

PREDICTING THE FUTURE THROUGH ACADEMIC DESIGN RESEARCH

Dr Mark Evans
Loughborough University, UK
M.A.Evans@lboro.ac.uk

1. CONTRIBUTING TO PRACTICE AND EDUCATION

As a relatively new field of scholarship, design research now confidently defines itself through distinctive academic journals, conferences and associations/societies. However, there is a tendency for the outcomes of academic design research to focus on academic endeavor, such as ways to support teaching and theoretical approaches to designing and design knowledge. This paper explores an alternative position in which the outcomes are extended beyond the academy by making direct contributions to design practice, design guidelines and design regulation. Whilst academic outputs inevitably result in journal publication, the most significant impact of the case studies discussed in the paper can best be described as 'non-academic' as embodied through: a high visibility livery for emergency vehicles that has been adopted in the UK and beyond (design guidelines); an approach for Digital Industrial Design (DiD) (design practice); a globally distributed design tool to facilitate understanding and collaboration by standardizing the language used for design representations (design practice); and revisions to a United Nations regulation to increase cyclist visibility when using the rear view mirrors on large goods vehicles (design regulation). The paper concludes that the rigor, specialist in-depth knowledge and ability to view real-world problems with a fresh pair of eyes enables academic design research to have significant and far-reaching impact beyond academia.

2. DIGITAL INDUSTRIAL DESIGN (DID) – A WEB-BASED RESOURCE FOR ENTIRELY DIGITAL MODELLING METHODS

A key contribution of academic research to design practice is in the impartial evaluation of new methods and approaches that have the potential to disrupt existing practice and identify opportunities for paradigm shift. The competitive and closed nature of professional practice also means that it has a natural tendency to evolve without open reflection and academic research can make a significant contribution to exploring the potential for change. Academic research has a history of reporting on the emergence of individual design technologies and their potential to impact on practice. There is therefore an inherent value in the contextualization of activities that must be undertaken before and after the proposed intervention to avoid exposure of a partial picture. To fully contextualize and build on stand-alone studies that have partially explored the role and contribution of digital methods to professional practice, this paper reports on a research project to investigate the potential for a complete model of practice in which all core activities of industrial design are undertaken using only digital methods. It is acknowledged that this represents a somewhat provocative approach as opinion is divided on the capacity of digital methods to replace established non-digital techniques. In developing the methodology for the study, the research sought to answer what digital tools and methods are available to replicate those of non-digital industrial design practice; how should digital tools and methods be employed to support an entirely digital approach to industrial design; and what are the key issues arising from the implementation of an entirely digital approach to industrial design?

Having developed a theoretical methodological approach, this was used as the basis for a complete industrial design case study that explored the potential to operate entirely digitally using two contrasting stylistic directions (Geometric and Organic). This included the use of a haptic feedback device to emulate workshop-based sketch

modelling and the production of a full color low fidelity appearance model as an alternative to a fabricated/painted appearance model. The process resulted in the production of significant material arising from the DID phases. The DID approach plus the designed outcomes were considered to be of value to students, educators, practitioners and researchers which led to a web-based tool being developed to demonstrate the process and outcomes. This included the phases of DID in the context of Concept Generation, Design Development and Specification; thumbnail images of the designed outputs that could be enlarged for greater clarity; and a brief overview of the project. The three phases of DID with thumbnail images of the designed outcomes can be seen in Figure 1.

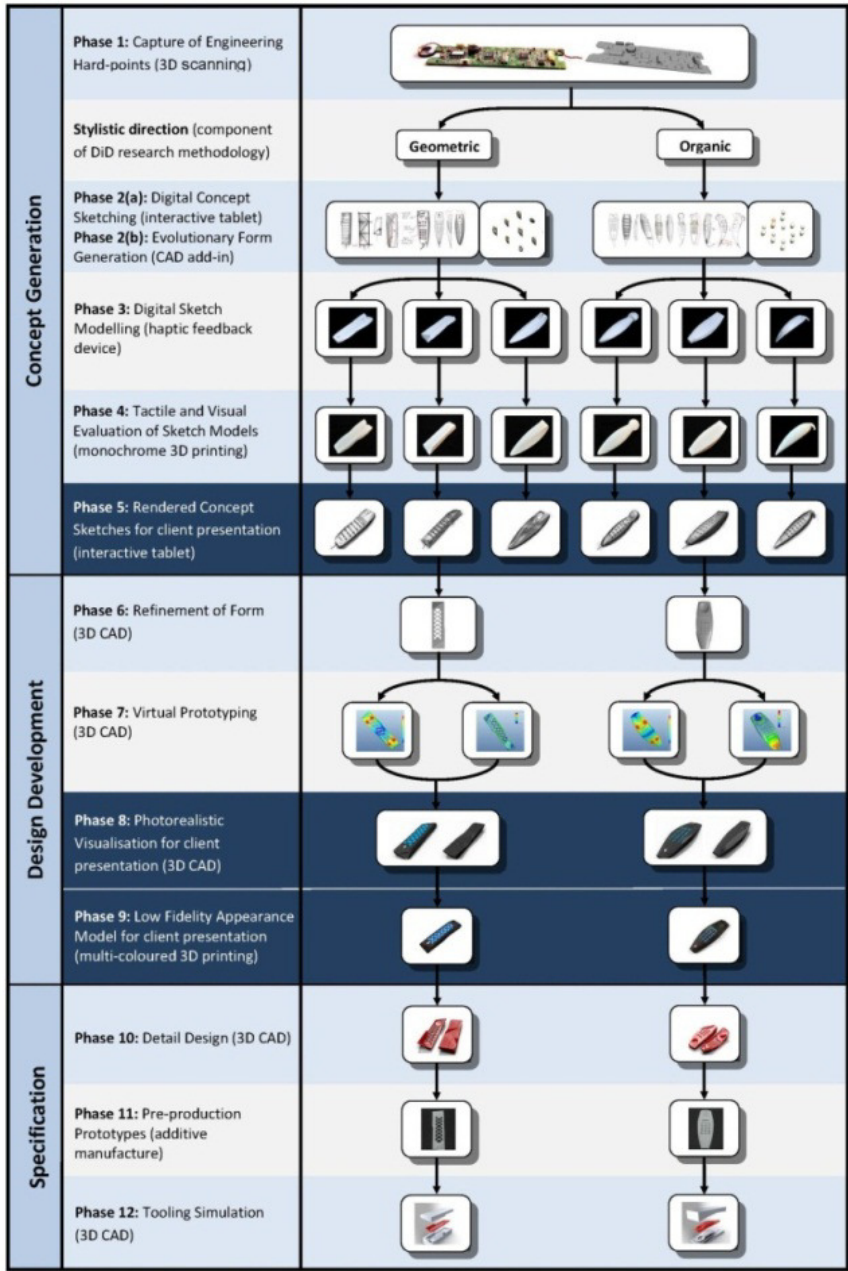


Figure 1. Interactive web-based dissemination tool

The DID approach to product development is available on an open access website at <http://www.lboro.ac.uk/microsites/lds/did/> with a full record of the project accepted for academic publication in 2015 in the International Journal of Product Development as a paper titled “Digital sketching and haptic sketch modelling during product design and development”.

3. ID CARDS – A TOOL TO SUPPORT COMMUNICATION AND UNDERSTANDING DURING PRODUCT DEVELOPMENT

The iD Cards smart phone app supports industrial designers and their stakeholders by increasing understanding in the use of design representations. The free app standardizes language and provides ready access to key information on 32 types of sketch, drawing, model and prototype; identifying when used and for what type of information. Originating from PhD research, the strategy was initially trialed through the distribution of 3000 fold-out cards by the IDSA. The app is now promoted and used by high schools, design schools, consultancies, manufacturing organizations and professional associations to support education, collaboration and design thinking.

A rigorous PhD-based approach was undertaken to identify/define the problem (literature review and empirical data collection); analyse the findings (NVIVO software with coding and clustering) and validate the resulting knowledge framework (empirical data collection). Whilst PhD-based research does not require the execution of the findings as a strategy in a commercial sense, the team felt that the outcomes were of such significance that every effort was undertaken to achieve this. There was, therefore, no budget beyond the PhD to implement the findings. With no financial resources available, the implementation of the strategy posed a significant challenge and the approach taken can best be described as network-driven; using the support of professional contacts who could see the contribution of the tool and were willing to support the process through modest resources and support in-kind. Whilst this may appear somewhat ad-hoc and opportunistic, the researchers had a deep-seated belief in what they had created and, fortunately, this belief was shared by the knowledgeable and influential contacts that were approached to support its implementation. The iD Cards app is now promoted on the IDSA website and its contribution to understanding the nature of industrial design was acknowledged in 2015 when the content was adapted for the re-launched website to define the nature of the profession and nuances of its methods. A video introduction to the app is available at <https://www.youtube.com/watch?v=ZgvjhywMSwY&feature=youtu.be> and a sample iD Card from each of the four sections of Sketches, Drawings, Models and Prototypes can be seen in Figure 2.



Figure 2. Core content of iD Cards app

4. UK NATIONAL POLICE LIVERY

There are 50 police forces operating within the UK, each of whom used to have their own individual marking livery for force vehicles. An implication of this was that across the national motorway network there was a lack of consistency for the visual representation of a police vehicle and associated lack of visibility, particularly for stationary vehicles. Given the complex and dynamic nature of the driving task, it was critical that drivers were able to process and respond efficiently to visual information. Emergency vehicles need to quickly obtain the attention of other road users and improving their conspicuity is a mechanism for achieving this. The UK Home Office Police Scientific Development Branch commissioned the User Centred Design Research Group to undertake research that would help define the country's first national police vehicle livery. The aim of the research was to determine for police traffic patrol vehicles operating in a motorway environment a suitable common standard of markings which enhances, at a distance, conspicuity and recognition as a police vehicle. The methods used focused on the development and evaluation of the livery through:

- Secondary data review - undertaken to identify the human factors issues relevant to improved conspicuity and the means for implementing these within a livery
- Laboratory trials - undertaken in the initial stages of the vehicle livery development to identify the performance and acceptability of the proposed markings prior to more complex road trials
- Road trials - undertaken with proposed 'Battenburg' vehicle livery for six months across 12 forces to obtain police driver feedback on its perceived suitability.

The methods were developed with the intention of addressing the following objectives:

- Enhance officer/public safety by reducing the likelihood of road accidents where conspicuity of the police vehicle is a factor.
- Be recognizable as a police vehicle up to a distance of 500 metres in normal daylight.
- Assist in high visibility policing so as to reassure the public and enhance the potential deterrent benefits of proactive traffic patrol activity.
- Readily identifiable nationally as a police vehicle but retain the ability to associate force corporate logos.
- Capitalize on the latest materials and systems available and seek to achieve a cost-neutral option when compared with the average costs of current liveries.
- Be acceptable to at least 75% of the staff using it.

The literature review highlighted the importance of improved contrast of the vehicle against its background. In the design phase this was achieved through the use of the color yellow since the light-adapted human eye is most sensitive to yellow-green wavelengths. Luminance (brightness) contrast was achieved through the use of passive materials i.e. fluorescent and retro-reflective for improved daytime and night-time conspicuity respectively. With respect to object definition, it was noted that large blocks of color were preferable; that the overall size/shape of the object should be emphasized; and that object outlining can have value (Harrison, 2004). Additionally, any pre-existing visual associations with the police could potentially contribute to the livery scheme. The realization of these factors into a vehicle livery is shown in Figure 3.



Figure 3. UK police force vehicle livery applied to Volvo estate

Key elements of the livery are:

- Block design balances camouflage against a recognizable identity, invoking a historical reference to 'Sillitoe tartan' of the police chequer band.
- Yellow material is fluorescent (aids daytime conspicuity) and is retro-reflective (aids night-time conspicuity) offering high contrasts with blue (that has a historical reference to the police service).
- Blue material is retro-reflective (aids night-time conspicuity) and contrasts with yellow.
- Outlining defines the vehicle shape

Laboratory trials were used to investigate the extent to which the proposed livery met the research aims and outperformed existing liveries. Slides depicting the side or rear views of a range of vehicles were presented tachistoscopically for a period of 0.3 seconds (the minimum time taken by a driver to glance at a specific road scene in order to obtain information) and the sample of public drivers were asked to instantly record which vehicle stood out the most. Overall, across both day and night-time conditions, the proposed livery outperformed the civilian and police vehicles it was assessed against. Feedback indicated that the proposed livery was perceived as distinctive and readily associated with the police.

Road trials identified opinions/attitudes of police drivers and investigated the durability and maintainability of the livery. Trials with 170 police drivers provided feedback by means of a structured, self-administered questionnaire in which 86% considered the proposed livery to be more conspicuous than their existing force livery; 70% favored its introduction; and 58% felt safer undertaking their duties in vehicles with the proposed livery. Within the UK, following the successful introduction of the Battenburg livery (so called due to the similarities of the block formation with the traditional cake), the 'Half Battenburg' (which has a single row of blocks) was then introduced onto urban/sub-urban patrol vehicles. Further development was then undertaken to extend the Battenburg livery for police motorcycles which represents a vulnerable user group in terms of traffic accidents.

All of the Battenburg liveries are now the subject of published Home Office guidance which states the impact of the Battenburg livery as being ' . . . very successful in enhancing safety, in building an image that is reassuring to the public and has a deterrent effect on those who seek to break the law on our roads' (Harrison, 2004). Additionally, it can be observed on the UK's roads that other emergency service organizations are adopting the Battenburg livery format. Whilst the colors differ, the block format is maintained and hence the Battenburg markings are now used to more broadly signify 'emergency vehicle' as opposed to police vehicle. Such services include: Ambulance, Fire and Rescue, HM Coastguard, Mountain Rescue, Rail Response, Highways Agency and National Blood Service.

Internationally, the US Fire Administration cited Battenburg as "the only example of international best practice" (US Fire Administration, 2009) while the Vice President of the American Ambulance Service stated that "It's safer for our responders, safer for the community and safer for the patients, because we can get there faster without having incidents of our own" (Groves, 2009). In addition, the chevron markings used to the rear of vehicles within the Battenburg livery have been incorporated within the National Fire Protection Association's standard for automotive ambulances 2013 edition (National Fire Protection Association, 2012). In New Zealand, the Police Executive agreed that all vehicles will carry a blue/ yellow half Battenburg livery since, as stated by Acting Assistant Commissioner for Crime Reduction and Public Safety, "this brings a consistent look to the marked vehicle fleet, with proven high-visibility and cost-savings associated with just one livery" (New Zealand Police Force, 2008). In Hong Kong, front line staff consider the Battenburg to "... definitely enhance the safety of police officers and road users as it is very conspicuous and can be spotted from far away" and that it is "clearly identifiable as a police vehicle" (Hong Kong Police Force, 2008).

5. IMPROVEMENTS IN THE CAPACITY FOR DRIVERS OF LARGE VEHICLES TO SEE CYCLISTS

This research concerns the development of a new volumetric vision assessment for Digital Human Modelling (DHM) and its application to transport. The research was commissioned by the UK Government who identified on-going concerns with blind spots in Large Goods Vehicles (LGVs) and their role as a contributory factor in road

accidents. In particular the number of side swipe accidents, and accidents with vulnerable road users, warranted further exploration. Road accident scenarios were identified from UK accident data, modelled and then evaluated within the DHM environment SAMMIE (Porter et al., 2004). A new assessment method was developed that creates a 3D projection of the volume of space visible through an aperture (direct vision), or reflected through a mirror (indirect vision). Using these projections vision was assessed for the scenarios using three different Category N₃ vehicles (Goods vehicles > 12 tonnes). The view afforded the driver was evaluated using multiple mirror and window aperture projections simultaneously, allowing the identification of blind spots (Summerskill et al, 2012).

The aim of the research was to identify potential blind spots for large goods vehicles (Category N₃). Driver's field of view assessments in vehicles have been performed using a number of tools and methods in recent years. A common approach to identify the field of view afforded to the driver is to use a 2D mapping approach in which the field of view through an aperture such as a window, or via a mirror, is projected onto the ground plane. This approach is also employed in regulatory standards to describe the minimum field of view for vehicles of various types (2003/97/EC, 2004).

In reality, the field of view is a complex 3D volume, only part of which may intersect the ground plane. Figure 4 shows the 3D volumetric projection of the field of view from the driver's side mirror of a UK car. A human is stood within the visible area as projected at the ground plane but the visible volume indicates that only their feet and part of their lower leg would be visible to the driver.

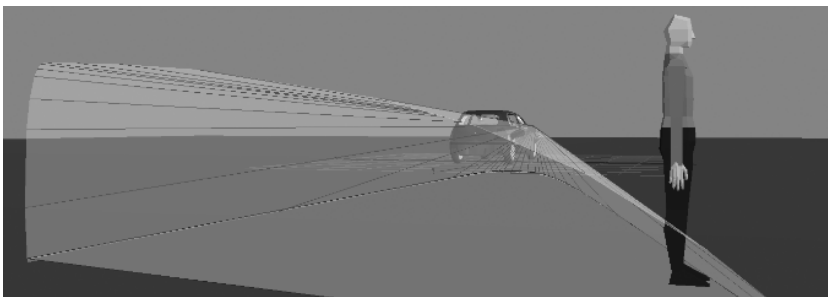


Figure 4. 3D volumetric field of view projection through a car's wing (side) mirror

To address these issues, a 3D volumetric field of view projection tool was developed and implemented within the SAMMIE DHM system. The aim of the development was to provide a tool that could be used to project the viewable volume as afforded by direct vision through an aperture such as a window, or by indirect vision through a mirror. In addition, multiple apertures / mirrors should be able to be projected simultaneously to support a full 360° evaluation of field of view around a vehicle.

Blind spot evaluations were supported through data collection and interviews with twenty LGV drivers with a broad range of size. In addition, three Category N₃ vehicles: DAF XF 105, the Volvo 480 and SCANIA R420 were selected based on sales data. The Volvo vehicle was left hand drive to allow an analysis of the situation for vehicles driving on UK roads (right hand drive layout) that originate from mainland Europe. The DAF and SCANIA vehicles were right hand drive. Each of these vehicles was digitized in three dimensions using the FARO ARM data capture system. These data were then imported into the SAMMIE DHM system for analysis.

Each of three vehicles were setup in the SAMMIE DHM system with accurate positioning and adjustability of controls and mirrors. Digital Human Models were created using the anthropometric data gathered from the smallest and largest drivers from the previous interviews and the virtual vehicles were adjusted to allow realistic driving postures to be recreated. Blind spots were analysed by projecting the mirrors and window apertures.

The identified blind spots were then tested by modelling scenarios derived from the UK accident data, within the DHM system. The scenarios focused primarily on the analysis of 'side swipe' accidents and those involving Category N₃ vehicles turning left at junctions in the UK and colliding with cyclists.

The research highlighted the benefits of using a highly visual 3D projection technique within a virtual environment to explore the issues of driver vision. Blind spots were found to exist for all three of the vehicles evaluated and all driver sizes. Scenario testing highlighted the potential for these blind spots to be a causal factor in accidents that occur on UK roads.

The analysis of a specific accident scenario that resulted in the injury of a cyclist was based upon the premise that the driver should be aware of the cyclist being in a location that is to the left of the Category N₃ vehicle before pulling away and starting the left hand turn. It was determined that it is possible for the cyclist to be completely obscured from the driver's vision for all of the test vehicles.

As part of the research performed potential solutions were analysed. An aftermarket mirror was identified that has the potential to fill the blind spot between the volume of space visible through direct vision, and the volume of space visible through current Class V mirrors. This mirror was tested in both real world and DHM analyses and was shown to allow the identified blind spot to be eliminated. Figure 5 shows an example of the DHM analysis.

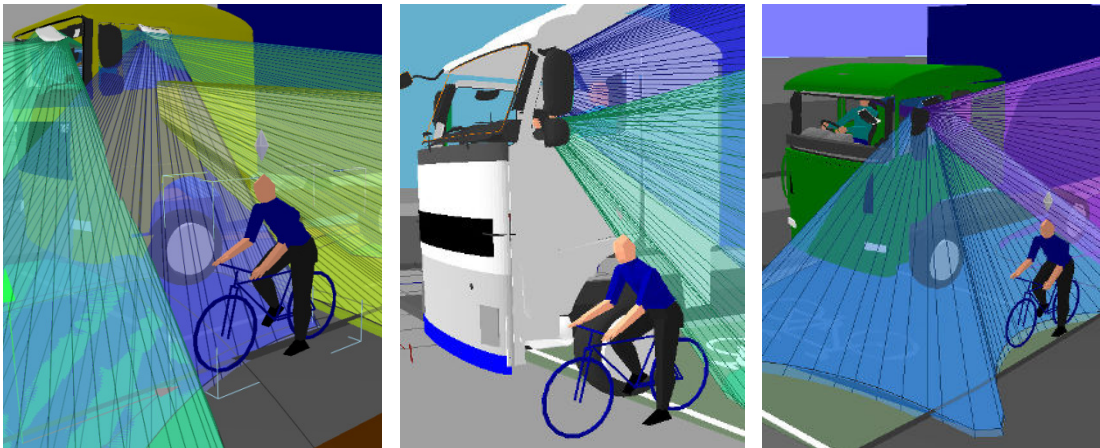


Figure 5. Images of DHM analysis

This research identified a key blind spot that had the potential to be associated with the accidents highlighted by UK accident data. This led to the definition of a proposed change to directive UN Regulation 46 which was presented at the 100th United Nations GRSG committee, and was accepted at the 101st GRSG meeting. The change proposed was to mandate an increased area of the floor that is visible to the driver, with the aim of removing the identified blind spots. It is hoped that the fitment of these larger mirrors will improve the field of view of all drivers of these vehicles and help to reduce potential accidents. It is therefore necessary to acknowledge the interplay between the reactive and proactive nature of design research by which academics both respond to and initiate opportunities.

6. CONCLUSIONS

Through the use of case study examples, this paper demonstrates the breadth of applications for academic design research, with examples of ways in which contributions to new knowledge have been made for design practice, design guidelines and design regulation. Methods and methodologies were selected to address the research questions posed for the specific project, with examples of strategies that employed experimental, social science and practice-based techniques. These approaches are typical of academic research but the ways in which impact can be facilitated are, as illustrated in this paper and the author's research group website (<http://www.lboro.ac.uk/departments/lds/research/groups/design-practice/resources/>), extremely diverse.

The case studies have been selected on the basis of impact beyond academia and, for this to take place, a high degree of engagement with external stakeholders was required. However, whilst some of the case studies had this in place at the outset of the project, others did not (e.g. iD Cards) and required the stakeholder engagement to leverage their full potential. The case studies demonstrate that, through the use of robust research methods and credible stakeholder engagement, academic research can make a valuable contribution beyond academia.

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