Engineering Analysis Report

Regarding

EA06-020: Toyota Sienna Power Liftgates

U.S. Department of Transportation
National Highway Traffic Safety Administration
Office of Enforcement
Office of Defects Investigation

June 2008

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I. OVERVIEW

A. Background

On August 2, 2006, The National Highway Traffic Safety Administration's (NHTSA) Office of Defects Investigation (ODI) opened a Preliminary Evaluation (PE06-029) to investigate unexpected liftgate closings on model year (MY) 2004-2005 Toyota Sienna vehicles. At that time, the agency had received eight complaints alleging that the liftgate had unexpectedly closed while open. Three of the complaints alleged four injury incidents resulting from unexpected contact of the liftgate to the person's head or body. ODI analyzed field and technical information from Toyota during the PE06-029 investigation and found that the rate of injury was significantly higher for those Sienna vehicles equipped with the power liftgate option. Based on that information, ODI upgraded the investigation to an Engineering Analysis (EA06-020) and refined the focus to investigate only the Sienna vehicles with the power liftgate.

ODI opened the EA06-020 investigation on December 1, 2006. ODI was now aware of 69 complaints with 14 alleged injuries based on the information collected during the PE investigation. The scope of the investigation was MY 2004 and 2005 Toyota Sienna vehicles equipped with optional power liftgates, however, during the EA investigation, ODI also collected and reviewed information on MY 2006 and 2007 Sienna vehicles based on similarity in design.

B. Subject Vehicle Population

The vehicles subject to the alleged defect are the MY 2004 through 2006 Toyota Sienna vehicles (herein referred to as subject vehicles) equipped with the optional power liftgate. Table 1 shows the subject vehicle population by model year.

Table 1. Subject Toyota Sienna Population

Model Year	2004	2005	2006	Total
Population	82,870	59,548	53,662	196,080

C. Alleged Defect

The alleged defect is unexpected closing of the power liftgate.

ODI found that liftgate support struts in the subject vehicles are susceptible to failing in significant numbers. Toyota reports the struts are not meeting their design life expectations. When the struts fail and cannot support the liftgate, a liftgate open to the fully-open position can drop and automatically close under power (i.e., close by the power liftgate motor). The user is unaware this may happen and reasonably anticipates

that the liftgate will remain in the fully-open position. Persons below the liftgate have been hit by the liftgate and injured.

ODI believes that the failure of the original equipment liftgate struts on the subject vehicles is the result of a defect in design and these struts will continue to fail in a similar and significant fashion as has been demonstrated by the facts gathered during the investigation. These struts exhibit a high early-life failure rate and an increasing failure trend. Failing struts pose a risk of injury to persons standing under the liftgate or accessing the rear cargo area in these vehicles.

D. ODI's Recall Request and Toyota's Response

On January 25, 2008, ODI requested that Toyota initiate a safety recall, in accordance with 49 U.S.C. § 30118-30120, to notify all owners, purchasers, and dealers to provide a free remedy for each of the subject vehicles. In its February 25, 2008 letter, Toyota stated that a safety recall is not warranted. Instead, Toyota cited its extended warranty program initiated in January 2008, to cover the cost of strut replacement within the first six years of ownership, regardless of mileage, on all MY 2004-2006 Sienna vehicles equipped with power and manual liftgates.

E. Toyota's Safety Recall

ODI informed Toyota that it does not believe the extended warranty program is an appropriate response to the safety risks presented by the failure of the struts. A warranty program does not correct the problem before it presents a risk to the operator. A safety recall will ensure that vehicle owners have notice of those safety risks and an opportunity to obtain a remedy before the struts fail, preventing a significant risk of injury. In its May 30, 2008 letter, Toyota stated that although it has not determined the alleged defect to be a safety-related defect, it will conduct a safety recall to replace the liftgate struts in each of the subject vehicles with newly-designed struts.

II. DESCRIPTION OF TOYOTA SIENNA POWER LIFTGATE SYSTEM

A. The Power Liftgate System

Mechanical Components

The liftgate is the large door on the rear of the vehicle. The liftgate is hinged on the top. The frame is steel and includes a glass backlight; the complete liftgate door weighs 71 pounds. The interior of the liftgate is covered with a plastic panel. There is a pull handle on the interior of the door that assists the operator in manually closing the door. The liftgate system is supported by two gas-filled struts, one on each side, that hold the liftgate up when fully-open (see photograph on next page). The liftgate is held closed by a mechanical latch located at the bottom center of the liftgate.

The operator may open and close the liftgate manually or electrically.

Electrically Powered Components

The main electrical components for the power operation of the liftgate are: the power liftgate latch, the control module, the electric motor, and the switch devices for turning the system on/off and for power actuation (power-opening and power-closing).

Manual Operation of the Liftgate

The liftgate can be opened and closed manually when the *Power Back Door Main Switch* is in the "off" position. This switch is located on the instrument panel to the lower left of the steering column.

Electrically Powered Operation of the Liftgate

To energize the power liftgate system, the *Power Back Door Main Switch* must be turned on. This is a master switch that provides electrical power for operation of the power liftgate system. This switch must be in the "on" position for the operator to either open or close the liftgate under power.

Power actuation can be started by depressing one of the appropriate buttons either on the *Remote Control Transmitter* (key fob) or on the *Power Back Door Satellite Switch* located on the vehicle's overhead console. When the operator depresses the button, the control module provides power to automatically unlatch the door and to the electric lift motor to open the liftgate to the fully-open position and stop. The electric motor is connected to a drive arm located on the left side of the liftgate. When the liftgate reaches the fully-open position, the motor stops and disengages from the drive mechanism. The door is held open by the combined lifting force of the two struts.

To power-close the liftgate, the operator may manually pull down on the handle strap attached to the liftgate, or press the button on the *Remote Control Transmitter* or on the *Power Back Door Satellite Switch*. Any of these actions will initiate power-closing.

Safety Features

When the liftgate begins to power-close or power-open, two audible warning beeps are emitted and the hazard lights flash twice.

Toyota refers to the liftgate safety features as "jam protection" and "pinch protection." The "jam protection" feature automatically reverses the direction of the liftgate motion

when the power liftgate control module detects an obstruction in the path of the moving door. The control module detects an obstruction by monitoring the change in speed of the drive motor. When the motor speed drops, the module senses this as an obstruction in the path of the moving door, then the module reverses the direction of the motor rotation and the door reverses its direction. The "pinch protection" feature uses touch sensors (pressure or contact sensors) along the side edges of the liftgate. If the touch sensors detect an object caught on the side of the liftgate, an electrical signal is sent to the control module and the module will reverse the direction of motor rotation.

B. The Liftgate Strut Design and Failure Modes

The liftgate strut is a supporting device for the liftgate. The strut is a high-pressure gas cylinder with a piston rod, a piston, and other internal components such as piston guide and seal for keeping the gas pressure contained within the cylinder. When the liftgate is closed, the struts are in retracted or gas-compressed condition. When the liftgate begins to open, the struts produce force during extension and provide lifting force for assist in opening the liftgate. When the liftgate is in the fully-open position, the struts provide the force necessary to maintain the liftgate in the open position.

This investigation revealed that the liftgate struts in a significant number of subject vehicles have leaked the internal high pressure gas. Toyota has identified the failure mode. In its April 6, 2007 letter to ODI, Toyota states, "Over time, seal damage may occur where the strut rod enters the strut body, resulting in leakage of the high pressure gas. The seal may be damaged by scratches on the strut rod, which may occur as a result of elastic deformation of the strut rod during operation (the strut rod may deform and contact the strut guide in the strut body), or some type of contamination (dirt, dust, etc.) which may enter the seal."

C. Toyota's Modifications of Liftgate Struts

To address the liftgate strut failures, Toyota implemented four changes to the design of the liftgate strut. The results from the first two changes (December 2003 and September 2005) were mixed and the failure rate of the liftgate struts remained high.

Toyota implemented the final two liftgate strut design changes into all MY 2007 Sienna vehicles in October and December 2006. These changes made the new struts more robust and appear to have improved the durability of the struts.

D. Power Liftgate Operation with Failed Struts

Struts that contain less than a full charge of gas produce a reduced lifting force. Depending on available strut lifting force, a fully-opened liftgate may close either without or with motor assist. After the liftgate reaches the fully-open position, the motor disengages. If the struts cannot support the liftgate, it will drop unassisted under the force of gravity. If the speed of the drop is sufficient to be detected by the control module, the motor will engage and assist in controlling the speed at which the liftgate

drops. If the drop speed is not sufficient to engage the motor, then the liftgate will drop slowly and then more quickly as it nears the closed position (the motor will not engage when the door is more than 1/2 closed regardless of the speed of closing). With significantly reduced strut lifting force, the liftgate in the fully-open position will quickly drop about ten inches then the motor will automatically engage to control the speed of closing. When the motor automatically engages, two warning beeps are emitted and the hazard lights flash twice the same as when the liftgate begins to power-close during normal operation.

III. TESTING

A. NHTSA's Testing

The Vehicle Research and Test Center (VRTC) has conducted extensive testing to understand the operation of the power liftgate in the subject Sienna vehicles under various strut and ambient conditions.

VRTC obtained three pairs of failed struts (struts B/C; D/E; and F/G) that were removed from subject vehicles, a new strut (strut A) purchased from Toyota dealer, and a pair (struts H/I) from an exemplar subject vehicle. The following is a summary of the test protocols and results.

- *Measure the minimum force required to support the liftgate in the fully-open position and other positions between the fully-open and closed positions*. Table 2 shows the minimum force required to support the liftgate in the fully-open position is about 200 pounds and it is slightly higher than 200 pounds in the lower liftgate positions. The height of a fully-opened liftgate is 72 inches when fully-functional struts are used.[1]

Table 2. Force Required to Support Liftgate

Liftgate Position (degrees down from fully-open)	Distance from Striker to Floor (in)	Force on Strut (lb)
0	72	200
15	63	206
30	51	210
45	40	218

[1] When the liftgate struts have leaked sufficient gas, the liftgate will open up to about 70 inches from the floor, then drop about ten inches and automatically close.

- *Measure the strut force at full compression at 35°F, 72°F, and 110° F.* Table 3a shows the results of this test.

Table 3a. Force Exerted by Each Strut at Full Compression

Strut ID	Strut Force (lb)		
	35° F	72° F	110° F
A	140	147	160
B	107	113	119
C	84	84	89
D	139	147	157
E	Total Failure		
F	130	133	147
G	47	50	55
H	125	133	141
I	134	129	150

Notes: (1) Strut A was a new strut. (2) Struts pairs B/C, D/E, and F/G were removed from complaint vehicles. (3) Struts pair H/I was removed from test vehicle.

- *Measure the strut force at full extension at 35°F, 72°F, and 110° F.* Table 3b shows the results of this test.

Table 3b. Force Exerted by Each Strut at Full Extension

Strut ID	Strut Force (lb)		
	35° F	72° F	110° F
A	113	119	129
B	85	88	94
C	68	68	74
D	117	121	128
E	Total Failure		
F	94	105	115
G	29	37	41
H	100	108	114
I	100	106	117

- *Install various samples of struts and record the result on power liftgate operation. Record the action of the liftgate after it reaches its apex: A) remains open; B) drops slowly; or C) drops suddenly followed by automatic motor engagement. Perform the test at room temperature and note the total available lifting force at both full compression and full extension of the strut(s).* Table 4 shows a transition from the liftgate remaining open to the liftgate closing under the force of gravity occurred between strut pair C/D (189 lbs at full extension) and pair C/H (176 lbs). The transition from the liftgate dropping slowly without engaging the motor to dropping suddenly and engaging the motor occurred between strut pair B/C (156 lbs at full extension) and pair G/H (145 lbs).

Table 4. Forces Exerted by Pair of Failed Struts

Strut ID	Force at Full Compression (lb)	Force at Full Extension (lb)	Category of Liftgate Action
D/H	280	229	A
D/F	280	226	A
D/I	276	227	A
F/H	266	213	A
H/I	262	214	A
F/I	262	211	A
B/D	260	209	A
B/H	246	196	A
B/F	246	193	A
B/I	242	194	A
C/D	231	189	A
C/H	217	176	B
C/F	217	173	B
C/I	213	174	B
D/G	197	158	B
B/C	197	156	B
G/H	183	145	C
F/G	183	142	C
G/I	179	143	C
B/G	163	125	C
D	147	121	C
A	147	119	C
C/G	134	105	C
H	133	108	C
F	133	105	C
I	129	106	C
B	113	88	C
C	84	68	C
G	50	37	C

Category	Description
A	Liftgate did not drop.
B	Liftgate dropped slowly without engaging motor.
C	Liftgate dropped and engaged motor.

Note: For Category C, liftgate can drop down up to 15 degrees or 10 inches from fully-open position before motor engages.

- *Install various samples of struts and record the liftgate drop rate and contact force exerted during the initial ten-inch drop of the liftgate and during power-closing at different positions between the fully-open and closed positions. Perform the test at room temperature and after a cold soak of struts.* Table 5 shows the results of this test.

Table 5. Drop Rate and Contact Force Exerted by Closing Liftgate

Strut ID	Liftgate Position (deg. down from fully-open)	72° F		35° F	
		Drop Rate (deg/s)	Contact Force (lb)	Drop Rate (deg/s)	Contact Force (lb)
B/C	10	0.1	0.7	22	145
D		33	214	44	289
F/G		9	54	23	173
C/G		34	240	49	279
B/C	30	10	28	11	58
D		12	68	13	66
F/G		13	58	12	59
C/G		14	67	13	69
B/C	50	0.2	N/C	14	52
D		15	60	14	62
F/G		14	50	14	50
C/G		14	61	14	63
B/C	70	0.2	N/C	12	29
D		8	34	12	35
F/G		10	28	7	29
C/G		11	36	9	35

N/C = No Contact
Note: Strut D was tested alone because strut E was totally failed.

- *Duplicate the condition of the liftgate unexpectedly closing under power without beeping and flashing of lights as alleged by some owners of subject vehicles.* Using different combinations of pairs of struts from complaint vehicles, VRTC duplicated the alleged failure condition by soaking a subject vehicle along with the struts in below freezing temperatures. The test reproduced a result of the liftgate motor not disengaging after the liftgate is power-opened. After the liftgate reached its apex, the liftgate immediately began a power-close sequence without any initial non-powered (ten inch) drop. The force (reverse force) exerted by the closing liftgate was about 20 pounds.

B. Toyota's Testing

Toyota provided the results of its liftgate testing of the Sienna and several peer and other models. To simulate failed struts on the Sienna, Toyota removed one strut and measured the contact force of a falling liftgate at a position of 64 inches above the floor (within the range of the ten-inch initial drop). Toyota reported the contact force was about 200 pounds. Using a similar test method on peer and other vehicles, the contact force ranged between 40 to 220 pounds. Toyota reported the force to reverse a power-closing liftgate and cause it to automatically reopen for the Sienna was about 50 pounds and that of peer and other vehicles ranged between 40 to 110 pounds.

C. ODI Analysis

Liftgate Operation with Failing Struts

The force to maintain the liftgate in the fully-open position is provided by the liftgate struts. As shown in Table 2, the Sienna liftgate requires a lifting force from the struts of about 200 pounds to maintain it in the fully-open position. A pair of original equipment liftgate struts provides (Table 3b) enough force to keep the liftgate in the fully-open position. When gas leaks from the strut, the amount of force the strut produces decreases. Also, when the ambient temperature decreases, the amount of force the strut produces decreases (Tables 3a and 3b).

When the force of the struts in the fully extended configuration is less than about 180 pounds, the liftgate does not remain in the fully-open position. Between about 150 and 180 pounds of strut force (Category B in Table 4), the liftgate falls relatively slowly (not power-close) until it nears the fully-closed position, at which point the liftgate will drop rapidly.

When the force of the struts in the fully extended configuration is less than about 150 pounds (Category C in Table 4), the liftgate initial drop without motor engagement is about ten inches from the fully-open position. Then, the automatic power-close feature engages and the liftgate will close under power. Lesser strut force will produce faster initial dropping speeds until the power-close engages.

- Initial Drop. During the initial drop sequence, the liftgate falls from a fully-open position and drops about ten inches. Any person standing underneath the liftgate who stands between five feet tall and five feet ten inches tall is in danger of being struck on the head by the falling liftgate. VRTC testing showed that, during this freefall, the liftgate can drop at a rate between 9 and 49 degrees per second and an object in the path of the liftgate could receive an impact between 54 and 289 pounds of force depending on the amount of gas in the struts (Table 5, liftgate position 10 degrees down from fully-open position).

- Power Closing. During the power-close sequence, any person in the liftgate's path is also in danger of being hit. VRTC testing showed the liftgate can drop at a rate between 7 and 15 degrees per second and requires between 28 and 69 pounds of contact force to stop power-closing and automatically reverse (Table 5, liftgate positions 30 to 70 degrees down from fully-open position). An unsuspecting person can be knocked to the ground or temporarily pinned by the closing liftgate until enough force is applied to reverse the movement of the liftgate.

Liftgate Warning Features

As mentioned above in this report, two audible warning beeps are emitted and the hazard lights flash twice when the liftgate begins to power-close or power-open. However, a few complaint reports indicated occasions when no warning sounds (beeps) or flashing of

hazard lights occurred as the liftgate unexpectedly closed. VRTC researched these phenomena using a Sienna test vehicle and produced test results exhibiting automatically power-closing of the liftgate without the Sienna providing any warning sounds or flashing lights. This occurred under certain conditions explained below.

VRTC found that in very cold temperatures, the liftgate motor may not disengage after the liftgate is opened. When this occurs, the liftgate immediately begins to power-close without warning beeps or flashing lights. An owner that is under the liftgate when the liftgate is closing in this manner—without any warning—is clearly in danger of being hit by the liftgate.

Toyota Test Results Compared with ODI Test Results

For the most part, Toyota's results of Sienna testing shared with NHTSA—initial drop force and force to stop and reverse a power-closing liftgate—are similar to NHTSA's test results.

IV. FIELD DATA ANALYSIS

A. Toyota Sienna

i. Complaints

Consumer complaints indicate that when the liftgate struts in the subject vehicles fail and the liftgate is opened (in most cases, via power actuation), it reaches the top and unexpectedly closes on its own. Consumers report that the problem was fixed by replacing the original struts. NHTSA has verified dozens of consumer complaints via inspections and testing of the allegedly failed struts and/or telephone interviews of the complainants.

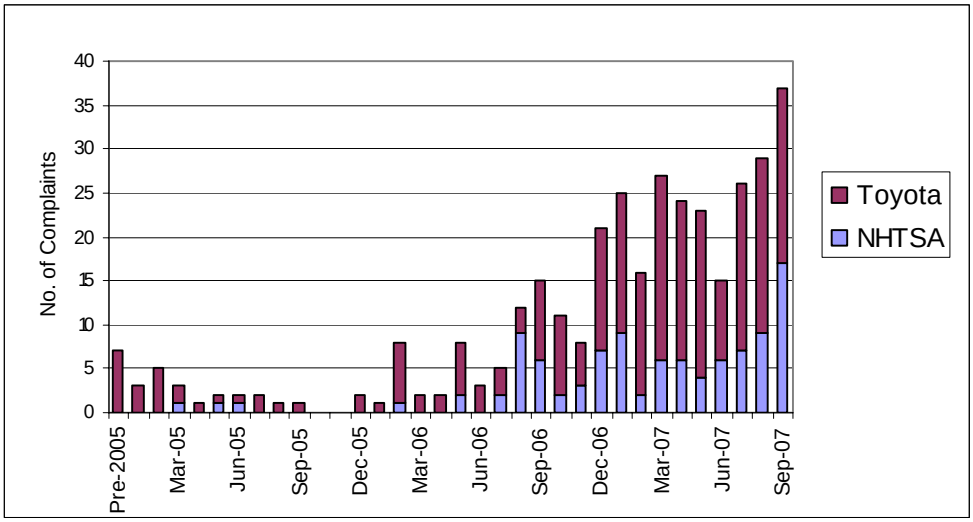
Table 6 shows the total number and rate of complaints reported to NHTSA and Toyota (as of September 2007) that relate to the alleged defect in the subject vehicles by model year. No complaints related to the alleged defect have been reported on MY 2007 Sienna vehicles. Figure 1 shows that reporting of complaints over time indicates an increasing trend.

Table 6. Complaints on Sienna Vehicles by Model Year

Model Year	2004	2005	2006	Total
No. of Complaints	249	93	3	345
Complaints per 100,000 vehicles	300.5	156.2	5.6	176.0

Note: NHTSA received additional 65 complaints from October 2007 through May 2008.

Figure 1. Complaint Date by Month/Year



ii. Warranty Claims

Toyota reported 12,453 warranty claims (as of September 2007) that involved the replacement of liftgate struts in MY 2004 through 2007 Sienna vehicles. Table 7 shows the number and rate of warranty claims by model year.

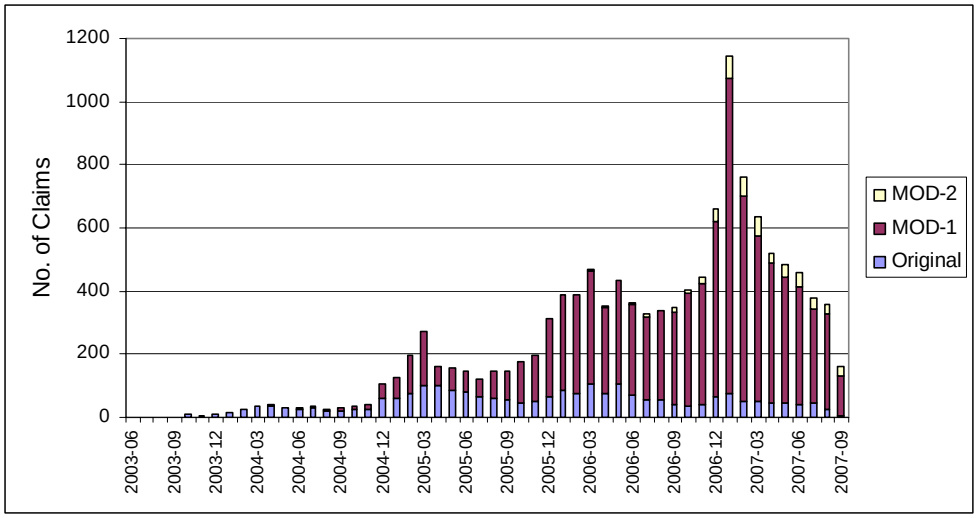
Table 7. Warranty Claims on Sienna Vehicles by Model Year

Model Year	2004	2005	2006	2007	Total
No. of Warranty Claims	7,939	3,989	524	1	12,453
Claims per 100 vehicles	9.6	6.7	1.0	0.05	6.3

Figure 2 shows that warranty claims for the subject vehicles have increased over time. Also evident is a seasonal trend with peaks during cold months. The graph shows warranty claims by strut design change[2] and repair date. Most of the subject vehicles were covered by the basic 3-year/36,000-mile warranty period; relatively few subject vehicles had extended warranties.

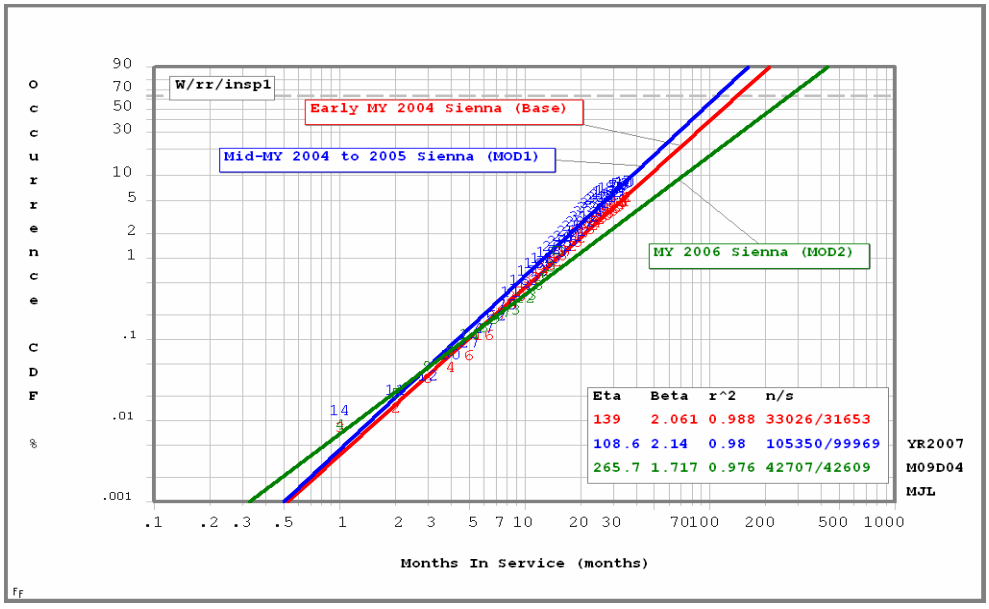
[2] The original design for the liftgate strut was used in MY 2004 Siennas built before December 2003; the first modification (MOD-1) was used in MY 2004 and 2005 Siennas built between December 2003 and September 2005; and a second modification (MOD-2) was used in MY 2006 Siennas built after September 2005.

Figure 2. Warranty Claims by Repair Month/Year



ODI performed a Weibull analysis using Toyota's warranty claim data for the subject vehicles. Figure 3 shows the result with each version of the strut used in the subject vehicles shown separately. The Beta value or the slope of each line represents the failure rate: the Beta is about 2.1 for both the original and MOD-1 strut designs and it is about 1.7 for MOD-2 strut design.[3] The Weibull analysis indicates an increasing failure trend for each version of the strut.

Figure 3. Weibull Analysis of Warranty Claim Data



[3] In Weibull analysis, Beta values greater than one represent an increasing failure rate, Beta values less than one represent a decreasing failure rate, and Beta value of one represents a steady or random failure rate.

iii. Injuries

ODI is aware of nearly 100 reported injuries due to the failure of the liftgate struts and resultant unexpected dropping and power-closing of the liftgate.[4] Although a majority of the injuries were minor soft tissue injuries such as bumps and bruises, several vehicle owners reported more serious injuries. For example, a 50-year-old resident of Illinois suffered a cervical sprain and nerve damage when his liftgate unexpectedly closed on him while he was reaching into his rear cargo area. He continues to experience constant pain and loss of muscle strength as a result of the episode, and accrued $50,000 in medical bills stemming from the incident so far. A 68-year-old resident of Utah suffered an injury to his rotator cuff and damage to his knee when his liftgate unexpectedly closed on him, jamming his knee against the rear edge of the vehicle. This person still needs to undergo surgery on his knee, and has accrued $18,000 in medical bills so far. A 51-year-old resident of California suffered a concussion while standing under his liftgate as it was opening. He was apparently struck in the head by the liftgate during its initial freefall before the power-close feature activated.

Other owners report injuries such as a cut on the forehead and a sprained back. Several owners were forced to the ground by contact with an unexpected liftgate closing. Twelve of the owners that reported injuries also reported the liftgate caused injuries on multiple occasions.

B. Real-World Observations

ODI observed the way people open a vehicle liftgate and go under the open liftgate to gain access to the rear cargo area. ODI made random and inconspicuous observations at the passenger arriving area at Reagan National Airport. We observed an assortment of minivans, SUVs and one station wagon. All but one vehicle had a manually operated liftgate. We observed that it was common for the person opening the liftgate to place their head and body beneath the liftgate before it completed its opening motion and reached a fully-open position.

C. Peer Vehicles

For a comparative study, ODI obtained complaint and warranty claim data from the manufacturers of the following vehicles: Ford Freestar/Mercury Monterey, Honda Odyssey, Dodge Caravan/Chrysler Town and Country, and Nissan Quest. Table 8 shows the number and rate of manufacturers' complaints, injuries, and warranty claims on these vehicles.

[4] ODI interviewed vehicle owners and confirmed an injury for many of the alleged injury reports, including those that did not describe an injury in the NHTSA's Vehicle Owner's Questionnaire (VOQ) reports.

Table 8. Toyota Sienna vs. Peer Vehicles – Manufacturer Data[5]
(Note: See description of acronyms at the bottom of table)

Model	Model Year	Vehicle Population	C	CR	I	IR	W	WR
Sienna	2004	82,870	105	126.7	15	18.1	5,839	7.0
	2005	59,548	13	21.8	1	1.7	2,175	3.7
	2006	53,662	0	0.0	0	0.0	175	0.3
Odyssey	2005	25,227	36	142.7	3	11.9	1413	5.6
	2006	23,982	5	20.8	1	4.2	123	0.5
Caravan/ Town & Country	2004	49,198	6	12.2	2	4.1	157	0.3
	2005	236,368	10	4.2	0	0.0	859	0.4
	2006	151,144	1	0.7	0	0.0	105	0.1
Freestar/ Monterey	2005	8,037	37	460.4	5	62.2	376	4.7
	2006	5,957	8	134.3	0	0.0	69	1.2
Quest	2004	57,055	40	70.1	1	1.8	69	0.1
	2005	23,638	12	50.8	0	0.0	358	1.5
	2006	12,107	0	0.0	0	0.0	99	0.8

C=Number of complaints
CR=Complaint rate (per 100,000 vehicles)
I=Number of injuries
IR=Injury rate (per 100,000 vehicles)
W=Number of warranty claims
WR=Warranty rate (per 100 vehicles)

D. ODI Analysis

Toyota Sienna

The field data shows that the Sienna liftgate struts have been failing in significant numbers while the vehicle is still under the basic 3-year/36,000-mile warranty. The failures are occurring at an increasing rate. The complaint rates related to struts failing on MY 2004 and 2005 Sienna vehicles are particularly high based on reports received by NHTSA and Toyota: 300.5 and 156.2 complaints per 100,000 vehicles, respectively (Table 6). The warranty claim rates for replacement of liftgate struts are also very high: 9.6 and 6.7 claims per 100 vehicles, respectively (Table 7). ODI's analysis of the warranty claim data indicates a steady increase in failures for the subject vehicles.[6] The overall warranty claim rate for replacement of struts in the subject vehicles is over six claims per 100 vehicles.

[5] This comparative analysis included only manufacturer complaint and injury data (VOQ reports were excluded) because, at that time, while 77 VOQ's were reported on the Sienna, only a few or no VOQ's were reported on each of the peer vehicle models. In addition, this analysis used Toyota's data as of March 2007 and peer manufacturers' data as of July 2007.

[6] Initial data regarding the MY 2007 Sienna vehicles manufactured with the final liftgate strut designs in October and December 2006 indicate improved field performance (lower incidence of failure) for the MY 2007 Sienna vehicles. As a result, Siennas manufactured after Toyota implemented the final liftgate strut design are not included as subject vehicles.

The real-world experience has shown that the liftgate struts in the subject vehicles do not appear to be performing to Toyota's expected life. The fact that the liftgate struts on the subject vehicles are failing at very high rates indicates a design defect in the liftgate struts. Toyota's several design changes and the results of these design changes on the performance of the liftgate struts buttress this conclusion—if the struts were not wearing out prematurely, a design change should not be necessary in order for the struts to meet Toyota's expected design life.

Toyota states that the subject vehicles have a jam protection feature that will reverse the direction of the closing (or opening) liftgate when it meets an obstruction. Toyota maintains that this feature, coupled with automatic initiation of the power close feature (which prevents freefall of the liftgate), are designed to promote safety. NHTSA's testing showed that the force required to reverse a power-closing liftgate by activating the jam protection feature is not insignificant. ODI's interviews confirming injuries to people show that the contact force is substantial enough to produce physical harm. Clearly, the jam protection feature does not prevent the injuries, both minor and serious, inflicted upon the owners of vehicles with failed liftgate struts.

When the liftgate drops and power-closes unexpectedly, unsuspecting persons, especially the elderly or children, standing in the path of a closing liftgate or reaching into the rear cargo area of the vehicle can be injured when struck by the closing liftgate. Owners have reported being knocked to the ground or temporarily pinned by the closing liftgate until enough force is applied to reverse the movement of the liftgate. Although the majority of reported injuries were minor in nature, several people have sustained serious injuries such as a cervical sprain with nerve damage, shoulder and knee injuries that required surgeries, and symptoms of a head injury consistent with a post-concussive injury syndrome.

Many injured owners reported that there were no problems with the liftgate prior to the injury incident. Others reported that an anomaly in its power operation (e.g., a slower opening speed) prior to the injury incident was an isolated incident and did not think the liftgate would later close unexpectedly as it did. In addition, some owners reported not hearing, or were unsure that they heard, an audible warning when the liftgate closed unexpectedly. Thus, the audible warning when the liftgate begins to power-close is not a sufficient warning effective in preventing injuries. The fact that at least twelve owners reported that an injury occurred on multiple occasions further confirms the unexpected and unforeseen nature of the alleged defect.

Peer Vehicles

The complaint, injury and warranty rates for the Toyota Sienna are high compared to peer vehicles.

The MY 2005 Freestar/Monterey[7] has the highest manufacturer complaint rate (using manufacturer's data) at 460 complaints per 100,000 vehicles (Table 8, column CR). The MY 2004 Sienna, MY 2005 Odyssey and MY 2006 Freestar/Monterey are all between 125 and 145 complaints per 100,000 vehicles. A lower rate is shown for the MY 2004 Quest (70) and all the rest are 50 or below. It should be noted that the liftgate struts used in the Odyssey vehicles were manufactured by the same supplier—Stabilus—that Toyota used in the Sienna vehicles. With respect to the complaint rate (using NHTSA complaint data), the Sienna has a much higher rate than each of the peer vehicles including the Freestar/Monterey (Footnote 5).

Using the manufacturer's data (Table 8, column IR), the MY 2005 Freestar/Monterey has the highest injury rate at 62 per 100,000 vehicles.[8] The MY 2004 Sienna is 18 and MY 2005 Odyssey is 12. All the rest are 4 or below.

For warranty claims (Table 8, column WR), the MY 2004 Sienna has the highest rate at 7.0 claims per 100 vehicles. The MY 2005 Odyssey is 5.6, the MY 2005 Freestar/Monterey is 4.7, the MY 2005 Sienna is 3.7, the MY 2005 Quest is 1.5 and the MY 2006 Freestar/Monterey is 1.2. All the rest are 0.5 or below. Both MY 2004 Sienna and MY 2005 Odyssey rates exceed the rate of MY 2005-2006 Freestar/Monterey.

V. TOYOTA'S SAFETY RECALL

On May 30, 2008, Toyota initiated a safety recall (NHTSA Recall No. 08V-244) to replace the liftgate struts in approximately 196,000 MY 2004-2006 Toyota Sienna vehicles equipped with power liftgates. However, in its May 30, 2008 letter, Toyota states it has not determined the "condition" of leakage of gas from the struts is a "safety-related defect" within the meaning of the federal vehicle safety laws. Nevertheless, the recall will provide the opportunity for the vehicle owners to obtain new struts that have the same design modifications incorporated into the Sienna vehicle production in October and December 2006. The new struts are more robust and should provide a much longer usage life than the struts originally installed in the subject vehicles.

VI. CONCLUSIONS

1. The originally-installed liftgate struts in Toyota Sienna subject vehicles have been failing prematurely at a high and still increasing rate.

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[7] In March 2006, Ford initiated a safety recall of all MY 2005 and some MY 2006 Ford Freestar and Mercury Monterey vehicles equipped with optional power liftgates (NHTSA Recall No. 06V-069). Ford stated that after the liftgate is power-opened, the liftgate motor disengages. When the struts fail, the liftgate can fall freely without prior warning. The recall remedy involved reprogramming the power liftgate control module to provide audible warning and to power-close in the event the struts cannot support the liftgate.

[8] At this time, there have been no reported injuries on MY 2005 and 2006 Freestar/Monterey vehicles that have received the recall remedy.

2. Liftgate struts may or may not be intended to last for the life of the vehicle but they are not considered a wear item requiring periodic maintenance or replacement. Toyota does not list the liftgate struts in the owner's or service manual as a regular maintenance item.

3. The liftgate struts do not appear to meet Toyota's design or expected life.

4. To address the liftgate strut failures, Toyota implemented four changes to the design of the liftgate strut in Sienna vehicles.

5. In the early-stage failure condition of struts, the liftgate can drop relatively slowly (without power actuation) until it nears the fully-closed position, at which point the liftgate will drop rapidly.

6. In the more advanced failure condition of struts, the liftgate drops about ten inches from the fully-open position and the automatic close feature engages and the liftgate shuts completely.

    a. During the first ten-inch drop, the liftgate can drop quickly and exert an extremely high force to an object or a person in its path.

    b. During the power-close stage, the liftgate can drop via power actuation and exert a significant force in order to stop closing and automatically reopen.

7. Unintended or unexpected closing incidents of liftgates have caused numerous injuries including several serious injuries.

8. The jam protection feature does not prevent the injuries, both minor and serious, inflicted upon the owners of vehicles with failed liftgate struts.

9. Many injured subject vehicle owners reported no liftgate problems (i.e., warnings) before the injury incident.

10. The audible warning (beeping sound) when the liftgate begins to power-close may not always occur and when it does, may not be a sufficient warning to an owner and is not effective in preventing injuries.

11. The failure experience of the model year 2004 Sienna ranks high among several peer vehicles.

12. Based on Toyota's action to conduct a safety recall (08V-244), this investigation is closed.