The economic analysis of transport costs of maintenance operations addresses an important consideration of maintenance center location. As is true of any economic analysis, it is merely a tool to provide the decision maker with the information to make effective decisions, not to provide the decision itself. Many other considerations must enter into the location decision: ease of center administration, the pattern of private and federal land ownership, distance to employee's existing residential locations, other facility location costs, and location of personal and agency services to employees.

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Highway Maintenance Game: A Manual Simulation Model for Training Maintenance Crews

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A manual simulation procedure was developed to supplement highway maintenance training in Louisiana. The game was designed with emphasis on the planning and scheduling of activities in order to train first-line administrators by simulating the performance of one week's work. This method appears to be effective on the basis of administration of the training package in four districts. Plans are being made to refine and automate this concept to better train maintenance supervisors.

Since the implementation of Louisiana's maintenance management system in 1969, field studies have revealed several scheduling problems that have limited the effectiveness of maintenance crews. Typical scheduling problems were related to lack of adequate forethought in order to achieve the most efficient use of available resources. For example, an extensive leveling job was scheduled without consideration of equipment availability. After five truckloads of hot mix had been delivered, the foreman realized that the roller was inoperative and that the hot mix could not be effectively applied. In numerous cases, additional people were assigned to activities simply because it was convenient, even though additional labor was not required.

Maintenance specialists who were charged with assisting parish superintendents to plan and schedule maintenance operations were surveyed. The survey led to the realization that only 50 percent of the superintendents were scheduling at all. Discussion with maintenance superintendents produced such comments as "maintenance cannot be scheduled", "scheduling time is wasted when things go wrong", and "scheduling takes too long".

Work was then begun to respond to these concerns through the development of a training course that included simulation of maintenance activities as a means to change the superintendents' attitudes and to improve planning skills. The training course was developed for presentation to first-level administrators--parish maintenance superintendents, foremen, and clerks. The course was designed to teach techniques that should help reduce the time required for scheduling maintenance. The roles of superintendent, foreman, and clerk were presented to show how each individual was expected to assist in the scheduling process. Realization that the superintendent is not expected to schedule all operations without assistance from his principal aides was expected to further speed the scheduling process. Finally, a manual simulation procedure was developed to accomplish five basic objectives:

1. Exercise techniques learned in the training course,
2. Examine the benefits of proper roles and interactions among key members of the parish organization,
3. Reduce the time required to perform scheduling tasks,
4. Demonstrate the feasibility and effectiveness of work-order scheduling techniques, and
5. Measure the level of potential effectiveness of the training process.

The manual simulation forced interaction among the three team members in a real-time enactment of the scheduling function; accomplishment of the work was handled in a quick-time fashion. A measurement procedure was also included in the simulation to determine how well the student had applied the techniques learned or acquired prior to the training.

MECHANICS OF THE GAME

A major effort was made to reinforce the idea that coordination and interaction among the three key people in the parish organization is necessary. Role-playing techniques were used during simulation of maintenance work to physically illustrate how

each individual was expected to assist the others to accomplish the scheduling function. The district was asked to provide the three key individuals in the parish organization so that a parish superintendent, a foreman, and a clerk constituted one training team. Where this was not possible, individual roles were assigned. Normally, it was expected that roles would be assigned within the individual's career path.

In order to place each team on an equal basis, a hypothetical parish, Pelican Parish, was developed, complete with maps, personnel, equipment, and the same set of initial conditions. Differences in outcome were directly attributable to the decisions made by the team. Pelican Parish maintains a road network of 449 miles, about average for Louisiana parishes; 29 miles of this system are Interstate highway. All facilities contained in Pelican Parish represented the average inventory of facilities found in Louisiana parish maintenance organizations. Resources used to maintain these facilities were also representative of average numbers. In conformance with the department's maintenance management system, 36 persons and 42 numbered equipment units were assigned to Pelican Parish. Each team was provided a copy of the superintendent's record of prescheduling inspections that listed all of the work found during the latest inspection of Pelican Parish. A list of carryover work from the preceding week and a list of expected operating conditions for the next week was also included at the outset.

The simulated day began at Friday noon. The team was required to schedule the work for the coming week. They were to consider any emergencies that they were aware of at the time, any work left over from the current week, and conditions found during the prescheduling inspection. Other considerations should have included alternative plans in the event of bad weather, material shortage, or similar problems. Each team was instructed to use work-order methods of scheduling in order to assign maintenance crews. These work orders were required to be prepared in advance by using all available data, including estimates of work quantity, materials, and productivity. At this time the foreman and clerk were instructed to assist the superintendent in scheduling work for the coming week. After next week's schedule had been completed, the clerk was instructed to begin preparing daily work orders for the primary and alternate plan. The clerk used standard daily work report forms for this purpose.

At this point the team was given some latitude. Since work orders may be prepared at any time prior to execution of the work, the team had the option of preparing work orders either a day or a week in advance. Regardless of the method used, the total effort is the same. When work orders were prepared in advance, they could be used on any day that the crew, equipment, and material could be scheduled as intended. If plans did not materialize, the schedule was abandoned, and a daily work report was prepared by the foreman to report what had been accomplished.

A parish work-control board was also provided to each team. The board showed the planned accomplishment for each function and the actual work accomplished for that function up to the biweekly period being simulated. This made the team aware of the annual plan and allowed them to consider the plan while decisions were formulated for the week being scheduled. Other special forms were provided to the team so that accomplishment could be tracked during the simulation.

Once scheduling was completed, the real-time part of the game was terminated, and a time-step method was used to simulate work performance. The clock was advanced to Monday morning and work performance began. Each day was simulated in three parts, morning, noon, and afternoon. Problems cropped up as the game proceeded. For example, on Monday morning four employees called in sick. Then at Monday noon, the state police called to report an accident at a bridge approach and to request that the surface be sanded to increase skid resistance. Monday afternoon was relatively quiet, and the plan proceeded on schedule.

At the completion of each simulated day, daily work reports were given to the maintenance specialist controlling the simulation. Each day was scored by assigning work accomplishment based on the decisions made and simulated conditions. If assigned crew and equipment were less than ideal for the condition and activity, an accomplishment penalty was administered. If additional people were assigned, no increase in productivity resulted unless these additional people were required for the specific condition. If an excessive haul distance was encountered, the team had to adjust the normal crew to add crew members and equipment for hauling in order to maintain expected productivity.

After the week had been simulated, the total accomplishment for each activity was multiplied by a weighting factor and summed for all activities in order to come up with a single score for each team. The weighting factor was calculated to penalize teams that had selected low-priority items ahead of higher-priority work. An ideal score was computed to allow the team to compare their performance against "perfect" decision making (20/20 hindsight). This method allowed results to be controlled by the priority and crew-assignment decisions of the team. In order to force the team to assess priorities, more work was assigned than could be accomplished within the one week provided.

SIMULATION PAPERWORK

A copy of Louisiana's standard daily work report is shown in Figure 1. This report can be used as a work order or as a work report. Its use was physically demonstrated during the simulation. An example of the superintendent's record of prescheduling inspections that supplies the work load the team must consider is shown in Figure 2. The list was supplied to each team at the beginning of the simulation. In addition, a detailed map of Pelican Parish was given to each team in order that travel distances could be estimated.

A list of Pelican Parish personnel was supplied; employees are listed in categories by job title and, for each employee, room is provided to indicate the work function planned for each day of the week. A similar list of equipment was supplied. A work-control board showing the status of planned and actual work through the current biweekly period is shown in Figure 3. The master work-schedule form used by the team to assign maintenance crews is shown in Figure 4. The master work schedule was prepared from the estimates contained in the superintendent's record of inspections and the maintenance management systems standards. A uniform list of function codes for district maintenance-work reporting was used by each team to schedule and report their work.

The game was controlled by the maintenance-training specialist through the use of a time-step narrative. An example follows for Tuesday morning:

1. Conditions: Rain started during the night and is continuing. Forecast is for clearing by mid-morning. Only the three employees on scheduled leave are absent. A check of the equipment shows that roller 250-001 is not operational. The local

Figure 1. Maintenance daily work report format.

FOREMAN'S DIST. OR SECT. _____ GANG NO. _____ GANG FOREMAN _____ DATE _____

LOCATION 1 -	LOCATION 2 -	LOCATION 3 -
WORK DESCRIPTION 1. 2. 3.	BAR NO. 1 _____ PARISH _____ FUNCTION NO. _____ SYSTEMS CODE _____ AUTH. CODE _____ CONTROL UNIT STRUCTURE CODE PROJECT NUMBER STRUCTURE NO.	BAR NO. 2 _____ PARISH _____ FUNCTION NO. _____ SYSTEMS CODE _____ AUTH. CODE _____ CONTROL UNIT STRUCTURE CODE PROJECT NUMBER STRUCTURE NO.	BAR NO. 3 _____ PARISH _____ FUNCTION NO. _____ SYSTEMS CODE _____ AUTH. CODE _____ CONTROL UNIT STRUCTURE CODE PROJECT NUMBER STRUCTURE NO.

EMPLOYEE NAME	MEN BORROWED FROM GANG NO.	HOURS	OVER TIME	HOURS	OVER TIME	HOURS	OVER TIME

EQUIPMENT TYPE	EQUIPMENT NO.	HOURS	MILES	HOURS	MILES	HOURS	MILES

DESCRIPTION OF MATERIALS USED AND/OR STOCKPILE LOCATION	QUANTITY	MEASURE CODE	QUANTITY	MEASURE CODE	QUANTITY	MEASURE CODE

ACCOMPLISHMENT	QUANTITY	MEASURE CODE	QUANTITY	MEASURE CODE	QUANTITY	MEASURE CODE

hot-mix plant expects to operate if the rain stops. District calls and needs two crew members to flag all day with a districtwide crew working in the parish.

2. Superintendent: Assign crew and equipment for wet-weather plan. Adjust plan as necessary because of the loaned crew members. Start the gang working on the wet-weather functions.

3. Clerk: Assist superintendent in making assignments; list assigned crew and equipment on work orders. List on the accomplishment sheet the accomplishments for each function worked on Monday. This will be continued all week so that weekly totals can be obtained easily for each function. It is important to fill in the "repair completed" column of the prescheduling inspection form daily when jobs are completed. For this simulation, the scorer will determine when jobs have been completed.

4. Foreman: Help the clerk with the tabulation of accomplishments. Complete any daily work reports from Monday, if necessary.

The following list illustrates a sample of the scoring instructions provided to each maintenance training specialist in order to assess the outcome of the simulation.

1. Compare crew and equipment on work report with normal crew on scoring charts (e.g., Table 1) and find correct line for normal, under, or over on

Figure 2. Superintendent's record of prescheduling inspections.

Date _____

Name _____

Control Section	Route	Log Mile or Mile Post	Notes	Estimated Quantity	Function	Action Scheduled	Repair Completed
42-05	LA 120		Non-Paved Shoulder needs reshaping - Both sides	10 mi	442	After next rain	
42-05	LA 120		NP Shoulder needs patching	15CY	441	Next week	
53-05	LA3191		Paved Shoulders need surface treat. patch. at Jct 504	8 CY	451		
53-05	LA 1		Potholes - Just East Jct 3191	4 Tons	412	Soon	
53-05	LA 1		Potholes in shoulder - Just S. Jct 485	7 Tons	452	Soon	

Figure 3. Work control board.

QUARTER 1 2 3 4

PERIOD ENDING September 20

Pelican PARISH

FUNCTION NAME		PLAN QUANTITY ANNUAL	PLAN QUANTITY THRU QUARTER	ACTUAL QUANTITY TOTAL TO DATE	ACTUAL QUANTITY BIWEEKLY PERIOD	MAN HOURS BIWEEKLY PERIOD	MAN HOURS TOTAL TO DATE	RATE M-H/QUANTITY PLAN	RATE M-H/QUANTITY BIWEEKLY PERIOD	RATE M-H/QUANTITY AVERAGE
BITUMINOUS SURFACE										
SURF. TREAT. PATCH.	411 cy	454	227	185	104	224	481	2.0	2.2	2.6
POTHOLE PATCHING	412 tons	481	144	130	26	168	793	5.0	6.5	6.1
PATCHING BASE	413 cy	492	172	123	91	224	282	2.0	2.5	2.3
HAND LEVELING	414 tons	964	289	255	70	168	488	2.0	2.4	1.9
MACHINE LEVELING	416 tons	2830	849	518	135	192	832	1.6	1.4	1.6
SPOT SURF. REPL'MT.	417 tons	782	391	387	0	0	1208	2.8	-	3.1
OTHER BIT. SURF. MTN.	419	3832	1150	1038	119	119	1038	1.0	-	-
CONCRETE SURFACE										
PATCHING SURFACE	421 cy	10	0	3	3	35	35	9.0	11.7	11.7
PREMIX PATCHING	422 tons	13	0	0	0	0	0	3.0	-	-
JOINT REPAIR	425 100 ln.'									
OTHER CONC. SURF. MTN.	429	280	70	65	0	0	65	1.0	-	-
GRAVEL OR SHELL SURFACE MAINT.										
PATCHING SURFACE	431 cy	218	11	8	0	0	11	1.2	-	1.4
RESHAPING SURFACE	432 mi	360	54	46	0	0	86	1.6	-	1.9
RESTORING SURFACE	433 cy	450	90	84	0	0	48	.6	-	.6
OTHER GRAVEL/SHELL SURF. MTN.	439	165	8	12	0	0	12	1.0	-	-
SHOULDER MAINTENANCE										
PATCHING NON-PAVED SHOULDERS	441 cy	1544	154	137	0	0	142	1.2	-	1.0
RESHAPING NON-PAVED SHOULDERS	442 mi	892	268	235	25	40	410	1.8	1.6	1.7
RESTORING NON-PAVED SHOULDERS	443 cy	1399	140	129	0	0	104	.7	-	.8
SURFACE TREATMENT PARCHING	451 cy	70	21	26	26	112	112	3.5	4.3	4.3
PREMIX PATCHING	452 tons	26	8	5	0	0	18	3.0	-	3.6
OTHER SHOULDER MAINTENANCE	459	1644	411	465	40	40	465	1.0	-	-
ROADSIDE & DRAINAGE MAINT.										
EROSION CONTROL AND REPAIR	461	1334	334	322	0	0	322	1.0	-	-
CLEAN/REPAIR DRAINAGE STRUCT.	462	3396	475	447	0	0	447	1.0	-	-
CLEAN AND RESHAPE DITCHES	463 mi	21	3.4	3.7	0	0	659	160.0	-	178.1
MACHINING DITCHES	464 mi	7	2.1	4.2	0	0	34	8.0	-	8.1
MOWING	470 ac	6477	2591	2706	415	504	3518	1.0	1.2	1.1
CUTTING BRUSH	471	3419	342	461	112	112	461	1.0	-	-
LANDSCAPE MAINTENANCE	472	334	84	60	0	0	60	1.0	-	-
LITTER CLEANING OF ROADSIDE	473 cy	1133	113	84	0	0	286	3.0	-	3.4
SERVICING LITTER BARRELS	474 brl	416	104	120	28	24	84	.6	.9	.7
HERBICIDE APPLICATION	476 ac	2283	1142	1307	206	72	664	.4	.3	.5
OTHER RDSD. & DRAINAGE MAINT.	479	1460	365	267	0	0	267	1.0	-	-
MISCELLANEOUS ROUTINE		54295								
LEAVE				2384	614	614	2384	1.0	-	-
OVERHEAD		10489	2622	504	72	72	504	1.0	-	-
BETTERMENT										

Figure 4. Master work schedule.

BEGINNING _____

DATE	CONDITION	FUNCT. CODE	CONTROL SECTION	ESTIMATED QUANTITY	CREW DAYS	CREW		PLANNED MANHOURS	EQUIPMENT	NOTES
						REQUIRED	ASSIGNED			

TOTAL MAN HOURS _____
SCHEDULED LEAVE _____
AVAILABLE MAN HOURS _____

crew and equipment. For any function reported in person hours, the daily accomplishment is the number of person hours for the function.

2. Accomplishment is based on crew and equipment assigned and number of hours worked, except as follows:

a. Functions 412 and 452 (see Figure 5) on Wednesday: Travel time to hot-mix plant reduces work time by 2 h. Award accomplishment for 2 h less than reported. (Two crew members may work 2 h on another function on same control section).

b. Function 413 on 115-02: Requires an extra flagman for normal accomplishment. Award accomplishment for one crew member fewer than actually assigned.

c. Functions 414, 416, and 417 on Wednesday: Travel time to hot-mix plant requires use of one extra dump truck and truck driver for normal accomplishment. Award accomplishment for one crew member and one equipment unit fewer than actually assigned.

d. Function 414 and 416 on 115-01: Same as b.

e. Function 414 and 416 on 115-02: Same as b.

f. Function 417 on 835-10: Same as b.

g. Function 441 on 42-05: Function requires only type I equipment operator and dump truck for normal accomplishment if Motor Patrol is working on same section (function 442) on the same day.

Each daily work report was carefully scored in order to properly evaluate the team's decision-making ability. The scoring method outlined in Table 1 exhibits a sample accomplishment assignment table the specialist used along with the scoring instructions to evaluate each activity based on the crew assigned and the number of hours assigned. Figure 5 provides an example of the minimum requirements for completion of a job to determine whether the crew must come back to that same location a second time in order to complete the activity. As mentioned earlier, the final score consisted of a combination of accomplishment and a weighting factor based on the priority of job assignment. An example of the final scoring sheet is shown in Figure 6.

RESULTS TO DATE

The training course and the simulation were tested in one highway district. From this test, several modifications were made to the simulation in order to speed the process and correct deficiencies noted. The training package was implemented by conducting a seminar for all maintenance training specialists within the state that included completion of the simulation with training specialists playing assigned roles.

It was expected from the outset that headquarters personnel would be required to attend the first training presentation in each district in order to overcome some of the negative attitudes that were expected. To date, four districts have administered this training package. Its effectiveness appears to be directly related to the attitude and enthusiasm shown by district management. In areas where district management has received this effort with a positive attitude and a sincere desire to conduct this training, the results have been extremely good.

Currently, the average score is 70.11 (N = 28), compared with a maximum possible score of 93. Results to date are summarized in Figure 7. During the pilot study, before-and-after tests were used to validate the audiovisual training given prior to simulation. Validation test scores are contained in Table 2. An average gain rate of 57 percent compares favorably with the expected gain rate of 70 percent used to evaluate the effectiveness of training materials. No before-and-after testing was conducted during implementation; simulation was used as the sole indicator of the effectiveness of training. Another two years will be required to

Table 1. Accomplishment assignment table for hand leveling.

Condition	Accomplishment (tons) Hours Worked 1	2	3	4	5	6	7	8
Short 2 CMs and 2 EUs	0	1.8	3.5	5.2	7	9.3	11.7	14
Short 2 CMs and 1 EU	0	2.1	4.2	6.4	8.5	11.3	14.2	17
Short 1 CM and 2 EUs	0	2.1	4.2	6.4	8.5	11.3	14.2	17
Short 1 CM and 1 EU	0	2.5	5	7.5	10	13.3	16.7	20
Short 2 CMs	0	2.5	5	7.5	10	13.3	16.7	20
Short 2 EUs	0	2.5	5	7.5	10	13.3	16.7	20
Short 1 CM	0	2.8	5.5	8.2	11	14.7	18.3	22
Short 1 EU	0	2.8	5.5	8.2	11	14.7	18.3	22
Normal (7 CMs, 6 EUs)	0	3.5	7	10.5	14	18.7	23.3	28
Over 1 EU	0	3.5	7	10.5	14	18.7	23.3	28
Over 1 CM	0	3.5	7	10.5	14	18.7	23.3	28
Over 2 EUs	0	3.8	7.5	11.2	15	20	25	30
Over 2 CMs	0	3.8	7.5	11.2	15	20	25	30
Over 1 CM and 1 EU	0	3.8	7.5	11.2	15	20	25	30
Over 1 CM and 2 EUs	0	4	8	12	16	21.3	26.7	32
Over 2 CMs and 1 EU	0	4	8	12	16	21.3	26.7	32
Over 2 CMs and 2 EUs	0	4.2	8.5	12.8	17	22.7	28.3	34

Note: CM = crew member; EU = equipment unit.

thoroughly analyze the results of this effort. We intend to conduct another survey of maintenance specialists to determine the amount of scheduling performed by the parish superintendents after the training has been given statewide. Judging from results achieved thus far, our expectations for the successful implementation of this process are extremely high.

FUTURE REFINEMENTS

Louisiana is currently constructing an automated maintenance simulation model in cooperation with Louisiana State University under a federally funded contract. The model is designed to electronically simulate highway maintenance operations and may be modified to play the highway maintenance game. This would allow training to be focused on the decision-making process by eliminating a great deal of manual effort now required. Completion of the automated simulation project is expected in September 1979. It will probably take another two or three years to convert the manual training simulation into an automated procedure.

Since data processing terminals are not readily available in support of the training function, this

Figure 5. Minimum requirements for completion of maintenance tasks.

FUNCTION	CONTROL SECTION	ACCOMPLISHMENT M	T	W	T	F	ESTIMATED QUANTITY	MIN. OF COMPLETION
412	53-05						4 tons	3.5
412	305-01						2 tons	1.8
412	359-01						5 tons	4.5
412	359-02						6 tons	5.4
416	114-03						40 tons	36.0
416	115-01 (Near Jct. 6)						20 tons	18.0
416	115-01 (Middle of control)						30 tons	27.0
416	115-01 (S. of Allen)						25 tons	22.5
416	115-02						35 tons	31.5
417	835-10						100 tons	90.0
417	835-12						20 tons	18.0
432	116-03						8 mi.	7.2
432	360-04						7 mi.	6.3
441	42-05						15 cy	13.5
441	359-02						9 cy	8.1
441	360-05						25 cy	22.5
442	42-05						10 mi.	8.8
443	362-01						150 cy	135
451	53-05						8 cy	7.2
452	53-05						7 tons	6.3
463	119-01						1½ mi.	1.35 mi.
464	360-04						2 mi.	1.76
470	835-08							(1 mach., 1 day)
470	455-04	(No minimum for Function 470, C.S. 455-04)						
471	114-03						12 mh	10.0
473	455-04						24 mh	21 mh

Figure 6. Final score sheet.

(A) TOTAL ACCOMPLISHMENT	(B) SCORE FACTOR	(A X B) SCORE	"IDEAL" SCORE	FUNCTION
	.18		27	411
	.5		12	412
	.14		16.8	413
	.18		25.2	414
	.11		32.45	416
	.22		25.3	417
	.04			419
	.54		14.36	421
	.3		12	422
	.04			429
	.12		8.1	431
	.13		3.25	432
	.04		10.6	433
	.04			439
	.12		8.1	441
	.14		3.71	442
	.05		20	443
	.21		16.8	451
	.21		8.4	452
	.04			459
	.04			461
	.04			462
	11.2		16.2	463
	.4		2	464
	.09		25.2	470
	.04			471
	.04			472
	.12		4.8	473
	.05		6.75	474
	.03		9.6	476
	.04			479
	.04			499
	.01			533
	.04			559
	.1			602
	.02			655
	.04			656
	.04			660
	.06			667
	.04			699

TOTAL SCORE

Figure 7. Results of manual simulation.

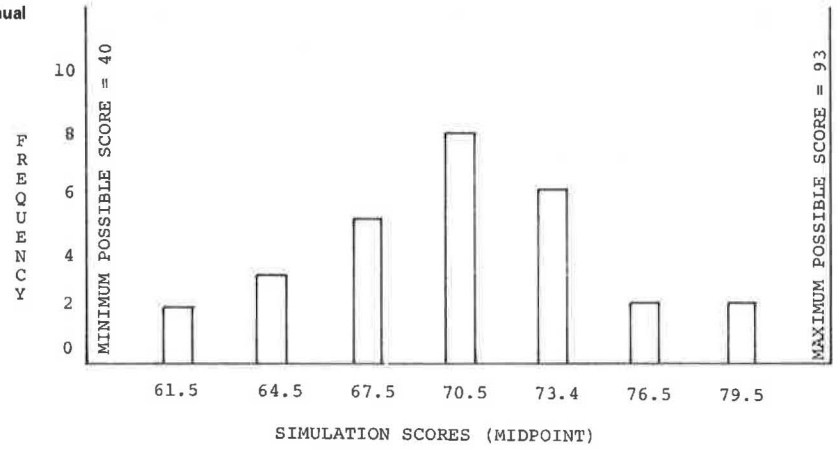

Table 2. Validation results.

Name	Before Training	After Training	Gain (%)
Guecho (ES II)	81	88	58
Phillips (superintendent)	78	90	55
Quatr. (superintendent)	80	92	60
Stein (superintendent)	77	86	39
Pascalin (foreman)	65	90	71
Babin (foreman)	75	91	64
Day (clerk)	86	98	86
Taylor (clerk)	88	93	42
Bezard (clerk)	77	86	39
Avg	78.5	90.4	57

problem will have to be resolved. Another proposal on the horizon that may lead to completely automating the scheduling process on a day-to-day basis would require terminals located in each parish office. Once this hardware is installed, the highway maintenance game can be made available to key parish personnel during slack periods to enhance scheduling proficiency. Maintenance managers hope that future technology will further reduce the cost of terminals and allow them to be used routinely for accomplishment of the training function.

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