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SURFACE VEHICLE RECOMMENDED PRACTICE

Submitted for recognition as an American National Standard

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Recommended Practice for Optimizing Automobile Damageability

Foreword—The cost of vehicle ownership has developed into a major interest for vehicle manufacturers. During the 1970s, fuel economy was a primary concern in the vehicle buyer's purchasing decision and in vehicle design. More recently, however, the steadily rising cost of vehicle insurance has surpassed fuel costs, to become the second highest element of the cost of ownership (Figure 1). Insurance costs are also significant factors in the United Kingdom and Germany (Figures 2 and 3.)

In addition to medical and litigation costs, two major elements of these rising customer insurance costs are collision repair and comprehensive costs, of which theft is the major contributor (Figure 4).

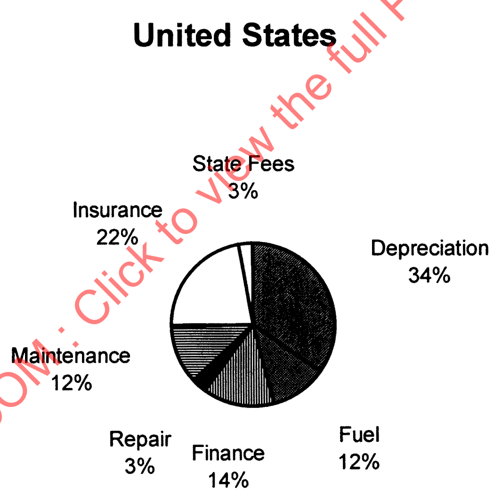

FIGURE 1—U.S. AVERAGE COST OF VEHICLE OWNERSHIP

United Kingdom

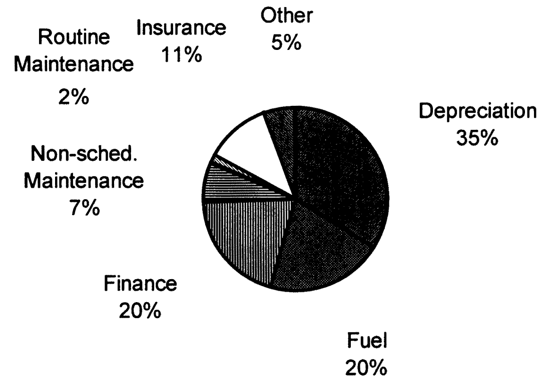

FIGURE 2—U.K. AVERAGE COST OF VEHICLE OWNERSHIP

Germany

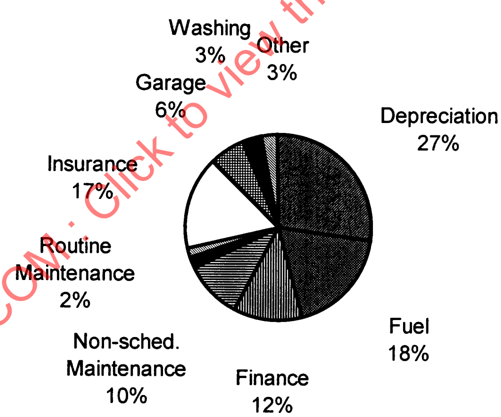

FIGURE 3—GERMAN AVERAGE COST OF VEHICLE OWNERSHIP

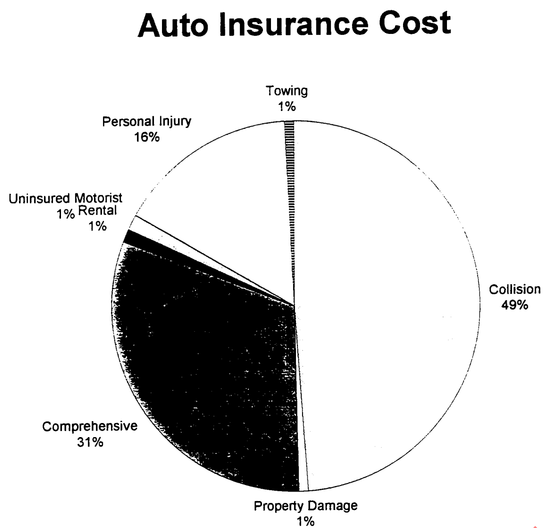

FIGURE 4—U.S. AUTO INSURANCE COST ELEMENTS

Automobile manufacturers, insurance companies, and the collision repair industry continue to work together to contain repair costs. Advanced vehicle platforms should be reviewed by insurance industry repair experts as early in the programs as possible, to insure that recommended actions can be considered for implementation.

Extensive data bases, such as those compiled by the Highway Loss Data Institute (HLDI) and Automatic Data Processing (ADP) are available, which provide vehicle and component damage statistics. Theft data statistics are available from National Insurance Crime Bureau (NICB) and HLDI. These statistics can be used to identify design-related vehicle features which have a significant effect on collision repair costs and to quantify the effects of design alternatives.

This SAE Recommended Practice will assist in the evaluation of future technological changes in vehicle design and manufacturing improvements, which may affect damageability and repairability. Such features as adhesive bonding of similar or dissimilar materials, repairability of composites, modular construction, tailored blanks, laser welding, aluminum spaceframes, etc., are becoming more important in future automotive designs. As an integral part of the design process, vehicle manufacturers should consider the effects of these new technologies and processes on damageability, repairability, and serviceability and develop the most efficient and practical field repair procedures possible. Design for damageability/insurability should facilitate practical, low cost, high quality collision repairs.

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1. Scope—This SAE Recommended Practice applies to all portions of the vehicle, but design efforts should focus on components and systems with the highest contribution to the overall average repair cost. (See 3.7.) The costs to be minimized include not only insurance premiums but also out-of-pocket costs incurred by the owner.

1.1 Purpose—The purpose of this document is to assist automobile manufacturers in optimizing their products' damageability, repairability, serviceability, and theft deterrence. This document should be considered concurrently with other parameters such as function, safety, cost, weight, manufacturability, recyclability, quality, styling, performance, marketability, etc. The main objective is to contain or reduce overall collision repair costs without compromising occupant safety, crashworthiness, and other design parameters.

2. *References*

2.1 Applicable Publications—The following publications form a part of this specification to the extent specified herein.

2.1.1 SAE PUBLICATIONS—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE J817—Engineering Design Serviceability Guidelines—Construction and Industrial Machinery
SAE J1142—Towability Design Criteria—Passenger Cars and Light Duty Trucks
SAE J1143—Towed Vehicle/Wrecker Attachment Test Procedure—Passenger Cars and Light Duty Trucks
SAE J1144—Towed Vehicle Drivetrain Test Procedure—Passenger Cars and Light Duty Trucks
SAE J1344—Marking of Plastic Parts
SAE J1828—Uniform Reference and Dimensional Guidelines for Unibody Vehicles
SAE J2069—Recovery Point Locations
SAE J2184—Service Garage Lifting Location
SAE J2235—Paint and Trim Code Location-1992
SAE J2376—New-Vehicle Collision Repair Information

2.2 Related Publications—The following publications are provided for information purposes only and are not a required part of this document.

2.2.1 SAE PUBLICATIONS—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE J1556—Stationary Glass Replacement
SAE J1573—Flexible Bumper Repair

2.2.2 "Vehicle Design Features for Optimum Low Speed Impact Performance," available from the Research Council for Automobile Repairs (RCAR), Autodata/Auto Konsult AB, Fryksdalsbacken 26, Box 2004, S-123 26 FARSTA (Stockholm), Sweden. Guidelines published in this document are similar to those included in SAE J1555.

2.2.3 "The British Insurance Industry's Criteria for Vehicle Security—Security System Evaluation, Passenger Cars," "New Vehicle Security Assessment, Passenger Cars," available from the Motor Insurance Repair Research Centre (THATCHAM), Colthrop Lane, Thatcham, Berkshire, England RG19 4 NP.

2.2.4 Canadian National Standard on Theft Deterrence Systems, CAN/UCC S-338.

2.2.5 DATA SOURCES—Both the insurance and collision repair industries can provide valuable insight into the most important damageability factors. Vast data bases are available in some countries, which provide detailed data on both collision and comprehensive losses. This data is the basis for the Design for Damageability/ Insurability-(DFI) process.

2.2.5.1 *Highway Loss Data Institute (HLDI)*—U.S. collision and theft data are available by individual make and model, including relative claim frequency, relative average loss payment per claim, and relative average loss payment per insured vehicle year. Special reports on specific collision and theft topics are also available.

2.2.5.2 *Automatic Data Processing (ADP)*—U.S. Collision claim data only, by individual make, model, model year, body style, and specific collision claim data at the component level, including involvement frequency, replace/repair ratios, part cost, labor time and cost, paint cost, average cost of repair or replacement, and most importantly expected cost (also known as cost contribution).

2.2.5.3 *Insurance Services Office (ISO, U.S.)*—Both collision and comprehensive (theft and glass) data available, including overall claim frequency, average repair cost, and loss per year (claim frequency x average repair cost).

2.2.5.4 *Individual Insurers*—Insurance ratings, low-speed crash test data, security rating assessments, etc.

2.2.5.5 *Repair Industry Associations*—U.S.: Automotive Service Association (ASA), Equipment and Tool Institute (ETI), Inter-Industry Conference on Auto Collision Repair (I-CAR), etc.

2.2.5.6 *Insurance Institute for Highway Safety (IIHS) (U.S.)*—Test results from 8 kph bumper impact tests.

2.2.5.7 *Vehicle Information Centre of Canada (VICC)*—Similar collision and theft claims data to that provided by HLDI. VICC also publishes ratings of individual vehicle models, based on expected actual loss costs. These ratings are used by Canadian insurers to set premiums.

2.2.5.8 *NRMA (formerly National Roads and Motorist Association, Australia)*—Test results from low speed offset crash tests and evaluation of vehicle anti-theft security.

3. Definitions

3.1 Average Loss Payment Per Claim (Average Vehicle Repair Cost)—The total of all loss payments (collision or comprehensive) made for claims for a group of vehicles, divided by the number of claims paid (as defined by HLDI).

3.2 Average Loss Payment Per Insured Vehicle Year—(Many insurers often refer to it as pure premium.) The product of claim frequency and average loss payment per claim (as defined by HLDI).

3.3 Collision Involvement Frequency—The number of claims for a group of vehicles, divided by the number of insured vehicle years (as defined by HLDI).

3.4 Component Involvement Frequency—The frequency that a component part or subassembly is involved in a collision, expressed as a percent of collisions (as defined by ADP).

3.5 Crash Parts—Parts most frequently involved in collisions, including bumpers, lamps, fenders, doors, decklids, etc.

3.6 Damageability—A continuous process (from vehicle concept through production and beyond) having the primary objective of reducing the customer cost of ownership by minimizing collision and comprehensive loss costs, which are paid for either by an insurance company or the vehicle owner. Damageability focuses primarily on real-world collision events and is an integral part of the crashworthiness design process. It is a subset of Designing for Insurability, which also encompasses comprehensive-type events such as theft, hail damage, glass breakage, etc.

3.7 Expected Cost/Cost Contribution—The amount which a specific component contributes to the overall average repair cost. It is the product of involvement Frequency and the Average Cost, where the Average Cost is the sum of Net Part Cost, Labor Cost, and Paint Cost (as defined by ADP). Expected cost generally applies to the prediction of future models; Cost Contribution applies to the actual performance of vehicles in production (as defined by ADP).

3.8 Repairability/Serviceability—A measure of the ease with which a damaged part, assembly, or system can be restored to pre-loss condition. (Reference SAE J817.)

3.9 Theft Deterrence—The degree to which a vehicle or portion thereof can resist unauthorized tampering during an attempted theft of the entire vehicle or portion thereof. The RCAR car security Design Guide and Evaluation System is one means of measuring theft deterrence. Also refer to the Canadian National Standard on Theft Deterrence Systems, CAN/UCC S-338.

4. General Design Considerations

4.1 How Insurance Rates are Determined—Fundamental to an understanding of how to design for insurability globally is the need to appreciate how insurance rates are established in the principal markets, as the strategies required must be tailored to meet the needs of the respective markets. It is also important to understand that insurance rate-setting processes are continuing to evolve, as a growing number of insurance companies and insurance organizations are declaring an interest in developing rating systems that take into account new vehicle-damageability, repairability, serviceability and theft-deterrence characteristics. Following is a summary of how rates are determined in some of these markets:

4.1.1 MAKE-MODEL RATING SYSTEM (UNITED STATES)—Rates are based on the Manufacturers Suggested Retail Price of the vehicles, and the historical collision and theft loss histories of the vehicle or its predecessors. The relationship between the loss ratio of a vehicle (claims paid out/premiums taken in) and the loss ratio of all vehicles covered by an insurance company determines whether discounts or surcharges are applied to the base insurance rating groups, which will respectively decrease or increase insurance premiums. Rates are updated annually.

4.1.2 LOW-SPEED CRASH AND THEFT ASSESSMENTS (UNITED KINGDOM, GERMANY, AUSTRALIA)

4.1.2.1 In the U.S., Six Factors Influence Insurance Ratings—The cost of replacement parts to reinstate the vehicle to its pre-crash test condition and times associated with the reinstatement of the vehicle following a 15 km/h, 40% offset right front and left rear crash test; vehicle performance (0 to 96 km/h) and top speed; new car price; availability and price of replacement body shells; and New Vehicle Security Assessment (NVSA) of the electronic and mechanical security systems. The results of the 15 km/h crash tests can contribute as much as 70% of the total points within the rating scheme. Once the damageability/ repairability or initial grouping has been determined by the crash test, this is then adjusted to reflect the results of the NVSA. The movement is generally confined to one group up or down, as applicable. Once the final grouping has been determined, it rarely changes.

4.1.2.2 In Germany, Three Factors Influence Insurance Ratings—The extent of damage from left front and rear 15 km/h, 40% offset crash tests, plus estimated costs from a simulated side collision, the cost of repairing the vehicle from these three impacts and the expected accident frequency of the vehicle. A security assessment is not part of the initial rate setting process, but historical collision and theft claims history influences the annual updates to insurance rates.

4.1.2.3 In Australia, Six Factors Influence Insurance Ratings—Vehicle value, the cost of spare parts for the vehicles, repair costs from a right front 15 km/h, 40% offset impact, amount of time required to repair the vehicle, the degree to which the vehicle is prone to theft, using an NRMA/RCAR 100-point rating system, similar to that used in the U.K., and the type of driver utilizing the vehicle.

4.1.2.4 In Canada, a Statistical Model (CLEAR) is used to Estimate the Initial Rating, Using Regression Analysis of a Number of Key Vehicle Parameters (wheelbase, body style, weight to horsepower ratio, price, etc.) that affect claim performance.—Frequency and severity (average size) of claims are evaluated separately for Collision/Property Damage, Comprehensive and Accident Benefits coverage, and separately for cars and trucks. The New Vehicle Assessment Program (NVAP) utilizes an assessment of 15 km/h, 40% offset front and rear crash test results, (procedures recommended by RCAR), and a security evaluation (presence of passive anti-theft system and alarm), to adjust the results of the initial CLEAR statistical modeling. Each year after vehicle introduction, rates are adjusted to reflect actual claims performance.

4.1.3 Other countries may use vehicle weight, horsepower or other factors to determine insurance rates.

4.1.4 Auto manufacturers also need to be sensitive to cost of collision or theft losses in developing countries, where insurance industries may not be well developed, and the primary costs are borne by the vehicle owners.

4.2 Design for Damageability/Insurability Objectives:

4.2.1 Minimize collision and non-theft comprehensive damage frequency and repair cost

4.2.2 Minimize total and partial vehicle thefts

4.2.3 Increase ease of collision repair

4.2.4 Increase the potential for quality collision repair

4.2.5 Minimize the frequency and repair cost of minor damage, often paid by the owner

4.2.6 Obtain the lowest possible owner insurance cost at new model introduction

4.2.7 Obtain a marketing advantage based on lowest cost of ownership through “lowest possible insurance costs”

4.3 Design for Damageability/Insurability Process

4.3.1 Compare real-world collision and theft performance of current and competitive models.

4.3.2 Establish targets and objectives for the new model, based upon the field performance evaluation and marketing objectives, and develop plans to achieve the objectives.

4.3.3 Identify issues and opportunities from new design and manufacturing technologies and experiences from past models.

4.3.4 Conduct reviews of new vehicle platform designs with insurance industry experts.

4.3.5 Quantify effects of design alternatives.

4.3.6 Monitor current field performance (insurance and repair industry).

4.3.7 Consider recommendations from the insurance and repair industries on design alternatives.

4.3.8 Evaluate computer simulations and full-scale and component tests, which are conducted during the course of vehicle development, to measure damage extent and repair costs. It is recommended that a well-defined series of tests be developed, that are recognized by the industry as a whole.

4.3.9 Provide new product information to insurance and repair industries, including collision-repair cost analysis, crash parts pricing, low-speed crash and security assessments, and specific repair procedures, as applicable.

4.3.10 Where applicable, work with insurance research organizations who are members of RCAR, national insurance industry bodies and individual insurers prior to new model introduction, to obtain the most appropriate rating for the new model at launch.

4.3.11 Monitor field performance of new model.

4.3.12 Evaluate collision-repair cost analysis and, as necessary, adjust assumptions, methodology, and process for future analysis.

4.4 Design for Damageability/Insurability Priorities

4.4.1 Collision repair costs can be minimized by focusing the design effort on areas of the vehicle having the highest expected cost/cost contribution. Figure 5 illustrates the typical systems and their relative contributions to the overall collision repair costs. Figure 6 illustrates the average distribution of collision impact points experienced by passenger cars and light trucks in the U.S. Figure 7 illustrates that over 40% of all U.S. collision claims are for amounts less than $1000. Yet, the HLDI average loss payment has ranged between $2500 and $3000 per claim for the last 5 to 7 years.

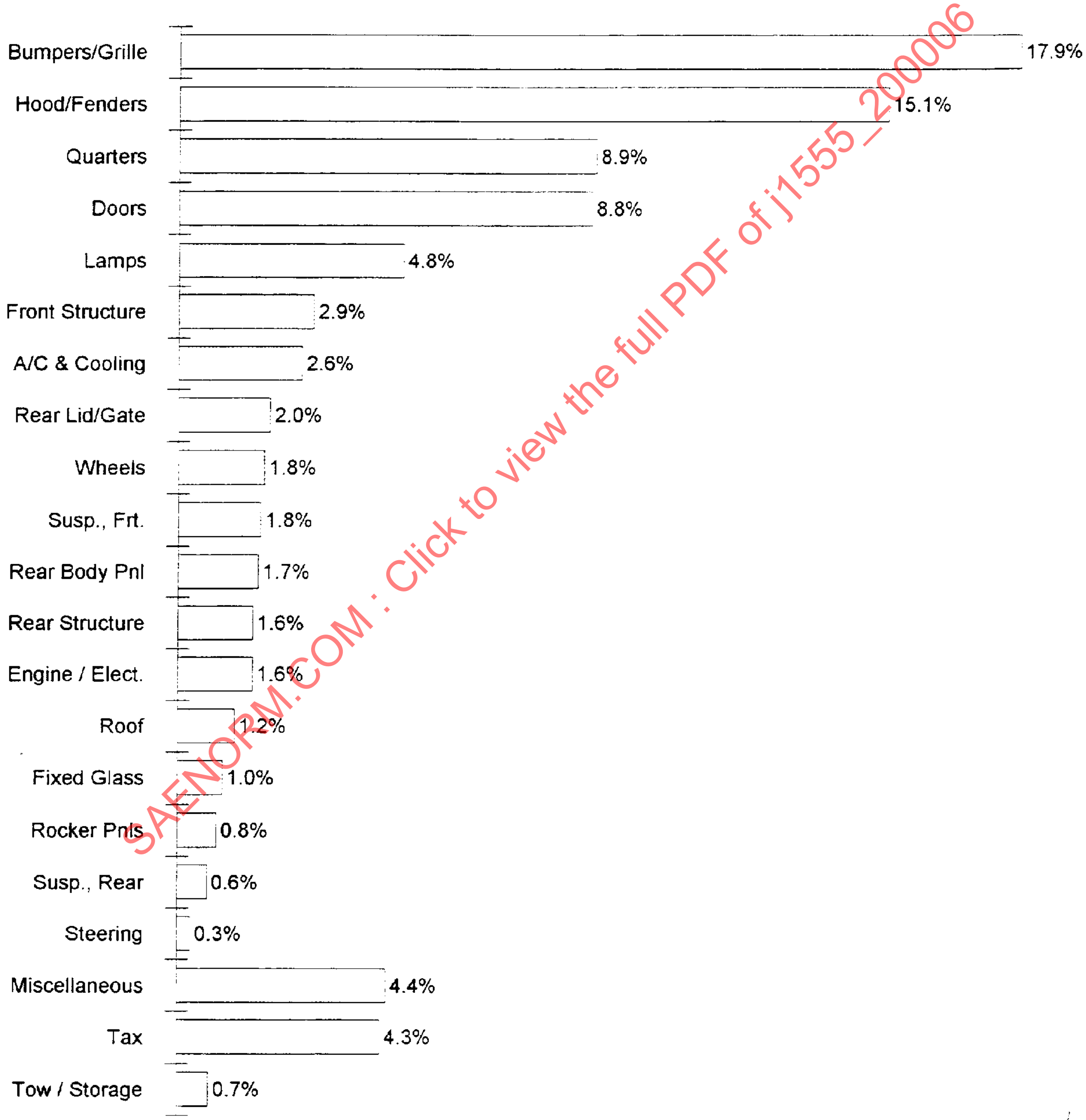


FIGURE 5—CONTRIBUTION TO AVERAGE REPAIR COST PASSENGER CARS AND LIGHT TRUCKS

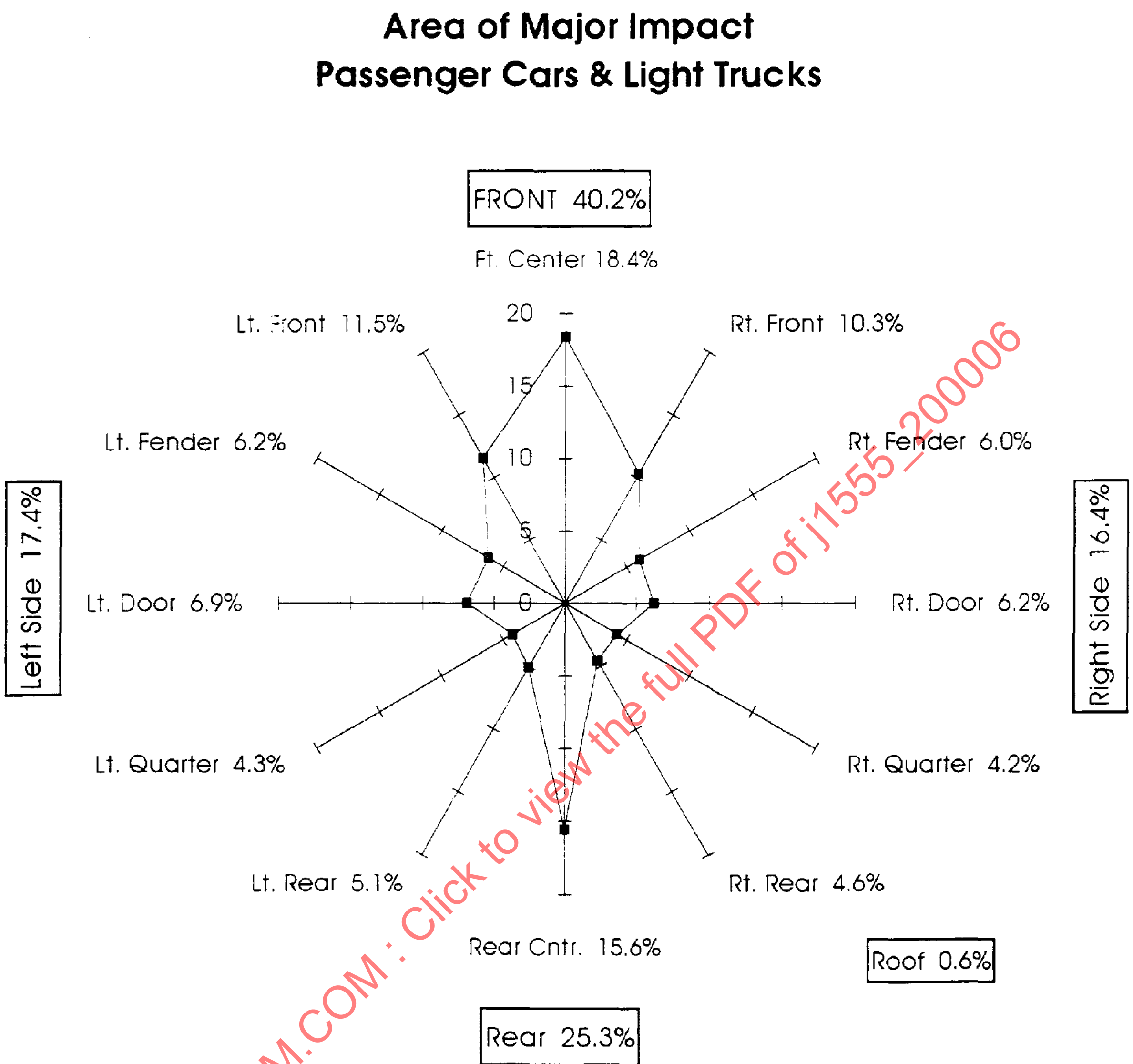


FIGURE 6—AVERAGE DISTRIBUTION OF COLLISION IMPACT POINTS

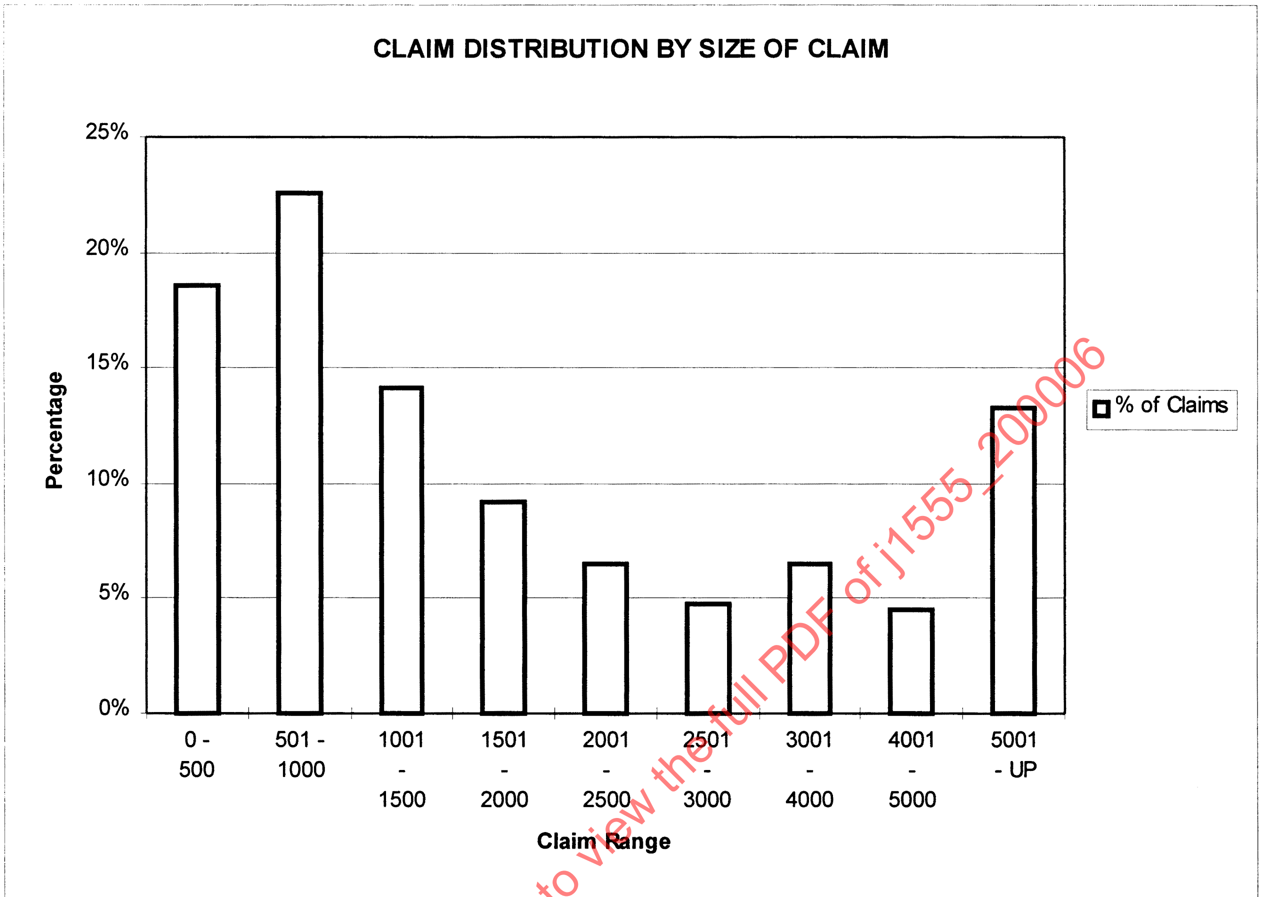


FIGURE 7—COLLISION CLAIMS BY SIZE OF CLAIM 1989 MODELS

4.4.2 While structural damage has a relatively low expected cost, the ability to restore a vehicle's passive restraint performance to its pre-accident condition may be severely limited, due to the position and overlap of structural members and reinforcements. Partial replacement procedures should be considered in early design reviews.

4.4.3 Design effort in the U.S. should be prioritized based on component expected cost/cost contribution, rather than any one of its individual variables: involvement frequency, part price, or average cost to repair or replace.

4.4.4 Design effort in those countries utilizing 15 km/h crash tests should be prioritized to minimize the potential for damage to components beyond the energy-absorbing elements of bumper systems (a bumper system being defined as including bumper covers or fascias, beams, energy absorbers, brackets, reinforcements and exterior ornamentation.)

4.4.5 Comprehensive costs can be minimized by focusing on the development of effective theft deterrence systems and glass replacement procedures.

4.4.6 Insurance costs should be minimized to gain a potential marketing advantage for a specific model and market. Loss control (cost and frequency) should be considered at the earliest phases of the design process. This should be considered along with all other vehicle design factors such as function, occupant protection, mass, styling, cost, durability, etc. To best meet these objectives of collision and comprehensive loss control, it is necessary to understand the real-world factors which affect these costs, and how these factors can be affected by vehicle design.

4.5 Factors Affecting Damageability/Insurability

4.5.1 COLLISION FACTORS

4.5.1.1 Claim frequency is primarily a DRIVER factor (demographics, lifestyle, etc.), but vehicle design (including bumper systems) can also influence frequency. The experience of the VICC is that collision frequency varies by 6:1 after removing the "driver" factor. Vehicle design significantly impacts collision frequency (e.g., ABS brakes and lighting systems, etc.)

4.5.1.2 Average collision repair cost is primarily a VEHICLE DESIGN factor, influenced by:

a. Ease of repair, removal, or replacement (labor time)
b. Part price/cost
c. Part location and attachment method
d. Proximity or clearance to adjacent components (i.e., underhood)
e. Damage resistance of components, and how crash energy is dissipated into the vehicle
f. Refinish costs

4.5.2 COMPREHENSIVE FACTORS

4.5.2.1 Theft Losses, consisting of:

1. Complete vehicle thefts (unrecovered and recovered stripped/damaged)
2. Component theft (styled wheels, wheel covers, removable glass tops, radio/tape players, batteries, composite lamps, computer control modules, "air bags," seats, etc.)

4.5.2.2 Glass Breakage (primarily stone damage to windshields)

4.5.2.3 Other miscellaneous (flood, wind, hail, etc.)

4.5.2.4 Fire

5. Clearance

5.1 Clearance between adjacent components should be maximized, where feasible, to minimize frequency of involvement in a collision.

6. Energy-Absorbing Elements/Bumper Systems—A bumper system being defined as including bumper covers or fascias, beams, energy absorbers, brackets, reinforcements and exterior ornamentation.

6.1 Review of Figures 5, 6, and 7 suggests that design improvements that reduce damage to bumpers and adjacent components during relatively low-speed collisions can significantly reduce collision claim frequencies, and to a lesser extent, reduce average loss payments.

6.2 The bumper system should be designed to minimize the expected cost/cost contribution of not only the bumper system but also the exterior panels, lamps, body or frame structure, and other adjacent components. In other words, consider the overall damageability of the vehicle when seeking to improve bumper performance. The goal should be optimum energy management and minimum repair costs.

6.3 To minimize labor time, the entire bumper system should be removable as an assembly, where feasible, with minimal fasteners and without removing other components.

6.4 The fasteners used to secure the bumper system should be accessible after moderate damage to the vehicle.

6.5 Bumper system attachment to the body structure should be with removable fasteners rather than welding. During an impact, fasteners connecting bar covers with body panels should enable displacement of the cover without damaging the body panels.

6.6 Plastic bumper covers and fascias, designed with features such as molded-in nameplates, textures, or narrow grooves, should be avoided, as they are difficult to repair and will increase cost.

6.7 Plastic bumper covers and fascias with molded-in colors should be avoided, unless there is a feasible, cost-effective procedure available to paint damaged parts.

6.8 Multi-piece assemblies are generally preferable to integrated designs (one piece fascia/beam systems), to allow repair or replacement of only the damaged components. Service parts pricing, labor times, and fastener accessibility should be considered to determine which approach offers the lowest expected cost.

6.9 Multi-piece, separately serviceable rub strips are preferred to integral designs.

6.10 Chrome-plated plastic ornamentation should not be located within the bumper impact zones.

6.11 Ends of bumper beams should extend far enough outboard to protect front and rear lamps, and any electromechanical items located behind the beam during corner collisions.

6.12 Painted bumper covers should be preferred over structural and not-painted bumper covers, because of repairability.

7. Exterior Panels and Components

7.1 Exterior panels and components should be removable using common procedures and tools. If other than common fasteners are used, the vehicle manufacturer should provide information on removal and replacement procedures to the repair industry. Regardless of attachment methods, the equipment and methods used to remove and replace body components must be practical in a body shop environment.

7.2 The material used to make exterior panels should be repairable using cost-effective methods which are practical in a body shop environment, and are consistent with individual manufacturing design criteria.

7.3 Panel designs should avoid compound curves, sharp radii, and stamped ribs, as such features are difficult and expensive to repair. However, these features may also serve other purposes, such as locating moldings, or creating additional strain into panels, which improves dent resistance.

7.4 Cosmetic damage to visible exterior panels should be repairable without removing panels from the vehicle.

7.5 Fenders should be designed to avoid or minimize the transmission of damage to the windshield.

7.6 Where feasible, all exterior panels that are crucial to the achievement of equal panel clearances should be mechanically attached, to facilitate field adjustment.

7.7 Doors should be mounted with bolt-on hinges (both sides of the hinge). Adjustability should be provided in the hinge mounting location and door striker. Where feasible, doors should be designed to be removed and reinstalled without disturbing the original adjustment (i.e., with removable hinge pins). Electrical wiring running into the door should be easily disconnected to facilitate door removal.

7.8 Damage-resistant, protective bodyside moldings should be located at the widest point on the body surface and be capable of absorbing low speed impacts without transferring energy to the body surface.

7.9 Bodyside molding and cladding with molded-in colors should be avoided, unless there is a feasible, cost-effective procedure available to paint damaged parts.

7.10 Access should be provided in the inner fender, door, and quarter-panel structures, to permit repair of minor damage to the exterior panel skins.

7.11 If hood and decklid ornaments cannot be avoided, they should be designed to minimize damage to mounting surfaces, if vandalized.

7.12 Grille and grille surround should be separate from the hood, or designed to minimize transmission of damage to the hood.

7.13 Bonded components should be serviceable at factory seams to allow rebonding of a new or recycled component. De-bonding procedures should be practical for a body shop environment and not require expensive, unique tools. Heat-sensitive adhesives should be field-repairable.

7.14 Exterior door handles, lock cylinders, etc., should be removable without extensive disassembly of the door, to minimize the time and cost of refinishing the door outer panel.

7.15 "Swing-away" outside mirrors will reduce the potential for damage to the doors if the vehicle hits a garage door opening, automatic teller machine, etc. Attachment should fail first.

7.16 Hood, decklid, and liftgate hinges should be bolted to the body, rather than welded, to reduce labor time.

7.17 Dent-resistant materials (bake-hardenable steel, plastics, etc.) should be considered to reduce overall expected costs.

7.18 Impact protectors in doors should be bolted, not welded.

8. Lamps

8.1 **Head Lamps—**Generally, the front grille and headlamp bezels (doors) should be separate parts to limit damage. However, in some instances, a single component may provide a lower expected cost/cost contribution than the sum of the individual components, generally because of its significantly lower part price. Bulbs should be serviceable without component R&R or special tools.

8.2 Separate headlamps, turn signals, and front side marker lamps may reduce replacement part costs versus integrated designs, but service part pricing, labor times, and fastener accessibility should be considered to determine which approach offers the lowest expected cost.

8.3 The more expensive the headlamp assembly, the more protection should be provided by the bumper system.

8.4 The more a front or rear lighting assembly wraps around the side of the vehicle, the more protection should be provided by the bumper system.

8.5 Separate taillamps, lenses, and rear decklid appliques are preferable to cross-car designs, to reduce service part costs. It is possible to design a cross-car theme with individual lamps and lenses.

8.6 Front and rear lamps should not be packaged in the bumper beams, because they have a greater probability of becoming damaged.

8.7 Headlamp assemblies should use sacrificial mounting tabs that can be serviced, rather than integrally mounted tabs, to avoid costly lamp replacement.

8.8 Hidden headlamps should be avoided (or designed with service in mind), because they result in higher labor and replacement part costs.

9. Engine Compartment Packaging

9.1 High-cost components should be located in low-involvement areas (generally rearward toward the cowl or front of dash), and inward (generally toward the longitudinal centerline of the vehicle). Figure 8 compares good and poor engine compartment designs.

9.2 Sacrificial brackets should be used for accessory drive, engine and transmission mounts, and mounting hardware to restrict damage to components and prevent damage to engine or transmission castings.

9.3 Mounting systems for high cost components should be designed to flex and allow some energy absorption prior to the component sustaining damage.

9.4 Avoid packaging any rigid components (e.g., cooling fans) in front of the radiator core or air conditioner condenser.

9.5 Accessible bulkhead connections for electrical and vacuum systems should be provided to reduce the number of connections involved during powertrain removal.

9.6 Sufficient clearance should be provided around components for removal and installation during collision repair procedures, without extensive removal of undamaged components.

9.7 Battery cables should be shielded to avoid defeat of anti-theft systems (Reference 16.2).

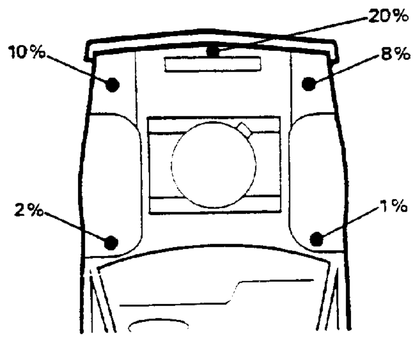
9.8 Components located fore and aft of the radiator core support should be designed and located in a manner which minimizes both impact vulnerability and energy transfer potential. Sharp edges and protruding bolts which may puncture the air conditioning condenser, radiator, battery oil cooler, etc., should be avoided.

9.9 The routing of air conditioning lines should allow replacement of the radiator core support side baffles without disconnecting the lines. This avoids the associated cost of recovering, recycling, and recharging of the system. Condenser/radiator modules should allow servicing of one system without opening the other system.

9.10 Avoid routing engine compartment wiring across the front of the vehicle. If this cannot be avoided, route along the top of the radiator support, not at the level of the bumper beam. Wiring repair procedures should be available, to eliminate any unnecessary replacement of major (costly) wiring harnesses.

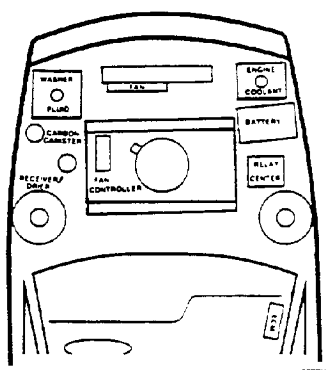
9.11 Routing fluid lines and wires inside enclosed body features should be avoided.

9.12 Where feasible, electrical components, such as connectors, fuse or relay panels, and protective covers, should have provisions for field replacement which does not necessitate the replacement of major (costly) wiring harnesses.



Locate High Cost Components in
Low Involvement Areas

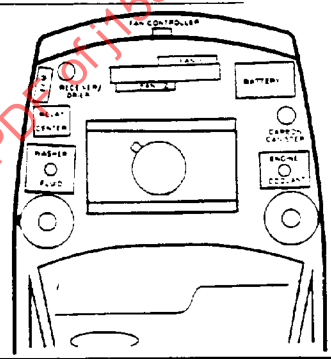
GOOD DESIGN PRACTICE



	Inv. %	X Cost	= Cost Contb.
Washer Bottle	12.0%	$ 6	$ 0.72
Cooling Fan	10.0	100	10.00
Coolant Rec.Bottle	10.0	8	0.80
Battery	8.0	75	6.00
Carbon Canister	7.0	59	4.13
Receiver/Drier	5.0	90	4.50
Relay Center	2.0	150	3.00
Fan Controller	1.0	140	1.40
ECM	0.0	110	0.00

Total Cost Contribution for Design $ 30.55

POOR DESIGN PRACTICE



	Inv. %	X Cost	= Cost Contb.
Fan Controller	28.0%	$140	$39.20
Fan 1 (Auxiliary)	15.0	100	15.00
ECM	12.0	110	13.20
Fan 2	10.0	100	10.00
Battery	10.0	75	7.50
Carbon Canister	10.0	59	5.90
Receiver/Drier	10.0	90	9.00
Relay Center	9.0	150	13.50
Washer Bottle	6.0	6	0.36
Coolant Rec.Bottle	4.0	8	0.32

Total Cost Contribution for Design $ 113.98

FIGURE 8—ENGINE COMPARTMENT PACKAGING FOR COLLISION PROTECTION

9.13 The battery should be located in a low-frequency area to prevent corrosion damage to sheet metal and other high-cost components. A battery's potential to spew or leak acid can increase its Cost Contribution well beyond its replacement cost.