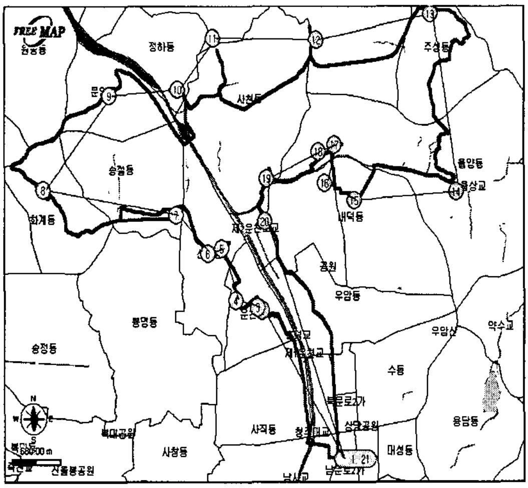
Implementation project of the system started on August, 2002 and the field test of the system was completed on November, 2003. The system is currently being used by all postmen for pick-up in the local post office(Cheongju) and will be used for delivery soon in the same post office. In the end of this year, the system will be applied to major cities including several post offices in Seoul which have more complicated geographic environments and more volume to be delivered/picked-up than the city used for our project.

Pick-up/delivery processes have been re-engineered so as to use the monitoring and control system. Several benefits have been provided by using the system. First, postman makes good pick-up/delivery plans (routes and schedules) more efficiently using pick-up/delivery sequence planning system. Especially, this system shows that it is very useful for a novice to make his pick-up or delivery plan. <Figure 3(a)> shows the pick-up sequence drawn up manually by postman using his pick-up knowledge and electronic map. The estimated total operated distance and time are 34.6 km and the 368 minutes, respectively. On the other hand, <Figure 3(b)> represents the pick-up sequence which was generated from R&S Engine of our system. In this case, the estimated total operated distance and time are 28.8 km and the 334 minutes, respectively. It is easy to recognize the improvement of complexity of the pick-up sequence.

Also, non-value added duplicated operations, which were performed manually, are eliminated using PDA execution system. In addition, customers' inquiries are handled more efficiently since CSR(Customer Service Representative) can observe real-time results of pick-up/delivery, and vehicle positions easily with pick-up/delivery monitoring system.



(a)



(b)

〈Figure 3〉 Pick-up sequence : (a) sequence by postman's knowledge, (b) sequence by algorithm

Since pick-up/delivery plans has been made more efficiently and unnecessary pick-up/delivery operations are reduced by using the system, service time for pick-up/delivery is significantly decreased. For example, one postman dealt with 30 pick-up requests per day (total 10 hours : 8 hours for pick-up service and 2 hours for parcel handling process in post office) on average before using the system. However, after using the system, the postman uses about 8 hours per day for the entire service which indicates 2 hours service time reduction. It means the big improvement of productivity because the postman can work for other mail processes during the remaining 2 hours.

6. Concluding Remarks

In this paper, we developed the intelligent monitoring and control system that applies GIS, GPS, and wireless communication, and optimization technologies for the pick-up/delivery service. The development of the system was the results of a project funded by the Korea Post. We first described the general requirements for pick-up/delivery service, and then modeled the system composed of three subsystems to improve pick-up/delivery process. Also, we implemented the intelligent monitoring and control system for the local post office of Korea Post. After performing the field test of the system, all postmen for pick-up are currently using the system in the local post office(Cheongju).

Our system will be upgraded continuously to improve customer service and pick-up/delivery process. For example, address management system will be combined with the monitoring and control system since right address information is necessary both in the GIS-based vehicle routing/scheduling and the monitoring of vehicles' positions. Address information should be corrected at the receipt stage of pick-up requests utilizing the address management system. Also, it is necessary to devise more elaborate mechanisms for the real-time reservation to handle new pick-up requests effectively. Those mechanisms may use information on vehicles positions and remaining pick-ups to balance workloads among postmen and meet customers' request times.

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