FRAMING IN DESIGN: A FORMAL ANALYSIS AND FAILURE MODES

Vermaas, Pieter (1); Dorst, Kees (2,3); Thurgood, Clementine (2)
1: Delft University of Technology, Netherlands; 2: University of Technology Sydney, Australia; 3: Eindhoven University of Technology, Netherlands

Abstract

This contribution presents a formal description of the design practice of framing and identifies two general modes in which framing can lead to failure in design projects. The first is called the goal reformulation failure mode and occurs when designers reformulate the goal of the client in a design task and give design solutions that solve the reformulated goal but not the original goal. The second is called the frame failure mode and occurs when designers propose a frame for the design task that cannot be accepted by the client. The analysis of framing and its failure modes is aimed at better understanding this design practice and provides a first step towards arriving at criteria that successful applications of framing should meet. The description and the failure modes are illustrated by critically considering an initially successful case of framing, namely the redesign of the Kings Cross entertainment district in Sydney.

Keywords: Framing, Design Theory, Design methodology, Failure modes

Contact:
Dr. Pieter Vermaas
TU Delft
Netherlands, The
p.e.vermaas@tudelft.nl

Please cite this paper as:
Surnames, Initials: *Title of paper*. In: Proceedings of the 20th International Conference on Engineering Design (ICED15), Vol. nn: Title of Volume, Milan, Italy, 27.-30.07.2015

1 INTRODUCTION

One of the powerful practices in the toolkit of designers and design thinkers is the framing of a design task, that is, the creation of a new perspective on a design task. Whereas in more traditional engineering design methods the emphasis was on the modelling of how designers solve the design tasks as they are set by clients, later, after the seminal work by Donald Schön (1983), design methods started to explicitly include the notion that designers need to reformulate the design tasks as given, and are often seen to distance themselves to a degree from the formulations by which clients present these tasks. This enables designers to creatively explore design tasks, break free of suggestions how solutions should look like that can come with the clients' formulation, and in this way broadening the solution space. This reformulation of design tasks is called 'framing' or 'reframing', and is now a prominent part of current design methods (e.g., d.School, 2011; Hekkert and Van Dijk, 2011; Dorst, 2015).
There are various sources for determining what framing is. One can return to Schön, one can analyse how it is spelled out in current design methods, or one can consult work in which framing has been studied more theoretically (Cross, 2006; Dorst and Cross, 2001; Dorst, 2011; Dorst, 2015). These sources all share the perspective that the use of framing by and large always leads to successful reformulations of design tasks; that by framing designers arrive at better and more innovative solutions and can overcome deadlock in design projects, as design tasks as set by clients are often ill-structured (Simon, 1984), wicked (Rittel and Webber, 1984) or just plain paradoxical (Dorst, 2006). In the literature one can find many discussions of design cases with framing that are in these senses successful. And although these discussions suggest that less fortunate cases may also be available, the possibility that framing may fail in a design project is more or less not considered, let alone studied. In order to improve the design practice of framing, we need to understand instances of when it goes wrong.

This contribution presents an analysis of framing with the aim to better understand this design practice and to explicitly define ways in which it may fail to be successful. It gives a somewhat formal description of framing and identifies two general modes in which framing can lead to failure in design projects, thus providing a first step towards arriving at criteria that successful applications of framing should meet. The description and the failure modes are illustrated by critically considering an initially successful case of framing, namely the redesign of the Kings Cross entertainment district in Sydney, Australia (Dorst, 2011; 2013). This design project has recently had an unfortunate sequel that calls into question the quality of the original frame, thereby demonstrating the need to better understand how to apply the design practice of framing successfully.
In Section 2 we introduce this case and in Section 3 we give our analysis of framing. In Section 4 two failure modes of framing are defined, and in Section 5 we reconsider the sequel of the Kings Cross design project.

2 FRAMING KINGS CROSS

For setting the stage, first a design project is described in which framing plays a pivotal role. This project is the redesign of Sydney's night-time entertainment district in Kings Cross (Dorst 2011, pp. 528-530).
Being the main night-time entertainment district in Sydney, Kings Cross has increasingly become a setting for antisocial behaviours and escalating crime. High volumes of young people attend on Friday and Saturday nights, and activities are predominantly concentrated on a small stretch of nightclubs. Some of the problems that occurred include drunkenness, violence, petty theft, and drug dealing. Previous attempts at solving the problem by the City of Sydney included the implementation of strong-arm tactics and the increasing of police presence; however, the additional security measures failed to enhance feelings of public safety and instead resulted in a grim atmosphere for all.
In 2008 designers from the Designing out Crime research centre[1] were asked by the City of Sydney to look into these issues and propose ways to reduce crimes and misdemeanours, in particular 'alcohol-related violence.' The designers concerned quickly realised that the situation had previously been

[1] http://www.designingoutcrime.com/

treated as a law-and-order problem requiring law-and-order solutions; however, the people involved were not actually criminals. Instead, they were just young people looking to position themselves in a social setting and to have a good time. The lack of structure of the nightspot together with the sheer volume of young people meant that they were becoming bored and frustrated, and consequently were not having a good experience at all – a problem only exacerbated by the additional security measures. The designers proposed a simple analogy in which large volumes of people already successfully come together and interact in a harmonious fashion: a music festival. They effectively reframed the problem by comparing the dysfunctional situation at Kings Cross with a well-organised music festival. They asked themselves what they would do if they were organising a music festival and this triggered new scenarios for action, as a well-organised music festival offers many facilities that are not currently available in the Kings Cross district but could easily be designed in. The designers worked in conjunction with the local government authority for Sydney to execute a variety of solution directions. One example was to organise transport. In a music festival, people would be able to get there but also leave when they want. In the entertainment district, train services ended around the same time that peak influx of patronage begins. Apart from the obvious improvement of providing more trains at the nearest station, the designers also implemented a back-up system of temporary signage to lead towards a different nearby station that has trains running all night. In all, about 20 ideas/solution directions resulted from this single frame of the 'music festival', and over a space of five years many of these have been trialled and implemented. These include the introduction of friendly 'Kings Cross Guides' that welcome visitors into the area, provide information on all the facilities and also double up as extra eyes and ears for the police, providing an early warning to officials when a situation looks like it might get out of hand.

The Kings Cross case shows how the creation of a new frame provides an entirely new approach to a complex problem situation, rather than attempting to generate solutions to a problem that cannot move forward in its original terms. A full description of the Kings Cross scenario and its resolution can be found in a previous paper by the second author (Dorst, 2013).

3 MODELLING FRAMING

For arriving at a more formal description of framing that can be applied to other design projects as well, one can use the case of the redesign of Kings Cross and abstract from its specificities.

Let a design task be captured by a situation S, a goal G that is to be realised, and possibly also a frame F[T], where it still has to be spelled out what this frame consists of. The situation S is a current state of affairs. In the described case, S is the original situation in the Kings Cross district, including the regular crimes and misdemeanours that take place in it. The goal G is the state of affairs that the client wants to realise. In the Kings Cross case, G is the situation that the City of Sydney envisages, that is, a situation in which the rate of crimes and misdemeanours is much lower as compared to the original situation S.

3.1 Frames

Schematically one can take a resolution of a design task as an action A by which a current state of affairs S can be transformed into the envisaged state of affairs G. Designers create this action A by exploring and evaluating solution directions, and designers arrive at these solution directions by analysing the current state of affairs S and by drawing from their knowledge of how to transform states of affairs. Framing can now be taken as characterising the current state of affairs S as resembling a particular type T of states of affairs with the aim of making solution directions available, namely those solution directions that are regularly applied to states of affairs of type T. Returning to the case: when the original situation S of the Kings Cross district is characterised as a situation of the type "crime scene", then this framing of the entertainment district suggests all kinds of possible solution directions associated with crime. For instance, for realising a more peaceful situation G, policing actions A come to mind such as surveying the area more severely, or banning first or multiple offenders. When, instead, the original situation S is characterised as being of the type T of a (poorly organised) "festival area", other possible solution directions come to mind, associated with the organisation and management of festivals. The same goal G of a peaceful district can then still be realised, but now through alternative actions A that come with the management of festivals, such as

providing information about transportation and introducing friendly 'Kings Cross guides' for assisting visitors of the Kings Cross district.
In this schematic description of designing, a frame can be modelled as the set of possible solution directions A for realising goals G in a state of affairs S that designers make available by characterising S as being of a type T of states of affairs. This modelling of a frame is rather operationalistic by black-boxing how designers arrive at frames; it simply identifies a frame with the role it plays in design, namely providing designers suggestions for solution directions to realise the goal G (Dorst, 2015). The value of this modelling does not lie in helping designers to find the frames or the solutions, but in identifying failure modes of framing, which will be the topic of Section 4. The introduction of the concept of types T of situations is motivated by the relation between metaphors and framing as can be found in the work by Schön. According to Schön framing in design may be analysed as taking a specific design situation S as being of a type T of situation, and doing so enables designers through their experience with past situations of that type T to arrive at solution directions.

3.2 Framing steps in design

A simple modelling of a design process with framing can then be as follows. This process starts with a design task (S,G) as set by the client: the client presents a current state of affairs S and asks for means to transform it into a desired state of affairs G. The designer then frames this design task by taking the current situation S as of being of type T, arriving by this step at a framed design task (S,G,F[T]). The frame F[T] provides the designer with actions A as possible solution directions to obtain the desired goal G, which are then explored for their feasibility. An action A may involve the deployment of products (extant, or yet-to-be-designed), let us call them P, and if a specific action A is chosen as the right one for meeting the design task, then the designer also gives a design description of the products P part of that action. These products may count as the final design solution, yet with the increased acknowledgment that design is about creating product-services, it may be more appropriate to model the design solution as the pair (A,P) of the accepted action A plus the products P involved.
This modelling is too simplistic to capture the rich design practices that lead to the creation of new frames. Designers may also reframe design tasks by either abandoning a frame they themselves introduced when initially framing the design task, or by taking distance from a frame that is suggested by the client. Clients may already steer the design process by including in the formulation of the design task possible solution directions. The City of Sydney, for instance, already presented the task to redesign the Kings Cross district as one of reducing crimes and misdemeanours, and in this way put the focus on finding ways to prevent visitors to the district from breaking the law. Both steps of reframing can be modelled as a map from an initial framed design task (S,G,F[T]) to a reframed design task (S,G,F[Ť]), were Ť is the new type of situations S is taken to be. Adding these steps to the modelling of framing implies that the design task as set by a client may be captured by the pair (S,G) when the client does not frame this task, and may be captured by the triple (S,G,F[T]) when the client does frame it.
A second broadening of the modelling is including the possibility that a designer when considering a design task as set by a client, not only considers alternative ways to characterise the situation S the client presents but also alternative formulations of the goal G the client has. This reformulation may involve making this goal G more precise, making it broader or replacing it by an underlying goal that is taken to be the motivation for the client to adopt the original goal G in the first place. In all these cases the original goal G is replaced by a new goal Ğ.
One can most probably add more reasoning steps for arriving at even more sophisticated models of framing; one can, for instance, include that designers can formulate themselves potential design tasks for clients (d.School, 2011). For finding two failure modes of framing the current modelling however suffices. So, let us take stock and take the design practice of framing as consisting of three types of steps (see Table 1). In a project the designer can take some or all of these steps, take a single step more than once, and do so in any order.

Table 1. Three framing steps; S = original situation, G = goal, Ğ = reformulated goal, F[T] = frame, F[Ť] = new frame

Goal reformulation in a design task:	(S,G) → (S,Ğ) or (S,G,F[T]) → (S,Ğ,F[T])
Framing the situation in a design task:	(S,G) → (S,G,F[T])
Reframing the situation in a design task:	(S,G,F[T]) → (S,G,F[Ť])

The original design task as set by a client can be without a (suggested) frame, to be modelled as (S,G), or be with a frame, modelled as (S,G,F[T]). This initial design task can at the start of the design project by the designer be framed, reframed or goal-reformulated. And during the design project the designer may again reframe the design task or reformulate the goal.
It is important to note that we distinguish here between the act of designers *interpreting* a design task in terms of clarifying their understanding, and *(re)framing* a design task in terms of generating an alternative perspective on a situation. An interpretation of a design task in isolation does not necessarily lead to solution directions, whereas framing, through its comparison to a desired situation, should lead the designer to solutions. Importantly, one could have an erroneous interpretation of the client's needs, which would inevitably lead to failure modes of their own.

3.3 Design solutions

For extending the modelling to the final design solution, one can add two more reasoning steps (see Table 2).

Table 2. Two additional design steps; A = action, P = product

Action identification:	(S,G,F[T]) → A
Product identification:	A → P

The step of identifying the action A demonstrates the role of frames in finding the design solution since it is the frames F[T] that make available solution directions to designers from which or through which they can identify an action A to realise the goal G. These additional two steps are not further considered in the analysis where framing can go wrong.
In Figure 1 three paradigmatic schemes of design projects are given, a first with only framing, a second with goal reformulation (and framing) and a third with reframing.

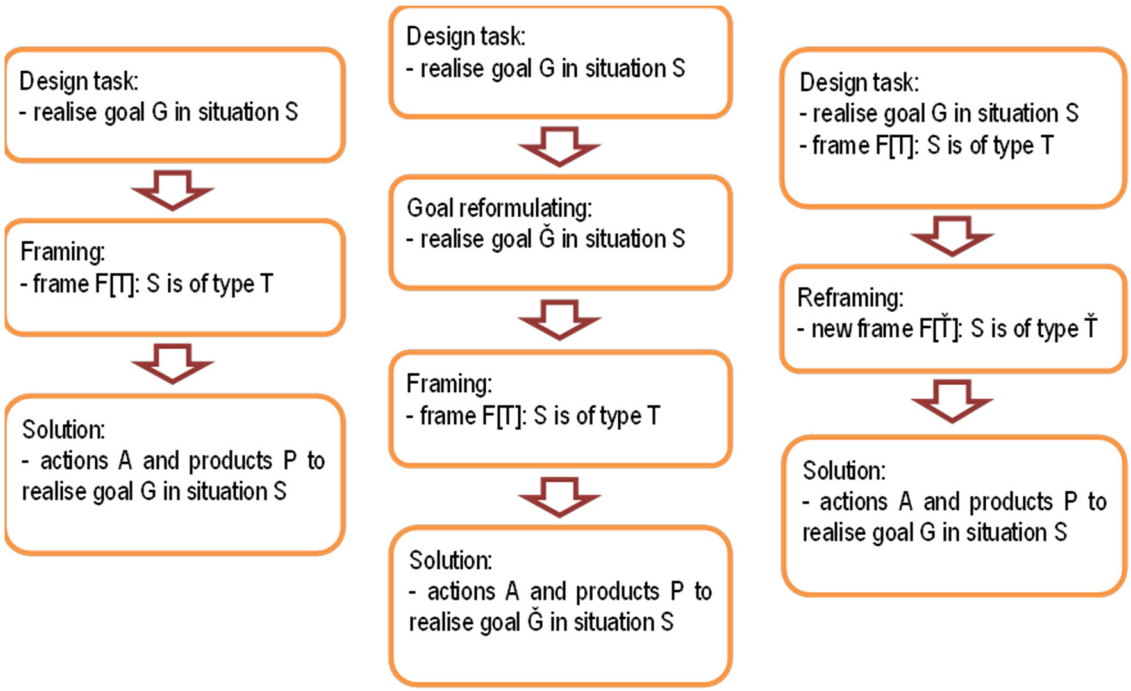

Figure 1. Three paradigmatic schemes of design projects with, from left to right, framing, goal reformulation and reframing

4 FAILURE MODES WITH FRAMING

How can framing go wrong? There are many ways in which a design project as a whole can fail, ranging from spending too many resources while finding a solution to not finding a solution at all. Two general ways in which a design project can fail are relevant to the question of what failure modes in design projects are introduced when the tool of framing is used. The first mode is that a project

leads to a design solution – actions A and products P – that does not realise the goal G as set in the design task (S,G) or (S,G,F[T]), and this possibility becomes realistic when a designer reformulates the goal G in the task. The second failure mode is that the design solution cannot be adopted by the client because the client cannot carry out the actions A or use the products P as intended, and this becomes imaginable when a designer introduces or adjusts a frame F[T].

4.1 The goal reformulation failure mode

The first failure mode that a project leads to a design solution that does not realise the goal G is of course a generic one, and may not be specific to framing. It can however be argued that the step of goal reformulation is making this failure mode rather realistic, even if one assumes that the design process is always successful by leading to a solution to the reformulated goal Ğ. With framing as modelled in the previous section, a design project leads to a solution to a design task (S,Ğ,F[T]) or (S,Ğ,F[Ť]) and that opens up the possibility that the client may observe that this solution does not realise his or her original goal G.
Let us call this first failure mode the goal reformulation failure mode.

> Goal reformulation failure mode:
> - The design solution (A,P) solves the reformulated goal Ğ but does not solve the original goal G.

If we further unpack this mode, three cases can be discerned.
First, the reformulated goal Ğ can be a more precise description of the original goal G that the client has set. Say, the City of Sydney in the Kings Cross case has the goal G to bring the number of public disturbances down and this goal is reformulated as getting the number of crimes and misdemeanours down. Non-criminal disturbances are then no longer addressed in the design project, say visitors getting aggressive, sick or overly noisy. When a successful design solution is found for this reformulated goal Ğ, the original goal is still not realised: the City of Sydney may take the design solution as a failure because the number on non-crime and non-misdemeanour incidents remains as they are.
Second, the reformulated goal Ğ can be a broader description of the original goal G. Say, getting the number of public disturbances down and improving the time to identify these disturbances. In principle the goal reformulation failure mode is now blocked, since a design solution that realises the broader goal Ğ, realises by definition the original more limited goal G. Yet when that reformulated goal is partially realised, failure may again surface. The elements that are added to the original goal G to arrive at the reformulated goal Ğ may have been achieved well but the original goal less. Consider, for instance, a design solution that swiftly and adequately warns when a public disturbance takes place but less adequately prevents them from happening. The City of Sydney may then again conclude that this solution does not serve the original goal G well.
Third, the reformulated goal Ğ can be an underlying goal that reveals motives of the client to set the original goal G in the design task. Say, the City of Sydney is motivated to get the number of disturbances down because of the political or public outcries about what happens in the Kings Cross district. A design solution to such an underlying goal Ğ need not be a solution to the original goal. For instance, a public relations strategy that convinces politicians, the media and the general public that the Kings Cross district is a relatively well policed area and much safer for visitors than, say, daily traffic during Sydney's rush hour, could be valid for assuaging the public's concerns about Kings Cross. However, this strategy may backfire when the public disturbances continue and are again dominating the headlines in the media. The original goal G then may resurface and the City of Sydney is faced with the fact that this goal was not addressed in the design solution to Ğ.

4.2 The framing failure mode

The second failure mode for framing is that a design solution (A,P) cannot be adopted by the client because the client cannot carry out the actions A or use the products P as intended. Superficially it may seem that this failure mode should not occur anymore in contemporary design. Since the analyses of Donald Norman (1990) of the operation of sliding doors and other products with unintelligible interfaces, the usability of products has enjoyed continuing attention in design. And the introduction of new products and services is currently typically accompanied with careful programs to make the required actions known to users. This is illustrated by the impressive global achievement that within a

couple of years all air travellers have learned to check-in for flights, a procedure that used to be carried out by the airlines companies themselves. Framing or reframing could however introduce new ways in which clients can be faced with design solutions they are unable to adopt. Return for this again to the case of Kings Cross.

By framing the Kings Cross district as a festival area and not as a crime scene new solution directions do become available to the designers, but this change of frame also implies taking distance for existing solution directions that came with the old frame. This taking distance from the existing approach may indeed be seen as the benefit of the new frame, yet it also can make the adopting of the design solution found with the new frame problematic. Taking the Kings Cross district as a festival area suggests, for instance, also selling alcoholic drinks on the streets of Kings Cross. However such a suggestion seems less suitable given the association between alcohol and violence, the very behaviour the designers are trying to prevent. Regardless, such solution directions need not compromise the reframing of Kings Cross: since they are manifestly not contributing to realising the goal of reducing the number of crimes and misdemeanours, and will soon be dropped if designers would even mention them to the City of Sydney. Other suggestions that come with the new frame and that are adopted by the City of Sydney may however turn out to be problematic as well. Consider, for instance, the grim looking bouncers in front of and inside clubs and the more authoritative police officers that in the original situation patrolled the Kings Cross district. They came with the old frame and may not have been very effective, but the bouncers and police officers are now part of the Kings Cross district. The new frame instead suggests adding staff to Kings Cross – the 'Kings Cross Guides' – that informs, guides and assists visitors, and that may consist of more open and communicative young people, visible by colourful uniform clothes. The new frame also suggests reducing the number of bouncers and police officers or minimally transforming their role to one of servicing rather than policing. And this solution to the Kings Cross district may be hard to adopt by, for instance, the Sydney police. The Sydney police are present at Kings Cross because there are often public disturbances in that district, and the police are required to be there, since it remains their task to prevent such disturbances or to arrest the people involved, 'music festival' frame or no 'music festival' frame. Designers may convince the City of Sydney and its police of the benefits of a different perspective on the area, and the Sydney police may acknowledge these benefits, yet the consequential change that is required in the behaviour of the police may be harder to achieve. One may argue that by its core values the police are unable to unconditionally adopt the new frame, and are prone to return to the old one as soon as public disturbances will actually take place, as will be the topic of Section 5.

Abstracting from this case, one can argue that a new frame F[Ť] introduced by designers in a design project has to be acceptable to the client: the client should agree with characterising the initial situation S as of type Ť and this characterisation should be compatible with the values the client has. If not, a design solution obtained within the new frame may fail to be adoptable to the client. Let us call this possibility in which a design project may lead to failure the frame failure mode:

Frame failure mode:
- The client does not adopt the design solution (A,P) by not accepting the frame F[Ť].

It is a mode that to our knowledge has not been studied as such, and for giving a typology of this mode, as we did for the goal formulation failure mode, further analyses and further cases are needed. For this analysis the literature on framing in the political sciences may be a useful source (e.g., Lakoff, 2004; De Bruijn, 2014). Hans De Bruijn, for instance, analysed debates in politics as guided by frames. Participants in such debates set up frames to present their views – the most well-known case being the "either you are with us, or you are with the terrorists" frame the U.S. President George W. Bush used in 2001 to rally support after the 9/11 attack. Participants are then facing the choice to accept the frames of their opponents, stay with their own frames or set up alternative ones. "Stepping into a frame" of opponents is in this literature taken to be disadvantageous since it forces participants to accept the perspective of the opponents. Returning to designing, one may analyse (re)framing in a design process as a proposition to the client to "step into the frame" T or Ť the designers identified, leading to the question under what conditions a client is capable or willing to accept the frame.

4.3 Avoiding failure

Both failure modes may in practice be avoided if designers regularly brief clients about the way they develop the original design task. And by introducing moments in this process at which clients and designers reconfirm explicitly the precise design task that will be addressed.
For example, within design agencies, notably in product design, there is the practice of creating a 'Return Brief' before contracts are signed and a design project starts. Such a Return Brief describes how the designer understands (and interprets) the design task and plans the project in accordance with this understanding. The creation of a Return Brief is not a neutral undertaking: it often quite clearly holds the seeds of the reformulation of the client's perceived goals and reframing of its initial frame.
Within design research, authors like Bryan Lawson have gone further and actually stated that briefing is "a continuous process" in design (Lawson and Dorst, 2009), possibly as an expression of the 'co-evolution of problem and solution', that is now widely accepted as being one of the core processes driving creative design.
And indeed, some empirical studies do seem to point to this: the design problem is kept fluid (within bounds) through all of the conceptual phase of the design project, and only really gets fixed at the moment a solution concept is chosen and approved for moving into embodiment design and implementation. However, with one noted exception in the field of Visual Communication (Paton and Dorst, 2011), there have been no elaborate empirical studies into these design practices. This is a grave omission, as the ability to reframe design tasks is now considered to be a key design tool and one of the cornerstones of the design thinking-movement in business schools and design schools.

5 REVISITING KINGS CROSS

For making specifically the second framing failure mode more concrete, we return for a last time to the case of redesigning the Kings Cross district. Unfortunately, in 2012 and 2013 a tragic course of events occurred that calls into question the validity and appropriateness of the imposed frame and that actually annulled the effect of the earlier design interventions in Kings Cross. Over the space of a couple of months, two separate incidents happened that severely shocked public opinion and resulted in direct Governmental intervention. In these incidents, both in the Kings Cross district, two young men were attacked by impulsive aggressors; they sustained a sudden 'single-hit' to the head, then cracked their skull as they fell on the pavement and died.
These tragedies and the public outcry that followed spurred the New South Wales Government (under which Sydney falls) into action, and new laws were passed that severely limit the opening times of pubs, bars and clubs in Kings Cross and surrounding parts of central Sydney.

One could argue that this response by the New South Wales Government is itself a case of wrongful framing: the Government felt duty-bound to respond to the outcry in the media that considered these two horrible incidents to be exemplars of 'alcohol-related violence'. This framing makes reducing the alcohol intake of people in the area by limiting the opening times of pubs and clubs seem a logical cause of action. However, the two incidents that these laws seek to address both were not related to an excessive intake of alcohol at Kings Cross at all (both occurring early in the evening, by perpetrators that had been drinking at home). Thus, the new laws would not have prevented the tragic deaths, and unfortunately will not prevent such events happening in the future. The framing that supported the Government's response can therefore be taken as suffering from the goal reformulation failure mode: the new laws may make that visitors drink less alcohol at Kings Cross (the reformulated goal Ğ) but might not avoid future incidents of this type (the original goal G). These critical points do, however, not take away that the design solutions made available with the festival frame also might not avoid such incidents. (For making some progress on this point it may be noted that there is in fact a pattern here: both incidents were linked, in the sense that both perpetrators were into muscle training and Martial Arts – the excessive consumption of muscle-building amphetamines and hormones might have contributed to their sudden aggression, unlocked by a small amount of alcohol – but the banning of such widely used substances has not been considered.)

These new Government regulations have devastating effects: young people now avoid the Kings Cross area altogether, and party in other parts of the city just outside the exclusion zone. Kebab shops, convenience stores, restaurants, and bars in Kings Cross are no longer profitable, they are now closing

their doors and unless something happens, this downward spiral will continue. Soon only the organised crime/drugs/prostitution-related businesses will be left in the area.
The net consequence of this tragic course of events and the Governmental response to it is that the solution for reducing the number of crimes and misdemeanours as derived by the designers with the new festival frame cannot be adopted anymore by the City of Sydney. The earlier choice of the City of Sydney to approach the Kings Cross district with this new frame has effectively been overruled by the New South Wales Government, forcing it to return to the old 'crime scene' frame and the use of strong-arm tactics for policing the district. Hence, the Kings Cross redesign project fell prey to the framing failure mode; the City of Sydney no longer adopts the design solutions (A,P) since it no longer will (or can) accept the proposed frame F[Ť].
One can analyse this failure in two ways. One can still say that the original 2008 project was successful, and reject that the reframing failed. One may, for instance, argue that the City of Sydney did accept the new festival frame and the design solution as found by it. And one can point out that the tragic events were not due to the situation at Kings Cross as created through the project, since the perpetrators got into their aggressive state outside the Kings Cross district. Moreover, the solution direction paid off in another way because since the project at Kings Cross, the City of Sydney has created a broader strategy called 'Open Sydney' to implement changes in other areas in the city that are similar to the ones the design project has led to for King Cross. Hence, the City of Sydney is now reinventing itself as an active framer and conductor of life in the city – effectively reformulating its goals as an organisation. Therefore, the original frame was a success of some sort.
An analysis that is more susceptible to failure is one in which it is accepted that the frame was apparently too weak for the City of Sydney to hold on to for the Kings Cross district in the face of the tragic deaths of the teenagers. In such an analysis it is accepted that this district is an intrinsically open area in which people may turn up that have already drunk elsewhere or are otherwise affected by drugs. And in such an analysis it is accepted that Sydney is part of New South Wales, with a State Government that also has a say about measures to be taken in Kings Cross. From this broader perspective the festival frame as proposed by the designers has proven to be acceptable to the City of Sydney at the time of the project (2008) but has proven to be unacceptable in the long run.

6 CONCLUSIONS

In this contribution we have considered the design practice of framing and presented a formal way of describing it. Our aim was to better understand this practice and to explicitly define ways in which it may fail to be successful. We argued that there exist two modes for framing to fail, which we called the goal reformulation failure mode and the frame failure mode. By the first mode framing fails when designers reformulate the goal of the client in the design task and give design solutions that solve the reformulated goal but not the original goal. By the second mode framing fails when designers propose a frame for the design task that cannot be accepted by the client. We illustrated these two failure modes with the case of the redesign of the Kings Cross entertainment district in Sydney.
The existence of these failure modes does not imply that framing is not a powerful design practice. Through framing, designers can arrive at creative and effective solutions to design tasks, as the Kings Cross case shows. Yet this example also demonstrates that framing is not a practice that inevitably leads to successful design solutions; care and critical evaluation are needed to steer the framing process in the right direction.
The analysis in this paper creates an initial understanding of this, and opens up a more critical research agenda on framing. We need to investigate what would be the criteria for a 'good' or perhaps 'strong' frame, and these insights in turn could lead to recommendations on how the framing process can be conducted well. The wealth of cases of framing that is available in design research is a good starting point for such research, and as mentioned, also the literature on framing in the political sciences may be a useful resource. Also, further research might lead to the identification of other failure modes than the two described here, eventually leading designers to employ this tool with even more sophistication and success.

REFERENCES

Cross, N. (2006) Designerly Ways of Knowing. London: Springer.
Dorst, K. (2006) Design problems and design paradoxes. Design Issues, Vol. 22, No. 3, pp. 4-17.

Dorst, K. (2011) The core of 'design thinking' and its application. Design Studies, Vol. 32, pp. 521-532.
Dorst, K. (2013) Shaping the design research revolution. In: Lindemann, U., Venkataraman, S., Kim, Y.S., Lee, S.W., Clarkson, J. and Cascini, G. (eds), 19th International Conference on Engineering design; Proceedings Volume DS75-01: Design for Harmonies. Seoul: Design Society, pp. 173-182.
Dorst, K. (2015) Frame Innovation: Create New Thinking by Design. Cambridge, MA: MIT Press, forthcoming.
Dorst, K. and Cross, N. (2001) Creativity in the design process: Co-evolution of the problem-solution. Design Studies, Vol 22, pp. 425-437.
D.School (2011) D.School bootcamp bootleg. http://dschool.stanford.edu/wp-content/uploads/2011/03/BootcampBootleg2010v2SLIM.pdf (accessed May 25, 2013)
De Bruijn, H. (2014) Framing: Over de Macht van Taal in de Politiek. Amsterdam: Atlas Contact.
Hekkert, P. and Van Dijk, M. (2011) Vision in Design: A Guidebook for Innovators. Amsterdam: BIS Publishers.
Lakoff, G. (2004) Don't Think of an Elephant! Know Your Values and Frame the Debate: The Essential Guide for Progressives. White River Junction, VT: Chelsea Green Publishing.
Lawson, B. and Dorst, K. (2009) Design Expertise. Oxford: Architectural Press.
Norman, D.A. (1990) The Design of Everyday Things. New York: Perseus.
Paton, B. and Dorst, K. (2011) Briefing and reframing: a situated practice. Design Studies Vol. 32, pp. 573-587.
Rittel, H.W.J. and Webber, M.M. (1984) Planning problems are wicked problems. In Cross, N. (ed) Developments in Design Methodology. Chichester: John Wiley & Sons, pp. 135-144.
Schön, D.A. (1983) The Reflective Practitioner: How Professionals Think in Action. London: Temple Smith.
Simon, H.A. (1984) The structure of ill-structured problems. In Cross, N. (ed) Developments in Design Methodology. Chichester: John Wiley & Sons, pp. 145-166.

THE 20TH INTERNATIONAL CONFERENCE
ON ENGINEERING DESIGN (ICED15)

DESIGN FOR LIFE

27th-30th July 2015
Politecnico di Milano, Italy

Organised By
Politecnico di Milano, Politecnico di Torino
and the Design Society

Proceedings of ICED15
Volume 3: DESIGN ORGANISATION AND MANAGEMENT
DS 80-03

Edited By
Christian Weber
Stephan Husung
Marco Cantamessa
Gaetano Cascini
Dorian Marjanovic
Francesca Montagna

Published by the Design Society, Glasgow, Scotland

First published in 2015

ISBN 978-1-904670-66-7

Printed by Lightning Source, Inc., La Vergne, TN, USA,
and by Lightning Source UK Ltd., Milton Keynes, UK

Preface by the Programme Chair

We welcome you to the proceeding of the 20th International Conference on Engineering Design 2015 (ICED 15) held at the Bovisa campus of Politecnico di Milano, Milan, Italy. The theme of the Conference is “DESIGN FOR LIFE”, inspired by EXPO 2015 in Milan.

These proceedings of ICED 15 contain 427 double-blind peer-reviewed and accepted papers. The proceedings are published in different forms: a book of abstracts and a soft-copy of all contributions on a USB-based memory device for conference delegates plus printed books (11 volumes), which are available to the public via a print-on-demand service. All these different forms of proceedings are numbered against both Design Society and ISSN/ISBN referencing to allow wider access, better referencing and improved citation in the near and distant future. Additionally, all papers contain a citation proposal for a reproducible citation. The 11 volumes of the books are structured according to the conference topics and the sequence of the sessions. All papers in the proceedings have successfully fulfilled the criteria for acceptance in ICED 15.

Continuing on from the changes introduced for ICED 13, the papers in the proceedings were produced by combining an automatically generated cover page, based on the contribution details in the Conference Management System (ConfTool), with the paper as submitted by the authors, starting with the introduction section. This procedure supports consistent data for the papers, the conference programme, the Book of Abstracts, etc.
ICED 15 and its proceedings are the result of the dedicated efforts of many people:

- the authors who submitted excellent papers (both in content and form),
- the reviewers who provided timely comments and positive feedback that helped to optimise the quality of papers,
- the chairs, assistant chairs and members of the Programme and Organising Committee and the Design Society Administration who had to deal with details galore in getting the conference and the proceedings planned, structured, organised and ready to go (it was also fun, though!).

Thank you all very much!

On behalf of the Programme Committee we hope that you enjoy the programme and participate fully in what is arguably the Premier engineering design research conference in the world. We also hope that you find time to discover Milan and EXPO 2015, that you meet old friends and make some new ones, and that – besides work – you also have as much fun as we had when preparing the conference!

Christian Weber
Programme Chair

Stephan Husung
Assistant Programme Chair

Preface by ICED15 Conference Chair

Having reached its 20th edition, ICED15 confirms to be a well-established conference in the scientific design community and we are very pleased and honoured to host this edition, which has received a very significant attention from researchers and practitioners throughout the world.

ICED15 is being organized at the same time and in the same location as the Universal EXPO. The EXPO has also inspired the theme of our conference - Design for Life - which has been further formulated as Design for a Healthy, a Sustainable and a Contented Life. While the submissions were arriving and the conference program was taking shape, we were very pleased to observe that this conference theme has indeed been picked up by many authors and has permeated their contributions. As an outcome of this emerging synergy between ICED and EXPO, we expect participants to return to their countries not only with the usual benefits that come from the ICED experience, but also with a stronger capability and determination to make positive and effective contributions to humankind through design research, education and practice.

If one looks at the program of previous ICED conferences, it is quite apparent that the field of design is continuously evolving, and that the Design Society community that is at the heart of ICED is also at the forefront of this continual evolution and adaptation to emerging opportunities and challenges. Specifically, ICED15 welcomes a growing number of contributions in fields pertaining to the human and social aspects of design, looking at humans both as actors and as recipients of the design activity. We all know that these advancements do not only take place in the formal presentation sessions, but also through other gatherings, including business meetings, information events, workshops and – of course –social events. The conference program has therefore been designed with the objective of providing ICED participants with a variety of opportunities for meeting and exchanging views.

All this will occur within the setting of a country such as Italy that – since ancient times, going through the Renaissance and until today – has been uniquely able to blend its technical know-how with an amazing quality of life. We therefore hope that you will make a memorable experience of ICED 15, the EXPO and of the ideal of Designing for Life.

Gaetano Cascini
Conference Chair

Marco Cantamessa
Conference Chair

Preface by the Design Society President

ICED 15, the 20th edition of the International Conference on Engineering Design (ICED) is coming back to Italy, the country where the idea of a design conference first took shape. The first ICED took place in Rome in March 1981. The aims were, as its initiator Vladimir Hubka wrote in December 1980, set towards: *"… determining the latest state of knowledge in areas of scientific design methods, and of gathering information about current results and future trends in research, to achieve a free co-ordination of scarce research resources."*

This year, we are not in Rome, but in Milan - and for a good reason. The city of Milan itself is a synonym for quality of design as a way of thinking and living, in activity or in outcome. The conference themes indicate the broadness of thinking about design in and around the host city and connect the conference with the Universal EXPO that is also taking place at the same time. ICED 15 participants will have chance to experience the dynamics of a city that reflects all of the dichotomies that define design old and new, the art and technology, the research and practice, the chaotic and systematic. In the past thirty-five years the conference has become the event where all the richness of design research from all the continents is presented and all aspects of design explored ICED 15 sessions are the results of continuous improvements in every aspect of conference organisation. The format of the conference is based on the previous events with a programme made up of plenary sessions, podium presentations, discussion sessions with a focused debate and workshops led by the Design Society's Special Interest Groups. In addition, the Young Members' Event and PhD Forum extend the networking opportunities of ICED 15 for younger or first-time participants. The ICED 15 programme will provide an exciting opportunity for researchers and practitioners to learn about the latest developments in design research and practice.

The programme of ICED 15 is the result of a joint effort from great teams that have been working together since the last ICED conference in Seoul. The Society extends its gratitude to all the authors who have submitted their papers and all the reviewers who have helped to select papers ensuring an outstanding conference experience for all participants. A special thank you goes to all the authors and Session Chairs who will make this experience possible.

Many things have changed through the last 19 conferences. The conference started in Rome by WDK (Workshop – Design – Konstruktion), has, since 2001, been organised by the Design Society. Design as a field has expanded tremendously and the conference programme has become more interactive and complex, opening new opportunities and challenges. Organising a conference with such a history takes an enormous amount of work and attention to detail. I would like to express sincere thanks of the Society to Gaetano Cascini and Marco Cantamessa and all colleagues from Politecnico di Milano and Politecnico di Torino who have made this conference happen. Special thanks also to Programme Chair Christian Weber and Assistant Programme Chair Stephan Husung and all the members of Programme Committee for ensuring that this conference presents a tremendous quality of content. Finally, thank you to all of the participants whose attendance and input are a constant sign that this conference and design as a field are going in the right direction.

Dorian Marjanovic
Design Society President

ICED15 Programme Committee

Christian Weber - TU Ilmenau, Germany
Stephan Husung - TU Ilmenau, Germany
Monica Bordegoni - Politecnico di Milano, Italy
Marco Cantamessa - Politecnico di Torino, Italy
Gaetano Cascini - Politecnico di Milano, Italy
Dorian Marjanovic - University of Zagreb, Croatia
Srinivasan Venkataraman - TU Munich, Germany

ICED15 Organising Committee

Gaetano Cascini - Politecnico Di Milano
Marco Cantamessa - Politecnico di Torino, Italy
Serena Graziosi - Politecnico Di Milano, Italy
Francesca Montagna - Politecnico Di Torino, Italy
Federico Rotini - Università degli studi di Firenze, Italy

ICED15 Scientific Committee

Agogino, Alice Merner - University of California at Berkeley

Agogue, Marine - HEC Montréal

Ahmed-Kristensen, Saeema - DTU

Albers, Albert - Karlsruhe Institute of Technology (KIT)

Allen, Janet Katherine - University of Oklahoma

Allison, James T. - University of Illinois at Urbana-Champaign

Almefelt, Lars - Chalmers University of Technology

Anderl, Reiner - TU Darmstadt

Andersson, Kjell - KTH Royal Institute of Technology

Andrade, Ronaldo - Universidade Federal do Rio de Janeiro

Annamalai Vasantha, Gokula Vijaykumar - University of Strathclyde

Aoussat, Améziane - ENSAM

Arai, Eiji - Osaka University

Arciszewski, Tomasz - George Mason

Aurisicchio, Marco - Imperial College London

Austin-Breneman, Jesse - Massachusetts Insitute of Technology

Badke-Schaub, Petra - TU Delft

Balan, Gurumoorthy - Indian Institute of Science

Becattini, Niccolo - Politecnico di Milano

Becetic, Sanja - University of Zagreb

Ben-Ahmed, Walid - RENAULT

Bender, Beate - Ruhr-Universität Bochum

Beneke, Frank - FH Schmalkalden

Bertoni, Marco - Blekinge Institute of Technology

Bhamra, Tracy - Loughborough University

Binz, Hansgeorg - University of Stuttgart

Birkhofer, Herbert - TU Darmstadt

Bjärnemo, Robert - Lund University

Björk, Evastina, Lilian - Gjövik University College

Blanco, Eric - Univ. Grenoble Alpes, G-SCOP, F-38000 Grenoble, France CNRS, G-SCOP, F-38000 Grenoble, France

Blessing, Lucienne - University of Luxembourg

Boa, Duncan R - University of Bristol

Bohemia, Erik - Loughborough University

Bojcetic, Nenad - Faculty of Mechanical Engineering and Naval Architecture, University of Zagreb

Boks, Casper - Norwegian University of Science and Technology

Booker, Julian David - University of Bristol

Bordegoni, Monica - Politecnico di Milano

Borg, Jonathan C. - University of Malta

Borgianni, Yuri - Free University of Bolzano-Bozen

Boujut, Jean-François - Grenoble Institute of Technology

Bouwhuis, Dominic G - TU Eindhoven

Broberg, Ole - TU Denmark

Brown, David C. - Worcester Polytechnic Institute

Burvill, Colin Reginald - University of Melbourne

Bylund, Nicklas - Sandvik Coromant

Cagan, Jonathan - Carnegie Mellon University

Caillaud, Emmanuel - Université de Strasbourg

Campean, Felician - University of Bradford

Cantamessa, Marco - Politecnico di Torino

Casakin, Hernan - Ariel University

Cascini, Gaetano - Politecnico di Milano

Cash, Philip - TU Denmark

Cavallucci, Denis - INSA Strasbourg

Chakrabarti, Amaresh - Indian Institute of Science

Chen, Wei - Northwestern University

Chen, Chun-Hsien - Nanyang Technological University

Childs, Peter R.N. - Imperial College London

ICED15 Scientific Committee cont.

Chiu, Ming-Chuan - National Tsing Hua University
Choi, Young Mi - Georgia Institute of Technology
Chu, Chih-Hsing - National Tsing Hua University
Clarkson, Peter John - University of Cambridge
Coatanéa, Eric - Aalto University
Collado-Ruiz, Daniel - Dynavio Cooperative
Cormican, Kathryn - National University of Ireland
Coutellier, Daniel - University of Valenciennes
Crawford, Richard - University of Texas at Austin
Crilly, Nathan - University of Cambridge
Cugini, Umberto - Politecnico di Milano
Culley, Steve - University of Bath
De Guio, Roland - INSA de Strasbourg
Deans, Joe - University of Auckland
Dekoninck, Elies Ann - University of Bath
Dhokia, Vimal - University of Bath
Dong, Andy - The University of Sydney
Donndelinger, Joseph A. - General Motors LLC
Dorst, Kees - University of Technology, Sydney
Duffy, Alex - University of Strathclyde
Duflou, Joost - KU Leuven
Eckert, Claudia - Open University
Egan, Paul Francis - ETH Zurich
Eifler, Tobias - Technical University of Denmark
Eigner, Martin - TU Kaiserslautern
Ekman, Kalevi - Aalto University
Ellman, Asko Uolevi - Tampere University of Technology
Emrah Bayrak, Alparslan - University of Michigan
Eppinger, Steven - Massachusetts Institute of Technology
Erbe, Torsten - Jenoptik OS GmbH
Ericson, Åsa - Luleå University of Technology
Eris, Ozgur - MITRE Corporation
Fadel, Georges M. - Clemson University
Fan, Ip-Shing - Cranfield University
Fantoni, Gualtiero - University of Pisa
Fargnoli, Mario - Ministry of Agriculture
Ferrise, Francesco - Politecnico di Milano
Filippi, Stefano - University of Udine
Finger, Susan - Carnegie Mellon University
Fischer, Xavier - ESTIA
Frankenberger, Eckart - Airbus
Fu, Katherine Kai-Se - Georgia Institute of Technology
Fujita, Kikuo - Osaka University
Fukuda, Shuichi - Keio University
Gardoni, Mickael - ÉTS / INSA de Strasbourg
Georgiev, Georgi V. - Kobe University
Gerhard, Detlef - Vienna University of Technology
Gericke, Kilian - University of Luxembourg
Gero, John - UNCC & GMU
Goel, Ashok - Georgia Institute of Technology
Goh, Yee Mey - Loughborough University
Göhlich, Dietmar - TU Berlin
Goker, Mehmet H. - Salesforce.com
Goldschmidt, Gabriela - Technion - Israel Institute of Technology
Gooch, Shayne - University of Canterbury
Gopsill, James Anthony - University of Bristol
Governi, Lapo - University of Florence
Graessler, Iris - Heinz Nixdorf Institute, University of Paderborn
Graziosi, Serena - Politecnico di Milano
Grimheden, Martin - KTH Royal Institute of Technology
Grobman, Yasha Jacob - Technion, Israel Institute of Technology
Gupta, Ravi Kumar - Ecole Centrale de Nantes
Gzara, Lilia - Grenoble Institute of Technology
Hales, Crispin - Hales & Gooch Ltd.
Hallstedt, Sophie - Blekinge Tekninska Högskola

Hansen, Claus Thorp - TU Denmark
Hasse, Alexander - FAU University of Erlangen-Nuremberg
Hatchuel, Armand - Mines ParisTech
Hicks, Ben - University of Bath
Höhne, Günter - Technische Universität Ilmenau
Holliger, Christoph - University of Applied Sciences Northwestern Switzerland
Holmlid, Stefan - Linköping University
Hong, Yoo Suk - Seoul National University
Horvath, Imre - Delft University of Technology
Hosnedl, Stanislav - University of West Bohemia
Howard, Thomas J. - Technical University of Denmark
Husung, Stephan - Technische Universität Ilmenau
Ijomah, Winifred - University of Strathclyde
Ilies, Horea - Universitry of Connecticut
Ion, William - University of Strathclyde
Isaksson, Karl Ola - GKN Aerospace Engine Systems
Jackson, Mats - Malardalen University
Jagtap, Santosh - Lund University
Ji, Haifeng - Massachusetts Institute of Technology
Johansson, Glenn - Jönköping University
Johnson, Aylmer - University of Cambridge
Jones, Simon Lloyd - University of Bath
Jowers, Iestyn - The Open University
Jun, Thomas - Loughborough University
Kannengiesser, Udo - Metasonic GmbH
Karlsson, Lennart - Alkit Communications AB
Kazakci, Akin Osman - Mines ParisTech
Keates, Simeon - University of Greenwich
Keldmann, Troels - Keldmann Healthcare A/S
Kim, Yong Se - Sungkyunkwan University
Kim, Kee-Ok - Sungkyunkwan University
Kim, Harrison - University of Illinois at Urbana-Champaign
Kiriyama, Takashi - Tokyo University of the Arts
Kishita, Yusuke - Osaka University
Kitamura, Yoshinobu - Osaka University
Kleinsmann, Maaike - TU Delft
Kloberdanz, Hermann - TU Darmstadt
Koh, Edwin - National University of Singapore
Kokkolaras, Michael - McGill University
Komoto, Hitoshi - National Institute of Advanced Industrial Science and Technology
Kota, Srinivas - Birla Institute of Technology and Science
Kovacevic, Ahmed - City University London
Krause, Dieter - Hamburg University of Technology
Kreimeyer, Matthias - MAN Truck & Bus AG
Kremer, Gul - Penn State University
Kroll, Ehud - Technion
Krömker, Heidi - Technische Universität Ilmenau
Krus, Petter - Linköping University
Kuosmanen, Petri - Aalto University
Le Masson, Pascal - Mines ParisTech
Leary, Martin John - RMIT university
Lee, Sang Won - Sungkyunkwan University
Legardeur, Jeremy - ESTIA
Lenau, Torben Anker - TU Denmark
Liem, André - Norwegian University of Science and Technology
Lindahl, Mattias - Linköping University
Lindemann, Udo - TU Munich
Linsey, Julie - Georgia Institute of Technology
Liu, Ying - Cardiff University
Lloveras, Joaquim - TU Catalonia (Universitat Politècnica de Catalunya)
Long, David Scott - University of Dayton
Lulham, Rohan - University of Technology Sydney
Mabogunje, Ade - Stanford University
Maier, Anja Martina - Technical University of Denmark (DTU)
Malak, Richard - Texas A&M
Malmqvist, Johan Lars - Chalmers University of Technology

ICED15 Scientific Committee cont.

Manfredi, Enrico - University of Pisa
Marjanovic, Dorian - University of Zagreb
Marle, Franck - Ecole Centrale Paris
Matta, Nada - Universite of Technology of Troyes
Matthews, Jason Anthony - University of the West of Englsnf
Matthiesen, Sven - Karlsruhe Institute of Technology
Maurer, Christiane - The Hague University
Maurer, Maik - TU Munich
McAlpine, Hamish Charles - University of Bristol
McDonnell, Janet Theresa - Central Saint Martins
McKay, Alison - University of Leeds
McMahon, Christopher Alan - University of Bristol
Meboldt, Mirko - ETH Zurich
Mekhilef, Mounib - University of Orleans
Merlo, Christophe - ESTIA
Millet, Dominique - SEATECH Toulon
Mocko, Gregory Michael - Clemson University
Moehringer, Stefan - Simon Moehringer Anlagenbau GmbH
Mohan, Rajesh Elara - Singapore University of Technology and Design
Montagna, Francesca - Politecnico di Torino
Moreno Grandas, Diana Paola - University of Luxembourg
Mortensen, Niels Henrik - TU Denmark
Mörtl, Markus - Technische Universitaet Muenchen, Germany
Mougenot, Céline - Tokyo Institute of Technology
Moullec, Marie-Lise Therese Lydia - University of Cambridge
Moultrie, James - University of Cambridge
Mulet, Elena - University of Jaume
Mullineux, Glen - University of Bath
Murakami, Tamotsu - University of Tokyo
Nagai, Yukari - Japan Advanced Institute of Science and Technology
Newnes, Linda - University of Bath
Ng, Ricky, Yuk-kwan - Vocational Training Council, Hong Kong
Nicquevert, Bertrand - CERN
Nielsen, Ole Fiil - Worm Development
Nomaguchi, Yutaka - Osaka University
Norell Bergendahl, Margareta E B - KTH Royal Institute of Technology
Oehmen, Josef - Technical University of Denmark
Öhrwall Rönnbäck, Anna B - Luleå University of Technology
Olsson, Annika - Lund University
Onkar, Prasad - Indian Institute of Technology Hyderabad
Otto, Kevin - Singapore University of Design and Technology
Ottosson, Stig - Gjøvik University College
Ouertani, Mohamed Zied - ABB / University of Cambridge
Paetzold, Kristin - University Bundeswehr Munich
Palm, William John - Roger Williams University
Papalambros, Panos Y. - University of Michigan
Parkinson, Matt - Pennsylvania State University
Pavkovic, Neven - University of Zagreb
Peters, Diane - Kettering University
Petersen, Soren Ingomar - ingomar&ingomar - consulting
Petiot, Jean-François - Ecole Centrale de Nantes
Pigosso, Daniela - Technical University of Denmark
Prakash, Raghu Vasu - Indian Institute of Technology Madras
Qureshi, Ahmed Jawad - Newcastle University
Radkowski, Rafael - Iowa State University

Raine, John Kenneth - Auckland University of Technology

Ray, Pascal - Ecole Nationale Supérieure des Mines de Saint-Etienne

Reich, Yoram - Tel Aviv University

Reid, Tahira - Purdue University

Remmen, Arne - Aalborg University

Ren, Yi - Arizona State University

Riel, Andreas Erik - Grenoble Institute of Technology

Riitahuhta, Asko Olavi - Tampere University of Technology

Rinderle, James - University of Massachusetts

Ringen, Geir - Sintef Raufoss Manufacturing

Ritzén, Sofia - KTH Royal Institute of Technology

Rizzi, Caterina - University of Bergamo

Robotham, Antony John - Auckland University of Technology

Rohmer, Serge - University of Technology of Troyes

Rosen, David - Georgia Institute of Technology

Rotini, Federico - Università degli Studi di Firenze

Roucoules, Lionel - ENSAM

Rovida, Edoardo - Politecnico di Milano

Russo, Davide - University of Bergamo

Sakao, Tomohiko - Linköping University

Salehi, Vahid - University of Applied Sciences Munich

Salustri, Filippo Arnaldo - Ryerson University

Sarkar, Prabir - Indian Institute of Technology Ropar

Sarkar, Somwrita - University of Sydney

Sato, Keiichi - Illinois Institute of Technology

Schabacker, Michael - Otto-von-Guericke University Magdeburg

Schaefer, Dirk - Georgia Institute of Technology

Schaub, Harald - IABGmbH

Seepersad, Carolyn Conner - University of Texas at Austin

Seering, Warren - Massachusetts Institute of Technology

Sen, Dibakar - Indian Institute of Science, Bangalore

Setchi, Rossi - Cardiff University

Shah, Jami - Arizona State University

Shea, Kristina - ETH Zurich

Sheldrick, Leila - Loughborough University

Shi, Lei - University of Bath

Shimomura, Yoshiki - Tokyo Metropolitan University

Siadat, Ali - ENSAM

Sigurjónsson, Jóhannes B. - Norwegian University of Science and Technology

Simpson, Timothy W. - Penn State University

Singh, Vishal - Aalto University

Škec, Stanko - University of Zagreb

Snider, Chris - University of Bristol

Söderberg, Rikard - Chalmers University of Technology

Sonalkar, Neeraj - Stanford University

Spitas, Christos - TU Delft

Stal-Le Cardinal, Julie - Ecole Centrale Paris

Stankovic, Tino - ETH Zurich

Stappers, Pieter Jan - Delft University of Technology

Stark, Rainer G. - Berlin Institute of Technology

Stetter, Ralf - University of Applied Sciences Ravensburg-Weingarten

Stevanovic, Milan - Markot.tel

Stören, Sigurd - Norwegian University of Science and Technology

Storga, Mario - University of Zagreb/Faculty of Machanical Engineering and Naval Architecture

Subrahmanian, Eswaran - Carnegie Mellon University

Suh, Eun Suk - Seoul National University

Summers, Joshua David - Clemson University

Sundin, Erik - Linköping University

Tahera, Khadija - University of Huddersfield

ICED15 Scientific Committee cont.

Tan, James Ah-Kat - Ngee Ann Polytechnic
Taura, Toshiharu - Kobe University
Terpenny, Janis P. - Iowa State University
Thoben, Klaus-Dieter - University Bremen
Tiwari, Ashutosh - Cranfield University
Todeti, Somasekhara Rao - National Institute of Technology- Goa, India
Tollenaere, Michel - Grenoble Institute of Technology
Tomiyama, Tetsuo - Cranfield University
Törlind, Peter - Luleå University of Technology
Trimingham, Rhoda - Loughborough uni
Troussier, Nadege - University of Technology of Troyes
Udiljak, Toma - University of Zagreb/FMENA
Uflacker, Matthias - Hasso Plattner Institute
Umeda, Yasushi - the University of Tokyo
Vajna, Sandor J. - Otto-von-Guericke University Magdeburg
Valderrama Pineda, Andres Felipe - Aalborg University
Valkenburg, Rianne C. - The Hague University of Applied Sciences
van der Bijl-Brouwer, Mieke - University of Technology, Sydney
Van der Loos, Mike - University of British Columbia
Vaneker, Tom Henricus Jozef - University of Twente
Venkataraman, Srinivasan - Technische Universität München
Vidovics, Balazs - Budapest University of Technology and Economics
Vietor, Thomas - Braunschweig University of Technology
Vukasinovic, Nikola - Faculty of Mechanical Engineering, University of Ljubljana
Vukic, Fedja - Graduate School of Design, Faculty of Architecture, University of Zagreb
Walter, Michael - Friedrich-Alexander-Universität Erlangen-Nürnberg
Wang, Charlie C.L. - Chinese University of Hong Kong
Wang, Yue - Hang Seng Management Colleage
Wartzack, Sandro - Friedrich-Alexander-Universität Erlangen-Nürnberg
Watanabe, Kentaro - National Institute of Advanced Industrial Science and Technology
Watty, Robert - University of Applied Sciences Ulm
Weber, Christian - Technische Universität Ilmenau
Weil, Benoit - Mines ParisTech-PSL Research University
Weiss, Menachem Peter - Technion - Israel Institute of Technology
Whitfield, Ian - University of Strathclyde
Whitney, Daniel E - Massachusetts Institute of Technology
Winkelman, Paul Martin - University of British Columbia
Wodehouse, Andrew James - University of Strathclyde
Wood, Kristin - Singapore University of Design and Technology
Yan, Xiu-Tian - University of Strathclyde
Yanagisawa, Hideyoshi - University of Tokyo
Yang, Maria - Massachusetts Institute of Technology
Yannou, Bernard - Ecole Centrale Paris
Yilmaz, Seda - Iowa State University
Zainal Abidin, Shahriman - Universiti Teknologi MARA
Zavbi, Roman - University of Ljubljana
Zeng, Yong - Concordia University
Zolghadri, Marc - Supmeca

Table of Contents

DESIGN FOR A HEALTHY LIFE

DESIGN FOR A CONTENTED LIFE

VOLUME 2: Proceedings of the 20th International Conference on Engineering Design (ICED15)

DESIGN THEORY AND RESEARCH METHODOLOGY, DESIGN PROCESSES

DESIGN THEORY AND METHODOLOGY

DESIGN RESEARCH METHODOLOGY

DESIGN PROCESSES

VOLUME 3: Proceedings of the 20th International Conference on Engineering Design (ICED15)

DESIGN ORGANISATION AND MANAGEMENT

VOLUME 4: Proceedings of the 20th International Conference on Engineering Design (ICED15)

DESIGN FOR X, DESIGN TO X

VOLUME 5: Proceedings of the 20th International Conference on Engineering Design (ICED15)

DESIGN METHODS AND TOOLS – PART 1

VOLUME 6: Proceedings of the 20th International Conference on Engineering Design (ICED15)

DESIGN METHODS AND TOOLS – PART 2

VOLUME 7: Proceedings of the 20th International Conference on Engineering Design (ICED15)

PRODUCT MODULARISATION AND ARCHITECTURE, SYSTEMS ENGINEERING, PRODUCT-SERVICE SYSTEMS

PRODUCT MODULARISATION AND ARCHITECTURE

VOLUME 8: Proceedings of the 20th International Conference on Engineering Design (ICED15)

INNOVATION AND CREATIVITY

INNOVATION

CREATIVITY

VOLUME 9: Proceedings of the 20th International Conference on Engineering Design (ICED15)

USER-CENTRED DESIGN
DESIGN OF SOCIO-TECHNICAL SYSTEMS

USER-CENTRED DESIGN

DESIGN OF SOCIO-TECHNICAL SYSTEMS

VOLUME 10: Proceedings of the 20th International Conference on Engineering Design (ICED15)

DESIGN INFORMATION AND KNOWLEDGE MANAGEMENT

VOLUME 11: Proceedings of the 20th International Conference on Engineering Design (ICED15)

HUMAN BEHAVIOUR IN DESIGN
DESIGN EDUCATION

HUMAN BEHAVIOUR IN DESIGN

DESIGN EDUCATION