

To use or not to use : which type of property should you choose?

Citation for published version (APA):

Appel - Meulenbroek, H. A. J. A., Kemperman, A. D. A. M., Kleijn, M. M. L., & Hendriks, E. H. E. (2015). To use or not to use : which type of property should you choose? *Journal of Property Investment & Finance*, 33(4), 320-336. <https://doi.org/10.1108/JPIF-09-2014-0059>

Document license:

TAVERNE

DOI:

[10.1108/JPIF-09-2014-0059](https://doi.org/10.1108/JPIF-09-2014-0059)

Document status and date:

Published: 01/01/2015

Document Version:

Publisher's PDF, also known as Version of Record (includes final page, issue and volume numbers)

Please check the document version of this publication:

- A submitted manuscript is the version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher's website.
- The final author version and the galley proof are versions of the publication after peer review.
- The final published version features the final layout of the paper including the volume, issue and page numbers.

[Link to publication](#)

General rights

Copyright and moral rights for the publications made accessible in the public portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the public portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the public portal.

If the publication is distributed under the terms of Article 25fa of the Dutch Copyright Act, indicated by the "Taverne" license above, please follow below link for the End User Agreement:

www.tue.nl/taverne

Take down policy

If you believe that this document breaches copyright please contact us at:

openaccess@tue.nl

providing details and we will investigate your claim.



Journal of Property Investment & Finance

To use or not to use: which type of property should you choose?: Predicting the use of activity based offices

Rianne Appel-Meulenbroek Astrid Kemperman Marleen Kleijn Els Hendriks

Article information:

To cite this document:

Rianne Appel-Meulenbroek Astrid Kemperman Marleen Kleijn Els Hendriks , (2015), "To use or not to use: which type of property should you choose?", Journal of Property Investment & Finance, Vol. 33 Iss 4 pp. 320 - 336

Permanent link to this document:

<http://dx.doi.org/10.1108/JPIF-09-2014-0059>

Downloaded on: 14 July 2015, At: 05:08 (PT)

References: this document contains references to 54 other documents.

To copy this document: permissions@emeraldinsight.com

The fulltext of this document has been downloaded 39 times since 2015*

Users who downloaded this article also downloaded:

Arvydas Jadevicius, Simon Huston, (2015), "Property market modelling and forecasting: simple vs complex models", Journal of Property Investment & Finance, Vol. 33 Iss 4 pp. 337-361 <http://dx.doi.org/10.1108/JPIF-08-2014-0053>

John McDonald, (2015), "Capitalisation rates for commercial real estate investment decisions", Journal of Property Investment & Finance, Vol. 33 Iss 3 pp. 242-255 <http://dx.doi.org/10.1108/JPIF-09-2014-0058>

Nick French, Michael Patrick, (2015), "The plethora of yields in property investment and finance: a summary", Journal of Property Investment & Finance, Vol. 33 Iss 4 pp. 408-414 <http://dx.doi.org/10.1108/JPIF-04-2015-0026>



Access to this document was granted through an Emerald subscription provided by emerald-srm:162423 []

For Authors

If you would like to write for this, or any other Emerald publication, then please use our Emerald for Authors service information about how to choose which publication to write for and submission guidelines are available for all. Please visit www.emeraldinsight.com/authors for more information.

About Emerald www.emeraldinsight.com

Emerald is a global publisher linking research and practice to the benefit of society. The company manages a portfolio of more than 290 journals and over 2,350 books and book series volumes, as well as providing an extensive range of online products and additional customer resources and services.

Emerald is both COUNTER 4 and TRANSFER compliant. The organization is a partner of the Committee on Publication Ethics (COPE) and also works with Portico and the LOCKSS initiative for digital archive preservation.

*Related content and download information correct at time of download.

To use or not to use: which type of property should you choose?

Predicting the use of activity based offices

Rianne Appel-Meulenbroek

*Real Estate Management and Development,
Eindhoven University of Technology, Eindhoven, The Netherlands*

Astrid Kemperman

*Urban Planning, Eindhoven University of Technology,
Eindhoven, The Netherlands*

Marleen Kleijn

Twynstra Gudde, Amersfoort, The Netherlands, and

Els Hendriks

Wicely by MCS, Antwerp, Belgium

Abstract

Purpose – Corporate real estate (CRE) is a costly and risky asset in need of more rigorous evaluation methods to support strategic decision making for portfolio and asset management. Especially the indirect added value on organizational revenues is hard to quantify, while it is gaining importance. The purpose of this paper is to describe a quantitative technique that predicts office use as input for CRE management (CREM) decisions.

Design/methodology/approach – After a literature study to identify relevant aspects influencing office use in modern work environments, a Bayesian belief network (BN) is constructed from a large database of 80,907 observations of office use in three organizations in Belgium and the Netherlands. Next specific evidence from future scenarios of organizational change is entered to discuss the application of BN for CRE decision-making processes.

Findings – This study showed that the use of activity-based offices might be influenced by a complex network of office design variables and user characteristics. The use of the predicting possibilities of a BN model can help CRE managers identify employee behaviour inside their offices. That information is valuable input for future workplace decisions and strategic CREM activities.

Practical implications – This study provides CRE managers with a model to gain knowledge on office use to get a better grip on how to add value with activity-based office concepts. The results obtained through using such a model can help support decision making on their office layouts.

Originality/value – Bayesian BNs have not been used in this area of research before. This paper provides both academics and practitioners with valuable insights in the possibilities of this methodology for the field.

Keywords Corporate real estate, Added value, Bayesian belief network, Employee behaviour, Office concepts, Portfolio decisions

Paper type Research paper

Introduction

Corporate Real Estate (CRE) is a costly resource, often the second largest behind labour cost (Oladokun, 2010; Pole and Mackay, 2009). It is also a risky asset (Liow and Ooi, 2000), especially in times of crisis. As organizations are striving for more value added, the pressure to achieve a more effective CRE asset management has increased



(Liow and Ooi, 2004). As Liow and Ooi state: “This means that existing real estate assets would be subject to more frequent and rigorous evaluation to justify their continual inclusion in the firm’s asset portfolio”. Others (Mc Donagh and Nichols, 2009; Bouri *et al.*, 2008; Roulac *et al.*, 2005) have also stressed the necessity to manage CRE more strategically.

For investors, portfolio management means achieving the optimal added exchange value through reducing costs and focusing on the market value of the assets. As Krumm and De Vries (2003) point out, corporate users are not very successful property traders because they need to fulfil business needs that might not match market timing. Managing CRE portfolios strategically means not only focusing on direct financial gains, but also including evaluation of added use value through its effect on the activities of the corporation/employees (Krumm and De Vries, 2003). Besides a focus on direct return (“Reducing costs”) and indirect return (increasing the “Value of CRE assets”), it is important to have insight in how the buildings in the portfolio are used and support important added values like employee satisfaction and organizational flexibility (Lindholm and Leväinen, 2006). But as De Vries *et al.* (2008) mention, there is a lack of outcome indicators to show added value of more intangible CRE values like this. Also, CRE managers know more about reducing costs than increasing revenue (Brown, 2008) and divert most of their attention to it (Krumm and De Vries, 2003). In terms of EVA this might not be the optimal way to increase profit. CRE management (CREM) should also focus on increasing revenues created in the primary process of the organization (Oladokun, 2010).

As Tay and Ooi (2001) point out, allocation of the workspace is a key issue confronting CREM; now even more than in 2001. New ways of working, new generations and changing lifestyles have required a new office concept since the turn of the century (Duffy and Tanis, 1993; Van Meel and Vos, 2001) and thus many organizations are investing in new or existing properties in the CRE portfolio to align with activities of their employees. For efficiency reasons, new ways of working are increasingly implemented using activity-based office designs, as these are supposed to result in cost reduction through the sharing of workplaces (Gorgievski *et al.*, 2010). This reflects well on the performance of the real estate portfolio. Not surprisingly, the activity-based office is rapidly being implemented by organizations worldwide (63 per cent of large enterprises had already rolled out new ways of working: Dixon and Ross (2011)). Besides cost reductions, these offices are also adopted to increase productivity of employees, strengthen image, increase collaboration and other organizational goals (Van Koetsveld and Kamperman, 2011). But opposite effects have been shown to take place too. Wrongful estimations of the required number and type of workplaces then lead to office environments that did not support new work processes optimally (Brennan *et al.*, 2002; Duffy and Tanis, 1993). Such a misfit between the user and the work environment can create workspace stress and negatively influence productivity (Rashid and Zimring, 2008; Vischer, 2007). It might look as if added value has been achieved through cost reduction, but for the corporation as a whole it might have been the opposite.

For strategic management it is essential to have access to data that can support decision making on office design based on expected user needs, besides the existing data on the direct financial effects. When organizations are considering a change in their CRE portfolio they often hire consultants to measure space usage and occupancy levels before and/or after changes are made. The data gathered that way are rich, but unfortunately are mostly analysed for deciding on changes that could increase direct return only (how many m²s can we cut?). So, even if data are gathered

on the use of these offices, this is often limited to measuring direct effects with cost related data for benchmarking (e.g. costs/m², m²/FTE). This kind of analysis ignores the actual use of the buildings and steers property investment decisions towards cheaper locations and using less m²s. But as De Bruyne *et al.* (2014) state “the office lay-out needs to suit the work processes and all the activities that employees perform while in the office”.

This paper describes a quantitative technique that makes use of these data to get insight in the indirect value of office design too (is the office used as intended and what are current employee preferences?). Specifically, this Bayesian belief network (BN) modelling approach can be used to describe and predict behaviour in activity-based offices, plus derive and represent the relationships between all variables influencing the complex relation between use and office design (e.g. Arentze and Timmermans, 2009; Keuleers *et al.*, 2001). Thus, it provides more insight than solely m² usage and therefore can support decision making better. It even provides the opportunity to predict the effect of possible changes in the future on the type of office space that is preferred. This way the data can also be used as input for risk management of investment decisions.

The first section describes literature on office environments and work activities and defines relevant aspects influencing the use of offices. After describing the research method, the Bayesian-network methodology is explained further. Then the data of office use of three organizations are presented to show how a BN can be derived from the data. This is followed by a discussion of how the results and methodology can be used to predict office use as input for portfolio management decisions. The paper ends with conclusions and recommendations for other real estate management aspects that Bayesian networks might be useful for.

Office environment and work activities

History has brought forward three main office types that are most common these days. De Been and Beijer (2014) labelled these “individual and shared room offices”, “combi offices” and “flex offices” and distinguish them based on the two dimensions layout/design and use. The first are buildings with more enclosed rooms with assigned seating and additional enclosed meeting rooms, plus some shared facilities. The combi office has open and transparent spaces with assigned workstations for everybody, with additional back up areas for specific concentrated activities. The flex office, also called the activity-based office, is designed like the combi office but has no assigned workstations. This means that all users, from employee till general management, can choose to work at all available workplaces and collective facilities, and nobody is allowed to claim their own workplace (Appel-Meulenbroek *et al.*, 2011). Because work activities in this office type can theoretically take place at all available facilities, not only at workplaces, from here on we will also speak of facilities rather than workplaces. Bodin-Danielson and Bodin (2009) further distinguish office types by adding three sizes of purely open plan offices. Van Koetsveld and Kamperman (2011) stick with the main three office types, placing them in order of appearance through time (from individual/shared room offices, through combi offices towards activity-based working (ABW)).

Bodin-Danielson and Bodin (2009) found that activity-based offices showed less days of sick leave, lower risk of emotional health problems and more reinforcement of interaction than other office types. Another merit of activity-based offices opposed to the other types is increased satisfaction with architecture and layout (De Been and Beijer, 2014). Blok *et al.* (2009) also found an increased level of perceived productivity, looking at the same organization in both types of work environments. But these studies

do not only show opposite results, but also mention disadvantages of activity-based offices, among which employees' negative opinion about the facilities, climate and privacy (De Been and Beijer, 2014), increased distractions (Blok *et al.*, 2009) and issues with ergonomics and personalization (Bodin-Danielson and Bodin, 2009). As Van Koetsveld and Kamperman (2011) state: "While precedents elsewhere can be valuable guides and while ABW may have demonstrable benefits, at the end of the day every company is unique and requires its own 'customised' solutions". De Bruyne *et al.* (2014) also agree that every company has its own version of new ways of working and that it is not easy to balance amount/type of workspaces with demand. They say that activities form the essential link between people and places.

The aim of this study is therefore to show how a BN can identify the specific relationships between aspects of the activity-based office environment, work activities and use of the office for the unique case that a CRE manager (or academic) needs to work with. As the work environment is "a tangle of relationships, processes, and context-specific behavioral norms and values" (Kampschroer and Heerwagen, 2005), many different variables have been included in past studies on post-occupancy evaluation of office designs. ABW (as the name implies) is built on the assumption that the activity determines which facility you need, which will make you change work settings during the day (Van Koetsveld and Kamperman, 2011). Several types of activities can be distinguished in service organizations (Tabak, 2009; Vos and Van der Voordt, 2001). The activities can differ on the level of concentration that is needed and whether they are formal or informal. Based on these studies, the following activities can be observed at a specific facility: "informal meeting", "work related activity" (reading, writing, typing, etc.), "formal meeting", "telephone/video" and "informal activity" (coffee/copying). Of course, a facility might also "not be in use", or the "user might be temporarily elsewhere".

The employees that carry out the work activities are not a homogeneous group. Their characteristics will probably influence the use of facilities as well, and are relevant data to steer on in case major changes in the workforce are foreseen. Rothe *et al.* (2012) and Hua *et al.* (2011) mention status (position), gender and age as relevant user variables. Tenure is expected to be relevant as well, as the time spent in a certain environment could very well affect the use and perception of it. Also, the number of part-time workers is expected to increase in the future (Mladenova and Gresty, 2012), and therefore an important aspect.

So, the facilities in an activity-based office have to support the organization, the individual users and their activities to provide added value. As said, literature prefers the idea that the best facility for conducting activities depends on the activity itself (De Bruyne *et al.*, 2014; Gibson, 2003). The activity conducted at a facility, according to this idea, depends on the characteristics of that facility. Note, that in this study the focus is not on functionality at a micro-scale, because ergonomics is assumed to be well-regarded in these new office concepts. Instead, (macro-) functionality is interpreted as the different facilities that are offered in the activity-based office (meeting areas, clusters, concentration booths, informal areas, etc.). If providing added value is the goal, these can and should be aligned when changes occur in the aspects discussed previously. Although the activity-based concept is defined as not having assigned workplaces, most organizations still have some assigned facilities. So the form of use (shared or not) is an aspect to take into account as well. Other facility characteristics, such as capacity, and the type of facility (concentration or communication) might also be related to the work activity and use of the facility.

Last, the design of the office that accommodates the facilities also determines the suitability of this facility for conducting an activity, as environmental psychology research has long proven. Most studies have focused on floor layout, which appears to have the biggest influence on worker performance (Hua *et al.*, 2011; Vischer, 2007) and thus on indirect added value. The degree of privacy, distraction factors, opportunities for interaction and appearance of this layout are important issues in choosing where to work. Juneja and Roper (2008) show how an outside view and people walking by inside the office influence the activities that can be performed at such a place. Outside views are also very important for user satisfaction (Loftness *et al.*, 2009). This indicates that zone is another relevant office design variable. Tabak (2009) compared studies focusing on the effect of the openness of the space on activities, and mentioned that open spaces have less confidential meetings. So, openness is assumed to be a relevant aspect, just like density and area size, shown by Hua *et al.* (2011) to affect collaborative behaviour.

Based on the literature, it can be concluded that a number of aspects is assumed to affect the use of offices of office environment that support new ways of working: facility characteristics, characteristics of the use, office design variables, and finally, characteristics of the users of the work environment (see Table I).

Research approach

Data collection

To show how the BN technique works and can be used to predict office use we needed appropriate data. Observation of work activities and use of the work environment has proven to be a good way to collect data about the use of workplace facilities (Runkel and McGrath, 1972). Therefore, 80,907 observations of workplace usage collected in three organizations (in Belgium and the Netherlands) in activity-based offices was obtained from an existing database. These data were collected by Wicely (www.wicely.com) in 2008 and 2009 with a specifically designed computer system (ABOOT). This system optimizes an efficient observation and reliability with pre-programmed questions specified for each variable and pre-coded answer categories. Observers walk around with an ABOOT tablet and only need to click the pre-coded answers at each facility. These organizations were chosen, because they agreed to use a badge system too. This allowed for us to also include user characteristics in the network. Note, that only information about the user characteristic age is missing because this was not available. As workplace and facility use might change during the day and over the days of the week (e.g. fatigue calls for less distraction to be able to focus), the usage of each facility was documented at least 12 times per day during all days of a normal working week, except during lunch breaks.

In total, 80,907 observations were used for this demonstration of BN, gathered at five different locations. The observations stem from three locations of a Dutch financial sector organization (735 facilities of which 618 workplaces, for 780 employees), one location of a Belgian financial sector organization (459 facilities of which 281 workplaces, for 434 employees) and one location of a Dutch municipality (87 facilities of which 68 workplaces, for 80 employees). We have combined the data from these organizations to obtain a large data set for constructing the BN network with all the variables identified from literature (see Table I for their answer categories in the database). As the data stem from only three organizations, it is difficult to generalize the results to other organizations. Therefore, the network structure informs specifically their CREM on the use of their offices by their employees, but is used as an example of how to apply BN modelling.

Variable	Categories	%
<i>Characteristics of use</i>		
Type of activity	1. Not in use	(% without 43.0 "not in use")
	2. User elsewhere	14.3 (25.1)
	3. Informal meeting	6.4 (11.3)
	4. Work related activity	27.5 (48.3)
	5. Formal meeting	6.1 (10.7)
	6. Telephone/video	2.1 (3.7)
	7. Informal activity (coffee/copying)	0.5 (0.9)
Workday	1. Monday	18.3
	2. Tuesday	18.9
	3. Wednesday	19.1
	4. Thursday	24.6
	5. Friday	19.2
Time slot	1. 8:30-10:30 a.m.	21.4
	2. 10:30-12:30 a.m.	24.0
	3. 1:30-3:00 p.m.	24.4
	4. 3:00-5:00 p.m.	30.2
Number of users present	1. 0 users	58.0
	2. 1 user	30.4
	3. 2-5 users	10.7
	4. 6-10 users	0.8
	5. > 10 users	0.1
Guests present	0. Not present	96.0
	1. Present	4.0
<i>Facility characteristics</i>		
Type of facility	1. Workplace	71.6
	2. Communication	17.6
	3. Other	10.8
Functionality	1. Meeting facility	18.3
	2. Cluster < 4 individuals	17.2
	3. Cluster > 4 individuals	43.7
	4. Concentration	8.0
	5. Work supporting	4.6
	6. Informal facility	5.5
	7. Individual workplace	2.7
Capacity	1. 0 users	9.3
	2. 1 user	70.9
	3. 2-5 users	13.7
	4. 6-10 users	5.5
	5. > 10 users	0.6
Form of use	1. Shared	90.8
	2. Assigned	9.2
<i>Office design characteristics</i>		
Area size	1. 1-10 m ²	5.9
	2. 10-50 m ²	24.0
	3. 50-150 m ²	27.4
	4. 150-250 m ²	21.9
	5. 250-350 m ²	14.9
	6. > 350 m ²	6.0

(continued)

Table I.
Variables used in the
Bayesian-network
model analyses and
their frequencies

Variable	Categories	%
Number of facilities in area	1. 1 facility	16.6
	2. 2-10 facilities	19.0
	3. 10-20 facilities	19.3
	4. 20-30 facilities	32.6
	5. > 30 facilities	12.6
Zone	1. Middle	8.7
	2. Circulation	37.2
	3. Window	54.1
Openness of the space	1. Open	69.0
	2. Closed	21.7
	3. Semi-open	9.3
<i>User characteristics^a</i>		
Position	1. Management	11.8
	2. Employee	88.2
Tenure	1. Fulltime	96.7
	2. Part-time	3.3
Gender	1. Male	69.1
	2. Female	30.9

Table I. Note: ^a $n = 80,907$, except for user characteristics $n = 37,080$

Bayesian BN modelling approach

A Bayesian BN can be used to derive and represent simultaneously all direct and indirect relationships and their directions between a set of variables (Heckerman *et al.*, 1995; Pearl, 1988). A network is the most flexible structure conceivable for the purpose of studying large groups of interrelated variables (Arentze and Timmermans, 2009). BN is a technique for reasoning under uncertainty and emerged from combined work of artificial intelligence, statistics, operations research and decision analysis (Arentze and Timmermans, 2009). A study using BN is for example Arentze and Timmermans (2009) who investigated a Bayesian-network model to predict and analyse the factors that influence activity travel sequences that are triggered by social-cultural events. Also, Kemperman and Timmermans (2014) used the BN modelling approach to explore the relationships between various types of green spaces in the living environment and the social contacts of the aging population in their neighbourhood.

In this study a BN is used to formulate and estimate the relations between the variables that directly and indirectly influence the use of workplaces in an activity-based office design. See Table I for an overview of the variables included in the model estimation. Including such a large number of variables in the model and finding meaningful interactions is a challenging task. Because variables are often highly correlated and the structure of their relationships is typically not clear (e.g. mediating effects, interaction effects, etc.) model variable selection and defining an appropriate structure for explanatory variables typically is difficult. A BN approach can overcome such difficulties as it derives and represents simultaneously all direct and indirect relationships and their directions between the set of variables. All these variables were included in the estimation for which a network-learning algorithm (that has been specifically developed to identify connections between variables) is used to derive the BN structure. Furthermore, a BN is a suitable modelling approach because the key variables in this study, type of activities performed at the workplace and functionality

of the facility are discrete variables and a BN, in contrast to for example structural equation modelling, by its very nature is highly adequate to handle categorical variables (Arentze and Timmermans, 2009; Kemperman and Timmermans, 2014). Other variables included in the analysis such as workday, type of facility, zone, organization type, etcetera are also of a discrete nature. Finally, network-learning algorithms are used to derive (as opposed to estimating some assumed) structure of the network. Bayesian networks have been specifically developed to identify the structure of connections between variables.

Formally, a BN is a directed acyclic graph in which the causal or temporal relations between the variables are represented by arrows. If there is an arrow from variable A to variable B, variable A is called the parent and variable B the child. For each variable a conditional probability table (CP table) is derived, which expresses the probabilities for that variable, conditioned on the values of its parent variables (if any). Network-learning algorithms are used to derive the network structure. Composing a BN from data involves first learning the network structure and then estimating the conditional probability tables. By setting a threshold the number of links in the network can be controlled: a lower threshold results in more links and a higher one in less links (Keuleers *et al.*, 2001). The standard threshold for establishing links between the variables is 1.0.

Power constructor (Cheng *et al.*, 2002) was used to learn the network structure and estimate the CP tables, because the algorithms behind this software are well tested and have proven high accuracy. The resulting network was visualized and compiled using Netica (Norsys Software Corp.). The BN-learning is based on the three-phase dependency method that develops the network based on tests of conditional independencies between pairs of variables (Cheng *et al.*, 2002). The three phases consist of drafting, thickening and thinning, explained extensively by Arentze and Timmermans (2009). The drafting phase is done, based on pair-wise tests of mutual information between the variables. This mutual information is defined as:

$$I(A, B) = \sum_{a, b} P(a, b) \log \frac{P(a, b)}{P(a)P(b)}$$

where P stands for probability. This information theory measure is expressed in bits and represents the information one can expect to gain about B once the value of A is known. The thickening phase takes indirect paths into account to look for conditional independence. If mutual information is left after considering the indirect paths, a link is added. The thinning phase again looks at each link, to test possible conditional independence due to the implemented changes during thickening. Then, the conditional probability tables are estimated based on the same data set using the expectation-maximization learning algorithm (Lauritzen, 1995). The initial graph is undirected, as it is based on mutual information. Arentze and Timmermans (2009, p. 317) explain how a final step orients the arrows: "A basic element of this procedure is to identify colliders (node Y is a collider in a network $X \rightarrow Y \leftarrow Z$) where no arc exists between X and Z". Because these colliders let information pass through them, they can provide clues on how to orient the arrows. If Power constructor should not succeed in directing a link, it will ask the user to do it.

Table I presents the variables and their categories included in the BN model estimation. When a facility is not in use there is, of course, no data available on user characteristics. Therefore, the data set was analysed in two separate networks.

The first network “the workplace” was created to explore the relations between the variables which may affect the use of a specific facility. It is based on all data from 80,907 observations, except the characteristics of the user as these are unknown when the workplace is empty. The second network “the user” was filled only with 37,080 observations of facilities that were being used at the time of the observation. Therefore it could take the characteristics of the user into account.

The threshold for establishing links between the variables was set at 2.0 for both networks, indicating that only very strong significant relations between the variables are shown (Keuleers *et al.*, 2001). This does not mean that other relationships do not exist, however they are less strong than the ones presented in the estimated network models.

The researcher can define constraints on the presence of links between variables and pre-define special cases for the network structure a priori based on domain knowledge. All three user variables were indicated as independent parent variables, because they, by nature, cannot be influenced by other variables. If the network contained links between variables that in practice cannot exist, these links were defined as forbidden links iteratively. Another type of restriction that was added is called partial ordering (this does not influence whether a link is made between the two variables, but if it is, this determines the direction of the arrow). We allowed the office design (area size, openness, zone and density) to influence the facility characteristics (capacity, functionality, type of facility and form of use) but not the other way around. For example, openness restricts creating a concentration facility, and sufficient area size makes it possible to communicate in larger groups. Another partial ordering was that the number of users might depend on the guests that are present. Also, the chosen design could depend on the type of activity, but not the other way around.

After constructing a BN, it may be applied to a particular scenario. For example, the effect of changes in work activities performed on the functionality of the facility can be predicted. Thus, for each or some variables values can be entered as a finding. Subsequently, probabilistic changes in other variables can be predicted and changes under certain conditions can be simulated. Every time new findings are entered into the network the CP tables of all variables can be updated based on probabilistic reasoning methods.

Results

Data description

The distribution of all the variables included in the analyses is presented in Table I. This provides insight in the actual use of the office during the observations. These data are then used to estimate a model (with Bayesian modelling) that provides predictions of office use based on the relationships between all variables within the network. During 43 per cent of the observations, the facility was not in use, which can be important information for CREM during post-occupancy evaluation of the new office design. It shows, in these cases, that their still might be room for more m^2 reductions. Or perhaps employees from another location can be stationed here, and the other building can be disposed of. When just looking at the observed facilities in use, almost half (48.3 per cent) was being used for regular work related activities, and 22 per cent for meetings (formal+informal). Also, during 25.1 per cent the facility was claimed (with a coat, papers, etc.), but the user was elsewhere. This shows that the intended new ways of working has not landed for all employees, because claiming is not allowed. CREM could decide to set up a programme to guide employees in changing this

behaviour and using the office concept as intended. During 4 per cent of the observations guests were present. Most of the employees work fulltime (96.7 per cent), and are not part of management (88.2 per cent). The case organizations had a population with 69.1 per cent male and 30.9 per cent female.

Qua type of facilities at the case organizations, 71.6 per cent is a workplace, 17.6 per cent is meant for communication and 10.8 per cent is of a different kind (e.g. library, lunchroom). The functionality of all the facilities in the database indicates that the activity-based offices contain a lot of the cluster facilities (60.9 per cent), and very few individual workplaces (2.7 per cent). Other observed functionalities are meeting (18.3 per cent), concentration (8 per cent), work supporting (4.6 per cent) and informal (5.5 per cent) facilities. Most facilities are designed for one user (70.9 per cent). Only 9.2 per cent of the facilities in the database were assigned specifically to employees.

The four office design variables show that the case organizations placed the facilities in many different area sizes, also making the number of facilities in the area diverse. Only 21.7 per cent of the facilities are inside closed areas, and 9.3 per cent in semi-open areas. More than half (54.1 per cent) is located in the window zone (possibly due to daylight legislation for workplaces in the Netherlands and Belgium), and only 8.7 per cent in a middle zone.

As said two BN models were estimated based on the data described above: “the workplace” and “the user”. In both networks, all available variables were included, except workday and time slot. Apparently these variables are not related to nor influence the other variables in the network for these organizations. Both networks show a similar structure, except that in “the user” network the user characteristics, gender, tender and position were included. Therefore, in Figure 1, the combined BN’s are presented. The arrows represent the estimated, significant relationships between variables. Below we discuss what this information tells CREM as input for future decision making. First the relationships of the model itself are discussed, and later how further predictions on this relationship can be used for additional information.

The network model (see Figure 1) shows that the design variables “area size”, “capacity”, “openness of space”, “density” and “zone” all are intermediate variables between type of activity and the functionality that is chosen by these employees. Also, all four office design variables are linked with each other, in which area size is the root

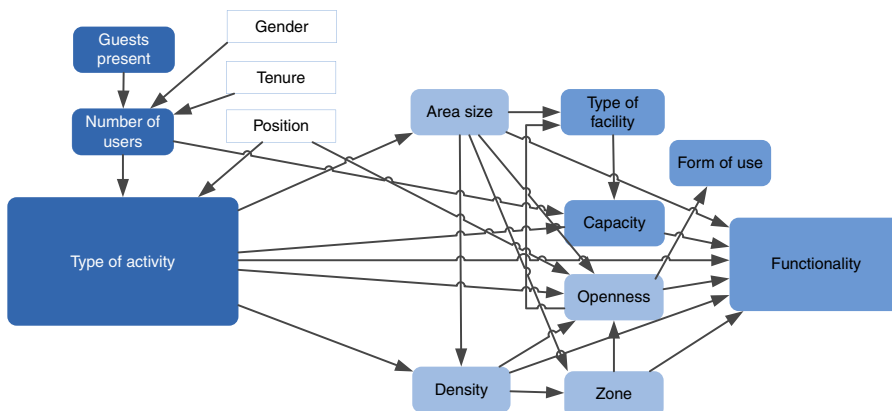


Figure 1.
Combined Bayesian
belief network model
“workplace” and
“user”

of the office design network, influencing the other three variables. This informs CREM, that their employees do not only choose where to work based on the design of the facility. Apparently, the office design plays an important role in their behaviour. Especially, the design of different area sizes in the layout deserves this CREM's attention.

The preferred capacity of the facility depended on the type of facility (workplace, communication or different), type of activity and the number of users. Capacity was the only facility variable that influences the choice for a certain functionality directly. The user variables only had a limited influence in this network. As can be expected, the type of activity depended on the number of users of a facility and the position (management or employee). More surprisingly, the number of users not only depended on whether guests were present, but also on gender and tenure (part-time/fulltime). Also, the preferred openness of the office design depends on the position of the user.

Predicting office use

Now that the data have been placed in a network connected by arrows, it is possible to generate probability (CP) tables to give a prediction of user behaviour at the office. This information can be used to support decision making on the portfolio as a whole. Figure 2 shows the "user" network including the probability tables. The bar diagrams show for each variable the probability distribution across the categories of the variable, based on relationships with the parents in the network. So, for example, if the organization maintains this distribution of activities and employees, 69.3 per cent of the activities would take place in open areas, 9.8 per cent in semi-open and 20.9 per cent in closed areas. Such an organization would probably see a lot of use of clusters (small 17.9 per cent, large 49.8 per cent), meeting facilities (13.9 per cent) and concentration facilities (9.3 per cent). The activities would take place in very diverse area sizes,

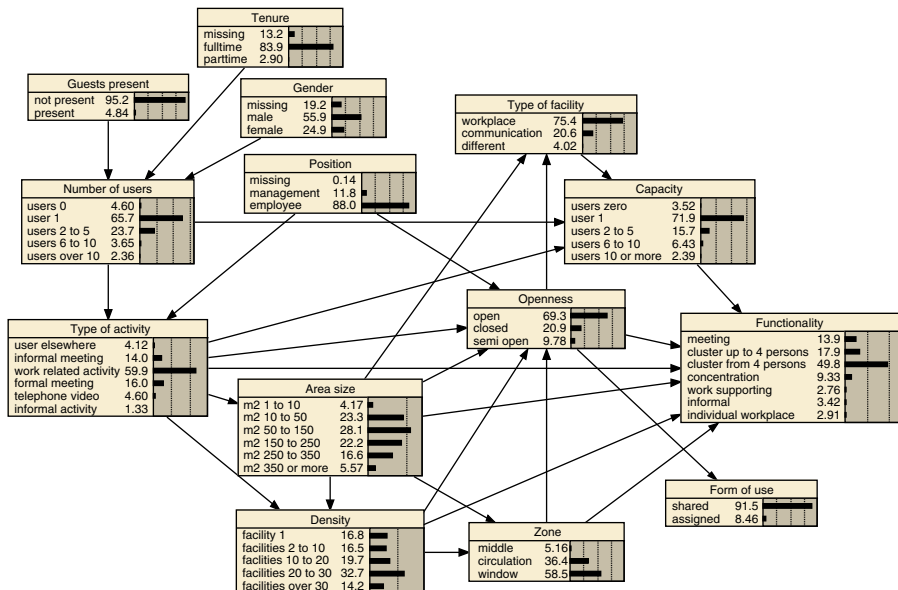


Figure 2. Bayesian belief network "user" with predictions

although medium sized areas (10-250 m²) are used most. This information can be used to evaluate the layouts in the current portfolio and might perhaps lead to significant changes, like divestment of assets which are largely unsuitable for the main type of activities of the employees. Or maybe a reshuffling of personnel can create a better alignment between CRE and the organization and thus add more value.

For this CREM it is interesting to study the indirect relationship between type of activity and functionality in more detail. Table II provides for each activity the probabilities for the chosen functionality. For each functionality we printed the activity that is predicted to be performed there relatively more often in bold text (meaning the biggest increase from average). Below we discuss how such tables can provide valuable insights.

Studying meeting activities in more depth, a big difference between formal and informal meetings is confirmed. Logically, the meeting facilities are the functionality that will be chosen most for formal meetings (55 per cent), but also the concentration facilities would be used for small formal meetings. This CREM might consider taking up the concentration facilities in a room booking system for meetings, as a back up when meeting areas are taken. It is notable, that these employees prefer to hold informal meetings at the workplace clusters. Only 1.5 per cent of informal meetings is predicted to take place at the informal facilities, which are specifically designed for this purpose (cosy corners, lunchrooms). This could make this CRE management reconsider the necessity of such facilities that do take up a lot of room and budget, and thus further increase cost reductions as intended with the implementation of ABW.

CREM can also study the effect that expected changes in the workforce should have on their portfolio in more depth, by entering evidence on user variables. The network shows (for these three organizations), that fulltime employees will relatively use workplaces in the open areas more often to do work related activities, while part-timers have more informal meetings in groups of 2-5 users. By monitoring a possible increase or decrease of part-timers in their workforce, they have early insight in necessary changes to their buildings. Male/female differences are very small, so less relevant for these organizations. The relation between position and the use of facilities might be input for a possible change in policy by providing dedicated workplaces for managers, as their use differed a lot from that of a regular employee. The managers are predicted to be involved more in both formal and informal meetings, and at the phone, which they

Type of activity	Meeting facility	Functionality of facility					
		Cluster ≤3 persons	Cluster ≥ 4 persons	Concentration	Work supporting	Informal facility	Individual workplace
Average	13.9	17.9	49.8	9.3	2.8	3.4	2.9
Work related activity	6.8	19.1	58.8	9.5	1.8	2.0	1.9
Informal meeting	12.0	<i>25.6</i>	<i>66.1</i>	2.9	1.4	1.5	1.3
Formal meeting	<i>55.0</i>	5.6	5.6	<i>12.9</i>	5.7	8.3	7.0
Telephone/video	10.2	20.3	45.8	9.5	4.6	4.9	4.8
Informal activity	10.9	10.9	10.9	10.9	<i>18.0</i>	<i>27.5</i>	<i>10.9</i>

Table II. Relationship between type of activity and functionality

prefer to do in more closed communication facilities. Unlike regular staff they tend to avoid the large open areas with clusters to do their work. However, implementing activity-based offices with exceptions for management are known to lead to discontent among employees. The BN provides CREM with an argument, but this still needs to be considered carefully.

Conclusions and recommendations

This paper provides information for CRE managers on how to gain more knowledge on office use in activity-based offices by using a BN modelling approach. The resulting network model shows the relationships between facility characteristics, characteristics of the use, office design variables and characteristics of the users of the work environment and helps to get a better insight in how various aspects influence office use in modern working environments. The BN network approach provides insight in where added value can be increased for future scenarios of organizational change by looking at the predictions for the use of the offices. It shows specifically where more value can still be added, both direct (which types of facilities in which offices will be vacant more often and can thus in general be decreased in numbers) and indirect (which facilities do employees with certain activities prefer to use, and should thus be offered in adequate numbers). This helps with strategic asset management, as it goes beyond the single snapshot view that is usually taken when reducing costs is the main focus.

When the real estate sector better understands the corporates needs and processes, they can better fulfil their needs. If CRE academics would repeat this type of use of BN on larger data sets and across a variety of industries and workplace designs, the output also provides prescriptive knowledge for office owners and investors. Such results would provide input on which office designs will be chosen by employees to perform their activities in general. This helps to make clear which types of offices are appropriate for modern ways of working of organizations in general and are thus future proof. These assets are generally most likely to yield a higher residual value, which "is usually more risky than the contractual lease payments" (Liow and Ooi, 2000). This information can help support decision making on which assets to buy/hold on to and which to sell. Similarly for owner-occupiers the lease vs buy decisions are supported, which is even more important for those among them that view property as an investment too. According to Liow and Ooi (2000) this is an increasing trend among corporates.

Academics using the BN methodology in other real estate-related studies can help provide the sector with more valuable insights. Areas of interest could be studying data sets of shopping behaviour to improve retail portfolios or building a network of variables influencing office vacancy to predict vacancy in the office market more clearly. In fact, in all real estate-related areas where there is a large set of variables and data available and the structure of their relationships is not known a BN is a useful method to find the appropriate structure and better insight in the related problems.

This study provided a new step towards insight in behaviour in activity-based offices. But further research into the relationship between personal characteristics and use of facilities as well as research on segmentation of users is very necessary. Also, possible other reasons behind the choice of the user could be included in future studies. For future research it might be of interest to combine data from different sectors and other organizational cultures and employee generations, to see how they differ with

respect to facility use. Finally, longitudinal studies to include the time between implementation of the office concept and the data gathering (as it takes time for employees to get used to their new environment), might provide more insights into the use of facilities in an activity-based office design.

Predicting the
use of activity
based offices

References

- Appel-Meulenbroek, R., Groenen, P. and Janssen, I. (2011), "An end-user's perspective on activity-based office concepts", *Journal of Corporate Real Estate*, Vol. 13 No. 2, pp. 122-135.
- Arentze, T.A. and Timmermans, H.J.P. (2009), "Regimes in social-cultural events-driven activity sequences: modeling approach and empirical application", *Transportation Research Part A*, Vol. 43 No. 4, pp. 311-322.
- Blok, M., De Korte, E.M., Groenesteijn, L., Formanoy, M. and Vink, P. (2009), "The effects of a task facilitating working environment on office space use, communication, concentration, collaboration, privacy and distraction", *Proceedings of IEA 2009 17th World Congress on Ergonomics*, pp. 1-7.
- Bodin Danielsson, C. and Bodin, L. (2009), "Difference in satisfaction with office environment among employees in different office types", *Journal of Architectural and Planning Research*, Vol. 3 No. 3, pp. 241-258.
- Bouri, G.G., Acoba, F.J. and Wu, P. (2008), "Organizational design: leading practice considerations for corporate real estate", *The Leader*, Vol. 7 No. 4, pp. 14-24.
- Brennan, A., Chugh, J.S. and Kline, T. (2002), "Traditional versus open office design: a longitudinal field study", *Environment and Behavior*, Vol. 34 No. 3, pp. 279-299.
- Brown, M.G. (2008), "Proximity and collaboration: measuring workplace configuration", *Journal of Corporate Real Estate*, Vol. 10 No. 1, pp. 5-26.
- Cheng, J., Bell, D. and Liu, W. (2002), "Learning bayesian networks from data: an information-theory based approach", *Artificial Intelligence*, Vol. 137 Nos 1-2, pp. 43-90.
- De Been, I. and Beijer, M. (2014), "The influence of office type on satisfaction and perceived productivity support", *Journal of Facilities Management*, Vol. 12 No. 2, pp. 142-157.
- De Bruyne, E., Beijer, M., Brunia, S. and Gosselink, A. (2014), "PACT: calculating nWoW accommodation that suits the organisations' work processes", *Proceedings of the 21st European Real Estate Society Conference*, pp. 1-8.
- De Vries, J.C., De Jonge, H. and Van der Voordt, T.J.M. (2008), "Impact of real estate interventions on organisational performance", *Journal of Corporate Real Estate*, Vol. 10 No. 3, pp. 208-223.
- Dixon, M. and Ross, P. (2011), *VWork: Measuring the Benefits of Agility at Work*, Unwired Ventures.
- Duffy, F. and Tanis, J. (1993), "A vision of the new workplace", *Industrial Development*, Vol. 38 No. 2, pp. 427-432.
- Gibson, V. (2003), "Flexible working needs flexible space? Towards an alternative workplace strategy", *Journal of Property Investment & Finance*, Vol. 21 No. 1, pp. 12-22.
- Gorgievski, M.J., Van der Voordt, T.J.M., Van Herpen, A.G.A. and Van Akkeren, S. (2010), "After the fire: new ways of working in an academic setting", *Facilities*, Vol. 28 Nos 3/4, pp. 206-224.
- Heckerman, D., Mandani, A. and Wellman, M.P. (1995), "Real-world applications of Bayesian networks", *Communications of the ACM*, Vol. 38 No. 3, pp. 24-26.
- Hua, Y., Loftness, V., Heerwagen, J.H. and Powell, K.M. (2011), "Relationship between workplace spatial settings and occupant-perceived support for collaboration", *Environment and Behavior*, Vol. 43 No. 6, pp. 807-826.

- Juneja, P. and Roper, K.O. (2008), "Distractions in the workplace revisited", *Journal of Facilities Management*, Vol. 6 No. 2, pp. 91-109.
- Kampschroer, K. and Heerwagen, J.H. (2005), "The strategic workplace: development and evaluation", *Building Research & Information*, Vol. 33 No. 4, pp. 326-337.
- Kemperman, A.D.A.M. and Timmermans, H.J.P. (2014), "Green spaces in the direct living environment and social contacts of the aging population", *Landscape and Urban Planning*, Vol. 129, pp. 44-54.
- Keuleers, B., Wets, G., Arentze, R. and Timmermans, H. (2001), "Association rules in identification of spatial-temporal patterns in multiday activity diary data", *Transportation Research Record*, Vol. 1752 No. 01-0190, pp. 32-37.
- Krumm, P.J.M.M. and De Vries, J. (2003), "Value creation through the management of corporate real estate", *Journal of Property Investment & Finance*, Vol. 21 No. 1, pp. 61-72.
- Lauritzen, S.L. (1995), "The EM algorithm for graphical association models with missing data", *Computational Statistics & Data Analysis*, Vol. 19 No. 2, pp. 191-201.
- Lindholm, A.-L. and Leväinen, K.I. (2006), "A framework for identifying and measuring value added by corporate real estate", *Journal of Corporate Real Estate*, Vol. 8 No. 1, pp. 38-46.
- Liow, k.H. and Ooi, J.T.L. (2000), "Current issues in strategic corporate real estate asset analysis and management", *Journal of Corporate Real Estate*, Vol. 2 No. 3, pp. 240-249.
- Liow, k.H. and Ooi, J.T.L. (2004), "Does corporate real estate create wealth for shareholders?", *Journal of Property Investment & Finance*, Vol. 22 No. 5, pp. 386-400.
- Loftness, V., Aziz, A., Choi, J., Kampschroer, K., Powell, K., Atkinson, M. and Heerwagen, J. (2009), "The value of post-occupancy evaluation for building occupants and facility managers", *Intelligent Buildings International*, Vol. 1 No. 4, pp. 249-268.
- McDonagh, J. and Nichols, G. (2009), "Business strategy and property strategy – how strong is the linkage?", *Journal of Corporate Real Estate*, Vol. 11 No. 4, pp. 213-228.
- Mladenova, I. and Gresty, M. (2012), "Alternative workplace strategies: building the business case", *The Leader*, Vol. 11 No. 4, pp. 26-33.
- Oladokun, T.T. (2010), "Towards value-creating corporate real estate assets management in emerging economies", *Journal of Property Investment & Finance*, Vol. 28 No. 5, pp. 354-364.
- Pearl, J. (1988), *Probabilistic Reasoning in Intelligent Systems: Networks of Plausible Interference*, Morgan Kaufmann, San Francisco, CA.
- Pole, S. and Mackay, D. (2009), "Occupancy cost reduction: proven techniques for these tough times", *The Leader*, Vol. 8 No. 4, pp. 12-17.
- Rashid, M. and Zimring, C. (2008), "A review of the empirical literature on the relationships between indoor environment and stress in health care and office settings: problems and prospects of sharing evidence", *Environment and Behavior*, Vol. 40 No. 2, pp. 151-190.
- Rothe, P., Lindholm, A.-L., Hyvönen, A. and Nenonen, S. (2012), "Work environment preferences – does age make a difference?", *Facilities*, Vol. 30 No. 1, pp. 78-95.
- Roulac, S., Adair, A., McGreal, S., Berry, J., Brown, L. and Heaney, G. (2005), "Corporate strategic decision making: a comparative analysis of companies in the industrial and non-industrial sectors", *Journal of Property Investment & Finance*, Vol. 23 No. 4, pp. 364-378.
- Runkel, P.J. and McGrath, J.E. (1972), *Research on Human Behavior; A Systematic Guide to Method*, Holt, Rinehart and Winston, New York, NY.
- Tabak, V. (2009), "User simulation of space utilization: system for office building usage simulation Eindhoven", doctoral dissertation, Eindhoven University of Technology, Eindhoven University Press, Eindhoven.

- Tay, L. and Ooi, J.T.L. (2001), "Facilities management: a 'jack of all trades'?", *Facilities*, Vol. 19 No. 10, pp. 357-362.
- Van Koetsveld, R. and Kamperman, L. (2011), "How flexible workplace strategies can be made successful at the operational level", *Corporate Real Estate Journal*, Vol. 1 No. 4, pp. 303-319.
- Van Meel, J.J. and Vos, P. (2001), "Funky offices: reflections on office design in the 'new economy'", *Journal of Corporate Real Estate*, Vol. 3 No. 4, pp. 322-334.
- Vischer, J.C. (2007), "The effects of the physical environment on job performance: towards a theoretical model of workspace stress", *Stress and Health*, Vol. 23 No. 3, pp. 175-184.
- Vos, P. and Van der Voordt, D.J.M. (2001), "Tomorrow's offices through today's eyes: effects of innovation in the working environment", *Journal of Corporate Real Estate*, Vol. 4 No. 1, pp. 48-65.

Further reading

- Appel-Meulenbroek, H.A.J.A., Havermans, D.W.Q., Janssen, I.I. and Van Kempen, A.J.M. (2010), "Corporate branding: an exploration of the influence of CRE", *Journal of Corporate Real Estate*, Vol. 12 No. 1, pp. 47-59.
- Blakstad, S.H., Hatling, M. and Bygdås, A.L. (2009), "The knowledge workplace – searching for data on use of open plan offices", paper presented at the EFMC 2009 Research Symposium, 16-17 June, Amsterdam.
- Inalhan, G. (2009), "Attachments: the unrecognized link between employees and their workplace (in change management projects)", *Journal of Corporate Real Estate*, Vol. 11 No. 1, pp. 17-37.
- Laihonen, H., Jääskeläinen, A., Lönnqvist, A. and Ruostela, J. (2012), "Measuring the productivity impacts of new ways of working", *Journal of Facilities Management*, Vol. 10 No. 2, pp. 102-113.
- Mooij, M. (2002), *Kantoorinnovatie: Efficiënt, Effectief, Flexibel en Creatief Werken in Een Duurzame Omgeving*, Kluwer, Alphen aan den Rijn.
- Schriefer, A.E. (2005), "Workplace strategy: what it is and why you should care", *Journal of Corporate Real Estate*, Vol. 7 No. 3, pp. 222-233.
- Steen, J. (2009), "Spatial and social configurations in offices", in *Proceedings of the 7th international Space Syntax Symposium June 8-11, Stockholm, Sweden*, TRITA-ARK-Forskningspublikation, Stockholm, 107, pp. 1-9.
- Van der Voordt, D.J.M. (2004), "Productivity and employee satisfaction in flexible workplaces", *Journal of Corporate Real Estate*, Vol. 6 No. 2, pp. 133-148.
- Van Meel, J.J. (2000), "The European Office, office design and national context", doctoral dissertation, Delft University of Technology, 010 Publishers, Rotterdam.
- Van Meel, J.J. (2011), "The origins of new ways of working: office concepts in the 1970s", *Facilities*, Vol. 29 Nos 9/10, pp. 357-367.
- Veldhoen, E. (2005), *The Art of Working. The Integral Meaning of Our Virtual, Physical and Mental Working Environments*, Academic Service, Den Haag.
- Vischer, J.C. (2006), "The concept of workplace performance and its value to managers", *California Management Review*, Vol. 24 No. 2, pp. 1-18.

About the authors

Dr Rianne Appel-Meulenbroek is an Assistant Professor in real estate at the Department of Architecture, Building and Planning (Eindhoven University of Technology). She is a Board Member of the European Real Estate Society (ERES) and sits on the editorial boards of the

Journal of CRE and *CRE Journal*. In her research, she approaches real estate as a production factor for (knowledge) organizations and uses innovative methods for studying buildings. Dr Rianne Appel-Meulenbroek is the corresponding author and can be contacted at: h.a.j.a.appel@tue.nl

Astrid Kemperman is an Assistant Professor of Urban Planning at the Eindhoven University of Technology. Her research focuses on the impacts of urban environments on human behaviour, with specific interest in physical activity and health, leisure activities, and shopping behaviour.

Marleen Kleijn participated in this research for her master thesis project. She is currently an Accommodation Consultant at the Twynstra Gudde, focusing on efficient use of real estate and its functionality, with a special interest in health accommodations.

Els Hendriks is Co-Founder of Wicely by MCS, and responsible for the development of the ABOOT software for analysis of activities in the office environment. MCS offers software and advisory solutions to gain insights into the portfolio performance in terms of total cost, risk reduction, employee satisfaction, brand perception and sustainability.