4 Preference-based Accommodation Strategy design and decision approach

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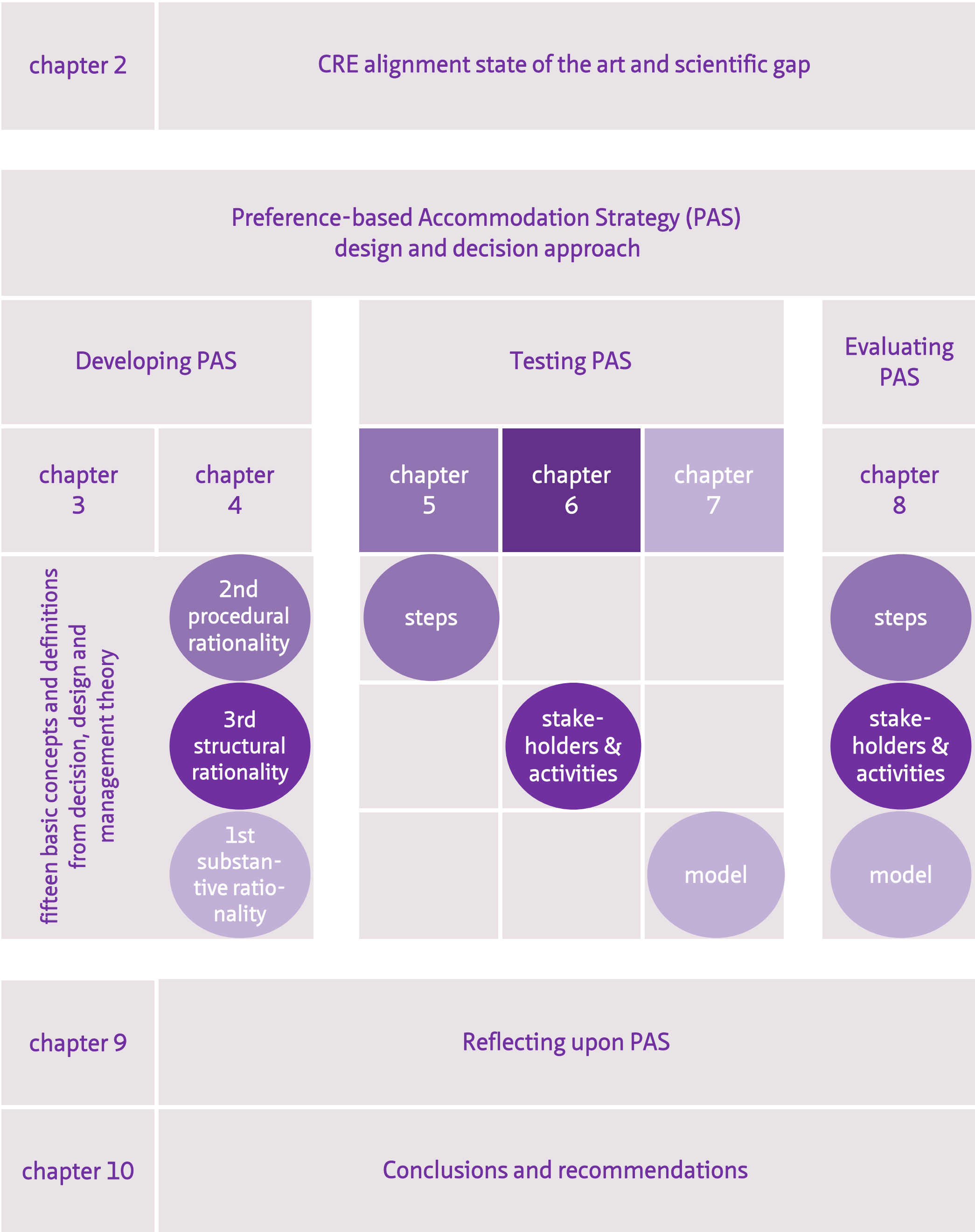
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4 Preference-based Accommodation Strategy design and decision approach

One of the long-standing issues in CREM is the alignment of an organization's real estate to its corporate strategy as I have shown in chapter 2. CRE alignment is even defined by some as the raison d'être of CREM, as the range of activities undertaken to attune corporate real estate optimally to corporate performance. Even though extensive research into existing CRE alignment models has provided us with valuable insights into the steps, components and variables that are needed in the alignment process, these models still fall short in two ways. Most models pay little to no attention to the design of a new portfolio and to the selection of a new portfolio that adds the most value to the organization.

The Preference-based Accommodation Strategy approach is a design and decision support tool to remedy these shortcomings and thereby enhance CRE alignment. The basic concepts and definitions for PAS have been explained in chapter 3. In this chapter, PAS is presented in its main development phases.

The research methods to develop, test and evaluate PAS are explained in paragraph 4.1. In paragraph 4.2 the main concepts and the three components of PAS are explained. Subsequently, these three components are discussed; the steps of PAS in paragraph 4.3, the stakeholders & activities in paragraph 4.4 and the generic mathematical model in paragraph 4.5. In the last paragraph 4.6, the coherence between the three components is explained as well as the conclusion.

4.1 Research methods to develop, test and evaluate PAS

In this paragraph the main aim of the research is addressed in paragraph 4.1.1 while the formal research method from operations research as used for the development of PAS is explained in paragraph 4.1.2. In paragraph 4.1.3 it is explained how the successfulness of the approach will be tested.

4.1.1 Main aim

The aim of the research is to enhance CRE alignment by improving CRE decision making in such a way that corporate real estate managers are able to determine the added value of a particular corporate real estate strategy quickly and iteratively design many alternative real estate portfolios.

In order to be able to do this two equally important parts need to be addressed:

1. Measure added value of a new alternative CRE portfolio:
   corporate real estate managers should be able to determine the added value of a particular corporate real estate strategy, i.e. corporate real estate portfolio;
2. Iteratively design alternative CRE portfolios:
   corporate real estate managers and involved stakeholders should be able to quickly and iteratively design alternative corporate real estate portfolios to find the portfolio with the optimal added value.

The approach should be generic so it can be used for a wide range of real estate portfolios.

The originality of this research to (1) define value as technically equivalent to preference and (2) use a design and decision approach for the alignment problem. By adjusting and expanding the Preference-Based Design procedure as particular technique from design and decision systems tested and evaluated on portfolio level in CRE alignment. This new approach is called the Preference-based Accommodation Strategy (PAS) design and decision approach. PAS is a decision support tool to remedy these shortcomings and thereby enhance CRE decision making.

The research question that will be answered is:

How can the Preference-based Accommodation Strategy design and decision approach successfully be developed and tested on corporate real estate portfolio level in order to enhance CRE alignment?

4.1.2 Research method to develop and test PAS

To answer the research question an appropriate design decision method has to be developed and tested. This developing and testing concerns design methodology and is focused on the question 'how to do' something i.e. how to develop, form, make an accommodation strategy? Methodological design questions can be answered based on operations research methodology that deals with operation-related problems (Barendse et al., 2012)[31]. Operations Research is a discipline that deals with the application of analytical methods to aid decision making and solve organizational problems. PAS is developed and tested in accordance with the five stages of an operations research project (Ackoff and Sasieni, 1968: p. 11):

1. "Formulating the problem;
2. Constructing the model;
3. Deriving a solution;
4. Testing the model and evaluating the solution;
5. Implementing and maintaining the solution".

PAS will be tested in three pilot studies. It can be argued that the application of a design and decision approach in practice is context-dependent. The results of using the same approach multiple times can be different depending on the people involved in the process, the roles and responsibilities of these people within the organization, the characteristics of the portfolio, i.e. the type of space it is applied to, etc. Applying this approach to multiple context-dependent cases yields more valuable results than just applying it to one case.

31 Note that this is in contrast to empirical research that deals with knowledge-related problems ('what is' type of research questions) and provides understanding about the past (Barendse et al., 2012). Empirical research provides knowledge (theories, predictions, concepts) that can be used to explain reality and formal studies produce artifacts (methods, ways of acting, instruments) that can be used to eradicate dysfunction in reality (Van Loon, 1998, p. XXXIII).

Note that in this research problem solving occurs on three different levels (see Table 4.1).

TABLE 4.1 Problem solving at three levels

Problem solving at three levels		
	Problem to be solved	**Problem solver(s)**
Level 1	Develop the PAS design and decision method The PBD procedure cannot be used on a portfolio level and the PBD procedure is not tested in practice	Ph.D researcher
Level 2	Build mathematical model In each pilot study to test PAS mathematical models need to be constructed to solve a practical problem	Systems engineer
Level 3	Design alternative real estate portfolio To design alternative CRE portfolios for the problem in practice in a particular pilot study	Stakeholders

In order to perform PAS in the pilot studies (level 3) empirical research is needed in stage 4 'Testing the model and evaluating the solution'. These questions as will be shown are part of PAS and will serve as a background for the model design.

4.1.3 Research method to determine the successfulness of PAS

PAS can be considered a *soft systems approach* because the problem situation is plural. This means that the 'what' question needs to be answered first. In the soft system approach the unanalyzed problem situation is the start. This in contrast to the hard systems approach which starts with an unambiguous problem situation and focuses on 'how the system must be arranged. The classification of PAS as soft system is based on a scheme of different system approaches as presented by De Leeuw (2002, p. 218) where the actors in PAS are pluralistic and mechanic (analyzable). However, it is possible that the actors in PAS can have different images of the situation and have different objectives. This means that it is not known if the structure of the system is transparent or not before the pilot starts.

PAS is considered to be successful if

1 The stakeholders are able to perform PAS , i.e. can the stakeholders perform PAS to solve problems?

2 If the stakeholders evaluate PAS positively, i.e. do the stakeholders want to use PAS to solve problems?

The first questions is answered if the stakeholders are able to solve the practical problem in their pilot study. Therefore, the operations research method as described in the previous paragraph is used.

In order to determine if stakeholders want to use PAS to solve problems another research method is used. To assess the impact of soft operations research methods (Joldersma & Roelofs, 2004, pp. 697-698) is used. They indicate that the impact on problem structuring can be measured in four different ways: (1) experiences with the method; (2) attractiveness of the method; (3) participants' observations on effectiveness of the method; and (4) observers' perceptions of the effectiveness of the method.

Each stakeholder has been interviewed minimally three times during the pilot study to evaluate PAS. In the first interview two questions are posed (see **Table 4.2**) and in the second and third interview three questions are asked about the first three aspects (see **Table 4.3**). The fourth aspect *'observers' perceptions of the effectiveness of the method*' has been answered by the researcher.

TABLE 4.2 Interview 1

Interview 1	
Evaluation	**Questions**
	What is your first evaluation of PAS ?
Expectations	What are your expectations of your participation in this project?

TABLE 4.3 Interview 2 and subsequent interviews

Interview 2 and subsequent interviews		
	Question	**Possible aspects**
Aspect 1: Experience	What was your experience with PAS ?	User-friendliness of the model, easiness of performing PAS
Aspect 2: Attractiveness	What is attractive of PAS ?	Mathematical model, visualization, involvement
Aspect 3: Effectiveness	Do you think that PAS is effective?	Acceptance of solution, time spent on achieving the solution

4.2 Main concepts and components PAS

The basic concepts and definitions of PAS have been discussed in chapter 3. The approach is based on two main concepts and has three components. The main concepts are explained in paragraph 4.2.1 and the three components are discussed in paragraph 4.2.2.

4.2.1 Two main concepts[32]

The main concepts of PAS are:

1. CRE alignment is seen as a design and decision process which requires integrating aspects of the domains of design, decision making and problem solving;
2. Adding value is a key concept in CRE alignment and therefore it requires the measurement of value. The measurement problem is solved by using a mathematical operational approach from decision theory where value is considered equivalent to preference.

Ad 1. CRE alignment as a group design and decision process

In a design and decision process the optimal portfolio is defined as the portfolio of buildings that best serves the aims of the organization within a particular set of boundary conditions. The most preferred or valuable solution in CRE alignment is sometimes seen as the accommodation with the highest financial performance (Weatherhead, 1997; Englert, 2001; Osgood, 2004). The highest financial performance is often either defined as the net present value (NPV) or as the economic value add (EVA) and is referred to as the shareholders' approach. However, in this research the stakeholders approach is used where all stakeholders are involved and are able to express their requirements in both financial, quantitative aspects (such as square meters) and qualitative aspects (such as aesthetics) s. That means that if - in the phase of selecting the best option, i.e. an alternative – this choice is not only based on financial aspects, then a kind of measurement of all these different values is needed to select the most preferred alternative. Since the decisions on the selection

32 These main concepts and components were published in Arkesteijn et al., (2017, p. 245), text slightly adjusted see numbering of main concepts, addition of words [..] and bold emphasis.

of accommodation strategies are rarely made by one decision maker, this process is regarded as group decision making. This means that measuring values should take place across all actors Arkesteijn et al., (2017, p. 245).

Ad 2. A mathematical operational approach; value is equivalent to preference

To ensure that the CRE alignment process adds value it is necessary to determine both the value of the existing real estate portfolio as well as the value of a proposed alternative portfolio. The assignment of values to objects such as real estate portfolios, i.e., the construction of value scales, is a fundamental concept of decision theory. Since value (or preference) is not a physical property of the objects being valued, it is a personal or psychological (sometimes referred to as “subjective”) variable and the measurement of value requires specifying both what is being valued and whose values are being measured.

To decide is to choose and the alternative that the stakeholders prefer is chosen and they prefer the alternative that adds (most) value. This means that value can be measured by measuring preference, that is, evaluating/judging the alternatives as to the value they add, and in this context, *value* and *preference* are equivalent. Evaluating is a human cognitive judgment which is consistent with the observation that the value of alternatives is a non-physical property of the alternatives and value is a personal/psychological variable. Of course, in multi criteria evaluation, some of the criteria, i.e. variables may be physical, for example, the floor size of a building Arkesteijn et al., (2017, p. 245).

PAS enables CRE managers and the stakeholders to actually calculate the added value of an alternative corporate real estate portfolio. The generic objective of PAS is to open the ‘black box of decision making’ in the existing CRE alignment models and to offer an approach in which it is able to select the best option, on more than financial criteria only.

4.2.2 Three components of PAS

PAS consists of three components based on the three types of rationality as used by De Leeuw (2002) based on Kickert (1979) (in De Leeuw, 2002) (see paragraph 3.1.1). The components are steps (procedural rationality), stakeholders & activities (structural rationality) and mathematical models (substantive rationality) (see Figure 4.1).

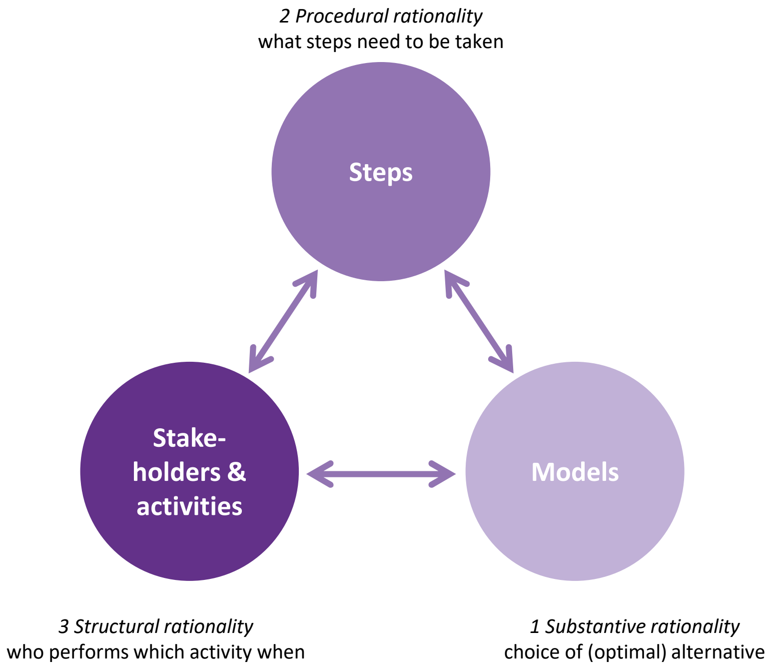

FIG. 4.1 PAS components and rationalities Note adapted from Arkesteijn et al., 2017, p. 245

"In the steps, decision makers define decision variables representing accommodation aspects and iteratively test and adjust these variables by designing new accommodations i.e. real estate portfolios. The alternative design that adds most value to the organization, i.e. has the highest overall preference, is suggested as the portfolio that optimally aligns real estate to corporate strategy. The activities that the participants perform are a series of interviews and workshops while in between the system engineer builds the accompanying mathematical models" (Arkesteijn et al.217, p. 245). The substance of the problem at hand is presented in the mathematical models, therefore although the generic part of the mathematical model as such has no substance as such. The mathematical model will enable the stakeholders to choose the best option.

4.2.3 Main development phases of PAS and its components

Due to the modular form of this thesis it is important to highlight the main development phases of PAS, its components and related publications. First of all, it is important to note that the three components as presented in the previous paragraph are components *in* the PAS design and decision method. The PAS has been roughly developed in four development phases. This means that the phases are *not part* of the method itself. In each of the development phases the focus was slightly different as is shown in Figure 4.2.

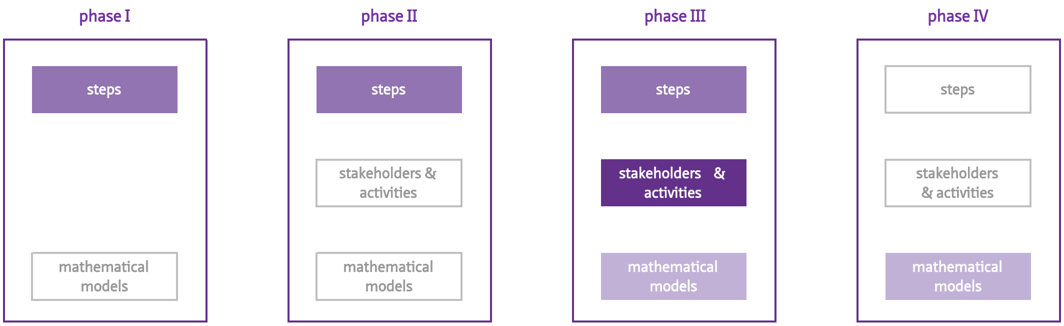

FIG. 4.2 PAS development phases and the focus on the components

In each of the development phases the focus was different (see Figure 4.3). The phases are:

First phase

In this phase the PAS steps have been developed and tested in a proof of concept. This was necessary as will be shown in paragraph 4.3 to make Binnekamp's PBD procedure applicable on CRE portfolio level. The proof of concept has been done in 2011 on the data obtained from a preliminary study at the development company of the municipality of Rotterdam.

Second phase

In this phase the PAS procedure has been further developed and tested. Amongst others, because the search algorithm as foreseen in the first development phase was not available, two PAS steps and the component stakeholders & activities were added. PAS has been tested in this phase in two pilot studies that have been conducted as part of the project 'Strategic portfolio management' at the Facility Management and Real Estate (FMRE) department of the TU Delft in the period of 2012-2013. The first pilot focused on the real estate portfolio of food facilities while the second one focused on the lecture halls. The second pilot study was published in 2015.

Third phase

In this phase PAS did not change much but in the journal paper the three equivalent components of the approach were highlighted. The publication in this phase is of the first pilot study at the TU Delft about the real estate portfolio of food facilities in 2012-2013. This first pilot study was published in 2017.

Fourth phase

In the fourth phase two optimization tools have been used to complement PAS . Firstly, a search algorithm was tested in 2014 on the data of the first pilot study food facilities. Secondly, in 2016, a third pilot study has been conducted at Oracle in which the brute force has been tested as optimization tool. The latter test was published in 2017 at the ERES conference. The brute force approach is preferable to the search algorithm as it finds a global optimum instead of a local optimum, but it cannot be used when a pilot is too complex.

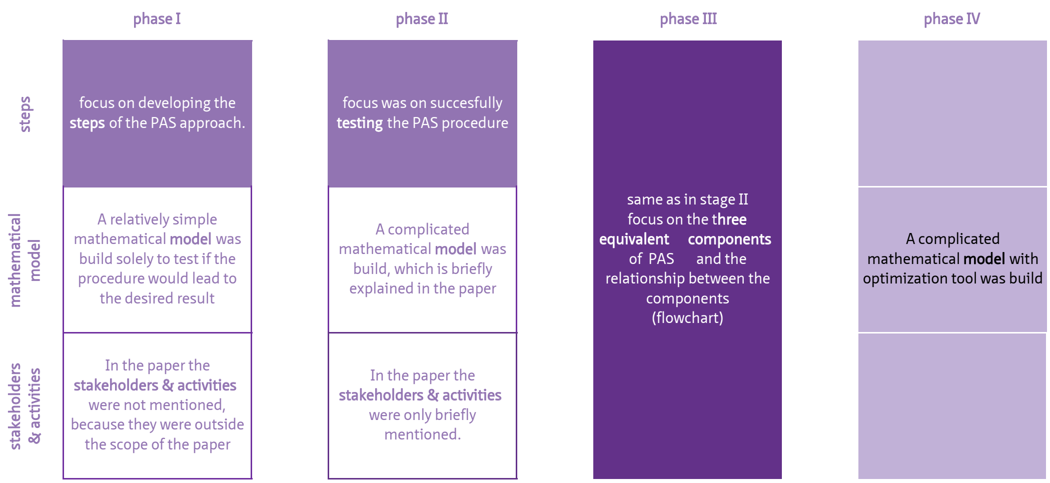

FIG. 4.3 Focus in each of the PAS development phases

Below the book and journal publications related to each phase are listed.

First phase

Arkesteijn, M. H., & Binnekamp, R. (2013). Real estate portfolio decision making. In A. V. Gheorghe, Macera, M. and Katina, P.F. (Ed.), *Infranomics: Sustainability, Engineering Design and Governance* (pp. 89-99). Dordrecht: Springer.

Second phase

Arkesteijn, M. H., Valks, B., Binnekamp, R., Barendse, P. and De Jonge, H. (2015). Designing a preference-based accommodation strategy: a pilot study at delft university of technology. *Journal of Corporate Real Estate, 17* (2), 98-121.

Third phase

Arkesteijn, M., Binnekamp, R., & De Jonge, H. (2017). Improving decision making in CRE alignment, by using a preference-based accommodation strategy design approach. *Journal of Corporate Real Estate*, 19(4), 239-264.

Fourth phase

De Visser, H., Arkesteijn, M., Binnekamp, R., & De Graaf, R. (2017). *Improving CRE decision making at Oracle: Implementing the PAS procedure with a brute force approach.* Paper presented at the European Real Estate Society (ERES), Delft.

The link between the phases, the components, pilot studies and papers is visualized in Figure 4.4.

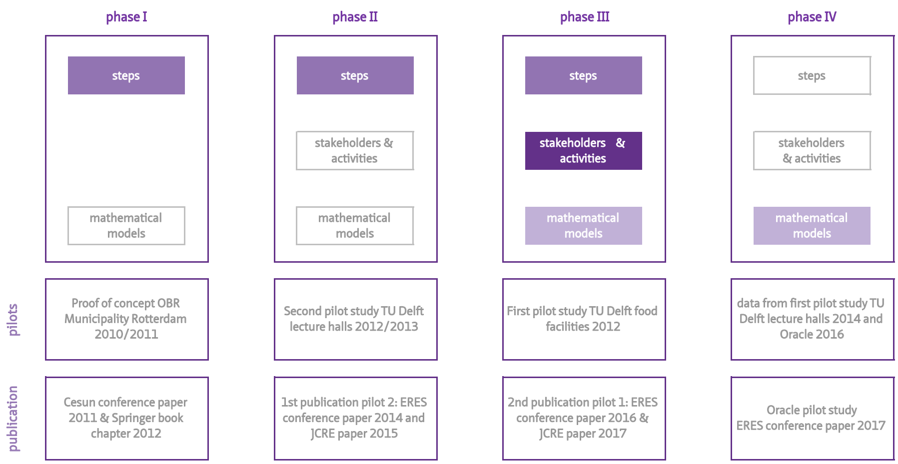

FIG. 4.4 PAS development phases, pilots and publications

4.3 PAS steps

In this paragraph the steps of PAS are presented (see **Figure 4.5**). The steps of PAS have been developed in multiple phases during the research project and in order to show this development process as well as the end result the first and the final version of PAS steps are presented.

1 The first version of the steps will be presented in paragraph 4.3.1. First, the necessity to further develop the Preference-Based Design procedure as developed by Binnekamp (2010) will be discussed and secondly the changes that have been made in the steps;
2 The final version is presented in paragraph 4.3.2. In this version all other changes that have been made during the development of PAS steps are addressed. First, the necessity to further develop the first version will be discussed and secondly the changes that have been made in the steps.

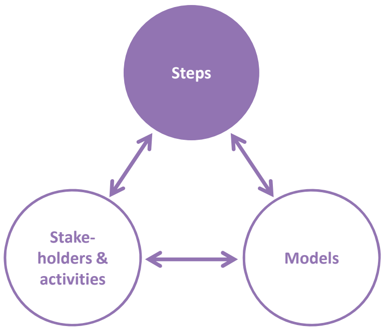

FIG. 4.5 Steps as component of PAS Note adapted from Arkesteijn et al., 2017, p. 245

4.3.1 First version of PAS steps

The first version of PAS steps[33] was developed in 2011 to enable the use of the PBD procedure on portfolio level and thereby being explicitly able to measure the added value of a new real estate portfolio in CRE alignment. These steps, or the

33 At that time I referred to the steps as the procedure, both terms can be used interchangeably in this paragraph.

new procedure as it was referred to at that time, were called the Preference Based Portfolio Decision system (PBPD), which was later referred to as PAS procedure. The new procedure was tested as a proof of concept with data from a preliminary pilot study. The development of the PBPD proof of concept was published and in this paragraph the relevant section 'Preference Based Portfolio design' (Arkesteijn & Binnekamp, 2013, pp. 94-97) of the paper is reproduced.

In this part the first stage 'formulating the problem' of the operations research project as discussed in paragraph 4.1 for the steps is addressed.

Necessity to develop PAS procedure

"It is necessary to convert the PBD procedure in two ways in order to be able to use it on portfolio level. Firstly it is important to note that in the PBD procedure [(Binnekamp, 2010, p. 121)] each combination of decision variable values defines no more than one alternative. However, with respect to the problem of real estate portfolio decision making, one combination of decision variable values could define more than one alternative. For instance, consider a portfolio consisting of 3 buildings; building A, B and C. Assume that we are interested in the percentage of buildings that serve societal goals. Also assume that building A is the only building within the portfolio serving societal goals. This means that removing building B or C would both result in a portfolio having 50 % of buildings serving societal goals. Conversely, setting this decision variable to 50 would define two alternatives (portfolio with building A and B and the portfolio with buildings A and C), not just one. To resolve this problem all possible portfolios need to be generated using the number of buildings in the current portfolio and the number of allowed interventions. Given i interventions and j buildings a total of i to the power of j combinations are possible. In this experiment the portfolio consists of 15 buildings and 3 interventions (remove, keep, renovate) are considered. A building can be removed from the portfolio for instance if it is demolished or sold. The total number of possible portfolios is the number of interventions to the power of the number of buildings ($3^{15} = 14,348,907$).

Secondly, approaching the generation of portfolios this way means that the performance of each portfolio is determined a posteriori. Going back to the previous example, removing building B is an example of a generated portfolio. Only after this portfolio has been generated it is possible to determine the number of buildings that serve societal goals with respect to the total number of buildings within that particular portfolio consisting of buildings A and C. However, within the original PBD procedure, the Bezier curve was divided in segments yielding a number of points on each curve. The x-coordinates of these points represented the performance of the alternative with respect to that design variable a priori.

As a result, it is no longer useful to divide the curve in segments to generate a set of points. Instead, the preference rating needs to be a function of the design variable value. This means that it is not possible to use a Bezier curve because this is a parametric equation. Instead, the decision maker needs to define 3 points relating decision variable values to preference ratings. The Lagrange curve defined by these points can then be found by means of curve fitting." Arkesteijn and Binnekamp (2013, pp. 94-95).

In the next part, Ackoff's second stage 'constructing the model' of the operations research project as discussed in paragraph 4.1 for the steps is addressed.

"The above changes mean that steps 2 and 5 of the original PBD procedure (see paragraph 3.1.13) have been changed as follows:

1. Specify the decision variable(s) the decision maker is interested in;
2. Rate the decision maker's preferences for each decision variable by fitting a curve through three decision variable value / preference rating coordinates as follows:
    a. Establish (synthetic) reference alternatives which define 2 points of the curve:
        - Define a 'bottom' reference alternative, 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, (x_0, y_0);
        - Define a 'top' reference alternative, 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, (x_1, y_1);
    b. Rate the preference for an alternative associated with an intermediate decision variable value relative to the reference alternatives. This defines the third point of the curve (x_2, y_2);
3. To each decision variable assign decision maker's weight;
4. Determine the design constraints;
5. Generate all design alternatives (using the number of buildings and allowed interventions). Then use the design constraints to test their feasibility;
6. Use the PFM algorithm to yield an overall preference score of all feasible alternatives." Arkesteijn and Binnekamp (2013, p. 95)

The preference curves can take different forms; some examples are given in **Figure 4.6**. The 'curve' can take the form of a straight line, a concave or convex form or a parabola.

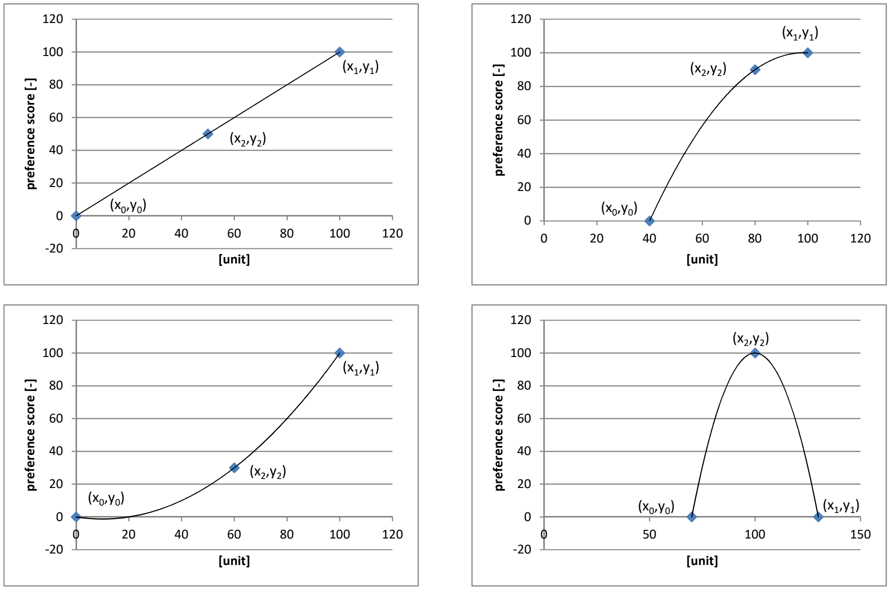

FIG. 4.6 Examples of preference curves

Proof of concept PAS steps

In the next part the third stage 'deriving a solution' of the operations research project as discussed in paragraph 4.1 for the steps is addressed. "In order to evaluate this new PAS procedure a case simulation is generated based on the prototype Public Real Estate system for the municipality of Rotterdam.

Step 1: Specifying the decision variable(s)

The following six decision variables for the specified stakeholders within this municipality are used. (1) Policymaker: the percentage of buildings within the (new) portfolio serving societal goals. (2) Policymaker: the percentage of buildings within the (new) portfolio having an overall preference rating of 40 or more on the criterion 'user satisfaction'[34]. (3) Technical manager: the percentage of buildings within the (new) portfolio having an overall preference rating of 40 or more on the criterion 'technical state'. (4) Asset manager The percentage of buildings within the (new)

34 Note that within this procedure preference is rated at an object and portfolio level. For example, 'user satisfaction' is rated on object level. The percentage of buildings within the (new) portfolio having an overall preference rating of 40 or more on the criterion 'user satisfaction' is rated on a portfolio level.

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portfolio for which the rent covers the cost. (5) Users: The gross floor area of the (new) portfolio and (6) Policymakers: The additional yearly rent due to renovation.

Step 2: the decision maker's preferences for each decision variable

Table 4.4 shows for each decision variable value the 3 points that relate decision variable values to preference ratings. These 3 points define a Lagrange curve (Figure 4.7). [Note this an be related to object level or to portoflio level].

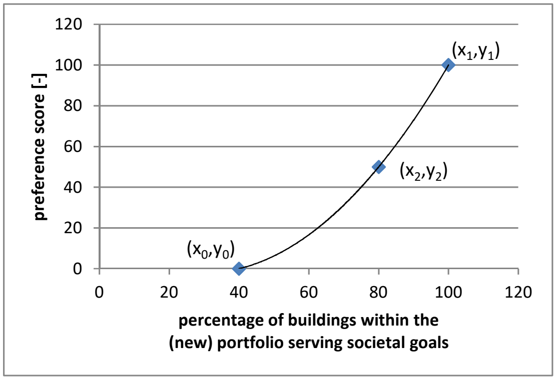

FIG. 4.7 Lagrange curve relating preference rating to percentage of buildings within the portfolio serving societal goals Note adapted from Arkesteijn & Binnekamp, 2013, p. 96

TABLE 4.4 Decision variables and associated decision maker's preference ratings Note adapted from Arkesteijn & Binnekamp, 2013, p. 96

Decision variables		Bottom reference (x_0,y_0)	Top reference (x_1,y_1)	Intermediate reference (x_2,y_2)
1	Percentage of buildings serving societal goals	100,100	40,0	80,50
2	Percentage of buildings scoring ≥40 on user satisfaction	100,100	0,0	50,70
3	Percentage of buildings scoring ≥40 on technical state	100,100	20,0	50,60
4	Percentage of buildings for which rent covers costs	100,100	0,0	50,60
5	Gross floor area	1628,0	1794,0	1709,100
6	Additional yearly rent due to renovation interventions	60k,0	0,100	30k,40

Step 3: Assigning decision maker's weight to each decision variable

Table 4.5 shows for each decision variable value the weight assigned by the associated decision maker.

TABLE 4.5 Decision variables and assigned decision maker's weights Note from Arkesteijn & Binnekamp, 2013, p. 97

Decision variables		weights
1	Percentage of buildings serving societal goals	10
2	Percentage of buildings scoring ≥40 on user satisfaction	10
3	Percentage of buildings scoring ≥40 on technical state	10
4	Percentage of buildings for which rent covers costs	10
5	Gross floor area	40
6	Additional yearly rent due to renovation interventions	20

Step 4: Determining the design constraints

For this experiment no design constraints are used.

Step 5: Generating all design alternatives

In this experiment the portfolio consists of 15 buildings and 3 interventions (remove, keep, and renovate). Of each building information relating to each decision variable is known. No design constraints are used, this means all design alternatives are considered feasible." Arkesteijn and Binnekamp (2013, pp. 95-97).

Step 6: Using the PFM algorithm to yield an overall preference scale

Table 4.6 shows the current portfolio and the portfolio '9388514' which has the highest preference ratings. In the first row all fifteen buildings of the portfolio are shown. The current portfolio is shown at the bottom. As can be seen each of the buildings has an intervention 1 which means the building will stay in the portfolio but no changes will be made. The overall preference rating of the current portfolio (keep all buildings) is 17.7. In portfolio '9388514' building 14 will be removed from the portfolio (intervention 0). Four buildings (numbers 1, 4, 10 and 12) will stay the same (intervention 1) the remaining buildings (numbers 2, 3, 5, 6, 7, 8, 9, 11, 13 and 15) will be renovated (intervention 2). In this case the highest rated portfolio '9388514' has an overall preference rating of 75,6 and thereby shows a possible overall performance improvement of 57.9.

TABLE 4.6 Current portfolio and portfolio with highest overall preference score (Legend interventions 0=remove, 1=keep, 2=renovate) Note adapted from Arkesteijn & Binnekamp, 2013, p. 97

Portfolio	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Rating
9388514	1	2	2	1	2	2	2	2	2	1	2	1	2	0	2	75.6
Current	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	17.7

In the next part, the fourth stage 'Testing the model and evaluating the solution' of the operations research project as discussed in paragraph 4.1 for the steps is addressed.

"The proposed PBPD procedure can be used at portfolio level because the two before mentioned limitations are removed. However, the use of the Lagrange curves which oscillate between their roots (knots) could create a problem a problem because they can take negative preference values. This problem is dealt with by directly visually feeding back the Lagrange curve defined by the points.

In this experiment the total number of possible portfolios is the number of interventions to the power of the number of buildings (3^{15}=14,348,907). If a portfolio consist of more buildings and more interventions will be considered, as is usually the case, the computer time needed to generate and evaluate all possible portfolios giving rise to the need for a search algorithm.

Despite these limitations, we see the proposed PBPD procedure and associated model as a proof of concept for applying it in practice" Arkesteijn and Binnekamp (2013, pp. 97-98).

4.3.2 Final version of PAS steps

During the development and the use of PAS most steps have been changed, either profoundly or only textually. In this subparagraph the final version of the steps are presented. Note this is after the use and evaluation of PAS , which will be presented in part II of this thesis.

In the development of steps (first version) it was foreseen that if a portfolio consist of more buildings and more interventions it would not be possible to generate all possible CRE portfolios in step 5 of the procedure. The solution for this problem was to devise a search algorithm. This search algorithm however, was not available at the time of the first two pilot studies.

Furthermore, in chapter 2, I concluded that the model needed to fulfill certain requirements. The stakeholders needed to be able to formulate well defined criteria and iteratively make/create/design alternative CRE portfolios. In the DAS frame, as presented in chapter 2, the iterative nature of the model is one of its key characteristics which needs to be incorporated in PAS procedure. Since in CREM it is common to have conflicting interest between the stakeholders, the stakeholders define their demand and subsequently need to see the effect of their requirements on possible solutions before finalizing their requirements. This enables the stakeholders to get what they want and at the same time understand what they want. It is assumed that this iteration between demand (requirements) and supply (CRE portfolio) would on enhance the acceptance of the results by the stakeholders. The stakeholders, as explained in chapter 3, are seen as decision makers on the one hand and designers on the other hand. This means that in step 5 of PAS the stakeholders needed to be able to design alterative portfolios next to the computer generated alternatives with an optimization tool.

During the use of PAS most of the steps were slightly adjusted and step 3 was changed. All steps were adjusted textually to formulate the steps from the perspective of the decision maker. Step 3 was adjusted to explicitly make it possible that multiple decision makers are able to use the procedure. The first version of PAS procedure was formulated for one decision maker while more decision makers were implicitly already foreseen. Although not formulated in the procedure, multiple stakeholders were part of the proof of concept as reported in the former paragraph (Arkesteijn and Binnekamp, 2013, p. 98). This has one other implication for the procedure as well. The weights between the decision variables of a certain decision maker are determined in step 3. However, the weights between decision makers were only implicitly part of the procedure (Arkesteijn and Binnekamp, 2013, p. 96). The implication therefore is to add to step 3 that the subject owner assigns the weights between the decision makers.

The final version[35] of the steps of PAS is:

1. Each decision maker specifies the decision variable(s) they are interested in;

2. Each decision maker rates their preferences for each decision variable by fitting a curve through three decision variable value / preference score coordinates as follows:
   a. The decision maker establishes (synthetic) reference alternatives which define 2 points on 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, (x_0, y_0);
      - 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, (x_1, y_1);
   b. The decision maker rates the preference for an alternative associated with an intermediate decision variable value relative to the 'bottom' and 'top' reference alternatives. This defines the third point of the curve (x_2, y_2);

3. Each decision maker assigns weights to their decision variables. The subject owner assigns weights to each decision maker;

4. Each decision maker determines the design constraint(s) their interested in;

5. Design alternatives are generated in parallel by:
   a. The decision makers who group wise design alternatives and use the design constraints to test the feasibility of the design alternatives and use the PFM algorithm to yield an overall preference score of these feasible design alternatives.
   b. The system engineer generates feasible design alternatives and uses the PFM algorithm to find the feasible design alternative with the highest overall preference score;

6. The decision makers select the design alternative with the highest overall preference score either generated by the decision makers or the system engineer.

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35 This final version of the steps differs from the steps that has been published in Arkesteijn et al., 2014, Arkesteijn et al., 2017. In this version the singular they is used for gender neutrality as explained in the introduction.

In order to develop the PAS steps, the stages of Ackoff and Sasieni (1968, p. 11) have been used several times. The major changes between the first and final version have been summarized in **Table 4.7**.

TABLE 4.7 Stages used in developing PAS steps

Stages	First version	Final version
1st Formulating the problem	The Preference-Based design procedure of Binnekamp cannot be used on portfolio level	The steps in the 1st version assumed that all possible portfolios could be generated. As a solution a search algorithm was foreseen, this algorithm was not available at the time of testing the procedure. The steps did not enable stakeholders to design alternative. portfolios themselves. The steps also did not allow the responsible management to assign weights between the decision makers (stakeholders).
2nd Constructing the model	Steps 2 and 5 of the procedure have been altered	Step 3 and 5 of the procedure have been altered. And textual changes have been made to all steps to formulate them from the decision makers perspective.
3rd Deriving a solution	A proof of concept has been made and a solution could be found	this version of the steps is tested in three pilots (see chapter 5 to 8)
4th Testing the model and evaluating the solution	The solution works; two problems can be foreseen in the future (Lagrange curves ad amount of alternative solutions)	

4.4 Stakeholders and activities in PAS

The second component of PAS is stakeholders & activities (see **Figure 4.8**).

In paragraph 4.4.1, firstly all relevant stakeholders in PAS are described and in paragraph 4.4.2 the activities that the stakeholders need to perform to be able to iteratively perform the steps that have been given.

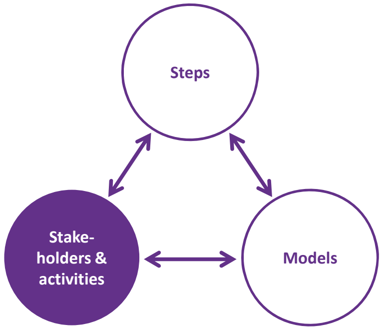

FIG. 4.8 Stakeholders & activities as component of PAS
Note adapted from Arkesteijn et al., 2017, p. 245

4.4.1 Relevant stakeholders for PAS

In this paragraph it will be shown that PAS is seen as an inter-actor approach and that three groups play a principal role in PAS . These are the responsible management, the stakeholders, and the systems engineer. After their introduction, the group stakeholders is further elaborated upon.

PAS is an inter-actor approach

PAS is an inter-actor approach as explained in chapter 3. The approach is referred to as inter-actor approach because it is possible to include actors outside of the own organization as well. However, the primary actors come from the same corporation (also referred to as organization). Therefore, it is very likely that there is a hierarchic relation between actors. This relationship normally would be referred to as multi-actor instead of inter-actor. Because in PAS the actors are not limited to the own organization, the approach is called an inter-actor instead of a multi-actor approach.

Three groups involved are involved in PAS

In PAS three main types of groups are involved; responsible management, stakeholders, and the systems engineer. In publications of the PAS, these groups have been referred to in different ways. At the same time, in different scientific domains these groups have different names. In business management, De Leeuw (2002, p. 281) distinguishes (1) the stakeholders, (2) the responsible management and (3) the managerial problem solver in his role as professional researcher and/or advisor. He visualizes this as a triangle around reality and states that managerial problem solving takes part in this arena. In design engineering, Dym and Little

(2004, p. 2) refer to the designer-client-user triangle, indicating the three parties involved in a design effort. 'The client, who has the objective that the designer must clarify; the user of the designed device, who has his own requirements; and the designer, who must develop specifications such that something can be built to satisfy everybody'. In **Table 4.8** the different names for these groups are shown with the preferred terminology in the first column.

In this thesis, each of the groups involved plays a different role. The responsible manager in the organization, sometimes in conjunction with the responsible real estate manager, selects the different types stakeholders who will be involved in the project. These are called relevant stakeholders. During a project the selected relevant stakeholders also have the opportunity to add other stakeholders to the project. It should be noted here that the responsible manager and real estate manager next to their role as responsible management also can be relevant stakeholder. The facilitator leads and facilitates the process while the system engineer builds the mathematical models. Sometimes one person fulfills both roles.

TABLE 4.8 Terminology of relevant groups

Preferred terminology	PAS (published papers)	Management (De Leeuw)	Design engineering (Dym and Little)
Responsible management	Subject owner	Responsible management	Client
Decision makers or stakeholders	Different terms are used: mostly decision makers and/or stakeholders but also sometimes users, participants,	Stakeholders	User
Facilitator & system engineer	System engineer	Managerial problem solver, advisor, researcher	Designer

Selecting relevant stakeholders

When selecting relevant stakeholders for the project, it is important, according to Den Heijer, to involve representatives of four stakeholder perspectives (see **Figure 4.9**) in the decision making process, so as to incorporate all relevant information and add value in the broadest sense (Den Heijer, 2011, p. 108). In the pilot studies this model has been used as reference to select relevant stakeholders. As can be seen, each perspective has his own icon and color. In the remainder of this thesis, when in tables or figures the stakeholders are mentioned, these colors and icons are used so that they can be easily visually recognized.

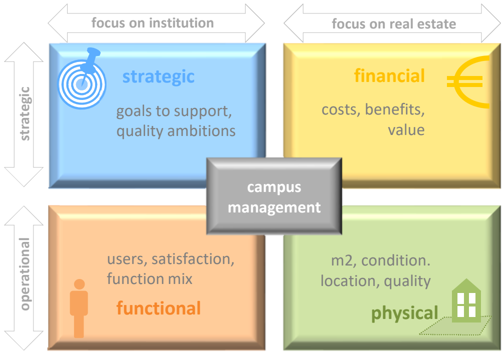

FIG. 4.9 CREM model Note from Den Heijer, 2011, p. 106

In this thesis stakeholders are viewed as the decision makers. As explained in paragraph 3.2, preference measurement, preferences always belong to a specific stakeholder. This means that in PAS each decision maker is responsible for their own criteria (step 1), preferences (step 2), weights (step 3) and design constraints (step 4). In step 6 the alternative with highest overall preference is the preferred alternative, i.e. chosen alternative. This means that the stakeholders and their preferences logically determine the chosen solution. Therefore we refer to them as the decision makers.

Viewing stakeholders as decision makers is different from most CRE alignment approaches, were it not exactly clear who does what, when and how. In these approaches the focus in on what needs to be done i.e. steps. This is also different from other types of problem solving approaches, were often consensus is sought in the program of requirements (defining the criteria) before designing solutions. In PAS , each stakeholder remains responsible for his requirements (step 1 to 4) and consensus is sought in the solution, i.e. the alternative CRE portfolio (step 5 and 6).

Note: When referring to user(s) in the published paper the word user has been used it in two different ways. On the one hand it referred to the user as indicated in the abovementioned CREM model and on the other hand to 'users' of this particular design approach and of course more specific, of the mathematical model. In hindsight for the latter meaning another term would have been more appropriate. Next to this in CRE management the word 'user' also causes confusion, because in this field the word both 'users' and 'end users' are commonly used. User mostly refers to the actual users of the space. However, sometimes the actual user of the space is referred to as end user. Mostly when people us the term end user, they refer to the whole end user organization, as does Den Heijer. However, as mentioned there are also authors that use the terms oppositely.

4.4.2 PAS activities[36]

In order to perform the steps of PAS in an iterative way the stakeholders needed to perform several activities. The activities consisted of interviews and workshops. The interviews were used to set the requirements which is done in steps 1 to 4 of PAS procedure and the workshops were used to design alternative CRE portfolios which is done in step 5 while the selection of the best alternative is done in step 6.

Interviews

1. Specifying decision variable(s);
2. Determining the decision maker's preference to each variable;
3. Assigning the decision maker's relative weight to each variable;
4. Determining the design constraints;

Workshops

1. Generating design alternatives;
2. Selecting the best alternative.

There is a feedback loop present from step 5 to step 1 to 4, i.e. to be able to perform the steps in an iterative way, so that, if the stakeholders do not accept the best design alternative, the model could be adjusted in accordance with the results in the intermediate steps. In order to facilitate this iteration, the interviews and workshops are completed a number of times in a sequence. This sequence can be performed more times if necessary. This process will be as follows:

- Interview 1;
- Workshop 1;
- Interview 2;
- Workshop 2;
- Interview 3.

The cyclical process of interviews and workshops allows the facilitator and system engineer to continuously adapt and improve the computer model, thereby providing a better reflection of the stakeholders' preferences. A better reflection equals a

36 The stakeholder selection and the activities have been developed for the first pilot food facilities at the TU Delft by the author. However, the activities have first been reported in the graduation thesis Valks (2013) with reference to the first pilot. Therefore, this text is almost similar to that in the graduation with small adjustments, based on the further development of PAS and the terminology that has been used.

better representation of reality. It also gives stakeholders the opportunity to adapt their decision variables and design new alternatives based on the insights that they gain during the process. In each PAS project two three hour workshops were scheduled and three one hour interviews per stakeholder.

Each interview and workshop will be discussed.

Interview 1

At the start of the first interview, the interviewee is introduced to PAS , the specific purpose of the project is and what is required of the stakeholder during the process. The objective of the interview is perform step 1 to 4 and determine his/her input for the mathematical model.

The stakeholders are asked to define the relevant criteria for them. They do this by first looking at the current problems in the CRE portfolio, secondly by indicating the objectives that they strive for with this particular real estate type and subsequently translating them into criteria. It is explicitly stated that they are free to determine whichever decision variables they wish to incorporate, and they are allowed to modify their decision variables, preferences and weights later in the process. The objective is completed if the required information for step 1 to 4 is collected. In **Table 4.9** the interview questions of the first interview are displayed. Each stakeholder receives a log of their input before the first workshop in which their answers are recorded.

TABLE 4.9 Questions in interview 1

Steps		Interview questions	
1	Specifying decision variable(s)	1.1	What are the current problems with [add the specific CRE portfolio]?
		1.2	What are the objectives that you wishes to achieve ?
		1,3	What decision variables reflect that objective?
2	Rating preferences	2.1	Assign a preference score of 100 to your most desired outcome
		2.2	Assign a preference score of 0 to your least desired outcome
		2.3	Assign a preference score between 0 and 100 to an intermediate outcome
3	Assigning weights	3.1	What are the relative weights between your decision variables?
4	Determining design constraints	4.1	What design constraints must be met?

Workshop 1

At the start of the first workshop, the facilitator repeats the specific purpose of the project, introduces the diary for the workshop and all stakeholders are introduced to each other. The facilitator shows the model to the stakeholders to give them a basic understanding of the model. The two main objectives of the first workshop are that the stakeholders (1) become familiar with the depiction of the problem in the computer model and (2) are able to use the computer model to design alternatives in order to gain insights in their own input as given in the first interview. It should be noted, that most stakeholders probably are not used to translating there objectives into concrete criteria on the one hand and never have been asked to define their own 'measuring scale' by rating their preferences according to step 2. In general, the stakeholders are divided in smaller subgroups and asked to perform a number of assignments.

Interview 2

Based on their experiences in workshop 1, in this round of interviews each stakeholder is allowed to adjust their variables, preferences, and weights and add new decision variables. The following interview questions are asked (see **Table 4.10**).

TABLE 4.10 Questions in interview 2

Steps		Interview questions/tasks	
1	Specifying decision variable(s)	1.1	Adjust and/or specify (additional) decision variable(s)
2	Rating preferences	2.1	Adjust and/or rate preferences (see 2.1 to 2.3 interview 1)
3	Assigning weights	3.1	Adjust and/or assign weights
4	Determining design constraints	4.1	Adjust and/or determine design constraints
Steps		**Interview questions/tasks**	
1	Specifying decision variable(s)	1.1	Adjust and/or specify (additional) decision variable(s)
2	Rating preferences	2.1	Adjust and/or rate preferences (see 2.1 to 2.3 interview 1)
3	Assigning weights	3.1	Adjust and/or assign weights
4	Determining design constraints	4.1	Adjust and/or determine design constraints

Workshop 2

In this workshop the decision makers continue designing alternatives to reach an optimal result together as a group (see **Table 4.11**). The decision makers have an adjusted mathematical model available based on the adjusted input in the second round of interviews with each of the stakeholders. The difference compared to the first workshop is that in this workshop, the stakeholders are already acquainted with the PAS model. In this workshop the stakeholders work together rather than individually. The focus shifts from understanding the model and adjusting the input towards designing alternatives and accepting the results as generated by the model.

TABLE 4.11 Assignments in workshop 2

Steps		Assignment	
5	Generating design alternatives	5.1	Design an alternative CRE portfolio with a higher overall preference score than the current portfolio taking into account the demands of all stakeholders
6	Selecting best design alternative	6.1	Select the alternative CRE portfolio with the highest overall preference score

In workshop 2 the sequence of assignments is the following :

- The stakeholders are split up into two groups. Both groups focus on designing an alternative reaching the highest preference score;
- The groups come together and discuss their findings, after which a combination is sought between the two alternatives in order to reach the alternative with the highest preference score.

Interview 3

In the third series of interviews, the decision makers are individually asked to confirm the selection of the best design alternative from the previous workshop. If all stakeholders individually accept this alternative the project is ended. However, if one or more stakeholders do not accept that alternative (with the highest overall preference score) as the best alternative this means that the empirical system has not been mapped correctly. If it would have been mapped correctly, all stakeholders would accept the outcome. Logically it follows that one of the stakeholders then needs to change the input in such a way that it better reflects their preferences. In that case, the exact same procedure is carried out as in the second series of interviews and the second workshop. If necessary, the cycle can be extended by repeating the interviews and workshop until a satisfactory result is reached, i.e. until all stakeholders confirm the alternative with the highest overall preference.

4.5 PAS generic mathematical models

In this paragraph PAS models are presented (see **Figure 4.10**).

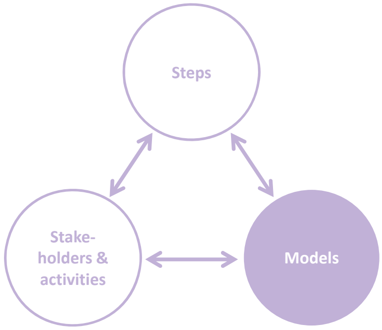

FIG. 4.10 Models as component of PAS Note adapted from Arkesteijn et al., 2017, p. 245

The objective of the mathematical model is to calculate the overall preference rating, i.e. *value* of an alternative real estate portfolio (future supply). In order to also determine the added value of this alternative real estate portfolio it is also necessary to calculate the overall preference rating of the current real estate portfolio. In this dissertation the added value of a real estate portfolio is defined as the difference between the overall preference score of the alternative real estate portfolio and the current real estate portfolio.

In paragraph 4.5.1 the principal formulas that are needed to calculate the overall preference score of any alternative are given. Secondly, in paragraph 4.5.2 the generic structure of the model is visualized. In paragraph 4.3 it was explained that alternative CRE portfolios can be generated in different ways. They can be designed by the stakeholders on the one hand and they can be computer-generated by an optimization tool. In paragraph 4.5.3 two different optimization tools are discussed.

4.5.1 Principal formulas of the mathematical model

The mathematical model starts with the input of an (any) alternative and therefore is independent of the way an alternative is generated.

The overall preference score is calculated using three generic formulas;

1. To convert the decision variable value into a preference score per decision variable;
2. To calculate the overall preference score per stakeholder;
3. To calculate the overall preference score for the alternative is calculated by aggregating all stakeholders' preference scores.

An alternative and decision variable value per decision variable as input

An alternative is in described as follows:

The state vector is an alternative in the form $(x_1,\dots,x_{16})$ where x_j is the state of an object j.

If the state vector is known, the decision variable value per decision variable can be obtained from the dataset. The decision variables will be specific for each pilot.

Preference score per decision variable per stakeholder

The decision makers define three points that relate decision variable values to preference ratings. A Lagrange curve[37] is then fitted through these three points (n=3). Because this curve is continuous this means that for any value of a decision variable value the preference rating can be found on the curve. Binnekamp (2010, pp. 101-102):

The Lagrange curve is a polynomial P(x) of degree ≤ (n = 1) that passes through *n* points $[x_1, y_1 = f(x_1)], [x_2, y_2 = f(x_2)], [x_n, y_n = f(x_n)]$

Lagrange formula, returning a value between 0 and 100 .

$$P(x) = Min\left(100, Max\left(0, \left(\frac{(x-x_1)(x-x_2)}{(x_0-x_1)(x_0-x_2)}\right)*y_0 + \left(\frac{(x-x_0)(x-x_2)}{(x_1-x_0)(x_1-x_2)}\right)*y_1 + \left(\frac{(x-x_0)(x-x_1)}{(x_2-x_0)(x_2-x_1)}\right)*y_2\right)\right)$$

37 It is possible that a stakeholder determines the points such that the line is straight.

The function *Min(a, b)* returns the minimum value of the value *a* and *b*.

The function *Max(a, b)* returns the maximum value of the value *a* and *b*.

It is possible that different stakeholders have defined the exact same decision variable and unit, but have determined different points. This means that although the decision variable value is the same, the preference score is different.

Overall preference score per stakeholder

Overall preference score for stakeholder *k* for alternative *i*:

$$O_{ik} = \sum_{j=1}^{n} w_{jk} \cdot P_{ij}$$

Where:

n number of criteria;
i index of alternative *i*;
j index of criterion *j*;
k index of stakeholder *k*;
w_{jk} weight of criterion *j* by stakeholder *k*.
O_{ik} overall preference score of alternative *i* by stakeholder *k*.
P_{ji} preference of alternative *i* for criterion *j*.

Overall preference score

Overall preference of all stakeholders *k* for alternative *i*:

$$T_i = \sum_{k=1}^{p} s_k \cdot \sum_{j=1}^{n} w_{jk} \cdot P_{ij}$$

$$T_i = \sum_{k=1}^{p} s_k \cdot O_{ik}$$

Where:

p number of stakeholders;
s_k weight of stakeholder *k*;
T_i overall preference score of alternative *i* by all stakeholders.

4.5.2 Basic structure of the mathematical model

The basic structure of the mathematical model is visualized in Figure 4.11.

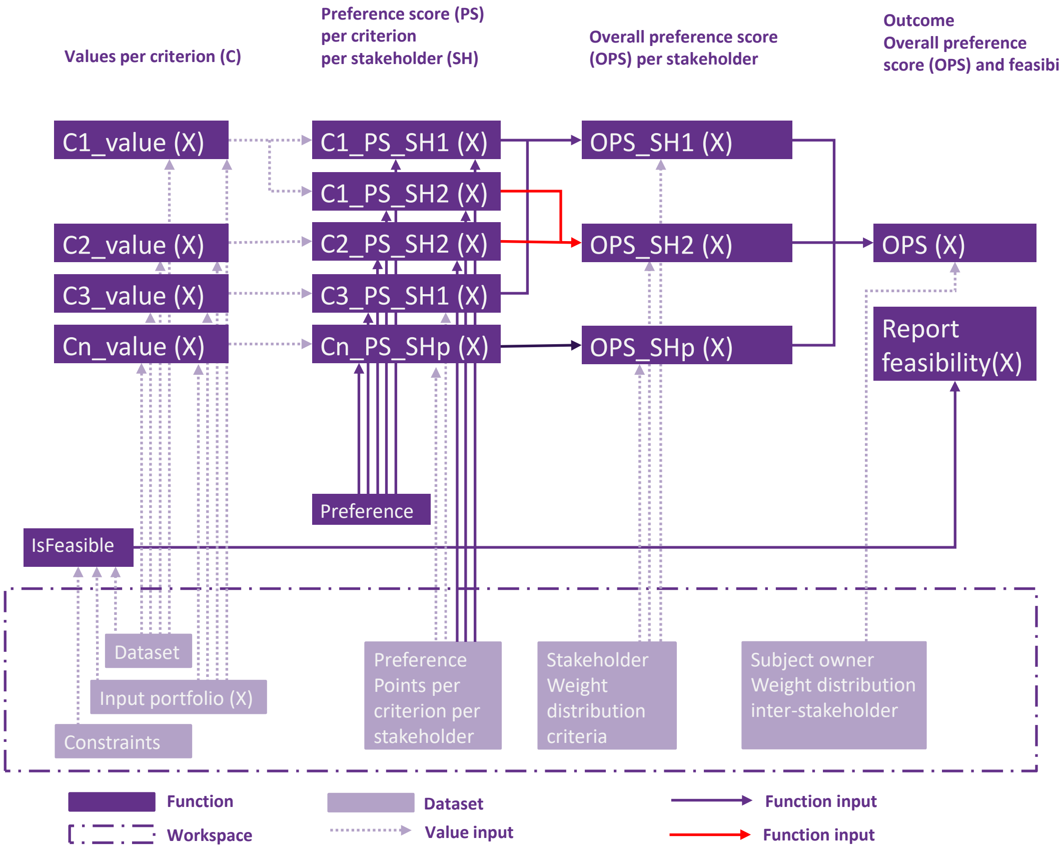

FIG. 4.11 Visualization generic mathematical PAS model Note based on de Visser 2016, p. 70

4.5.3 Two techniques to generate the optimal alternative

In the fourth stage of the development of PAS , as explained in paragraph 4.2, two optimization tools have been used. This is done to be able to select the optimal alternative, i.e. the alternative with the highest overall preference score. In the previous paragraph it is explained that the stakeholders design alternatives and that the alternative with the highest overall preference score is chosen. However, although this is the best alternative that can be designed, and thus is satisficing, it is not sure if another alternative exists with a higher overall preference score.

In paragraph 4.3.1, all alternatives were generated in the proof of concept. In more complicated real life pilots it is likely that the number of alternatives will be so large that generating and evaluating these will consume too much computer time . In this research two optimization tools will be tested. Firstly, a search algorithm will be tested and secondly, a brute force approach. Both will be explained in general in this paragraph.

Search algorithm

A search optimum finds a *local optimum*. A *local optimum* is a solution that is better than any other feasible solutions in its immediate, or local, vicinity (Ragsdale, 2008, p. 342), However, a given local optimal solution may not be the best possible solution, or *global optimum,* to a problem (see **Figure 4.12**). A search algorithm can be used in situations with a large number of alternatives.

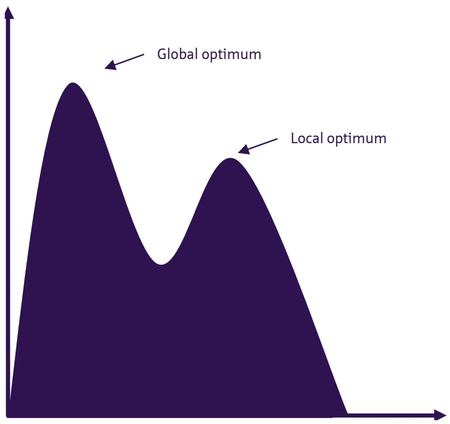

FIG. 4.12 Visualization global and local optimum

Brute force

If a pilot is not too complex, it is possible to generate all alternatives with a brute force approach. In computer science, brute-force search or exhaustive search, also known as generate and test, is a very general problem-solving technique and algorithmic paradigm that consists of systematically enumerating all possible candidates for the solution and checking whether each candidate satisfies the problem's statement (Wikipedia, n.d.). A brute-force search is used when the problem size is limited. if a problem is complex (see paragraph 3.1.12) and cannot be used if the combinatorics cause an explosion of alternatives. After all alternatives have been generated they are ordered on overall preference score, similar as has been done in the example in paragraph 4.3.1. This means that the global optimum can be determined.

4.6 Conclusion and coherence between three PAS components

PAS is developed using the fifteen basic concepts and definitions from chapter 3. All three rationalities are used to open the black-box of decision making and structure PAS to achieve CRE alignment. The three PAS components are the steps (procedural rationality), the stakeholders & activities (structural rationality) and the mathematical model (substantive rationality). For PAS to be operational all components need to be connected coherently. The coherence between the components is shown in the flowchart (see **Figure 4.13**).

The three components in the flowchart each have their shade of purple (as in **Figure 4.13**). The stakeholders & activities are displayed in the first four columns (dark purple), the steps are given in the intermediate columns (purple while the model building is presented in the last column (light purple).

Following the flowchart, it is explained which activity is performed by whom and which steps are done in that particular activity. Following the arrows in the flowchart it shows how the information of one step is input for the next step. The flowchart stops in the last interview if each stakeholder individually accepts the alternative with the highest overall preference score as the selected alternative. If one of the stakeholders does not accept this alternative this means that (part of) their input does not reflect their preferences correctly and needs to be adapted accordingly. The adapted input is goes back to model building (n) and the continues in the flowchart represented until all stakeholders accept the best alternative.

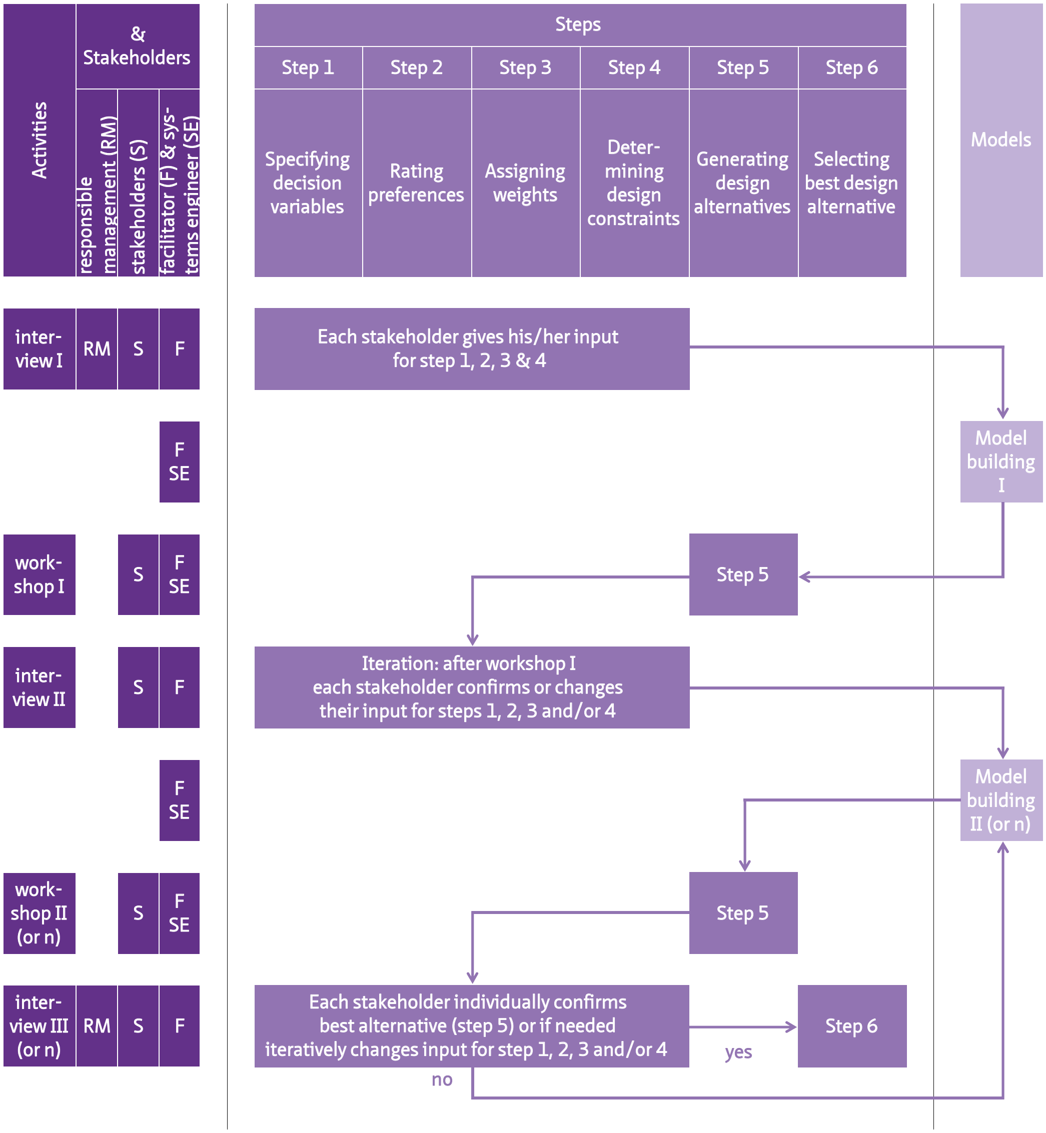

FIG. 4.13 PAS Flowchart Note adapted from Arkesteijn et al., 2017, p. 248

Reflection to the requirements (chapter 2)

The developed PAS approach fulfills all requirements as presented in chapter 2 that are logically needed to enables CRE managers to measure the added value in their CRE alignment process. For each of the characteristics/requirements this is done as follows.

Formulating demand

The PAS approach is *integral* because all relevant stakeholders can be involved and are able to specify all types of requirements (qualitative and quantitative). The approach is *explicit* because their CRE accommodation strategy is stated in objectives and/or related problems and expressed in well-defined operational criteria. The approach is also *personal* because each criterion is established by a specific stakeholder and is linked to this stakeholder during the whole process.

Designing alternatives

The PAS approach enables the stakeholders to *design* alternative CRE portfolios (future supply) themselves in the mathematical model. The approach is *iterative* by having a feedback loop after the potentially last interview, but first of all by having an active interplay between demand (step 1 to 4 in the interviews) and supply (step 5 in the workshops) that enable the stakeholders to state what they want, but also to understand what that means when projected onto the CRE portfolio. If their demands were not correctly understood or thought through the system engineer is able to adjust the model or the stakeholders to adjust their input. The PAS approach is able to determine the CRE portfolio with the *optimal* added value because next to the design which produces an alternative real estate portfolio with the highest overall preference, an optimization tool is able to search the portfolio of feasible alternatives for another alternative with potentially a higher overall preference score.

Selecting an alternative

The PAS approach is able to *indisputable* determine the best alternative because the performance of an alternative because the individual criteria are aggregated into one overall performance rating, the overall preference score. The approach is *correct* because it ensures that if scales are used to measure so-called qualitative requirements (non-physical properties) strong scales (Barzilai, 2010) are used.