

A Philosophical Analysis of Designing

Results from the Delft Dual Nature of Technical Artifacts Program

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1. Introduction

Designing sometimes yields results that are miraculous from a technical point of view. The first light bulb must have been magical to those who first encountered it, as may be the new 555 passengers Airbus A380 to us when we see it take off from Schiphol Airport. From a philosophical point of view designing is, however, wondrous at all times. Design methodologists typically characterise designing as a process that starts with goals or desires of clients, and ends with a material description of a new product by which the client is helped. Philosophically speaking, goals and desires are intentional concepts by which we describe the thoughts and actions of conscious beings, whereas those material descriptions of products usually are phrased in structural concepts, by which we describe physical objects. Whereas philosophers have for centuries been trying to make some headway in understanding how these intentional and structural ways of describing the world are related, designers, apparently, move freely and systematically between these two modes of describing the world. As part of the *Dual Nature of Technical Artifacts* research program – funded by the Netherlands Organisation for Scientific Research (NWO), and carried out by and large in the period of 2000-2004 at the Philosophy Department of Delft University of Technology – we have analysed design processes from this philosophical perspective. In this contribution we sketch some of the main results.

The starting point of the program is that material technical artefacts – henceforward called simply products – such as light bulbs and airplanes, have, philosophically speaking, a dual nature: they have an intentional nature that is captured by, for instance, the ascription of technical functions to products, and they have a structural nature captured by a physical description of the product. Central tasks of the program were to analyse the notion of technical function, and to capture the relation between the intentional and structural natures of products. Answering these questions lead us first to describing using and designing in terms of what we called *use plans* for products (section 2) and to defining functions of products relative to their use plans (section 3). Secondly, we coupled this description and definition to the more usual descriptions of using and designing (section 4) and the more usual understanding of functions (section 5). Thirdly, we answered our philosophical question by giving at least the conceptual relation between intentional and structural descriptions of products (section 6). We end this contribution (section 7) with presenting a more detailed picture of design processes as they appear from our use plan account.

2. Designing as transforming goals into use plans

There is no consensus in the design methodology literature about how to characterise the process of designing. It is often taken as a process in which required functions are transformed into descriptions of the physics of products that can perform these functions (e.g. Gero 1990; Roozenburg and Eekels 1995). But wider characterisations by which designing starts with goals and ends with much more than descriptions of products are available as well (e.g. Hubka and Eder 1998; Eekels and Poelman 1998).

There is, moreover, no consensus on how to define the terms by which these characterisations are typically given. For some authors the term function, for instance, refers to intentions and purposes of designers (e.g. Gero, Tham and Lee 1992), but for others (or for the same authors at later times) to the behaviour of the product itself (e.g. Rosenman and Gero 1998). This forced us, as philosophers aiming at analysing the notion of function as used in designing, away from the neutral role of observing and into a more active one of reconstructing concepts. More precisely, we had to engineer our own definition of technical functions, for philosophical literature too, does not provide for an unambiguous meaning of the term (this literature is dominated by analyses of the concept of function in biology, and the few authors that do analyse technical functions in philosophy already disagree; Neander (1991) associated functions with goals of designers and users, Cummins (1975) takes them as capacities of the products). The definition we arrived at relates functions of products to what we called the *use plans* of these products. So, before giving this definition, we will have to introduce use plans.

Briefly summarised, a plan, a concept philosophically elucidated in action theory (Bratman 1987; Pollock 1995), is an ordering of actions considered by an agent for achieving a goal. A use plan for a product is defined by Houkes and Vermaas (2004a) as a plan in which at least one of the considered actions involves the manipulation of the product. Use plans were initially introduced by Houkes et al. (2002) in order to analyse product using and to establish a relation between using and designing. ‘An agent uses product *x*’ is spelled out as the carrying out of a use plan for the product by the agent as a means to achieving the goal associated with the plan. So, for example, ‘Alice drives her car’ means on our approach that Alice manipulates the car by executing a plan consisting of the usual driving actions for achieving the goal of transportation.

Designing is taken as the source of the use plans available to agents to achieve goals with. On this view, designing is not so much a process focussed on the description of material things, as it is one in which plans are developed: designing starts with a goal; then a use plan is developed consisting of an ordered sequence of actions by which the goal can be achieved; and only if some of these actions involve the manipulation of objects that do not yet exist, new products are designed. So, if a client comes in and explains to the designer that she wants to travel from A to B, the designer does not immediately start thinking about products but first considers a series of actions by which the client can obtain her goal. Such actions may consist of ones in which no objects are manipulated – walking – and may consist of manipulations of objects that already exist – cars – and that not yet exist – say, a teleporter. And only in that latter case the designer starts designing a product as well.

This use-plan account analyses the interaction between designers and users mainly in terms of the communication of use plans and the transfer of products: designers aid users in realising their goals by constructing a use plan to be executed, which includes manipulations of available objects and, possibly, newly designed products. In line with this, designers should not present the relevant plans to prospective users by merely handing over the relevant products;

instead, designers should communicate the actions and goals defining the plan. Presenting just the product would be largely worthless to users. Unless the use plan is highly entrenched or can be communicated exclusively through features of the product, a user who does not know the plan will be clueless.

Our characterisation of designing is revisionary. The concept of a use plan is not a concept one finds in the literature on designing. Also, an agent can already be said to be designing if s/he develops and communicates a new use plan for an existing product. Creating products, usually regarded as the paradigm of designing, is merely a special case on our characterisation. Hence, in order to establish its worth, we have to take up the challenge to show, on the one hand, the usefulness of the revision, and, on the other, its ability to reproduce the usual description employed in designing. We hold the position that the way in which we can describe the relation between using and designing by means of use plans, and the way in which we can capture the communication between designers and user, already makes this concept useful. In the next section we show the usefulness of our revision for defining technical functions.

3. Function ascriptions

Using the concept of use plans of products, one can capture functional descriptions of products by the following definition (Houkes and Vermaas 2004b; Vermaas and Houkes 2005; the definition is phrased in terms of the more philosophical term ‘artefacts’):

An agent a ascribes the capacity to ϕ as a function to an artefact x , relative to a use plan p for x and relative to an account \mathcal{A} , iff:

- I. the agent a has the capacity belief that x has the capacity to ϕ , when manipulated in the execution of p , and the agent a has the contribution belief that if this execution of p leads successfully to its goals, this success is due, in part, to x 's capacity to ϕ ;
- C. the agent a can justify these two beliefs on the basis of \mathcal{A} ; and
- E. the agents d who developed p have intentionally selected x for the capacity to ϕ and have intentionally communicated p to other agents u .

So, an agent can ascribe the capacity of transporting people on the ground to a car relative to the car's use plan with the goal of travelling, when the agent believes that the car has this capacity and that this capacity is relevant to the effectiveness of the plan (condition I), when the agent can justify this by, say, experience, knowledge or testimony (condition C), and when the designers of the car indeed designed or selected the car for this capacity (condition E). The labels ‘I,’ ‘C,’ and ‘E’ refer to (idealised) philosophical construals of the meaning of the function concept. The above definition integrates elements of these construals, and for this reason Houkes and Vermaas called it the ICE-definition of function ascriptions.

By this definition a function refers to a capacity of the product itself. But functions are also related to the goals of designers and users via the concept of use plans; the capacity of a product that corresponds to a function of the product is by the I-condition supposed to contribute to the effectiveness of the plan to achieve the goal for which it is designed to be used.

One may wonder whether the definition may be simplified by removing the concept of use plans; one can simply replace ‘use plan p for x ’ by ‘ x 's goal g ,’ thus freeing the definition from our fabricated concept. Such a more economic version of the definition has, however, the disadvantage that one ends up with an undesirable proliferation of functional descriptions of

products. If, for instance, a product is in part designed for the goal of using up an otherwise redundant stock of the company's electrical components, then the capacity of the product to rid the company of this stock can be ascribed to the product with the simplified definition. By including the concept of use plans – and this shows again the usefulness of the concept – such secondary goals do not allow for function ascriptions; these goals and the corresponding actions to achieve them, are typically not communicated to the users of the product, hence they do not lead to function ascriptions on the above definition.

The C-condition also prevents another undesirable proliferation of functional descriptions, namely ascriptions of functions products reasonably cannot perform on the basis of their physical makeup. Hence, ascribing the function of teleportation to two cardboard boxes simply because someone claims to have designed or selected the boxes for the goal of travelling, is ruled out.

The E-condition emphasises the role of designers in function ascriptions by requiring that the capacities corresponding to a product's functions, are capacities for which the designer of the use plan for the product designed or selected the product.

The above definition is central to the Houkes-Vermaas account of functional descriptions of products, but not exhaustive. A second, and secondary, definition is introduced to cover functional descriptions that refer primarily to roles of products in larger systems and less to the process of designing. A clear example of an ascription of such a functional role is given by the description of a short-circuited electrical system in an industrial plan as an unintentional detonator of an explosion that has taken place in the plant.

4. Types of using and designing

By giving the ICE-definition of function ascriptions we already carried out our central philosophical task of analysing the notion of technical functions. And by doing so, we also captured the relation between the intentional and structural natures of products. By the ICE-definition, these natures are conceptually connected when a function is ascribed to a product: a function refers to a physical capacity of the product itself, and is related to the goals for which designers designed the product and users use it, because this capacity is supposed to contribute to the effectiveness of the product's use plan to achieve this goal. But further research has led to a more enlightening analysis of how functions relate the intentional and structural natures of products. In order to present this analysis in the next section, we first turn to the second part of our challenge, namely to show that our revisionary analysis can reproduce more usual descriptions employed in designing. Here we focus on the use-plan account of using and designing as sketched in, for instance, Vermaas and Houkes (2005), the ICE-definition is considered in the next section.

Our description of *using* of a product as the carrying out of a use plan may seem not to be too eccentric. Users consider products as means to their goals, and on our account this means that they know of the use plans that designers have developed for these products, and that they thus can take the products as objects by which they can achieve the goals that are part of the use plans by carrying out the actions in plans. Designers present these use plans to the users, and this typically does not take place by direct communication, but through the usual channels of manuals, information distributed via marketing, advertisement and sellers, through signs ranging from use-cues and explicit symbols integrated in consumer goods, or through explicit training courses for professional equipment. Users may also ascribe functions with the ICE-definition but this is not necessary; the description of products in terms of plans is in principle sufficient for

users: it says what to do with products and what for. A cleaning agent, for instance, can already be used when the user knows that it yields a clean surface if the cleaning agent is applied to the surface in a particular way. Moreover, if users ascribe functions to products, they do so in rather unscientific, colloquial terms. A user can ascribe the capacity to remove stains to the cleaning agent, which refers to a physical capacity of the substance in non-scientific or technological terms. The knowledge (the account \mathcal{A} mentioned in the ICE-definition) by which users justify function ascriptions (in order to satisfy condition C of the definition) may also lack physical or technological depth and consist simply of experience by the user or of testimony originating from the designer.

Our description of designing might, however, be too liberal to reflect the paradigmatic sense of the word. The advantage of this is that we can broaden our analysis; a disadvantage is that the analysis loses contact with its paradigm. Therefore, to reconnect, we start by defining *altruistic expert product designing* as designing in which not only a use plan is developed for a product or products, but also new product(s) are described on the basis of expert scientific and technological knowledge, and the plans and products are made available to other persons. Altruistic expert product designing is designing as it is typically done by professional (engineering) designers. They typically ascribe functions to the products described, do so in considerable physical detail, and justify the ascriptions on the basis of their expert scientific and technological knowledge.

By now weakening or changing the extra conditions that define this first and paradigmatic case of designing, other ‘activities’ concerning products can be identified as designing as well. For instance, if the condition that new products are described is dropped, one has the case in which professional designers and engineers advise clients to obtain their goals with products independently of whether these products need to be described as well or already exist. The designer then develops a new use plan for the products, may need a lot of expert knowledge to do that, communicates the plan to other persons, but need not describe a new product. An example of such *altruistic expert designing* in which no new product was described may be the discovery that Aspirin can also be used by cardiac patients for preventing blood clots. The development of the corresponding new use plan, that is, the right way of administering Aspirin for this new goal, required expert knowledge, but not the development of the drug itself. The designers engaged in such cases of designing typically also ascribe functions to the products they consider, do so in considerable physical detail, and also justify them on the basis of their expert scientific and technological knowledge.

This last case could be included because our account construes designing primarily in terms of use plans rather than products; the following two cases can be included by allowing that the knowledge involved in designing may also be everyday-life or layman knowledge. *Altruistic amateur designing* is the case in which persons that are not professionally trained designers or engineers develop a new use plan for existing products and communicate this plan to others. Candle wax can be removed from cloths by ironing the stains through brown paper, and this defines clever but non-standard use of brown paper. Chairs can be used for standing on, and this is generally seen as improper use of the chairs. These altruistic amateur designers and the people to whom the new use plan is communicated can also ascribe functions. The descriptions of the physical capacities corresponding to these functions will be less scientific or technological, and the knowledge by which these function ascriptions are justified typically consists of experience. The functions ascribed are often compared with the functions products have relative to their original ‘expert-designer’ functions, for instance when it is asked whether chairs also have

‘standing on’ as a function. On our account the difference between this function and the original ‘sitting on’ function is that the latter is defined relative to the original use plan developed for the chair by expert designers, whereas the former is picked up in time by chairs relative to a new use plan that is connected to a well-known alternative way of using the chair.

A final case worth mentioning is what we call *personal amateur designing*. In this case a (lay)person develops a new use plan for an existing product and does not communicate it to others. An example is Simon Vestdijk, the Dutch writer, who used his vacuum cleaner as a means for preventing loss of concentration. While he was working, he switched on his vacuum cleaner to drown out background noises. Vestdijk may have also ascribed a corresponding function to his vacuum cleaner (this ascription may then have satisfied the ICE-definition as soon as one accepts that communication of use plans may include memorising them for later use). And if he did, the description was again less scientific or technological, and the knowledge that justified it consisted of experience. At first sight, this type of personal manipulation of products may be seen as use that does not cohere with the proper way of using the product concerned; it is idiosyncratic or funny use (and altruistic amateur designing is sometimes more positively characterised as innovative use). The use-plan analysis shifts the way in which this manipulation can be understood away from using by designating it as designing. And there are indeed principal differences between the using of products in accordance with the original intentions of designers and according to personally fabricated plans. A user knows that using products in accordance with the original intentions of designers is rational due to the scientific and technological knowledge designers have. The user has, furthermore, a right to assume that this use is rational: if the vacuum cleaner does not clean, he can reclaim his money. The use of products according to personal plans may be rational on the basis of personal experience, but there is no such thing as a legal right to assume that this use is rational. Had Vestdijk’s vacuum cleaner failed at some point to keep him focussed, he would not have gotten his money back. And this is a matter of principle; it is not as if Vestdijk would have had at least some right to reclaim a small percentage of his money.

5. Function ascriptions in designing

It can be shown that the ICE-definition of function ascriptions satisfies a number of minimal requirements any account of technical functions should satisfy (Houkes and Vermaas 2004b). As we mentioned, it satisfies, for instance, the requirement that physically unreasonable function ascriptions should be ruled out. A disadvantage of the definition is that it explicitly relates functions to use plans of products and thus, at first sight, does not reproduce the way designers ascribe functions to products. Since the concept of use plans is of our making, designers most probably do not relate functions to use plans. It can, however, be shown that on our analysis designers can to a large extent suppress explicit references to use plans, in particular when they ascribe functions to components of products in accordance with the ICE-definition (Vermaas 2005). Functions are on our analysis again ascribed to those components relative to use plans of those components. These use plans are developed by the original designers of the components and used by designers of the products that contain the components. A component use plan can have the form “compose the components c, c', c'', \dots in configuration k in order to obtain a product x with the capacity to ψ ”. Relative to this plan the designers of the product x can then ascribe the physicochemical capacities to ϕ of c , to ϕ' of c' , and so on, as functions to these components by the ICE-definition, provided that these capacities physically ‘add up’ to a product with the capacity to ψ . It can now be argued that designers will interpret this component use

plan, not as a plan that is communicated to them by colleague designers and that consists of actions “compose the components c, c', c'', \dots in configuration k ” aimed at the goal “to obtain a product x with the capacity to ψ ” but as a technological rule they know themselves about how these component make up the product x . This rule may have the form: “the composition of the components c, c', c'', \dots in configuration k yields an product with the capacity to ψ ”. By this interpretation, the ICE-definition simplifies to the form (the product as a whole is again referred to as an artefact, and the designer of that artefact is called an engineer):

An engineer e ascribes the capacity to ϕ as a function to the component c , relative to the composition of c, c', c'', \dots in configuration k of an artefact x with the capacity to ψ , and relative to scientific and technological knowledge, iff:

- I. the engineer e has the capacity belief that c has the capacity to ϕ in the configuration k , and the engineer e has the contribution belief that if x has the capacity to ψ , this is due, in part, to c 's capacity to ϕ ; and
- C. the engineer e can justify these two beliefs on the basis of scientific and technological knowledge.

In this ICE-definition for function ascriptions to components, references to use plans disappear: a physical capacity to ϕ is ascribed as a function to component c of a product relative to the composition of the product and relative to a capacity to ψ of the whole product. The engine of a car, for instance, can be ascribed the function to deliver propulsion relative to the car and the car's capacity to transport people. Hence, explicit references to goals or actions drop out (although it can be argued that the identification of the capacity to ψ of the product relative to which functions can be ascribed to its components, still refers to the goals and actions associated with the product) and this turns the ICE-definition into one that, in our view, comes close to how designers think about function ascriptions.

For function ascriptions to products as a whole a similar solution is not available, meaning that we have to take such function ascriptions by designers as at least tacitly referring to use plans.

6. Functions as conceptual drawbridges

By means of these results we are now in a position to give a more detailed answer to our question of how the intentional and structural natures of products are related. As we already said, function ascriptions connect these two natures, and we can now show that they do so in quite a sophisticated way that is tailor-made for the case of using and/or designing at hand.

Users, as we said, need not ascribe functions to products. Users can stick to descriptions of products in terms of use plans only, and if they do, their descriptions of products refer primarily to the intentional nature of the products: products are associated with plans consisting of goals and actions, and those are all intentional concepts. But when users do ascribe functions to a product, they add a structural element to their description of the product: users then ‘highlight’ one particular physical capacity of the product that makes the product a means to the goals of the product's use plan, and thus contrast it with other capacities of the product that are not relevant for obtaining these goals. This structural element can be captured in rather unphysical, colloquial terms, meaning that users indeed can highlight this structural element without being required to have full knowledge of science and technology. Hence, users can employ the concept of function as an easy conceptual bridge from the intentional nature to the

structural nature of products. This bridge can be used by the user to cross from his or her intentional use-plan characterisation of products and expand the description to structural terms, and this bridge can be drawn in order to ‘cloak’ the structural nature of products.

When designers ascribe functions to products, they highlight the physical capacities of the products that play a role within the use plans for the products. By explaining how these products physically have these capacities, and how these capacities contribute to the effectiveness of their use plans, the concept of function connects the intentional descriptions of the use plans of the products to detailed physical descriptions of the products themselves. For designers the concept of function is thus again a conceptual bridge between the intentional and structural natures of products, but now it seems to be a fixed bridge: functions of products refer to both physical capacities and to use plans. An exception is the ascription of functions to components of products. As we sketched in the previous section, designers may ascribe functions to components relative to the composition of the encompassing product and relative to a capacity to ψ of that product. By such function ascriptions designers can cloak the intentional use-plan descriptions of the products, and focus on the physical structure of the products that explains how they can perform the ascribed functions.

The concept of function thus provides, by the Houkes-Vermaas analysis, a bridge by which users and designers can connect the intentional and structural natures of products. And the concept also provides a means by which they can separate these natures. Functions thus form a beautifully ‘engineered’ conceptual bridge that users and designers can draw or not draw depending on their descriptive needs.

7. Reconstructing the design process

A lot has been said about the instrumental usefulness of our analysis to understanding the notion of function, but it also has more to say on the process of designing itself. Designing, at least when it is taken in the paradigmatic sense of altruistic expert product designing, involves the devising of both a use plan and (a description of) a product. Therefore, it comprises a twofold transition, first from users’ goals to use plans, and, secondly, from use plans to products. In practice, of course, these two transitions are not ordered chronologically; they will typically take place concurrently and in close interaction. Let us look at both of them in more detail.

A design process starts with a given goal from a client and the first thing a designer then needs to do is to come up with a use plan: a series of actions that, if carried out properly, will lead to that goal. One way to do this is to break down the main goal into simpler sub-goals that, if achieved subsequently and systematically, lead to realisation of the main goal – a process we might call *goal decomposition*. Once these simpler goals have been fixed, one or more series of actions are required to realise them. At some point, these actions must involve manipulations of the product being designed. A somewhat stylised example is the design of the first washing machine by William Blackstone in 1874. His goal was, obviously, clean clothes. Given some background knowledge about water, soap, and dirty clothes, he could easily come up with something like the following decomposition of his main goal: (1) bringing the dirty laundry in contact with soap water, (2) have dirt and soap react with each other, and (3) get rid of dirt and remaining soap. The corresponding actions would roughly be: (1) put the dirty laundry in a tub filled with soap water and soak it, (2) tumble the laundry and rub it firmly against each other and the sides of the tub by means of the mechanisms of the washing machine, and (3) empty the tub and wash away the dirty soap water.

Goal decomposition is a crucial step in designing, as it determines the ‘division of labour’ between the product and the user. It establishes what prospective users are supposed to do, roughly how and when the product is supposed to be used, and part of the product’s operational principle. To the extent that a design process involves the reengineering of an existing product or the design of a highly standardised or common product, the available options for goal decomposition will be limited. Goal decomposition can also take the form of automating tasks that were previously carried out by hand. The washing machine is a good illustration: the actions performed by the first washing machines were not radically different from what people had been doing by hand before; it was just that they could now be performed more efficiently by operating the machine.

The second transition is from use plan to (the description of) the product. As the ICE-function theory stipulates, a given use plan delimits the desired capacities of the new product and hence fixes its function(s). But once this main function is given, the challenge of the second transition is to realise that function by a material structure and this is where *functional decomposition* comes in. The main capacity of the new product must be analysed into ‘smaller’ and ‘simpler’ capacities; capacities that, if manifested in a programmed fashion, realise the overall function of the product. At some point, functional decomposition stops either because it has reached a point where off-the-shelf solutions are readily available for implementing the sub-function (sub-capacity) or because the decomposing sub-functions are ‘atomic’ and unsusceptible to further decomposition. In the former case, the appropriate component(s) can be selected from product guides, catalogues, etc. but in the latter case, a new component may have to be developed or invented in order to implement that sub-capacity. Here, knowledge about the properties and behaviour of materials and constructions provided by the engineering and natural sciences can help, but engineering creativity and inventiveness is probably most important. Let us give another example to clarify the idea: the use plan for a bicycle determines the function of the bicycle, i.e. the main capacity (capacities) it is to have. This overall function is then decomposed into sub-functions such as sitting a human person, translating movement of legs to movement of wheels, allowing for steering, and so on. Finally, when sufficiently simple decomposing functions have been identified, the implementations of these functions can be selected, such as the bicycle’s seat, pedals, handlebars, and so on.

We must admit that this picture of designing is still sketchy. In fact, further research on the nature of the design process is still being carried out. Specifically, we are looking into questions about how goal and functional decomposition work, whether there are different types of decompositions, how these two decompositions relate to physical decompositions of products in their material parts, and to what extent it is possible to reconstruct designing as a broadly rational endeavour with identifiable (inference) steps.

8. Conclusion

In this contribution we presented a number of results of the NWO research program *The Dual Nature of Technical Artifacts*, as it was carried out at the Philosophy Department of Delft University of Technology. The main results are a use-plan account that provides an integrated description of using and designing in terms of the common concept of use plans, and the ICE-definition that spells out what it means to ascribe a function to a product. This description and definition is revisionary relative to usual descriptions of using and designing and to function ascriptions in designing. We showed that, nevertheless, the use-plan account can reproduce this usual description and that the ICE-definition when applied to components of products, becomes less

revisionary. We also sketched a picture of designing that follows from our account. If we take seriously the idea of a use plan, designers not only devise material products through a process of functional decomposition, they also devise use plans through a process we called goal decomposition.

Research at the Delft Philosophy Department led to other results as well. Ones that are relevant for this contribution are analyses of use knowledge (Houkes 2005), the normativity of functional descriptions of product (Franssen 2005), the social aspects of functional descriptions (Scheele 2005), and the nature of technological explanations (De Ridder 2005). (Many of these results have been presented in Scheele and Vermaas 2003, which is a volume in Dutch.) The use-plan analysis was, furthermore, of use for analyses of design methodologies; in Dorst and Vermaas (2005) and Vermaas and Dorst (2005) it is contrasted with the methodology of Gero (1990). And it is, of course, our intention that it will be of use for other projects in designing as well.