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Subject Area: VI Public Transit Responsible Senior Program Officer: Christopher W. Jenks

Responding to Vandalism of Transit Bus and Rail Vehicle Passenger Windows

This TCRP digest provides a summary of findings from TCRP Project C-4, "Enhancement of Vehicle Window Glazing for Vandal Resistance and Durability," conducted by the University of Dayton Research Institute. Included in the digest are brief descriptions of current and emerging methods available to address the passenger window vandalism problem.

INTRODUCTION

Transit vehicle windows have become high profile items because of problems with vandalism and related maintenance. Whereas the window used to last the life of the vehicle or was changed-out only on that rare occasion when it was chipped or broken, it has now become a consumable item requiring frequent change-outs, considerable maintenance resources, and the logistics of maintaining an inventory of spares. In New York City alone, the MTA New York City Transit reports that properly maintaining vandal-etched bus and rail windows costs $60-70 million annually. In addition, surveys indicate that the cost of vandalism for mass transit is increasing by 11 percent per year, which means that it is doubling every 6.5 years. This rise in vandalism has caused many transit agencies to rethink windows and window issues. Vandal resistance and quick change-out of the windows are becoming high priorities to transit agencies with vandalism problems.

There are essentially three ways to attack the vandalism problem: (1) the development of repair techniques for the current system, (2) material solutions to the problem, i.e., materials or material systems that provide resistance to vandalism, and (3) prevention. Prevention includes police/security, maintenance, and operator involvement, as well as transit authority policies, punishment, legislation, surveillance, and other technologies. Service life and maintenance issues are a function of the procured system and the operating environment. Strategies to improve service life and reduce maintenance problems have implications for new procurements in terms of specifications for durable, relatively trouble-free, vandalism-resistant technologies.

Under TCRP Project C-4, research was undertaken by the University of Dayton Research Institute to (1) compile information on transit bus and rail vehicle window vandalism and current and emerging window glazing technologies with potential applicability to the transit industry and (2) develop guidelines to assist transit agencies in the preparation of procurement specifications related to transit bus and rail vehicle passenger windows.

Three documents were produced from the project: (1) *TCRP Report 15*, "Procurement Specification Guidelines for Mass Transit Vehicle Window Glazing," prepared for transit maintenance and procurement specialists concerned with the development of specifications for the purchase of durable and vandal-resistant bus or rail vehicle passenger windows and window systems; (2) an unpublished final report, "Enhancement of Window Glazing for Vandal Resistance and Durability," which provides the details of extensive surveys conducted during the project of domestic and foreign transit systems, window

system manufacturers and suppliers serving transit and other industries, transit vehicle manufacturers, and vandalism and graffiti experts; and (3) this *Research Results Digest,* which provides a brief summary for transit managers of the information contained in the final report. Copies of *TCRP Report 15* and the project final report are available through the TCRP, 2101 Constitution Avenue, N.W., Washington, DC 20418.

VANDALISM AND GRAFFITI

Vandalism has become increasingly present and visible in the public sector over the past 35 years. Graffiti is the main form of defacement to publicly owned property. The national cost of property removal and replacement due to vandalism and graffiti exceeded 7 billion dollars in 1994; more than 1 billion dollars was spent to remedy glass etching.

Over the past 3 years, vandalism in the form of scratching, scribing, and etching windows has become a problem for most transit authorities; for some it has grown to epic proportions. Unlike spray paint and marker graffiti, window scratching and etching cause permanent damage and cannot be cleaned with a solvent or repainted. Glass window etching and scratching can compromise the structural integrity of the window, reducing its resistance to impact and increasing the potential for passenger injury.

In this project, vandalism and graffiti are considered in several forms. These include defacement, "artwork," messages, and tagging. The last three contain elements of self-recognition/public recognition. Targets for vandalism have included exterior structures such as signs, buildings, walls, and bridges; interior structures such as malls, elevators, and escalators; elements of the public transportation system such as buses and light rail transport systems; and other transportation systems vehicles like railroad cars and semi trailers. Since a desire for recognition is inherent in the act of vandalism, permanence of the graffiti or other damage is of prime importance. Glass and plastic windows, enclosures, and mirrors provide durable canvases for the "artwork." Windows in particular (they cannot be repainted, are not easily resurfaced in situ, and are costly to replace) invite graffiti.

Vandals use a number of objects to scratch, scribe, etch, cut, scuff, or deface transparent materials, and ground transportation vehicles sustain damage ranging from breakage of the window panels to scratches and scuffs to elaborate drawings or messages. These messages may be written in English or encrypted with special characters that are intelligible only to persons "in the know." These groups have underground publications that encourage, interpret, and teach this vandalism. The Internet is also being used to spread information on the best places to "hit" and the tools to use. Some prestigious universities even offer courses in "Graffiti Art."

Vandalism of windows in ground transportation vehicles was concentrated mostly in large metropolitan areas, but now has spread to smaller cities nationwide.

RESULTS OF TRANSIT SURVEY

Problems with durability and vandalism/etching of the windows vary widely among the transit systems. Some transit systems describe the condition of their windows as a disaster with a very high percentage currently etched or damaged and a very high graffiti/ vandalism/etching rate (in terms of incidents per day or week). Some systems report almost no problems. Overall, problems with window etching are increasing throughout the transit community. Of the systems with major problems, some realize what should be done to fix the problems, but cannot afford to spend the "one dollar required to save one hundred dollars."

There are two distinct groups that have minimal or no problems with window vandalism. The first group is located in areas where the "fad" has not become popular. The second group is in areas where, though graffiti and vandalism are high, anti-graffiti measures (maintenance, security, and driver practices) discourage and control it. Also, there is a variation in severity of the vandalism problem within a given agency between the various modes of transit. Commuter rail systems are often relatively free of damage, while other modes of transit in the same area are not. This is often strictly a function of the ridership. Commuters tend to be older, more responsible citizens. The other transit modes which carry school-age children and young adults are more likely to sustain damage. Buses and trolleys are easy targets for vandals because stops are frequent and security is less than on other transit modes.

TRANSIT WINDOW MAINTENANCE AND ENGINEERING ISSUES

Window system issues dealing with graffiti include the need for easily procured replacements and easy maintenance, especially quick change-out of windows. Transit maintenance staffs, already overburdened with spare vehicle shortages and the work required to keep vehicles fueled and operating, have little time remaining to take on special tasks like window maintenance and change-out. Prior to the surge in graffiti problems of the past few years, windows were changed only when they "wore out." Many window designs are not conducive to maintenance and quick change-out. Curved window panes, while aesthetically pleasing, have a number of inherent disadvantages including increased cost and limited procurement sources. Flat windows,on

the other hand, are less expensive, are widely available, and can be changed relatively easily between window material systems. Most transit and maintenance personnel indicated that they would not procure new vehicles with curved windows.

Typical change-out time for most vehicles, including rail cars with the rubber gasket "zip-strip" edge designs, is half an hour or more. This results in significant additional maintenance time when a number of windows require changing on a night shift; this hits a transit system with a "zero tolerance/no vehicle in service with graffiti" standard particularly hard.

Of the three window types currently available, fixed windows are the most attractive from a maintenance standpoint, followed by transom windows, and sliding windows. Transom windows have been chosen as a compromise by many agencies for although they are more complex than fixed windows, they are less prone to failure than sliding windows.

MATERIAL SOLUTIONS

Background--There is no consensus among transit authorities on which existing transparent material systems is the best. For certain modes of transit, the material system is dictated by regulations. Existing transparent window materials in use include safety glass, coated acrylic, and coated polycarbonate.

Glass provides superior service life and is impervious to chemical attack, aging, and environment. Moreover, glass is the most difficult material to scratch. But its drawbacks are that it is heavy, cannot be refurbished easily, and has higher liability because of flying glass when a window breaks.

Acrylic can be refurbished (ground, polished, and recoated) but it does not provide the impact protection of laminated safety glass or polycarbonate (acrylic fractures into large jagged pieces when broken). Acrylic is subject to hazing and crazing, it burns, and it requires a protective coating.

Polycarbonate provides superior impact resistance but its softness is susceptible to abrasion and scratching, as well as environmental and chemical attack, and it must have a protective coating.

All of these materials, glass, acrylic, and polycarbonate are less expensive in the flat condition. Forming them into shapes or curvatures increases the window cost.

Durability of plastic materials is a function of the type of plastic or coating system and the environment to which the window is exposed. Plastic ages and degrades from the effects of time, temperature, moisture, and ultraviolet light. Other aging factors include pollution; chemicals used on or in the vicinity of the windows (cleaners, graffiti removers, solvents, fuel, etc.); abrasion from cleaning; scratching from cleaning or with foliage, signs, etc., while in motion; and impact damage and vandalism (etching, scratching, and carving). The use of brush washing systems and graffiti removal substances may affect the durability of plastic transit windows. To illustrate the negative effects of environmental conditions, at one transit system, hardcoated acrylic bus windows last approximately 2 years before they are severely crazed (i.e., a crack-like surface phenomenon in plastics). The same acrylic bus windows used by a number of other systems virtually never craze. What are the differences? Climatic conditions (temperature, moisture, and UV dosage), air pollution, bus washing fluids, and the frequent use of graffiti removal substances all take their toll.

Refurbishment--Another method under evaluation is window refurbishment. To date, this has only been economical on acrylic windows. The acrylic windows are removed from service, ground, polished, and recoated at a refurbishment/repair facility, and returned to the transit authority. There are a number of logistical complications relating to refurbishment, which include record keeping, storage, and shipping. There are significant savings, however. One system reported paying $240 to have acrylic bus windows (which cost $1000 new) refurbished. The pressures of refurbishment and competition have resulted in significant reductions in the cost of new acrylic transparencies. This reduction of the margin in cost between new and refurbished windows has reduced the attractiveness of refurbishment for some agencies.

Sacrificial Plies and Films--Several relatively new vandalism-resistant material solutions are immediately available and are currently being evaluated and/or procured by various transit agencies. One of these is a sacrificial ply system which is an inexpensive piece of plastic held to the window's interior side with two-sided tape, or is held in place by the window frame itself. These plies can be replaced quickly after being vandalized. A stock of die-cut sacrificial ply panels can be kept on hand for quick change-out. A $10 to $15 cost per replacement is reported, and change-out time can be as short as 5 min. A second vandalism-resistant material solution is a peel-ply protective film placed over the interior of the window. When this peel-ply is damaged, it is stripped off and replaced. Peel-ply products are also inexpensive, but do not change-out as quickly as the sacrificial ply products. A stock of die cut, peel-ply sacrificial films can be maintained for quick change-out. A $5 to $10 cost per replacement is reported, and change-out time can be as short as 15 min. However, vandals have been known to lift the peel-ply and scratch or etch the substrate.

Anti-Spall Technologies--Anti-spall films have been developed specifically to combat "smash and grab" robberies, car-jacking, and hurricanes. They are applied to the interior surface of glass

windows to prevent glass spall when the window is damaged and are already being used by a number of transit systems. The impetus to use the product is to reduce the possibility of passenger injury resulting from spalled (flying) glass. In some cases, the relatively soft anti-spall film is further protected from carving and etching by a sacrificial acrylic ply.

Coating and Aerospace Transparency Technologies--A number of technologies that have been developed for the aerospace industry have application to transit system windows. For example, polyurethane coatings and liners have been developed that increase the durability of plastic transparencies. These new materials are significantly more resistant to scratching, scuffing, abrasion, chemical attack, and weathering than uncoated plastics. Polyurethane liners have self-healing properties (gouges and imprints and abrasion damage disappear with time and/or with the application of heat). The aerospace industry has also conducted significant research over the past several years to combat chemical crazing of acrylic airline cabin side windows. A number of advanced coatings are being flight tested, but no concrete data is available to indicate which coatings provide the best service life.

Another concept that is being evaluated by the aerospace industry is an acrylic side window clad with a very thin (0.030 in.) chemically tempered glass ply. This glass does not shatter on impact and only retains damage at the impact site. The interlayer adhesive system prevents the glass from spalling. This type of system would both prevent crazing and abrasion damage of acrylic bus windows and substantially increase durability of exterior surfaces. Cost would be a significant factor, however. Another emerging technology is diamond-like-carbon (DLC) coatings, which have very attractive properties for this application, including excellent abrasion resistance, chemical resistance, thermal resistance, and durability. This technology has not yet been evaluated for use in transit systems.

PREVENTIVE SOLUTIONS

Survey findings indicate that the one system which controls vandalism is an integrated team approach to zero tolerance. Zero tolerance means "no vehicle in service with graffiti." The integrated team includes drivers, security, maintenance personnel, and may even include the passengers. This zero tolerance approach should be a structured proactive cooperative effort.

Practices of this zero tolerance team may include anti-graffiti education, immediate reporting of problems, immediate response to problems, routine and random uniformed and undercover patrols, video surveillance, rewards and bounties, truancy sweeps, documentation of incidents, inter-agency sharing of tag documentation and tagger files, prosecution of all vandals (treatment of vandalism as a crime), punishment including arrest and detainment as well as vandal and parental monetary fines and responsibility for damages, and immediate cleanup/repair of vandalism/ damage (within 24 hours or less). Customer respect is an important issue. A clean, presentable, and comfortable system fosters customer respect and the teamwork that produces it strengthens bonds within the community. When team members feel pride for a community system, they tend to take a personal interest and responsibility for the system.

RECOMMENDATIONS FOR FUTURE PROCUREMENTS

Recommendations for future procurements include procuring flat windows and specifying window systems that allow very fast change-out (5 min or less is desirable). To achieve quick change-out, these window systems may require items such as dry seals on the outboard side of the window and a clamped interior frame, which is removed easily after removal of a number of specialty head (e.g., Torx) quarter-turn fasteners. These window systems for new procurements should specify provisions for sacrificial ply protection (peel-ply protection does not require any special provisions since it does not require its own frame). The least complex window systems are preferable, such as fixed windows. Transom windows are more complex, and sliding windows are the most complex and the most troublesome. The window frames should be clear anodized aluminum or stainless steel. Black anodized aluminum has proven to be a target for carvers because of its high contrast qualities when carved. Additional in-depth treatment of future procurements is addressed in *TCRP Report 15*, "Procurement Specification Guidelines for Mass Transit Vehicle Window Glazing."

CONCLUSIONS AND RECOMMENDED RESEARCH

There is no known material that is impervious to vandalism. Glass is more difficult to scratch than plastics and has superior durability, but it is subject to damage when attacked with hard objects (carbide-tipped scribes, rocks, gemstones). Each basic window material--glass, acrylic, and polycarbonate--have their particular advantage. Where vandalism is severe, sacrificial plies and peel plies provide the best protection. Glass spall can be eliminated or reduced by using an interior anti-spall film. Increased durability of acrylic and polycarbonate may be achieved with different coating systems like the durable, soft, abrasion and chemically resistant polyurethanes used in the aircraft industry, or with thin glass exterior ply technologies currently under evaluation.

There are several recommendations for future work. They are

- In-depth evaluation of candidate coatings (such as polyurethanes or DLC) on polycarbonate and acrylic to resist vehicle brush washing damage and extend service life;
- Evaluation of thin glass ply technologies on the exterior of plastic windows to resist vehicle brush washing damage and extend service life;
- Testing of polycarbonate plies to provide sacrificial ply vandalism resistance and spall protection for glass; and
- Study of transit police/security prevention techniques and prevention technology.