HOW INNOVATION METHODS CONTRIBUTE TO PRODUCT DESIGN WITH PEM FUEL CELL TECHNOLOGY FOR CLEAN URBAN MOBILITY

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1. Introduction

According to business models, innovation results in new markets for new products and services. In this scope innovation is not just a matter of implementing advanced technology in existing products, but particularly a matter of sensing new market opportunities which are created by new technology. In this paper we will focus on the design of mobile products with integrated proton exchange membrane fuel cells (PEM FC), because PEM fuel cells are considered an innovative technology which can greatly contribute to the improvement of urban air quality. At present potential applications of PEM FC are being assessed through research and development, and they are still in the process of being integrated into products. Hence, technological research and product design may both contribute to innovations at this stage in the development of PEM FC.

Until now most FC powered mobile products have been developed and engineered [1] [2] [3] with the aim to replace internal combustion engines of cars in the medium-size range. The main reason is found in the fact that unlike vehicles equipped with internal combustion engines (ICE) or hybrid cars, FC powered vehicles are quiet and do not emit green house gasses (GHG), polluting gasses or particulates at the vehicle tail pipe [4]. As such FC vehicles have a great potential to reduce noise and GHG emissions due to transport and to improve urban air quality. However expected FC vehicle's retail prices in the medium-size and –price range might be too high to compete with similar gasoline ICE vehicles without financial governmental policies. Here we refer to a positive scenario [4] in which a FC vehicle's retail price will be 50 % higher compared to a similar ICE vehicle in 2010. To overcome this potential bottleneck regarding the development of a market for FC vehicles, it would make sense to develop new product concepts for FC powered means of transport.

Fifteen product concepts based on hydrogen technology have been designed by 30 master students of the Studies of Industrial Design Engineering at University of Twente (NL). Because of their capability to integrate several different aspects of product development, industrial designers might be skilled for product innovation. Aspects of innovative product development are technology, creativity, human factors, design & styling, marketing and societal aspects [5]. During the design process several innovative design methods were applied, among which lead user theory, platform driven product development, TRIZ, technology road mapping and visualized scenario development. In our paper, it is analyzed how these innovative design methods can be applied in order to better integrate PEM fuel cells in vehicles.

Industrial Design Methods (IDM's) play an important role in product development. IDMs convert market needs into detailed information for products that can be manufactured. Moreover

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they focus on the utility of consumer products. In this paper we would like to assess the effect of IDMs on product innovation - for the specific case of FC powered transport in urban areas - by posing the next research questions

- What kind of products result from the application of IDMs ?
- What is the effect of IDMs on the product development process ?
- How do IDMs favor product innovation ?

The answers will add to ongoing research at the Department of Design, Production and Management of University of Twente on IDMs for product-integrated energy technologies [5][6][7]. Moreover the results might be useful to make PEM FC technology fit for consumer applications and to prepare a future sound mass market.

To start with in Section 2 we will describe the IDMs applied. Next, in Section 3 we will first describe the case. Subsequently we will present resulting product concepts and discuss the effect of IDMs on product innovation. The paper will be completed with conclusions.

2. Industrial design methods

Eleven different industrial design methods are applied in this paper. Below they are listed and briefly described; for more details we refer to [5].

1. Platform Driven Product Development

A product platform defines a set of related products, a so-called product family that can be developed and produced in a time- and cost-efficient manner. Features of a product platform are modularity, connecting interfaces and common standards. By development of a product platform, companies can reach different markets (and customers) with less effort than by developing separate products.

2. Virtual Brainstorming

The starting point of a creative design process is a mission statement which can be linked to market demands (trends), basic assumptions (requirements) and possible restrictions (problems). By means of brainstorming varied aspects of the mission statement can be recorded and possibly used when a project advances.

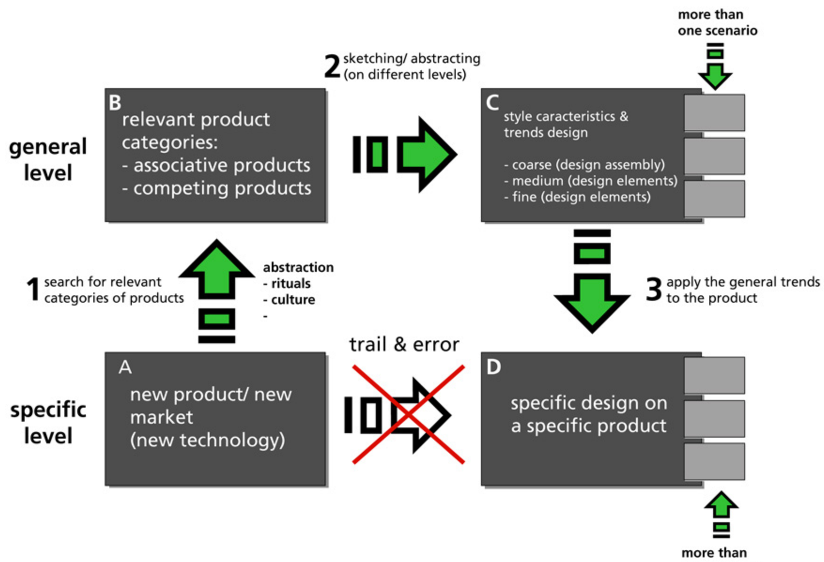

Figure 1. Scheme representing a procedure for innovative design & styling by Stevens [8]

3. Scenario Development

Scenarios describe the context of the user environment and the most important aspects of a design problem. Scenarios can be written down or visualized by collages, story boards and small movies. By means of scenario development design solutions can be found which result in functional products under many dynamic circumstances.

4. Lead User Study

According to the theory of Von Hippel lead users can provide useful information to product designers. Lead users are those who are the first to face needs that will eventually affect a larger market. By identifying and interviewing lead users, emerging market needs for PEM FC can be channeled into the development of innovative products.

5. Innovative Design & Styling

Design & styling is an asset for technological innovation. Cars, modern durables, and consumer products require a high degree of integration between functional and aesthetic aspects of design. A market of vehicles with integrated PEM FC can be promoted by studying the image that potential users of a proposed vehicle wish to project and designing it so that it meets those aesthetic requirements. Figure 1 represents a procedure for innovative design & styling.

6. Innovation Phase Model

The innovation phase model aims to combine the intrinsic value of technology optimally with opportunities in the market. Divergence, selection and convergence of search fields related to technology and markets lead to innovative technology-product-market combinations.

7. Technology Roadmapping

A technology roadmap establishes a correlation between identified market needs and trends with existing and emerging technologies for a specific industry sector. Technology roadmaps usually cover 3 to 10 years and are used in strategic product planning, research planning and business planning.

8. TRIZ

TRIZ can be applied to estimate the probability of technology developments. TRIZ is a Russian acronym meaning Theory of Inventive Problem Solving. It is a comprehensive method based on long term patent research leading to certain basic rules governing problem solving in product development.

9. Risk Diagnosing Methodology

Companies must take risks to launch new products speedily and successfully. In this scope Risk Diagnosing Methodology (RDM) aims to identify and evaluate technological, organizational and business risk in product innovation.

10. Innovation Journey

In the case of technology-based product design, product development often follows certain patterns. By examining the so-called innovation journeys of products in different fields, one may gain tools for assessing the potential innovation journeys of new products using PEM FC.

11. Constructive Technology Assessment

New products must be promoted by manufacturers and retailers, must be approved by a competent authority in accordance with industry rules and standards, and must meet with acceptance from consumers. Constructive technology assessment focuses on these processes and how to improve them.

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Figure 2. a) FC powered personal vehicle (1.3 in Table 1) and b) matching product platform. Design by Joost Avezaat and Dirk van der Steen.

3. Results

3.1 Description of the case

From September to November 2006 a design project took place in the framework of a master course about innovation theories at the School of Industrial Design Engineering of University of Twente. In this project design teams focused on the conceptual design of an innovative vehicle or transport system based on hydrogen technology which contributes to improved urban mobility in the forthcoming decade.

Figure 3. FC MPV named Panthera (2.1 in Table 1), developed by using innovative design & styling by Robin de Pruyssenaere de la Woestijne and Tim Mengerink.

IDMs were offered to the young designers to be adapted in the design process. Three methods were compulsorily, namely platform driven product development, visualized scenario development and virtual brainstorming which took place in cooperation with fuel cell experts in the T-Xchange virtual reality laboratory. From the remaining 8 methods at least 3 should be applied in the design process.

3.2 Resulting products

Table 1 shows 15 varied product concepts resulting from the design project. To enter a future market successfully the designers adapted to different innovation strategies leading to 6 product categories called Down-scaling, High-end market, Transition, Water Transport, Extreme Innovation and Cultural Connection.

Category 1 is called Down-scaling and is based on the strategy to decrease costs of a FC vehicle by diminishing the size of the expensive element, the FC system itself. Hence, this category comprises lightweight single passenger vehicles for urban areas, see Figure 2.

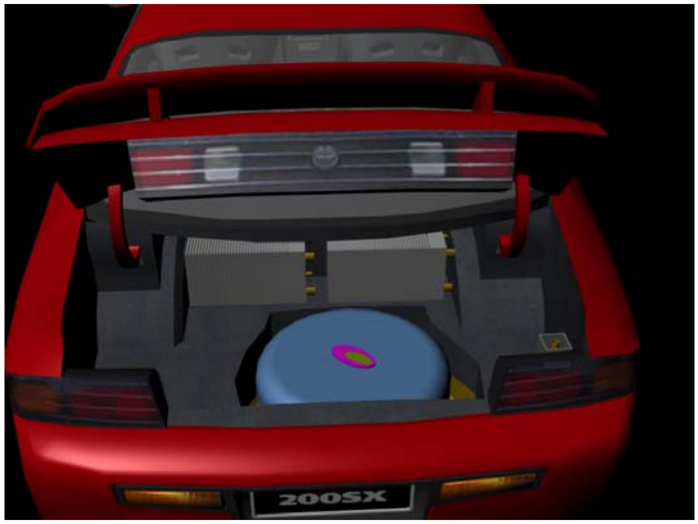
In Category 2, the High-end market, costs don't matter. Vehicles such as SUVs and MPVs can be found in this category. Not only the installed FC power of the example shown in Figure 3 is higher than average, but also the luxury interior and the option to drive by wire are expected to contribute to its popularity.

So-called Transition products are grouped in Category 3. By the implementation of environmental policies in an existing market of ICE vehicles, a demand will be created for new products and services which support customers to adapt easily to the use of Fc vehicles. An example, a FC installation kit for an existing ICE car is shown in Figure 4.

Category 4 comprises Water transport assuming that FC boats are almost economically feasible yet. Figure 5 shows an FC powered ferryboat.

Category 5 covers Extreme innovation which could be applied to attract customers to a new technology by eye-catching design and styling or additional technical features. An example is shown in Figure 6; a FC powered tourist vehicle for sight seeing of inner cities with a remarkably pettable image.

To end with in Category 6 called Cultural connection designers aimed to position FC vehicles in a cultural setting.



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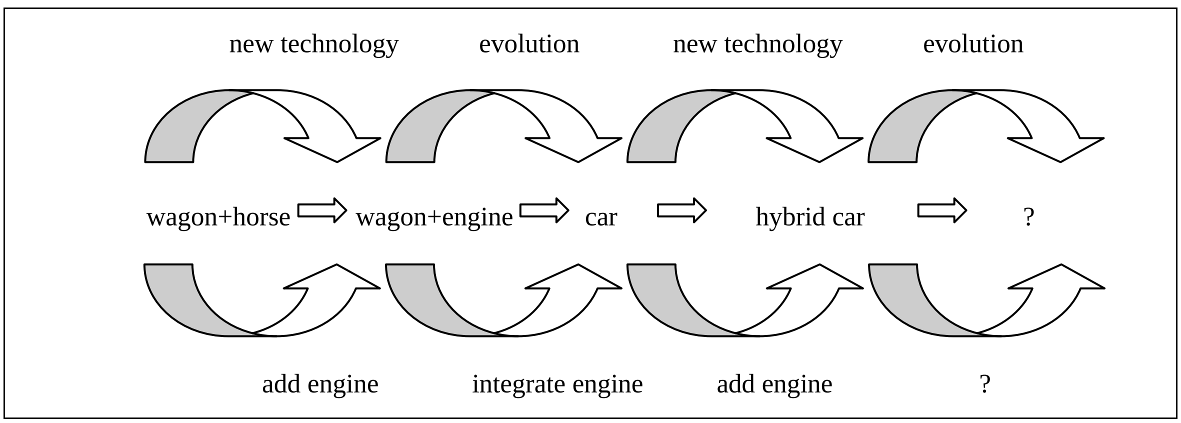

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Figure 4. a) FC installation kit for ICE passenger cars (3.1 in Table 1) developed by using b) TRIZ trends of evolution. Design by Tim Gorter, Geert Loeffen and Sander Schrijver.

3.3 Evaluation of IDMs

Besides compulsory methods such as platform driven product development (Figure 2), virtual brainstorming and scenario development (Figure 6), methods applied most are lead user study (66 %) and innovative design & styling (66%). Followed by innovation phase model (53 %) and technology road mapping eventually in combination with TRIZ (40 %) (Figure 4). Remaining IDM's were applied in about 20 % of the cases.

Hence, we might conclude that the application of six IDM's - namely platform driven product development, virtual brainstorming, scenario development, lead user study, innovative design & styling and the innovation phase model – might be sufficient to fully complete an innovative design process.

Besides this, we noticed that the application of technology road mapping and TRIZ lead to more original and more technical product concepts. In Table 1 it can be found that this particularly applies to the categories Transition and Extreme innovation.

Finally we observed that convincing product concepts are better embedded in a context; the design process is supported by risk diagnosis, innovation journey or constructive technology assessment.

Table 1. Product concepts and the installed FC power P_{FC} in relation to IDMs applied during the design process. Prescribed methods such as platform driven product development, virtual brainstorming and scenario development are not included. LU= Lead User study, ID&S = Innovative Design &Styling, IPM = Innovation phase model, TRM = Technology Road Mapping, RD = Risk Diagnosing methodology, IJ = Innovation Journey, CTA = Constructive Technology Assessment.

	Product description	**P_{FC} (kW)**	**LU**	**IDS**	**IPM**	**TRM/ TRIZ**	**RD**	**IJ**	**CTA**
	Category 1: Down-scaling								
1.1	Spider, small personal vehicle	15	+	+	+				
1.2	H_2, single passenger vehicle	10	+	+		+			
1.3	Small personal vehicle	15	+	+					
	Category 2: High-end market								
2.1	Panthera – MPV	120	+	+				+	
	Category 3: Transition								
3.1	FC installation kit for ICE cars	40			+	+	+		
3.2	Rental FC vehicles for urban areas	3-60		+	+	+	+		
	Category 4: Water transport								
4.1	H_2 water taxi	8					+		
4.2	Ferryboat	2000	+					+	+
	Category 5: Extreme innovation								
5.1	Tourist vehicle	3		+	+				
5.2	Circular personal vehicle	5	+	+	+	+			
5.3	Commuter's vehicle	30	+	+	+				
5.4	Inner city goods transporter	50	+	+	+	+			
5.5	DMFC shoes with active damping	0,002	+			+			+
	Category 6: Cultural connection								
6.1	Vehicle for Chinese market	25		+	+		+		
6.2	Rickshaw	5	+					+	+
			10	10	8	6	4	3	3

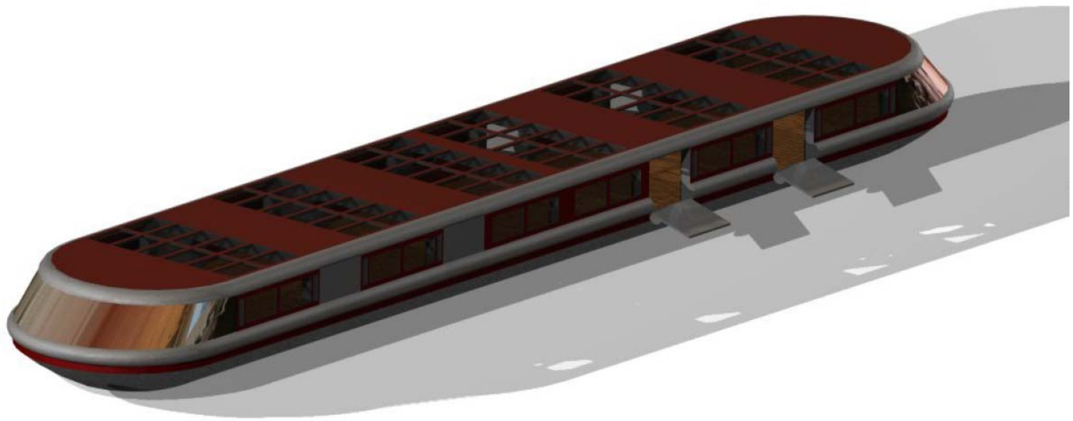

Figure 5. FC ferryboat for 200 passengers (4.2 in Table 1). Design by Stef Pieterse and Ted Gottenbosch.

4. Conclusions

The application of IDMs resulted in a broad range of varied innovative products. We may conclude that creativity was fostered by this specific composition of IDMs. Among the product concepts were many that were surprising, however none of the FC vehicles developed in this case was a medium-sized FC car.

From an assessment of the relation between product concepts and IDMs applied we concluded that

- six IDM’s can support a complete product innovation process
- lead user studies can provide useful information about emerging markets
- innovative design and styling can be used to improve the image of technical products
- technology roadmapping and TRIZ can be applied to innovate more technically
- risk diagnosis, innovation journey and CTA can help to embed an innovative product in a context.

To better investigate the effect of creativity on innovation we would like to further research on fostering creativity in design processes with the aim to develop future FC products which fit to customers’ lifestyles.

5. Acknowledgements

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Figure 6. a) Inner city tourist transporter (5.1 in Table 1) and b) accompanying scenario of a tourist during sightseeing of a city. Design by Jorn Jokker and Mathijs Wullems.

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7. Biographies

Dr. Angèle Reinders is currently assistant professor in the Department of Design, Production and Management of the University of Twente (UT) in the Netherlands. Her research focuses on innovative product design with solar and hydrogen technology. She is a member of the advisory committee of the UT research school Impact and she teaches in the master's studies program. Prior to joining UT in 2002 she worked at Delft University (NL), where she investigated direct methanol fuel cells for portable applications. In 2001, Dr. Reinders worked as a scientific advisor in the Asia Alternative Energy Program of the World Bank in Washington D.C. From 1993 to 2000, she was associated with Utrecht University (NL), where she investigated, life-cycle aspects of energy systems and energy consumption of households in the European Union. She received her doctoral degree from the Faculty of Chemistry at Utrecht University in 1999. Her Ph.D. dissertation covers the analysis of the field performance of photovoltaic solar energy systems. Dr. Reinders completed a master's degree in Experimental Physics in 1993 at Utrecht University, specializing in Material Physics and Energy Physics.

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