Automated Cone Machine

Business Development Case

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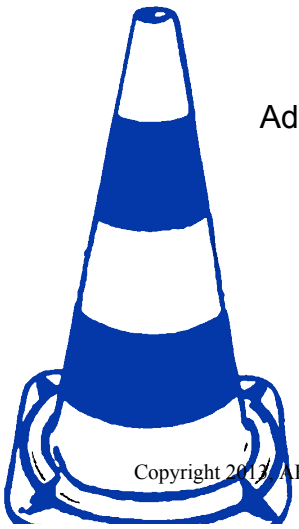

Program Overview

About the UC Davis Graduate School of Management (GSM):
The mission of the UC Davis Graduate School of Management is to be a leader in management research and education. As part of the world's premier public university, we pursue significance, excellence and scholarly rigor in our research, teaching and service to the people of California. We emphasize curiosity, creativity and high standards in the generation and transmission of theoretical and practical knowledge relevant for business.[1]

About the California Department of Transportation (Caltrans):
Caltrans manages more than 45,000 miles of California's highway and freeway lanes, provides inter-city rail services, assists more than 100 public general aviation airports and works with local agencies. Caltrans carries out its mission of improving mobility across California with six primary programs: Aeronautics, Highway Transportation, Mass Transportation, Transportation Planning, Administration and the Equipment Service Center.[2] Caltrans as a whole has an annual budget of $8 billion, of which $393 million is appropriated for maintenance activities.

About the Advanced Highway Maintenance and Technology Center (AHMCT):
The Advanced Highway Maintenance and Construction Technology (AHMCT) Research Center has been developing robotic equipment and machinery for highway maintenance and construction operations. It is a cooperative venture between the University of California at Davis and the California Department of Transportation (Caltrans). The research and development projects have the goal of increasing safety and efficiency of roadwork operations through the appropriate application of automation solutions.[3]

[1] UC Davis GSM Mission Statement, http://www.gsm.ucdavis.edu/visitors_center/about_us.htm#Mission%20Statement
[2] About Caltrans, http://www.caltrans.ca.gov/aboutcaltrans.htm
[3] "Development Of A Prototype Telerobotic System For Debris Vacuum Positioning," AHMCT Research Report, 12/31/01

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1 Abstract

This project was intended to evaluate the business case for the Automatic Cone Machine developed at UC Davis for CalTrans. Within this paper, we look at the cost of the machine, operation cost, and savings, to determine what kind of payback period can be expected.

2 Project Description

2.1 Elevator Pitch

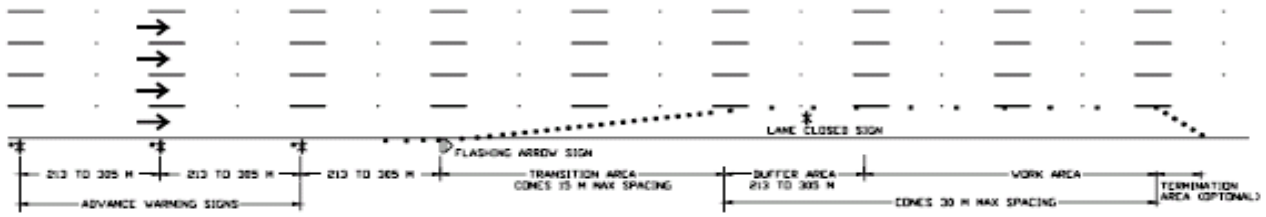
The ACM is an automated cone deployment and retrieval machine that offers fast, efficient cone placement and retrieval while reducing worker exposure to traffic and repetitive motion injuries.

2.2 Value Proposition

2.2.1 Current Cone Placement Methods

Lane closures typically have 3 advanced warning signs before the start of any cones. The cones begin with a taper, with cones placed every 15 meters, and then in the work area, cones are placed every 30 meters. Within that area, there are also periodic lane closure signs.

Figure 1. Lane Closure Specification



Current methods for deployment involve using a worker sitting in a low bucket seat, near the roadway, to drop or retrieve cones. There is a conveyer belt used to move cones along the length of the truck. Each truck can hold 160 cones, double stacked, and requires a minimum of 2 persons to operate, one driver and one worker in the back, with longer closures sometimes using 3-4 workers to reduce fatigue. The cone truck can operate at a speed of 5-10 Mph, and a typical closure requires 20 to 60 minutes for both set-up and retrieval. The current cone body truck conveyor belt system costs approximately $12,000 above the cost of the truck chassis.

2.2.2 Cost Comparison

A cost comparison was performed to determine if the ACM would be more cost effective on a per closure basis and consequently if the ACM would provide Caltrans with a reasonable return on capital investment.

2.2.2.1 Lane Closure Length Scenarios

Since the size of the crew required to place and retrieve cones varies with the length of the lane closure, some assumptions were made regarding the proportion of lane closures that fall into each of three length categories: short, medium and long (Table 1). A short closure is one in which less than 80 cones are used (single stack capacity of the cone truck), representing closures of less than one mile in length. For this type of closure, two workers are required in the current Caltrans cone truck: driver and cone setter in the back. A medium length closure requires a double stack of cones and an additional worker in the back of the cone truck to help the cone setter. A long lane closure, which is assumed to be over five miles long, requires an additional worker in the back as well as a refill of cones at some point during the operation.

The proportions of each closure length are assumed but come from a meeting with a District 3 maintenance crew[4]. In the meeting, the maintenance supervisor stated that a capacity of 80 cones would be sufficient for about 75% of closures. Really long closures (6 to 7 miles) were reported as being rare,

[4] Craig Mincer, D03 Sunrise Region

and the assumption was made that closures of this length represent about 5% of the total lane closures used by Caltrans.

Table 1. Closure length scenarios

Scenario	Length	% of Closures	Workers per Cone Truck	Workers per ACM
Short	Less than 80 cones	75%	2	2
Medium	80 to 160 cones	20%	3	2
Long	More than 160 cones	5%	4	2

Combined set-up and retrieval time using either the current cone body truck or the ACM was assumed to be 40 minutes, 70 minutes and 120 minutes for short, medium and long closures respectively. Implicit in this assumption is that there is no time savings using the ACM compared with the cone body truck.

2.2.2.2 Labor Rate

The following are labor rate data for Caltrans workers used in IMMS reporting[5].

- Maintenance Worker: $27.58
- Caltrans Equipment Operator I: $32.26
- Caltrans Equipment Operator II: $34.61
- Caltrans Maintenance Supervisor: $41.74

Typically, a 15% to 20% overhead rate is applied to hourly labor costs. Using this data, an average hourly rate of $39.15 (including 15% overhead) was constructed.

2.2.2.3 Equipment Rental Rate

The $30 daily equipment rental rate for the cone body truck is a composite number from data in the Caltrans equipment Rental Rate Book (Table 2)[6]. The $74 daily rental rate for the ACM is estimated by scaling the cone body rental rate by the capital cost. The total cost for the cone body truck is about $47,000 ($35,000 chassis plus $12,000 conveyor), while the total ACM cost is expected to be as high as $115,000 ($35,000 chassis plus $80,000 automated equipment). $74 = ($115K/$47K)*$30.

Table 2. Cone Body Truck Rental Rates

Eq. No.	Description	Rental Rate
01037	CONE BODY	$25.77
01137	CONE BODY DIESEL	$25.99
01147	UTILITY-CONE SETTER ONE-TON D	$33.75
01235	CONE BODY AUTOMATIC SUPER	$34.11
01237	Cone Body, 1-Ton, Super Duty, Gas	$25.99
01247	Utility Cone-Setter, Super 1-Ton, Gas	$26.55
01337	CONE BODY	$26.97
01347	UTILITY CONE-SETTER 1-TON DSL	$24.07
01437	CONE BODY	$26.97
01537	CONE BODY DIESEL	$28.84
01837	CONE PICKER	$26.74
01937	CONE BODY (BAY BRIDGE SPECIAL)	$34.12

[5] Caltrans Courtney Morrison
[6] http://www.dot.ca.gov/hq/eqsc/rentalrates/RentalRateBook.pdf

2.2.2.4 Total Yearly Lane Closures

A range of total possible lane closures per ACM was estimated. The minimum number of lane closures is assumed to be 72 (24 lane closures per year per crew, with 3 crews sharing the ACM). On the high end, it is assumed that the ACM would be usable 200 days of the year.

2.2.2.5 Baseline Cost Comparison

Using the data and assumptions presented above, the ACM and cone body truck costs were compared directly on labor and equipment (Table 3). The ACM is not cost effective for short lane closures because the additional equipment cost embodied in the rental rate is not offset by any labor savings. For the medium and long lane closures the ACM begins to become cost effective.

The yearly cost savings estimates are calculated by multiplying the per closure labor savings by the estimated number of closures per ACM, across the range of total lane closures per year. For maximum utilization (200 days per year per ACM), each ACM is expected to save $3,393 in labor costs.

In addition to cost savings, the ACM is expected to reduce worker exposure to traffic by replacing one to three workers in the back of the cone body truck with a single operator in the ACM cab. This is calculated to be 253 worker hours assuming maximum ACM utilization.

Table 3. Cost Comparison – Baseline Case

Per Closure Cost Comparison	Cone Body Truck				Automated Cone Machine		
Closure Length	Short	Medium	Long		Short	Medium	Long
Labor (CT Workers)	2	3	4		2	2	2
Setup and Retrieval Time (minutes)	40	70	120		40	70	120
Labor Cost (@ $39.15 per worker hour)	$52.20	$137.03	$313.20		$52.20	$91.35	$156.60
Equipment Rental Rate (Per Day)	$30.00	$30.00	$30.00		$74.00	$74.00	$74.00
Total cost per closure	$82.20	$167.03	$343.20		$126.20	$165.35	$230.60

Cost Savings Per Closure			
Closure Length	Short (75%)	Medium (20%)	Long (5%)
Labor cost savings per closure	$0.00	$45.68	$156.60
Equipment cost savings per closure	-$44.00	-$44.00	-$44.00
Savings with ACM per closure	-$44.00	$1.67	$112.60

Yearly Cost Savings	Short	Medium	Long
Assumed applicability	75%	20%	5%
Number of closures (Low)	54	14	4
Number of Closures (High)	150	40	10
Annual Cost Savings per Truck (Low Use)	$1,221		
Annual Cost Savings per Truck (High Use)	$3,393		
Reduced Worker Exposure (hours)	253		

A sensitivity analysis was also done around two key variables involved in the ACM cost comparison: set-up and retrieval time and number of workers in the ACM cab. Two additional scenarios were created to determine the effect of these variables on the cost effectiveness of the ACM:

- The ACM reduces set-up and retrieval time by 25% compared to the cone body truck
- One worker can drive and operate the ACM instead of two as assumed in the baseline case

2.2.2.6 Cost Comparison Assuming Time Reduction

The scenario presented in Table 4 assumes that the ACM is 25% more efficient at setting up and retrieving traffic cones. The max estimated annual labor savings increases to $6,656 compared to the baseline case, but the amount of traffic exposure reduction remains the same.

Table 4. Cost Comparison – Time Reduction with ACM

Per Closure Cost Comparison	Cone Body Truck				Automated Cone Machine		
Closure Length	Short	Medium	Long		Short	Medium	Long
Labor (CT Workers)	2	3	4		2	2	2
Setup and Retrieval Time (minutes)	40	70	120		30	52.5	90
Labor Cost (@ $39.15 per worker hour)	$52.20	$137.03	$313.20		$39.15	$68.51	$117.45
Equipment Rental Rate (Per Day)	$30.00	$30.00	$30.00		$74.00	$74.00	$74.00
Total cost per closure	$82.20	$167.03	$343.20		$113.15	$142.51	$191.45

Cost Savings Per Closure			
Closure Length	Short (75%)	Medium (20%)	Long (5%)
Labor cost savings per closure	$13.05	$68.51	$195.75
Equipment cost savings per closure	-$44.00	-$44.00	-$44.00
Savings with ACM per closure	-$30.95	$24.51	$151.75

Yearly Cost Savings	Short	Medium	Long
Assumed applicability	75%	20%	5%
Number of closures (Low)	54	14	4
Number of Closures (High)	150	40	10
Annual Cost Savings per Truck (Low Use)	$2,396		
Annual Cost Savings per Truck (High Use)	$6,656		
Reduced Worker Exposure (hours)	253		

2.2.2.7 Cost Comparison Assuming One Worker per ACM

The scenario presented in Table 5 assumes that only one worker is required to drive and operate the ACM. The max estimated annual labor savings increases to $9,918 compared to the baseline case, but the amount of traffic exposure reduction remains the same.

Table 5. Cost Comparison – 1 Worker per ACM

Per Closure Cost Comparison	Cone Body Truck				Automated Cone Machine		
Closure Length	Short	Medium	Long		Short	Medium	Long
Labor (CT Workers)	2	3	4		1	1	1
Setup and Retrieval Time (minutes)	40	70	120		40	70	120
Labor Cost (@ $39.15 per worker hour)	$52.20	$137.03	$313.20		$26.10	$45.68	$78.30
Equipment Rental Rate (Per Day)	$30.00	$30.00	$30.00		$74.00	$74.00	$74.00
Total cost per closure	$82.20	$167.03	$343.20		$100.10	$119.68	$152.30

Cost Savings Per Closure			
Closure Length	Short (75%)	Medium (20%)	Long (5%)
Labor cost savings per closure	$26.10	$91.35	$234.90
Equipment cost savings per closure	-$44.00	-$44.00	-$44.00
Savings with ACM per closure	-$17.90	$47.35	$190.90

Yearly Cost Savings	Short	Medium	Long
Assumed applicability	75%	20%	5%
Number of closures (Low)	54	14	4
Number of Closures (High)	150	40	10
Annual Cost Savings per Truck (Low Use)	$3,570		
Annual Cost Savings per Truck (High Use)	$9,918		
Reduced Worker Exposure (hours)	253		

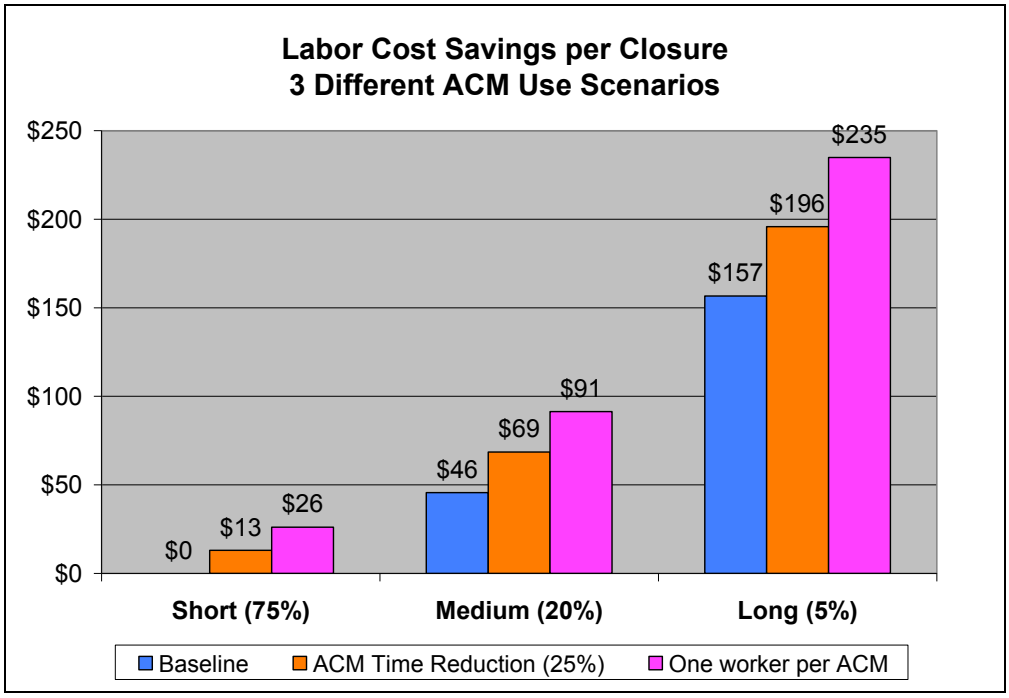
2.2.3 Summary of Benefits to Caltrans

2.2.3.1 Per Closure Cost Savings

Figure 2 compares the expected labor cost savings per closure for the three ACM usage scenarios (baseline, 25% time reduction, one worker per ACM) for each of the three closure length scenarios. Clearly the ACM is most cost effective for longer closures where more workers can be replaced by the automated equipment. Also enabling a single worker to operate the ACM from the cab would be more

cost beneficial than if the ACM were able to reduce set-up and retrieval time by 25%, though interviews with road crew units indicates that this is a very unlikely usage scenario.

Figure 2. Per Closure Labor Cost Savings Comparison Chart



2.2.3.2 Return on Investment

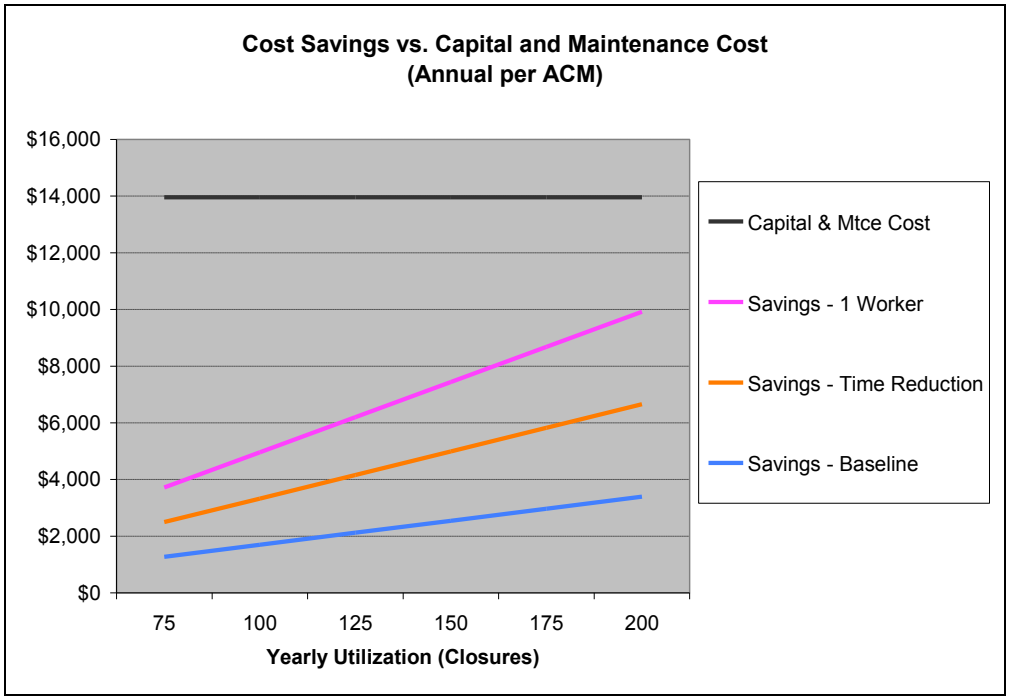
Calculating return on investment involves comparing the expected cost savings from using the ACM with the difference in capital and maintenance costs between the ACM and a cone body truck. Table 6 outlines the data and assumptions used in the ROI analysis. The difference in capital cost is $68,000, while the difference in yearly maintenance cost is estimated as $7160. The cone body truck maintenance is assumed to be 7% of capital cost (typical for Caltrans equipment). The ACM maintenance cost is assumed to be 3% higher because it is a new technology.

Table 6. ACM vs. Cone Body Truck Capital and Maintenance Costs

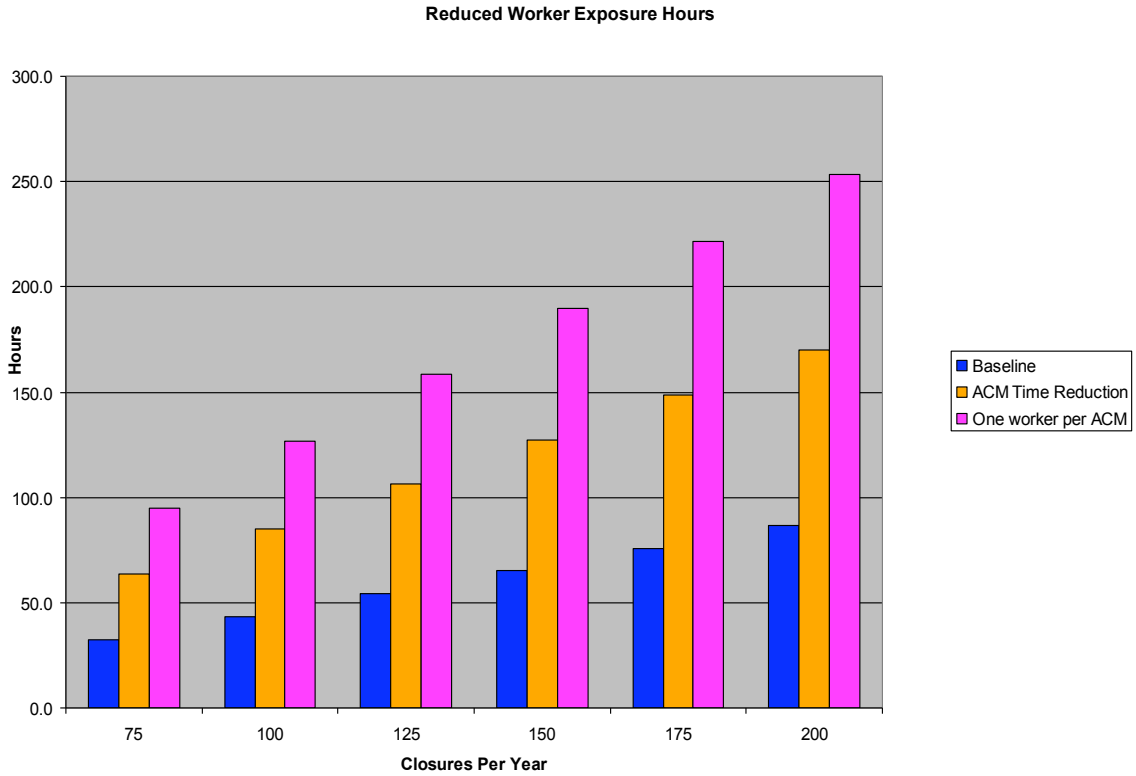
Capital / Maintenance Cost Comp	Cone Body	ACM	Diff
Capital Cost	$12,000	$80,000	$68,000
Yearly Mtce (% of Capital)	7%	10%	3%
Yearly Maintenance Cost	$840	$8,000	$7,160

Figure 3 shows the expected labor cost savings for each of the three different ACM usage scenarios and the difference in amortized capital and maintenance cost across a range of ACM utilization. In order for the ACM to provide a positive return on investment, the yearly cost savings must exceed the expected additional amortized capital and yearly maintenance cost. The capital cost differential ($68,000) is amortized over 10 years ($6800) and added to the maintenance cost differential ($7160) to get a total yearly cost savings requirement of $13,960. As the chart shows, none of the three usage scenarios, even at maximum utilization will provide enough yearly labor cost savings to justify the additional capital and maintenance cost. In other words, the ACM is not expected to provide a positive return on investment.

Figure 3. Cost Savings vs. Capital and Maintenance Cost

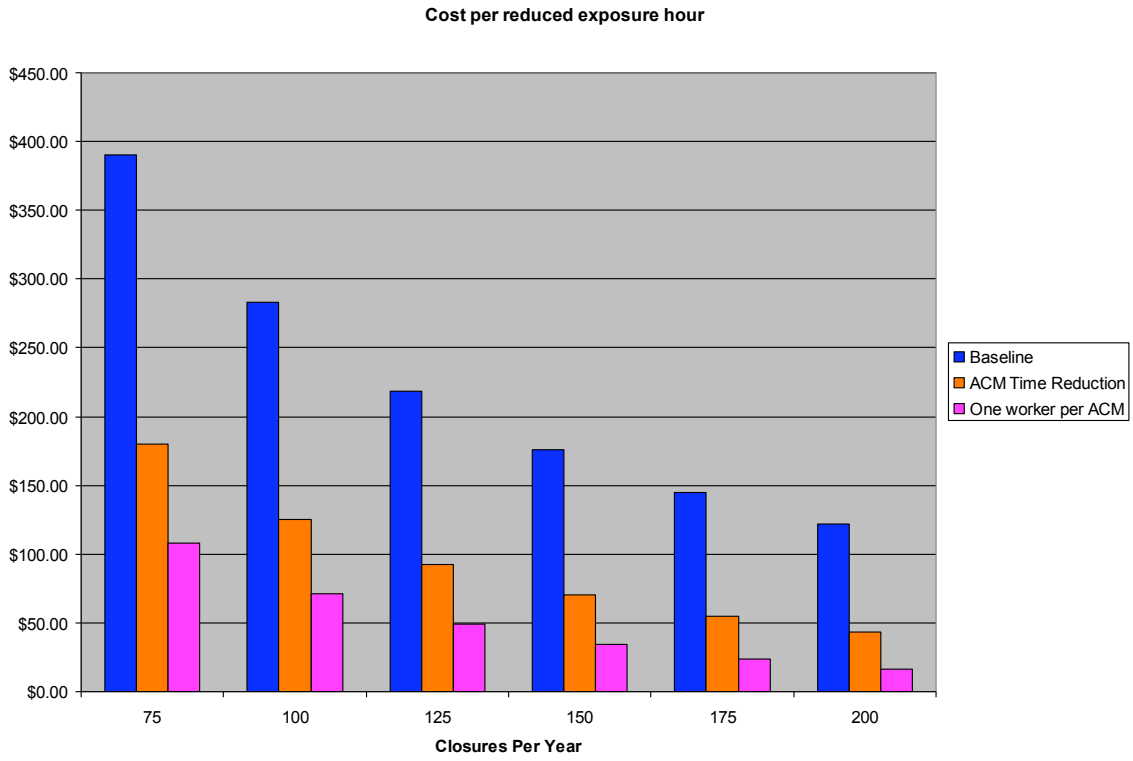


2.2.3.3 Worker Exposure to Traffic



One of the principle benefits of the ACM is reducing traffic exposure by eliminating one or more workers in the rear of the cone body truck. In addition to traffic exposure, manual cone placement also subjects workers to repetitive motion and the corresponding risk of injury.

Since the labor cost savings from using the ACM does not appear to justify the additional maintenance and capital costs, the real benefit from the additional expenditures will be a reduction in worker exposure to traffic. In ten years of safety data reviewed for cone related injuries, $1.4 million was paid related to injuries related to cone manipulation, with an additional $400K paid in traffic related injuries while placing cones. Depending on usage scenarios and rates of usage, costs of reducing exposure could be well below $50/hour. This number is very reasonable when compared to other costs CalTrans incurs in pursuit of safety (e.g. Shadow vehicles, police on site, etc)



2.3 Project Objective

The purpose of this project is to develop a business case to support the deployment of the Automated Cone Machine into the Caltrans work place. The business analysis will examine the costs and benefits of the technology at multiple levels:

- Cost/benefit analysis for individual Caltrans tasks
- Return on investment analysis for the deployment of the ACM within Caltrans
- Cost/benefit analysis that factors in public welfare and policy objectives (reduced traffic delays, injury accidents)

3 Technology

3.1 Description[7]

Figure 4. Automated Cone Machine Prototype

Video is available at: http://www.ahmct.ucdavis.edu/a_upvideo/cone.mpg

The ACM can automatically place and retrieve traffic cones. This machine fits onto existing Caltrans traffic cone trucks and all operations are controlled from within the cab by either the driver or a second operator. The AHMCT machine places cones in the forward travel direction and retrieves them in either forward or reverse directions at speeds up to 10 mph. The machine is designed so that no on-site set-up is required, and both deployment and stowage of the mechanism is simple and fast. The entire operation is under control of the driver, who remains in the truck cab during both deployment and retrieval. The machine is designed so that manual operation, as currently performed, is still possible in the event of unusual circumstances.

Design Features

- By default, the Cone Machine handles generic 28 inch highway cone. It can be readily modified to handle other sizes of cones.
- The Cone Machine is controlled using simple switches.
- The automated equipment occupies minimal space on standard trucks. A standard vehicle envelope is maintained when not handling cones.
- By default, 80 cones can be stored in stacks laying on side. The carrying capacity can be readily modified.
- Cones can be placed in the forward direction, on either the left or right side.
- In the default configuration, you can automatically space cones every 25, 50 or 100 feet and while traveling at a speed of 10 MPH. Spacing choices are readily modified.
- You can retrieve upright or knocked-over up cones on either the left or right side while traveling either in a forward or reverse direction.

The manufacturing cost for the automated cone machine is expected to be about $50,000, with a retail price of $60,000 to $80,000. This pricing does not include the truck chassis, which usually costs Caltrans about $35,000.

[7] AHMCT Cone Machine, http://www.ahmct.ucdavis.edu/index.htm?pg=Cones

3.2 Status

The automated cone machine project was started around 1993 by a need from inside Caltrans for a safer way to drop and retrieve cones for Bay Bridge routine maintenance. The first step in the design process was a test-bed unit that revealed that picking-up cones was the major challenge to be solved.

Using the knowledge gained in the test-bed, a fully functional unit (ACM1) was designed, developed and prototyped. ACM1 was taken into the Caltrans equipment fleet and used in Districts 4 and 11. ACM1 is currently on loan to Traf-tech, who is licensing the ACM patent from UC Davis.

Use of the first prototype revealed that the cone carrying capacity of the unit was too small and that the mechanism tended to hang over the road during use. The mechanism has been redesigned to address these issues, but a fully functional second prototype has not been created. The latest design is expected to be expandable up to 300 cones.

3.3 Intellectual Property

The ACM retrieval apparatus is protected under US patent number 6,056,498 (5/2/2000) which is owned by the UC Regents. The patent has been exclusively licensed to Traf-tech, although Caltrans is allowed to manufacture their own units. Since Caltrans funded the research that lead to ACM, they have rights to a royalty free license in California, meaning that UC Davis does not receive revenue for sales to Caltrans but any sales made outside of California are subject to royalty fees. Information regarding field of use and duration of the license are not available because of confidentiality issues.

4 Traffic Control Market

The traffic control market generally consists of two main groups, state highway maintenance crews, and private construction crews. Very generally, private construction crews tend to do more long closures, and as such may be better candidates for the ACM.

5 Recommendations

Our recommendation is to closely look at where long, frequent closures are used. Short, infrequent closures do not appear to offer sufficient labor savings to justify the costs. If the procedure could be changed such that one operator was sufficient, then the ACM becomes more financially viable.

6 Acknowledgements

We'd like to thanks all the Caltrans maintenance workers who patiently answered our questions, especially Craig Mincer. Also we'd like to thank Caltrans.