# Cost of Light Rail Collision Accidents

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This paper estimates the full costs of collision accidents on the Santa Clara County light rail system in San Jose, California. Per-accident costs to the transit agency are estimated, including money paid out and staff time spent, based on 6 years of accident records. Costs are estimated for injury and noninjury accidents and by accident type. Additional costs to society are also estimated based on previous studies of highway crash costs. The average cost of an injury accident was found to be $206,411 to society as a whole, of which $3,972 was to the transit agency. The average cost of a noninjury accident was found to be $9,111 to society as a whole, of which $1,872 was to the transit agency.

The purpose of this paper is twofold: first, to provide a methodology for estimating the costs of collision accidents on light rail systems and second, to present a case study of light rail collision costs on the Santa Clara County Transportation Agency (SCCTA), located in San Jose, California. Comprehensive collision costs are estimated both to the TA and to society as a whole.

This study is part of a larger project, funded by the California Department of Transportation (Caltrans), on the application to light rail transit of safety measures that use Intelligent Vehicle Highway Systems (IVHS) technology. Renewed interest in public transit among transportation planners and government agencies has led to a renaissance of light rail in recent years, particularly in California. Nine U.S. and Canadian cities have built light rail systems in the past 2 decades, and many others are either planning or debating such systems. California has four recently built systems, in San Jose, Sacramento, San Diego, and Los Angeles, in addition to the classic streetcar lines operated by the San Francisco Municipal Railway (Muni).

Although light rail transit has a good safety record, there are opportunities to further reduce the number and severity of accidents involving light rail vehicles. In selecting countermeasures to use, however, the benefits of accident reduction must be weighed against the costs of implementation.

To perform such an assessment, integrated models of collision occurrence, severity, and cost are required. These models must be sensitive to the effects of countermeasures in reducing the incidence and severity of collisions involving light rail vehicles and must reflect the cost savings of such reductions. The larger study therefore includes accident analysis to identify hazard conditions and critical events leading to collisions. An extensive set of possible countermeasures, ranging from simple refinements of existing procedures to applications of advanced sensor and actuator technologies, has also been identified. Assessment of the potential effectiveness and real-world feasibility of these countermeasures is presently underway. When this is complete, it will be possible to use the system of models described earlier to estimate the economic value of countermeasures, both in the aggregate and by cost category. When such estimates are combined with estimates of countermeasure cost (which will be developed at a later stage of the study), a rational basis for selecting which countermeasures to implement will be established.

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## BACKGROUND

### Safety Investment

Safety investment decisions can be based on a variety of criteria (*1,2*):

1. Cost-benefit ratio: total costs and total benefits are quantified in dollar values, and investment is made to the point at which incremental investment equals the incremental benefit obtained. Although theoretically appealing, cost-benefit analysis is rarely applied. Many benefits of accident reduction are difficult to label with a dollar value, and attempts to do so can be highly controversial.
2. Cost-effectiveness: projects are ranked based on the amount of safety improvement per dollar spent. If a fixed level of resources is available, projects are completed in ranked order, starting with the most cost-effective, until resources are used up. In this case, the benefits do not have to be monetized; they can be lives saved, injuries prevented, and so on. An example of cost-effectiveness analysis is the prioritization of railroad-highway grade crossing improvements.
3. Threshold safety level: a minimum acceptable level of safety is set. This is commonly done based on a comparison to analogous systems or to previous system performance. An alternative approach, rarely used in practice, is to conduct an explicit risk-benefit analysis (*1*).
4. Industry and government standards, both formal and informal, for vehicles, stations, traffic control devices, and operating procedures are followed. Rather than prescribing an acceptable level of safety, these standards promote behavior and decisions on the part of managers and line personnel consistent with "safe" operation.
5. Decisions are made on an ad-hoc, perceived-need basis.

In practice, transit agency decisions in matters related to safety are characterized by the last two of these approaches. Light rail technology extends back to the streetcar era, so there is extensive experience on which to base standards for safe equipment, facilities, and operations. With these as a baseline, individual agencies take further steps to increase safety by responding to problem areas revealed by the occurrence of accidents and near-misses, as well as the perceptions of agency personnel.

Cost-benefit analysis cannot and should not replace these procedures, but it can extend the capabilities of transit operators to identify cost-effective actions to improve safety. Analyses of the incidence and severity of light rail collisions will, at a minimum, validate more subjective assessments of safety problem areas and

may substantially alter them. Evaluations of the economic costs of these events make it possible to determine whether resources should be redirected to safety from other areas, and if so, how such resources should be spent. Furthermore, by distinguishing costs to the agency from costs to society, it is possible to determine when a safety expenditure is in the agency's own narrow self-interest and when it may be appropriate for society to encourage or subsidize such an expenditure. The latter is particularly important in light of the increased flexibility of regional planning agencies in allocating federal transportation funds resulting from Intermodal Surface Transportation Efficiency Act (ISTEA) legislation, as well as increasing pressure from the Clinton Administration that all transportation investments using federal funds undergo cost-benefit analysis (*3*).

### Accident Cost Analysis

A growing body of literature exists on the costs of highway accidents. Studies by the National Safety Council, the National Highway and Traffic Safety Administration, and the FHWA have attempted to quantify the total societal losses, both economic and noneconomic, due to highway accidents (*4–6*). The most recent study, *The Cost of Highway Crashes*, estimated the annual comprehensive cost to be $334 billion in 1988 (*6*). As the authors point out, this cost represents the maximum rational investment in highway safety above and beyond current levels. The present study draws on this work for a number of costs that could not be found directly.

Although considerable safety-related work has been done in the transit field, to the best of the authors' knowledge no thorough study exists on the costs of crashes involving transit vehicles. Also, although previous reports have recognized the need for evaluating transit safety measures on a cost-effectiveness basis (*7*), a methodology for doing so has not yet been proposed.

## SYSTEM OVERVIEW

Santa Clara County's light rail line began running in 1987 and by 1991 had expanded to the 21-mi (33.8-km) system currently in operation. The system has three major sections: a separate right-of-way in the median of North First Street, with signalized grade crossings at intersections; a downtown pedestrian mall; and an exclusive right-of-way along the median of the State Route 87 freeway. Maximum operating speeds on each section are 35, 10, and 55 mph (56, 16, and 89 km/hr), respectively. The system layout has much in common with that of other recently constructed light rail lines in North America.

Through 1993, a total of 169 collision accidents with motor vehicles, pedestrians, and bicyclists have occurred on the system. Of these, 50 have resulted in one or more minor injuries, two in a severe injury, and three in a fatality (one was a possible suicide). Collision accidents per vehicle-mi have steadily declined to nine per 100,000 vehicle-mi (5.6 per 100,000 vehicle-km) in 1993. This compares favorably with other light rail properties (*8*). Despite the exclusive use of signalization and extra signage for left turns along North First Street, the majority of accidents (63 percent) have resulted from drivers turning left in front of parallel-running trains, and 10 percent are from mirror-image, right-turn accidents on the downtown pedestrian mall. The predominance of so-called "left-turn" accidents is common to most light rail transit properties (*9*).

## METHODOLOGY

For this analysis, accident costs are broken down into two categories: costs that accrue directly to the transit agency and costs that are borne by all other elements of society. Agency costs can be further categorized as direct disbursements per accident, direct disbursements per year, or time contributions by agency employees. Categorization may vary among transit agencies; for example, some process claims in-house, and others contract out for claims work. The cost categories identified for this analysis are summarized in Table 1.

Direct agency costs for each accident were estimated from agency records whenever possible. Estimates of typical staff time spent per accident were provided by light rail division staff. Rider delay per accident was also estimated from agency records. Other costs incurred by individuals, as well as emergency response costs, were estimated using national data from *The Cost of Highway Crashes*. Average costs per accident were then calculated based on whether or not the accident resulted in injury. Ideally, costs would be broken down using a more refined injury scale (including differentiation by minor injury, severe injury, and fatality); however, a lack of data on severe injuries precluded this. Costs were also tabulated based on accident type. Disaggregation of costs by accident characteristics should be helpful in assessing the cost-effectiveness of specific countermeasures.

### Direct Agency Costs

#### *Property Damage, Claims Administration, Claims Payments, Legal Expenses*

Itemized data were available from agency records for July 1990 through the end of 1993, a total of 76 accidents. SCCTA contracts with an outside adjustor to estimate damages and to process claims against other parties and claims against the agency. Therefore, administrative costs and claims paid out by the agency for property damage and bodily injury were available on a per-accident basis. Legal costs and attorney fees were also obtained from internal memos. Data from previous years were inflated to 1993 dollars based on the Consumer Price Index (*10*). Claims payouts by the agency were incurred in roughly 10 percent of cases, reflecting that the transit agency is rarely found legally liable in light rail collision accidents. On the contrary, the transit agency was able to partially or fully recoup costs from the other party in a substantial proportion of cases.

From a societal perspective, claims paid and received by the transit agency are transfer payments rather than actual costs. Therefore, in determining social costs, claims paid by the agency are subtracted from nonagency costs, and claims paid to the agency are added to nonagency costs. Such transfer payments do not change the overall cost to society.

#### *Operator Overtime*

When an accident occurs, SCCTA relieves the operator for 1 to 2 hr to impound the vehicle and fill out reports. The operator is replaced from a pool of "extraboard" operators waiting on standby. Most extraboard operators are used for purposes unrelated to collision accidents (such as sickness and no-shows), so it is doubtful that this

**TABLE 1 Description of Cost Categories**

| Cost Category | Description | Payer | Source of information |
|---|---|---|---|
| Agency property damage | Damage to LRVs and other agency property | Transit Agency | Agency records |
| Claims administration | Damage adjustment; processing of claims for and against agency | Transit agency | Agency records |
| Claims payments | Claims for bodily injury and property damage paid out by agency | Transit agency* | Agency records |
| Claims received | Claims payments received by agency from individuals | Society** | Agency records |
| Legal & court expenses | Legal counsel and court fees paid by the agency | Transit agency | Agency records |
| Operator overtime | Overtime paid by agency to LRV operators | Transit agency | Estimated by light rail division staff |
| Supplementary service | Bus bridge or van shuttle around accident scene | Transit agency | Occurrences from agency rcords; service costs estimated |
| Revenue loss | Immediate or long-term revenue loss due to lost ridership | Transit agency | Time-series analysis of ridership |
| Catastrophic Insurance | Agency insurance against catastrophic liability or property damage | Transit agency | Agency records |
| Accident response | Staff time spent responding to scene, filling out reports, and investigating accident | Transit agency--time cost | Estimates by agency staff |
| Replacement operator training | Training for new operators to replace operators who have taken permanent leave as result of accident | Transit agency--time cost | Estimates by agency staff |
| Misc staff support | Other staff time: employee assistance program, requests for information from public | Transit agency--time cost | Estimates by agency staff |
| Emergency response | Response to accident by police, fire, and medical transport | Society (local government) | Response from agency records; response costs from *(6)* or estimated |
| Injury costs | Costs associated with injuries incurred | Society | Injury level from accident records; costs per injury from *(6)* |
| Property damage | Vehicle & other property damage to other party | Society | Costs per vehicle, by injury level, from *(6)* |
| Rider delay | Delay to light rail system users due to accident | Society | Agency records of system delay and ridership |
| Road travel delay | Delay to road users | Society | From *(6)*, according to cross-street classification |

* Subtracted from societal costs

** Subtracted from agency costs

pool could be reduced by reducing the number of collision accidents. Although each operator is guaranteed a standard number of hours of pay, it is possible, given a shortage of extraboard operators, that an operator may need to work overtime. The agency incurs additional expenses for overtime, which is compensated at 1.5 times the hourly wage rate. Records of overtime on a per-accident basis were not available, but the agency estimates that no more than 2 hr are accrued for a typical accident.

*Supplemental Service*

If both tracks are blocked for a long period of time, supplemental service such as a bus bridge or van shuttle must be provided to transport passengers to their destinations. To provide a bus bridge, an extraboard operator may be used, a deadhead may be available, or a bus may be diverted from an existing route. Although the last option may incur additional costs through rider delay on other

routes, actual examples are rare that this component was ignored. Provision of alternate service was infrequent (a bus bridge was provided in 4 percent of accidents, and some additional cases of van shuttles may not have been recorded). Data on the length or nature of such service were not available, so a crude estimate of $48 per service provision (1 hr of operator time plus overhead) was used.

*Revenue Loss from Lost Riders*

A loss of riders due to accident delay could occur either immediately or over the long term. For this study, the immediate loss of fare-paying riders was assumed to be negligible; the vast majority of accidents caused system delays of 15 to 20 min or less, and it was assumed that this would not be enough time to drive a significant number of riders away. (Even if a significant number of riders found alternative transportation, the one-time revenue loss would be small compared with other accident costs.)

To look at long-term effects on ridership, a time-series regression model of ridership was constructed. A regression model was used to relate dependent variables that may impact ridership to monthly ridership levels from 1987 through 1993. Accidents were incorporated in a number of ways, including gross accidents per month, injury and noninjury accidents, and delay caused by accidents. No significant relationship between accidents and ridership was found; therefore, the cost of lost ridership was assumed to be zero for this study.

*Catastrophic Insurance*

SCCTA is self-insured against everything but catastrophic claims (over $5 million) and severe agency property damage (over $200,000). Purchasing commercial insurance only for catastrophic situations is a practice common to most transit agencies (*1*). Although SCCTA's light rail division has never had a claim approaching the $5 million limit, insurance costs are still fairly significant: $25,000 in 1993, or over $500 when allocated on a per-incident basis. The extent to which costs could be reduced through a reduction in accidents, however, is not clear. Previous research (*1*) has found that there is some effort to account for risk when setting insurance rates, but in a highly intuitive, negotiated manner.

SCCTA purchases insurance with 10 to 12 other counties; light rail accidents, therefore, are a very small percentage of the total accidents that occur in this pool of transit agencies. Rates for the TA have declined in recent years because of a good safety record with no large losses. According to TA insurance staff the rate depends primarily on the past history and forecast probability of large accident claims, rather than the total number of accidents. Although the likelihood of a severe accident occurring is certainly related to the total number of accidents, the insurance agency does not appear to explicitly evaluate this relationship when setting rates. Therefore, it is assumed for this study that a simple reduction in the number of light rail accidents would not lead to a corresponding reduction in insurance expenses, and insurance is not included in the per-accident cost tabulation.

## Agency Staff Time

*Accident Response, Reporting, and Investigation*

When an accident occurs, central control is called, and one or more supervisors respond to the scene; both a supervisor and the operator fill out an accident report. The supervisor then files the information, and reports are reviewed regularly by an accident review committee. In addition, a report must be filed with the California Public Utilities Commission. The light rail division estimates that a total of 2.5 to 3 hr of supervisor staff time is spent responding to accidents and processing reports. In addition, operators are paid 0.5 hr overtime for filling out a report. Reporting and investigation times appear to increase greatly in the event of a severe or fatal accident; a conservative estimate of 8 hr was used in this study. To monetize time costs, annual salaries were computed on an hourly basis and were multiplied by 2.6 (based on standard agency practices) to account for fringe benefits and overhead.

*Training of Replacement Operators*

In rare cases, an operator may take permanent leave because of severe psychological trauma after an accident. This has happened once at SCCTA. If so, the operator must be replaced, and retraining costs are accrued. The light rail division estimates that roughly 128 hr of staff time and 5 weeks of operator time are involved in training the operator, for a total time-cost of $9,700. If no new operator is available, additional overtime expenses will be accrued instead. In addition, after severe or fatal accidents, operators are given 1 to 2 days leave to recover from the psychological effects of an accident. This may cause a shortage of operators and the accrual of more overtime. Specific data were unavailable, so this absence was valued at 1.5 days at the standard wage rate.

*Other Staff Support*

The most significant additional portion of agency staff time was in the county's insurance division. Staff time spent on transit incidents was estimated at 90 percent of a full-time staff person plus 45 percent of a clerical support person. Ten percent of this time was estimated to involve light rail incidents, of which half were collision accidents. Total cost was estimated to be $248 per accident, based on the total number of accidents for 1991 through 1993.

Other staff costs are relatively minor. The TA operates an Employee Assistance Program (EAP), which offers counseling or other aid to operators who have suffered stress. The program costs $16,180 annually; the transit agency estimates that 1 percent of program time is related to light rail collision accidents. Allocating costs to injury accidents only, the cost would be $22 per injury accident.

SCCTA has not incurred any exceptional public relations expenses because of light rail accidents, but the agency does have a Public Information Officer who may respond to inquiries about accidents. The agency estimates a 3 percent response time to accidents; given a 7.5 percent allocation of accidents to light rail, a negligible per-accident cost of $15 may be assumed. In the case of a catastrophic accident it may be necessary for a transit agency to incur additional public relations costs. This is an area for further investigation.

## Other Societal Costs

*Emergency Response*

Emergency response may take the form of the local police department, fire department, or medical transport. In addition, SCCTA

contracts with the sheriff's department to provide protective services for the division. Police, sheriff, and ambulance response were noted on the accident report forms. Fire department response was found in agency records.

Fire department and ambulance response costs were taken from *The Cost of Highway Crashes*. The average fire department response cost $550 in 1987 dollars (*6*); ambulance response averaged $221 for hospitalized cases and $167 for nonhospitalized cases, in 1992 dollars (T. Miller personal communication, 1994). The proportion of hospitalized versus nonhospitalized cases was not known from accident records, so a round figure of $200 was used. Typical police and sheriff response costs were estimated using a total response/processing time of 1 hr for police and 0.5 hr for sheriff. Personnel costs of $68 per hour were assumed, based on payroll size and employment figures for police departments, adjusted for California wage differentials and for fringe benefits and overhead (*10*).

### *Injury-Related Costs*

Because of the limited scope of the study and privacy concerns, no attempt was made to estimate actual accident- or injury-related costs to private parties. Instead, national estimates of per-injury costs according to KABCO injury severity were taken from *The Cost of Highway Crashes* (Table 2). KABCO is the injury coding scale most commonly used by police departments in accident reporting. The scale is K = killed; A = incapacitating injury; B = evident, nonincapacitating injury; C = claimed injury; O = no injury. The limitations of the KABCO system in describing injury severity and relating to actual cost are discussed elsewhere (*6*). However, a lack of better information about the nature and severity of injuries prevented the use of a more refined injury scale.

Injury-related cost categories include hospitalization and other medical expenses; vocational rehabilitation; household production; lost wages; insurance administration; "workplace" costs including lost productivity and retraining; emergency services; legal/court costs; and pain and suffering. On a case-by-case basis, actual costs will differ considerably from average cost estimates. The study assumes, however, that on the average costs according to injury level are the same as those estimated nationally from highway crash data.

Most categories were applied directly, based on the number and severity of injuries in each accident. However, some categories had to be adjusted because of the unique nature of the study. Emergency services were eliminated, having already been estimated on a per-response basis. Legal expenses were adjusted, because it appears that light rail accidents are less likely to involve court proceedings and legal expenses than the typical highway accident. The vast majority of attorneys are reimbursed as a percentage of the settlement won, 29.4 percent on the average. Court costs and fees average another 2 percent (*11*). Therefore, other-party legal expenses were estimated by taking 31 percent of compensation paid by the transit agency to other parties. This probably underestimates actual legal expenses because in some cases parties may sue their own insurance company or contact an attorney without going to court. Insurance administration costs were not adjusted and may slightly overestimate actual costs because the light rail agency's administration costs are already included. Per-injury insurance administration estimates are based on the costs eligible for compensation, medical, lost wages and household production, and property damage, and published administrative expense ratios (*6*).

Pain and suffering are a large component of comprehensive injury costs. Estimates are based on numerous studies of willingness to pay to reduce risk (for example, the amount that automobile consumers are willing to pay for airbags or other safety-related features). Pain and suffering costs should not be ignored as part of the overall cost to society, even though their measurement is imprecise. Studies of willingness to invest in safety at a personal level should be directly applicable to the determination of societal levels of safety investment.

### *Property Damage to Private Vehicles*

Property damage to private vehicles was also taken from *The Cost of Highway Crashes*, with cost estimates on a per-vehicle basis according to injury level. Damage estimates of "minimal," "moderate," and "major" were available from accident reports, but the correspondence of these levels to actual cost is unknown. However, an analysis of the correlation of injury level to reported damage level did show a significant positive relationship within the accident data set, so it seems reasonable to base property damage costs on injury level. Again, on a case-by-case basis, costs will differ markedly. A property damage cost of $150 was assumed for bicycle accidents.

### *Rider Delay*

To estimate rider delay, train-minutes of delay were taken from agency records and were multiplied by estimates of the number of riders affected, based on agency ridership surveys by time of day and location. Delay is probably overestimated because the delay of two consecutive trains would actually result in many riders catching the first train instead of the second train. Nevertheless, the estimates of 29.1 passenger-hr for a noninjury accident and 80.3 passenger-hr for an injury accident should serve as a reasonable approximation. Delay time was valued for passengers at 67.5 percent of the average national wage rate (*6*), adjusted for California

**TABLE 2 Costs per Injury by KABCO Severity (1988 Dollars)**

| Injury Level | Hosp/ Med | Voc Rehab | Household Production | Wages | Insurance Admin | Workplace | Pain & Suffering |
|---|---|---|---|---|---|---|---|
| K | $5,859 | $0 | $92,014 | $428,316 | $43,751 | $6,186 | $1,743,917 |
| A | $9,660 | $69 | $3,250 | $11,728 | $2,470 | $961 | $133,925 |
| B | $1,742 | $24 | $845 | $2,946 | $721 | $333 | $22,858 |
| C | $1,017 | $19 | $522 | $1,782 | $484 | $223 | $9,927 |
| O-Per Vehicle | $73 | $1 | $71 | $135 | $155 | $45 | $369 |

Source: Miller et al, 1988

wage differentials, with wage information from the U.S. Bureau of Census (*10*).

*Road Travel Delay*

*The Cost of Highway Crashes* gives crude figures for road travel delay, estimated from simulations, for highway accidents. Estimates are provided for freeways, arterials, and collector streets. For this analysis, these delay estimates are applied based on the classification of the cross-street where the accident occurred. Delay is valued at 90 percent of the wage rate for drivers and 67.5 percent for passengers (*6*). (The differential between driver and passenger delay values reflects the greater disutility of time spent driving compared with time spent riding in a vehicle.) Again, this should only be considered a first approximation, and actual delay values may vary considerably.

## RESULTS

### Estimated Costs

A breakdown of average costs by agency and nonagency categories and by accident severity is given in Table 3. Costs by cost category are given in more detail in Table 4. Direct and indirect costs to the transit agency averaged $2,568 overall, including $1,872 for a noninjury accident and $3,972 for an injury accident. Additional costs to society, including pain and suffering, totalled $7,238 for each noninjury accident and $202,439 for each injury accident.

Overall, the most substantial component of agency costs was vehicle damage ($3,915 per accident), followed by claims administration ($1,174) and legal costs ($874). On average, however, $4,311 of the agency's total costs were recouped from the other party involved in the accident. Legal costs and claims paid tended to be infrequent (less than 10 percent of all accidents) but relatively large, averaging $9,161 and $2,969, respectively, in cases in which they did occur. Catastrophic insurance was also a relatively substantial cost when calculated on a per-accident basis ($660 in 1993), but it is not clear that a reduction in accidents would lead to a near-term reduction in insurance costs, so this was not included in the total cost estimate. Agency staff time and driver overtime costs were smaller but still substantial, at $560 per accident. Costs were not substantially greater for minor injury than for noninjury accidents. Also, no measurable long-term impact on ridership was found.

For costs not borne by the agency, emergency response, rider delay, and road user delay costs were a relatively minor component except in property damage-only accidents. Emergency response costs averaged $163 per accident; rider delay averaged 63.5 passenger-hr or $548. Again, a few cases of unusually high delay skewed the average somewhat.

### Reliability of Estimates

Detailed agency cost data were available for 53 noninjury and 23 injury accidents. The costs for noninjury accidents were relatively consistent, and therefore the estimates for property damage-only accidents may be considered fairly reliable. The cost per injury accident, however, could be highly influenced by just one or two large claims, on the order of hundreds of thousands or even millions of dollars, which may occur once every few years. No claims over $16,000 were paid by the agency in the 3.5-year time period for which records were available, but one $300,000 claim (not included in the data set) was recorded in the first 3 years of the system's operation. If this $300,000 claim payment had occurred in the period covered by the data set, average agency costs would have increased from $2,870 to $6,544 per accident. Claims payments would have comprised 40 percent of agency costs rather than 6 percent. Therefore, the cost estimates for injury accidents should be regarded as less reliable because of the more variable nature of the data. It should also be noted that claims cases can sometimes take many years to resolve, so it is possible that costs have been underestimated for the existing data set.

**TABLE 3 Average Cost per Accident and by Accident Severity**

**a Average Cost Per Accident (1993 dollars)**

| | |
|---|---|
| Transit Agency | $2,568 |
| Non-Agency | |
| Direct | $22,817 |
| Pain & Suffering | $49,096 |
| Total Societal | $74,481 |

**b Average Cost by Accident Severity**

| Injury/Fatality | | Property Damage Only | |
|---|---|---|---|
| Transit Agency | $3,972 | Transit Agency | $1,872 |
| Non-Agency | | Non-Agency | |
| Direct | $55,171 | Direct | $6,786 |
| Pain & Suffering | $147,268 | Pain & Suffering | $452 |
| Total Societal | $206,411 | Total Societal | $9,111 |

**TABLE 4 Average Cost by Cost Category and Accident Severity (1993 Dollars)**

| Cost Category | All Accidents | Injury/ Fatality | PDO |
|---|---|---|---|
| Total Accidents | 166 | 55 | 111 |
| **Transit Agency** | | | |
| Direct--Per Accident | | | |
| Property Damage | $3,915 | $2,657 | $4,538 |
| Claims Processing | $1,174 | $1,609 | $959 |
| Claims Payments | $320 | $800 | $83 |
| Claims Received* | ($4,311) | ($4,311) | ($4,311) |
| Legal & Court Expenses | $874 | $2,428 | $104 |
| Operator Overtime | $75 | $89 | $69 |
| Supplementary Service | $2 | $4 | $0 |
| Revenue Loss | $0 | $0 | $0 |
| Direct--Annual | | | |
| Catastrophic Insurance** | $0 | $0 | $0 |
| Indirect--Staff Time | | | |
| Accident Response, Reporting & Investigation | $191 | $215 | $179 |
| Replacement Operator Training | $58 | $176 | $0 |
| Misc. Staff Support | $269 | $284 | $262 |
| **Non-Agency** | | | |
| Emergency Response | $154 | $241 | $111 |
| Property Damage | $1,780 | $2,463 | $1,442 |
| Injury-Related Costs | | | |
| Medical, Lost Production, Legal, etc. | $16,368 | $48,161 | $614 |
| Pain & Suffering | $49,096 | $147,268 | $452 |
| Delay | | | |
| Rider Delay | $397 | $692 | $251 |
| Road Travel Delay | $128 | $123 | $130 |
| Transfer Payments | | | |
| Claims to TA* | $4,311 | $4,311 | $4,311 |
| Claims received from TA | ($320) | ($800) | ($83) |
| Total Societal Cost | $74,481 | $206,411 | $9,111 |

* Breakdown by injury vs. non-injury not available
** Cost not allocated on a per-accident basis

### Costs by Accident Type

Costs were also broken down by accident type (Table 5). Accidents were classified as "left-turn" (parallel-running vehicle turns left in front of the light rail vehicle (LRV)); "right-angle" (motor vehicle pulls out from a side street); "motor vehicle-other" (including mostly right-turn and anti-parallel, left-turn accidents), and "pedestrian/bicycle." Differences by agency cost category, including LRV damage, claims administration, claims payments, and legal expenses, were tested for significance using a Tukey studentized range test on the variable means. LRV damage and total itemized costs were significantly greater for right-angle accidents than for other types, and claims processing and legal expenses were significantly greater for pedestrian and bicycle accidents, due to the greater probability of injury in such accidents.

Costs for most other categories were defined based on injury severity, and differences in costs among accident types should be caused primarily by differences in the proportion of injuries sustained for each type. A significance test on total nonagency costs showed that costs were substantially higher for pedestrian and bicycle accidents, again due to the greater probability of injury. Differences among accident types involving motor vehicles were insignificant.

### Transferability of Results

Although the cost methodology developed is generally applicable, the usefulness of the actual numbers is limited because actual data were taken from only one transit property. When considering costs to other light rail transit properties, both geographical differences in wage rates, legal costs, and so on and differences in operating procedures, equipment, and system characteristics may lead to different costs among properties.

**TABLE 5 Cost by Accident Type (1993 dollars)**

| | 1 Left-Turn | 2 Right-Angle | 3 Other M. V. | 4 Ped/Bicycle | Total (Motor Veh.) | Total (All Accidents) | | |
|---|---|---|---|---|---|---|---|---|
| Total Number | 106 | 14 | 27 | 16 | 147 | 163 | | |
| Total W/Itemized Costs | 44 | 8 | 16 | 8 | 68 | 76 | | |
| Transit Agency -- Itemized | | | | | | | | |
| Property Damage | $3,017 | $16,995 | $1,094 | $408 | $4,472 | $3,915 | ** | 2 sdt 1,3,4[a] |
| Claims Processing | $1,016 | $1,259 | $987 | $2,191 | $1,038 | $1,174 | ** | 4 sdt 1,3 |
| Claims Payments | $210 | $0 | $0 | $2,016 | $136 | $320 | * | 4 sdt 1,2,3 |
| Legal & Court Expenses | $309 | $771 | $381 | $5,201 | $380 | $874 | ** | 4 sdt 1,3 |
| Total Itemized | $4,552 | $19,025 | $2,462 | $9,816 | $6,026 | $6,283 | ** | 2 sdt 1,3 |
| Total Agency[b] | -- | -- | -- | -- | -- | $2,568 | | |
| Non-Agency | | | | | | | | |
| Direct | $10,138 | $13,227 | $8,990 | $142,034 | $10,221 | $22,817 | ** | 4 sdt 1,2,3 |
| Pain & Suffering | $9,561 | $18,626 | $6,305 | $419,006 | $9,827 | $49,096 | ** | 4 sdt 1,2,3 |
| Total Societal | $21,558 | $40,677 | $16,065 | $565,839 | $22,370 | $74,481 | ** | 4 sdt 1,2,3 |

* = F-test for difference of means significant at 0.10 level
** = F-test for difference of means significant at 0.05 level
[a] read as "cost for type 2 (right-angle) accident is significantly different than for type 1, 3, or 4"
[b] Data unavailable by accident type. Total is less than "Total Itemized" due to claims received.

In general, highway accident costs tend to be slightly higher in California than for the nation as a whole; costs in Santa Clara County seem to be close to the statewide average. The statewide cost per claim in 1989 was $8,187 for bodily injury claims and $1,638 for property damage claims, compared with a nationwide average of $7,950 and $1,380, respectively (this average excludes states with no-fault insurance) (*12*). Pain and suffering, the greatest component of full societal cost, accounted for 27 percent of bodily injury awards in Santa Clara County, also roughly the statewide average. Although the propensity to award compensation for pain and suffering varies across regions, in general it is treated as a multiple of tangible costs and therefore increases proportionally as medical and other costs increase (*13*).

Overall, costs in Santa Clara County would be expected to be higher than average because of a number of factors. Compared with the national average, wage costs are 11 percent greater in California and 22 percent greater in Santa Clara County (*10*). Differences in the insured vehicle fleet, such as a greater proportion of small and urban-garaged vehicles, also lead to higher-than-average claims losses (*14*). Therefore, agency-related costs for the SCCTA should be higher than for a light rail system located in an area of average wage rates and accident claim costs. Note that most nonagency costs are already based on national averages.

Costs to the TA could also be affected by the proportion of uninsured motorists in the region, which would affect the agency's ability to recover costs from the motorist. In 1990 the proportion of uninsured motorists was estimated to be 20 to 25 percent for the state as a whole and 15 to 20 percent for the San Francisco Bay area (*15*). In urban areas where the proportion of uninsured motorists is higher, the TA would be expected to recover a smaller portion of its costs.

Another source of cost variation among properties would be differences in the proportions of accidents involving injuries, severe injuries, and deaths. System characteristics, particularly operating speed, are a primary determinant of accident severity. A logit severity model, based on data from the light rail systems in Santa Clara County and San Francisco, showed (as expected) that the probability of an accident resulting in injury increased significantly as the speed of the light rail vehicle increased. "Left turn" accidents were also found to have a higher probability of injury than other accident types, as did accidents that occurred during the morning and evening peak hours. (Left turn accidents were not significantly more severe for the Santa Clara data set alone.) Therefore, systems that operate at speeds upward of 40 or 45 mph through grade crossings would tend to have more frequent and severe injuries, and therefore higher accident costs, than the Santa Clara system, which operates at a maximum of 35 mph. Severity may also depend on other system characteristics, such as the configuration of grade crossings.

## POLICY IMPLICATIONS

### Significance of Severity

As demonstrated in the crash cost literature referenced in this paper, total societal costs are highly dependent on the severity of injuries in the accident. A fatality can have costs an order of magnitude greater than an incapacitating injury, which may in turn have costs an order of magnitude greater than a minor injury. In the case of a transit agency's costs, another dimension enters the picture: the probability that the agency will be found partially or fully responsible for an accident. Because of a widespread emphasis on safe sys-

tem design and operating procedures and the limited potential for driver error on a rail transit system, this probability seems quite low for the new light rail transit properties. It is certainly nonnegligible, however, and even a single severe or fatal accident can result in liability claims in the hundreds of thousands of dollars, 10 to 100 times the cost for a "typical" accident. The fact that the agency has "deep pockets" may add to the likelihood that it is sued in the event of a severe accident. Transit agencies realize this and set aside a substantial pool of money for self-insurance purposes in addition to carrying outside catastrophic insurance. Overall, the implication is that any measures a transit agency can take to protect itself from liability could have potentially significant payoffs.

Qualitative evidence also shows that other costs increase substantially in the case of a severe accident. Agency staff spend many hours responding to the accident and conducting follow-up investigations. A lengthy police report is filled out and, in the case of a fatality, the California Public Utilities Commission (PUC) sends an investigator to the scene of the crash. In extreme cases, an operator may need to take extended leave, resulting in personnel shortages or retraining costs. Finally, severe accidents can also have disproportionate effects on public perceptions of safety. Cheaney et al. (*1*) note that society displays a degree of tolerance for noncatastrophic accidents but may react strongly to accidents they perceive as "catastrophic."

Overall, reducing the severity of accidents may be even more productive than reducing the absolute number of accidents. For example, earlier detection of a potential accident could allow a greater reduction in LRV speed before impact, thereby reducing the probability of injury. The expected cost reduction could then be calculated. The results of the cost severity analysis may also be useful in narrowing the focus of countermeasure implementation. Although the total number of pedestrian and bicycle accidents was small (10 percent of all accidents), this category was particularly expensive; the probability of the accident resulting in injury was almost 60 percent, and all three fatalities were in this category. Therefore, efforts to reduce pedestrian accidents may have significantly larger payoffs on a per-accident basis than efforts to reduce vehicle accidents. Conversely, right-turn accidents on the downtown pedestrian mall, where operating speeds are low, rarely resulted in injury or substantial property damage and may deserve relatively little attention.

### Implications for Safety Investment

A transit agency acting in its own economic self-interest may be expected to invest in safety improvements up to the point where the costs of such improvements equal the benefits to the agency. However, investment beyond this point can still achieve significant societal benefits that do not accrue to the transit agency. This becomes more true as the severity of the accident increases because most injury-related costs (by far the largest component of injury accident costs) are not borne by the transit agency. For the data set analyzed the net cost paid by the transit agency was a very small proportion of the total accident cost.

Although the potential for liability is an incentive for transit agencies to make larger safety investments, it does not increase the monetary risk to the level of full societal costs, particularly because the light rail agency is rarely found at fault. The disparity between costs to the transit agency and costs to society suggests that safety investment decisions should be made at the societal level rather than at the level of one particular agency. Legislators, for example, may wish to fund safety investment programs independently of the transportation agency's operating budget. As mentioned earlier, the full societal cost of an accident represents the maximum rational public expenditure to prevent such an accident (*6*). In the likely event that safety programs are funded at a lower level, legislatures might conduct an explicit comparison of the cost-effectiveness of various safety improvement programs across both transportation and nontransportation areas. Such a comparison would help society achieve the maximum benefit (in terms of accidents, injuries, and deaths prevented) per dollar spent.

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