



Technology Development Center

MARKET RESEARCH REPORT

Phase I: Municipal Needs for Road Maintenance and Road Maintenance Equipment

Results of Focus Group Interviews

Prepared by

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A focus group market research study was conducted in 1994 to identify high priority road maintenance and construction needs by California cities and counties. Participating California municipalites conveyed their needs for:
- Consolidating the functions of vehicles to reduce the number of vehicles required to be transported to a job site
 - Rugged devices to increase their efficiency in the areas of debris removal, graffiti removal, dust and other pollution control, traffic control, shoulder maintenance and construction, pothole patching, grinding and vegetation abatement;
 - Increasing the durability of construction and maintenance materials to extend their useful life
 - Equipment which improves the safety of workers
 - Equipment which improves compliance with environmental standards
- The data collected, while not statistically quantifiable, does provide sufficient information to broadly describe the areas of concern for the participating municipalities and will be used to develop more accurate survey instruments.
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Phase I Report: Municipal Needs for Road Maintenance &
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Executive Summary

A focus group market research study was conducted in 1994 to identify high priority road maintenance and construction needs by California cities and counties. Participating California municipalities conveyed their needs for:

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- Increasing the durability of construction and maintenance materials to extend their useful life
- Equipment which improves the safety of workers
- Equipment which improves compliance with environmental standards

The data collected, while not statistically quantifiable, does provide sufficient information to broadly describe the areas of concern for the participating municipalities and will be used to develop more accurate survey instruments.

Disclaimer

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The counties of: Fresno, Los Angeles, Mariposa, Merced, Orange, Placer, Riverside, Sacramento, San Bernardino, San Joaquin, Santa Barbara, Shasta, Tehama, Toulumne, and Ventura.

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1. Introduction

1.1 Problem

The University of California's Advance Highway Maintenance and Construction Technology (AHMCT) Program would like more accurate information on the perceived needs of municipalities for maintaining and constructing roadways in California. This knowledge will allow the Program to focus its research and development efforts in those areas which of high priority.

1.2 Objective

This study will identify areas in road maintenance and construction where improved technology has the potential to create high value for California cities and counties.

1.3 Background

Previous research work to determine the market and appropriate price for a crack and joint sealing device designed by AHMCT engineers, indicated that a basic knowledge of the needs of cities and counties (the potential customers for the new technology) would be valuable to all current and future research projects. AHMCT would increase its effectiveness if it focused its efforts to solve the highest ranked problems of these organizations.

1.4 Scope

Focus group panelists represented a diversity of California cities, towns and counties. Both small to large municipalities were represented across all geographic regions of the state. A majority of the members were street superintendents though several foremen were included to ensure the front-line, hands-on, physical perspective was present in addition to the financial, budgetary and overall efficiency point of view.

2. Technical Discussion

2.1 Test Conditions

2.1.1 Test Facilities

Focus group panels were held in private board rooms of one of the participating municipalities.

2.1.2 Test Procedures

This study used the focus group technique for obtaining qualitative information to be used for the purpose described in section 1 of this report. The focus group relied upon group interaction when focused on a series of topics introduced by a discussion leader. Each participant in a group of five to nine people is encouraged to express views on each topic and to elaborate or react to the views of other participants.

The discussion guide used to moderate the groups is included as "Appendix A." The guide was a rough agenda to stimulate a productive discussion, rather than a precise dialogue for exact execution.

As the need for new technology was uncovered, panelists were asked to name existing products which address all or a portion of the area of interest. In some cases, panelists were able to name a product, manufacturer and location, in other cases only a portion of that information or no alternative products at all. This report includes all information panelists provided, but did not research alternative products and company names/locations.

All facts presented were expressed in the groups, though every finding is not accompanied by a phrase such as "according to panelists." Facts did not arise through and were not verified by any research outside of the groups. The study was broad in scope (to capture all areas where improved technology is needed) rather than in-depth in any specific area. Sufficient detail has been captured to guide AHMCT in selecting appropriate areas for more technically in-depth inquiry, design concept development, and possible development of new technology.

Individual speakers are not quoted, since they were promised anonymity to insure truthful and valid responses.

Appendix B lists the five panels, the members and their affiliations.

2.2 Test Results/Discussion of Test Results

2.2.1 Introduction

Test results and discussion of results have been combined due to the qualitative nature of the study. The results of the study are not the individual responses to questions asked by the interviewer. Rather it is an interactive process whereby the interviewer make instantaneous decisions as to the direction of the discussion, going back to the discussion guide when enough information has been obtained in a specific area, or the discussion goes off in an unwanted direction. A transcript of the discussion was not made to protect the identity of the participants.

2.2.2 General Results

2.2.2.1 Versatility in equipment

Cities and counties represented are tired of taking three or four pieces of equipment to job sites, but have no choice because many road operations (detailed in this report) require a separate piece of equipment for each step in the process. One panelist had done a job the day before the focus group where eight workers had to drive to the job site to transport the different pieces of equipment needed. Participants said many of their routine jobs could be less time and labor intensive if one-pass technology was created, or if at least several functions could be combined into single units of equipment.

As an example, several panelists say they have written specs for their own pothole patch trucks to try to make them more versatile: They have tried to include the following features: propane heating & electric heating for summer & winter use, crew cab (so a whole crew can travel to a job site minimizing the need for extra vehicles), emulsion tank for tacking, storage tank for accumulating dug-out asphalt, hydraulic hammer for digging-out pavement, vibratory plate, and vibratory roller.

2.2.2.2 Price of reconfigured equipment

New equipment which combines the functions of old pieces of equipment can cost at least as much as the sum of the costs of the functions which are combined.

Assuming each function on a new piece of equipment works as well as the existing equipment for that function, more versatile equipment will eventually save agencies wage/salary expense on certain operations, as a portion of the labor currently used in those operations becomes unnecessary. For each worker eliminated, an agency saves up to \$330 dollars per day, per worker (at current compensation levels) on that operation. It is not clear that this savings effects an immediate and proportional increase in the acceptable purchase price for the new equipment, however, since workers will usually be used elsewhere rather than dropped from the payroll when a particular operation is automated.

To more accurately estimate acceptable prices for specific concepts for new equipment (including all factors driving agency valuation of the equipment), it will be necessary to develop new equipment concepts with descriptions of features, and then to survey agencies to quantify expected savings.

2.2.2.3 Durable devices for routine operations

Since state of the art equipment is already available for overlays, panelists said they want tough new devices to ease the plethora of other procedures they regularly perform. Many examples of routine procedures which consume a great deal of agency resources are presented throughout this report, and include: debris removal, graffiti removal, dust and other pollution control, traffic control, shoulder maintenance and construction, pothole patching, grinding, and vegetation abatement. "Give us things that are economical, inexpensive, simple, and that work in our daily activities," they said. "Workers are a rough and tumbly lot, so make the designs durable--if you make a little machine, make it a tough little machine."

2.2.2.4 Increased automation and one-pass technology

There is a general personnel shortage in the agencies interviewed,

which supports any increased automation possible in maintenance and construction activities.

Automated technology which allows faster performance of routine tasks with less physical discomfort could raise morale.

Long operations are necessary because workers have to run several different vehicles (in separate passes) on jobs that could be completed very quickly if one-pass technology was available, or because workers have to wait for materials to cool or dry.

2.2.2.5 Dislike for small repetitive maintenance procedures

Workers like performing operations where they can see the results of their work, such as overlays or seal coats. Conversely, they hate potholing and other activities "which are ten minutes here and ten minutes there" and where they cannot point to a tangible result of their efforts at day's end.

2.2.2.6 Closer relationship between design people and people who actually perform road work

Panelists think a closer relationship between workers and designers would be valuable. An example of this desire is that agencies would rather have gutters designed not to plug up so easily, rather than a fancy machine to unplug them. Panelists and workers hate cleaning gutters and they feel that if engineers knew how unpleasant that task was, they might have put effort into designing gutters which were less prone to plugging.

2.2.2.7 Reliable information on performance of different materials so they know what to use

"You always hear about Caltrans materials tests, but you never hear about the results."

2.2.3 Improve Compliance with Environmental Standards

2.2.3.1 Particulate Dust Control

From the Federal Clean Water Act of 1988, a strong emphasis on particulate dust control has arisen in cities and counties. And participants expect their responsibility in controlling dust emissions to increase sharply during the next five years.

Existing Methods Cities and counties use several dust inhibitors or "palliatives": Lignium sulfate, SS1 oil with water (bio-degradable, emulsion-based, and also used as a tac coat before overlays), magnesium chloride (from Morton and Leslie Salt), and pine-tar-based derivatives from CalFresno Oil and Witco (Bakersfield). Plain water is also used on occasion.

Palliatives or inhibitors form a slight mat over the top of the dirt and are usually applied when the ground is slightly wet. As a group they currently have two drawbacks: (1) they can cause slippery road conditions when they become wet (especially magnesium chloride and lignium sulfate), and (2) they must be applied often--a least once per week in heavy traffic areas, and once every three weeks in light-traffic areas. Diesel fuel was used in the past and reported to be more effective than the materials which are currently permitted environmentally.

Preparation of roadway, time of year and soil conditions influence length between applications. For example, certain soils retain moisture well and allow less frequent application, and summer applications last longer than winter applications.

New Technology Panelists want an improved palliative: (1) environmentally-sound (does not cause residue problems when soil samples are taken in areas where it has been applied), (2) longer lasting between applications, and (3) does not increase roadway slipping. Current application methods are satisfactory; finding an environmentally-permitted palliative material with good performance is the only issue.

"Dust control is only a step or two behind water run-off," according to panelists, and with the Clean Water Act, they expect to be spending a great deal of their time on dust control in the future-- "If the law comes out like I've heard it said it will, we are going to have to 'spend all of our time' for the first few years preparing our shoulders and all of our dirt roads." Currently, cities and counties do not have to treat all their shoulders and off-road areas, but they expect to soon have to treat a much larger portion of their total dirt surfaces.

2.2.3.2 Filtration Entrapment

Another result of stricter pollution controls is that agencies need a way to trap debris before it flows into catch basins. Examples of debris that must be trapped are concrete dust, asphalt grindings, sedimentation (from saw-cutting, sanding and oiling), and silt from construction work and erosion. Panelists say that most often it is the thick slurry of saw blade cuttings and water that they need to catch, and that they cannot leave it in the street, run it down the gutter, or dump it in storm drains.

Existing Methods An effective entrapment system would allow agencies the luxury of flushing work site debris away with water, but without polluting. "The easiest way to clean up dust and debris from work is to send a water truck out, shoot it into the gutter and let it flow to the catch basins" said panelists. The alternative is using a street sweeper, which is very expensive, and many municipalities do not own sweepers.

Another application would be in new subdivisions, according to one panelist, "Everything is new, then all the builders come in and do final grade and foundation work. Exposed aggregate and debris washes into the gutter and into the storm line, where it 'sets up' [and reduces capacity for flow...[the aggregate is] extremely difficult to clean out." Water cannot drain properly, and road conditions deteriorate. Currently, the best (and admittedly-primitive) method for controlling this problem is to put hay bails on storm drains above catch basins to filter out debris. But when citizens see water backing up into the street, they often move the hay bails to allow the water into the catch basin. The hay bail approach is reportedly a new mandate under the Clean Water Act--the manuals actually say to use hay bails over the gutter and storm drains, according to panelists.

New Technology Panelists envisioned that water could flow into an entrapment bag, material or device that fit in a storm drain. Debris would be caught and workers could periodically dispose of the bags or empty containers. Panelists had seen nothing on the market resembling this concept, with the exception of "spill socks," which "sit in the gutter and catch oil." They imagined removing a grate from the catch basin to install the entrapment system, then replacing the grate after the system was in place.

The problem, panelists said, will be devising an entrapment system that does not create a dam and divert water from its intended path. Participants have experimented with many fabrics, but with little success. They have impressed squares of fabric with shovels and laid them over catch basins; but the fabric always "puckered up," created a dam, and prevented water from flowing into the basin," they said. "They have got to devise something they can hook underneath the inside of the grate" said one panelist, "so water flow into the basin will not be interrupted." The water which passes through the system will need to be free of cement, asphalt, oil, etc., so it can run through the storm drain without environmental impact.

Sometimes work is performed mid-block, with cars parked along the sidewalk, "half a mile" (.8 km) from the catch basin. An entrapment system which laid in the gutter without interrupting water flow would be very valuable in these instances. Panelists envisioned picking-up a 9-kilogram (20-pound) bag of sediment from the gutter periodically, if a feasible design could be developed.

Even a tape that stuck to concrete or asphalt would allow workers to come up with "something crude," to trap debris. Panelists say they could tape their filter fabric in the gutter, and water would flow over the tape and through the filter material, catching a good portion of the debris.

A filtration entrapment system like this would be the "best thing since the paper clip" they said.

2.2.4 Improve Safety: From Equipment-Caused Injuries

2.2.4.1 Injuries from breaking hoses

Hoses break, spew on workers and burn them. Hot AC at 204°C (400°F) on a tac truck is usually spread with a spray bar, except in tight corners where the hose is used and hence where accidents happen. Sometimes the hose is 20 years old, so part of the problem is not replacing old hoses when prudent (probably because of lack of funding rather than negligence). Hot oil (for example, SS1 oil at 93°C (200°F) is sprayed through the hoses also.

Hydraulic hoses are generally manipulated by equipment rather than manually operated, but they also fail and burn workers. Hydraulic hoses on bacos split on the boom below where workers are operating and spray them. A worker in a ditch gets sprayed when a stiff-legged hose (a hydraulic hose on a stiff support leg on a baco) breaks.

Improved hose material and/or a design which fails in a way which is less dangerous are desired. But rather than new technology, the best solution to this problem may be just replacing hoses more often.

2.2.4.2 Injuries resulting from maintenance trucks backing into workers

Existing Methods This infrequent occurrence is sometimes caused by failure of the alarms which are supposed to ring when trucks are backing up. Workers are also sometimes injured when the alarms are working, however, because they are so used to hearing the sound of the alarm that they do not respond to it on a time when it is for real.

Some agencies have used a mud flap which stops the truck when a contact of one kilogram (two pounds) is made. One panelist said this system reduced back-up accidents 30% in his agency.

Another system mentioned uses TV cameras with infrared beams to monitor the zone behind the truck and prohibit backing when an object is picked-up. One agency put these on 33 city vehicles, such as school buses (but not on off-road vehicles), at a cost of \$1,500 per vehicle. They believe several lives of children were saved, since several children had been killed after getting off school buses before the system was installed and the tragic tale did not repeat after the new equipment was in place.

New Technology Perhaps back-up alarms should alternate between different sounds so workers do not habituate to them. Or perhaps the current alarms (which sound every time a truck backs up) could

still be used, but a louder alarm (that the workers do not hear very often) could be created, which would only ring when some sort of sensor picked-up a worker behind the truck during or before a back-up.

Panelists feel there is ample room for improvement with infrared beams systems. A child, they explained, is often too low to be picked-up by the beams. And in off-road job sites, if the beams are set close to the ground, snow, mud and piles of dirt activate the system incessantly and irritate drivers/operators. As a result, the systems are often turned off on-site and workers frequently operate with a false sense of security since they do not know when the systems are off. A design which surmounted some of these limitations would be valued and would probably save some lives.

2.2.4.3 Back injuries

The personnel shortage results in many occasions when one worker lifts an object which requires two workers for safe lifting. "Lift gates," "cable lifts," & "Tommy lifts" are helpful when used, but workers often do not always use them.

One panelists made an interesting comment in this regard: He said that in the old days, when the job was much more manual, he saw less back injuries than at present. He attributes this apparent contradiction to the fact the workers are less aware of their physical limits and of correct lifting form in the current environment where lifting aids make the need for manual lifting less frequent.

2.2.5 Improve Safety: From Injuries Caused by Failure to Control Traffic

Existing Methods Workers are often injured by motorists passing through the work zone. These injuries occur in several ways:

1. Cars speed up during a long work zone after the first worker slows them at the beginning of the site.
2. Motorists drift into the work area while passing through the work zone.
3. Unintentional paddle signals are given: The worker controlling traffic displays the slow paddle and unintentionally tells the motorists coming the other way to stop because the paddles say "slow" on one side and "stop" on the other. Sometimes workers hold the paddle to their bodies to prevent giving an unintentional message to the motorists coming the other way. An improved "stop and go" sign which allowed a choice of "slow" or "stop" on each side (independently of what the other side said) would help; limited programmability might be valuable as well.
4. Drunk drivers enter the work zone at high speed: Participants say this happens at all hours of the day. Three workers were killed recently in Southern California when a drunk driver entered the work zone and drove into a ditch with them.

New Technology Workers were adamant that automatically-controlling traffic would be valuable, but extremely difficult. They said successful traffic control requires human decision and judgment on the spur of the moment--workers have been fired for "just standing like a stop sign when they are assigned to traffic control;" they are considered a hazard to everyone in the work zone because they do not "stay on top of the situation" and make good split-second decisions. AHMCT was given a clear challenge when one participant remarked, "There's nothing you can design to help with a stupid driver."

One panelist said that he thought making each car stop individually (with a "stop" rather than just a "slow" sign) was the only way to improve work zone traffic safety. The drawback with this approach is longer traffic delays which the public and hence the work teams do not like.

One participant commented that to improve safety, giving workers a way to do their jobs faster would be more valuable than any sort of traffic control innovation, "If you want to help us, figure out a way to get us in and out of the work zone faster"--less total motorists would have to be routed through a work zone when completing a job and the chance of an injury would be lowered. In addition to faster and more versatile equipment, faster-drying materials might also be required if the faster equipment reached the limit of current materials on setting or drying. Also, more versatile equipment would shorten the work zone by making it unnecessary to use many different pieces of equipment at job sites. Traffic-related injuries might decrease because shorter hold-ups would result in less frustrated motorists who would pay better attention to work zone conditions and workers' positions.

Several ideas for automated traffic control were captured during the course of the discussion.

2.2.5.1 Transverse light barrier

Design a transverse light barrier which would extend across the road at the beginning of the work zone and make a loud sound if a motorist came into the work zone above a certain (adjustable) speed. The same type of system could also sound an alarm when a worker stepped outside of the safe zone (the coned area).

On infrequently traveled roads in the mountains, for work zones on blind turns, the light barrier could work with a ringer system to warn both motorists and workers when they were about to meet.

2.2.5.2 Portable, programmable traffic control system

Design a portable traffic control device. Programmable signage could be placed at each end of the work zone. A pavement loop could measure the volume of traffic from each direction so an automatic controller could make decisions about when and how long to stop cars from one direction so travelers coming from the other

direction could pass through the work zone. The system would have to be sophisticated enough to know if the last motorist from one direction had passed all the way through the zone before it turned the other direction loose. It would be necessary for a worker to be able to manually-override the automatic control any time personal judgment dictated.

The manual override and programmability would be crucial since, as one panelist said, "Every work zone is different." Sometimes it would be necessary to stop traffic from both sides to bring a truck into the zone, for example--it would probably be best to handle situations like this through personal judgment and manual intervention, according to panelists. In mountain sites, for example, one often cannot see from one end of the work zone to the other, so a person might need to stand in the middle of the zone and supervise (with override capability) the automatic regulating of traffic at either end of the zone.

The system would have to include the following additional features: (1) the ability to say "stop," "go," "detour" and other messages, (2) a light-beam-activated alarm which could be set to ring if a motorist crossed the plane of the work zone on a red light (regardless of speed), or set to ring if somebody entered the zone above a specific (programmable) speed, (3) light weight, so one worker could lift it into a truck (or else a small trailer-mounted unit), (4) simple to operate--"so I don't have to be a rocket scientist to use it," (5) the ability to post a red light (an appealing idea since motorists are strongly conditioned to stop when they see a red light), (6) a price tag not exceeding \$10,000.

2.2.5.3 Getting motorists' attention at work zones

Studies have shown that putting up something unusual slows motorists more effectively than standard methods. In one study, a gorilla with a paddle slowed motorists more effectively than any of the other concepts evaluated. In another Australian study, a woman in a bikini had the best slow down rate. In Europe, work crews use a mannequin with a sign. Participants sarcastically said that a sign reading "Slow, Fresh Oil" is more effective than "Slow, Workers Exposed" since people are more focused on protecting their cars than protecting workers. A couple of panelists doubted any gadget could get careless motorists' attention as effectively as a large man waving a paddle and screaming at problem motorists to slow down.

Participants expressed a great deal of frustration at not being able to get motorists' attention. They said that traffic control is becoming a bigger and bigger problem, "People are paying less and less attention to cones, signs, etc." No explanation was offered, but there was unanimous agreement that motorists are becoming less and less attentive to work zone messages. According to panelists, the key is to find a way to get motorists attention that is not abnormal, because putting something abnormal at the front of a

work zone (like a portable speed bump) is "a lawsuit waiting to happen."

2.2.5.4 Image of police is an effective attention-getter

Dummy squad cars (a parked police car at a work zone without an officer inside) are very effective, as are police officers writing tickets at the work site. The city of Stockton has had good luck with the latter method; they say that within a few weeks traffic slows down nicely as word spreads that failure to take work zones seriously is expensive.

Since the image of a police car or a police officer is a highly-effective way to get motorists attention, one very creative idea would be a hologram of a police officer or a squad car.

2.2.5.5 Protection against the exceptionally-dangerous drunk driver

The automated traffic control system (discussed earlier) might be very effective in preventing injuries in many situations, even those involving the high-speed drunk who enters a work zone with lethal potential. This injury prevention power might arise if the system could be used with portable barricade devices or attenuation vehicles, as well as cones, to keep workers in the safe areas of the zone (behind impact absorbing devices) at all times.

For smaller budgets, it appears the best way to protect workers from this individual is some sort of an alarm which warns the workers of danger (a motorist in the work zone at high speed or from an unexpected direction) while they still have time to react. "Workers get relaxed inside a cone pattern, thinking they are safe," one panelist said. Caltrans currently uses a canister with a horn in it, which the look-out can press to warn the work zone of danger. One panelist said he thought an alarm that was set to ring when cars entered the work zone too fast would drive residents crazy because it would ring so often. It seems this problem could be overcome by setting a large margin between the alarm-activation speed and the posted speed limit.

2.2.6 Shoulder Equipment

Existing Methods Agencies currently use the following equipment for the five steps in constructing roadway shoulders:

| Procedure (step) | Equipment necessary |
|--|---------------------|
| Laying the gravel and rock in a two-foot strip | 10-wheel truck |
| Grading or "striking" | Grader |
| Rolling | Roller |
| Spraying with water | Water truck |

Compacting/vibrating

Vehicle with a vibratory plate

Because a separate piece of equipment is required for each step, much time is spent transitioning between steps. What would take 15 minutes with a one-pass technology consumes four hours or more. Personnel requirements are intensive: A separate operator is required to drive each unit to the job site, as well as two flaggers for traffic control. Shoulder work is a prime example of how more versatile equipment could improve safety: The work zone would be shortened, and a smaller number of workers would be exposed to traffic.

New Technology Panelists said they want equipment which combines as many of the above functions as possible. They also need the system to include automatic application of an environmentally-sound sterilant (for weeds) and an environmentally-sound stabilizer (to prevent shoulder degradation).

Further prompting revealed it would make sense to combine the water truck and sterilant/stabilizer applicator as one unit, and the material hauler and placer (system to put the shoulder material on the roadway evenly in a .6-meter (2-foot) wide strip, grader, roller, and vibration compactor as a second unit. (The water truck would be needed in many other areas, so it should not be combined with everything else and dedicated to shoulder work. As a separate unit it could travel to shoulder work sites when necessary, but also contribute to many other operations.

Panelists also had the following suggestions regarding this new piece of equipment:

1. To conserve material, time and money, the mechanism which lays the shoulder material down should do so accurately because "graders can not move a lot of dirt."
2. To protect the roadway, the grading function should be sensitive enough to put the right amount of pressure in the right place (panelists said current graders often damage the roadways because the blade operator either pushes the blade or the rock into the road surface).
3. On the water truck, the sterilant should mix in at the nozzle, so the water tank would not become contaminated.

One participant (in a different group from the one which suggested separating watering and shoulder material application from the other functions) had the following idea for a more versatile piece of shoulder equipment: "With an auger you could take the shoulder material out of the truck, auger it over to the side of the truck, place it in a hopper, and place it in a [.6-meter] 2-foot wide strip. A vibrating screen could be included to pass over the work next, as well as a water sprinkling system (which could come before or after the vibration)."

Since motor graders alone cost about \$100,000, it appeared that many cities might co-purchase and share, or rent the sort of equipment envisioned. (Again, feedback suggests that a new system will sell if its price does not exceed the sum of the prices of the machines it combines into one unit, regardless of whether public agencies or rental business turn out to be the direct purchasers).

2.2.7 Shoulder Materials

Shoulders are worn away by rainy weather, cars, wind, and weeds growing through them. Failure occurs when the compaction between the dirt and the pavement degrades, forming a lip. Lawsuits from fallen motorcyclists and bicyclists often result. Agencies currently lack an affordable, environmentally-sound shoulder treatment material which effectively postpones this failure.

Existing methods. All current, environmentally-acceptable alternatives for treating shoulders are emulsions which only "sit on the surface" and do not penetrate adequately. In the past, agencies prevented wear-away for up to four years by treating shoulders with a by-product of the gasoline refineries called "SemiPave," from Golden Bear Oil Company in Bakersfield. Other effective substances which are no longer environmentally-condoned are ground asphalt and a product panelists called "reclamite." Cement is also prohibited in certain sections currently, (e.g. next to water), and when it is allowed agencies lack an effective means of applying it to shoulders.

Much frustration is expressed over ..."environmentalists shutting down our effective procedures to maintain a safe road system."--"We used to have good road oils; now we have to use emulsions." One participant said his agency currently has an extensive grading program to maintain the integrity of the compaction between the dirt and the asphalt, which consumes \$175,000 per year. He has tried polymers and magnesium chloride, but both become slippery when wet. Panelists said latex modified oils are also permitted currently, but perform poorly.

New technology Agencies need an effective shoulder agent that does not harm the environment.

2.2.8 Graffiti Removal

This was a important issue, especially in Southern California--San Diego allocated over 1 million dollars for a graffiti removal program this year. Though graffiti defaces asphalt, rocks, trees, rocks and signs, an estimated 80% of it is found on concrete and masonry surfaces ("block"). Materials typically used are: spray paint (lacquer is harder than enamel to remove), engine-coating paint, indelible markers, magic markers, shoe polishes, and ink pens. One marker called "mean streak," retailed with all the others, is especially hard to remove. Some graffiti enthusiasts use rollers, leaving high volumes of paint to be removed. Spray paint is the most common material used, but there is a trend toward greater use of marker pens.

Existing Methods A plethora of "solutions to graffiti" are currently marketed, but none perform cost-effectively, according to the panelists-- "None of the 'environmentally-safe' or 'user friendly' products work well... You have to scrub for hours and it takes the paint off the signs." Another panelist remarked, "Once you get the graffiti off you have ruined the sign with the products available." Citrus-based products are widely marketed for use (one panelist receives one sales call per week trying to sell him an environmentally-safe citrus product). Participants said citrus products generally work poorly, but are somewhat more effective on signs than on walls. The general theme was that all the products available are more expensive to use than simple repainting of graffitied walls, and that a cost-effective system for signs is needed.

The products which have been tried by the agencies represented fall in three general categories:

Type 1: Chemicals intended to allow wipe-off of graffiti but spare the paint and/or host surface underneath:

Citrus-based products and acetones are the big sellers right now because they are safe to the environment and to the user. Sherman Williams makes a special soap designed to wash off Graffiti. Two products which panelists do not consider safe to the environment are: (1) a "waxy" product called "right away," which comes in an aerosol can, applies as a gel, and is used on signs and walls before sand blasting, and (2) "Poly Varn" from a Los Angeles company, which is used on signs and also comes in an aerosol can. With most of these products, one applies 30 to 60 seconds prior to wipe-off. These products are notorious among panelists for removing the wording and reflective coating from signs in addition to removing graffiti.

Type 2: Chemicals which pretreat a sign or wall to ease future graffiti removal:

After graffiti has been put on a sign treated with one of these products, the coating (and graffiti) can be peeled off and the sign retreated with a new coating. One panelist said one such product worked poorly for his agency because applying it to the signs was difficult and time consuming: (1) it required an air compressor and spray rig on their sign trucks, and (2) using, cleaning and flushing the systems involved turned out to be inefficient and expensive. Also, panelists say these remedies exceed their budgets at \$25 per Liter (\$100 per gallon)--treating all their signs at this price is not feasible; they can only do a few.

Type 3: A hard sheeting which mitigates adherence of graffiti materials is applied to a surface of concern (more often a sign than a wall):

Signs can be bought with the sheeting already on them, and sheeting can be bought separately to sheet signs already in place. 3M makes one of these coating products. Another company, Nicolite of Long Beach, makes a sign sheeting with a graffiti-resistant ink on it. Panelists say it works well for spray paint on signs, but makes signs a third more expensive, adding \$10

or \$12 to the cost of an average sign. Nicolite is trying to prove their product is better than 3M's through tests with Caltrans.

One panelist mentioned a hard, epoxy coating available for walls. He did not like it because it required purchase of a special cleaner from the same company (Hilke Company) to remove the graffiti, and because each time graffiti was removed, the wall had to be retreated. Furthermore, this product did not remove some graffiti paints.

Graffiti is an area of great frustration for the panelists. "It is a matter of escalation," remarked one participant, "...we find a better product to remove it, then they come up with something that is harder to take off. And we end up destroying our signs."

Repainting No system currently available is more cost effective for walls than just repainting or respraying, according to panelists. Used paint is available for a lower price than new paint, but the greater frequency with which it must be applied (it does not last as long as new paint) makes it more expensive to use when the additional labor is factored in.

Though it is still more expensive than repainting, the most cost-effective way to pretreat a wall, according to panelists, is spraying or rolling on a sacrificial wax coating. Graffiti can later be removed by pressure-blowing hot water, or by scrubbing with a cleaner. The hot water option entails the danger of handling pressurized water at nearly 90°C (200°F).

New technology Agencies want an effective, safe (to the individual applying and to the environment) way to remove graffiti without damaging the host surface or the paint on the host surface.

A pre-treatment which would allow them to wash graffiti from walls and signs just by driving by with a water truck would also be desirable. They would much prefer repeated wash-offs to the repainting, hydroblasting and sandblasting procedures they currently employ.

A new system will have to be less than the cost of repainting, since this is the least expensive method currently at agencies' disposal. One way to achieve this goal would be to develop a system that allows non-pressurized, cool-water wash-off of graffiti after the initial treatment of a wall or sign.

Panelists offered the following additional ideas: (1) Develop stickers you can put over signs that have been gratified (rather than trying to remove the graffiti)--the stickers would have to mimic the message the original sign in wording and reflectivity. (2) Construct a box with a microwave system that would break down all but the desired paint with sound waves when a maintenance vehicle drove past the graffiti site. "They are using lasers to remove tattoos of particular colors now, so why couldn't they do this?" asked one participant.

the job site in an environmentally-acceptable form. Any portion of the debris not hauled or ground-up fertilizes the next generation of nuisance plants.

(6) Flail mowers perform poorly on larger vegetation: Much of what agencies must cut is too large for the flail mowers. Panelist disagree with the manufacturers claim their products can flail a 15-centimeter (6-inch). "They [flail mowers] flail it down but won't get it all, and will leave parts of it intact, in a jagged mess"--environmentalists and the general public do not like this. Oleanders, small eucalyptus and pines are removed manually with two workers, a chain saw and a wood chipper. The routine, "cut and pull and throw in the chipper," is very manual and "wastes a lot of time." Oleander leans into the traffic when it grows too tall, so it must be controlled. When one is cut, another grows to fill the space--agencies need an efficient way to drive by periodically and keep a whole patch under control.

New Technology Agencies want a versatile system which can automatically cut down bushes, shrubs, grass, oleander, and small 20-centimeter (8-inch)-trunk pine and eucalyptus trees. The machine would need to cut cleanly, so it would not be necessary to cut every Nth plant again with a chain saw. Aesthetics are important to the agencies; an improved machine would have to cut everything down neatly.

Furthermore, panelists want the system (or a companion system) to automatically pick-up cut, trimmed or chemically-killed debris. With this second step, it will be possible to remove workers from the roadway and reduce exposure to traffic. Panelists said automatic grinding or mulching (to environmental specifications) of the debris would be just as valuable. The key is that, regardless of whether debris is hauled or mulched, agencies do not want to manually pick it up. Panelists know of no technology which precludes manual pick-up of debris, other than machines which pick-up leaves, but are ineffective on larger vegetation.

The big question for the participants was whether the same system could handle both brush and trees for one-pass control of vegetation--20-centimeter (8-inch) diameter trees are very difficult to cut down, panelists said.

One person said a machine to address these issues might look like a mower, a leaf-pick-up machine (with a suction motor) and a truck; the mower [or other cutting system] would need to be on a boom that could extend for cutting. A leaf pick-up machine looks like a garbage truck with a suction motor on the side and a 40-centimeter (15-inch) hose, according to panelists.

A tub grinder could perform the on-site grinding if coupled with an automatic system for picking-up and feeding debris to it, panelists said.

One person commented that if sheared at the base (with a ban saw or other shearing mechanism), rather than plucked or flailed, brush would be more amenable to automatic pick-up. The big pieces of debris could be

subsequently hauled away or ground on-site with a tub or other grinding equipment.

Panelists commented that a shearing system would have to be able to tolerate occasional rocks, beer cans, bottles, etc. The system would need to be tolerant to dirt as well, unless a way to preclude entrance of dirt into the system could be developed. One group thought that some (but not most) brush would have to be grabbed by some method in order to be sheared. Hydraulic logging shears are available, according to panelists, with arms that grab a tree, shear it, and feed it to a grinder.

Tub Grinders are made by More Bark, and Quinn Company in Fresno. Large ones cost \$150,000 and are found in almost any logging operation (for environmental compliance). They grind stumps and entire trees. Panelists said something this large would not be necessary, and would not fit on the side of the road anyway. The trunks that must be cut are a maximum of 20-centimeters (8-inches) according to panelists.

A creative idea was offered: Build a laser or x-ray machine that drives along the shoulder and sterilizes seeds before they sprout. Certain seeds are sterilized these days before you buy them (poppy, marijuana, and cooking oil), according to this panelist, so maybe this would be possible.

Pricing A price of \$200,000 would be tolerable to several agencies represented, given their expected volume of usage and provided "...the thing worked." Another small advantage of such a system, one panelist pointed out, is that crews would not develop poison oak anymore. Some panelists predicted that private contractors would want to buy such a machine and specialize in vegetation control.

Chemical abatement Agencies are currently struggling to find an environmentally-sound, cost-effective, pre-emergent treatment for weeds. If an indiscriminant product leeches after application, property and trees can be damaged resulting in lawsuits. As with dust emissions, environmental constraints have become more stringent with weed abatement; at present, contractors must be licensed to perform any weed abatement work in California.

Agencies have used effective sterilants ("Krobar" was the name of one product) and diesel oil on road shoulders. Some pre-emergents can still be used, but they do not kill all weeds. Spared strains proliferate once susceptible weeds that were naturally controlling their growth die. Examples of this phenomenon (according to the panelists) are the following: Available products kill Johnson Grass but in so doing allow Tumble Weed to thrive. Star Thistle and Tar Weed are also very difficult to control.

Herbicides, such as "Round-up," kill living plants on contact but do nothing to control emerging weeds. Some agencies currently use a mixture from Caltrans (which includes "Karmex," "Round-up," "Princep," and a sterilant of unknown manufacture), but said their ultimate goal would be an

environmentally-safe product that treats an area for a long period of time, kills all weeds, and does not leech or kill trees.

2.2.10 Gutter Cleaning

Existing methods Currently, the cities and counties in the panel use a grader to "pull the gutter" (pull the dirt out) and lay it in a row on the side of the road, and a loader to load it in two or three dump trucks--at least four vehicles are used. Some counties and cities are a step ahead if they use a "travel loader," which scoops up debris with a belt and shoots it into a dump truck behind.

New Technology Participants want way to skip the step of laying the ditch debris on the road prior to pick-up; they want a machine that can transfer debris directly from the ditch to a dump truck, and which fits on the back of a grader or loader. Participants say such a machine does exist and resembles a shoulder machine--a scoop brings the material over and loads it onto a truck that travels beside it. But according to participants, this machine only works for wide, "perfect roads;" they would like a more flexible and versatile system, which can operate in more restricted spaces.

Mountain areas have "high side gutters," paved gutters, one meter (three feet)-wide, on the high side of a "super elevated" road. Street sweepers and motor graders are not effective at cleaning these gutters, according to panelists. Water with clay in it flows from the "cut banks" into the gutters. When the water "settles out," the clay remains in the gutter and becomes too hard to be removed manually with a shovel. Agencies would like a gutter design that prevents this occurrence altogether, or at least a mechanism for performing the maintenance procedure if a better design is not forthcoming.

2.2.11 Tarping Loads to be Hauled

At present, almost everything (other than asphalt and concrete) must be tarped for transport. Reportedly, workers often fall from the tops of trucks when setting tarps in place.

Existing Methods Automatic tarps are currently available, said panelists, but "...none of them work worth beans; they are not versatile." When hauling brush, blackberry vines, branches, etc., it was explained, one must get the tarp over the brush and down to the sides of the truck bed--this procedure must be done manually with all of the "automatic" tarps they have seen. Three basic tarp designs have been tried by panelists:

Type 1: Lowest automation: A tarp is manually put in position; its only automation is that it returns by itself when released, by rolling like a blind.

Type 2: A series of ribs, like an accordion: Several metal rods on a track enclose a load, reportedly ineffective on high brush-type loads.

Type 3: A mechanically-driven tarp swings to the top of a load: These are prone to failure, according to panelists, "The mechanism gets bumped by the bucket of the loader and they never work right again...debris falls into

the machine and it stops working... the exterior arms working the tarp are too prone to damage, which causes failure of the system." The general theme seems to be that the concept is okay (when it works it can handle high loads), but the design is not suitable for the rough usage conditions to which it is subjected.

New Technology Agencies want an automatic tarp that is more versatile and hence works without manual intervention on these different kinds of loads. Such a tarp would make conditions safer for workers and speed clean-up and hauling operations. The tarp would need to fit (cover) truck beds 2.5 meters (8 feet) wide and 5 meters (16 feet) long.

2.2.12 Equipment Cleaning

Trucks, paving machines, rakes, shovels, and "laten boxes" must have asphalt and oils cleaned from them in an environmentally-safe fashion. Panelists say nothing is currently available that works well for this.

Existing Methods Oils (such as SS1 oil which is used for tac coating prior to overlays) and asphalt materials (pothole-fillers, crack sealers/fillers) have to be cut and cleaned from equipment at the end of each day. By "cut" panelists mean that a solvent of some type must be used to soften the material before disposal.

Some panelists currently spray the beds of their trucks with soybean oil (a biodegradable material); they sprayed them with diesel fuel before environmental regulations tightened.

New technology Panelists want an effective and environmentally-safe method of cleaning materials from their equipment and cutting them.

2.2.13 Pothole Repair

Current agency protocol in pothole patching entails manual raking of patch material after it has been laid down, which reportedly injures workers shoulders and promotes absenteeism. Panelists also dislike the traffic exposure with this highly-manual procedure.

Existing Methods Panelists are aware of semi-automated pothole-patching technology currently available. Wildcat of Montana makes "Road Patcher" and Rosco (located on the East Coast) makes patch trucks which are distributed by Hawthorn of San Diego. Both sell for \$80,000 to \$100,000 and automatically mix rock and emulsion at the nozzle of application eliminating manual operations.

One panelist had seen an advertisement for a similar truck which uses a solution of rock and emulsion which is pre-mixed at the plant. This truck "conveyers" asphalt out of a flat bed and places it in the pothole being repaired, and it includes a vibrating mechanism. All patching functions are controlled from the cab, which reduces worker exposure to traffic. Panelists very much liked the safety of in-cab control. A negative aspect of this system is that any material not used by the end of the day hardens and is

wasted. Another panelist had seen a similar portable unit for the back of trucks. Panelists could not remember the manufacturer of either of these systems.

All "automated" pothole systems were criticized by the panelists because they do not perform "dig-outs" on alligatored sections of roadway which need to be excavated until the strong portion of the road (to which the patch will adhere) is found. Historically, pothole-patching equipment that has come to market has not been satisfactory, according to panelists.

New technology A couple of panelists had heard of the Carnegie Melon machine and joked that it probably costs \$800,000. All panelists laughed. Perhaps a smaller pothole machine would appeal to the market, just as smaller crack sealing innovations (small relative to the entire Automated Crack Sealing Machine) are valuable to the many agencies with limited budgets. A price of \$100,000 certainly seems acceptable, however, since there is pothole-patching equipment available for that price currently, and since agencies spend so much of their time repairing potholes. Perhaps the market can bear a higher price for a complete system like the one described in the next paragraph, but a more in-depth study of pothole patching and possibly a survey will be necessary to resolve the issue.

Panelists would like a pothole machine which (1) from controls in the cab automatically transfers material from the truck to the repair hole, (2) uses a material other than the hot asphalt and rock premix (which hardens if not out of the truck by the end of the day), and (3) performs dig-outs.

2.2.14 Pothole Patching Material

Existing Methods Raisch of San Jose sells "QPR," a high-quality cold patch product with a large amount of emulsified oil in it; but it costs four times as much as other materials. Panelists say it can be applied in a hole with 15 centimeters (6 inches) of water for an effective repair of one year. Panelists believe SHRP has developed other products with the same performance, but say QPR is the only one available in this area. Regular cold mix costs \$33 per tonne (\$30 per ton) and QPR costs \$143 per tonne (\$130 per ton). Advertisers even claim one can resurface on top of QPR. With this product, crews do not have to repair the same pothole three or four times in one season.

New Technology Panelists want better patching materials. They want an affordable material that can be applied when there is water in a pothole, since "95% of potholes are generated during the rainy season." Such a material would enable a first-visit repair, instead of temporary fills which require a second visit (within three or four months) under dry conditions for a true repair (a seal). A great deal of labor would be saved with such a material.

Agencies want a cheaper material which performs like QPR. Another idea would be to develop a quick-drying system so the cheaper material can be used to make repairs under wet conditions.

2.2.15 Removal of Raised Pavement Markers

Agencies often have to remove raised pavement markers prior to overlays or restorative seal coating procedures (chip and slurry seals). Panelists say they would greatly benefit from a system which could mount or sit on the back of a pick-up truck and remove raised pavement markers without "flinging them" and without requiring workers to leave the vehicle. Panelists believe it is easier to remove and replace markers than to cover them or in some other way protect them when an overlay or restorative coating procedure is performed.

2.2.16 Legends and Street Painting

Striping of pavement lines is automated, but the painting of words is not. Participants were surprised that an automatic system to paint street legends has not already been developed. This automatic machine would need to allow rapid painting of words and numbers, as well as rapid changing between words and numbers to be painted. Need for manual traffic control would also be mitigated if the machine could place cones (to be left in place until the paint dried) when it painted a section of the street. Panelists suggested "a giant dot matrix of some sort, with computer control." The system would need to paint characters (letters, numbers, arrows) from .3 to 2.5 meters (1 to 8 feet)-tall. Gerber makes such a machine which works in a production mode, but it is not portable to the job site.

Thermoplastic is more expensive but lasts longer than paint. If a system could be developed to automatically put down thermoplastic letters and numbers, it would have the potential to save even more labor, time and money than an automatic painting system.

2.2.17 Root Control and Sidewalk Repair

Sidewalk, curb and gutter repair are very manual, involving breaking concrete with jack hammers and moving it around--activities which often cause back, wrist and knee injuries. Concrete finishing work is especially hard on the wrists, and back injuries proliferate, despite that fact that "skid steers" are available to help workers lift heavy objects. Roots, panelists say, are usually the cause of sidewalk, curb and gutter repair. Agencies would benefit from a material which controlled growth of only problem roots (and spared trees), for use before sidewalk replacement was necessary.

Existing Methods The only available automated equipment for this sort of work, according to panelists, are jack hammers for "Bacos," which can reach the sidewalk from the street. The same attachments are also available for small "Bobcats," which "definitely work on the curb and gutter," according to panelists, and which "can possibly get on the sidewalk."

Automated pieces of equipment which aid in construction of long sections of curb and gutter are available according to the agencies represented, but automated equipment for short sections of maintenance or repair work are not. Versatility is again a theme--agencies currently have to bring separate

pieces of equipment in for each of these procedures--one city represented performs 18 to 36 meters (20 to 40 yards) per day of sidewalk repair; they remove concrete one day and pour the next, using 5 or 6 pieces of equipment at a time: dump trucks, root pruners, bacos, jack hammers and "various other trucks." Panelists want greater automation in this area.

New technology Since curb and gutter work typically only extend three meters (ten feet) to either side of a problem root, panelists say they would get a great deal of value from a machine which could: (1) break, grind-up and spit unwanted concrete into a truck, (2) work in a restricted space, (3) plain or cut problem roots, (4) clean out an area well enough for new concrete to be laid, and (5) pour new concrete in the appropriate places. A creative idea offered for the first function was to design some sort of laser tool that would break cement into powder instead of impacting it.

Innovations in this area would be very valuable, said panelists--several agencies represented have sidewalk repair backlogs of three or four years, and indefinite curb and gutter backlogs--sidewalks are the priority because of the tripping/lawsuit hazard. An upper bound on what such a machine could cost would be \$200,000, according to several panelists, if it performed all the functions listed above--some cities currently spend as much money on curbs and sidewalks as they do on asphalt work. Five to seven crew members currently travel to a sidewalk, curb and gutter repair site, which costs \$1,500 per day for labor alone.

2.2.18 General Roadway Grinding

Grinders are used to repair big potholes or "alligators" (sections of roadway badly damaged by cracks or other holes), according to the panelists. Asphalt grinding is a large expense for agencies. One panelist commented, "The most costly thing we do is grinding AC for one reason or another."

Few local agencies own grinders (Los Angeles is an exception and owns several) because (1) they are priced at \$160,000 and up, (2) some agencies only use grinders three weeks out of the year, and (3) maintaining grinders is time-consuming and expensive--grinders often break, according to panelists, so they prefer to rent these complex machines from another organization which fixes broken grinders for them and delivers a replacement grinder to a job site when one fails (valuable once a work crew has been dedicated to a site for the day). Also, grinders are very expensive to operate after the initial purchase because their teeth have to be replaced often. Caltrans has several grinders they "share all over the state," according to participants.

When agencies cannot use grinders, they repair alligators by digging out the holes to prepare them for repair (which sometimes involves sawing). All panelists concur that grinding is more efficient.

Existing Methods Aside from the affordability and maintenance issues, panelists say current grinders could be improved:

(1) Current grinders cause great inefficiency when drum width has to be changed, since changes are performed manually and "take about three hours." Panelists want a variable-drum grinder which can change grinding width from .6 to 1.8 meters (2 to 6 feet) at the touch of a button. With such a grinder, they could save time on the wide grind sections, and conserve asphalt on thinner sections which would not have to be overground by a drum width larger than necessary.

(2) Some grinders require an extra lane closure. While front-load grinders may require only one lane closure, side-loaders with the truck beside them use 25 feet, requiring two lanes to be closed. The front-load type requires less space, and panelists do not express dissatisfaction with them on the space issue. Space issues are very important to cities and counties.

New Technology In regard to pricing, panelists currently feel 1-meter (3-foot) drum models could be priced up to \$300,000, and a 1.8-meter (6-foot) drum models for \$500,000. A municipality might rent a unit for \$6,500 per week. Panelists say they would probably not buy grinders, but it appears rental agencies would opt for a more versatile model because of its rental preference by agencies.

2.2.19 Special Grinding Applications

Agencies perform smaller grinding in several areas: sidewalks, flow line lips (the lips in the curb/gutter next to the sidewalk that keep water off the roads by channeling it to storm drains), rolled curbs (puckered asphalt where the asphalt meets the curb), and areas where lane stripes, lane line thermoplastic or raised pavement markers must be removed. With the exception of flow line lips, there is a grinder available for each of these applications, but panelists again want versatility: If AHMCT could make a machine for all or most of these applications, which also cut roots, it would be a big success according to the agencies represented.

Rolled curbs Rolled curbs up to 15 centimeters (6 inches) high can arise anywhere the asphalt meets the curb, and are often found on islands and radii, where they are an important concern to agencies because pedestrians trip, fall and sue. Rolled curb repairs are effected by grinding a perfect match between the asphalt and the curb, or by over grinding the asphalt slightly and adding some new asphalt to make a match.

This grinding operation would be the most challenging application from among the "special grinding applications," said panelists; it would require grinding up to 15 centimeters (6 inches) deep in a 46 to 61-centimeter (18 to 24-inch) width. Ingersol Rand makes a 50-centimeter (20-inch) drum, ride-on grinder suitable for rolled curbs which also grinds around manholes. The unit costs \$50,000, a price panelists said cannot be justified for this application alone. However, if the unit could perform the other types of grinding listed above, a purchase price this high would be tolerable according to panelists. Anrak (located in Sacramento) or Ingersol Rand (well-established everywhere, headquarters unknown) make machines specifically for rolled asphalt which cost \$160,000 to \$200,000) and which grind in a 61-centimeter (24-inch) width. With very few exceptions, local

agencies rent these machines when they need to use them, rather than purchasing them.

"Bobcat" makes a small, 46-centimeter (18-inch) grinder, which cannot even survive a demonstration on this demanding application, according to one panelist. "All small units [grinders] have been unreliable, and they 'float' too much--every time they hit a hard piece of asphalt they pop out of the ground; you want to end up with a specific depth so you can put an inch of asphalt everywhere."

Flow line lip maintenance Trees and their roots often move flow line lips in the curb/gutter just enough to prevent flow. A machine which provided a quick, shallow grind would allow them to restore flow in these situations without replacing large, 4-meter (14-foot) sections of curb--"If you could grind in these situations, you could buy another 5-8 years before replacing the curb and gutter." Bartell makes a sidewalk grinder with a vacuum system and a special flow line lip attachment, but the system is not productive on flow line lips, said panelists. They want a machine specially designed for flow line lips which is productive--one that can do "[1.6 kilometers] a mile of flow line lip in one day."

Sidewalk grinding Unlike with curbs and gutters, a root usually makes only .6 to 1 meters (2 to 3 feet) of grinding necessary on a sidewalk; this is because sidewalk sections are only 1.2 meters (4 feet) long. It is not uncommon, according to panelists, for the same root to necessitate only a 4-meter (14-foot) curb and gutter grind, because curb and gutter sections are this long. Since agencies often proceed down a street alternating between sidewalk and curb/gutter work necessitated by the same roots, a machine which worked on both would take efficiency an order of magnitude higher by allowing a one-pass operation. Sidewalk grinding is usually only 2.5-centimeters (1-inch) deep, according to panelists, and sidewalk grinders are available in a walk-behind design for about \$8,000.

Lane strip and raised pavement marker removal "Line movers" with small Honda engines are available, but they do not leave a smooth enough surface to be satisfactory to panelists. Furthermore, most grinders overheat and "gum-up" when used to remove thermoplastic. Panelists said some grinders work on paint stripes, some on thermoplastic lane markers, but none they have seen work well on both; a grinder which worked on asphalt and concrete and which did not gum-up on thermo applications would be very attractive to the panelists. Walk-behind line and thermo grinders are currently available for about \$5,000. Heavier, ride-on, trailered units cost about \$50,000.

Root cutters Current root cutters can sit it on the sidewalk and reach most roots. But from behind the curb and gutter they cannot reach over the top of the curb and cut roots on the other side of the sidewalk. A better way to cut roots, coupled with a grinder which worked effectively on sidewalks and flow lines would allow permanent repairs in many situations where sections of sidewalk are currently replaced.

New Technology Regarding design, panelists thought the big questions were (1) whether a walk-behind unit could be constructed to handle the rolled curb application, or (2) whether a grinder big and strong enough for the rolled curb application could get up on the sidewalk or in some other way perform sidewalk work. "The sidewalk is [1.2 meters] 4 feet wide," said one panelist, plants protrude, access can be difficult, weight of the equipment can be prohibitive, and sprinklers, trees, fire hydrants, planter boxes and street lights all challenge the operator. "To get on the sidewalk you could use a handicap ramp, but the other obstacles would be difficult," remarked another.

On sidewalk grinding, the machine would only have to grind 2.5 centimeters (1 inch) deep. But the unit would need a "swing adjustment" according to panelists, to allow one side of a tilted piece of sidewalk to be ground more deeply than the other. If the piece of equipment is 1.2 meters (4 feet) wide, the entire unit will not be able to swing and adjust when it is on the sidewalk; as a result, the design must allow the cutting head to move with respect to the rest of the unit in order to negotiate the sidewalk application. "The cutting head will have to slide back and forth or move in some way while also maintaining a grade."

Panelists said that if designing a grinder that could do a 46 to 61-centimeter (18 to 24-inch) grind 15 to 20 centimeters (6 to 8 inches) deep (for rolled curb), and which could also perform the other applications was too difficult, a grinder which went up to 30 centimeters (12 inches) could accommodate rolled curbs by making two passes. Panelists said that grinding a 30-centimeter (12-inch) asphalt strip 15 centimeters (6 inches) deep would still require a much stronger machine than would the other applications.

Smoothness of the finished product would be important, especially when grinding off raised lane markers or rolled curbs, said panelists. "A rough finish can be permeable. If you knock off the roll on a rolled curb you want a smooth finish, especially if you are not going to put new asphalt down." Curb and gutter work would require a smooth finish also. Panelists thought the smooth finish could be easily achieved by putting a large number of teeth on the grinder.

Panelists foresaw little difficulty designing a grinder that would accommodate both concrete and asphalt since through changing of teeth, many currently-available grinders address both surfaces.

Available grinders are not effective on commercial gutters (which are square), and agencies lack an effective means to remove paint from them. One agency has experimented with a lawn edger with "garage modifications," but with only limited success. The ability to grind commercial gutters would also be a valuable feature for the system.

Panelists were adamant that the system should not be too noisy, and should be safe to use.

Pricing Agencies expressed an interest in buying (not just renting) a grinder that performed the better part of the applications mentioned, provided the

price was not much higher than \$50,000. But even if the price was up to \$200,000, the machine would probably be purchased by rental agencies and rented to cities and counties.

2.2.20 Post-Grind Clean-up

Existing Methods When working with concrete, agencies clean up debris (mostly dust) with a vacuum recovery system, or a wet vacuum system (if the debris is wet).

Conversely, asphalt clean-up is very manual, involving hand-brooms, though sweepers sometimes assist. A "kick broom" is somewhat helpful, according to panelists--it can pull debris out of a wedge-cut area and push it up to a flat surface where a sweeper (following behind) can pick it up. Sweepers are sometimes used directly on the cut, but panelists said sweepers do not work on a one-meter (three-foot) or smaller cut.

New Technology Participants foresee vacuum systems arising for paint and thermoplastic removal, but not for asphalt, because of the high weight and production of material. According to panelists, current grinders pick-up 80% to 90% of the asphalt, but it takes a crew a half day to recover the remaining 10%. Labor would be saved and exposure to traffic lessened with an automated asphalt clean-up system that serviced smaller asphalt work holes.

Modern concrete grinders have a vacuum right on the cutting head, according to panelists; material never falls back down in the hole after being cut because it is sucked directly into the recovery tank. In general, there is not a manual clean-up problem with concrete grinding. However, a concrete flow line lip machine that ground 1.6 kilometers (1 mile) in a day would cause a clean-up problem similar to the asphalt scenario because of the high production of debris. Panelists say 18 to 27-meter (60 to 90) foot applications would arise for a productive flow line machine when all 4 corners at an intersection were done. And although a 2.5 to 6-meter (8 to 20-foot) grind restores flow for a problem caused by one root, one panelist said he often does 6 jobs of this size on one street when he arrives to fix one section, because all the gutters are the same age and he usually spots other necessary repairs. In situations like this, a large volume of ground-up cement would be produced with a high-production flow line lip machine, so an effective recovery system would need to be included (or developed as a companion product).

2.2.21 Asphalt and Concrete Sawing

Diamond edge bladed saws are often lubricated and cooled with water to mitigate overheating and gum-up. Blades are available for asphalt, concrete. Lineal production with current saws is contingent upon depth of cut and hardness of the cut material. All curb and gutter installations, all utility trenches, pipeline work, water leaks, etc. are potential saw applications: A chunk of asphalt or concrete must be removed with a neat cut and subsequently replaced.

Existing Methods Shortcomings of saws are the following: (1) Saws generally leave a mess; cars track a mixture of water and ground-up material from the saw cut groove all over the street. (Agencies expect that stricter pollution laws will soon make it necessary to capture this material rather than washing it down the storm basins). (2) Production is slow: If agencies are sawing dry, two workers cut while the others wait to perform the rest of the repair. If sawing wet, they saw one day and return the next day to perform the rest of the repair.

New Technology A faster, dry saw would turn many two-day repairs into one-pass procedures, making it unnecessary to set-up and take down traffic control twice for each repair. A laser or acoustic cutter (something other than a blade) could provide a solution.

2.2.22 Rubberized Asphalt

Rubberized asphalt (asphalt with recycled tires mixed in) yields a quieter, smoother ride than standard asphalt. It also lasts longer--according to one panelist, the city of Phoenix has chip seals (a restorative seal coat composed of rubberized asphalt and rock which sits on top of the road) 20 years old, that did not begin to show reflective cracks until 10 or 11 years after installation. In some cases rubberized asphalt lasts 20 years without any maintenance, according to panelists, who say normal asphalt overlays last only 10 years under heavy traffic conditions.

Current Methods But there are drawbacks to rubberized asphalt. Panelists say it is harder to grind traffic lines off rubberized asphalt--when removed or dug-out, it "gums-up" equipment (grinders are an example and were discussed earlier).

Also, unlike its regular counterpart, rubberized asphalt cannot be recycled. Panelists say that rubberized asphalt can not be reheated, and that "plants do not want it because it causes problems."

New Technology Panelists would like a change in equipment or the rubberized asphalt itself so that they can grind it and dig it out effectively, and so they can effectively remove stripes (paint or thermoplastic) from this material. And they would like to be able to recycle rubberized asphalt.

Agencies also want less expensive rubberized asphalt products. Rubberized asphalt costs \$60 to \$82 per tonne (\$75 per ton) compared to \$33 per tonne (\$30 per ton) for regular. There is too little competition in rubberized asphalt products currently, according to one panelist. Recently, when he was working in the Southern California market, only one contractor could perform rubber chip work, and he charged \$6 per square meter (\$5 per square yard). This may be an example of monopoly rather than cost-based pricing.

2.2.23 Lower Priority Areas

2.2.23.1 Automated catch basin clean-up system

The EPA mandates that small water retention basins have to be managed properly. According to panelists, The Federal Water Clean Act of 1988 mandates that water be retained for 24 hours before release, and that silt be scraped off the bottom of basins and ponds (a process known as "scarification"). An automatic scarification system would be appealing to cities and counties with a large number of small water retention basins.

2.2.23.2 Automatic culvert cleaner

This procedure was described as being very difficult. Usually done manually, the procedure is notorious for producing cases of poison oak. Unless culverts are completely plugged-up, said panelists, high pressure hydro-vacs are not a cost-effective solution. A fully or semi-automatic way to clean out culverts that could fit on a small truck would be valuable to cities and counties with culverts in their borders. Perhaps the same system that cleaned catch basins (above) could also address culverts.

2.2.23.3 Prevent injuries from stepping off trucks

Workers often twist ankles when stepping down from trucks and other equipment. "The workers themselves usually find a solution," according to one participant, "...since they are the ones getting hurt." However, any clever ideas in this area would have value.

2.2.23.4 Prevent falling from the top of trucks

Workers often fall from the top of trucks. An example of when this happens is when they are setting tarps on debris in the truck beds (discussed earlier). Any creative ideas in this regard would be appreciated.

2.2.23.5 Improved paint striping system

Ideally, panelists would want such a system to lay longer-lasting paint stripes, and also to quickly, easily and completely remove stripes to prevent ambiguous lane markings (a safety hazard). Panelists say there is a good striping machine currently available, but that it does not address the strip-removal problem.

2.2.23.6 Automatic rake

This could be used for raking the "match joint" during lane paving and for raking after pothole patch material has been laid down would spare the workers' shoulders and might allow them to spend less time close to the center line in construction zones (where they tend to get hurt).

2.2.23.7 Cooling systems for the body

Workers want a way to shield their bodies from the heat and to breathe fresher air during operations involving hot asphalt. Insulated shoes would also increase the comfort of workers.

2.2.23.8 Improved spreader box

Panelists want a more durable spreader box to be used in shoulder work--"one that does not fall apart."

2.2.23.9 Improved thermostat

Current thermostats often fail to keep material hot; panelists reach a job site, find their material solid, and waste a great deal of time and money.

2.2.23.10 Transport material to overlay job sites more quickly

The bottle neck in overlay operations, according to panelists, is getting the asphalt to the work site; the application equipment available is very effective. Panelists saw no solution, since they said the traffic jam they cause while doing the overlay also prevents their trucks from reaching the job site.

2.2.24 Areas currently Addressed by AHMCT

2.2.24.1 Automatic line striping

Agencies will appreciate the automatic line-striping machine. Currently, one worker drives the truck while another steers the carriage and "goes blind after staring at the road for hours on end," according to panelists.

2.2.24.2 Automatic pavement marker

Some panelists want an automatic pavement marker at a reasonable cost that would put the adhesive down, lay the marker, and handle different spacings and different types of markers.

2.2.24.3 General hazardous material clean-up

Agencies want a way to clean up tires and everything else (especially dangerous materials) that get dumped in public areas. They are not sure how to handle certain dangerous materials, so an automatic system that precludes direct contact with any material that makes them uncomfortable would be well-received.

3. Conclusions

The study was broad and not deep; it was designed to uncover areas where improvements in maintenance/construction technology could create the most value for city and county agencies. Several areas with very strong potential for value creation through innovation have been identified:

| | | |
|---------------------------|------------------------------------|---------------------|
| particulate dust control | equipment cleaning | legend painting |
| filtration entrapment | pothole repair | gutter cleaning |
| automated traffic control | root control and sidewalk repair | tarping |
| shoulder equipment | asphalt and concrete sawing | rubberized asphalt, |
| shoulder materials | post-grind clean-up | |
| graffiti control | special grinding applications | |
| vegetation control | removal of raised pavement markers | |

The strongest overall theme is that California agencies need more versatile equipment.

4. Recommendations

If AHMCT desires more data to determine which concepts are promising enough to warrant study and development, TDC recommends the completion of Phase II of our proposal which uses a survey to estimate the value potential of the different concepts. High priority concepts would be chosen for new equipment designs, followed by additional market research with focus groups and/or interviews (as was done for crack sealing devises) to further refine the features of the equipment.

APPENDIX A

DISCUSSION GUIDE

Good afternoon and thank you for coming. I'm John Jervis and working for the AHMCT at U.C. Davis. AHMCT is a research and development program at the university with a charter of "expanding the state of the art in road maintenance." It's jointly funded by the university and Caltrans.

To reiterate, the purpose of this group is to uncover the areas in road maintenance or construction where improved technology would be most valuable to cities and counties; and to identify the shortcomings of current technology in those areas.

I'm going to lead us through an agenda to guide the discussion. Keep in mind that I am moderating a discussion between all of you, rather than presenting a seminar or teaching you something. On the contrary, I will try to steer the discussion so that you end up teaching me what equipment improvements would create the most value for you in your jobs.

We will concentrate on routine operations, not unusual ones--areas where improved technology would be valuable because it would enhance frequently performed operations which currently consume a lot of resources.

One of the most important things we will do is brainstorm to tap into your extensive experience in road maintenance and see what ideas you have to improve existing equipment or create new equipment. (What should be built? What should it look like? What should it do? etc.)

I'll need to interrupt every so often to keep the discussion on track, so please do not be offended when I do so.

The group will last two hours, and then we'll serve lunch.

Are there any questions before we begin?

Begin:

Where do your road maintenance programs need better technology? (For this and the other exercises, let your imaginations run wild. Don't worry about whether it would be technologically possible to give you what you want; let AHMCT worry about that).

What just doesn't seem to work as well as it should? What seems like it ought to be better or easier?

Is there a certain place where you have trouble or get frustrated with the technology you're currently using? Are there any certain bottlenecks caused by your equipment? Have you ever looked at an activity you perform and said, "this should be a lot easier," or "why can't they make something that does that better?"--just write down the first couple of answers that come to mind.

Discuss: (Everyone reads their answers. One or two key areas are identified. Panelists are prompted for bottlenecks, safety hazards, shortcomings of current technology, etc. in each area).

Where in your road maintenance operations would greater automation be most valuable to you?

Discuss:

Where is road maintenance/construction most dangerous or most in need of safer methods? Which areas concern you the most or seem to offer the most potential for improvement? Where and when do your workers get hurt? Do motorists ever get hurt?

Discuss:

Where does road maintenance/construction need to be more efficient? In other words, where is it inefficient in your estimation? Are there any certain times or activities which frustrate you? Which seem wasteful? Where bottlenecks occur?

Discuss:

Where could improved technology save your agencies the most money? What activities are the most expensive? Which ones seem like they should be able to be accomplished at less expense? Why?

Discuss:

Is there anything you or your workers really hate doing? Any activity which is dreaded a week or even a day in advance?

Discuss:

Where does the infrastructure need to be more reliable? Where is its current reliability unacceptable to you? Are there parts of infrastructure which characteristically fail? Which plague you with great inconvenience or expense when they fail?

Discuss:

Where do construction or maintenance activities cause the worst congestion or traffic delays? Are there particular operations which are done at certain times of day (or night) because they are more costly in terms of traffic delay? Are they more dangerous?

Discuss:

Where are you most concerned about the environmental impact of your road construction or maintenance activities? These could be areas of personal concern or guilt arising from your own individual environmental consciousness, or concern about your agencies' liability.

Close:

Before we close, how would you summarize what the group said here today? What were

the most important points? Has anything been left unsaid? How would you characterize the theme of this discussion?

What could have worked better here today? How?
End.

Panel 4: City of Fresno

Counties:

| | | |
|----------|----------------------------|---------------------------------------|
| Fresno | Dave Nunez Dick Mueller | County Road Superintendent Foreman |
| Merced | John Graves | Road Superintendent |
| Mariposa | Bob Johnson | Street Superintendent |
| | Dave Tucker | Street Engineer |
| Tuolumne | Newell Eggar | Street Superintendent |

Cities:

| | | |
|--------|--------------------------|--|
| Fresno | Gary Dille Fred Momen | Street Superintendent Assistant Mngr Street Maintenance |
|--------|--------------------------|--|

Panel 5: City of Stockton

Cities:

| | | |
|----------|--|--|
| Stockton | Wayne Smith Dan Davis Glen Mathews | Engineer, Public Works Foreman Foreman |
| San Jose | Larry Benson | Division Head |
| | Terry Murdock | Maintenance Supervisor |
| Lodi | Curtis Juran George Bradley | Street Supervisor Street Superintendent |

Counties:

| | | |
|-------------|--------------|------------------------|
| San Joaquin | Bruce Parker | Street Superintendent |
| Sacramento | Chico Magana | Department of Airports |
| Placer | Clark Newton | Street Superintendent |

Shoulder work:

construction
widening
repairing

Road safety device maintenance:

signal lights
legend painting (painting words or numbers on the streets)

Other:

vegetation and weed abatement
tree trimming
striping
signing