

ANALYSIS OF THE STRUCTURAL DESIGN PROCESS OF THE ADAPTIVE REUSE OF BUILDING STRUCTURES

Sander Pasterkamp^{1,2}

¹ Delft University of Technology, Faculty of Civil Engineering
P.O. Box 5048, NL-2600GA Delft, The Netherlands
e-mail: S.Pasterkamp@tudelft.nl

² Pieters Bouwtechniek

Keywords: adaptive reuse, buildings, engineering design, grounded theory.

Abstract. *In the field of structural building engineering there is a market shift taking place as a result of the growing number of buildings that are listed as cultural heritage, secularization, the economic situation and the increasing office vacancy rate in Europe and the US. More and more structural engineering firms that were designing and constructing new buildings now move to maintenance and adaptive reuse of existing building structures. But how does this shift influence the way in which engineering firms work? What is the influence of adaptive reuse of existing building structures on the structural design process? Unlike fields like architecture and especially industrial design that have a strong design tradition, in structural engineering until now engineering design has been regarded more as a craft that has to be learned in practice than as science. As a result of this, arguments to answer those questions are hard to find in literature (with a few notable but little cited exceptions such as the paper How designs develop by S.J. Macpherson c.s.[2]). To fill this gap an analysis has been made of the way in which the design process of adaptive reuse projects is supposed to work according to literature and professional associations, and of the way it really works in practice. Grounded theory method is used to generate concepts to explain the way structural designers work in such projects. Preliminary results show that standard descriptions of the engineering design process (generally from abstract to detail as for instance suggested in The Architect's Handbook by J.A. Demkin c.s.[3]) do not correctly describe the way in which this design process really works. Not only did the redesign process of existing building structures not work as expected by both clients and practitioners; even the structural design process of new building projects can be seen in a different light. It is expected that the results of this research eventually might lead to different contracts between clients and engineering firms in the future.*

1 INTRODUCTION

Just like in many other countries in Europe, for over a century the growth of the built-up area in the Netherlands was a given, peaking in the post-war reconstruction period (1940 – 1965). But in the last decade and especially since the beginning of the latest economic crisis (2008), the continuing growth of the building stock seems to have come to a halt. This new economic reality pushes many different actors, among which many engineering firms, to adapt the way they work.

Every week another church building in the Netherlands becomes vacant. Under the influence of changing social views, the aging of church members and the reducing number of young people, church communities continue to lose members. It is estimated that of the approximately 1,800 Roman Catholic churches in the Netherlands only about 1000 will remain. A large number of church buildings has become vacant as a result of the merger of three protestant denominations into the Protestant Church in the Netherlands (PKN)[4].

We have 18,000 hectare of outdated industrial areas, partially belonging to our so-called industrial heritage. In the Netherlands there are more than 7 million m² of vacant offices and more than 14,000 vacant stores.

For instance, the Dutch Economic Institute for the Building Industry (EIB) in 2010 published a report [5] on the vacancy rate in the Dutch office market, commissioned by the Dutch Ministry of Housing, Spatial Planning and the Environment. They concluded that between 1995 and 2009 the office stock in the Netherlands had increased from 33.3 million m² to 47.4 million m². In the same time the office stock in use had increased from 31.2 million m² to 41.1 million m². This means that in the same period both the absolute and relative number of vacant offices had risen sharply. The vacancy rate had increased from 2.2 million m² to 6.3 million m² by the end of 2009 - this means that 13.3% of the office stock was empty. The EIB expected a further increase in vacancy. Indeed in a 2012 report by the Dutch Association of Brokers NVM reported a vacancy rate of almost 16% at the end of 2012 [6]. The increase could have been even bigger if not 400,000 m² of vacant rentable office space had been taken out of the market by demolition and adaptive reuse. According to the EIB a healthy market should have a friction vacancy of 4 to 5%. The surplus is overcapacity.

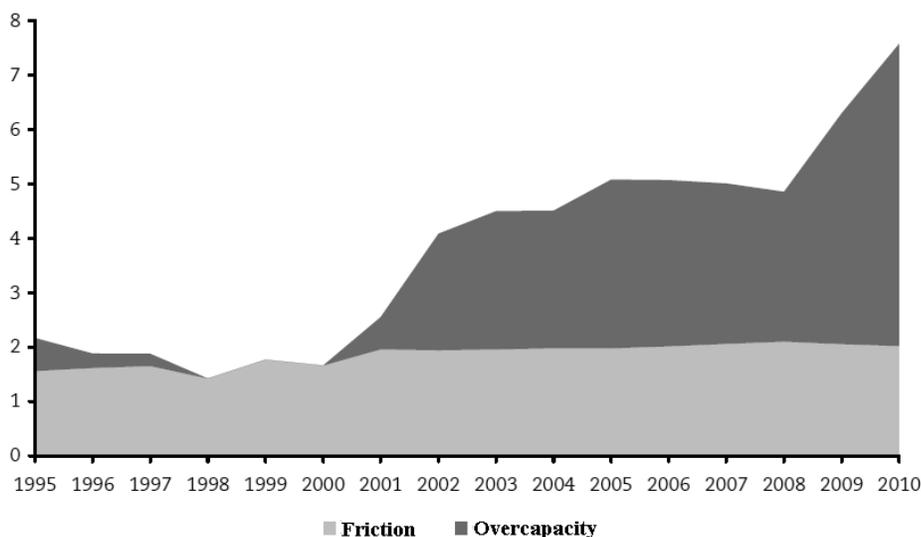


Figure 1: Friction vacancy and overcapacity in the Netherlands, in million m², source: [5]

The current owners of enumerative real estate usually cannot afford to let their buildings stand vacant for a longer period of time. Many buildings are being refurbished to attract new buyers or tenants. If the prospect of refurbishment does not raise enough interest (often the owner does not want to spend money on refurbishment if there is not yet a new tenant in sight) a change of function is considered. This requires a redesign of the building, resulting in adaptive reuse.

The decreasing work volume of new building projects and the rapidly increasing demand for adaptive reuse has led many architects and engineering firms to bid for reuse projects. These firms often have a lot of experience with the design of new construction projects. This raises the question: in what way does the design of a project that incorporates adaptive reuse of existing structures differ from a design project where the entire load-bearing structure can be designed literally from scratch?

2 THEORETICAL BACKGROUND

2.1 Design Cycle

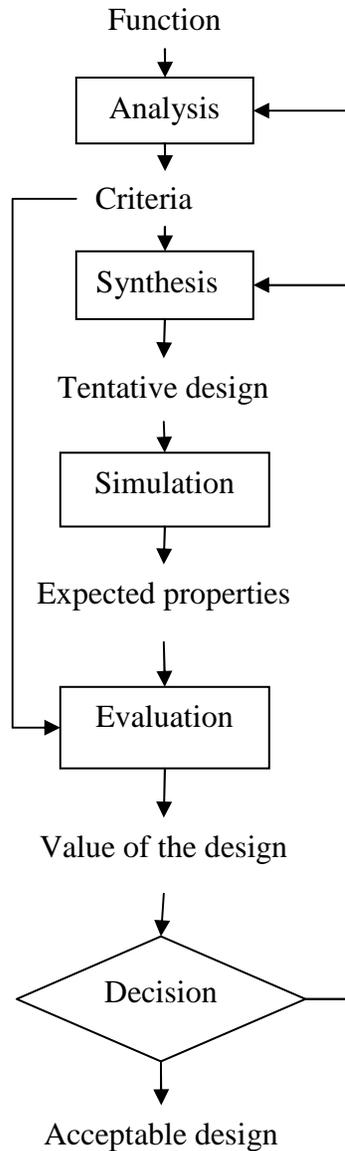


Figure 2 The Basic Design Cycle according to [1]

How is engineering design done in the structural design industry according to literature? Ir. N.F.M. Roozenburg and prof.dr. J. Eekels propose in [1] a basic cycle of design. They state that design is basically a trial-and-error process that consists of consecutive empirical cycles wherein the knowledge about the problem and the design increases in a spiraling fashion.

This classical idea of the way a design develops is reflected in many different documents from around the world. In 2009 the Dutch association of architects BNA together with the Dutch association of consulting engineers ONRI (now NLingenieurs) published the Standard Task Descrip-

tion or STD [7] as part of the DNR, a set of general terms and conditions for the building design industry. The introduction to this document says:

In the STD the design process of buildings and their direct surroundings is unraveled into tasks. The STD answers the question: ‘What should be done in the various design phases in order to come to a responsible design and to an adequate implementation of that design?’ the task list is multidisciplinary; it contains the aligned tasks for all relevant design disciplines.

The STD splits up the total building process into ten different phases, namely:

1. Initiative/feasibility;
2. Project definition;
3. Urban design;
4. Concept design;
5. Design development;
6. Technical design;
7. Pricing and contract formation;
8. Execution – executable design;
9. Execution – project management;
10. Use/exploitation.

These phases accurately describe the traditional building design process. Design of an increasing level of detail takes place in phases 3, 4, 5, 6 and 8.

A similar document from the UK is the RIBA Plan of Work. It is a model for the building design and construction process published by the Royal Institution of British Architects (RIBA). Like the Dutch STD it assumes an abstract-to-detail design order. The Architects Handbook of Professional Practice [3] gives a format for allocating responsibilities in a building design process to various contract parties. It too assumes the standard design paradigm and accompanying levels of detail.

2.2 Level of Detail

To answer the question from the introduction, let us first look at engineering design in general. In [8] prof Spitas analyses the engineering design process and different contributing paradigms are identified. This analysis is supported by a questionnaire-based survey of design engineers to evaluate the industry’s perception and use of systematic design paradigms. After a literature study Spitas sees three different design paradigms: (1) from abstraction to detail or AD, (2) from detail to detail or DD, and (3) from detail to abstraction to detail or DAD.

The first paradigm, AD, is the formal, traditional paradigm of standards and textbooks. It is predominantly sequential, proceeding from the more abstract to the detailed. It starts with laying out a specification. It then proceeds to explore and evaluate potentially useful concepts, evaluating them and elaborating the most promising solutions further to produce the final detailed design.

The second paradigm, DD, uses an existing product as input for a new, moderately altered product that fits the new specifications. Just like the AD paradigm it too starts with laying out a specification, but instead of creating concepts “out of the blue”, immediately existing solutions for similar problems are investigated as possible solutions for the new design problem. This reduces the flexibility of the design process and reduces the chances of discovering truly revolutionary new solutions, but greatly speeds up the design process as was shown further in [9].

The third paradigm, DAD, at first sight looks like the DD paradigm, but it does not only use existing solutions as input for the search for a solution; it also uses existing concepts and tries to create new concepts from existing embodiments and concepts. It thus reaches a higher level of abstraction than the DD paradigm while still retaining some of its most significant advantage, speed.

Spitas' research is primarily aimed at industrial design but at least one of the paradigms he mentions can also be found in the field of structural design.

The governing opinion in academia about design is that it literally starts with a tabula rasa or blank slate. From this the designer tries to conjure solutions to the design problem that fit the specifications. This is basically the AD paradigm. It matches very well the design methods as described in the STD, the RIBA Plan of Work and the Architects Handbook of Professional Practice. At the faculty of Civil Engineering of the Delft University of Technology, where the author of this paper is currently employed, the AD paradigm is taken as the foundation for the structural design courses.

2.3 Adaptive Reuse

But when we try to apply this method to the adaptive reuse of existing structures, it doesn't seem to fit. An existing structure already has an infinite level of detail at the beginning of the adaptive reuse design process. This should then be entered into the cycle of design. How this is supposed to be done is yet unclear.

The Architect's Handbook [3] contains a chapter 17.10 about historic preservation where the need for special knowledge of historic structures is stressed. It says that a thorough analysis of the existing structure should be made. It also says (pp. 486) that in the design phase, issues related to working on a historic structure should be coordinated with the standard steps of the building design process throughout design and construction. How the first and second steps are connected is left to the experience of the architect.

The British RIBA Plan of Work and the Dutch Standard Task Description have a similar approach. The STD too mentions a survey of the current state of the structure in case of renovation and restoration, but tries to catch both project types under one list of tasks in order to facilitate projects that incorporate both reuse and new construction. How the results of this survey work out in the following design phases is not described.

3 METHODOLOGY

In classical scientific research quantitative research methods are used. This means that before the actual research is conducted a hypothesis is formed based on a theory, after which this hypothesis is tested in a test setup where the quantitative results of the manipulation of control variables are measured. The aim is to verify or falsify the theory. In order to investigate the introduction of adaptive reuse on the design process, quantitative research methods are less useful for two reasons. The first reason is that the science of design is a field that is still highly "under construction". In literature many descriptions of design methods can be found, such as those discussed in chapter 2. Why these methods are successful is not exactly clear because a supporting deeper scientific theory is still under development [10]. For everyday design practice this does not have to be a problem. However if a new situation comes up that may require a new design method, this lack of theory becomes a problem because if the forming of theory is not yet finished, in classical science there can also be no hypothesis other than a random guess. The second

reason is that building projects involve a lot of people, a lot of money and possibly valuable historical constructions, which makes them less suitable for experiments.

To overcome these problems a research technique from the social sciences is being used. Instead of experimenting with building projects, existing adaptive reuse building projects are being investigated and data is collected. The purpose of this is then that a new theory should be derived from the data. This strategy for analyzing data is called the 'grounded theory' approach [11] because the theory is grounded in the data.

Pure grounded theory requires the complete absence of theory in the beginning of the research. But in this case the researcher himself had already been involved in two adaptive reuse projects in the past. Whether this is an advantage or a disadvantage is a matter of dispute among grounded theory specialists [12]. Having prior knowledge of the field can ease the forming of theory, yet it can also influence this process. At least the previous experience of and the literature study by the researcher has resulted in an early hypothesis about the influence of adaptive reuse on the design process. This hypothesis is:

“The introduction of adaptive reuse in the design process forces this process from AD to DAD.”

It is important that during the grounded theory research the validity of this hypothesis is considered with an open mind by the researcher. However, no-one would claim to enter the field completely free from the influence of past experience and reading. We can only hope that the advantages of prior knowledge will overshadow the disadvantages.

To get data to ground the new theory in, a series of adaptive reuse projects has been and continues to be investigated. Data gained include:

- Task descriptions as agreed upon by engineer and client at the start of the project;
- Drawings, calculations and other reports from various stages of the project;
- E-mails and other correspondence;
- Interviews with people involved.

By gathering a wider range of data types instead of limiting the research to just one type (e.g. drawings) the construct validity of the research was improved by 'triangulation'. This means that the requirement for corroboration between different data sources significantly enhances the reliability of the data and therefore of the theory.

4 OBSERVATIONS

The research is currently underway. Two consulting practices have so far supplied information about various adaptive reuse projects and a third one has agreed to assist in the near future. In the following table a list is presented of the type of projects investigated.

Table 1: Projects analyzed so far

	1	2	3	4	5	6	7
Original function	Post Office	Bank	Office, laboratory	School	Various	Office	Office
Location	Philadelphia	Philadelphia	Amsterdam	Amsterdam	Amsterdam	Alkmaar	Utrecht
New function	Office	Museum, Conference center	Office	Daytime center	Shops	Office	Office
Client	Developer	Museum	University	Government	Developer	Developer	Developer
Original year of construction	1935	1865-1960		1988	1750 - 1905	2000	1987
Demolition (partial)	Yes	Yes	Yes	Yes	Yes	No	Yes
Internal expansion	No	No	No	No	Yes	Yes	No
External expansion (horizontal)	Yes	No	Yes	No	No	No	No
External expansion (vertical)	Yes	No	No	No	No	Yes	No

4.1 Patterns which Emerged from the Data

Although the acquired data is still far from exhausted, open coding has already resulted in the emergence of three significant patterns.

The first pattern is the attention to detail in the early stages of the design development. A consistent difference is found in the level of detail in the topics discussed, both in words and in computer models, between the various standard design process descriptions discussed in chapter 2.2 and the projects studied. For instance, for the reuse of all concrete structures the amount of present reinforcement was always a governing factor in the preliminary design stage. The first job is always to look for existing construction drawings. If these are not available this is considered a serious handicap in the early design stage.

The second pattern is what one engineer interviewed called the naivety of the client. It turns out that in all cases the client expected the level of detail and the time spent on detailed calculations in the preliminary design of an adaptive reuse project to be the same as for a new development. Contract conditions are regularly just copies of the client's standard contracts, without much consideration for the very specific demands of adaptive reuse (first pattern). The need for a search for existing drawings and measurements of the structure is always recognized, but the consequences for the structural design process afterwards are not. An example of this is a project where the exact measurements of the existing building structures were entered into 3D digital models in the concept design stage, where the contract prescribed that only the general scope, conceptual design and the scale and relationships of components of the project had to be established.

The third pattern is the notable continuing design development during the execution phase. Four out of seven projects are being or have been executed at the moment of writing. In two cases insufficient data about the original structure was available during design, which required investigation of the existing structure during demolition and construction. In one case the original drawings were available, or so it was thought; after the project had started it turned out that the foundation on the drawings and the real foundation were completely different (piles vs. raft). In another case the execution of the project in a built-up area required a different construction material (prestressed concrete) than originally envisioned (steel).

5 PRELIMINARY CONCLUSIONS

The influence of the much higher level of detail that is required in the early design stages of a structural design that incorporates adaptive reuse is consistently underestimated by clients, but also by professional associations. There is a need for a new functional description of the design process that recognizes this influence. Such a description would help structural designers in doing their job, and it would also enable them to better explain to their clients why standard contracts should not be used for extensive rehabilitation, alteration and reuse projects. Due to the economic situation in the past and the complex nature of the design process this field is still highly in development.

The classical design cycle as described by Roozenburg and Eekels can also be recognized in reuse project design as performed by structural designers in practice. Whether other design methods could perform better is still an open question. The research finding so far suggest that here too the classical design cycle at least produces useful results. But the design cycle starts at a

much more detailed level. It also continues during the construction phase with much further reaching consequences. The clear theoretical line from abstract to detail is missing.

A new hypothesis that can be considered in the next stage of this research project is that designing for adaptive reuse is not a project on its own, but should be seen as the continuing of the original design process. This would put more responsibility on designers to enable their successors to do their job, e.g. by making sure that as-built drawings are made – something that is now still often skipped because it does not result in profit for those involved in the first design.

REFERENCES

- [1] Roozenburg NFM. Produktontwerpen, structuur en methoden. Utrecht: LEMMA; 1991.
- [2] Macpherson SJ, Kelly JR, Webb RS. How designs develop: Insights from case studies in building engineering services. *Construction Management and Economics*. 1993;11:475-85.
- [3] Demkin JA, American Institute of Architects. The architect's handbook of professional practice. Student ed. New York: J. Wiley; 2002.
- [4] Harmsen HW, G.M. van der. De Oude Kaart van Nederland: leegstand en herbestemming. The Hague: Atelier Rijksbouwmeester; 2008.
- [5] Zuidema ME, Martin van. Kantorenleegstand, Probleemanalyse en oplossingsrichtingen. 2010.
- [6] Bak RL. Stand van zaken Nederlandse kantorenmarkt. Nieuwegein: NVM Data & Research; 2013.
- [7] BNA. DNR-STB 2009, Toelichting en takenoverzicht. 2009.
- [8] Spitas C. Analysis of systematic engineering design paradigms in industrial practice: A survey. *Journal of Engineering Design*. 2010;22:427-45.
- [9] Spitas C. Analysis of systematic engineering design paradigms in industrial practice: Scaled experiments. *Journal of Engineering Design*. 2011;22:447-65.
- [10] Dixon JR. On research methodology towards a scientific theory of engineering design. *AI EDAM*. 1987;1:145-57.
- [11] Strauss AL. The discovery of grounded theory; strategies for qualitative research. New York: Aldine; 1967.
- [12] Heath H, Cowley S. Developing a grounded theory approach: a comparison of Glaser and Strauss. *International journal of nursing studies*. 2004;41:141-50.