

Some Cues to Design Effective HMI for Green Car in Fiat Group Automobiles

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ABSTRACT

Environmental issues have become a full part in the process of developing vehicle concepts: new driving technologies as alternative fuels or hybrid engines will be applied on a much wider scale in the future. The design of CNG vehicles introduces new problems dealing with the in-vehicle user interface alternative fuels symbols, specific indicators and switches, that we try to discuss in this paper.

Categories and Subject Descriptors

H 5.2 [User Interfaces]: *benchmarking, ergonomics, evaluation methodology, screen design.*

General Terms

Design, Human Factors.

Keywords

Benchmark, Bi-fuel vehicle, CNG, Fiat, Green Car, HMI, Icon, User Interface.

1. INTRODUCTION

Environmental issues have become a full part in the process of developing vehicle concepts. There is a large agreement about companies being responsible not only for the technical performance of their products, but also for their environmental impact. This results into growing expectations towards car manufacturers, concerning strategies and design policies which meet the environmental challenges of the future. As a whole,

this new trend of the automotive industry may be labelled "Green car".

The "Green car" approach must be translated into concepts which are able to meet challenging environmental results. [11]. So far, the proposals from the car manufacturers are very different: from lightweight and smaller passenger vehicles filled by alternative fuel, new diesel and hybrid engines to completely alternative driving concepts. New driving technologies as alternative fuels or hybrid engines will be applied on a much wider scale in the future, mainly because of two principal reasons: the environmental reason and the increasing fuel costs [18].

For that matter, one of the latest trends of the automotive industry is to directly produce vehicles using Compressed Natural Gas (CNG) as a transportation fuel. The immediate advantage of using CNG is to reduce tailpipe emissions [10].

The mass production of CNG vehicles introduces new problems dealing with the in-vehicle user interface as the instrument panel cluster indicators and the usability of the user controls. Aspects like alternative fuels symbols, specific indicators and switches have been poorly discussed so far in the human factors literature. Minimum HMI requirements concerning bi-fuel vehicles are defined by government regulations or the relevant national or international standards, as the norms of the International Standards Organization, ISO. Little research results are available about the usability of such systems, and there are no specific guidelines aimed at designing in-vehicle HMI for bi-fuel vehicles. Since users' awareness about the state and functioning of bi-fuel vehicles is a key factor for environmentally responsible driving, we believe special

attention must be paid to these issues. This paper is about Fiat Group Automobiles experience in designing bi-fuel HMI, and it aims at providing some basic cues for discussion, that will hopefully be transformed in design guidelines through future work.

2. BI-FUEL VEHICLES: CNG BASIC FEATURES

Generally gaseous fuels are very clean fuels with low emissions and they are easy to use in the engine. The main component is methane CH₄ which has a very good ratio between carbon and hydrogen. Generally speaking, gaseous fuels (especially methane) have only half of the CO₂ emissions than oil based fuels [10]. Using gas in a power engine is not in truth a problem, because power engines burn always a gaseous mix inside. The problem is storing the gas in the car in a quantity that allows the car to drive about 500 km without a tank stop. For this reason it is necessary to use CNG (Compressed Natural Gas) or LNG (Liquefied Natural Gas) [10].

CNG requires a very strong tank to store it by a pressure of about 200 bar and who has also enough security reserves in case of an accident [10]. The tank station has the same problem. On the other hand LNG needs very low temperature to stay liquid. It can only be managed with very specialized high-tech tanks with expensive materials and a robust isolation. This is the reason why many companies which produce engines that can be fed by gaseous fuels choose CNG [10].

3. CONCEIVING AN APPROPRIATE HMI

Under an HMI perspective, some specific requirements must be met in bi-fuel vehicles. In order to have a user-friendly interaction, the instrument cluster must provide a set of information that makes the user aware of the current state of the vehicle.

Therefore, the user basically needs the following instruments:

- Fuel indicators (for CNG and for gasoline), be they digital or analogical
- Fuel switch¹, automatic, manual or both.

More specifically the user needs to know:

- About the fuel level
 - the precise fuel level,
 - when the vehicle points out the fuel reserve (for both fuels)
 - the presence of a failure to the fuel level sensors or in the system
- About the fuel switch:
 - The current carburant in use
 - When the vehicle automatically changes fuel

¹ The switch is fundamental to give the user the possibility to shift from a carburant to another. A user-friendly bi-fuel vehicle implements an automatic switch from CNG to gasoline when the CNG tank is empty.

3.1 Identifying Criticalities

Further requirements come from the product's identity standpoint: particularly, discontinuities with respect to the other versions of the same vehicle must be minimized. When this is not possible, the new components must however be designed in order to support the CNG car driver's needs.

Each indicator mentioned in the previous paragraph has been introduced into the dashboard of new Fiat bi-fuel green cars (i.e., Fiat Grande Punto Natural Power), after a careful evaluation of pros and cons which appeared in different solutions.

Two types of instrument cluster display may be installed on Fiat Green Cars, i.e.:

- Comfort display: it is a segment display², with a dot matrix row employed to write messages and menu items.
- Matrix display: it is an all dot matrix display, fully reconfigurable, the layout of which was designed to accommodate different types of information, alarms and menus.

Thereby the major criticalities were about:

1. The introduction of the CNG indicator into the available display, because of their little dimension both for Comfort display and Matrix one, that made it difficult to design a proper CNG reserve strategy

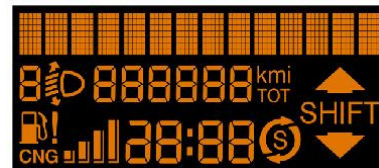


Figure 1 A picture of the Comfort display

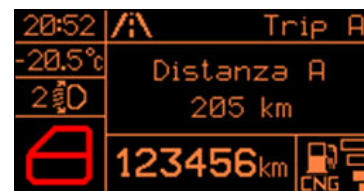


Figure 2 A picture of the Matrix display

2. The fuel switch that involves the status change of several components: the switch button, the telltale on the instrument cluster, the information management on the trip computer³ menu. All this information and

² Any modification to this display is a serigraphy.

³ The Fiat Trip Computer shows the user useful information about his/her current trip, such as average speed, covered distance, time and so on. For the bi-fuel vehicles it is important to maintain separated the data concerning gasoline feed and those concerning CNG feed.

these changes have to be consistent, in order to assure the correct understanding of the current fuel level. This point has an intrinsic criticism, concerning the automatic or manual fuel switching. When the vehicle automatically switches from a fuel to another, the driver's situation awareness⁴ should not be compromised: the system must correctly communicate the happened switch as it does for any state changes.

3.2 Overview of Existing Solutions

In order to know the state of art of the HMI for bi-fuel vehicle currently existing in the market, a review of existing solutions was conducted, in order to understand whether market players do identify the same information priorities, and therefore to which extent it is possible to define a common base for minimal CNG-related information. The methodology adopted is a typical shorter version of Camp benchmarking method [3]. The techniques of exploratory research and marketing research⁵, had been used.

The most significant examples are reported in the following:

3.2.1 Citroen C3

The main features of the HMI of this vehicle are (see fig. 1):

1. The CNG indicator is analogical and is placed in the dashboard centre;
2. The icon for the CNG is a gas bottle
3. The fuel switch has the CNG icon and a led

The main advantages of this solution are:

3. The CNG indicator has a very exhaustive scale of values
4. Both the CNG indicator and the gasoline one are always available for the driver

The main drawbacks are:

1. The meaning of the big telltale on the right with the crossed CNG icon is not so immediate: it may indicate a failure of the CNG system or the empty gas tank
2. The set of CNG instruments is quite cumbersome⁶



Figure 3 Citroen C3 bi-fuel: dashboard instruments [source: www.metanoauto.com, consulted on 18/06/2008]

3.2.2 Mercedes Class B

The main features of the HMI of this vehicle are:

1. Visualisation of the current fuel type in the instrument cluster central display ;
2. Visualisation of both fuel autonomy, discerned by icons
3. The CNG indicator is a sort of thermometer, joined to the gas bottle icon
4. The CNG status (on/off) indicator is placed in the rev counter (see fig. 2)

The main advantages of this solution are:

1. there is a clear difference between the CNG and the gasoline icon (see fig. 2)
2. the CNG indicator has a very exhaustive scale of values (see fig. 3)

The main drawbacks are:

1. it is not clear where is the gasoline indicator

⁴ Situation Awareness is formally defined as “the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning and the projection of their status in the near future [9].

⁵ Exploratory marketing refers to research techniques, in which data is gathered from a small group of respondents and they not analyzed with statistical techniques [16]

⁶ Dashboard space-saving is a crucial matter in designing in-vehicle devices.



Figure 4 Mercedes Class B bi-fuel: panel cluster instruments [source: www.metanoauto.com, consulted on 18/06/2008]



Figure 5 Mercedes Class B bi-fuel: panel cluster instruments, focus on the CNG indicator [source: www.metanoauto.com, consulted on 18/06/2008]

3.2.3 Volkswagen Touran

The main features of the HMI of this vehicle are:

1. There are no difference between the normal dashboard and the bi-fuel one;
2. There is no fuel switch: the vehicle is conceived as a CNG vehicle, which essentially uses gasoline when the gas tank is empty.
3. The CNG indicator is into the instrument cluster and replaces the gasoline one. The gasoline level is showed, by a four rank scale
4. The CNG icon is pretty particular: it composed by a gas bottle joined to the petrol pump.

The main advantages of this solution is:

1. the CNG indicator has an exhaustive scale of values (see fig. 3)

The main drawbacks are:

1. the gasoline indicator is not very detailed
2. the CNG icon is difficult to understand.



Figure 6 Volkswagen Touran: panel cluster instruments, focus [source: www.metanoauto.com, consulted on 18/06/2008]

From the competitors benchmark analysis we can assess that there are two graphic aspects that particularly impacts on the usability of the HMI: the CNG icon and the exhaustiveness of the CNG indicator scale.

4. DESIGNING EFFECTIVE HMI FOR GREEN CAR

The success of a product is determined by its technology, its look and feel and its usability. Concerning a bi-fuel vehicle, the in-vehicle Human-Machine Interface is the convergence point for technology, look and feel and usability. The HMI let the driver know the engine performance, the fuel consumption, through displays and components with a pleasant design, that are easy to manage.

The design of the HMI of the Fiat Grande Punto Natural Power faced the developing of more effective methods for driver-side interior design and evaluation. The evaluation of the effectiveness and of the usability of the chosen HMI required the investigation of some crucial aspects [15]

1. which perceptual responses are more relevant to ensuring quality of a design,
2. the interrelations among perceptual responses and objective measures

- whether current assumptions regarding driver behaviors, and tools for specifying these behaviors, are valid for the design and evaluation

As stated before, for Fiat bi-fuel vehicles two types of displays were available: the Comfort (measures: 86x35 mm) and the Matrix (measures 67x35 mm). Both displays have quite little dimension, that didn't allow introducing a detailed CNG indicator scale. The adopted solution was characterized by a four rank scale⁷, in order to improve intelligibility despite precision.



Figure 7 The CNG indicator for the Fiat Auto Comfort display.

There are no ergonomic guidelines that support the designers in choosing the scale ranks and precision. Hence the Fiat solution didn't refer to some ergonomic guidelines but referred to the Fiat HMI design experiences and on general usability guidelines commonly adopted in the scientific literature, that made possible to formulate assumptions about driver behavior and the his/her interaction with the HMI. The usability guidelines commonly face other automotive HMI issues, like for example, display dimensions, menu items optimal number, touch screen interaction design. In this case we founded few indications about bi-fuel indicators, that had to be inferred from normal fuel indicators design norms.

The new field of the HMI for bi-fuel vehicles lacks of proper guidelines for HMI designers.

4.1 The problem of the icon: some criteria to select a proper CNG icon

As come out from the competitors benchmark, the designing of a proper icon is not a simple matter. First the icon has to be easy to understand, second there is an ISO symbol for CNG, but it is not mandatory and the benchmark gives the evidence.

Fiat experiences in the development of such an HMI allows to start formulating some design principles about the selection of a proper icon for the CNG feed. The starting point for this selection are the design recommendations of the Federal Highway Administration.

As stated from the Federal Highway Administration (US Department of transportation), there are some aspects that critically impact on the understanding of the icon [5], that are properly relevant in the selection of the adequate CNG icon:

- the level of realism
- the level of detail
- the driver perception

- the driver acceptance of general or specific icons⁸

The first two points can be primarily judged by experts, while the other two points need both experts judgment and experimental data to be evaluated. In the FGA case study, particularly attention was accorded to level of realism and driver perception, in order to promote and improve icon identification.

The literature gives some design principles that take into account the mentioned aspects.

About realism [5],[12], we can state that:

- For general or abstract concepts, less detailed symbols such as caricatures or silhouettes are most appropriate.
- When several symbols have the same general shape or profile, detail is necessary to make them distinct from one another. In this case, a simplified drawing is the most suited solution.
- For small, familiar symbols with a distinct profile, use an outline. However, when the symbol is too thin to be recognized in this format, a silhouette is preferred.

Also about the detail level, the literature [5] offers some practical principles:

- Design symbols on a 20 x 20 unit grid, making sure that no significant detail is smaller in size than 1 square unit [13] [1].
- Lines and other continuous aspects of the symbol do not need to span one grid square.
- Significant details within a symbol should subtend, at a minimum, 3 degrees of visual angle [14].
- Line thickness for a significant detail should subtend, at a minimum, 2 degrees of visual angle [14].

About the perception the principles of icon design principally recommend to base the design on the visual characteristics of the icon without reference to its intended function or meaning. For in-depth examination, there are interesting literature [2] [6] [7] [8].

The driver acceptance of general or specific icons is an important aspect in order to minimize driver memory requirements and system complexity, general icons should be used as long as they do not negatively impact driver acceptance or performance. Well-designed general icons will be acceptable to most drivers under most driving circumstances. The exception to this seems to be safety-related messages (e.g., collision avoidance icons). For safety-related messages, specific icons will provide higher levels of driver acceptance than do general icons [5] [17] [19] [4].

⁷ The ranks become five, if we consider also the zero level (the empty tank).

⁸ The specificity of an icon refers to the information provided about the specific nature of an in-vehicle message despite of a general class of in-vehicle messages. Specific icons provide more detailed information about a driving situation or conditions, while general icons provide information about a wide driving situation or class of conditions without further specifications [5].

In conclusions, the Fiat Auto choice about the icon for the CNG fuel took particularly into account the guidelines concerning realism, joined to the factory police that prefers to follow ISO standards, when they are. In fact the fuel tank with the international acronym CNG is the [ISO 2575: 2004 (E)] icon to indicate CNG fuel [see fig. 6], despite of other gas fuel indicator are present [see fig. 7].

Anyway realism choice concerning icon design carry out some difficult, referring to what stated by [5] [12] about general or detailed level of concept abstraction and representation. In the case of CNG fuel level the less detailed symbol representing the fuel tank complies with the first statement of the guideline, but doesn't fit the second one: "When several symbols have the same general shape or profile, detail is necessary to make them distinct from one another". In the CNG fuel level case study there is the problem that the chosen icon is closely similar to the gasoline one. Adopting the ISO standard for CNG icon collides with the design recommendations of the Federal Highway Administration [5] [12].

This example shows that clearer and more complete design guidelines for "green car" and bi-fuel vehicles HMI are needed.



Figure 8 ISO icon for CNG fuel

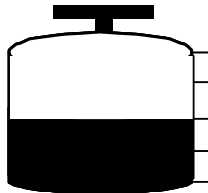


Figure 9 An example of other representation for CNG icon

5. CONCLUSIONS AND FUTURE WORK

To adapt the HMI of current vehicles to the information and commands requirements of bi-fuel systems introduces new challenges dealing with the in-vehicle user interface. The problem of two coexisting fuel indicators, the situation awareness of the driver about the current fuel used by the vehicle engine, the design of proper icons, the evaluation of the standards. There are few guidelines to support designers at developing an effective green car HMI. The Fiat Group Automobiles is gathering different experiences in designing bi-fuel HMI, and with this paper Fiat aims at giving some basic cues, that will evolve in design guidelines when user test results will be available.

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