# Form Characteristics of an Electric Vehicle

**Dirk van Gogh [1], Kikuo Emoto [2], and Hiroshi Shimizu [3]**

[1] *Department of Architecture, Fine Arts and Audiovisual Art, Dirk.vanGogh@hogent.be*
[2] *Faculty of Environmental Information, Keio University, emoto@sfc.keio.ac.jp*
[3] *Faculty of Environmental Information, Keio University, hiros@sfc.keio.ac.jp*

## Abstract

*The shape of today's vehicles on the actual automotive market is based on the packaging design of an internal combustion engine (ICE) that is very different of that of an electric vehicle (EV). In this paper specific form characteristics that express the difference between an EV and an ICE vehicle are researched and illustrated. Based upon these determinations, three different outer designs are applied on one and the same high performance electric vehicle, named KAZ. At first, KAZ represents a half box car that is shaped by two different units colored in 2 gray colors, two 'air intakes' are set in the front of the car left and right and secondly, KAZ is reformed to be driven on a traffic road. The third KAZ shaped with a renewed form design of the front panel, shows an environmental friendly and full electric powered expression.*

## Keywords

*electric vehicle, design, modeling*

## 1. INTRODUCTION

Consumers of the general automotive market need to be convinced of the advantageous characteristics of electric vehicle technology [Shimizu, 2001], which is important for our environment [Kondo et al., 1996], as well as for more comfortable traffic [Magetto, 1998]. Therefore, form characteristics are indispensable to visualize the specificity of an electric vehicle (EV), so that its environmental friendly image and its highly efficient technology can be clearly seen by the world wide public. The shape of today's vehicles on the actual automotive market is based on the packaging design of an internal combustion engine (ICE) [Shimizu, 1996], which is very different from that of the EV technology. On the traffic road, the outer design of an EV looks similar to a normal conventional gas oil engine vehicle, because its form design does not express its difference [van Gogh, 2001]. For this reason, form characteristics are researched and created to express the specificity of an electric vehicle.

In this paper, based upon the EV technology that can be applied to a vehicle, exclusive form characteristics are researched. New specific form designs with pure 'electric vehicle image' shapes are proposed and visualized. And finally 3 types of styling designs are applied on to one and the same running electric vehicle prototype, KAZ [Shimizu, 2001], which means Keio Advanced Zero Emission Vehicle.

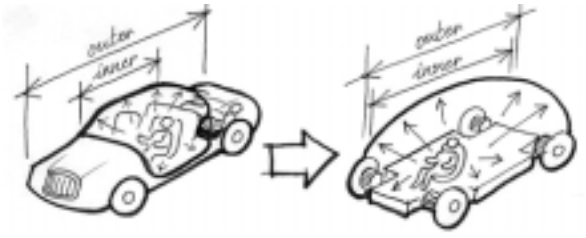
## 2. FORM CHARACTERISTICS OF THE EV-TECHNOLOGY

### *2.1 The effect on design of EV system technology*

To create a pure electric vehicle image three original system technologies are applied: the in-wheel drive system, the component built-in frame system and the tandem suspension system [Shimizu, 2001]. Each system technology has an effect on the outer and inner design of the vehicle and new merits have arisen for the designer to be able to reshape the body structure and to originate form details for an EV.

### *2.2 The effect on design of the in-wheel motor system*

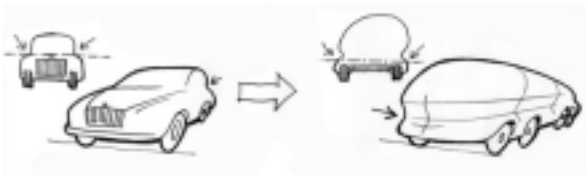
When the in-wheel motor system is applied on to an EV, the space for the motor, reduction gears, wheel bearing and mechanical brake is assembled in one compact-sized motor system that is set inside each driving wheel. This entails that the space in the cabin can be increased [Shimizu, 2001], which can be brought to expression through three form characteristics: a transparent interior equalising inner and outer space, a low styling line at the outside and '2 air holes' in the front left and right. Firstly, not needing an engine room offers the most efficient space for interior arrangements of the vehicle. Comparing the outer dimensions of an ICE-car with that of an EV, a wider interior cabin space can be made on the same dimension. To turn this advantage into a unique




internal combustion engine vehicle (ICEV) electric vehicle (EV)

**Fig. 1** Inner and outer space can be equalised on an EV

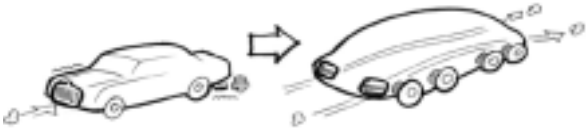
form design, a transparent interior is proposed where the passengers as well as the driver can look to the total size of the inner and outer dimension in one view as shown in Figure 1.
Secondly, an ICE vehicle is shaped with a styling line at the middle elevation on the outside of the vehicle which represents the type of the gas oil engine that has been roofed in. Such a line from the hood to the trunk, as can be seen on many ICE cars, as shown in Figure 2 (a), isn't needed anymore on an electric vehicle. EV's in wheel motor systems are located at the same level as the height of the wheels, so it is much more evident to shape a styling line at a low height, as shown in Figure 2 (b).



(a) ICEV (b) EV

**Fig. 2** Low styling line at the side of the EV

Thirdly, as the engine of an ICE car has to be cooled, the cooling grid was always typical of the image and the type of car. The character of the ICE car is closely intertwined with the motor in use. Many brands, by the way, represent the inventor of the motor. Consequently the form of the grid in the front is the expression of the capacity and the character of the model.
Such an ICE car grid is replaced by two 'air holes' on an EV, two openings in the each front left and right side of the car, which allow the necessary cooling for the in-wheel motor. The same image as a conventional ICE car is connected to the size and type of the cooling grid thus formal styling design and size of the two 'air holes' in the front of an EV are giving a specific expression to an EV as shown in Figure 3.



ICEV EV

**Fig. 3** Two air holes in the front left and right on an EV

### *2.3 The effect on design of the component built-in frame (CBF)*

In an ICE vehicle there are mufflers and propeller shafts under the floor. In an EV and when an in-wheel motor system is applied, all these components are neglected so that no transmission axles are needed under the floor. Because the space under the floor becomes available, a well-built flat frame structure is situated under the floor and all major components are inserted into the vacant space of the structure. The effect of this technological innovation on the form design of the body structure is that the car can be transformed to a 1/2 box model, providing a very flexible and versatile interior arrangement and the height of the EV is measured lower, compared with today's similar ICE.
The first consequence is the 1/2 box vehicle type that replaces the 3 box car model. An important change in car-styling design happened when the horse was replaced by an ICE motor. Because of this, the first car models came into being and many of them looked like the earlier coaches as illustrated in Figure 4.

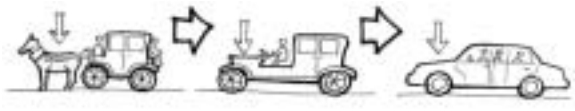
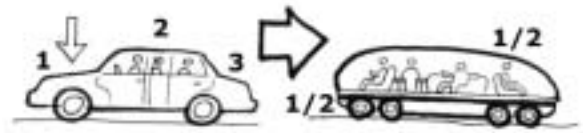


**Fig. 4** From 'Coach Image' to 'Car Image'

After almost a hundred years the actual design with a characteristic 'car-identity' came into being: the hood, the passenger cabin and the trunk, which can be seen as a 3 box vehicle. In the case of an EV 1/2 box type the vehicle is divided into a passenger's cabin and a running chassis, so that total cabin space can be considered as one user space, where trunk, seats or tools are integrated and easily installed on one and the same chassis as shown in Figure 5.




ICEV's 3 box type EV's 1/2 box type

**Fig. 5** From 3 box vehicle type to 1/2 box vehicle type

The cabin is one 1/2 box and the chassis the other 1/2 box which makes the form characteristic of a totally different vehicle. Every cabin has its own identity, likewise the 1/2 box vehicle type makes it possible to share

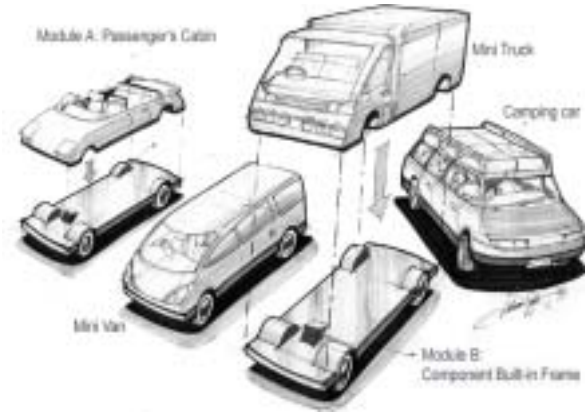
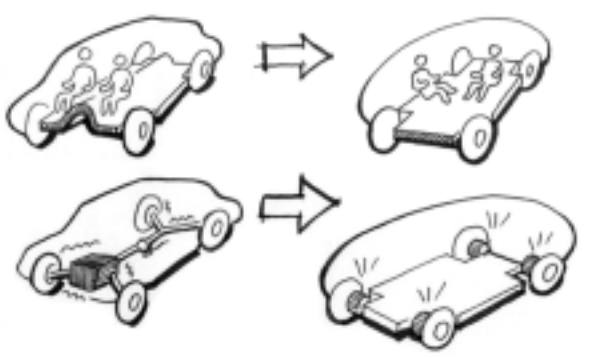



**Fig. 6** Different cabins on one and the same chassis

one and the same running chassis with different cabin types as shown in Figure 6.
The second consequence is the characteristic of a very flexible interior arrangement on the full flat floor of an EV. This replaces the ICEV's two line seat arrangement as it was in between the axle housing in the middle of the car. On an ICEV, in between the passengers, a hump was created hiding the transmission rods of the motor to the wheels for the forward motion. An ordinary design of an ICE vehicle therefore makes no visible difference between the shape of the technical construction and the shape of the passenger's cabin.
On an EV, the difference between the movement part and the user's cabin is evidently obtained by the versatile seat arrangement inside the cabin and the 'high tech' flat floor base as illustrated in Figure 7.



Two line seat arrangement EV's versatile interior arrangement

**Fig. 7** Difference of the interior seat arrangements between an ICE vehicle and an EV

The third consequence is the low height of an EV compared with today's similarly designed ICE-cars. The flat and strong structure of the floor was delineated so that a footboard of 28 cm could be made practical to get in and get out of the vehicle very easily. When the inner space is made the same as on a ICEV, the outer height can be set lower on an EV, thanks to all the integrated components, so that the space inside the cabin increases, as can be seen in Figure 8.

**Fig. 8** Low height of an EV thanks to the CBF

### *2.3 The effect on design of the tandem wheel suspension system*

The EV technology of the tandem suspension where a large sized wheel is separated from two smaller sized wheels effects three form characteristics on the body structure: a multi-wheel expression is made, axles can be constructed in the middle of the car and finally a free door concept can be installed.
Firstly, a multi wheel expression is made possible. As the power is generated by an in-wheel motor system on each wheel, the expression of high performance is related to the amount of wheels on the chassis of an EV. As a result, the classically long hood of an ICE car can be replaced by possibly removable hubs as shown in Figure 9.

**Fig. 9** Long hood becomes hubs on each wheel

Secondly, the component built-in frame combined with the tandem suspension makes the position of each axle on the chassis easier to design and uncomplicated to modify as its structure is not only low but also has a simple structure [Onishi, 2003]. For that reason the structure no longer needs one axle in the front and the other at the back as it was on conventional ICE vehicles. As a form characteristic of an EV, the axles can be set anywhere on the chassis without trouble as illustrated in Figure 10.

**Fig. 10** Many wheel axles can be set anywhere

Thirdly, the doors to get in and out can be put anywhere. As the large wheel is replaced by smaller wheels, it makes it possible to foresee a door concept everywhere on the chassis. A door can even be positioned above a tandem wheel suspension, thanks to its limited sized wheelhouse and because each oil compressor is connected by an oil pipe that is integrated in the component built in frame, as shown in Figure 11.

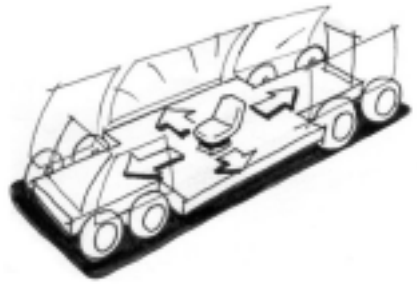


**Fig. 11** A door concept can be positioned anywhere

The following chart, as shown in Table 1, represents the outline of the form characteristics that are originated based upon the most recent EV technology. Using this chart, any electric vehicle concept can be shaped into a

**Table 1** Outline of the specificity of an EV

| EV technology | Form Characteristics of an EV | Effect on the Concept Design of an EV |
|---|---|---|
| *In-Wheel Motor System (IWDS)* | - a **transparent interior** without motor room<br>- a **low styling line** at the side of the vehicle<br>- **two air holes** in the front left and right | - **inner and outer space can be equalized** on the body structure<br>- the **wheels can be enveloped** by replaceable hubs covering the motors<br>- the air-intake can be foreseen at the side for **cooling** the in-wheel motors |
| *Component Built-In Frame (CBF)* | - **½ box** vehicle type<br>- **versatile interior** - and seat arrangements<br>- the total **height** of the EV is made **low** | - different **cabins can be installed on one and the same chassis**<br>- **different functions** inside the vehicle can be obtained<br>- the **outer** size of the chassis corresponds with the **inner** size of the cabin |
| *Tandem Wheel Suspension System (TWSS)* | - a **multi wheel** expression is made<br>- **axles** can be set **anywhere** on the chassis<br>- doors can be put above the TWSS | - the **performance** of the vehicle can be related to the **amount** of wheels<br>- the **position of each axle** can be modified easily on the CBF-chassis<br>- a **free door concept** can be generated on the cabin |

more specific manner which is much different to that one of an ICE vehicle.

## 3. SPECIFIC DESIGN CHARACTERISTICS TO SHAPE A PURE ELECTRIC VEHICLE IMAGE

### *3.1 Double direction drive, symmetric styling design*

Taking into account the above mentioned form characteristics, integrated applications are generated and offer a specific styling design for shaping an EV.

A dual direction drive f.i. can be applied when quick motion to the front or the back is needed. Considering time as an important factor in transportation, passengers can be transferred more quickly without turning the vehicle.

To express that an EV drives equally fast forwards as it does in reverse, a symmetric packaging design is prepared as shown in Figure 12.

**Fig. 12** Symmetrical styling for a double direction drive

### *3.2 The presence of electricity is expressed by means of the EV line on the outside*

The battery content can be expressed by means of a green-yellow line applied around the car. In this way the battery content is visualised on the exterior and an EV expresses more of an 'own' car image as illustrated in Figure13.

### *3.3 Two pairs of wheels with distance and two pairs with limited distance in between*

Depending on the position of all exits and entries on an EV, the setting of the wheel axles on the chassis follows the most efficient seat layout of the vehicle. Therefore it is possible that the TWSS offers two pairs of wheels with distance and two pairs with limited distance in between

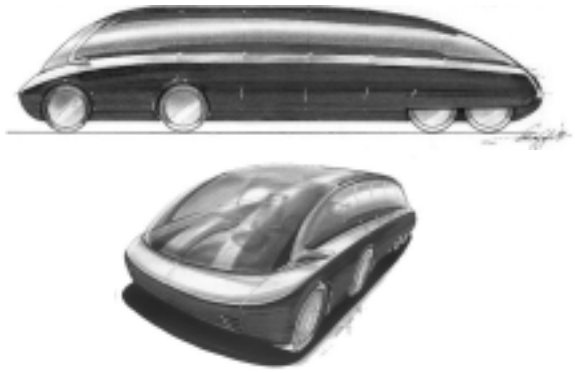


**Fig. 13** Battery content, visualised at the exterior of an EV

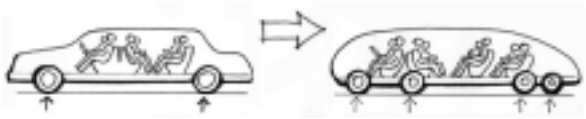


**Fig. 14** The setting of the wheel axles on the chassis follows the seat layout of the EV

on one and the same vehicle as shown in Figure 14.

Connection potentials of different EV's to each other exist thanks to the flexible possibilities to apply the pairs of wheels on a different EV's chassis structure. In this way a specific feature of an EV is generated in future applications.

## 4. APPLICATION OF THE FORMAL DESIGN CHARACTERISTICS ON THE RUNNING PROTOTYPE OF KAZ

### *4.1 KAZ model I 2001, for Geneva's Motor Show*

As most developed EV's are related to small vehicles with a low performance, as we f.i. can see inside today's airports and public spaces, a high performance electric vehicle KAZ was developed based upon today's recent EV technology to change this 'low value EV image' [Shimizu, 2001].

A running prototype was developed in and presented at first in Geneva's 'Salon de l'Auto'2001. To convince the public opinion that the shape of an EV is really different from an ICE car, the above researched elements of the form characteristics should be applied as best as possible, so that its styling design should be a consequence of the 'EV technology'. Therefore, in each faze of the KAZ's development from the first sketches to the final prototype, these form characteristics were being taken into account and evaluated as if it was possible to install it on a real running prototype. On the following vehicle types of KAZ, built upon one and the same chassis, each form design related to the 'EV technology' that could effectively be put into reality is explained.

When KAZ was shaped to be presented at first as a concept car at Geneva 'Salon de l'Auto 2001, the form char-

acteristic of a 1/2 box vehicle type was shown clearly. Dividing the passenger's cabin and the running chassis by using a renewed low styling line in dark gray under the titanium colored gray of the outside, the 1/2 box design characteristic was made visual, as can be seen in Figure 15.


**Fig. 15** Form design of the '1/2 Box Type'

Besides the form characteristic of EV's equalized inner and outer space, inside the cabin is expressed by the small dimensioned front nose and the limited sized back part, as shown in Figure 16.

**Fig. 16** Form design of the 'Equalized Inner and Outer Space'

### *4.2 KAZ model II 2002, for driving on the road*

After the first presentation in Geneva, KAZ was reshaped and adapted for the legislation of today's traffic road, because KAZ should be seen on the road showing its fundamental differences in the structural and form design, compared to conventional automotive technologies.

For the reason of legislation, the front glass is being replaced, side mirrors have been set and a wiper is being installed as well as opening windows being added at the side of the frontal swing doors.

On the traffic road most vehicles are ICE cars and the motor of an ICE car has to be cooled the cooling grid was always typical of the image and the type of car.

With the running prototype of KAZ, this is replaced by '2 air holes', 2 openings in the each front left and right


**Fig. 17** Form design of the '2 Air Holes'

side of the car, which allows the necessary cooling for the 8 wheel motors while driving, as can be seen in Figure 17.

### *4.3 KAZ model III 2003, for Detroit Motor Show*

Reconsidering that the specificity of the presence of electrical energy should be expressed by means of an EV light line on the outside, a renewed front panel is shaped presenting the electrical data on the 'front display line' of the KAZ vehicle. This renewed 'front display line' integrates also the side mirrors, the wiper and the frontal lights, as illustrated in Figure 18 and as presented at Detroit's Motor Show 2003.

**Fig. 18** Form design of a 'Front Display Line'

In addition, the presence of electrical energy stored by the lithium-ion batteries in the chassis can also be expressed by an illuminating line at the side. This line visualizes the battery content and it can bring the 1/2 box vehicle type to expression by lighting up at the po-

**Fig. 19** The battery content is visualized by the form characteristic of an 'EV Light Line' at the side

sition of the separation of the cabin and the chassis, as shown in Figure 19.

As the in-wheel drive systems are also typical for an EV, the wheels can be illuminated lightly so that this difference of power supply of an in-wheel drive, compared with the power supply of an internal combustion engine can be seen more exactly. This is represented on the side view as illustrated in Figure 20.

**Fig. 20** Form design of slightly lighting up 'in-wheel drive's' on the side of an EV

## 5. CONCLUSION

This paper shows specific form characteristics to shape a specific EV design that is very different to an ICEV. To show this difference, a high performance running prototype, named KAZ, was developed to illustrate how far those form designs can be applied to a real vehicle. For this reason, new form characteristics were originated on paper at first and verified afterwards during the development of the real model of KAZ. Our investigation convinced us that from the first KAZ to the third KAZ, each following reshaped and modified KAZ model is expressing a more accurate EV image. The form characteristics can be applied on any type of electric vehicle that must be produced, so that its explicit difference to an ICEV can be expressed without misunderstanding. By realising such form characteristic based vehicles, the public opinion can, behind this fashioned styling design, be convinced of the advantages of an EV as there is the positive impact of energy consumption and its environmentally friendly concept originated by the most recent EV technology.

## References

Kondo, Y., Y. Moriguchi, and H. Shimizu, Analysis of $LCCO_2$ for the Electric Vehicle IZA and a Gasoline Vehicle, *Research Report*, Vol. 17, No. 5, 486-492, 1996.

Magetto, G., Electric Vehicle Technology: a Worldwide Perspective, A Technology Roadmap for the Future, Digest No.1998/262, *IEE Colloquium*, 1998.

Onishi, M., S. Matsugaura, T. Nakamura, K. Kawakami, and H. Shimizu, Maneuverability performance of Tandem Wheel Suspension system, *Proceedings EVS 20*, 15-19, 2003.

Shimizu, H., K. Kawakami, Y. Kakizaki, S. Matsugaura, M. Ohnishi, D. Gogh, J. Norek, and L. Melotti, KAZ the Super Electric Vehicle, *Proceedings The 18th International Electric Vehicle Symposium*, 245-248, 2001.

Shimizu, H., J. Harada, L. Chan, K. Kawakami, and J. Ochiai, The Eco-Vehicle, a Sustainable Personal Transportation System, IPC-VI Designing for a Sustainable Future, *Conference proceedings*, 1996.

van Gogh, D., and H. Shimizu, Concept of 'KAZ' The Start of a New Generation in Car Design, *Proceedings The 18th International Electric Vehicle Symposium*, 190-191, 2001.

van Gogh, D., K. Kawakami, H. Shimizu, J. Norek, and L. Melotti, Design Concept of High Performance Electric Vehicle "KAZ", Bulletin of JSSD, *The Science of Design*, Vol. 49, No. 6, 27-36, 2003.

(Received May 6, 2004; accepted June 23, 2004)