abstract

Within the discipline of industrial design engineering “dfx” is a common abbreviation for “design for x”, in which the “x” refers to several goals like sustainability (dfs), assembly (dfa), disabled (dfd), etcetera. As more industrial design engineers are employed within the Faculty for Architecture in Delft, especially at the chair for Product Development, the frames of thinking of industrial design engineers are gradually introduced in this faculty. With respect to living environments, the architect regards the house in the first place as a building, while an industrial design engineer tends to regard a house as an industrial product. In the research project “Concept House” both disciplines meet each other, leading to challenging discussions on the subject of living. From the point of view of industrial design engineers the design of a house would be translated to “design for inhabiting” or “design for living” (dfl). The house itself would be regarded as “just another” product with a complex system of functionalities which will realize together the main function which can be defined as “living”.

1 Introduction

Industrial design engineering is a young discipline of less than 100 years old, while architecture is an old discipline of several thousands of years. Another difference is that industrial design engineering deals with products which last 10 years at most, while architects mostly design for products to last for of many decennia with a secret hope that the building still exists after thousand years. Not many architects aspire the design of temporary buildings. Because of the long term scope of architects they are, with respect to user demands, dependent on their own vision, as the vision of the user will change anyway as time goes by. This phenomenon leads to a strong feeling of responsibility with architects. Architects tend to defend, much more than industrial designers, cultural values. Still Industrial design engineers determine more and more the living environment of citizens. Cars influence a the image of a street nearly as much as houses do. Street-furniture, garden-furniture, playing devices, street lights, sunscreens and sheds are all products which are designed mainly within the domain of industrial design engineering and which influence also our living environment and even the image of a house. The difference with architects is mainly that the industrial engineers do not think too much about the longer term and about cultural values. They base their list of demands upon the actual needs and values of the stakeholders which are not only the inhabitants, but also the local government, the manufacturer and the service-organization.

In design for living, architects as well as industrial design engineers should play there role, and it is important to use the best of both disciplines. This paper presents an evaluation of design science, as developed within the domain of industrial design engineering, applied in architecture, especially in the field of housing. Starting point is the basic design cycle of Roozenburg/Eekels.
2 Basic Design Cycle

In the faculty for industrial design engineering of Delft University, where the author was educated, and worked for approximately one year as a research manager, the students are given extensive instruction on design methodology and the "basic cycle of design". However, the field of scientific design research requires a close adherence to the cycle of empirical scientific inquiry. Both cycles are presented in Figure 1.

![Basic Design Cycle Diagram](image)

In the traditional approach, science produces new knowledge as an input for the design process. In practice, science and design have more than a linear relation. Design is used in scientific research to realize, e.g. test facilities. On the other hand, scientific research can be carried out as part of the design process, e.g. user-investigation or product testing.

Especially in the analysis phase in the design cycle can be regarded as research. The analysis phase should lead to new knowledge and to criteria for a new industrial product design. The simulation and evaluation phase can also be regarded as application research in that the assumption that a simulation is representative for practice could be regarded as a hypothesis.

In many cases scientific research implies the design of experiments, while the graphs used to illustrate a process can be regarded as graphical design. High-quality scientific design could be regarded as design in which the research-oriented parts of the design process are carried out according to the rules of scientific research. Design science often requires a meticulous use of design methods and tools.

These considerations are applicable as well to architecture as to industrial design engineering. However the methods and tools which are used in both disciplines differ significantly, at least in education.

It is interesting to see how the “mental geography of residential environments” can be seen from the viewpoint of an industrial design engineer. The frame of these considerations is the proposition that industrial designers as well as architects are “creators of value”.

3 The concept of Design

In the context of industrial design engineering many authors wrote about the concept of design and about the subject of design research. Horvath (2001) analyzed the field of engineering design research, which manifests as a platform for exploration, description, structuring, rationalization and application of design knowledge and technologies. Design research can, according to Horvath, be regarded as “interpreting knowledge and linking it to design goals”, but also as “generating design goals from technological opportunities”.

Eekels (1982) defines four categories with respect to product innovation:
- Industrial product design functions, subordinate to
- Product development functions, subordinate to
- Product planning, subordinate to
Societal development.
For him, design is thus sub-ordinate to societal development.

Kotler (1976) claims, just as Eekels that a product is nothing more than a package of functions. Material objects are just a means to realize those functions. Kotler would not regard a house as a material object, but as a complex of functions. Eekels also introduced another hierarchy with respect to product design. He claims that objects can obtain functions, that functions can fulfill needs and that the fulfillment of needs can lead to value. He explains this concept by means of spectacles. Using the properties of glass the function of displacement of the focal point of light is realized. With this function a need, for example reading can be fulfilled. With this fulfillment a value can be realized, for example, personal development.

When we link these thoughts to the subject of the “design of living environments”, or “dfl”, it is obvious that the scope of the architect is more extensive than the scope of the industrial design engineer. The industrial design engineer mostly will focus on a limited set of objects which form this living environment. Also he/she will focus on more specific needs of the “user” of this environment. Where the architect and the industrial design engineer meet each other is, without doubt, on the subject of value. The ultimate goal of a product, and of a living environment is human value.

3.1 The concept of value

It is important, in this context, to make a difference between human value and product value. The ultimate goal of a product is human value. Product value can be defined as “instrumental value”. Product value is, according to Miles (1961), not directly linked to human value but to product functions. Miles defines (product-) value as the functions wished (Fw) divided by sacrifices to realize those functions (S). So, when the sacrifices are high, the product may lose value.

An important issue with respect to value are the, so-called, “secondary effects”, which can bring a product value down considerably. For example: A chair can be used to sit on, thus fulfilling a need. However, a chair is more than an object to sit on. A chair can be a means to show off (positive function) but it also takes up room (negative function) and bumping against it may hurt. The idea that human value is equivalent to product value is dangerous, as numerous examples illustrate.

We can formulate three main conditions for product value leading to human value:
1. The function should offer a positive contribution to aimed human activity
2. The function should not demand insuperable changes of standards and values
3. Side-effects of the function should not over compensate the primary value

In industrial design engineering as well as in architecture extensive product function analysis should be performed to ensure that the new function complies with the three conditions. Product functions can be structured in many ways. Examples are:
- Primary functions and secondary functions
- Primary functions and support functions
- Positive and negative functions
- Functions meant for different users
- Technical and emotional functions
- Learn and use functions

Secondary functions enable applications other than the primary application. For example: A radiator for central heating has as primary function to heat a room, but a secondary function can be to dry towels. Secondary functions can increase the value of a product, as long as the secondary function is desired. Concessions to the main functions bring value down. As Miles postulated: value is functions wished divided by sacrifices (Fw/S).

Support functions enable the primary function. A radiator needs facilities to enable this to be mounted on a wall and to open or close the water supply. In the past, these functions were seen as inevitably evil and received little attention from the designer. Nowadays, we recognize that support functions can raise the overall value of a product. Secondary functions can make a difference, especially now that primary functions are becoming more and more similar.
Every artifact produces side effects. While side effects concerning environmental impact and safety are closely monitored, many other go unnoticed. Take the example of the chair. Many negative functions can be defined which can be regarded as side effects. For example:

- It takes up room
- Sitting, it is impossible to reach as far as standing
- The chair reduces your view of things
- The chair loses value if you buy too many chairs
- Etc.

The same holds for functions intended for other persons than the primary users. Many different users have to cope with the product, including manufactures, warehouse managers, transporters, wholesalers, packagers, retailers, users, DMU's (decision making units), servicemen, recyclers etc. Sometimes the influence of secondary users is even more important than that of the primary user. For detergent bottles, the supermarket organization determines the overall shape because it has to fit on the supermarket shelves.

4 Objectivity and subjectivity

Special attention should be paid to the difference between objective and subjective functions. Before doing so, the terms objective and subjective need to be defined.

- The term “objective” is mostly interpreted as “based on reason”.
- The term “subjective” is mostly interpreted as “based on sense”.

The terms objective and subjective are directly related to the terms object and subject.

In case of an object, the initiative belongs to the observer (observer’s objective). In case of a subject, the initiative belongs to the product (experience by the observer).

An artifact can be seen both as an object, and a subject. We can covet an object for a certain purpose. We talk about and think about a subject. An opinion about an artifact, means, in fact that we regard it as a subject, while if it is something we want; we regard it as an object. The distinction between the product as an object and the product as a subject leads to the definition of two function groups: objective functions, which comply with the (conscious or unconscious) objective of the user and subjective functions, which comply with the (conscious or unconscious) experience of the designer.

In this context, objective functions are defined as the extent to which an artifact is able to assist the user in a physical, perceptual or informational way. Subjective functions are defined as the extent to which an artifact is able to influence the mental experience of the user. The diagram below shows a breakdown of objective and subjective functions.

![Diagram showing breakdown of product values]

Figure 2. Breakdown of product values

An “objective function” is based on functionality. The functionality is defined as something that an artifact can perform, independently of an objective. In a certain context there may be an objective (application) for this functionality. For example: A material changes color at a certain temperature.
This functionality becomes a function where it is used to provide the user with the information that the soup is ready to be consumed.

A “functionality” is based on objects. To ‘invent’ a new functionality, it is necessary to associate objects with a property. For example: A material can be associated with its low melt temperature. That association may lead to the ‘invention’ of the functionality: “temperature sensing by melting materials”. In the context of fire doors, this could lead to the (objective) function of preventing the door from falling out. The functionality of temperature sensing is, in this function, combined with other functionalities, for example, the functionality that melted materials lose their mechanical resistance. Because of this functionality, a spring is released which presses a pawl in a hole on the doorpost.

An “object” is based on matter in a certain “structure”. For example: Plastic is a material which becomes an object after it is brought into a certain structure. Foaming it is one of the options. This foam has certain properties and association with these properties may lead to the functionality “absorption of water”. Within the context of housecleaning, this may lead to the (objective) function of window cleaning. The plastic foam has other properties, which may lead to other functionalities, such as the absorption of kinetic energy.

Subjective functions result in “experience” and experience is related to “emotion”. Emotion originates from “meaning”, but to create emotion, a certain “context” is required. For example: Certain clothes can, as a subjective function, provide people with a feeling of freedom and independency. They are meant to be worn (meaning) when going hiking. Wearing them in the midst of a town on a rainy day, will not yield the same emotional status. Another example: A coffin in the context of the burial of a loved one leads to different emotions than a coffin in the context of a Dracula film.

A meaning is based on a “subject” (in the meaning of topic). The subject can be the image of a chair. To be able to see that the chair is intended for use as a garden chair, it should be associated with prototypical features, which belong to a garden chair.

These prototypical elements are defined in the language of forms called “semantics of form”. White plastic is still one of the prototypical features of a certain class of garden chairs. Mostly we recognize the meaning of a product immediately by interpreting one or more prototypical features.

A subject can be described as data in a certain “structure”. Through our senses we constantly receive data. Those data are associated with each other and are combined into information items that are specified here as “subjects”. For describing a subject we use language, gestures and symbols. For example: a subject is our holiday. We describe our holiday, using language and, for example, imitation of a peculiar person we met, and photographs.

The value of an artifact is a combination of objective and subjective values. We expect an artifact to perform objective functions, which we are able to define precisely. Our opinion about the artifact, however, is not only based upon the objective values, but for an important part on the subjective values. The artifact can do exactly what was expected, yet still we can hate it, for example when we associate its form with an unpleasant environment.

### 5 Design for living

Key question is if design for living (dfl) is a (sub-)discipline within the domain of design which differs significantly from other design (sub-)disciplines like design for assembly, design for manufacturing, design for all, etcetera.

We can imagine several categories of differences in this respect.

- The design subject
- Design networks
- Design culture
- Knowledge

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1 The term “prototypical features” refers to form properties, which are typical for the product related to its function (Muller).
5.1 The design subject

It is obvious that the design subject differs between architecture and industrial design engineering. Generally spoken, the design subject of an industrial design engineer refers to a well specified object which functions within a more or less complex context. The subject of an architect mostly refers to a, generally spoken, badly specified object which not only functions within a complex context, but which in itself forms the context in which a great amount of products (of industrial design engineers) function.

We could compare the situation with a stage play in which the industrial design engineers design the attributes and the architect the scenery. Both influence the general image of the play, and both should be geared to each other in order to bring the message meant by the director.

But, after all, the attributes as well as the scenery can be regarded as design subjects, and, according to Arthur Eger (2004) design subject can differ extremely with respect to the phases in which products are situated. Eger has defined five phases in the history of individual product types.

Products, generally speaking, start as defective function performers. After a time, the market will no longer accept this and the product function has to be optimized. It has to function adequately, be reliable and be safe. Competitors force the original product manufacturer to find new unique selling points, in the form of accessories, design and ergonomic features. This phase is called itemization. The next step, segmentation, is also the result of competition in the market and leads to different users being offered dedicated products. Finally, a level is reached where users look for tailor-made products or seek to exert considerable influence on the design of a product. Research by Eger proved that it is quite easy to position products in one of the phases and that there is substantial agreement between interviewees in this respect.

It is interesting to notice that architecture is less easy to position architecture in these levels. It depends however how we look at it.

When we look at the materialization of buildings, many of them should be positioned a level one or may be two. But when we look at houses as such, segmentation is a common phenomenon and even individualization is is an important issue these days. However, with respect to itemization developments are dissatisfying. E.g. locks on cars are far more sophisticated as locks on houses.

5.2 Design networks

Important with

B&A Group claims that three organizational shells can be distinguished, which influence the innovation process at small or medium sized enterprises (SME’s). The organizations in the inner shell are used the most intensively; the threshold for those in the second and third shell seems too high. ²

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² Several organizations, e.g. Syntens in the Netherlands, are specially oriented towards SME’s.
The communication between these shells can be seen as a constraint. Probably, industrial design engineers, because of their higher education, are able to communicate on each level. They may function as an intermediary between SME’s and organizations in the outer shells. As yet, no research has been conducted to prove this assumption.

Joanneke Kruijsen (1999) developed in her thesis a theoretical model for analyzing the photovoltaic diffusion process. In this model, the dissemination of a technology is analyzed by a network approach with two characteristics: the diffusion network level and the product development level. Within the network function, Kruijsen distinguishes four factors: technology development, stimulation by government, use and product development. In the product development process, she distinguishes four main phases: analysis, synthesis, simulation and evaluation. There are direct links between product development and technology development as well as with the user. Technological development offers technological options and the user offers user’s desires. For the stimulation process, it is necessary to have information about user wants as well as about technological options.

The model of Kruijsen can be useful. The complementary question in this study, which is not answered in the model, is how the interaction takes place and which factors determine the quality of the interaction.

Models like presented in figure 5 and figure 6 could be made for architecture, and probably they would show somewhat different. E.G. the influence of the government and social organizations would be much more complex, which will count also for the organization of the industry.

### 5.3 Design culture

Far too many people do not regard technical innovation of importance of culture. Probably, the reason is that many people with interest in technical innovation are not too much interested in culture, while many art-lovers do not know much about technical innovation. The contrast between culture and technological innovation was not always as strong as it is today, although the domains once again
seem to be growing toward one another. In the days of Leonardo da Vinci, artists regarded technology as a tool for making works of art. Nowadays, more and more artists are looking for opportunities to express themselves, using new technological developments.

That a cultural gap still exists becomes obvious from the infrastructure of professional organizations. ICSID is an international organization with a yearly conference in the field of industrial design. ICED is a similar organization in the field of industrial design engineering. There is no cooperation between the organizations and the conferences attract different visitors.

However, culture is more than art. It can be regarded as the existing system of values and standards. We will not elaborate on this subject in this context and limit ourselves to referring to the work of Johannes Eekels (1982). However, for the acceptance of a new technology, standards must often be modified. These standards can be related to the technology itself, but are related most of the time to the function, which is realized by the technology. People generally show no resistance to sensor technology, computer chips and wireless communication, but they have problems with having a chip in the body which tracks their every position.

Industrial designers and architects have some ability to influence standards by the way they present the product functions, but of course there are other, more important factors, like branding. There are many examples. In 1970 it was possible to buy small cassette players with headphones. They were, for example, used in museums to guide people through the building. At that time, no such products were sold for listening to music in the train or while biking or jogging. Sony’s “Walkman” did not introduce a new product, in the first place, but new standards. In fact, Sony proclaimed that using the technology in the train or on the bicycle was socially acceptable. It could be regarded as a “self-fulfilling prophecy”. The same happened in the case of the McDonalds drive-in restaurants. McDonald proclaimed that eating in a car was socially acceptable. It stimulated the sales at gas stations as well.

Of course, the need for listening to music in a train and for eating in a car already existed. It was “not done” because of the most important constraint of new product development: social acceptability. The importance of this constraint varies as the function is more or less related to social standards and values. The threshold for introducing a new type of fastener is lower than the threshold for a new kind of transport system.

We can distinguish formal standards and informal standards. The examples of the Walkman and the McDrive refer to informal standards. However, formal standards can also be influenced. A CEO of a manufacturer of special trailers says that he earns his living by trespassing against the standards for road transport. Sometimes objects with special dimensions need to be transported that are not allowed on the road. Nonetheless, they somehow have to be moved. The company therefore specialized in building special trailers that are ‘as safe as possible’. In the end, a license is always obtained. Referring to the cases discussed in this thesis, standards seem to play an eminent role on many occasions. In the case ofaramid, for example, a kind of "long stocking" was developed and introduced as a means to escape from high buildings. This stocking could probably have saved many lives on the eleventh of September. It is conceivable that in a few years, the availability of such a product in skyscrapers will have become a standard.

When we focus on the differences between industrial design engineering and architecture, we can conclude that the slowness of society with respect to the development of values and standards is even more an issue in architecture than in industrial design engineering. It is more easy to introduce a new means of making coffee (Senseo Crema), than to introduce a new means for unlocking a front door.

5.4 Knowledge

To make decisions, a designer must have the four types of knowledge distinguished by Eekels (1983) (factual, intuitive, normative and methodical) at his or her disposal. The distinction between these four kinds of knowledge explains why apparently simple design decisions are sometimes so complex. Take, for example, a new way of finishing a metal panel, offered by a supplier.

• He provides all the factual knowledge, which, however, is no guarantee that he will do as he says.

• Intuitive knowledge is needed which is derived from earlier experiences, and from the way the person, acts. The decision on whether or not to use the technology requires:

• normative knowledge, which provides information about whether the properties of the finishing method meet the requirements. Making a decision can nonetheless prove difficult, and therefore

• methodic knowledge is needed, to furnish a decision-making approach. There are many ways to come to a decision, as explained in the book “Industrial product design: Fundamentals and Methods” by Roozenburg/Eekels (1995).
What we can conclude with respect to this classification is that it is easier for industrial design engineers to visualize a product in a representative way. Although visualization systems are improving rapidly, it is still difficult to visualize the aspect of scale in architecture, which makes decision-making a special issue in architecture.

Another difference is the knowledge about users. In architecture users are much more difficult to define, not at least as a result of the longer average lifetime of a building compared with an industrial product.

Another highly elucidating classification is the division into:

- **Strategic knowledge**
- **Tactical knowledge**
- **Operational knowledge**

Industrial designers should be aware of the difference, as disregarding one of the categories may lead to malfunctioning. These three kinds of knowledge provide the answers to three different questions:

**Strategic:** what are we going to do? (Know what)

**Tactical:** what do we need (to know/to be able to) to do it? (Know how)

**Operational:** where do we find what we need? (Know where)

These different types of knowledge are relevant for the corporate level and for the individual level.

**Strategic knowledge**

Insufficient attention for the “know what” question on the corporate level means that activities will be dictated by circumstances. Many situations are what they are because of circumstances and not because of policy. A methodic approach can help to avoid these situations. On the individual level, poor attention to strategic knowledge can lead to redundancy of the skills of a person in an organization. An organization should help individuals with developing a strategic plan for themselves, starting from their personal ambitions. To build a strategic plan, the person should develop knowledge about the possibilities.

**Tactical knowledge**

Most organizations pay attention to the building up of tactical knowledge, but they can only do so if they have a clear picture of what the plans are. The same holds for individuals. Too often, training programs are based only upon current knowledge needs.

**Operational knowledge**

Operational knowledge is, generally speaking, not a problem. Most operational knowledge is available somewhere. The main question here is the “make or buy” question. Nowadays, it is impossible to have all the operational knowledge needed in the company. Close cooperation with the relevant knowledge sources is therefore necessary.

When we compare industrial design engineering with respect to this classification of knowledge, we might conclude that strategic information (know what) plays a different role in architecture than in industrial design engineering. For architecture a perception of society in general on the short, as well as on the long term is more important than for an industrial design engineer. The focus of most industrial design engineers is on marketing and business development.

We can conclude that this is reflected in the educational programs of both faculties in Delft.

With respect to tactical knowledge (know how) there is also quite some difference between the disciplines. Methodology is a more important issue in industrial design engineering than in architecture. In both disciplines increasing attention is paid to design tools, especially computer tools and rapid prototyping technology. Visualization is an issue in both disciplines.

With respect to operational knowledge there is quite some difference between the disciplines. The amount of technological options seems much larger for the discipline industrial design engineering than for architecture. In industrial products generally much more technologies are represented with respect to material technology, manufacturing technology, surface treatment, product graphics, display technology, etcetera. Of course, in building the amount of technology increases rapidly, but he
Architects involvement appears to be much less than in industrial design engineering. Industrial design engineering is not divided in e.g. general architecture, urbanism and interior architecture.

6 Conclusion
The faculty Industrial Design Engineering has its roots in the faculty of Architecture as well as in the Faculty of Mechanical Engineering. During several decennia Industrial Design Engineering has developed independently from Architecture. The focus shifted during that period from pure design to industrial innovation. Although many differences are discussed in this paper, we can expect that the disciplines will develop in each other's direction in the coming years. In architecture, industrial building will receive more and more attention and, in industrial design engineering the focus will more and more be on human value. This will be reflected in the new curriculum of the faculty for Industrial Design Engineering.
REFERENCES


