Passenger Cars

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Overall Trends

1 Introduction

First, Table 1 examines passenger vehicle production in the leading vehicle manufacturing countries. The vertical column on the right side of the table shows the increase or decrease in vehicle production in 2012 compared to 2011 as a percentage. The 138.4% increase in production in the U.S. is particularly remarkable. In 2011, the level of vehicle production in the U.S. did not even reach the 3 million vehicle mark, but suddenly in 2012 the production exceeded 4 million vehicles, which surprised many people.

The U.S. is now seeing a recovery in the economy and overall business confidence, including home sales. This has already become a news story in many places, but the U.S. is an advanced automotive society and automakers anticipated actions around the world for recovery. Consequently, these automakers implemented a significant increase in production to help meet this demand. The U.S. is also a country in which a rise in gasoline prices can have a large effect on vehicle sales (demand). The increase in production is also likely to be partly a sensitive response to this situation as well.

Europe stands in stark contrast to the U.S. Only the UK increased production in 2012 (109% of 2011) but production in this country did not exceed 1.5 million vehicles. The other European Union (EU) member countries all showed negative growth in vehicle production in 2012. Vehicle production even in Germany, which plays the central role in the EU economy, decreased by approximately 8% in 2012. Vehicle production in both Spain and Italy, where economic conditions have deteriorated seriously, declined by at least 15% in 2012.

The overall economic downturn in the EU that was brought on by the financial crisis in Greece seems to be very persistent and economic conditions in 2013 will likely depend greatly on its progress. Vehicle production in South Korea is also not growing actively. In addition, although the economies China, India, and Brazil are growing robustly, there are signs of a temporary decline in momentum.

The table also shows trends in Japan. The increase in vehicle production in Japan in 2012 was second only to the U.S. This was an increase of approximately 20% compared to 2011 and total vehicle production exceeded 8.5 million vehicles. However, this increase in production is in comparison to 2011, which was affected by the

Table 1 Passenger vehicle production in leading manufacturing countries.

		2012	2011	2012 /2011 (%)
Japan		8 554 219	7 158 525	119.5
U.S.		4 105 853	2 966 133	138.4
Canada		1 040 298	990 483	105.0
	Germany	5 388 456	5 871 918	91.8
	UK	1 464 906	1 343 810	109.0
	France	1 682 814	1 931 030	87.1
	Italy	396 817	485 606	81.7
	Spain	1 539 680	1 819 453	84.6
EU		17 382 025	※ 18 279 084	95.1
South Korea		4 167 089	4 221 617	98.7
China		15 523 658	14 485 326	107.2
India		3 285 496	※ 3 038 332	108.1
Brazil		2 623 704	2 534 534	103.5
World total			※ 59 870 838	0.0

Source: Japan Automobile Manufacturers Association (JAMA). There are 27 countries in the EU.
※ Revised
Note 1) The values for Japan are the definitive final reported values and the values for the other countries are the preliminary figures announced by the International Organization of Motor Vehicle Manufacturers (OICA).
Note 2) The number of vehicles for the U.S. and Canada excludes SUVs and other models that are considered as trucks in those countries.

Great East Japan Earthquake that caused a temporary suspension in all vehicle production, as well as other negative impacts on the whole automotive industry. In addition, the entire Japanese economy was stagnant in 2011. Therefore, it is probably a good idea to consider this big increase in 2012 vehicle production in light of these conditions and subtract a little away from it.

The Japanese vehicle production data from 2010 can be used to gain some more perspective. In that year, approximately 8.3 million vehicles were produced. Therefore, vehicle production in 2012 was 102.9% of 2010. In other words, Japan's total vehicle production has finally returned to the original levels before the natural disasters in 2011. Prior to the major economic downturn in the wake of the collapse of the Lehman Brothers financial services firm in 2008, Japanese automakers were producing nearly 10 million vehicles a year. Therefore, there are some expectations that Japan can ride a wave of recovery and once again approach that level of production in the future.

Of course it is a mistake to make judgments about a country's overall economy based only on vehicle production, but this data can be used as one indicator for reference. Even so, there is a feeling that the recovery of the U.S. will help it back into a position to once again lead the world's economy. Originally, passenger vehicle production in the U.S. (excluding trucks) is less than half that in Japan and close to one-quarter of that in China.

2 State of Vehicle Production, Sales, and Exports

Next, Table 2 shows passenger vehicle production according to the manufacturer and the country. There were no major changes in the manufacturers that regularly appear at the top of this list, but Toyota Motor Corporation made a great comeback after falling down the list due to the effects of the natural disasters in 2011.

This table also shows that manufacturers in the U.S. market had the largest increases in production. The substantial increases reported for U.S. Toyota, American Honda, and Fuji Heavy Industries are particularly noticeable.

If vehicle production is ranked according to the country of production, then China is far and away the number one producer, followed by the U.S., Japan, Germany, and South Korea. However, if the vehicle category is limited to just passenger vehicles, then the order changes to China, Japan, Germany, South Korea, and then the U.S.

Table 2 Passenger vehicles production according to manufacturer and country.

Ranking in 2010	Manufacturer	Country	2012	2011	2012 /2011 (%)
2	Hyundai Group	South Korea	3 125 607	3 068 693	101.9
3	VW Group	Germany	2 158 444	2 581 575	83.6
1	Toyota	Japan	3 170 289	2 473 546	128.2
4	PSA	France	1 017 436	1 233 455	82.5
8	BMW	Germany	1 043 732	1 005 259	103.8
5	Nissan	Japan	1 035 726	1 004 666	103.1
6	Daimler Group	Germany	963 633	997 628	96.6
9	Suzuki	Japan	886 781	811 689	109.3
10	Mazda	Japan	830 294	798 060	104.0
12	GM Daewoo	South Korea	768 449	795 415	96.6
14	GM	U.S.	840 700	721 501	116.5
11	Ford Germany	Germany	685 358	720 411	95.1
7	Honda	Japan	996 832	687 948	144.9
15	Mitsubishi	Japan	448 598	536 142	83.7
16	Fiat Group	Italy	394 620	483 868	81.6
17	Daihatsu	Japan	633 887	479 956	132.1
19	Renault	France	359 532	444 862	80.8
18	Opel	Germany	387 525	442 040	87.7
20	Fuji Heavy Industries	Japan	551 812	366 518	150.6
21	American Honda	U.S.	639 108	349 969	182.6
24	GM Canada	Canada	0	※ 76 453	0.0
23	Ford	U.S.	419 907	※ 311 814	134.7
22	U.S. Toyota	U.S.	531 876	268 314	198.2
13	SEAT(VW)	Spain	—	—	

Source: automobile association in each country
※ Revised
Note 1) Value for Daimler/Chrysler
Note 2) There is no SEAT (VW) numerical data for 2011

Table 3 Passenger vehicle production in Japan.

	2012	2011	2012 /2011 (%)
Standard vehicles	4 686 112	4 180 361	112.1
Small vehicles	2 252 672	1 861 279	121.0
4-wheeled mini-vehicles	1 615 435	1 116 885	144.6
Total	8 554 219	7 158 525	119.5

Source: JAMA

In the U.S., the light truck category of vehicles receives preferential taxation and is extremely popular as a regular means of transportation for many people. As a result, the U.S. produces a large number of commercial vehicles and is clearly the largest producer of such vehicles followed by China, Thailand, Canada, and Japan.

Table 3 shows a more detailed breakdown of the vehicle production data for Japan in Table 1. The breakdown of vehicle production in Japan is very obvious and the increase in mini-vehicle production in 2012 compared to 2011 is remarkable. One reason for this may be the greater effort by Honda to develop mini-vehicles, resulting in the launch of some extremely popular models.

In the same way that the light truck category of vehicles is very popular in the U.S., mini-vehicles are very popular in Japan. First of all, these kinds of vehicles are less expensive to maintain and also meet a growing demand for small vehicles that are easy to drive in a country with an increasing number of elderly citizens. In many ways, mini-vehicles tend to be a solid choice for people living in Japan. Due to various social and other reasons, it is likely that mini-vehicles will remain popular into the foreseeable future.

The data in Table 3 compares vehicle production in 2012 with that in 2011. As above, it should be compared with 2010 for additional perspective. Standard vehicle production in 2012 was 96.7% of 2010, small vehicle production increased to 104.3%, and mini-vehicle production increased to 123.8%. Total vehicle production in 2012 was 102.9% of 2010. This comparison reveals that the increase in production in 2012 was not actually all that dramatic, and indicates that customer interest is clearly more oriented toward compact vehicles in Japan.

Table 4 shows the number of passenger vehicles that were exported from Japan according to the destination. The number of vehicles that were exported to North America in 2012 is of course higher than that in 2011, but the largest increase was to the Middle East, followed by robust exports to Oceania. In contrast, the number of vehicles that were exported to Europe, Asia, and Central America all decreased.

Table 4 Number of passenger vehicles exported from Japan according to destination.

	2012	2011	2012 /2011 (%)
North America	1 863 688	1 563 450	119.2
Europe	833 397	962 585	86.6
Oceania	394 762	334 519	118.0
Asia	376 490	406 581	92.6
Middle East	386 729	314 258	123.1
Central America	121 712	133 200	91.4
South America	151 029	146 169	103.3
Africa	66 537	67 154	99.1
Other	1 750	1 988	88.0
Production (4-wheeled vehicles) year × vehicle model January 2011 to December 2012	4 196 094	3 929 904	106.8

※ Revised
Source: JAMA

Table 5 Passenger vehicle sales in Japan.

	2012	2011	2012 /2011 (%)
Standard vehicles	1 411 700	1 139 910	123.8
Small vehicles	1 602 951	1 246 126	128.6
4-wheeled mini-vehicles	1 557 681	1 138 752	136.8
Total	4 572 332	3 524 788	129.7

Source: JAMA
Note 1) The classification criteria of the sales statistics are based on the license plate number.

In addition, the total number of vehicles sold within Japan in 2012 increased to 129.7% compared to the number sold in 2011 (Table 5). Since the data for 2011 was 83.7% of the previous year, this underlines the strong comeback of Japanese automakers. Standard vehicle sales in 2012 were 99.4% of those in 2010, small vehicle sales were 106.3% of 2010, and mini-vehicle sales were 121.3% of 2010. The total number of vehicles sold in 2012 was 108.5% of 2010.

The highest annual vehicle sales on record in Japan stands at over 5 million vehicles. Although vehicle sales in Japan have not yet returned to that level, very good signs of recovery are emerging in the Japanese vehicle market, driven by the popularity of mini-vehicles. However, it must not be overlooked that this data for 2012 benefited from measures to promote sales, such as Japan's preferential tax scheme for environmentally friendly vehicles and the like.

It should also be pointed out that, even as overall vehicle sales in Japan are increasing, the majority of this increase is coming from smaller vehicles. This is worrisome to automakers because it is more difficult to ensure

Table 6 Used vehicle sales in Japan.

	Standard vehicles	Small vehicles	4-wheeled mini-vehicles	Total	Compared to previous year (%)
1995	994 311	3 845 076	727 259	5 566 646	106.6%
1996	1 233 553	3 750 582	836 474	5 820 609	104.6%
1997	1 406 089	3 626 978	1 009 430	6 042 497	103.8%
1998	1 493 744	3 309 426	1 111 282	5 914 452	97.9%
1999	1 551 703	3 127 783	1 273 383	5 952 869	100.6%
2000	1 742 786	3 050 087	1 448 546	6 241 419	104.8%
2001	1 830 588	2 913 775	1 552 297	6 296 660	100.9%
2002	1 861 694	2 744 604	1 714 827	6 321 125	100.4%
2003	1 910 017	2 640 456	1 809 840	6 360 313	100.6%
2004	1 984 562	2 524 764	1 777 866	6 287 192	98.9%
2005	2 002 563	2 460 410	1 890 154	6 353 127	101.0%
2006	1 959 739	2 304 226	2 033 569	6 297 534	99.1%
2007	1 810 596	2 105 122	2 022 866	5 938 584	94.3%
2008	1 728 090	1 944 766	1 995 333	5 668 189	95.4%
2009	1 619 370	1 855 071	1 864 874	5 339 315	94.2%
2010	1 592 110	1 816 696	1 873 466	5 282 272	98.9%
2011	1 542 614	1 733 519	1 906 523	5 182 656	98.1%
2012	1 688 606	1 826 335	2 133 725	5 648 666	109.0%

Source: Japan Automobile Dealers Association (JADA) and the Japan Light Motor Vehicle and Motorcycle Association

good profitability with such vehicles. This means that there are still many issues to be resolved in the future, such as the need to reduce costs even further and the creation of new value for the customer.

3 State of Used and Imported Vehicle Sales

Table 6 shows the number of used vehicle sales in Japan. There has been negative growth in used vehicle sales for 6 straight years since 2006, but there were clear signs of a recovery in 2012 and this negative trend was finally reversed. The total number of used vehicles sold in 2012 was 5,648,666 vehicles, an increase of 109% compared to the previous year. Compared to the continuous downward trend up to that point, this data shows a move in a robust direction.

Used vehicle sales for each vehicle classification all increased from 2011 as follows: standard vehicle sales were up by 109.5%, small vehicle sales were up by 105.4%, and mini-vehicle sales were up by 111.9%. These improved sales were driven by a large number of vehicle users switching to more compact-sized vehicles, which created a significant influx of higher class or higher quality vehicles into the used vehicle market, stimulating sales from users wishing to upgrade.

Sales of imported vehicles in Japan have continued to show strong growth. Imported vehicle sales fell significantly following the economic downturn after 2008, but steady growth has continued since 2010. In 2012, imported vehicle sales exceeded 300,000 to reach a total of 333,380 vehicles. This broke the previous record and set the mark for the highest imported vehicle sales this century.

Table 7 shows a list of popular automakers importing vehicles into Japan. The list is headed by Volkswagen, which remains as popular as ever, followed by BMW, Mercedes-Benz, Audi, and MINI, meaning that the top 5 imported car brands in Japan are all produced by German automakers. This clearly indicates the enduring popularity of German vehicles amongst Japanese customers.

The absolute number of Alfa Romeo vehicles sold in Japan is small, but its massive increase in sales compared to 2011 is impressive. It is thought that the introduction of the new Giulietta contributed to this outcome. Alfa Romeo is clearly a unique brand with a personality that German vehicles do not have. Its vehicles provide a fashionable and passionate impression that can be enjoyed by the driver and is a brand that cannot be overlooked. French vehicles also showed strong sales results, except for Peugeot, and both Volvo and Ford also increased sales in 2012.

In contrast to the German brands, whose popularity has remained relatively stable, the popularity of the other automakers is strongly influenced by the introduction of new vehicles and the evaluations of those vehicles. It is common for the business performance of these automakers to fluctuate widely. The top selling imported

Table 7 Imported vehicle sales in Japan.

Ranking in 2011	Ranking in 2010	Manufacturer	2012	2011	2012 /2011 (%)
1	1	VW	56 188	50 631	111.0
2	2	BMW	41 102	34 195	120.2
3	3	Mercedes-Benz	41 901	33 207	126.2
4	4	Audi	24 163	21 166	114.2
5	5	BMW MINI	16 212	14 350	113.0
6	6	Volvo	13 878	11 787	117.7
7	8	Peugeot	5 649	6 137	92.0
8	9	Fiat	5 667	5 960	95.1
9	7	Suzuki (vehicles produced overseas)	1 028	3 091	33.3
10	10	Porsche	4 661	3 658	127.4
11	13	Renault	3 108	3 066	101.4
12	11	Ford	3 543	2 975	119.1
13	15	Citroen	3 795	3 092	122.7
14	19	Jeep	4 977	3 154	157.8
15	12	Alfa Romeo	4 452	1 863	239.0
16	14	Honda (vehicles produced overseas)	185	941	19.7
17	17	Jaguar	1 014	1 020	99.4
18	18	Dodge	930	962	96.7
19	16	Toyota (vehicles produced overseas)	4 660	2 600	179.2
20	20	Hyundai	44	32	137.5
		Other	63 437	56 820	111.6
			300 594	260 707	115.3

※ Revised
Source: JAMA

Table 8 Passenger vehicles sales in leading manufacturing countries and share of Japanese vehicles.

	2012	Japanese vehicles (within the total)	Share of Japanese vehicles (%)	2011	2012 /2011 (%)
Japan	4 572 332	4 332 786	94.8	3 524 788	129.7
U.S.	7 241 900	3 025 873	41.8	※ 6 089 403	118.9
Canada	748 530	312 654	41.8	681 956	109.8
Brazil	2 851 540	277 605	9.7	※ 2 647 245	107.7
China	15 495 240	2 587 295	16.7	14 472 416	107.1
India	2 781 919	1 354 209	48.7	※ 2 510 313	110.8
UK	2 044 609	313 188	15.3	1 941 253	105.3
Germany	3 082 504	279 054	9.1	3 173 634	97.1
France	1 898 760	174 656	9.2	2 204 229	86.1
Italy	1 402 089	138 371	9.9	1 748 143	80.2
EU+EFTA total	12 518 167	1 519 751	12.1	※ 13 606 999	92.0

Source: automobile association in each country
Note 1) Japanese vehicles refer to all Japanese brand vehicles and includes those produced overseas.
Note 2) The number of vehicles for the U.S. and Canada excludes SUVs and other models that are considered as trucks in those countries (Source: Ward's).
Note 3) Calculated from the 27 countries in the EU and 3 countries in the European Free Trade Association (EFTA: Iceland, Norway, and Switzerland) (source: European Automobile Manufacturers' Association (ACEA)).

vehicle brand is Volkswagen with sales exceeding 50,000 vehicles. In addition, the MINI brand is in the top 5 of imported vehicles with sales exceeding 15,000 vehicles in 2012. However, aside from Volvo in 6th position, every other automaker is a long way from reaching sales of 10,000 vehicles. Volume is not completely irrelevant and overcoming this hurdle is one key for boosting sales numbers in Japan, including through the scale and structure of the importer.

Finally, Table 8 shows passenger vehicle sales in the leading vehicle manufacturing countries and the share of those sales that are made up of Japanese vehicles. Sales in 2012 were 108.5% of 2010. Vehicle sales in each country are largely controlled by the economic conditions in those countries and increase or decrease accordingly. However, the share of the total vehicle sales by Japanese

Table 9 Vehicles produced in Japan that were registered in 2012.

Date announced	Manufacturer	Vehicle name	Fuel consumption (km/liter)	Vehicle weight (kg)	Engine type	Displacement (cc)	Transmission	Price (10,000 yen)	Selling point
2012/2/2	Toyota	86	13.4	1 190–1 250	Horizontally-opposed 4 cylinder	1 998	6-speed super ECT and 6-speed MT (6MT)	199.0000–305.0000	Pure sports car
2012/2/3	Fuji Heavy Industries	BRZ	13	1 190–1 250	Horizontally-opposed 4 cylinder	1 998	E-6 AT and 6 MT	205.8000–287.1750	Pure sports car
2012/2/16	Mazda	CX-5	18.6	1 440–1 620	Inline 4-cylinder diesel	2 188	6AT	205.0000–319.0000	Skyactiv-G and D
2012/4/25	Nissan	Cima	16.6	1 930–1 950	V6	3 498	7M-AT	735.0000–840.0000	2-clutch hybrid
2012/5/11	Toyota	Corolla Axio	21.4	1 080–1 090	Inline 4-cylinder	1 495	Super CVT and 5 MT	137.7000–208.9000	11th generation
2013/7/23	Toyota	Porte	20.6	1 100–1 230	Inline 4-cylinder	1 496	Super CVT	145.0000–191.0000	Single left-side sliding door, flat floor
2012/8/1	Mitsubishi	Mirage	27.2	860–870	Inline 3-cylinder	999	CVT	99.8000–128.8000	Low fuel consumption, low cost
2012/8/20	Toyota	Auris	19.2	1 220–1 300	Inline 4-cylinder	1 496	Super CVT and 6 MT	171.0000–225.0000	Conspicuous rear styling
2012/8/28	Nissan	Note	25.2	1 030–1 110	Inline 3-cylinder	1 198	Xtronic CVT	124.9500–167.4750	Supercharger
2012/9/6	Suzuki	Wagon R	28.8	750–840	Inline 3-cylinder	658	CVT	110.9850–136.7100	ENE-CHARGE, ECO-COOL slogan
2012/9/25	Fuji Heavy Industries	Subaru XV	15.8	1 655–1 665	Horizontally-opposed 4 cylinder	1 995	CVT	219.4500–246.7500	Compact crossover
2012/10/5	Nissan	Latio	22.6	1 030–1 040	Inline 3-cylinder	1 198	Xtronic CVT	138.8100–169.8900	Global small sedan, made in Thailand
2012/10/25	Mitsubishi	Outlander	15.2	1 440–1 530	Inline 4-cylinder	1 998	INVECS-Ⅲ 6 CVT	242.7000–310.0000	SUV
2012/11/1	Honda	N-ONE	27	840–900	Inline 3-cylinder	658	CVT	115.0000–154.7750	Ambitious model from Honda
2012/11/13	Fuji Heavy Industries	Forester	15.2	1 440–1 590	Horizontally-opposed 4 cylinder	1 995	CVT and 6MT	208.9500–293.6850	X-Mode system
2012/11/20	Mazda	Atenza	22.4	1 430–1 510	Inline 4-cylinder diesel	2 188	6EC-AC and 6MT	250.0000–340.0000	Skyactiv-G and D/i-ELOOP system
2012/12/5	Nissan	Sylphy	15.6	1 230–1 240	Inline 4-cylinder	1 798	Xtronic CVT	193.7250–2389800	Global mid-size sedan
2012/12/20	Daihatsu	Move	29	810–920	Inline 3-cylinder	658	CVT	119.1000–137.1000	First smart assist in a mini-vehicle/ individual cylinder combustion control
2012/12/25	Toyota	Crown Royal Hybrid	23.2	1 540–1 680	Inline 4-cylinder	2 493	Electronic CVT	353.0000–536.000	Pop-up hood and color
2012/12/26	Mitsubishi	Outlander PHEV	67 (18.6/60.2)	1 770–1 820	Inline 4-cylinder	1 998		332.4000–429.7000	2-motor hybrid/S-AWC system

manufacturers is showing consistently strong growth. However, the decrease in this share of vehicle sales in Italy and China is a little worrisome.

4 Selling Points of New Vehicles in 2012

Table 9 shows a list of the vehicles produced in Japan that were newly introduced in 2012. Basically, these are all brand new vehicles or vehicles that were subject to a full model change, but some derivative models are also included. Since the fuel efficiency of vehicles differs depending on the specifications, only the best fuel economy data was chosen and the corresponding engine is also listed. The price column shows the range from minimum to the maximum price.

One of the most surprising points is the large number of vehicle models that are now equipped with a CVT. The CVT has become an essential part of many new vehicles as one means of improving fuel efficiency and also to help vehicles qualify for Japan's preferential tax scheme for environmentally friendly vehicles. The CVT, which can change steplessly through an infinite number of effective gear ratios, exercises cooperative control with the engine to drive the vehicle very efficiently. This is particularly useful in Japan, where there is a lot of stop-and-start urban driving, and it is also advantageous in test cycle fuel economy measurements.

The following sections take a closer look at the selling points of the newly released models from each automaker.

4.1. Toyota Motor Corporation

The Auris was the first vehicle to be exhibited facing backwards at a new vehicle release exhibition (Fig. 1). This was done intentionally in an attempt to appeal to customers with its conspicuous and individualistic rear-end design. The TV commercial for this vehicle features a non-Japanese male model and it too has become a topic of conversation.

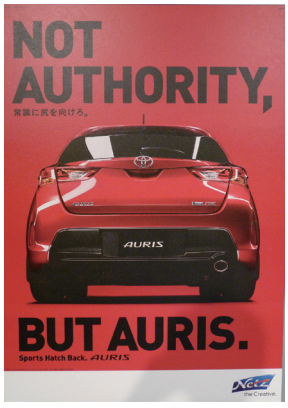


Fig. 1 Appealing rear styling of the Auris.

The new Crown (Fig. 2) features a hybrid model with lower engine displacement. This model has emerged as the flagship model for the Crown and the price has been held down. Its fuel consumption is 23.2 km/liter, which is phenomenal for vehicles in this class. The vehicle is equipped with a plethora of safety equipment, including the adoption of a pop-up hood (Fig. 3) to stay ahead of the competition in pedestrian safety. The front of the vehicle is equipped with a sensor. When this sensor detects a collision with a pedestrian, the rear portion of the hood is designed to lift upward and create extra space

Fig. 2 Noteworthy special pink color of the Crown.

Fig. 3 Pop-up hood that contributes pedestrian protection.

between the hood and the engine to lessen the severity of the impact on the pedestrian. This new safety system also demonstrates the great attention to detail characteristic of a Toyota flagship model.

4. 2. Nissan Motor Co., Ltd.

Excellent fuel efficiency is promoted through various means during the development of environmentally-friendly vehicles. Japanese automakers have pursued this through the use of hybrid drive trains, while European automakers have taken the lead in reducing the size of engines and the number of cylinders.

Nissan has adopted the European approach on the Note through a 3-cylinder 1.2-liter engine. This is a Miller cycle engine (Fig. 4 and Fig. 5) combined with a supercharger (Fig. 6) instead of a turbocharger, resulting in a rare type of engine configuration. The supercharger is equipped with an electronic clutch system that engages and disengages the supercharger for optimum efficiency.

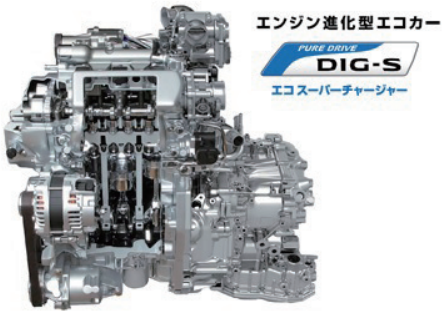


Fig. 4 3-cylinder Miller cycle engine of the Note.

Fig. 5 3-cylinder Miller cycle engine of the Note.

Fig. 6 Supercharger of the Note.

The Cima premium sedan was introduced as an exclusive hybrid model that perfectly fits the role of a flagship vehicle. A special characteristic of this hybrid vehicle is its 1-motor, dual-clutch arrangement (Fig. 7). On an actual test drive, the engine stop function seemed to activate quite frequently, meaning that the vehicle is driven under motor power more often up to the high-speed driv-

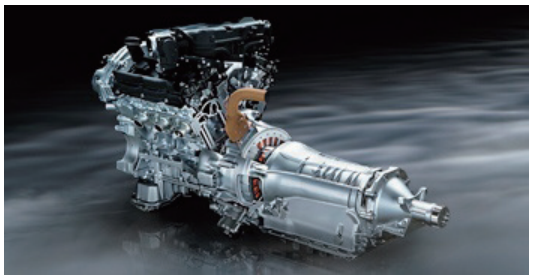


Fig. 7 1-motor, dual-clutch hybrid system of the Cima.

Fig. 8 Large tailgate opening of the N-BOX+.

ing range. Energy regeneration efficiency was improved by separating the engine and the motor, and the vehicle is able to achieve fuel economy that is truly surprising for its class. The fine precision of the different controls is also impressive.

4. 3. Honda Motor Co., Ltd.

Although Honda launched the N-BOX+, it was omitted from the list in Table 9 since it is derived from the N-BOX. However, it does feature different body structure characteristics. Specifically, this vehicle features a tailgate that opens to reveal a very wide opening (Fig. 8) and a lower vehicle height. In combination with the inclined floor structure, these features offer users a new degree of freedom and convenience. These new ideas and innovations, which allow the vehicle to be utilized for a variety of different purposes, have been well received. The creation of a compact standard model that incorporates this same sense of design is eagerly expected.

The N-ONE was also a major topic of conversation (Fig. 9). The design of the N-ONE is very reminiscent of the old N360 (Fig. 10) that first helped Honda achieve success as a 4-wheeled vehicle manufacturer. This vehicle was also designed to achieve a level of quality above all other mini-vehicles. In stark contrast to the N360, Honda is

Fig. 9 Optional two-tone color scheme of the N-ONE.

Fig. 10 N360 Sunroof released 45 years ago.

not looking to compete with other manufacturers on low price. Rather, the strong impression gained from the advertising and PR of the N-ONE is that Honda is targeting customers who want higher quality, even at a slightly higher price. Offering a two-tone color scheme amongst the color variations also helps to exude a fashionable and slightly premium allure.

4. 4. Mazda Motor Corporation

Looking one step ahead with its Skyactiv technology, Mazda introduced the CX-5. It also released the Atenza (which went on sale in 2013) equipped with both the Skyactiv-D and G variants (Fig. 11). The pioneer into the field of clean diesel technology was Nissan Motor Co., Ltd. with the X-Trail, but the introduction of the CX-5 shows that other automakers are finally willing to accept diesel engines as a normal technology. This engine is both very innovative and is also receiving high praise for its tuning and running stability.

The Atenza (Fig. 12) was released in both sedan and wagon formats that feature beautiful styling. It is also available with a 6-speed manual transmission (6MT) to appeal to car lovers who want to really enjoy the driving experience. At the same time, this vehicle was also designed to achieve thorough environmental performance. To reduce the amount of wasted energy, it features the i-ELOOP regenerative braking system as standard equipment and uses high-capacity electric double-layer capacitors to store regenerative energy (Fig. 13). The

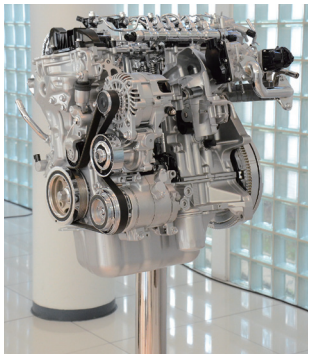


Fig. 11 Skyactiv-D, 2.2-liter diesel engine.

Fig. 12 Well-regarded styling of the Mazda Atenza.

Fig. 13 Capacitors that store regenerated energy.

ability to take advantage of the instantaneous charging and discharging characteristics of these capacitors is a new innovation.

4. 5. Fuji Heavy Industries Ltd.

The BRZ (Fig. 14) is a pure sports car that was jointly developed with Toyota to utilize the low-center-of-gravity design that is the specialty of the boxer engines cultivated by Subaru over the years. Recently, there has been rising concern about the falling number of people who like and have a strong interest in vehicles. However, the introduction of this type of sports car creates more opportunities for having fun and enjoying driving. Therefore, it was given high marks for possibly planting the seeds of future vehicle and racing fans.

Fig. 14 The BRZ is a sibling to the Toyota 86.

Fig. 15 The Forester easily overcoming large bumps.

Fig. 16 The XV compact urban crossover.

Subaru also released a new Forester (Fig. 15) with the potential of a genuine SUV, the XV (Fig. 16), which is equipped with a four-wheel drive (4WD) system designed for urban environments, and the XV Hybrid as a top-level model in 2013. There is certainly a feeling that Subaru has gained momentum. Subaru has definitely established itself as a leading manufacturer of boxer engines and all-wheel drive (AWD) systems. On top of earning the customer's trust, the prices and appeal of Subaru's vehicles are also major appealing points. For example, the X-Mode system performs all the required vehicle controls automatically to ensure that the vehicle does not lose grip, even under adverse conditions that cause each wheel to lose ground-contact force.

4. 6. Mitsubishi Motors Corporation

Mitsubishi is also characterized as a SUV specialist. The Outlander was completely re-designed and launched

Fig. 17 The 2-motor Outlander PHEV with similar driving characteristics to an EV.

Fig. 18 Various remote controls are possible through a mobile terminal.

as a vehicle with superior environmental performance in tune with the times. Two months later Mitsubishi also released the Outlander PHEV (Fig. 17). This vehicle gained attention for its unique hybrid system that uses an electric motor in both the front and back of the vehicle. The innovative aspect of this parallel hybrid system is that the controls attempt to mimic the running of an EV as closely as possible. The hybrid system can even switch to a series hybrid format depending on the driving conditions. In other words, there are cases where the engine is only used for generating electricity and the vehicle is switched to EV drive mode. Although the power of the engine is not transmitted to the rear wheels, the front and back motors are used to provide drive to all four wheels and the vehicle is also equipped with the Super All-Wheel Control (S-AWC) system that distributes the drive power to the left and right sides of the vehicle. In addition, the vehicle is fully equipped with a plethora of other advanced technology and equipment (Fig. 18).

The Mirage brand of vehicles was resurrected (Fig. 19) and is now equipped with a 3-cylinder 1-liter engine. This vehicle has a surprisingly low price of under 1 million yen ($10,000 USD), but its strongest appeal is as the most fuel efficient conventional registered vehicle in Japan. In some ways, the attributes of this vehicle rival those of mini-vehicles.

Fig. 19 The Mirage leads all new vehicles in fuel economy.

Fig. 20 The Wagon R was introduced with improved environmental performance.

4. 7. Suzuki Motor Corporation

The huge success of the Wagon R (Fig. 20) played a big role in building up Suzuki to become the number one mini-vehicle manufacturer. A major characteristic of the new Wagon-R model is improved environmental performance, typified by the Suzuki Green Technology, which received the RJC Technology of the Year Award. One part of this new technology is ENE-CHARGE, a mild-hybrid system that has been promoted heavily in TV commercials. This is combined with an idling stop function and an electric air-conditioning system called ECO-COOL to help reduce unnecessary fuel consumption and achieve a fuel consumption of 28.8 km/liter. Incidentally, these same technologies and methods were adopted on the Alto sedan, which achieved a fuel consumption rating of 33 km/liter, one of the best of all mini-vehicles. The ENE-CHARGE system uses the energy (electric power) from the regenerative braking system to charge a small lithium-ion battery that is located beneath the front passenger's seat (Fig. 21 and Fig. 22). This battery is then used to provide electric power to the audio system and other equipment. This makes it possible to reduce the load on the alternator that is driven by the engine. Another special characteristic of this technology is that the ECO-COOL system can maintain the operation of the air-

Fig. 21 The ENE-CHARGE lithium-ion battery is located below the front passenger's seat.

Fig. 22 A small box tray under the front passenger's seat is an appealing and thoughtful design point.

conditioner to a certain extent even when the engine is turned off during idling stop.

4. 8. Daihatsu Motor Co., Ltd.

A new type of tall wagon-styled cars, which are small in size but offer more interior space, are very popular and have become the mainstream for mini-vehicles in Japan. Many of these vehicles are now packed with advanced technologies to improve environmental performance and safety, and this style of vehicle has become a core model for many Japanese automakers. The Daihatsu Move (Fig. 23) is another example of this. It achieves a fuel consumption rating of 29 km/liter and is equipped with a remarkable amount of enhanced equipment. This is the result of repeated small improvements over time, but there was clearly an attempt to pursue every kind of efficiency, from a CVT that incorporates thermo-management technology to individual cylinder combustion control, an advanced i-EGR system, and the like (Fig. 24). Daihatsu has also added an idling stop function to all of its vehicles as standard equipment and the smart assist safety system to some of its models. This smart assist system uses laser radar as part of a low-speed collision-

Fig. 23 The Daihatsu Move, a popular tall wagon-styled car.

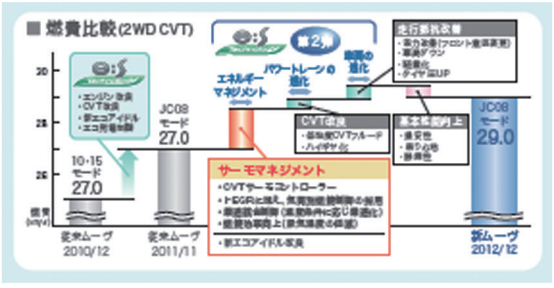


Fig. 24 Various technologies to improve fuel efficiency.

Fig. 25 Smart safety technology equipped on the Move.

avoidance device that automatically applies the brakes when the vehicle is traveling at a speed of 30 km/h or less and a potential collision is detected. This should make it possible to avoid a collision is many cases and also significantly decreases the damage that is suffered in the event of an actual collision due to the reduced speed (Fig. 25).

1 Major Topics this Year

The Mazda Atenza encapsulates some of the key vehicle design trends this year (Fig. 1). It was honored as one of the top 3 vehicles for the 2013 World Car Design of the Year Award. The vehicle that was eligible for the award was the Atenza model that was introduced in 2012. Three cars were chosen as the finalists for this award, the Atenza, the Jaguar F-Type and the Aston Martin Vanquish (Fig. 2 and Fig. 3). The award was finally won by the F-Type.

Vehicle designs appeal to people's emotions. In simple terms, designs instantly strike the viewer as one that is liked or disliked. However, elements contained within a design are not simple and include things such as the quality of the various vehicle functions and creative methods of making the vehicle ready for mass production (productivity). Design also incorporates expressions of the vehicle's inherent value that are related to artistic and cultural connotations. As a result, the design has a major impact on the product appeal of the vehicle itself.

For this reason alone, it is extremely difficult to evaluate a given vehicle design. Consequently, there is a tendency for attention to be drawn to vehicles with very innovative designs that make a strong impact and designs on the most novel, premium models, as well as if the vehicle is selected for the World Car Design of the Year Award.

Therefore, the fact that the Atenza (called the Mazda6 in Europe) in the comparatively orthodox sedan category managed to enter the top 3 suggests that it was widely judged to be a beautiful vehicle with excellent balance in the overall workmanship. It is also proof that the Atenza has been recognized as an outstanding product that stands as a fitting symbol of the year's best designs from amongst the many new models that were introduced.

In hindsight, the vehicle seems to express the passion that Mazda poured into the new development and it also features numerous uncompromising details that show the spirit of the development team. The unbridled enthusiasm of the development team clearly paid off in the end. From the development of the concept through to the finished product design, the unwavering application of methods to appeal to the customer contributed in no small part to the final achievement.

At the same time, the Atenza is also fully equipped with the SKYACTIV technology that Mazda advocates as an innovative, next-generation technology. This technology is a newly-developed and ambitious product. Mazda is aiming to achieve both driving pleasure and environmental friendliness while promoting a design study under the Soul of Motion slogan (Fig. 4). The Shinari and Takeri concept vehicles that were developed under this

Fig. 1 Mazda Atenza.

Fig. 2 Jaguar F-Type.

Fig. 3 Jaguar's Director of Design, Ian Callum, and the F-Type.

Fig. 4 Mazda Shinari and Takeri design studies.

slogan were well received. In particular, the flow of the design from the nose to the waist line to the rear of the vehicle creates a unique and characteristic body line by providing a strong impression of dynamism. This design gives these vehicles the image of a sports sedan and, by carefully layering on other design cues, a new, fresh, and appealing product is created that can easily differentiate itself from other 4-door sedans. This is truly a case of the strength of a good design. It is also an excellent example of the heavy responsibility of vehicle design to both appeal to the market as a vehicle (product), and to express the approach (strategy) of the manufacturer.

2 The Front Face of the Vehicle to Establish Brand Image

This topic overlaps with the previous one about Mazda, but there is now an obvious tendency on the part of automakers to adopt a uniform design for every vehicle in the lineup as a method of nurturing brand image. Not having a lot of models in the model lineup also helps, but the face of Mazda has established itself in the market already.

In other words, an icon that unifies the brand image was introduced so that anyone could instantly recognize a Mazda vehicle with a single glance. The adoption of a design that possesses at least one point of similarity, even if it is a different vehicle model, is a means of creating a single face for an entire family of vehicles. The accent on the different models is on the front face of the vehicles.

As a specific example, Mazda has adopted a reverse 5-sided pentagon grille (Fig. 5) that was initially called a 5-point grille, for the design of the radiator face. This whole design concept started back in the late 1990s when Mark Fields was the president of Mazda and the company started incorporating a sporty image into the character of Mazda's vehicles under the ZOOM-ZOOM

Fig. 5 Pentagon-shaped grille of the Mazda Atenza.

Fig. 6 Spindle grille of the Lexus GS450h.

slogan. The adoption of the 5-point grille was announced soon after that and a consistent stance in the manufacturer's design has been built upon ever since. This design philosophy has now become firmly established over the more than a dozen years that have passed since then.

Lexus, the premium brand of Toyota Motor Corporation, has also attracted attention to its design through the same method. In this case, Lexus has adopted a powerfully molded front grille, called a spindle grille (Fig. 6). The number of different Lexus models using this same design has increased as minor changes and model changes have presented opportunities to tweak designs. The aims of Lexus are clear: by creating a common face for the Lexus vehicle family through the adoption of similar front ends, Lexus can assert its individuality while clarifying its brand image.

Originally, Lexus employed a neat and well-defined front face on its vehicles that was referred to as the resolute look. This has been changed to a more dynamic style to express an evolution in design and to present a more straightforward image. Since the Lexus brand uses Progressive Luxury as its current design theme, it

Fig. 7 Volvo C30.

Fig. 8 Kidney grille of the BMW i8 concept.

Fig. 9 Kidney grille of the BMW R1200RT.

is possible that the spindle grille will change into something else in the future. However, for the time being, this is the face of the Lexus brand.

In addition, even though it does not present as strong a character as the designs described above, Subaru has also been employing a similar trend in its design through the use of an inverted trapezoidal grille and its 6-star constellation ornament. The design employed by the Swedish automaker, Volvo, features a diagonal stripe through the radiator grille that is well-known worldwide thanks to its simplicity and for evoking the Volvo-like nature of the design (Fig. 7).

The brand that is famous for using this design technique for many years is BMW from Germany. The historic front grilles of BMWs are referred to as kidney grilles and have been cultivated over the past 80 years. The sizes and shapes vary and there is no single grille design that is the same for every vehicle. However, anyone seeing these grilles is readily aware that the vehicle is a BMW. It is also remarkable that this design aesthetic is applied just as thoroughly to BMW's 2-wheeled products as well as its 4-wheeled vehicles (Fig. 8 and Fig. 9).

Of course the methods and techniques employed by automakers to establish their brand images are not limited to just the design. It is not possible to easily decide whether creating a similar front face for a whole family of vehicles is the correct strategy or not.

However, Japanese vehicle brands frequently seem to lose contact with history by lacking a consistent stance in design. There are many cases in which Japanese automakers have abandoned and resurrected vehicle names that customers had grown accustomed to or changed the name of next generation vehicles. Japanese automakers have also have tended to employ hastily formulated design strategies and often seem to become confused and almost panic-stricken about policy changes.

All policies have positive and negative aspects. However, even if a company makes repeated innovations, it will only gain the trust and empathy of the customer by providing consistency and sticking to certain aspects no matter what else changes. Design can help to create this feeling.

3 Powerful Expression through LED Headlamps

The words facial features are often used to describe the different parts of a person's face and the term front face can be used in the same way for a vehicle. The headlamps on the left and right sides and the radiator grille in the center of the front face of a vehicle are equivalent to the eyes and nose on the face of a person. As described in the previous section, the nose of the vehicle can contribute to the creation of a similar front face for a family of vehicles and also help to giving the vehicle a certain facial expression. In combination with the nose, the design of the eyes also plays a vital role and helps to express the concept of the vehicle.

The use of LED headlamps has come to occupy the mainstream in current front face headlamp design. Although the majority of vehicles using LED headlamps

Fig. 10 Headlamp of the Mercedes-Benz E Class.

Fig. 11 Headlamp of the Volkswagen Golf.

Fig. 12 Maserati.

are still premium and high-grade luxury models, there is already strong momentum behind expanding the use of LEDs to other vehicles. Such features are no longer a rarity.

LED headlamps are very bright, but have a low light intensity. The voltage required to emit light must also be balanced, so there are many cases of multiple LED lamps being used together. There are already many examples of LEDs being used in the tail lamps of vehicles as LEDs have an environmentally-friendly (power saving) image. Approximately 10 LED lamps may be used just on one side.

LED lamps are versatile enough to be arranged in lines (Fig. 10) or used in novel designs to create light lines via other methods. As a result, LEDs can be used to express a piercing look or a strong and gorgeous impression (Fig. 11 and Fig. 12). LEDs are already indispensable to many designers as one means of expressing the design intention. Even focusing exclusively on functionality, LEDs do not use much power and have excellent durability. As long as the cost can be brought down, the use of LEDs in vehicles will only increase in the future and these features will likely become even more popular with customers.

Fig. 13 Last original Volkswagen Beetle.

Fig. 14 Volkswagen New Beetle.

4 Incorporating Popular Classic Vehicle Designs as a Motif in Modern Designs

Vehicle designs of a half century ago are being revived in the present day. The Volkswagen Beetle (Fig. 13) that took the world's popular vehicle market by storm has been revived in the current era dressed in similar forms (Fig. 14 and Fig. 15). Its smile-inducing design and great sales produced a major success that is already a famous story in the automotive industry. Following this success, other brands such as MINI (Fig. 16 and Fig. 17) and manufacturers such as Fiat with the 500 (Fig. 18 and Fig. 19), and some U.S. manufacturers have also tried reviving other famous vehicles from the past.

There are cases of vehicle designs that created a big splash at motor shows, but then simply petered out and did not amount to anything more. However, designs that hearken back to a classic model that once ruled the mar-

Fig. 15 Volkswagen The Beetle.

Fig. 16 Original Mini Cooper (Rover).

Fig. 17 MINI.

Fig. 18 Original Fiat 500.

Fig. 19 Fiat 500.

Fig. 20 Honda N-ONE.

ket often have many elements that seem to naturally remind customers of those bygone days. There were classic models like that in Japan as well, but the N-ONE (Fig. 20) released by Honda in November 2011 was the first to be launched as a mass production vehicle. Predictably it became a big topic of discussion in the automotive industry.

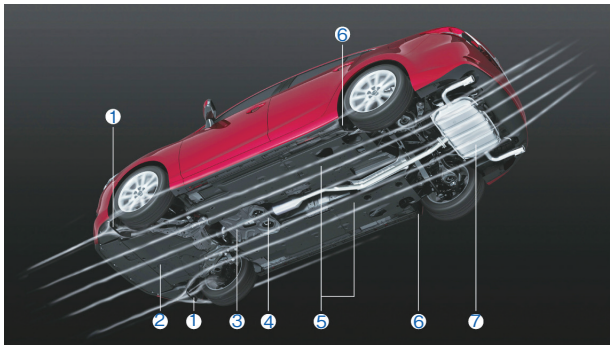
The origin of the N-ONE is the N360 (Fig. 21) that was introduced back in 1966. That period was the start of the motorization period of Japanese history and that model captured the hearts of the younger generation at that time (the baby boomers). It became a huge hit and firmly established Honda's position as a major Japanese 4-wheeled automaker.

However, other than the shared design elements, these two vehicles have very little else in common, especially in engineering terms. In fact, all that really remains from the N360 are vestiges of its front face and rear end. Some people in older generations may look at this design and remember the older model with some nostalgia, but the real aims of a design that uses a classic model as a motif is to evoke a unique sense of affection, create fresh appeal, incorporate the approach of the manufacturer, and the like. If customers feel that the design provides a sense of stylishness and the designers can master this fully, then a new feeling of delight can also be created.

Japanese automakers have already built up a long history. Consequently, if both automakers and customers

Fig. 21 Honda N360.

Aerodynamic parts used on the underbody



(1) Front tire deflector
(2) Engine under cover
(3) Tunnel cover
(4) Large tunnel member
(5) Center floor cover
(6) Rear tire deflector
(7) Flap-shaped silencer

Fig. 22 Underbody aerodynamic parts on the Mazda Atenza.

take the time reflect on the past, then other models may well follow in the footsteps of the N-ONE.

5 Vehicle Designs Evolving with the Times

Vehicle designs are always changing. There is repeated movement in the most characteristic portions, such as the body lines and the composition of the front face, but there is never any going back, just continuous evolution. This is not only due to changes in styling trends, but also due to continuous change in related issues, such as the pursuit of the required functionality, advances in materials, innovations in manufacturing technologies, and the like.

One of the special characteristics of vehicle design in recent years has been the pursuit of greater environmentally-friendly performance. Any kind of waste is being thoroughly eliminated to achieve better fuel efficiency. The vehicle design is being refined down to the finest details of the vehicle body to help improve aerodynamics.

Fig. 23 Underbody aerodynamic parts on the Mercedes-Benz B Class.

As better aerodynamic performance is pursued, this has led to designs with rounded corners and vehicles with narrowed rear ends. The rear end of the vehicle has a large impact on how the airflow is directed, so automakers have tended to put a lot of effort into perfecting the design in great detail.

The underbody of the vehicle is one area where there is still a lot of room to improve aerodynamic characteristics, so automakers are now starting to give this area more attention. The aim is to design the underbody to be as flat as possible by adjusting the shape of the vehicle body and the layout of the parts, as well as by applying new covers (Fig. 22). These efforts have even included the use of special flaps directly in front of the tires to intentionally generate air turbulence and alleviate some of the direct wind pressure on the tires (Fig. 23). All automakers are pursuing the same target of improved aerodynamic function, but there are fine differences in the points of emphasis, technological skill, and creativity of each manufacturer, which result in major differences in individual designs. This is what makes vehicle design work so interesting.

At the moment, automakers are working to reduce vehicle weight, which this has produced innovations in materials and processing technologies. If these advances can be combined with the wave of engine downsizing, it should not be that difficult to develop lighter vehicles. This may be a bit of an overstatement, but if collision mitigation (collision deterrence) technology increases in popularity and is used on more and more vehicles, then a very strong vehicle body to help ensure safety in a collision may no longer be necessary. It would also contribute to a significant reduction in vehicle weight and even better fuel efficiency. It may not be too far fetched to say that this era is right around the corner.

Vehicle Body Structures

1 A Close Relationship with Design

With a few exceptions, the monocoque structure has become the mainstream vehicle body structure for passenger vehicles at the current time. Some innovations in this basic structure have been seen over the years, but there have been few drastic changes. However, there has been an accumulation of incremental advances, as with vehicle design. Various new techniques, such as in materials and production methods, have been incorporated and there is no end to the improvements and maturation (progress toward higher efficiency) of the production system.

To survive in this industry in the midst of a wave of globalization, every automaker must increase production efficiency, even if only by slight amounts. When it comes to making changes to the vehicle body structure, automakers are always looking at ways to rationalize and reduce cost.

Vehicles have always been one of the best examples of mass production. Moreover, the advantages of creating an economy of scale are huge when attempting to succeed with a product that has such a high unit price. This affects everything, from the amount of production, the regions where production takes place, and the regions where the product is purchased, as well as the logistics of the materials and procuring parts from the suppliers. Efforts to reduce costs and take advantage of the benefits of mass production, including currency exchange rates, are the most important priority.

Many hopes and expectations are pinned on a product becoming highly regarded in the market and succeeding in terms of sales, which includes the sales strategy and sales promotion activities. These sales results have a significant impact on an automaker's profits. Therefore, a far-sighted, sound strategy for the medium and long-term is always required.

The exterior design of the vehicle determines the external appearance and the interior design forms the inside of the cabin. The industrial design that creates the structure of the vehicle body in conjunction with these other types of design also plays a major role. Furthermore, a macro-scale concept of the body structure that goes beyond just a single vehicle model is also an important factor.

2 Vehicle Body Structures

In simple terms, the design of the vehicle body structure starts with the selection of the parts that will be used and the distribution of (competition for) each space. This is performed to see how each of the essential mechanisms (parts), such as the composition of the cabin (seats) and trunk, as well as the engine, are going to fit within the vehicle. The design must also consider the vehicle's development concept and the expression of the original character that the designers want to emphasize. The vehicle functionality that is appropriate to that character must also be constructed, and the design must also facilitate the work of assembly workers. Balancing all of these competing demands makes the overall creation of a vehicle body structure a difficult job.

The vehicle's interior environment (the feeling of spaciousness and ease of use) can be changed depending on where the fuel tank is located and if the engine is designed to be compact. Then it becomes possible to make the cabin larger, even if the vehicle's body size stays the same. The adoption of front-wheel drive with a transversely mounted engine is one culmination of many efforts to rationalize these different factors (Fig. 1 and Fig. 2).

In recent years the downsizing of engines has become a prominent trend and new 3-cylinder and 2-cylinder engines have been introduced. This helps to ensure even more space in the engine compartment and some vehicles have even been created with an obvious amount of empty space. If it becomes commonplace for vehicles to be equipped with such compact engines, then the vehicle body structure should also be reviewed in conjunction with these changes to make the vehicle body even more compact and lightweight without sacrificing cabin space. This extra space can be utilized for any number of different purposes, such as improving the comfort of the vehicle cabin and improving safety. The size of this contribution cannot be overstated.

For example, in hybrid and electric vehicles it is necessary to have enough space to mount the batteries. Several years ago when the first generation of the A-Class developed by Mercedes-Benz was introduced, one

Fig. 1 Honda N-BOX.

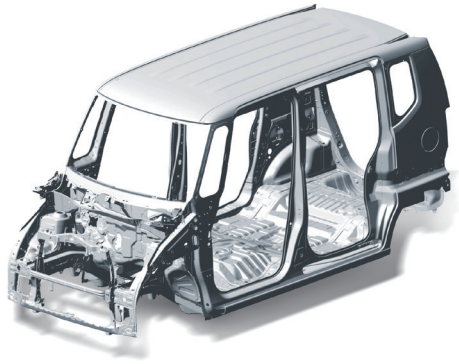


Fig. 2 Body of the Honda N-BOX.

of its special characteristics was a thick, flat floor design that attracted a lot of attention as an intentional design choice that anticipated the eventual mounting of batteries in the floor at some point in the future. However, at this time, the spread and adoption of battery electric vehicles (BEVs) is slow and fairly restrained. In addition, if a BEV uses in-wheel motors, the drive system would have a different relationship with the engine, and it is thought that the vehicle body structure would take on different forms to match the individual arrangements of equipment and systems.

Furthermore, in developed nations with a well-maintained system of roads, there are an increasing number of vehicles that are no longer equipped with a spare tire, since the puncture risk has decreased (Fig. 3). Run-flat tires that allow a vehicle to be driven for a certain distance after a puncture have also been introduced. Consequently, it may no longer be necessary to ensure space for a spare tire in the trunk. The vehicle body structure will also likely adapt and change little by little to keep pace with these changing times.

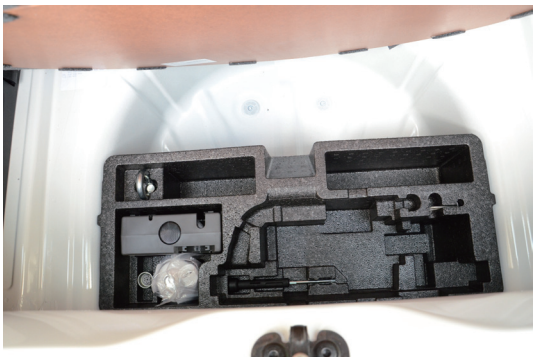


Fig. 3 Below the floor of the trunk in the Volkswagen up!

Of course, there are still many other essential structural requirements that must be incorporated into the vehicle body. For example, there must be countermeasures designed into the body to ensure safety in the event of a collision. A strong cabin to protect the vehicle occupants and a surrounding structure that will absorb the energy of the collision are just one of the essential requirements. The structure must be able to protect the occupants from any type of collision accident, starting with frontal and offset collisions. Even in a worst case scenario, a strong cabin that will ensure enough space for the occupants to survive a collision is now an important requirement. Vehicle safety has improved dramatically by combining airbags with other safety equipment. Collision safety requirements are becoming stricter every year and vehicles must now be designed to handle rollover accidents and to absorb collision energy from side impact collisions as well as from front and rear collisions. Currently, the number of fatalities from traffic accidents is continuing to decrease in Japan, and there is no question that improved vehicle safety has made a major contribution to this outcome.

Many automakers are now focusing on providing greater protection to pedestrians in the event of a collision as the next goal for vehicle safety. In fact, some vehicles are already designed with a certain amount of extra space between hard parts, such as the engine. The hood of the vehicle and the hood itself may even have a structure that helps to absorb impacts. There are also some vehicles that are equipped with a pop-up hood mechanism that lifts the hood up during a collision with a pedestrian to help mitigate pedestrian injury (impact values) (Fig. 4). The latest V40 model Volvo is even equipped with the world's first exterior airbag specifi-

Fig. 4 Pop-up hood of the Toyota Crown.

Fig. 5 Pedestrian airbag of the Volvo V40.

cally for pedestrians (Fig. 5).

Safety measures are an excellent way for automakers to express an image (intention) of safety to the customer. Therefore, safety equipment and vehicle body structures will continue to be enhanced and improved for the foreseeable future. This is a slight digression from the current topic, but if the various driving support systems continue to advance and vehicles become less likely to become involved in accidents (i.e., if vehicles are no longer at risk of collision), then the strong and safe vehicle bodies that have been developed up until now may no longer be necessary. In this case, extremely lightweight vehicles may eventually be introduced. If this happens, the materials used in the vehicle body structure may switch from metal to the use of plastics or other materials that are more environmentally-friendly.

Returning to the main topic, vehicles that are manufactured today often have a larger size body and thicker doors compared to vehicles from several generations ago. Another result of pursuing a stronger body structure is that vehicle weight has increased. Since environmental friendliness is also now a key aim, reducing vehicle weight has become one of a number of important issues that cannot be ignored. Reducing the weight of the vehicle is also essential to reduce environmental impact and improve fuel efficiency.

About a half century ago it was not at all uncommon for the popular cars of the day to achieve fuel consumption of 20 km/liter. Of course, this is not exactly a fair comparison because there were fewer traffic signals and vehicles were not equipped with air conditioning in the past. Up until the time that customers became more environmentally conscious and fuel efficient hybrid vehicles became more popular, there were still many cases where the greatest amount of time and effort went into improving the vehicle's dynamic performance, even on vehicles that were the subject of repeated technological innovations. From the standpoint of simply fuel efficiency, there are absolutely no signs of improvement whatsoever. One of the major reasons for this is the increased weight of these vehicles, which has a negative impact on fuel efficiency.

The environmentally-friendly vehicles of today, such as hybrid vehicles and those equipped with smaller sized engines, are attaining fuel economies that exceed the performance of those older vehicles from a half-century ago. However, today's customers are also demanding higher performance. This means that every automaker is undertaking meticulous efforts extending down to individual parts and introducing fundamental innovations in an unparalleled effort to reduce the weight of vehicle bodies.

3 Pursuit of Weight Reduction

Efforts to reduce vehicle weight are not new. Each time that a model change is carried out, the scale of the vehicle body seems to expand and the vehicle weight also increases. Successive changes to the vehicle become an opportunity to implement significant weight reductions, which can be promoted as one of the vehicle's sales points. The constant layering and overlapping of diligent, steady efforts with the proactive introduction of innovative new technologies ultimately result in significant reductions in vehicle weight. This helps to create huge value for new models when combined with improvements in power performance and fuel efficiency.

Efforts to reduce vehicle weight start at the level of trying to reduce the weight of each individual part, but automakers are also pursuing more efficient designs for the vehicle body structure and carefully selecting the materials that are used. This is where advances in CAE analysis are extremely useful and high-tensile steel sheets are also now being actively used. A high-strength

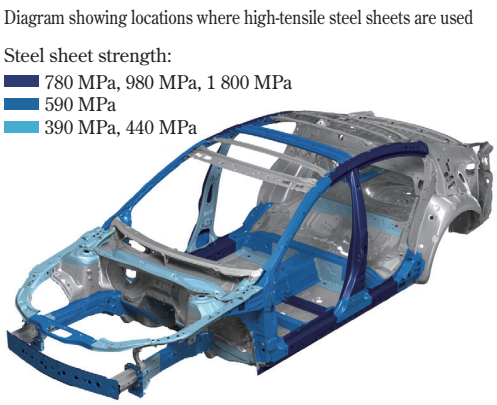


Fig. 6 High-tensile steel sheets in the Mazda Atenza.

Fig. 7 Image of stiff sections of the Volkswagen Golf body.

and lightweight vehicle body is finally completed by optimizing the designs of stampings, ribs, and stiffeners and also the welding methods (Fig. 6 and Fig. 7).

The use of high-tensile steel sheets can lead to higher costs, but if adopted prudently and effectively, then the strength of the body can be increased while also reducing weight. Consequently, the use of materials with different tensile strengths in the vehicle body is increasing. In addition, there are also many examples of the use of plastics and aluminum in the outer panel parts of the body to help achieve a significant reduction in vehicle weight.

In the realm of premium cars, the latest model from Jaguar, the F-Type, has a vehicle body structure that is made entirely from aluminum. This body does not contain a single weld and instead is held together with rivets and adhesive (Fig. 8). The all-aluminum vehicle body itself has existed for some time now, but production techniques are changing and improving with each attempt over the years.

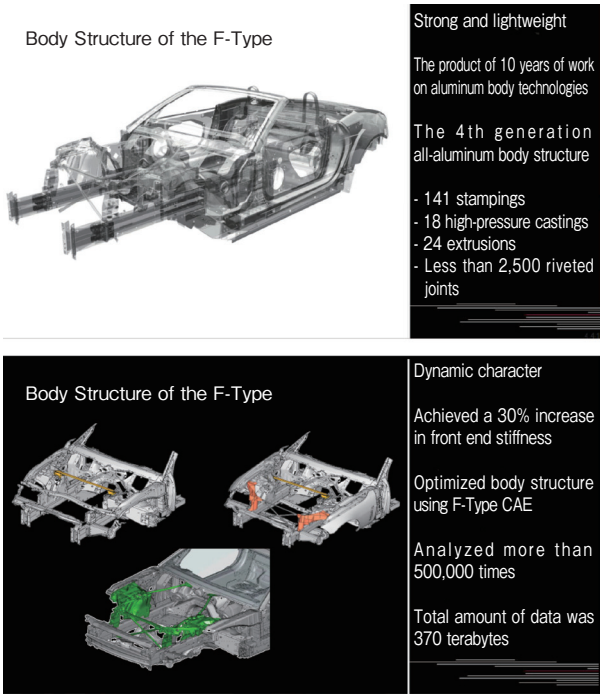


Fig. 8 Aluminum body of the Jaguar F-Type.

4 One Basic Design for Multiple Vehicle Models

Finally, one last characteristic of vehicle body design in recent years that cannot be overlooked is the concept of a single body structure to be used for multiple different models. This is referred to as the modularization of the vehicle platform. It has not yet progressed to the level where a sibling model can be released by simply changing the outer panel parts, but it can cover 3 different vehicle types. Considering the derivative models from these 3 types, then a large number of models can be covered by one vehicle body.

Of course, different models will have different vehicle widths and wheel bases, so it will still be necessary to adjust the body to each of these specifications, but having vehicle models that all use the same main parts will significantly improve productivity. Up until now there have been numerous examples of multiple models sharing a common vehicle body, both from a specific automaker and from partnerships between manufacturers. However, the idea of having a single vehicle body that can cover a wide variety of different vehicle ranks is now being put into practice.

A representative example of this production method is the latest design from Volkswagen, called the Modular

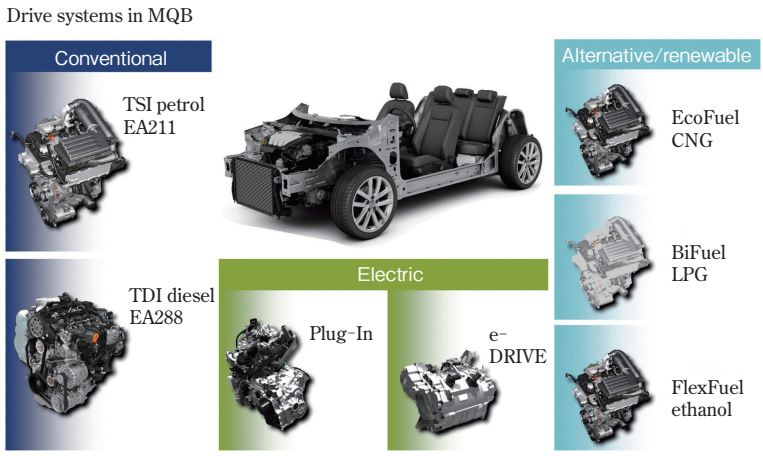


Fig. 10 Volkswagen MQB 2.

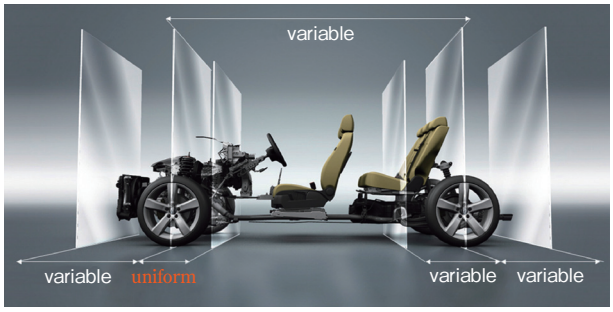


Fig. 9 Volkswagen MQB.

Transverse Matrix (MQB) (Fig. 9 and Fig. 10). Both the Audi A3 and the latest 7th-generation Golf were created using this modular vehicle body. The MQB can even be used for 2 other models with body sizes that are both larger and smaller than the Golf. In other words, this single body can cover 3 different sizes of vehicles, from the Polo to the Golf and up to the Passat. The basic structure is the same from the toe board at the foot of the driver's seat to the front axle, but it is possible to vary the size to accommodate different wheel bases, front and back overhangs, and the like. The special characteristic of this vehicle body is this structure, which allows for each of these different portions to be combined together.

Volkswagen's plan is to deploy the MQB globally over the next 10 years and achieve production of 4 million vehicles. It is already making a major contribution to higher efficiency in production plants, reducing the time needed to complete assembly of a vehicle by about 30% compared to a conventional vehicle body. The MQB is flexible enough that it can handle the changes in vehicle design that will be required in the future and it can also be used for BEVs. The cost benefits from this large scale production are enormous, so there is little doubt that other global automakers will introduce the same concept in designs and plants in the future as well.