

INNOVATIONS WITHIN DBFMO PROJECTS FROM A MAINTENANCE AND ENERGY-USE POINT OF VIEW

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Abstract

In most literature integrated contracting and procurement is assumed to result in more innovative solutions as a result of the intended process integration. This paper explores Design Build Finance Maintain Operate (DBFMO) cases in the Netherlands on resulting innovations focusing on maintenance and energy-use. It is assumed that in DBFMO contracts innovations on these aspects are of direct benefit for the contractor and thus the most easy to detect.

Two DBFMO office projects were compared with five traditionally build office projects. Applied research methods are explorative interviews with clients and contractors about DBFMO-contracting, case-studies focusing on maintenance costs and energy-use calculations and expert interviews with contracting parties.

Within the DBFMO cases four design choices can be considered to be innovations on maintenance and energy use. Out of the expert interviews it has been identified that four design choices of the two DBFMO cases are new solutions directly related to the way the projects were procured. The innovations detected in the case studies can be considered as the successful transfer of knowledge between departments of one contractor that would have worked independently in case of a traditional procured project.

Keywords: DBFMO, PFI, PPP, innovation, maintenance, energy-use, performance specifications

INTRODUCTION

Bundling design, construction, maintenance and operations (DBFMO) is strongly advocated by the Dutch government to improve the performance of the construction industry. The overarching term for this construction organization is Public Private Partnership (PPP) or Private Finance Initiative (PFI).

In the discussion on the benefits of these projects, the private financing is often seen as a

condition to execute the projects with assumed large advantages for public clients. Besides this several other benefits are often assumed, with regard to these project types as listed by Blayse and Manley (2004), Akintoye et al.(2005) and Leiringer (2006): lower project cost (Haynes and Roden, 1999), shorter construction time (Tiffin and Hall, 1998), competitive advantage (Lemos et al., 2003), higher overall quality of the end product (Regeringskansliet, 2000) and benefits accruing from letting the private sector be innovative in its solutions (Construction Industry Council, 1998).

Conditions for better DBFMO project outcomes

In the PPP literature some arguments are presented for the supposed conditions to achieve innovations within DBFMO projects compared to traditional projects. The first one is the integration of activities and therefore a more collaborative environment. Secondly, the demand of the client is described in performance specifications (output specifications). The third argument is the possibility of optimizing through long life cycle commitments. The last argument is about the risk transfer from public to private parties. These issues will be further discussed, because they appear not to be as obvious as they might look at first sight.

The first argument is about the collaborative environment. One provider (mostly a contractor) is responsible for the delivery of several activities over a relatively long period (20-30 years). Therefore a common view is that this could lead to better collaborative working between the different disciplines involved. In practice a special unit (special purpose vehicle) is established which is concerned with the bidding. This special unit will not execute the work themselves, but is subcontracted to other departments within or outside the providers company, like construction and maintenance. Leiringer et. al. (2009) present a case study of a large construction firm that works with PPP projects. The case study clearly illustrates how managers responsible for service operations struggle in having any real impact on key design and construction decisions. Even within PPP projects there might be struggles between the construction department and the departments responsible for operations like maintenance and facilities management. The different activities are often subcontracted separately by the special purpose vehicle, resulting in fragmented interests and non-collaborative working as in traditional projects.

The most common way to formulate the accommodation demand within PPP projects is by performance specifications. Whereas the traditional approach focuses on detailed description of the building, the performance approach only focuses on performances in relation to a certain use. A provider can therefore choose solutions that are able to deliver the performance in the most efficient way (e.g. Sexton and Barrett, 2005). In a publication of the Dutch Regieraad Bouw (2005) it is claimed that formulating the demand in performance specifications is an important stimulant for letting a provider be innovative in choosing a solution. However, Leiringer (2006) suggests that due to the performance approach a provider will likely choose a solution that fits best to the existing knowledge and available techniques within their organization instead of choosing new or unique innovative solutions.

The third argument is about the possibility to optimize on life cycle costs due to longer commitments. In case of DBFMO projects multiple activities of the construction process are outsourced for a longer period to one contractual partner, namely the special purpose vehicle and the demand is formulated in performance specifications. The focus within DBFMO projects is more on the use in form of accommodation services and less on the physical building as a product delivered at a certain moment in time. Due to the longer obligations it can be suggested that a DBFMO provider focuses more on life-cycle costing by optimizing

initial investments and operational costs. Leiringer et. al (2009) claim in their case study that there is little contact between the maintenance and construction department and therefore the possibility to influence the design is minimal: “Such decisions remain dominated by an institutionalized mindset that prioritizes traditional cost cutting over any consideration of through-life operational value”.

The last argument is about the risk transfer from the public side to private parties. This can be beneficial to a public client because the chances for budget overruns are smaller (HM_treasury, 1999). Whether a larger risk transfer to private parties will lead to innovative solutions is questionable (Leiringer, 2006). Especially the development and application of innovative solutions entails additional risk, therefore the doubt in the previous mentioned reasoning seems logical.

It might be concluded that there are different opinions and types of reasoning whether or not a DBFMO provider will be innovative in its solutions to deliver the accommodation services asked for.

This study is focused on finding empirical evidence for innovations on maintenance and energy-use in DBFMO office projects in comparison with traditional office projects. The main research question is: Can innovations be detected in case a DBFMO construction organization is applied instead of a traditional construction organisation? Two DBFMO cases in the Netherlands are explored on resulting innovations focusing on maintenance costs and energy-use. It is assumed that in DBFMO contracts innovations on these aspects are of direct benefit for the contractor and thus the most easy to detect.

THEORETICAL FRAMEWORK

First the context of DBFMO projects is discussed. The second part explains how innovations on maintenance and energy-use can be defined and how they can be measured. In the last part the conceptual model used within this research is described.

DBFMO context

When a DBFMO construction organization is applied, the client is demanding an accommodation service instead of a building delivered as a product at a certain moment in time. Within a predetermined performance specification a client buys, usable space or functionality for a certain period. This is in sharp contrast with the traditional construction organization where an amount of square meter floor area is bought as a building. A provider of a DBFMO project delivers the accommodation services through a model consisting of process parts and physical parts. The process parts consist of different activities that have to be performed during the contract period like designing, building, maintaining and operating the physical parts.

Based on decomposition models for design decision making, as described by for instance Prins (1992) and Leupen (2005), in the theoretical framework a building is decomposed in physical parts in terms of single components, component compositions) and ensembles. Components and their aggregations must have meaning in terms of usage, construction and/or their life-cycle, and as such are meaningful for design decisions as well as maintenance and operations.

The influence that can be exercised on the initial investment and operational costs is the highest in the design phase. According to Kohnstamm and Regterschot (1996) the influence in design phase is 30% for the investments costs and 65% for the operational costs. However these figures that often can be found in the literature do not make clear in which proportions the different costs per activity (design, build, operations) are represented. Evans et al. (1998) give the ratio 1:5:200, where 1 represents the cost for construction, 5 the costs for maintenance and building operations and 200 the business operating costs. However this ratio seems to be highly questionable, because no data can be found in the original study on which the numbers are based (Hughes et al., 2004). One generic ratio seems also debatable because every structure or building is (relative) unique. A building as a whole is unique due to a one-off composition of spaces, materials and products. At a lower level e.g. building materials or construction methods a building often is relatively less unique. E.g. a floor finishing will not differ that much between buildings.

The process parts were not investigated within this research, because it is not clear how the process parts influence exactly the design decisions and whether they stimulate innovations. So it is assumed that all the supposed advantages of the integrated process parts have to work out on the physical parts of the structure (components, component compositions and ensembles).

Innovation on maintenance and energy-use

The term innovation is in many ways ambiguous and its wide applications has led to many definitions depending on how innovation as a phenomenon gets meaning in a variety of contexts. Definitions can be found in for instance Rogers and Schoemaker (1971), Slaughter (1998), Kleinknecht (2000), Aa and Elfring (2002) and, Garcia and Calantone (2002). Most of the definitions found contain uniqueness of new developed inventions in terms of products, markets, systems and technology combinations. In case of determining project based innovations on DBFMO construction projects these definitions aren't applicable and can't be made operational.

In order to get a better understanding of innovations from a maintenance and energy-use point of view, explorative interviews were held with staff members of a large construction firm, an architect's firm and a client who were involved in DBFMO projects. In total 11 people were asked the following questions: (1) How to define innovation on maintenance and energy-use within a context of DBFMO projects? And (2) how to detect and to measure innovations on maintenance and energy-use in case of DBFMO projects? Ten respondents stated on the first question that innovations are mostly seen as the application of life-cycle costing. The application of products and solutions that in a traditional setting are considered to be too expensive, can be seen as innovative. The majority of the interviewees answered on the second question that innovations can be detected in the design process in terms of low life-cycle cost solutions and on the physical parts of the structure due to the uniqueness of product choices and materials.

Based on the outcomes of the explorative initial study innovation on maintenance and energy-use is defined as: A better performance compared to similar traditional build projects on maintenance and energy-use by developing and applying new and improved products and solutions on the physical parts components, component compositions and/or ensemble level, which are integrated into a structure and delivering accommodation services at an agreed level for a predetermined period.

Innovation according to this definition is not a goal on itself, but has to contribute value to the accommodation services. Innovation is measured via the so-called object method. This means that innovations themselves are investigated and not the company that creates the

innovations (Archibugi and Sirilli, 2001). The possible innovations are classified into project bounded and project unbounded innovations, due to the ‘relative’ unique nature of structures and buildings.

Conceptual model

As argued before it might be assumed that by both the integration of the process activities design, build, maintain and operate as well as the open solutions space by specifying the demand in performances, a provider of DBFMO constructions can offer accommodation services in a more efficient way especially in terms of life-cycle optimizations. If the structure is performing better on maintenance and energy-use by developing and applying new and improved products and solutions on the physical parts in comparison to traditional projects, it is an innovation within the context of this research. This has been visualized in a conceptual model, as depicted in Figure 1.

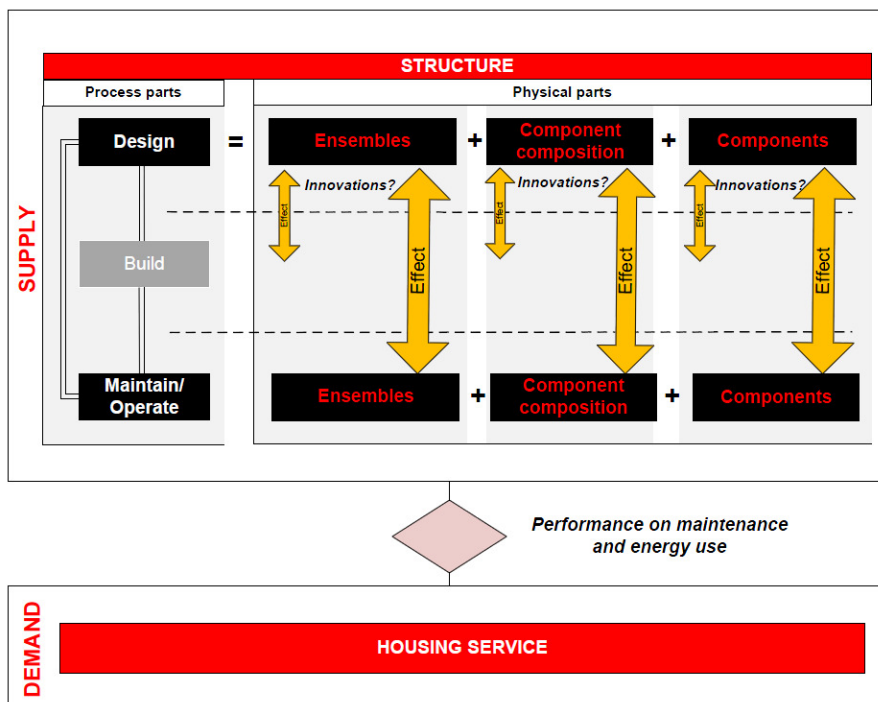


Figure 1: Conceptual model

RESEARCH METHODOLOGY

The research is focused on finding empirical evidence for the assumption that DBFMO projects stimulate innovations within maintenance and energy-use on the physical parts of a structure. A qualitative case study method was adopted as part of an engagement with a construction company, which has executed a large number of PPP projects in the Netherlands. This company is a leading PPP contractor at the Dutch market and has provided the data that was needed to conduct this research. The case study research consists of two components. First the ‘better performance’ on maintenance and energy-use had to be

determined. Second the solutions were assessed in order to determine if the better performing solutions could be classified as innovations according to the applied definition.

Case studies

In this research two DBFMO projects from a large contractor in the Netherlands are investigated. These two cases are compared with the traditional projects by means of long-term maintenance plans and expected energy consumption in order to identify possible innovations. The traditional projects were selected based on criteria for their properties in terms of comparability. Data of the traditional projects was received from maintenance consulting firms and facility management organizations. In Table 1 the different characteristics of the cases and projects studied as well as the methods used for data retrieval are shown.

Project criteria	Case DBFMO 1	Case DBFMO 2	Project trad 1	Project trad 2	Project trad 3	Project trad 4	Project trad 5
Information source	Strukton	Strukton	X	X	X/RWS	RWS	Tax departm.
Location	The Hague	Groningen	X	X	X	Middelburg	Apeldoorn
Function	Office	Office	Office	Office	Office	Office	Office
Building type	low-rise	high-rise	low-rise	low-rise	high-rise	low-rise	low-rise
GFA (m2)	68.000	47.731	12.500	25.000	50.328	11.872	13.845
Building layers	5	24	5	5	23	5	5
Quality of maintenance	3	3	3	3	3	-	-
Consideration period (y.)	25	20	40	25	30	-	-
Operation time (hours p.d)	14	13	NA	NA	NA	NA	NA
Price level	dec-05	mai 07	march 09	apr-03	aug-03	NA	NA
Available data							
Maintenance (S,B en T)*	S, B and T	S, B and T	S, B and T	S, B and T	S, B and T	-	-
Energy use (E)	E	E	-	-	E	E	E

* Structural, Building services and Tangible assets

Table 1: Indicative properties per case/project

Maintenance costs data-analysis

In order to determine a –potential- better performance on maintenance long-term maintenance plans of two DBFMO projects were compared with long-term maintenance plans of traditional projects.

Comparing buildings on maintenance costs is difficult due to the unique nature of buildings as a whole. “Every building is affected by its location, height, composition, energy consumption and a plethora of other differentiation points – all of which make each building unique” (Hughes et al., 2004). When a building is decomposed to smaller parts e.g. elements, the uniqueness is more relative. Maintenance costs are generally found in practice, related to a classification in elements. The maintenance costs were not re-classified and aggregated to components, component compositions and ensembles. Besides practical reasons for not doing this, it was not a necessity because the cost analysis is used to get an idea where possible innovations on components or their aggregations could be found. Also according to the applied definition it might be assumed that components and their aggregations are project specific and cannot easily be compared.

According to Daly et al. (2003) a number of factors have a strong influence on the maintenance costs. To compare different buildings on maintenance costs the following factors are identified, see Table 2 and Table 3. These factors were used, given the characteristics of the two DBFMO cases, for the selection of traditional build projects getting comparative data and to correct the data by differences in building characteristics.

Function	Offices
Construction year	> 2001
Project size	> 10.000 m ²
Floors	Indicative
Quality maintenance	Quality (Conditionniveau) equal to or higher than the traditional projects

Table 2: Factors that must be equal

Gross floor area	Cost and consumption is expressed per m ² GFA
Price level	Corrections using the BDB index
Consideration period	Equeal consideration period
Operating time	Corrections if possible

Table 3: Factors that must be corrected

A long-term maintenance plan is in essence an activity planning where dissimilar sequences of costs are modelled for a certain period. In the different maintenance plans different types of maintenance are identified. In the analysis the following types of technical maintenance are taken into account: preventive maintenance, corrective maintenance and replacements. In order to compare different sequences of costs the net present value was calculated, due to the time value of money. Besides the net present value the nominal value was calculated. The nominal value does not take time influences and price increases into account. The net present value method seems suitable because identical project lives are taken into account in the comparison. The maintenance costs are shown per element in €/m² gross floor area (GFA).

Within structural maintenance the elements floor finishing and ceiling finishing are good comparable because they are almost equal to the gross floor area of a building. Elements like façade finishing and roof finishing can result into disturbing outcomes due to different shape factors. An example of the disturbing effect of shape differences in buildings on the maintenance cost for roof finishing is shown in Table 4. When the maintenance costs are calculated per m² GFA, building one seems to be the most cost efficient. When the costs are calculated per roof surface the costs are equal, due to different building typologies. Building one is a high rise typology and building two can be seen as low rise typology.

For the building services the following elements seem to be comparable: heat generation, cold generation, ventilation and lighting.

Influence shape factors	Building 1	Building 2
GFA	50.000	12.000
Roof surface	1.000	2.400
Maintenance cost roof per year	€ 6.500	€ 15.600
Maintenance costs per m² GFA	€ 0,13	€ 1,30
Maintenance costs per m² roof	€ 6,50	€ 6,50

Table 4: Influence of shape factors on maintenance cost per m²/GFA

Energy-use analysis

The energy consumption of a building is also related to a number of factors, which are mostly unique per building. In the research the energy performance is expressed in consumption per Mega Joules instead of costs. Energy costs are affected by the oil price which can give a disturbing effect in a comparison. According to a publication of SenterNovem (2007) the

following factors can be distinguished that influence the energy consumptions in buildings: function, project size, year of construction and the operating time. With regard to energy consumption the use of gas and electricity were taken into account and are diverted into the unit Mega Joules (MJ) per year per m² gross floor area.

Innovations?

Indications from the previous analysis of a better performance by lower maintenance costs of elements or lower energy use were discussed by means of expert interviews. The interviews (seven in total) have been held with staff who were involved in the design phase of the DBFMO cases. Per better performing element on maintenance costs or a better performance on energy consumption the interviewees have been asked the following questions: (1) Is the motivation for the application direct or indirect?; in other words is the design solution focused on reducing maintenance costs and/or energy-use, or is it a secondary advantage? (2) Can the applied solution be seen as innovative as defined in this research? (3) Is the solution project bounded or project unbounded? This framework of analysis has been visualized in Figure 2.

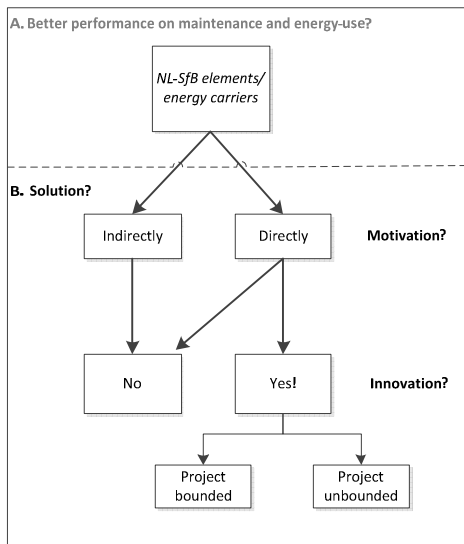


Figure 2: Analysis framework for the expert interviews

5. FINDINGS

The findings are presented by type of analysis: maintenance costs, energy-use and expert interview, and by case.

Maintenance costs performance

For case one only the structural (architectural) maintenance costs could be analysed because the cost data for the building services maintenance was not available. The values shown in Figure 3 are nominal values because the net present values showed a similar trend as the nominal values. The absolute values as shown in the graphs are fictitious, the relative differences are real.

The graphs show significant lower cost levels for the DBFMO cases.

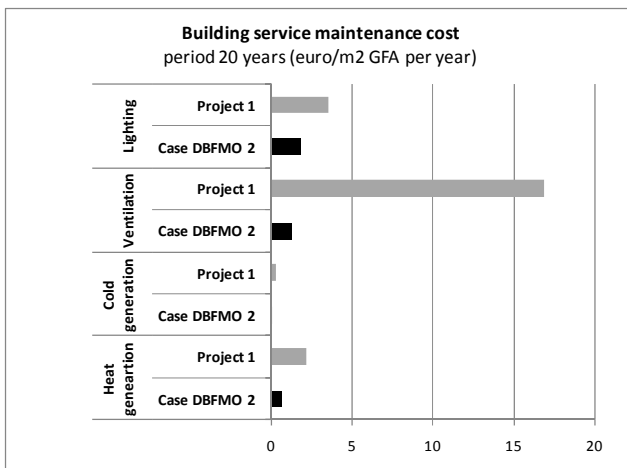
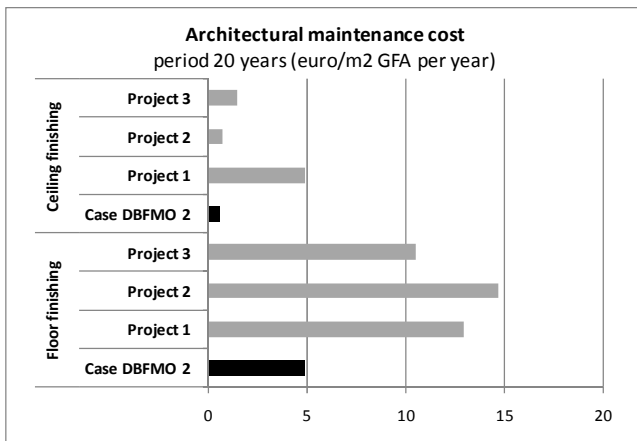
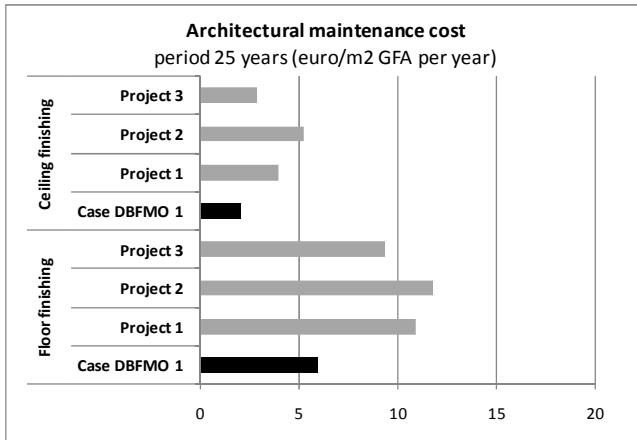


Figure 3: Maintenance costs performance of the case studies

Energy-use analysis

It was not possible to compare the energy consumption at element level because the data was only available per energy carrier (gas and electricity).

Figure 4 shows that the DBFMO cases are performing better than the traditional cases even without corrections for longer opening hours for the DBFMO cases.

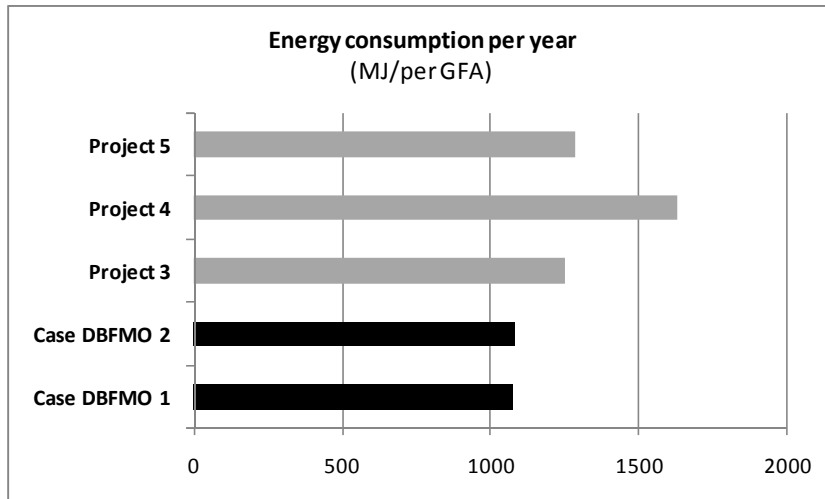


Figure 4: Energy-use as analysed within the cases

Expert interviews

In the interviews with experts the results of the data analysis were discussed, including the researchers ideas on innovations found within the cases according to the constituted definition within this research. The analyses of these interviews have resulted in the following findings.

Innovation on maintenance

Floor finishing: Carpet is the dominant floor finishing in the two DBFMO cases. In case one a carpet tile is applied. During the design phase a specific carpet tile was developed by the architect, contractor and supplier, resulting in seven different tiles differing in colour, weaving and pattern. The tiles are randomly produced, packed and mounted in the structure. Because of these special developed carpet tiles it is less visible when a single tile has to be replaced. The new tile does not stand out as a new tile in a ‘carpet’ with the old tiles. Therefore fewer replacements are expected to take place during the operational phase. This solution can be seen as an innovation on the ensemble because this solution has been developed and improved the use of a carpet tile. The carpet tile itself is not an innovation; the pattern that is developed that only works when seven or more tiles are placed together, can be seen as an innovation.

Ceiling finishing: The solution for the ceiling as applied in the DBFMO cases have an indirect link with maintenance. The choice for a climate sealing in case DBFMO 1 is based on energetic considerations. The advantage for the maintenance can be considered as indirect. The ceiling finishing for case DBFMO 2 is also based on energetic considerations and therefore it is not an innovation on maintenance.

Heat generation/cold generation: In case DBFMO 2 a heat pump is applied to warm and cool the structure. Out of the analysis a better performance can be discerned. However the interviewees refute this outcome. The heat pump is according to a number of interviewees more expensive on maintenance than a traditional heat system but has energetic advantages. In contrast with the data analysis the interviewees cannot see any advantages with regard to maintenance. Therefore the heat pump cannot be seen as an innovation on maintenance.

Ventilation: The choice for the ventilation concept of case DBFMO 2 is driven by a maintenance point of view. The fresh air is blown in the room via a raised floor and the exhaust air is collected in the room and exhausted via a central duct. This solution entails no ventilation ducts within the office spaces. Less ventilation ducts means less maintenance. The contractor and advisors developed this design solution in the design phase. Therefore this solution can be seen as an innovation on maintenance.

Lighting: Due to lower lighting level demand less lighting elements are installed, which are compensated with individual desk lights. Interviewees could not explain the better performance that came out of the maintenance costs analysis. It can be argued that less base lighting result in less maintenance. However interviewees argue that this is compensated by the extra individual desk lightning. So this aspect can't be seen as an innovation on maintenance.

Innovation on energy-use

Façade concept: The façade concepts of both DBFMO cases are not commonly applied solutions. First the façade concept of case DBFMO 1 will be explained. This case is in essence a renovation project. The existing structure was posing a problem for the transportation of exhaust air within the building and large thermal bridges were present. In order to overcome these two design issues, a double skin façade is applied to reduce the thermal bridges and to transport fresh and exhaust air in the façade. The individual elements cannot be seen as innovations. However, the solution as a whole is an innovation on ensemble level, which enables a reduction in energy consumption. The façade concept of case DBFMO 2 is specially developed with regard to sun influences. The façade consists of a fin, which differs in length and height to optimize sun radiation and light entry in all seasons of the year. In this way a reduction of energy consumption is expected because less heating, cooling and lighting has to be applied. This second façade concept can also be seen as an innovation on ensemble level.

Heat/cold generation: In both DBFMO cases the heat and cold generation is produced by a heat pump. This system can generate more efficiently heat or cold in relation to traditional heating systems. Interviewees conclude that it is a fairly normal system within offices. Therefore this is not classified as an innovation within the context of this research.

CONCLUSION AND DISCUSSION

Within the DBFMO cases four design choices can be considered to be innovations on maintenance and energy-use (two per case). See Figure 5. The design choices perform better on maintenance costs or energy use than the traditional projects selected for comparison. The four design choices on the physical parts are applied new and improved products and solutions related to the way the project was procured (DBFMO) and how parties involved collaborated to provide qualitative solutions.

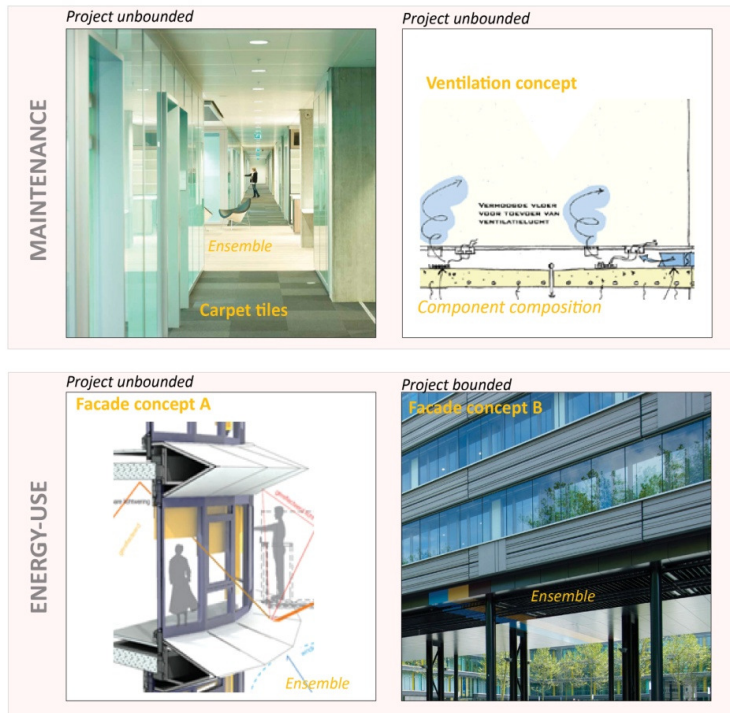


Figure 5: Innovations on maintenance and energy-use (www.mvsa.nl (2011) and Strukton (2008))

The conceptual model, where a classification of design choices is introduced in components, component compositions and ensembles proved to be useful to identify innovations. For example, the carpet tile floor finishing itself is not an innovation and is done for decades. However, using the conceptual model the use of carpet tiles could be analysed as an innovation on ensemble level.. The pattern of the tiles is developed in collaboration between architect, the tile supplier and the maintenance specialist. Together they found a concept of seven tiles, which visually worked satisfactory after random replacement of tiles. The floor finishing contributes to the overall architectural expression of the interior of the building, and is aiming to reduce maintenance costs substantially over time. The ventilation concept is an innovation on component composition level. In this solution less components are used, because the raised floor is used to transport fresh air. In this way less maintenance costs are expected due to less applied components that require maintenance. Both façade concepts of the cases are innovations on ensemble level aiming to minimize energy consumption, but also contributing significantly to the architectural expression of the exterior. A larger case environment is needed to strengthen the applicability of this method for identifying innovations on project level.

Considering the findings of the research the DBFMO construction organization has a positive influence on the development of innovations on maintenance and energy-use. A number of conditions are described in the introduction that could be of influence on an innovative environment of DBFMO projects: the collaborative environment, the use of performance specifications, optimising life-cycle costing and risk transfer between public and private partners. Which relations exist between the conditions and the innovations is not explicitly investigated in this research, although some explanations are found based on the expert

interviews held after the data analysis. The innovations found in the case studies can be considered as the successful transfer of knowledge between departments that would have worked independently in case of a traditional procured project. Besides innovations found on the physical parts, other small incremental innovations on service delivery by the DBFMO-contractor were mentioned in interviews, dealing with the conditions of life-cycle costing and performance specifications, e.g. monitoring the condition of building components in-situ.

In the research only two DBFMO cases were investigated due to limited number of DBFMO projects in the Netherlands, making the conclusions difficult to generalize for all DBFMO projects. In general the conditions of DBFMO projects shape an innovative environment.

The performance data of the DBFMO cases on maintenance costs and energy-use is based on expected results, as the delivery dates were too recent for reliable actual cost data. The data used are provided by the contractor, which has made the calculations of the maintenance costs and energy-use on the basis of the preliminary designs. In this research it has been assumed that this data should reflect the real costs rather accurately, because risk-averse parties like the contractor in case are liable for these expected costs over up to two decades. The maintenance data and expected energy-use performance is calculated based on confidential data sets, therefore the validity could not be determined.

Comparing buildings on costs in general is rather problematic due to their unique character. It was not possible to get identical projects with regard to the case characteristics. In terms of case selection often the researchers were faced with limited available data on life-cycle costs, long-term maintenance plans and energy consumption performance. Instead of comparing buildings as a whole it proved possible to compare a number of elements. The maintenance costs and energy consumption analysis was about detecting possible innovations and not to compare similar solutions on cost or energy consumption efficiency.. However, on their contribution to the total life-cycle cost performance conclusions cannot be drawn.

Further research should be conducted on three areas: (1) The contributing issues why exactly innovations are arising in this type of construction organization; (2) The study has to be repeated with more cases and should be based upon actual cost data and real energy performance data for better validity; (3) A new study could focus more on the life-cycle cost efficiency of whole projects related to innovations detected.

REFERENCES

- Aa van der, W. and Elfring, T. (2002). "Realizing innovation in services *In: Borst et al. (2009) Prestatiegericht samenwerken bij onderhoud.*" Scandinavian Journal of Management 2: 155-171.
- Akintoye, A., Bing, L. Edwards, P.L. and Hardcastle C. (2005). "Critical success factors for PPP/PFI projects in the UK construction industry", Construction Management and Economics 23(5):459-471.
- Archibugi, D. and Sirilli, G. (2001). "The direct measurement of technological innovation in business", Innovation and Enterprise Creation: Statistics and Indicators, European Commission (Eurostat), Luxembourg.
- Blayse, A.M. and Manley, K. (2004). "Key influences on construction innovation", Construction Innovation, 4 (3): 143-54.
- Construction Industry Council. (1998). Constructor's key guide to PFI *In: Leiringer, R.*

(2006) *Technological innovations in PPPs*.

Daly, J. Vijverberg, G. and Van der Voordt, T. (2003). "Modelmatig berekenen van onderhoudskosten." *Facility Management Magazine* **16 (112)** (Augustus): 19-25.

Evans, R. H., R. Haste, N. Jones, A (1998) *The long term cost of owning and using buildings*, Royal Academy of Engineering, London.

Garcia, R. and Calantone, R. (2002). "A critical look a technological innovation typology and innovativeness terminology: a literature view." *Product innovation management* **19**: 110-132.

Haynes, L. and Roden, N. (1999). "Commercialising the management and maintenance of truck roads in the United Kingdom *In: Leiringer, R. (2006) Technological innovations in PPPs.*" *Transportation* (26).

HM_treasury (1999). How to construct a public sector comparator *In: Leiringer et. al. (2006) Technological innovation in PPPs: incentives, opportunities and actions.*

Hughes, W., Ancell, D., Gruneberg, S. and Hirst, L. (2004). "Exposing the myth of the 1:5:200 ratio relating initial cost, maintenance and staffing costs of office buildings."

Kleinknecht, A. (2000). Indicators of manufacturing and service innovation *In: Borst et al. (2009) Prestatiegericht samenwerken bij onderhoud.*

Kohnstamm, P. P.L. H. Regterschot (1996). De manager als bouwheer *In: Jellema I (2004) Inleiding bouwnijverheid.*

Leiringer, R. (2006). "Technological innovation in PPPs: incentives, opportunities and actions." *Construction Management and Economics* 24(3): 301-308.

Leiringer, R., Green, S.D. and Raja, J.Z. (2009). "Living up to the value agenda: the empirical realities of through-life value creation in construction." *Construction Management and Economics* **27**(March 2009): 271-285.

Lemos, T., et al. (2003). "An examination on the sustainable competitive advantage of PFI projects *In: Leiringer, R. (2006) Technological innovations in PPPs.*" *Construction innovation*(3).

Leupen, B., (2005) *Ontwerp en analyse*, Uitgeverij 010, Rotterdam.

Prins, M. (1992) *Flexibiliteit en kosten in het ontwerpproces*, Technische Universiteit Eindhoven, Eindhoven.

Regeringskansliet (2000). "Alternative financing through partnerships *In: Leiringer, R. (2006) Technological innovations in PPPs.*"

Regieraad Bouw (2005). *Aanbestedingsregels moeten innovatie bouw stimuleren. tussentijds advies over juridisch kader aanbestedingen*, Regieraad Bouw.

Rogers, E.M and Schoemaker, F.F. (1971). *Communication of innovation: A cross cultural approach* *In: Borst et al. (2009) Prestatiegericht samenwerken bij onderhoud.* The Free Press. New York.

SenterNovem (2007) *Kompas, energiebewust wonen en werken. Cijfers en tabellen 2007*, Sittard.

Sexton, M.G. and Barrett, P. (2005). "Performance-based building and innovation; balancing client and industry needs", *Building Research & Innovation* 30(2): 142-148.

Slaughter, E.S. (1998). "Models of construction innovation", *Journal of Construction Engineering and Management* 124(3): 226-232.

Tiffin, M. and Hall, P. (1998). "PFI - the last chance saloon *In: Leiringer, R. (2006) Technological innovations in PPPs.*"