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A Computer-Based Routing and Scheduling for a Public Library System

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ABSTRACT

Purpose: A computer-based routing and scheduling system of a delivery van was developed for a Public Library System. The computer-based model was based on the closest unvisited destination as well as other system constraints and was implemented using a computing language. The solutions were compared to the existing manual solutions and policy changes due to the implementation of the system are also discussed.

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KEYWORDS Routing, Scheduling, Public Library

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Introduction

Routing and scheduling are just a small, but integral, part of the logistics process. Logistics can be defined as the entire process of moving goods into, through, and out of the firm [9]. The last step in the logistics process, routing and scheduling goods from distribution centers to customers, is often the most difficult and costly process of the entire operation which has become an increasing important managerial problem.

According to Bodin et al. [4], given a set of demand locations for service in a transportation network over which a vehicle may travel, decisions concerning the spatial configuration of vehicle movement are classified as routing problems. On the other hand, if explicit consideration is given to the times at which various locations are visited, one is faced with a scheduling problem. In many instances, the spatial and temporal decisions of both routing and scheduling problem interact heavily and results in a combined routing and scheduling problem.

Routing and scheduling problems are notoriously difficult to solve [4]. To further complicate the matter, each problem is usually unique and requires special attention to meet system constraints. The use of analytic techniques can be of tremendous help to the decision-maker in solving the routing and scheduling problems. With the availability and acceptance of personal computers in businesses of all sizes, a computer-based system can be used by the decision-maker as a valuable tool to arrive at decisions and furthermore, make policy recommendations to the management.

The literature is abundant with papers on routing and scheduling problems. The intention of this paper is to report on the development of a routing and scheduling system for a library and not on a literature review. The interested reader is referred to the excellent work of Bodin et al. [4] for further reading. Also, over the years, various practical applications have been reported, for example, review Alameen et al. [1], Bartholdi et al. [3], Chapleau et al. [5], Clark and Wright [6], Evans and Norback [8], Groër et al. [10], and Min [12].

In this paper, we describe the development and implementation of a computer-based routing and scheduling system for a library system. During the past few years, routing and scheduling problems in business have been solved by using artificial intelligence based metaheuristics such as genetic algorithms, particle swarm optimization, and simulated annealing techniques, for example, see Asih et al. [2], Griffis et al. [9], and Talbi et al. [13]. However, in this study, the computer-based system was developed based on the nearest unvisited location and also incorporated additional system constraints that were unique to the situation. Next, we introduce our specific problem and present the approach taken to solve the problem.

Background

The Winding Rivers Library System (WRLS) is a public library system serving seven counties in Western Wisconsin with its offices located in La Crosse. The WRLS provides delivery service to thirty-two (32) public libraries as well as thirty-eight (38) non-public libraries (high schools). Delivery is defined by management as a formal method of transporting pieces of resource material, equipment, or printed information among members of a set population on a regular basis. There are over thirty different items ranging from new books to requests for system library books; from brochures to interlibrary loan requests; from film projectors to bulk loans. At the time of this study, a single van was used to provide delivery service. Some libraries were serviced on a weekly basis while others were visited once every other week during the open hours of the library. The delivery period of concern is for the months between August through June, i.e., the school year.

It should be noted that our study was part of a larger project. WRLS conducted a cost study on delivery to fulfill an obligation to the State of Wisconsin [7]. The purpose of the cost study was "to provide information comparing costs of services offered to public libraries with costs of services extended to other types of libraries." Internally, at WRLS, the study was used as a tool in budget preparation, in contract negotiations, to explain the variety as well as amount of cost involved in providing library services, and route efficiency, among others.

Existing Delivery System

Prior to the development of the computer-based system, it was imperative to analyze the existing delivery system. If the current delivery system was providing adequate service, then there was no need to further investigate the possibility of a new system. So, an in depth review of the existing system was undertaken.

The existing system consisted of four routes: A, B, C, and D. These four routes and a four month scheduled period are shown in Table 1. This was the first piece of information provided to us by WRLS. Each route consisted of a weekly delivery schedule for the days of Monday, Tuesday, Wednesday, and Friday with no deliveries scheduled for Thursday. Thus, each route repeated itself after every four weeks. The existing delivery system was being utilized due to past practice of the van operator. It can be noticed that route B is the same as route D and route A is almost the same as route C. These four routes are shown in Table 2. The total mileage for the four week period for the four existing routes was 1224 miles.

Through initial consultation with the services supervisor, the four routes were collapsed into two routes and designated as routes A and B with slight adjustment as shown in Table 3.

This new delivery system provided essentially the same level of service to its patrons with a reduction in the total mileage for the four week period.

This improvement was implemented immediately, and it was agreed upon with management to further investigate into the development of a computer-based library routing and scheduling system. This system would then promptly provide the supervisor with the delivery schedule and mileage associated with any route changes in the future.

The Computer-Based System

In the development of the computer-based system, the following factors were carefully considered: the nature of the business environment we were dealing with, scarce State funds for the library system, limited hardware and software (one personal computer), and a time constraint of about four months to complete the work. Given these limitations, we were asked to develop a computer-based system which will quickly evaluate the feasibility of various routes. The testing of the system would then take place during the summer months and its full implementation during the Fall which corresponds to the start of the school year. The system evolved in the following way:

1) Development of the Database: The database was developed from the data collected for the cost study conducted earlier by WLRS for the State. This information was verified, and additional information gathered through interviewing the supervisor, staff personally responsible with the delivery system, and the van operator. A from-to chart of distance was imputed as well as the time windows during which the deliveries were acceptable at various destinations.

2) Route Division: It was quite obvious that it would be virtually impossible to incorporate every destination into a single route on a daily basis. Furthermore, it was requested by the supervisor that the delivery was to be spread over a four day work period. Therefore, route divisions had to be established. In the cost study, WRLS labeled various destinations according to their usage rates as well as according to the van delivery frequency. The usage rates were labeled as high, middle (upper and lower), and low. The delivery frequency was on weekly basis to the destinations which had high and upper middle demand rate. The remaining destinations were served every other week. Given the existence of such a procedure, and that the management wanted to eventually serve all destinations weekly with a four delivery days, a four cluster route division adaptation of Chapleau et al. [5] clustering approach seemed very appropriate to utilize for this application. To accomplish this aspect, each destination was assigned a color representing service usage. Red for high usage and blue for upper middle use requiring preferably weekly service, and green for lower middle use and black depicted low usage requiring fortnightly service. This process allowed us to group the destinations into four clusters, one for each day of the week for service, with relatively equal proportion of various usage rates in each cluster.

3) Route Selection: Once the clusters were formed, a simple heuristic procedure was selected for the route selection. This heuristic was based on the closest unvisited city approach; for example, see Turner et al. [15]. In this procedure, time windows were checked, when a city was selected. If the delivery window was not feasible, then the selected city was not included in the route. The procedure then generated a route based on the desired destinations to be visited whose feasibility was then evaluated by the supervisor.

Computational Experience

The computer-based system was written in Turbo Pascal. When the four cluster destinations were considered, we were able to achieve a total of approximately 800 miles [793 miles to be exact]. Thus, a savings of 431 miles over the existing delivery system was achieved. In terms of the cost of delivery, in the year of the study, the cost of delivery was $18,272 and it was estimated that it will rise to $23,378 during the next two years. Also, 62% of the cost was based on the number of stops at public libraries and the rest for the non-public libraries. Cost in terms of the number of items handled, public libraries accounted for 86% and the remaining for the non-public libraries. Thus, a decrease in mileage of about one-fourth was a substantial savings to WRLS. Furthermore, we were able to include additional destinations into the tour of the week.

The executable code was provided to the supervisor at WRLS. A hands-on demonstration of the system was scheduled and presented to the individuals involved with the delivery system. The initial reaction was extremely favorable. The users were asked to experiment with the system before the start of the next school year.

Policy Implications at WRLS Due to the New System

The system gave a chance to the staff at WRLS to experiment with diverse options. It gave them the flexibility to generate alternative routes quickly. With the aid of the system, WRLS was able to convert from a combination of weekly and bi-weekly service to weekly service at the request of the libraries. Also, the system provided them with a listing of open hours of the libraries which was a tedious manual task which helped them in the conversion process except for five smaller libraries. The system now provided them with more accurate mileage estimates than before for accounting purposes (especially for future cost analysis required by the state). According to the Manager of WRLS, "Our new schedule, which was produced with the help of the computer, has been in use since September 2. ..... Overall, the program has proved to be useful in the efficient improvement of the WRLS delivery service."

Table 1: Winding Rivers Library Van Delivery Existing Route Schedule

January					February					March					April				
M	T	W	T	F	M	T	W	T	F	M	T	W	T	F	M	T	W	T	F
Route B					Route B					Route B					Route C				
	1	2	3	4					1					1	1	2	3	4	5
Route C					Route C					Route C					Route D				
7	8	9	10	11	4	5	6	7	8	4	5	6	7	8	8	9	10	11	12
Route D					Route D					Route D					Route A				
14	15	16	17	18	11	12	13	14	15	11	12	13	14	15	15	16	17	18	19
Route A					Route A					Route A					Route B				
21	22	23	24	25	18	19	20	21	22	18	19	20	21	22	22	23	24	25	26
Route B					Route B					Route B					Route C				
28	29	30	31		25	26	27	28		25	26	27	28	29	29	30			

X - Holiday, No Van Runs / - School Closing, No Stops at Schools

Table 2: Details of Existing Routes A, B, C, and D

Monday	Tuesday	Wednesday	Friday
11:30 – 4:00	**11:30 – 4:45**	**10:30 – 3:15**	**11:30 – 4:00**
ROUTE A			
1. Chaseburg School	1. La Crosse County PL	1. West Salem HS/PL	1. La Crosse County PL
2. Coon Valley School	2. Sparta PL	2. Bangor HS	2. Onalaska HS
3. Westby HS	3. Tomah PL	3. Sparta HS	3. Holmen HS
4. Cashton HS	4. New Lisbon PL	4. Black River Falls HS/PL	4. Galesville PL/HS
5. Broodwood HS	5. Mauston PL	5. Merrillan PL	5. Blair PL/HS
6. La Farge PL/HS	6. Royall HS	6. Alma Center PL	6. Taylor PL/HS
7. Viroqua HS	7. Elroy PL	7. Lincoln HS	7. Whitehall PL/HS
8. De Soto PL/HS	8. Kendall PL	8. Melrose/Mindoro HS	8. Independence PL/HS
	9. Ontario PL		9. Arcadia PL/HS
	10. Viroqua PL		10. Trempealeau PL
	11. Westby PL		
12:00 – 4:45	**11:30 – 4:45**	**9:30 – 4:30**	**11:30 – 4:15**
ROUTE B			
1. Osseo PL/HS	1. La Crosse County PL	1. West Salem PL	1. La Crosse County PL
2. Mondovi PL/HS	2. Westby PL	2. Sparta HS	2. Galesville PL/HS
3. Gilmanton HS	3. Viroqua PL	3. Necedah PL/HS	3. Blair PL/HS
4. Cochrane-Fountain HS	4. Ontario PL	4. New Lisbon PL/HS	4. Whitehall PL
5. Alma PL/HS	5. Kendall PL	5. Mauston PL/HS	5. Osseo PL
	6. Tomah HS/PL	6. Royall HS	6. Strum PL/HS
	7. Sparta PL	7. Elroy PL	7. Independence PL/HS
		8. Wonewoc PL/HS	8. Arcadia PL/HS
		9. Hillsboro PL/HS	9. Trempealeau PL
		10. Wilton PL	
		11. Norwalk PL	

PL: Public Library HS: High School

Monday	Tuesday	Wednesday	Friday
11:30 – 4:00	**11:30 – 4:45**	**10:30 – 3:15**	**11:30 – 4:00**
ROUTE C			
1. Chaseburg School 2. Coon Valley School 3. Westby HS 4. Cashton HS 5. Broodwood HS 6. La Farge PL/HS 7. Readstown PL 8. Viroqua HS 9. De Soto PL/HS	1. La Crosse County PL 2. Sparta PL 3. Tomah PL 4. New Lisbon PL 5. Mauston PL 6. Royall HS 7. Elroy PL 8. Kendall PL 9. Ontario PL 10. Viroqua PL 11. Westby PL	1. West Salem HS/PL 2. Bangor HS 3. Sparta HS 4. Black River Falls HS/PL 5. Merrillan PL 6. Lincoln HS 7. Melrose/Mindoro HS	1. La Crosse County PL 2. Onalaska HS 3. Holmen HS 4. Galesville PL/HS 5. Blair PL/HS 6. Taylor PL/HS 7. Whitehall PL/HS 8. Independence PL/HS 9. Arcadia PL/HS 10. Trempealeau PL
12:00 – 4:45	**11:30 – 4:45**	**9:30 – 4:30**	**11:30 – 4:15**
ROUTE D			
1. Osseo PL/HS 2. Mondovi PL/HS 3. Gilmanton HS 4. Cochrane-Fountain HS 5. Alma PL/HS	1. La Crosse County PL 2. Westby PL 3. Viroqua PL 4. Ontario PL 5. Kendall PL 6. Tomah HS/PL 7. Sparta PL	1. West Salem PL 2. Sparta HS 3. Necedah PL/HS 4. New Lisbon PL/HS 5. Mauston PL/HS 6. Royall HS 7. Elroy PL 8. Wonewoc PL/HS 9. Hillsboro PL/HS 10. Wilton PL 11. Norwalk PL	1. La Crosse County PL 2. Galesville PL/HS 3. Blair PL/HS 4. Whitehall PL 5. Osseo PL 6. Strum PL/HS 7. Independence PL/HS 8. Arcadia PL/HS 9. Trempealeau PL

PL: Public Library HS: High School

Table 3: Details of New Routes A and B

Monday	Tuesday	Wednesday	Friday
12:00 – 4:45	**11:45 – 4:45**	**9:00 – 4:30**	**11:45 – 4:45**
ROUTE A			
1. Osseo PL/HS 2. Mondovi PL/HS 3. Gilmanton HS 4. Cochrane-Fountain HS 5. Alma PL/HS	1. Westby PL 2. Viroqua PL 3. Ontario PL 4. Kendall PL 5. Tomah HS/PL 6. Sparta PL	1. La Crosse County PL 2. West Salem PL 3. Sparta HS 4. Necedah PL/HS 5. New Lisbon PL/HS 6. Mauston PL/HS 7. Royall HS 8. Elroy PL 9. Wonewoc PL/HS 10. Hillsboro PL/HS 11. Wilton PL 12. Norwalk PL	1. Onalaska PL/HS 2. Galesville PL/HS 3. Blair PL/HS 4. Whitehall PL 5. Osseo PL 6. Strum PL/HS 7. Independence PL/HS 8. Arcadia PL/HS 9. Trempealeau PL
11:30 – 4:00	**11:30 – 4:45**	**10:30 – 3:15**	**11:30 – 4:00**
ROUTE B			
1. Chaseburg School 2. Coon Valley School 3. Westby HS 4. Cashton HS 5. Broodwood HS 6. La Farge PL/HS 7. Readstown PL 8. Viroqua HS 9. De Soto PL/HS	1. Sparta PL 2. Tomah PL 3. New Lisbon PL 4. Mauston PL 5. Royall HS 6. Elroy PL 7. Kendall PL 8. Ontario PL 9. Westby PL 10. Viroqua PL	1. La Crosse County PL 2. West Salem HS/PL 3. Bangor HS 4. Sparta HS 5. Alma Center PL 6. Lincoln HS 7. Merrillan PL 8. Black River Falls PL/HS 9. Melrose/Mindoro HS	1. Onalaska HS 2. Holmen HS 3. Galesville PL/HS 4. Blair PL/HS 5. Taylor PL/HS 6. Whitehall PL/HS 7. Independence PL/HS 8. Arcadia PL/HS 9. Trempealeau PL

PL: Public Library HS: High School

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Reviewers Memorandum

Reviewer's Comment 1: Article has tried to justify the topic "A Computer-Based Routing and Scheduling for a Public library System" as it tries to describe the development and implementation of a computer-based routing and scheduling system for a library system.

Reviewer's Comment 2: The literature is abundant with papers on routing and scheduling problems. The intention of this paper is to report on the development of a routing and scheduling system for a library and not on a literature review.

Reviewer's Comment 3: Even though the paper is crisp then also it tries to cover all the necessary aspects. It has been presented in a systematic and comprehensive manner. Also, sufficient number of references are provided for the readers.

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Editorial Excerpt

The article has 1% of plagiarism which is the accepted percentage as per the norms and standards of the journal for the publication. As per the editorial board's observations and blind reviewers' remarks the paper had some minor revisions which were communicated on a timely basis to the authors (Sohail) and accordingly all the corrections had been incorporated as and when directed and required to do so. The comments related to this manuscript are noticeably related to the "**A Computer-Based Routing and Scheduling for a Public library System**" both subject-wise and research-wise. The present research article aims to develop a computer-based routing and scheduling system of a delivery van for a Public Library System. The computer-based model was based on the closest unvisited destination as well as other system constraints and was implemented using a computing language. The solutions were compared to the existing manual solutions and policy changes due to the implementation of the system are also discussed. Overall, the paper promises to provide a strong base for the further studies in the area. After comprehensive reviews and editorial board's remarks, the manuscript has been categorized and decided to publish under "**View Point**" category.

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The acknowledgment section is an essential part of all academic research papers. It provides appropriate recognition to all contributors for their hard work and effort taken while writing a paper. The data presented and analyzed in this paper by (Sohail) were collected first handily and wherever it has been taken the proper acknowledgment and endorsement depicts. The author is highly indebted to others who had facilitated in accomplishing the research. Last but not least endorse all reviewers and editors of GJEIS in publishing in a present issue.

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