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Publication date
2017

Document Version
Final published version

Published in
24th Annual Conference of the European Real Estate Society (ERES 2017)

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Abstract

Purpose–Alignment of corporate real estate to a corporation's business strategy is a long-standing issue. In the past multiple models have been developed to support this process, but research shows that they fall short on certain parts of the CRE alignment activity, often lack transparency and fail to choose the real estate strategy that delivers most value to the organisation. The Preference-based Accommodation Strategy (PAS) procedure has been proposed as a solution to these issues and results in two pilots are positive. However, to optimise the results, a brute force approach should be implemented in the procedure. This paper reports on a pilot study wherein this PAS procedure 3.0 was tested and evaluated.

Design/methodology/approach–A literature study is conducted to develop a theoretical basis for the implementation of a brute force approach in the PAS procedure. This procedure is implemented in a pilot study by building a mathematical model. During the pilot the users improved the reflection of their preferences in the model, in an iterative process of manually designing portfolio alternatives. A brute force approach is applied to the final model to yield the optimum portfolio alternative. The implementation of the brute force approach is evaluated and it is determined if the approach yields a higher preference rating than the stakeholders can achieve by manual design.

Findings–The pilot study shows that the brute force approach is able to improve the results over the manual design and yields a 7% increase in the real estate alignment compared to the current portfolio. The evaluation results reveal that the implementation process results in acceptance of- and trust in the model. Moreover, the users are very positive about the PAS and indicate that the model better reflects their preferences than their current process. They even indicate that they want to incorporate the tool in their daily decision-making process.

Research implications–This pilot study was less complex than previous pilots, therefore the PAS procedure 3.0 should be tested in more complex pilots to discover the boundaries of the brute force approach but to use it where possible.

Practical implications–This pilot study has shown that the PAS procedure 3.0 is able to improve the corporate real estate (CRE) decision-making process and hereby improve the corporate real estate (CRE) alignment. This will result in more added value of real estate to the businesses in which the tool is used.

Keywords – Corporate real estate management, CRE Alignment, Decision-making, Preference measurement, Decision support systems

1. Introduction

Large, multinational companies often have large real estate portfolios to manage. MasterCard, Phillips and Shell, they all have offices, factories and plants around the globe that have one goal; to support the core activities of the organisation. In order to manage this portfolio effectively, they have a real estate department with professionals solely dedicated to the management of the company's real estate. This is called corporate real estate management (CREM) (De Jonge et al., 2009).

Alignment of corporate real estate (CRE) and corporate strategy has been a long-standing issue in CREM (Heywood, Kenley, & Waddell, 2009, pp. 5-7). This alignment is defined as '*[...] the bringing into harmony things that differ or could differ [...] by making them consistent or in agreement with each other*' (Heywood, 2011, p. 2). According to Den Heijer (2011, p. 91), the core of real estate management (REM) is the added value of real estate to the performance of an organisation. Added value can be realised by adjusting costs and revenues and by meeting more qualitative goals, this can be done through the alignment of CRE strategy and business strategy (De Jonge et al., 2009, pp. 9-10, 17; Heywood, 2011, p. 1). Generating this added value is an issue as practitioners indicate that they have trouble in achieving alignment (Heywood, 2011, p. 11).

Heywood (2011, pp. 2, 3, 6) points out several possible causes to this alignment problem. From the available alignment models, he identified a total of 15 different components that constitute the alignment activity. One of the most plausible causes of the alignment problem is that none of the models employs the complete set of components (Heywood, 2011, pp. 5-6). As a consequence, none of them captures the full bandwidth of the alignment activity, which makes it hard to select a model to apply in practice (Heywood, 2011, pp. 6, 10).

Arkesteijn, Valks, Binnekamp, Barendse, and De Jonge (2015) reviewed a selection of the above alignment models and conclude that most of them do not aggregate criteria ratings in an overall rating, are not transparent in generating alternatives and have no well-defined procedure to arrive at the selection of the best alternative. Moreover, none of the methods incorporates correct preference measurement (Arkesteijn & Binnekamp, 2013, p. 94; Arkesteijn et al., 2015, p. 103).

As a consequence of these issues with current models, as Heywood (2011) argues, it seems that current alignment processes are ruled by heuristics, i.e. intuitive judgement of a situation (Kahneman, 2011, p. 89). Kahneman (2011) puts this in perspective by making a distinction between two systems in our brain. The first system works intuitively and provides a solution for a situation almost instantly. This is the system responsible for heuristics. In complex situations, system two helps us to solve the issue in a structured way (Kahneman, 2011, pp. 7-17). However, system one sometimes misses obvious information in the assessment of a situation (Kahneman, 2011, pp. 22-27). This could result in severe errors in the assessment of the alignment state. Moreover, it hampers transparency, since the assessment cannot be reproduced. The risk of errors and the lack of transparency ask for a well-structured approach towards alignment.

This is also stated within the CREM domain by, i.a. Den Heijer (2011) and Razmak and Aouni (2015, p. 101) whom point at the increasing complexity of the decision-making processes in CREM, caused by increasing numbers of stakeholders and a growing information load.

Therefore, research into alignment models is important to achieve a better state of alignment. This results in a higher added value of real estate to a corporation.

1.1. The PAS procedure

Arkesteijn et al. (2015) propose the preference-based accommodation strategy (PAS) design procedure as a solution to the issues above. The PAS originates from the procedure for preference function modelling (PFM) that was developed in order to properly capture user preferences, since current alignment models lack proper preference measurement (Arkesteijn & Binnekamp, 2013, pp. 90-91; Barzilai, 2005, pp. 173-174; Binnekamp, 2010, p. 81). The PFM procedure is only an evaluation methodology. Therefore it was transformed to the Preference-Based Design (PBD) methodology and further developed into the Preference-Based Portfolio Design (PBPD) procedure in order to make it suitable for designing portfolio alternatives and calculating the overall preference rating (Arkesteijn & Binnekamp, 2013; Binnekamp, 2010, p. 3). The PBPD is later on referred to as the PAS procedure (Arkesteijn et al., 2015, p. 103) and a second version was developed (Arkesteijn et al., 2015, p. 105).

The PAS procedure comprises of the following six steps that are used to build a mathematical model of the situation at hand (Arkesteijn et al., 2015, pp. 105-106):

Step 1: Each decision-maker specifies the decision variable(s) that he/she is interested in.

Step 2: Each decision-maker rates his/her preferences for each decision variable as follows:

- The decision-maker establishes (synthetic) reference alternatives, which define two points of a Lagrange curve.
  - A “bottom” reference alternative is defined, which is the alternative associated with the value for the decision variable that is least preferred, rated at 0. This defines the first point of the curve (x0, y0).
  - A “top” reference alternative is defined, which is the alternative associated with the value for the decision variable that is most preferred, rated at 100. This defines the second point of the curve (x1, y1).
- The preference for an alternative associated with an intermediate decision variable value relative to the reference alternatives is rated. This defines the third point of the curve (x2, y2).

Step 3: Each decision-maker assigns weights to his/her decision variables. The subject owner assigns weights to each decision-maker.

Step 4: Each decision-maker determines the design constraints he/she is interested in.

Step 5: The decision-makers generate design alternatives group wise and use the design constraints to test the feasibility of the design alternatives. The objective is to try to maximise the overall preference score by finding a design alternative with a higher overall preference score than in the current situation.

Step 6: The decision-makers select the design alternative with the highest overall preference score from the set of generated design alternatives.

An important new element in the procedure is the measurement of stakeholder preferences in step two that is based on a Lagrange interpolation of their preference scales (see figure 1), i.e. the relationship between the physical values for each criterion and their preference.

Contrary to the current models, the PAS provides a well-defined procedure to generate alternatives and select the best one based on its preference rating. Using the PAS results in a transparent decision-making process, since all components that determine the overall preference rating can be traced back easily to the client statement compiled in the first four steps of the procedure.

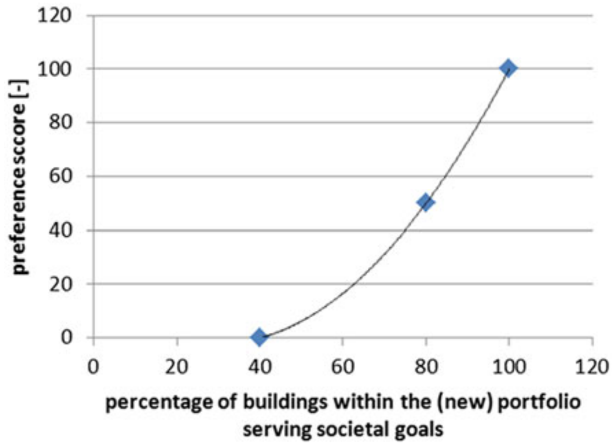

Figure 1 – Example of a Lagrange curve (Arkesteijn & Binnekamp, 2013, p. 96)

Compared to other alignment models, the procedure makes it possible to combine quantitative data with qualitative assessment and the translation of both elements into one single preference rating for each real estate portfolio alternative (Arkesteijn et al., 2015, p. 103; Valks, Arkesteijn, Binnekamp, Barendse, & De Jonge, 2014, p. 2). The process of designing portfolio alternatives is aimed at finding the portfolio alternative with the highest preference rating, which makes the PAS into a goal-oriented system.

The PAS is a typical MCDA tool for solving multi-objective design problems (Belton & Stewart, 2002, pp. 13, 15, 19). It has been developed as an independent procedure that does not replace other models (Arkesteijn et al., 2015, p. 118).

1.2. Problem definition

The first pilot study with the PAS showed that participants are able to determine their preferences and improve the portfolio preference rating compared to the current rating, based on their conjunct preferences (Arkesteijn et al., 2015, p. 117).

The pilot study provides the stakeholders with an iterative process of designing portfolio alternatives and adapting the model. This self-design enables the participants to develop insights in the effects of their preferences on the overall rating and of the interventions in the portfolio. These insights are incorporated in the model by adjusting the input provided in step 1-4 (Arkesteijn et al., 2015, p. 106). The pilot study showed that both types of iterations help to achieve a higher overall preference rating and a better representation of stakeholder preferences by the model, moreover they help to understand the model and to improve the stakeholders' acceptance of the result (Arkesteijn et al., 2015, pp. 117-118).

The question, however, is if the overall preference rating that is found by the participants is also the highest possible rating, given the stakeholders' preferences and constraints imposed on the outcome. One way to find out is to generate all possible alternatives and calculate their overall preference rating. This so called brute force approach was taken in the first proof of concept with the procedure that consisted of a relatively simple case of 15 buildings and 3 possible interventions. In this case the number of possible portfolio alternatives was more than 14 million (3 to the power of 15 = 14.348.907) (Arkesteijn & Binnekamp, 2013, pp. 94-97). The authors realised that cases are usually more complex, i.e. with more possible alternatives. Therefore, they recommended to develop a search algorithm to find an optimum alternative in more complex cases, since generating alternatives in the self-design process and finding an optimum alternative is expected to become both increasingly complex and time consuming (Arkesteijn & Binnekamp, 2013, p. 98).

However, due to the complexity of the problems approached with the PAS, the resulting models are non-linear. This creates limitations for an algorithm when it comes to finding the optimum portfolio alternative. Within such a model, the algorithm searches for higher values until it finds a peak or optimum. This is called a local optimum, since there might exist other optima with higher values that the algorithm is unable to identify. Only in linear models, a solution can be found that is "the" optimum, or global optimum[1]. Despite the aim to test the procedure on a more complex case, this pilot has a relatively low complexity.

Due to the relatively low complexity of the pilot, it was possible to use a brute force approach. This approach could substitute step 5 and 6 of the PAS procedure. However, Arkesteijn et al. (2015, pp. 117-118) make the recommendation, not to completely substitute the self-design of portfolio alternatives, since this would diminish the added value of this self-design as described above.

The next step in this PAS research project is to implement the brute force approach in the PAS procedure. This is the third version of the PAS procedure, in this paper referred to as the PAS procedure 3.0. The brute force approach could be implemented in two ways: substituting the entire process of self-design in step 5 or adding it to the process of self-design, in step 6. This PAS procedure is applied to a pilot study, based on literature study. It is assumed that the brute force approach can find an alternative with a higher preference rating compared to the self-design process, hence it is able to achieve a higher added value for the organisation. This pilot study is evaluated in order to make improvements in the future.

2. Research methods

This research and design project comprised of a so-called design problem that required the design of an artefact to properly arrive at a solution (Barendse, Binnekamp, De Graaf, Van Gunsteren, & Van Loon, 2012, p. 1). The process of building a mathematical model of the PAS in the pilot study was structured by the cyclical model developed by Barendse et al. (2012, p. 6). This model establishes the relationship between the formal design process and the empirical process that is required to evaluate the design and report on the improvements (Dym & Little, 2004, pp. 24-25). It comprises of the following stages (Barendse et al., 2012, p. 6; Dym & Little, 2004, pp. 24-25):

1) Client statement
2) Specifications
3) Conceptual/preliminary design
4) Detailed design
5) Clash of design with client statement

Based on these stages, the PAS procedure was implemented in an iterative process of workshops and interviews, by means of the cycle shown in figure 2. The steps 1-4 of the PAS procedure were completed in stage one of this cycle, step 5 and 6 in stage three. The model building process took three interviews and two workshops in the following sequence; I-W-I-W-I, which means that the cycle in figure 2 was completed twice.

In each interview round, the stakeholders were invited to make adaptations to the client statement and the PAS procedure was evaluated.

[1]Based on n.a. (2015). *Local Optima vs. Global Optima. Retrieved 22/02/16 from*

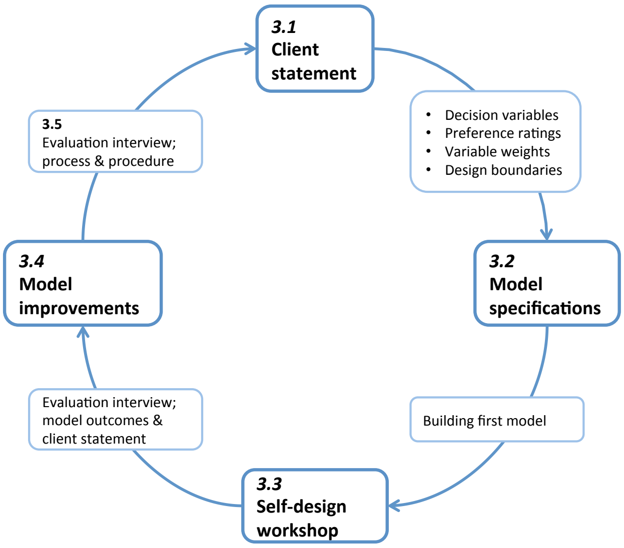

Figure 2 – Model design iterations in the formal cycle (own illustration based on Barendse et al., 2012, p. 6)

The evaluation of the PAS procedure was based on a literature study into successful implementation of Decision Support Systems (DSSs) (Riedel et al., 2011). The PAS procedure can be seen as a decision-oriented DSS, according to the definition (Razmak & Aouni, 2015, pp. 101, 113; Riedel et al., 2011, p. 232), since it focuses on one specific decision-making process and helps in generating and selecting relevant options. Riedel et al. (2011) identify participation and involvement of stakeholders in the DSS development process as a key element to achieve system acceptance (Riedel et al., 2011, pp. 248-254, 258-259, 266-267). In addition to this, actual system use requires the users' trust. Trust is made operational as the expectations of the user regarding the tasks the system will perform (Riedel et al., 2011, p. 270). The process of establishing trust is enhanced by participation and involvement (Riedel et al., 2011, pp. 270-273; Wærn & Ramberg, 1996, p. 23), since this helps to develop expectations of the model capabilities and enables user influence on the system characteristics. This could bring in accordance the expectations of the system and system performance and thereby establish trust.

The elements that help to establish acceptance and trust were combined in a checklist (see appendix 1) and divided into three evaluation categories, as suggested by Joldersma and Roelofs (2004):

1) Experiences with the method;
2) Attractiveness of the method;
3) Perception of effectiveness of the method (combined with the observer's perception of the effectiveness of the method).

In this pilot study a mathematical model was built in Matlab to apply the PAS to the pilot study. The Matlab model uses the weighted sum algorithm for aggregating individual preference ratings into an overall preference rating for portfolio alternatives and individual locations. However, the aggregation of preference ratings using the weighted sum algorithm is problematic, for details see Binnekamp (2010). Instead, the PFM algorithm is to be used according to correct preference measurement theory (Barzilai, 2005, 2010) as implemented in Tetra. Although the stakeholder worked in the interactive setting with the weighted sum, this paper only presents the correct Tetra ratings.

The brute force approach was applied to the final model and generated a ranking of all feasible portfolio alternatives. The portfolio alternative that came first, is the global optimum solution. Also the stakeholders were provided with insight in the top-5 portfolio alternatives and had the possibility to indicate whether or not they accept the number one portfolio alternative.

In addition, generating all feasible alternatives requires discretisation of the solution space for each criterion, defined by the preference curve. This means that the infinite number of possible values between e.g. 2 and 5 kg for a imaginary criterion is cut in pieces of e.g. 0,5 kg, resulting in 7 possible alternative values.

3. Oracle pilot study description

The PAS procedure was applied to a real-life pilot at Oracle, a multinational ICT company. The Advanced Planning (AP) team of the real estate department executes their global real estate strategy by conducting location studies in order to identify locations, i.e. cities or metropolitan areas, where a Line of Business (LOB) can expand its activities. The team uses a scorecard process in order to rate a selection of locations on a set of criteria with weights that are adapted by the LOB. The LOB then selects a location from the resulting ranking of locations.

This pilot study comprised of a location study conducted for LOB 1 EMEA that searches for an additional location[2]. The general aim of the new location is to attract millennials. In addition to this, the location should be attractive for native English speakers and costs should be taken into account only as a minor criterion.

In this pilot study, a representative selection of 22 of the original 39 criteria was used, together with all 32 locations from the original study, including six locations currently in the portfolio. The criteria were confirmed and provided with weights by a representative of LOB 1 and covered multiple perspectives from within the LOB. So effectively one stakeholder was involved that brought in criteria in this pilot. In addition to this, two users from the AP team were involved. The pilot study provided a second opinion on the original study outcomes and resulted in an optimum portfolio for LOB 1.

4. Results

This section presents the results for each step of the PAS procedure.

Step 1: specify the criteria the user is interested in
The criteria in the study are based on five categories that are of interest to LOB 1 (see table I). Only a small part comprises of cost related criteria, as a result of the aim to find a location that attracts millennials. Therefore, the category that covers aspects of the ease of hiring native English speakers and millennials is the largest.

Categories of interest	Number of criteria
Costs	2
Ease of sourcing native speakers & millennials	10
Labour environment	3
Fit to LOB 1 EMEA vision and value proposition	3
Government support	4

Table I – Categories covered by the criteria

Step 2: determining preferences
The preference curves were established according to the PAS procedure. The users determined a least preferred reference alternative $[x_0, y_0]$ and the most preferred reference alternative $[x_1, y_1]$. The shape of the curve was determined by means of an intermediate reference $[x_2, y_2]$. The representative of LOB 1 established one third of the preference curves, the representatives from the AP team established the remainder.

[2] Data is coded for confidentiality reasons

Decision maker	Criterion	$[x_0, y_0]$	$[x_1, y_1]$	$[x_2, y_2]$
LOB 1	Criterion A	[146506, 0]	[53270, 100]	[93000, 80]
	Criterion B	[50, 0]	[15, 100]	[26, 50]
	Criterion C	[2.4, 0]	[5.8, 100]	[2.9, 20]
	Criterion D	[2, 0]	[6.5, 100]	[3, 10]
	Criterion E	[200, 0]	[2700, 100]	[800, 60]
	Criterion F	[50, 0]	[1000, 100]	[150, 70]
	Criterion G	[50, 0]	[800, 100]	[100, 50]
	Criterion H	[4, 0]	[7, 100]	[5, 10]
	Criterion I	[114, 0]	[25, 100]	[90, 10]
	Criterion J	[30, 0]	[95, 100]	[70, 90]
	Criterion K	[300, 0]	[40, 100]	[200, 10]
	Criterion L	[25, 0]	[90, 100]	[45, 80]
	Criterion M	[3, 0]	[6,2, 100]	[5.4, 90]
	Criterion N	[21.6, 0]	[0, 100]	[8, 40]
	Criterion O	[1, 0]	[5, 100]	[4, 85]
	Criterion P	[3, 0]	[6, 100]	[5, 80]
	Criterion Q	[35, 0]	[57, 100]	[40, 40]
	Criterion R	[30, 0]	[76, 100]	[65, 90]
	Criterion S	[2.5, 0]	[6.6, 100]	[4.2, 60]
	Criterion T	[2, 0]	[6.5, 100]	[4.5, 80]
	Criterion U	[61, 0]	[1, 100]	[30, 20]
	Criterion V	[62, 0]	[1, 100]	[44, 15]

Table II – Criteria and their respective preferences

An example of a preference curve is that of criterion B (see figure 3). The least preferred reference alternative was set at the highest acceptable physical value, the most preferred reference was set at a low physical value. For the intermediate reference alternative, the stakeholder took the physical value of their benchmark location #10 in order to avoid rating too much in favour of locations with a lower physical value.

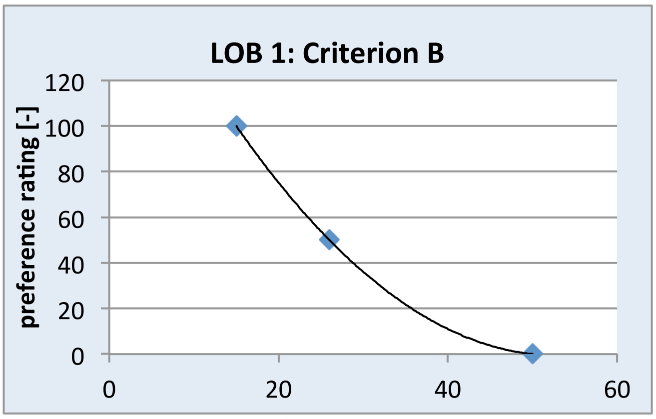

Figure 3 – Lagrange interpolation relating preference rating to the physical value of criterion B for the location portfolio of LOB 1 (own illustration)

Step 3: assigning weights
The representative of LOB 1 assigned weights to the criteria (see figure 4). These weights might incorporate progressive insight in their effects, because the implementation of the results of the initial study has already started. There is no stakeholder weight included in this study, as there is only one stakeholder representative that provided criteria.

Step 4: determining design constraints
During the pilot study, the users formulated a total of four design constraints (see table III). The first constraint is based on the number of locations in the current portfolio of LOB 1 and the desire to find one additional location.

The other three constraints determine the possibilities for the selection of this alternative location, since they determine that some locations cannot be left and that each of the regions should be covered with a location. These regions are determined to maintain a certain language coverage by the LOB, i.e. Roman, Germanic, Arabic and Slavonic languages. The cost constraint determines that the costs for more expensive locations should be compensated by cheaper locations.

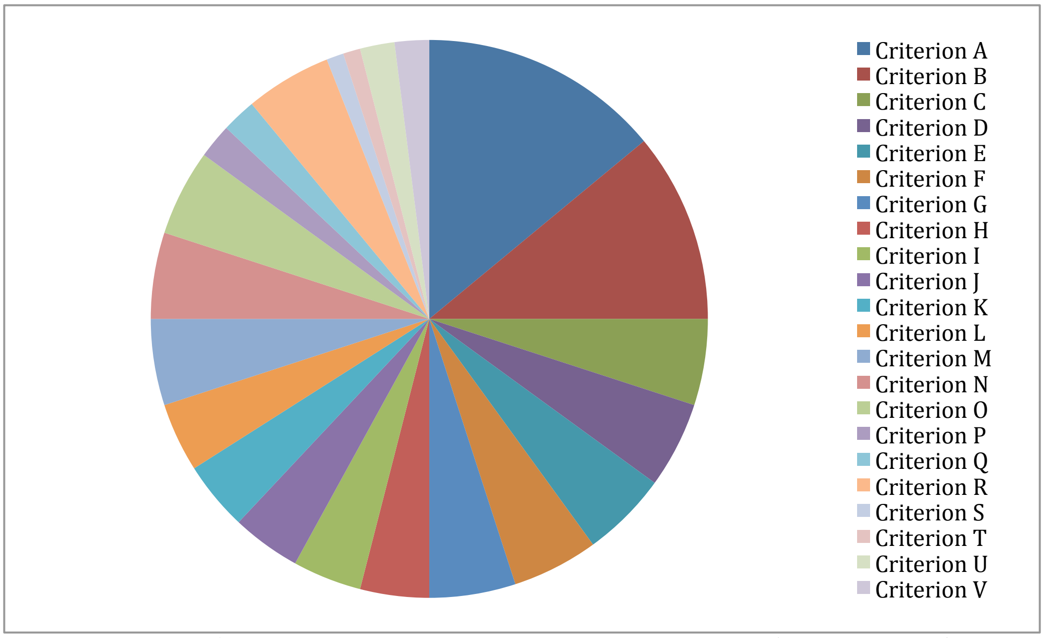

Figure 4 – Criterion weights determined by the decision maker (own illustration)

Decision maker	Design constraint
LOB 1	The new portfolio should consist of 7 locations
	The location #10 should always be included
	At least one location should be selected in each of the following regions: Northern-Europe (N-EU); Southern-Europe (S-EU); Eastern-Europe (E-EU); Middle-East (M-E); Russia (R); UK & Ireland (UK&I)
	The average annual costs p.p.p.y. of the new portfolio ≤ the average annual costs p.p.p.y. of the current portfolio

Table III – Design constraints incorporated in the model

Step 5: generate alternatives

The outcomes of the pilot study comprise of a ranking of all locations, based on preference rating, a set of portfolio alternatives from the self-design process and the optimum alternative from the brute force approach.

Comparing location rankings

A ranking of locations was the main output from the original location study, therefore the users compared the PAS ranking to the original ranking (see table IV). The PAS ranking was checked in Tetra, which showed that all preference ratings where a little higher. Nevertheless, only two locations switched one place. This is a confirmation of the close approximation that the weighed sum calculation provides for the actual value.

The comparison showed that roughly 2/3rd of the top-15 of locations in the original study returns in the top-15 of the PAS outcome. Moreover, location #13, which was selected by LOB 1 after the initial study, moves from place 17 to place 4 in the PAS ranking. This is an initial indicator that the PAS model quite closely reflects the stakeholders' preferences in a more accurate way than the original scorecard procedure.

Table V shows that there are quite some locations that go a lot of steps up or down in the ranking. However, there are also a few locations that stay in the same position. Among the latter are the first and second most preferred location. Moreover, 21 of the 32 locations stay within a minor shift of 3 places up or down.

Output original study		Output PAS model		
Rank:	**Locations:**	**Rank:**	**Locations:**	***Overall weighted location rating:***
1	Location 21	**1**	Location 21	72
2	Location 10*	**2**	Location 10*	71
3	Location 22	**3**	Location 32*	70
4	Location 25*	**4**	**Location 13**	68
5	Location 23	**5**	Location 2	62
6	Location 32*	**6**	Location 8	62
7	Location 2	**7**	Location 22	61
8	Location 17	**8**	Location 24	61
9	Location 16	**9**	Location 23	60
10	Location 24	**10**	Location 20	59
11	Location 20	**11**	Location 3	57
12	Location 29	**12**	Location 5*	57
13	Location 18*	**13**	Location 19	57
14	Location 31*	**14**	Location 9	55
15	Location 26	**15**	Location 25*	55
16	Location 3	**16**	Location 18*	55
17	**Location 13**	**17**	Location 17	54
18	Location 27	**18**	Location 7	53
19	Location 15	**19**	Location 1	52
20	Location 8	**20**	Location 6	51
21	Location 19	**21**	Location 4	51
22	Location 14	**22**	Location 14	51
23	Location 5*	**23**	Location 29	48
24	Location 9	**24**	Location 16	47
25	Location 7	**25**	Location 26	43
26	Location 6	**26**	Location 31*	43
27	Location 28	**27**	Location 27	43
28	Location 1	**28**	Location 11	41
29	Location 30	**29**	Location 15	38
30	Location 4	**30**	Location 28	36
31	Location 12	**31**	Location 12	34
32	Location 11	**32**	Location 30	32

*Table IV – Location ranking from the PAS model compared to the ranking from the original study (* = location in current portfolio)*

Generating alternatives

The goal of designing portfolio alternatives is to maximise the overall portfolio preference rating within the established design constraints. This pilot incorporates one possible intervention, which is to switch locations on and off to design a portfolio alternative. Hence for each region, the users had to find the location that resulted in the highest overall preference rating for the portfolio.

The optimum feasible portfolio alternative designed by the stakeholders is *Optimum self-design*, which is shown next to the portfolio with the LOB's current choice, *Current & Location 13* (see table VI). *Optimum self-design* is accepted by the stakeholders as the final outcome of the self-design process, which confirms that the model closely reflects their preferences.

Step 6: selecting the best alternative

The complete pilot comprised of a total of more than 3,3 million possible portfolio alternatives, however due to the design constraints imposed to the solution space, only 4.480 feasible portfolio alternatives remained. This number could be generated using the brute force approach. When the correct values for the top-5 portfolio alternatives were obtained in Tetra, the number 3 alternative went to place five. Also Tetra showed an insignificant difference of 0.01 in the rating for number 1 and number 2.

The number one portfolio alternative, *Global optimum*, has a higher preference rating than found by the stakeholders. This confirms the hypothesis that it is possible to find a portfolio alternative with a better preference rating than the stakeholders are able to find. Moreover, the ranking showed that there are 78 portfolio alternatives with a better rating than found by the users.

Locations:	Output original study (rank)	Output PAS model (rank)	Change in rank
Location 1	**28**	**19**	9
Location 2	**7**	**5**	2
Location 3	**16**	**11**	5
Location 4	**30**	**21**	9
Location 5*	**23**	**12**	11
Location 6	**26**	**20**	6
Location 7	**25**	**18**	7
Location 8	**20**	**6**	14
Location 9	**24**	**14**	10
Location 10*	**2**	**2**	0
Location 11	**32**	**28**	4
Location 12	**31**	**31**	0
Location 13	**17**	**4**	13
Location 14	**22**	**22**	0
Location 15	**19**	**29**	-10
Location 16	**9**	**24**	-15
Location 17	**8**	**17**	-9
Location 18*	**13**	**16**	-3
Location 19	**21**	**13**	8
Location 20	**11**	**10**	1
Location 21	**1**	**1**	0
Location 22	**3**	**7**	-4
Location 23	**5**	**9**	-4
Location 24	**10**	**8**	2
Location 25*	**4**	**15**	-11
Location 26	**15**	**25**	-10
Location 27	**18**	**27**	-9
Location 28	**27**	**30**	-3
Location 29	**12**	**23**	-11
Location 30	**29**	**32**	-3
Location 31*	**14**	**26**	-12
Location 32*	**6**	**3**	3

Table V – Locations and their rank in the PAS model compared to the rank in the original study (* = location in current portfolio)

As shown in table VI, the alternative *Global optimum* includes the minimum number of three of the six locations from the current portfolio, i.e. 10, 31, 32, just to meet the regional design constraints. As such, it differs from the optimum found through self-design, which also includes the current location 25. In addition to this, the location with the highest individual preference rating, location 21, and location 13 are included. The fact that location 21 is included is the most important difference with the alternatives designed by the users. At the same time it is a very logical step in the design of the optimum portfolio, since this is the only way to realise the highest possible portfolio preference rating. The stakeholders indicated that they expected such an outcome and accept this as the final outcome of the pilot study. The *Global optimum* portfolio alternative provides an improvement of 7% in the preference rating over the current portfolio, whereas the optimum found through self-design achieves an improvement of 5%.

The global optimum portfolio alternative yields the preference ratings per criterion, presented in table VII. The right column shows that on several criteria the preference rating decreases a few percent compared to the current portfolio, however this is compensated by a few large increases.

Name:	***Current portfolio***	**Current & Location 13**	**Optimum self-design**	**Global optimum**
Locations:	*Location 5*	Location 5	Location 8	Location 10
	Location 10	Location 10	Location 10	Location 13
	Location 18	Location 13	Location 13	Location 17
	Location 25	Location 18	Location 17	Location 21
	Location 31	Location 25	Location 25	Location 27
	Location 32	Location 31	Location 31	Location 31
		Location 32	Location 32	Location 32
Preference rating:	*61*	**63**	**64**	**66**
Difference	*-*	**3%**	**5%**	**7%**

Table VI – Comparison of optimum portfolio alternatives to the current portfolio and the actual choice by LOB 1

Decision maker	**Criterion**	**Preference rating d_0**	**Preference rating d_1**	**Difference (%)**
LOB 1	Criterion A	86	87	2
	Criterion B	10	18	91
	Criterion C	57	60	5
	Criterion D	30	35	16
	Criterion E	77	100	30
	Criterion F	100	100	0
	Criterion G	100	100	0
	Criterion H	20	23	16
	Criterion I	45	41	-10
	Criterion J	76	79	4
	Criterion K	38	36	-4
	Criterion L	100	100	0
	Criterion M	76	79	5
	Criterion N	8	24	187
	Criterion O	85	82	-3
	Criterion P	68	65	-4
	Criterion Q	85	90	5
	Criterion R	69	76	10
	Criterion S	77	82	6
	Criterion T	70	74	7
	Criterion U	23	21	-9
	Criterion V	33	41	24

Table VII – Preference rating per criterion; current (d_0) and future (d_1) state of the portfolio Global optimum alternative

5. Evaluation of the results

In general the users evaluated the improved PAS very positively. They were especially positive about their involvement in the iterative model development process, which made them understand the PAS and model principles. One of the AP team users indicated that:

"she feels inclined to put more thought in fewer criteria, which means a choice for quality over quantity."

They also indicated that the use of preference curves, the selection of criteria and the adaptations made in the design constraints between the two workshops, made the model reflect their preferences and the actual decision-making process very well. Also the model usefulness was rated highly by the stakeholders, the portfolio optimisation with the brute force approach amplified this. The representatives of the AP team were specifically enthusiastic about the visual feedback and ease of use of the design interface.

The above evaluation results confirm that the users accept the model. Also from the evaluation interviews it followed that the users developed their expectations of the model performance during the model development process, while at the same time contributing to the input and characteristics of the model. This brought the final model performance into accordance with their expectations, which resulted in trust in the model. Moreover, the users accept the outcomes of the brute force approach as the final outcome of the pilot study, which indicates that the PAS model closely reflects their preferences. They regard the brute force approach as a useful addition to the self-design process, which adds up to their positive perception of usefulness. However, one of them preferred the second alternative slightly more, since Oracle already has a small office in one of the locations. Nonetheless, this does not affect the assessment of the brute force approach since both differ only insignificantly. Still, adding some criteria could improve the representation of the stakeholders' preferences in the portfolio alternatives.

These results imply a positive user experience with the PAS. Also they indicate that they find it an attractive method and would like to use it in their daily decision-making process. Moreover, the model is perceived as an effective tool in the decision-making process, both by the stakeholders and the observer. These results again confirm that the brute force approach should be implemented in addition to the self-design process. As indicated by the LOB 1 representative,

"it is an excellent data driven tool to support the decision-making process."

However, there are also suggestions for improvement. The users suggested providing a manual with directions for each step of the PAS procedure in order to be able to involve business users more easily. Also one of the users touched upon improving the graphical presentation of the model output in order to be able to present the results directly to her executives.

The development of the criteria and design constraints over the course of the pilot study is shown in table VIII. It shows that after workshop 1, the users included three extra constraints, which confirms that the users gained insight in the effects of their input through the self-design process and were able to adapt it accordingly. This resulted in a better representation of their preferences in the model. However, no iterations were made in the criteria. This could be due to the existing case that was used, for which the criteria were already deemed suitable. Finally, the table shows that the brute force approach was able to find a portfolio alternative with a higher preference rating than the stakeholders could find in the second workshop.

6. Conclusions

The aim of this research project was to implement the brute force approach in the PAS procedure and apply the procedure in a pilot study to find the added value of the brute force approach. The evaluation of this pilot was meant to provide insights for further development of the PAS procedure.

Previous pilots with the PAS showed an increasing level of complexity in the number of stakeholders, criteria, constraints and objects. In comparison, the case in this pilot study was less complex (see table IX). Still, the outcomes of the brute force approach show that even in a more simple case there is a clear boundary to the preference rating found by the stakeholders. Moreover, it can be concluded that a brute force approach is even more preferable as it finds a global optimum instead of a local optimum.

Compared to Oracle's current scorecard system, the location ranking from the PAS model showed an improvement in the representation of the users' location preferences, induced by the use of preference curves, and it is more efficient in rating additional locations. Also in the goal-oriented self-design process, the users found an optimum alternative with a higher preference rating compared to the current portfolio. Moreover, the brute force approach was able to find a global optimum portfolio alternative with an even higher preference rating that was accepted by the users as the final outcome of the pilot study.

Interview 1	Workshop 1	Interview 2	Workshop 2	Interview 3	Brute Force
Criterion A					
Criterion B					
Criterion C					
Criterion D					
Criterion E					
Criterion F					
Criterion G					
Criterion H					
Criterion I					
Criterion J					
Criterion K					
Criterion L	**Result: 71 (+10)**				
Criterion M					
Criterion N			**Result: 64 (+3)**		**Result: 66 (+5)**
Criterion O					
Criterion P					
Criterion Q					
Criterion R					
Criterion S					
Criterion T					
Criterion U					
Criterion V					
Constraint 1					
		Constraint 2			
		Constraint 3			
		Constraint 4			

Table VIII – Development of the criteria and boundary conditions

Characteristics:	Food facilities, Delft University of Technology	Lecture halls, Delft University of Technology	EMEA location portfolio Oracle
New or existing case	New	New	Existing
# Stakeholders	4	6	1
# Criteria	17	28	22
# Design constraints	6	5	4
# Interventions	5	11	1
# Objects	14	18	32
Preference rating current portfolio	43	58	61
Preference rating optimum alternative	96	69	66
Optimisation tool applied	No	No	Yes, a brute force approach
Modelling programme	Excel	Excel	Matlab

Table IX – Comparison of PAS pilots; Pilot food facilities (Arkesteijn, Binnekamp, & De Jonge, 2016, pp. 7-13), Pilot lecture halls (Arkesteijn et al., 2015, pp. 109-117)

The development of the PAS procedure 3.0 was based on determinants for successful DSS implementation. During the iterative model building process, the stakeholders gained understanding of the model and the effects of their input, which helped them to make valuable improvements. This improved the reflection of their preferences in the model.

The pilot study was evaluated very positively. The stakeholders felt very much involved and feel comfortable with the model and its output. Also, the evaluation showed that the process resulted in acceptance of- and trust in the model. This confirmed the findings from the DSS literature study on how to implement the brute force approach.

The final portfolio alternative showed an improvement in alignment of 7%. This means that the model is capable of increasing the added value of real estate to the organisation by improving the decision-making process. These findings are significant since Oracle's current alignment process is already quite advanced, however they still regard the improvements made with the PAS as important and indicate that they would really like to use the tool in their actual decision-making process and implement its outcomes.

7. Recommendations

Since the pilot study was evaluated very positively, an important recommendation is to so use the PAS procedure with the brute force approach implemented in addition to the self-design process.

However, this pilot included only one stakeholder and only one intervention was available. Therefore, another recommendation is to apply the PAS procedure in more complex pilots including multiple stakeholders and multiple interventions. This is expected to provide additional insights in the boundaries of the self-design process. Nevertheless, it is recommended to use a simple model to explain to the users how the procedure works. This helps to make the stakeholders understand the model, which increases their acceptance of- and trust in the model and its outcomes.

The brute force approach provides the important advantage that it finds the global instead of the local optimum alternative. Therefore it is valuable to find the boundaries for this approach in terms of the number of feasible alternatives combined with the calculation time in which these can be processed. Regarding these boundaries it is recommended to develop a search algorithm for those cases that are too complex for a brute force approach. In relation to this, it might be worthwhile to test the performance and reliability of a future search algorithm by comparing its outcomes with the output of a brute force approach in cases with increasing complexity.

Acknowledgments

Conducting this pilot study at Oracle would not have been possible without the enthusiasm and effort of Carol Leipner-Srebnick, Director Real Estate Advanced Planning at Oracle and Katie Davenport, Global Location Strategy Programme manager at Oracle.

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Appendix 1

Process (p)/ system (s)	Characteristic	Evaluation category (Joldersma & Roelofs, 2004)	Resulting effect (Riedel et al., 2011)
P	Participation & involvement of users (Riedel et al., 2011); user consultation (Van Loon, Heurkens, & Bronkhorst, 2008)	Experience	System acceptance
P	Stakeholder interaction (Van Loon et al., 2008)	Experience	System acceptance
P	Iterative system development (Van Loon et al., 2008)	Experience	System acceptance
P	Perceived control (Riedel et al., 2011)	Attractiveness	System acceptance
P	Familiarise with backside of the system (Riedel et al., 2011)	Experience	Trust in the system
P	Clear system goal (Van Loon et al., 2008)	Effectiveness	System acceptance
S	Complexity (Riedel et al., 2011)	Attractiveness	System acceptance
S	Calibrated variables (Van Loon et al., 2008)	Attractiveness	Trust in the system
S	Perceived usefulness (Riedel et al., 2011)	Attractiveness	System acceptance
S	Purpose (Riedel et al., 2011)	Attractiveness	Trust in the system
S	Perceived ease of use (Riedel et al., 2011)	Attractiveness	System acceptance
S	Performance reliability (Riedel et al., 2011)	Effectiveness	Trust in the system
S	Justification of outcome (Riedel et al., 2011)	Attractiveness/ Effectiveness	Trust in the system

Checklist for evaluating DSSs and their development process