THE CODE AS A MANAGEMENT TOOL

There are three areas in which the code facilitates and improves management procedures: financial management, performance management, and management information.

Financial Management

In the past the allocation of funds for routine maintenance work on all-purpose trunk roads and highways has been resource led. That is to say, a sum of money was set aside each year within the total amount available for maintenance work, which was largely based on previous outturn costs for routine maintenance. Little or no account was taken of relative performance or the number and type of specific inventory items to be maintained. There is no doubt that across the national road network standards have been uneven. The object of the code of practice is to achieve more uniform standards. This, together with inventory data, will allow the allocations of funds to be made on the basis of need. This should result in a more cost-effective use of resources.

The code identifies in precise terms how much work is to be done and what will be paid for. This ensures that realistic estimates for routine maintenance funds are received from agents.

Inventories are being prepared of the highway infrastructure on national roads in each agent's area and the inspections under the code of practice will be cross-referenced to these. The allocation of funds is to be made on the basis of the inventory and the standards prescribed in the code, taking account of any local variations.

Performance Management

One of the main purposes of introducing a code of practice is to provide some form of control over performance. As already indicated, such control has been limited, with no facility for regulation on a quantifiable basis. The code with the proposed reporting system provides this.

Management Information

The increasing awareness of the public and their greater criticism of the actions of public bodies make it essential to have effective management information systems to be able to deal with complaints. The introduction of the code itself reinforces the need for these systems because it embodies standards that will be used as a basis for judging whether duties have been properly discharged.

The department has commissioned a study to produce suitable software for handling maintenance management information. This will be compatible with the department's network information system.

REFERENCES

1. Report of the Committee on Highway Maintenance. Ministry of Transport, London, 1970.
2. Report on a Study of General Maintenance and Winter Maintenance of Trunk Roads and Motorways. Department of Transport, London, 1982.

Publication of this paper sponsored by Committee on Maintenance and Operations Management.

Review of Sign Overlay Procedures in Virginia

FRANK D. SHEPARD

ABSTRACT

The sign-refurbishing procedures used by the Virginia Department of Highways and Transportation are discussed with special attention to cost, manpower, time, and quality of the product. In addition, the results of a questionnaire survey made to obtain information on procedures used in other states are presented. Recommendations concerning the most cost-effective and expeditious method of refurbishing signs in Virginia are presented.

Traffic signs are a primary means of warning and guiding motorists, and they must be properly maintained at all times to aid the safe and efficient flow of traffic. Newly fabricated signs have good visibility and legibility; however, the reflective sheeting on the face of the signs deteriorates from exposure to weathering and the accumulation of grime. Once this deterioration reaches the point at which the sign is no longer effective, the sheeting should refurbished or replaced.

Maintaining the large number of signs on the nation's roads demands a substantial effort, espe-

cially now that many of the signs erected during construction of the Interstate and urban arterial systems are deteriorating to the point of requiring replacement. Also, refurbishment has to be done under increased traffic flows as a result of increases in travel demand, which causes concern for the safety of both the highway user and the maintenance employee. This concern, coupled with motorist delays resulting from unavailability of sign messages while they are being refurbished, necessitates the use of efficient refurbishment procedures.

In Virginia it was thought to be imperative that an expeditious sign-refurbishing program be established to support the state's efforts to economize without sacrificing safety. Also, it was thought to be important that the refurbished sign be of a quality to assure effective information and guidance for the motorist. In this regard, it should be noted that there has been some concern about possible problems associated with the waviness ("hot spots") of refurbished signs in which overlay panels are used.

Various methods of refurbishing are used in Virginia, including replacement and the application of overlay panels, and each method requires certain manpower, material, equipment, and so on. In view of the foregoing concerns, it was believed that a review of the Virginia Department of Highways and Transportation sign-refurbishing program was timely and would provide information for optimizing the economics and effectiveness of the program.

PURPOSE AND SCOPE

The purpose of this study was to examine the procedures used by the department for refurbishing signs with the intent of recommending improvements. Specifically, information concerning the cost of refurbishment, the time and manpower required, problems encountered, safety, and the quality of the finished product was desired. Also, a survey of other states was made to obtain information concerning their refurbishing procedures.

The investigation was limited to large ground-mounted and overhead guide signs.

PROCEDURE

Information was obtained in Virginia through the use of a questionnaire and from observations of sign-refurbishing projects around the state. Also, a questionnaire was sent to the other states to solicit information on their refurbishing procedures, problems, and so on.

In addition to a study of the methods now used by the department, a new overlaying procedure developed by the 3M Company and designated Grade 9800 System 5 was observed on several of the field projects monitored. System 5 is a high-intensity-grade retroreflective sheeting with a thin, semirigid backing coated with a pressure-sensitive adhesive. This material can be applied over the existing sign in the field.

The questionnaire sent to each of the department's eight districts gathered information on methods of refurbishing and the materials and fabricating process used. Information relating to the refurbishing procedures, manpower, cost, problems, and so on, was obtained through observation of 13 sign-refurbishing projects around the state. Each project was closely monitored from the time the refurbishing process was initiated in the shop until it was completed in the field. Of the projects observed, six involved refurbishing in the field with overlay panels attached with rivets, and one involved attaching overlay panels in the field by using rivets and an adhesive. Five of the projects involved the use of the System 5 procedure for refurbishment. On one project, the entire sign was replaced.

VIRGINIA SURVEY RESULTS

The results are based on data received from the questionnaire sent to each district and from the observation of the shop and field procedures used for the refurbishing projects observed.

Method of Refurbishing

A summary of the elements of the sign-refurbishing procedures used in the Virginia districts is shown in Table 1. All districts use 4-ft aluminum panels for overlaying. These are sized in the shop to fit the sign to be refurbished and are faced with encapsulated lens background sheeting. Five districts use these panels to overlay their signs in place on the highway and attach the overlay panel to the old sign with rivets, two use rivets plus an adhesive, and one either replaces the entire sign or uses riveted overlays. One of the districts that uses an adhesive in addition to the rivets overlays the sign in place in the field, and the other brings the sign into the shop for overlaying. It is noted that two districts are trying the new System 5 method.

Shop Preparation

Riveted Panels

For riveted panels the overlay panels are prepared in the shop by sizing the 4-ft-wide aluminum panels to correspond to the sign to be refurbished and applying the encapsulated lens sheeting. These panels are then either carried to the field for application, which is the procedure used by most districts, or applied in the shop to the old sign, which is brought in from the field. The copy is also applied in the shop by most of the districts, as will be discussed later.

System 5

The only shop time required for the System 5 process is that for cutting and preparing the copy, which is normally applied in the field. Although one district experimented with applying the copy to the System 5 material in the shop, this procedure is not recommended because the sheeting can be damaged by excessive handling (bending, crimping, etc.), which makes it difficult to align and match in the field.

Sign Replacement

For the project on which the sign was replaced, the new sign was fabricated in the shop with directly applied copy, taken to the field, and erected in place of the old sign.

Sign Surface Preparation

Preparation of the sign to be refurbished differs according to the method of overlaying. Initially, the sign is stripped of all demountable copy,

TABLE 1 Elements of District Refurbishment Procedures

	District							
	Bristol	Culpeper	Fredricksburg	Lynchburg	Richmond	Salem	Staunton	Suffolk
Refurbishing procedure								
Overlay on highway								
Rivet in place	X	X		X		X	X	X
Rivet and glue in place					X			
Overlay in shop (rivet and glue)			X					
Replace on highway (erect in place)				X				
System 5		X				X		
Fabrication procedure								
Application of copy								
Direct applied in shop	X	X		X	X		X	
Demountable in field						X		X
Demountable in shop			X					
Aluminum overlay thickness (in.)								
0.040			X	X				
0.063		X			X			X
0.080	X					X	X	
0.125				X				
Panel width (ft)	4	4	4	4	4	4	4	4
Rivet spacing (horizontal/vertical) (in.)	20/20	12/18	–	–	16/8	24/14	8/16	8/8
Crew size								
Shop	2	2	–	7	3-4	2	2	3
Field	3	3-4	–	8	3	3	3	3

rivets, and so on, which would prevent an overlay panel from lying flat on the surface. For signs to be refurbished with riveted overlay panels, the panels are simply aligned and riveted. For signs to be riveted and glued, an adhesive is applied to the overlay panel and sign before attachment.

Figure 1 shows a sign being prepared for the application of System 5 material, which is limited to surfaces that are smooth, clean, and dry. For weathered surfaces that exhibit spalling, ply separation, delamination, or poor adhesion of the paste, all loose material should be removed by scraping and brushing before the System 5 material is applied.

Although instructions for application of System 5 are provided, some uncertainty exists concerning the degree of deterioration (weathering, spalling, ply separation, delamination, etc.) beyond which System 5 should not be applied. Also, because System 5 adheres to the original sign surface, any dents, bends, and so forth, will be visible; therefore, judgment should be used in selecting signs to be refurbished. Nevertheless, many imperfections can be overlaid without any significant problems.

FIGURE 1 Sign preparation for System 5 material.

Overlay Panel Thickness

In Virginia aluminum overlay panels 0.063 and 0.080 in. thick are used for most large guide signs. Panels 0.040 in. thick have been used, especially for smaller signs; however, this thinner material is more difficult to handle and is more susceptible to the formation of hot spots. There are no data for comparison of the 0.063-in. and 0.080-in. panels; however, based on the assumed cost of each material, the 0.080-in. material costs approximately $\$0.50/ft^2$ more than the 0.063-in. material when new ($\$0.32/ft^2$ for recycled material). The prices may vary with individual bids and quantities. Acceptable results are reported in Virginia for both the 0.063-in. and 0.080-in. thicknesses.

As was previously noted, the System 5 material is a thin, semirigid aluminum with an encapsulated lens retroreflective sheeting.

For the project on which the sign was completely replaced, 0.125-in. aluminum was used.

Attachment of Overlay Panels

Riveted Panels

For riveted overlay panels, a rivet spacing of between 8 and 20 in. horizontally and vertically is used; however, rivets are spaced closer along the edges. Sufficient rivets should be placed to secure the sign and minimize waviness, but too many rivets will detract from the appearance. Figure 2 shows an overlay panel being aligned and Figure 3 shows it being riveted. For the projects on which riveted overlay panels were used, no problems were encountered and the panels were aligned and riveted expeditiously.

Riveted and Glued Panels

In the past some districts attached the overlay panels by using only an adhesive, because this method gave a smooth surface. However, problems were encountered when the old sheeting bearing the adhe-

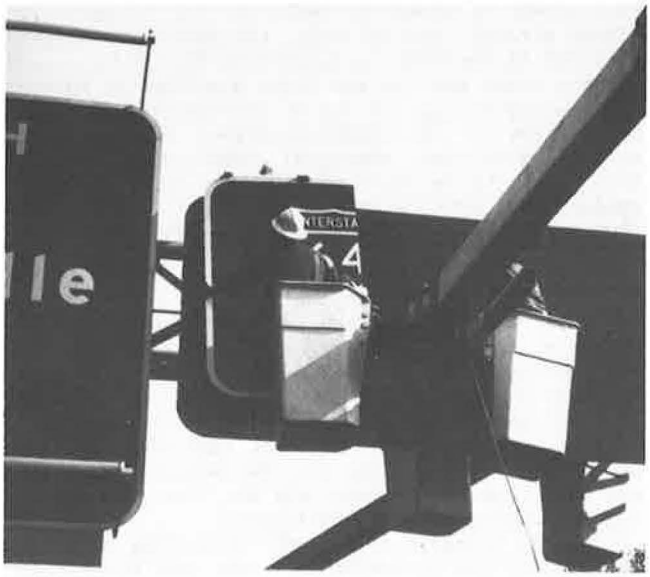

FIGURE 2 Aligning overlay panel on in-place sign.

FIGURE 3 Riveting overlay panel to in-place sign.

sive delaminated and caused the overlay panel to become detached. In an attempt to prevent this situation, rivets were used in addition to the adhesive to secure the panel.

For the refurbishing method employing rivets and an adhesive, the adhesive is uniformly brushed onto the in-place sign and the overlay panel, and the panel is aligned and secured to the sign. Care must be taken when the overlay panel is aligned, because once the adhesive-covered surfaces come in contact, it is very difficult to realign or remove the panel. Also, care must be taken to ensure that the adhesive does not get on the face of the panel and that the cemented surfaces are kept free of dirt, trash, and so on. Using an adhesive in addition to rivets extends the process by requiring extra care in handling and aligning the panels.

System 5 Material

The System 5 material is backed with a pressure-sensitive adhesive and is attached by aligning the 2-ft sheets and pressing them onto the surface with a rubber roller or a soft cloth. No rivets are used in this procedure. Figure 4 shows application of the System 5 sheeting. This procedure requires more field application time than that used for riveted overlays because additional time and care are required in preparing the old sign surfaces and aligning and applying the material. Data on shop and field manpower and time requirements are given later. It should be noted that although it is important to refurbish a sign as quickly as possible, workmanship is also important and special care should be taken in handling and applying the panels. For example, some problems were encountered when the System 5 sheeting wrinkled or captured air bubbles, primarily because the sheeting was improperly crimped or applied. There were also situations in which wind caused problems in application, especially for very high signs.

FIGURE 4 Applying System 5 sheeting.

Application of Copy

Five of the eight districts use directly applied copy for riveted overlay panels; they find that this method is more convenient and cheaper than the alternatives. The directly applied copy is attached in the shop and under favorable conditions, because it can be easily positioned and there is no concern for work-site protection because of traffic. Figure 5 shows copy being aligned in the shop for overlay panels that are to be riveted. Fabricators using demountable copy cite the advantage of being able to change the message without changing the background; others using directly applied copy indicate that changing messages is not a problem. The districts using demountable copy report that the copy is removed from the sign, taken back to the shop, covered with reflective sheeting, brought back to the sign, and reattached. Unless spare letters are available and taken to the field, this process takes more time than using directly applied copy and renders the sign useless for guidance for longer periods of time. In some cases, the sign message may be gone for a day.

For System 5 overlays, the position of the old copy is measured from the old sign and the new copy positioned and applied directly over the System 5 overlay in conformance with these measurements.

FIGURE 5 Shop application of directly applied copy.

Figure 6 shows the application of the copy. It is difficult to get smooth edges when the copy is cut out of the System 5 materials in the shop. With tin snips, two cuttings were sometimes required to get the edges straight and flat. Also, machine pressing, or shearing the copy and border, created a concave area around the edges that made it difficult to get the copy and border to lie uniformly flat on the sign. After approximately 6 months, some deterioration, probably caused by irregular edges, around the edges of the copy and border was noted. Consideration should be given to ways of improving the quality of the copy and border, for example, an improved procedure for cutting in the shop or precut copy and borders.

Shop and Field Manpower Requirements

A summary of the shop and field manpower requirements for the refurbishing projects monitored during this study is shown in Table 2. All projects employed directly applied copy; the System 5 copy was prepared in the shop but applied in the field.

Shop times are the man hours required to prepare the overlay panels for field application, including preparation of the aluminum blanks for the background reflective sheeting, application of the sheeting to the metal blanks (roller and heat application), and application of the copy and border. The shop times did not include any allowance for cutting and preparation of letters, borders, and shields.

Field manpower requirements include man hours for loading and unloading at the shop and in the field, removing copy and border from the in-place sign, preparing the sign surface, and installing the overlay panels. Travel and lane-closure times were not included because they vary according to the sign location and number of signs refurbished per trip.

Table 2 also gives the total time that the sign was out of service, that is, the message was either not visible or incomplete, and the time that maintenance personnel were on the highway.

For the System 5 method of overlaying, shop time is required for preparing the copy and border, but all copy and border are usually applied to the sign in the field.

Figure 7 shows plots of the total man hours (shop and field) required for the methods of sign refurbishment versus the total area of the signs on the projects monitored. Sufficient data were available for the procedures in which the overlay panels were fabricated in the shop with directly applied copy and attached with rivets to the sign in the field and for the application of System 5 material in the field. For riveting and glueing in place and sign replacement, data were available for only one project each. In order to obtain estimates of the man hours for these refurbishing procedures with limited data and different sign sizes, lines were drawn through the single points with assumed slopes identical to those for the riveted overlay projects.

Only two of the available projects were used to establish the curve for the refurbishing procedure in which System 5 material was used. The two were completed by the Culpeper District and represent the last two of six System 5 overlay projects in that district. These projects were used because the System 5 overlaying procedure is new and time was required for the workmen to become familiar with the material and procedures.

In considering the refurbishing procedures normally used by the department, it is obvious from the curves that the method of using riveted overlay panels attached in place requires the least number of man hours for completion. Overlaying in place by using rivets and glue takes significantly more man hours, whereas sign replacement requires substantially more man hours than either overlay method. On the basis of data gathered from the last two System 5 refurbishing projects, this new method requires slightly fewer total man hours than either of the riveting methods.

FIGURE 6 Applying copy to System 5 overlay.

Crew Size and Equipment

The crew size varies among districts, ranging from two to four persons for shop preparation depending on the method of refurbishing. The crews used in the field for applying both the overlay panels and the System 5 material ranged from three to four men, with the exception of sign replacement, which required more. Unless there are reasons for having a larger work crew, it appears that a three-man crew is appropriate.

Most districts use a bucket truck and a flatbed for refurbishing. These vehicles appear appropriate

TABLE 2 Shop and Field Manpower Requirements for Refurbishment Procedures

Item	Overlay with Rivets by Sign Area (ft^2)						Rivets and Glue[a]	Overlay with System 5 by Sign Area (ft^2)					Replacement[g]
	80	119	138	163	173	224		116[b]	158[c]	109[d]	126[e]	214[f]	
Shop													
No. of men	1.5	–	2	2	2	2	3.5	0	0	0	0	0	7
Man hours	4.1	–	6.9	7.0	7.8	10.1	20.1	0	0	0	0	0	30.8
Field													
No. of men	3	5	4	4	2.5	–	3	5	4	3	3	4	8
Man hours	3.1	6.2	6.0	5.5	5.6	–	13.2	20.3	16.9	17.0	9.9	13.2	23.7
Total man hours	7.2	–	12.9	12.5	13.4	–	33.3	20.3	16.9	17.0	9.9	13.2	54.5
Message unavailable (hr)	0.63	0.97	1.20	–	1.48	–	2.83	3.58	3.75	3.73	2.72	3.88	2.83
Personnel on road (hr)	0.87	1.13	1.38	–	2.03	–	3.15	3.97	4.08	4.13	3.03	4.22	3.17

Note: Dash indicates data not available.

[a]Sign area 213 ft^2.

[b]Project date July 1981.

[c]Project date April 1982.

[d]Project date June 1982.

[e]Project date August 1982.

[f]Project date September 1982.

[g]Sign area 182 ft^2.

for the refurbishing procedure used, with the exception of sign replacement, which may require more vehicles.

Cost of Refurbishing

A cost comparison of the refurbishing procedures is shown in Table 3. In establishing relative costs, sign sizes of 80 ft^2 (small), 140 ft^2 (medium), and 200 ft^2 (large) were used. The total costs do not include those for hand cutting of copy, space rental, or miscellaneous items such as rivets, glue, and tools.

Materials

Costs for materials are those currently being paid by the department for blank aluminum sign material and silver and green encapsulated lens sheeting. The costs of aluminum for the overlay panels were calculated by using costs for recycled aluminum, which is now being used by the department. Also, a salvage value for the overlay panels was included because they can be recycled.

Labor

The labor costs for shop fabrication and field application were estimated by superimposing lines representing the three sizes of signs on Figure 7 and multiplying the resulting total man hours by the hourly wage. Labor costs for travel and work-site protection were calculated by assuming 1.5 hr per day for travel to and from the sites and an assumed 1.0 hr per sign for work-site protection. The cost of labor was taken from the Culpeper District and represents an average hourly rate with additives included.

Vehicle Rental

Vehicle costs were estimated by using the daily rental costs for a bucket truck and a flatbed truck

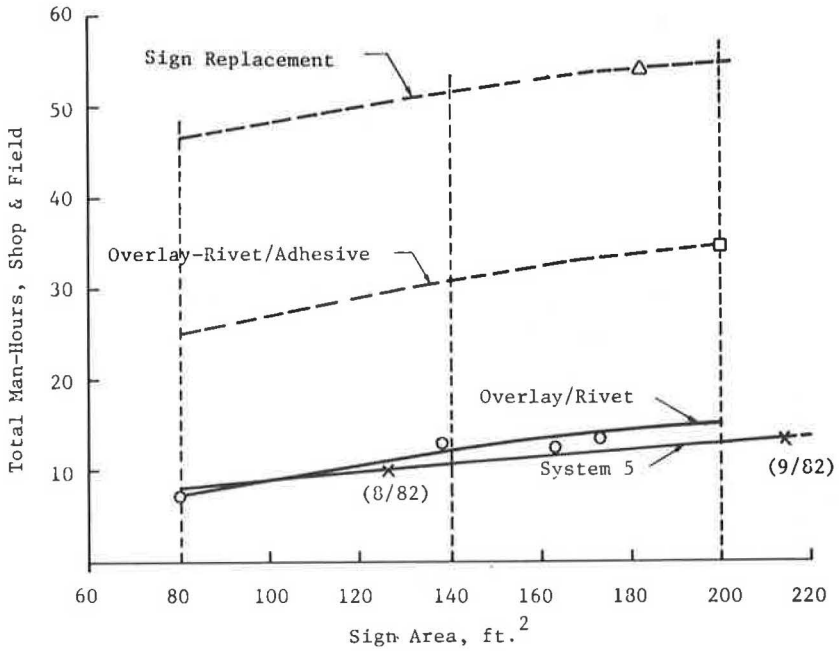

FIGURE 7 Total man hours for refurbishing procedures.

TABLE 3 Cost of Refurbishment Procedures

	Procedure														
	Rivet in Place[a] by Sign Area (ft^2)			Rivet in Place[b] by Sign Area (ft^2)			Rivet and Glue in Place[c] by Sign Area (ft^2)			System 5 by Sign Area (ft^2)			Replace Sign[d] by Sign Area (ft^2)		
Cost ($)	80	140	200	80	140	200	80	140	200	80	140	200	80	140	200
Material															
Aluminum blanks	45	79	113	71	124	177	45	79	113				105	183	262
Reflectorized sheeting															
HI green ($2.94/$ft^2$)	235	412	588	235	412	588	235	412	588				235	412	588
HI silver ($2.94/$ft^2$)	64	111	159	64	111	159	64	111	159				64	111	159
S-5, HI green ($3.65/$ft^2$)										292	511	730			
S-5, HI silver ($3.05/$ft^2$)										66	115	165			
Total material	344	602	860	370	647	924	344	602	860	358	626	895	404	706	1,009
Labor ($9.94/hr)															
Total (shop and field)	72	119	150	72	119	150	249	293	328	81	104	129	463	517	552
Travel and work-site protection (cost per sign)	45	52	75	45	52	75	75	52	75	75	52	75	75	75	75
Total labor	117	171	225	117	171	225	290	363	397	133	179	204	538	592	627
Vehicle rental (per sign)	37	55	110	37	55	110	55	110	110	55	110	110	152	152	152
Total cost of refurbishing	498	828	1,195	524	873	1,259	700	1,080	1,373	546	915	1,209	1,094	1,450	1,788
Total cost per square foot	6.23	5.91	5.98	6.55	6.24	6.30	8.75	7.71	6.87	6.83	6.54	6.05	13.68	10.36	8.94

Note: HI = high intensity; S-5 = System 5.

[a]Sign blank 0.063 in. thick.

[b]Sign blank 0.080 in. thick.

[c]Sign blank 0.063 in. thick.

[d]Sign blank 0.125 in. thick.

in the Culpeper District. This total daily cost was adjusted depending on the number of signs refurbished per day, which resulted in a vehicle cost per sign.

Total

The total cost of refurbishing is given for each sign size and per square foot in Figure 8. Of the procedures normally used for sign refurbishing in Virginia, the most economical method used overlay panels fabricated in the shop with directly applied copy and attached in the field with rivets. The procedure with 0.063-in. aluminum was approximately $0.32/$ft^2$ cheaper than that with 0.080-in. material.

The application of overlay panels (0.063 in.) with rivets and glue was more expensive, costing between $0.89 and $2.52/$ft^2$ more (depending on sign size) than when rivets alone were used. As might be expected, replacing a sign is significantly more expensive than overlaying.

The cost of using the System 5 material was higher than the riveted-in-place method of refurbishing for small and medium sign sizes, costing approximately $0.61/$ft^2$ more than 0.063-in. aluminum

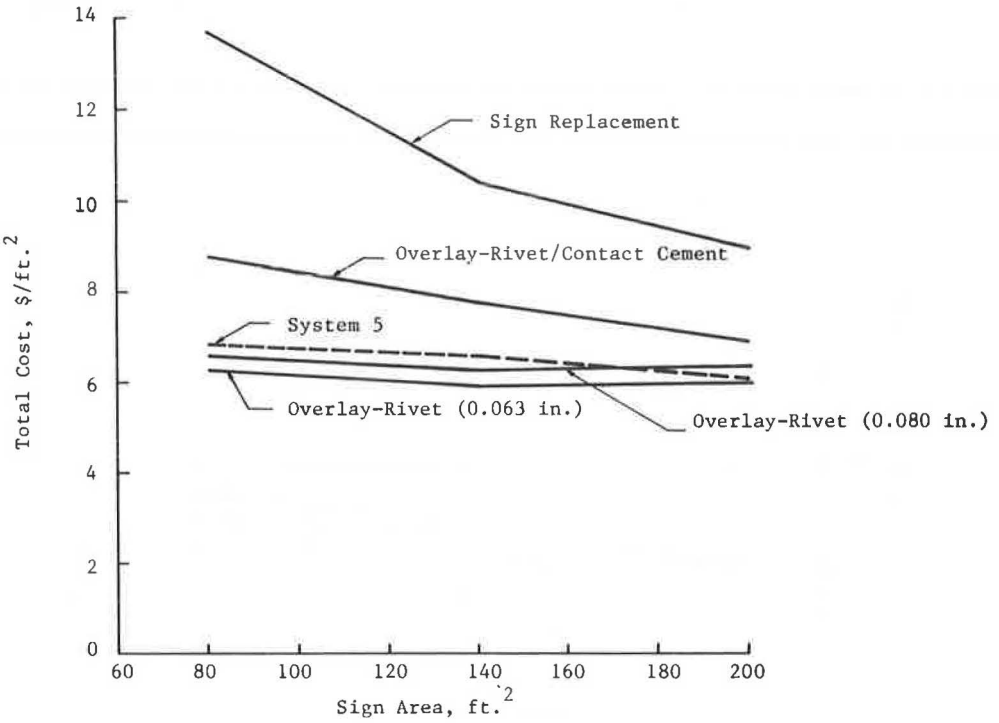

FIGURE 8 Total cost of sign refurbishing.

panels and $0.29/ft² more than 0.080-in. panels. For large signs, the cost per square foot for System 5 material was approximately equal to that for the 0.063-in. panels and less expensive ($0.25/ft²) than that for the 0.080-in. panels.

The total cost of sign refurbishing will vary according to the number of signs refurbished per trip, the number of man hours for fabrication and erection, the cost of sheeting, the aluminum sign panel salvage value, and so on. Good planning and the effective use of manpower are therefore important in ensuring an efficient refurbishing program, because many of the costs are fixed.

Exposure to Traffic

The length of time that the sign crew is on the highway refurbishing the sign and exposed to traffic and the length of time that the message is unavailable for guidance are shown in Figure 9. Both of these times are shortest for the riveted overlay with directly applied letters. The other methods require substantially more time, with the System 5 procedure requiring at least twice the time (1.5 to 2 hr) because the message is applied in the field. Although data are not available, use of demountable copy on riveted overlay panels (copy taken to the shop for sheeting application) would take more time on the highway and time during which the message was absent than use of riveted panels with directly applied copy.

In the interest of safety, it is important to minimize the time spent on the road refurbishing signs, especially where there is congestion or high traffic volumes. Also, where the availability for motorist guidance is important, the time required for refurbishing should be kept to a minimum. However, there are areas where these factors are not so critical.

Quality of Refurbished Signs

The relationship between the costs of the refurbishing procedures and the quality of the refurbished sign in terms of durability and legibility has been the subject of a great deal of discussion. For example, it has been noted that use of the most economical procedure, overlaying with aluminum panels, tends to produce signs with wavy surfaces, especially at rivet locations, that cause hot spots at night.

Problems with hot spots caused by wavy overlay panels were acknowledged by personnel in some districts; however, these were not believed to be of great concern. Various opinions were given concerning the cause of sign waviness, especially at the rivet locations. Some theorize that the overlay panel, being thinner than the background sign, tends to react more quickly to temperature variations, and that there is thus a differential in expansion and contraction between the two. Also, some district personnel stated that the thinner aluminum overlay panels presented more problems with hot spots.

At all the district shops visited, it was observed that the new aluminum material used for overlaying was uneven. The material was not uniformly flat; that is, one edge would lie flat on the floor, whereas the opposite edge would be wavy. This unevenness would keep an overlay panel from lying flat against the face of the sign being refurbished.

The unevenness of the aluminum sheeting could decrease the effectiveness of adhesives used for attaching overlay panels. Personnel in one district commented that the adhesive used would not hold after a period of time, and those in another district reported that overlay panels separated from the background sign when the adhesive failed. In light of these problems, and considering the extra cost, time, and inconvenience of using adhesives, the procedure should be questioned.

Overall, the System 5 method produced a refurbished sign of good quality for those installations in which care was taken in applying the material and the sign to be overlaid was in good condition. Periodic observations were made of all the signs refurbished with System 5, and after 1 year most of them were in good condition. One sign showed numerous air bubbles or circular areas in the sheeting. Before refurbishing, numerous rivets were removed from this sign and the old sheeting exhibited spalling. The sign was prepared according to instructions and primed before application of the System 5 material. Close examination of the bubbles revealed that

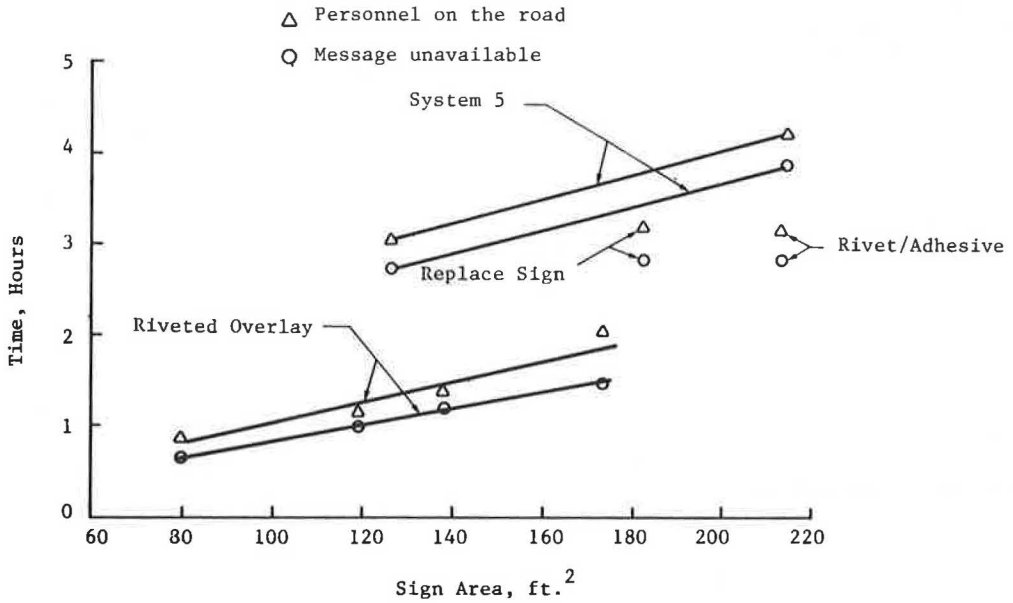

FIGURE 9 Time for personnel on the road and message unavailability.

the problem resulted from a lack of adhesion between the System 5 material and the background panel. In some cases this was caused by small protrusions, especially at the old rivet holes, which prevented the sheeting from adhering uniformly to the back panel. Possible contributions to the problem include entrapment of air during application and entrapment of solvent caused by incomplete drying of the primer, which cannot diffuse through the aluminum. Care should be taken to ensure a smooth surface for the application of System 5. It is difficult to see any entrapped bubbles unless they are viewed at a slight angle from beneath or beside the sign. They cannot be detected at night and do not influence the legibility of the sign. Also, the bubbles do not appear to increase in size.

Data are not available on the long-term durability and visibility of the System 5 material because it is a new product. Therefore, observations will continue to be made.

STATE SURVEY RESULTS

Questionnaires were sent to 49 other states to solicit information on their refurbishment practices and procedures. The general items covered in the questionnaire and the responses are discussed in the following paragraphs.

Method of Refurbishing

About half (51 percent) of the states reported that they refurbish their guide signs by attaching overlay panels in the field, 13 percent replace the sign, and 34 percent either replace the sign or attach overlay panels. The System 5 method of refurbishing is being used experimentally by 47 percent; however, only 2 percent are using System 5 or other commercial overlays exclusively.

Of the signs refurbished, 58 percent are overlaid in place, 16 percent are lowered to the ground, and 7 percent are taken to the shop.

Fabrication of Overlay Panel

Most (94 percent) of the states use aluminum overlay panels with thicknesses varying from 0.032 to 0.080 in. Most overlay panels are either 0.040 or 0.060 in. thick; the thicker panels are generally used for larger signs. Eighty-eight percent of the states reported using the same thickness for all sizes of signs.

Seventy-four percent of the states use 4-ft-wide overlay panels; 77 percent use a butt joint and 14 percent use an overlap joint.

Rivets are commonly used (87 percent of the states) for attaching the overlay panel to the sign backing. Most rivets are either 1/8-in. diameter (48 percent) or 3/16-in. diameter (39 percent) with spacing varying from 6 to 24 in.

Placement of Copy

Directly applied copy is used by 43 percent of the states to refurbish their signs; 30 percent use demountable copy and 23 percent use either directly applied or demountable copy. Four percent use button copy.

Most states (59 percent) apply copy in the shop; however, 21 percent do this in the field. Eighteen percent apply copy both in the shop and in the field, depending on the circumstances.

For those states applying copy in the field, 33 percent measure from drawings, 22 percent measure from the original sign, 19 percent drill through the existing holes, and 15 percent measure from either the drawing or the original sign.

Problems Related to Field Overlay Installations

Fifty-nine percent reported no problems related to work methods and handling of overlay panels, whereas 13 percent noted problems with handling and damage in transport. Thirteen percent indicated problems related to traffic control and equipment use. Seven percent reported problems with wind.

Appearance of Overlay

Generally, there was satisfaction among the states with the final appearance of their overlaid signs; 53 percent reported no problems. Ten of 34 states noted problems with hot spots; however, in 4 states the problems were cited as minor, whereas in 1 the hot spots were blamed on excessive rivet drawdown, and 1 attributed then to prior damage.

The sign overlay materials and procedures used by all states were examined to determine whether the problem with hot spots was associated with overlay panel thickness, rivet size, or rivet spacing. For 0.040-in. material, five states reported hot spots, whereas six had none. Four states had a problem with 0.060-in. to 0.063-in. panels, whereas eight reported no problem. None of the six states using 0.080-in. material reported problems with hot spots or legibility.

There were no apparent influences of either rivet size or rivet spacing.

Criteria for Refurbishing Guide Signs

Seventy-three percent of the states responding have a criterion for determining when guide signs should be refurbished. Of this number, 87 percent inspect the signs, and 13 percent use age as the criterion. Inspection involves day, night, or day and night observation of appearance, visibility, and so on.

Questionnaire Comments

Most comments concerned the procedure for refurbishing included in the foregoing discussion. Some of the more relevant comments are as follows:

1. Aluminum panels 0.040 in. thick were tried (overlapping away from traffic) but it was found that the surface warped or became wavy, perhaps because the thin overlay contracted or expanded at a different rate than that of the original sign background. Now 0.080-in. overlay with 1/8-in. rivets (24 in. vertically and 12 in. horizontally) is used with no problems.
2. The new decade will see much refurbishment of existing signs. The procedure used will depend on which takes the most labor to erect--a new sign or an overlay--plus the cost of materials.
3. There is a saving of approximately 200 percent with overlay as opposed to fabrication of a new sign.
4. Costs have gone up to $\$12/ft^2$, including furnishing and applying new button copy. (Overlay panels were usually attached in field; encapsulated lens with rivets used).
5. All refurbishing is done by contract. Recent

osts are $12 to $13/ft², depending on quantity price includes necessary traffic control) compared ith $15 to $17/ft² for new extruded aluminum sign anels [encapsulated lens overlay panel (0.040 and .063 in.) riveted in place].

CONCLUSIONS AND RECOMMENDATIONS

Of the procedures used for sign refurbishing in Virginia, overlay panels fabricated in the shop with directly applied copy and attached in the field with rivets is the fastest and most economical. It is believed that this method is an effective and economical means of refurbishing signs and that the department can save a significant amount of money if it adopts the method for use throughout the state and utilizes personnel and equipment as recommended. Little or no surface preparation is necessary and signs can be overlaid in the summer and winter. Also, this procedure requires the least exposure to traffic for maintenance personnel and equipment and also results in the least amount of out-of-service time for the sign.

Although problems with hot spots were acknowledged in some districts, they were not believed to be of great concern. This belief was confirmed by responses to the nationwide questionnaire, which indicated no problems with hot spots.

It is believed that under certain conditions, as noted in this paper, the System 5 method of refurbishing large guide signs is an acceptable alternative. This method, although more expensive, is in the cost range of the riveted-overlay method of refurbishing and, on the basis of a limited observation period, results in a refurbished sign of good quality.

The nationwide questionnaire survey, to which approximately 92 percent of the states responded, showed that slightly more than half of the states refurbish signs by attaching overlay panels in the field and that 13 percent replace the signs. Fifty-eight percent of the signs overlaid in the field were refurbished in place; however, 16 percent were lowered to the ground. Directly applied copy is used more than demountable copy and both are applied in the shop by 59 percent of the states. Most states (94 percent) use aluminum overlay panels of thicknesses ranging from 0.032 to 0.080 in. Most panels are either 0.040 or 0.060 in. thick; the thicker 0.080-in. panels are generally used for larger signs. Rivets are typically used to attach the overlay panels and are usually spaced from 6 to 24 in.

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Evaluation of Bus Maintenance Manpower Utilization

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ABSTRACT

Proper manpower planning for transit bus maintenance has not received the same attention as operator manpower planning; yet it is crucial to the economical operation of transit agencies. Maintenance managers have relied on simple ratios such as buses per mechanic or maintenance man hours per mile of operation to perform this function. Recognizing the need for a reliable, relatively uncomplicated maintenance manpower planning technique, NCTRP contracted for this study. Detailed maintenance manpower data were collected from 15 public transit bus agencies that represented a cross section of these agencies in different parts of the country. Consideration was given to the vast differences in the agencies in terms of fleet size, fleet composition, topography, climate, and fleet use. Maintenance manpower requirements were developed on the basis of detailed work activities by vehicle subfleet and functional area. A series of statistical applications were made to compare the range of maintenance requirements and account for variances in time to repair and frequency of repair by vehicle system and subfleet. The manpower utilized by public transit bus operators is reported by vehicle subsystem and by major work activity. This analysis provides the basis for an uncomplicated manpower model that will enable maintenance managers to better plan their manpower requirements on the basis of the specific site criteria of the agency.