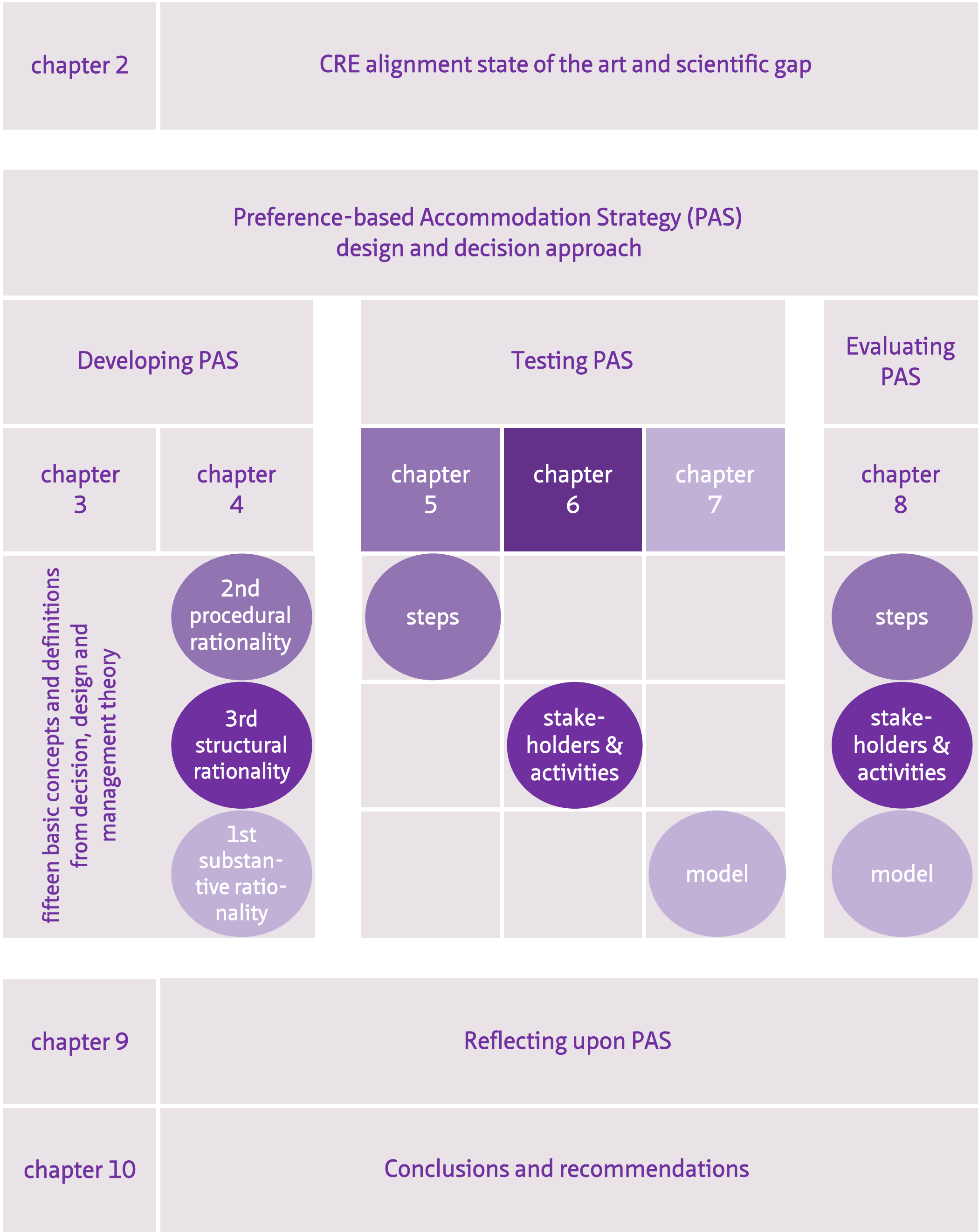
3 Basic concepts and definitions of the PAS design and decision system



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3 Basic concepts and definitions of the PAS design and decision system

In this chapter, using basic concepts and definitions from management science, decision theory and design methodology, I shall outline the methodological aspects, characteristics and features of the Preference-based Accommodation Strategy (PAS) design and decision system, which I developed for the formation of a corporate accommodation strategy.

This outline serves first and foremost as a simple way of representing and modeling the PAS design decision system. It also enables the methodological characteristics of PAS design and decision making to be set out in a way that allows analysis and evaluation of the suitability of the applications of this system in real life corporate accommodation strategy processes. Finally, it should be possible to incorporate past experience into the framework, and to generalize and summarize it in order to benefit the further development of the PAS design decision system. The PAS design decision system will be referred to as PAS.

In chapter 2 the existing alignment models were assessed on eight different assessment criteria and it has become clear that decision making receives very little attention in the models. The two main problems were that (1) it remained unclear how alternative CRE strategies are made on portfolio and building level and (2) most problems occur when selecting an alternative; none of the models has an overall performance measure that incorporates both quantitative and qualitative criteria, and uses correct measurement. Although in paragraph 2.2 all assessment criteria have been introduced, some of the concepts will be explained in this chapter. In chapter 2.3 the models have been assessed on their use of correct measurement for instance. In paragraph 3.2 it will be explained what correct measurement is and why it is important.

The chapter is structured as follows:

- Fifteen basic concepts underlying the PAS design system are explained in paragraph 3.1;
- Preference measurement as core concept is explained in more detail in paragraph 3.2;
- Preference-Based Design as other core concept is explained in more detail in paragraph 3.3;
- A comparison of the foundations in different scientific field in given in paragraph 3.4;
- The chapter ends with a conclusion and comparison in paragraph 3.5.

3.1 Basic concepts and definitions

Each of the fifteen basic concepts is presented in a subparagraph. The fifteen basic concepts and definitions are:

1. Three types of decision making rationality;
2. Goal-oriented human system;
3. Concept of the overall performance measure;
4. Definitions of problems, goals and value;
5. Multiple criteria;
6. Specification and modeling of design problems;
7. Multi actor design-decision-management system;
8. Prescriptive mathematical decision system;
9. Preference measurement;
10. Overall preference score as performance measure;
11. Problem solving system;
12. Operational representation of the design (solution) space;
13. Preference-Based Design method;
14. Design management system;
15. Human activity system.

3.1.1 Three types of decision making rationality in PAS

In order to structure the decision making process in PAS three types of rationality are used: *substantive rationality, procedural rationality and structural rationality*[15] (Kickert in De Leeuw, 2002).

The classification scheme of these types is displayed in **Table 3.1**. The first type is *substantive rationality* in which it is about the choice of an (optimal satisfactory) alternative. Here, De Leeuw states that there are different subtypes but all of them are about the choice – with or without handicaps – of an alternative. This type is characterized by the fact that there is only one decision maker, and the aspect of time (order) is mostly disregarded. In the second type, the *procedural rationality*, the focus is not on the content of the decision but on the way that the decision is made. Decision making processes are seen as steps ordered in time leading to a decision. In this type, a meta level is present, since it is about decision making. The third type is *structural rationality* – which is, like the former, a meta level. It addresses the question of what is an appropriate (the best, satisfactory) organization for decision making. The decision problem is the order in which the various participants need to be dealt with by whom in the decision making process. The decision is seen as the result of a decision making process in time in which more decision makers participate. In many decision making processes more decision-makers play a role and this is only taken into account at this level of structural rationality (Kickert, in De Leeuw, 2002, p. 249-258).

TABLE 3.1 Three types of rationality (based on Kickert, in De Leeuw, 2002)

Rationality	Focus i.e. level	Time	Individual / group
First: substantive	Content: choice of an (optimal or satisficing) alternative – with or without handicaps	Not taken into account	Individual decision maker (one-mind system)
Second: procedural	Meta-level: process (decision about how to make the decision)	Taken into account	Individual decision maker (one-mind system)
Third: structural	Meta-level: organization of the decision making (order, participants, aspects)	Taken into account	Groups of decision makers (multi-mind system)

15 The types of rationality have also been explained in chapter 2 when assessing current alignment models.

In the substantive approach, the basic concept is that a choice is made with handicaps. When referring to handicaps, De Leeuw (2002), indicates that he is aware of the limits of rationality. This means that the original rationality concept of the *homo economicus* is not used, because it has been stretched far by Simon's *bounded rationality*. According to Simon (1997), human decision makers have a bounded rationality: they are not perfectly informed and also have a limited capacity for information processing. They are not looking for maximum but for satisficing alternatives. The search for alternatives stops as soon as an alternative with a satisfactory outcome is found.

Concluding: In PAS all three rationalities are used to open the black box of decision making in CRE alignment. The *substantive rationality* enables the decision maker to choose an alternative. The stakeholders have a bounded rationality, this means that an alternative is selected if it is satisficing for the stakeholders. The *procedural rationality* enables the decision maker to take into account the time perspective when selecting an alternative and the *structural rationality* enables that more than one decision maker is involved. These three rationalities are also used to structure the PAS approach.

Clarification about the concept of rationality

Since the three rationalities are used as basic concept, it is important to note that rationality is not seen as opposite to intuition and creativity (De Leeuw, 2002, p. 266). Intuition, according to him, can be seen as an implicit and inexplicable form of rationality. Intuition is not similar to chance (coincidence) but the decision maker cannot say why he makes a certain decision. Intuition and rational analysis seem to be complementary parts of effective decision making (Sadler- Smith & Sparrow; Simon, in Volker, 2010, p. 50).

3.1.2 PAS as a goal-oriented human system

In PAS, the decision makers who set the goals of the accommodation strategy, are incorporated and therefore the system can be portrayed as *a goal-oriented human system*.

The concept of the goal-oriented system has its roots in Operations Research (OR). OR[16] is a discipline that deals with the application of advanced analytical methods to help make better decisions. These analytical methods are used to understand and structure complex problems, after which they can be applied to improve the performance of a system. The basis of operations research can be found in a formulaic notation used by Ackoff and Sasieni (1968). This notation displays the structure of a generic decision making problem where U represents the goal that one wants to achieve.

$$U = f(Xi, Yj)$$

U = the utility or value[17] of the system's performance
Xi = the variables that can be controlled: the 'decision' or 'choice' variables
Yj = the aspects of the situation over which we have no control (environment of the problem)

Ackoff introduced systems engineering in operations research and is the principal representative of the methodical system approach. A system approach, according De Leeuw, is a way of thinking in which coherence plays a major role in all kinds of forms. He defines a system as a collection of objects (elements) chosen by the spectator that are related in such a way that no (groups of) elements are isolated from the others. A relation is seen as a (causal) relationship between A and B. Often the relationships are reciprocal, with the effect being the cause and vice versa. The methodical system approach is a specific method for solving practical problems with an emphasis on the interdisciplinary approach (De Leeuw, 2002, pp. 88, 96, 98).

This methodical systems approach is part of the so-called hard system approach, which focuses on systems that deal with goals that are not problematic (i.e. known). The counterpart within the systems approach is the soft systems approach. In these systems, as De Leeuw (2002, p. 92) explains, "the problem situation is ambiguous".

In order to position this basic concept more precise, the distinction that Franco and Montibeller (2010) make between the *expert* and *facilitated mode* in operational research is used. Franco and Montibeller (2010, p. 489) explain the different modes as follows: "… the expert mode, where the operational researcher uses OR methods and models that permit an 'objective' analysis of the client's problem situation,

16 Or operational research in British usage; also indicated as management science

17 Note that in this formula goal, utility and value are used as equivalent.

together with the recommendation of optimal (or quasi-optimal) solutions to alleviate that problem situation.” The facilitated mode is: “An alternative mode of engagement [is] to conduct the whole intervention together with the client: from structuring and defining the nature of the problem situation of interest, to supporting the evaluation of priorities and development of plans for subsequent implementation. In this latter mode, the operational researcher works throughout the intervention not only as an analyst, but also as a facilitator to the client.” Within the facilitated mode Franco and Montibeller (2010, pp. 495-496) distinguish three types: facilitated problem structuring (also known as soft OR methods), facilitated system dynamic and facilitated decision analysis.

The basic assumptions of the expert mode are: (1) problems are real entities (2) the analysis should be ‘objective’, (3) clients want optimal solutions and (4) implementation of scientifically-based analysis is straightforward. The basic assumptions of the facilitated OR approach: (1) problems are socially constructed entities, (2) subjectivity is unavoidable, (3) clients want ‘satisficing’ solutions and (4) participation increases commitment for implementation. The basic assumptions of the facilitated mode roughly overlap with the soft systems approach, although the facilitated mode also is used in the hard systems approach i.e. decision analysis (Franco and Montibeller, 2010, p. 491).

Concluding: PAS is based on the hard and soft goal-oriented systems approach with primarily the facilitated operations research mode as foundation. The soft systems approach enables the decision makers to set goals and achieve a satisficing result, i.e. design alternative. The hard systems approach enables decision makers to choose an optimum alternative.

A goal-oriented human system is a system which seeks to achieve a certain goal or goals, and consists of some decision makers. As Van Loon, Barendse & Duerink (2012) explain ”such a system contains decision makers distinguishes it from empirical systems (systems in which processes are autonomous, natural and spontaneous). In the literature, a model of a goal-oriented system is often referred to as a normative (prescriptive, operational) model, and a model of an empirical system is a descriptive (analytical, theoretical) model" (Van Loon, 1998).

3.1.3 The concept of the overall performance measure in PAS

PAS has built in one *overall performance measuring* procedure for all participating decision makers together including all decision makers.

In the field of CRE Alignment two decision-theoretical approaches are often used: the shareholder approach and the stakeholder approach. In the shareholder approach social welfare is maximized when all firms in an economy attempt to maximize their own total firm value. He explains that *firm value* is simply the long-term market value of this expected stream of benefits. This approach has its roots in economics and finance. The stakeholders approach has its roots in sociology amongst others in organizational behavior and strategic management. The shareholder approach receives criticism among others from Robert Kaplan and David Norton, the originators of the balance scorecard, which is the managerial equivalent of stakeholder theory, that purely financial measures of performance are not sufficient to yield effective management decisions (Jensen, 2010, p. 39).

Jensen's (2010) states that these two approaches are often seen as opposites, but he argues that they are different in nature and complementary. In fact, Jensen (2010, p. 33) states "… whether firms should maximize value or not, we must separate two distinct issues;

1. Should the firm [organization] have a single-valued objective?;
2. And, if so, should that objective be value maximization or something else ... ?"

In the shareholder approach, value maximization is the *scorecard* for the organization but it says nothing about how to create a superior vision or strategy. Nor does it tell employees or managers how to find or establish new initiatives or ventures that create value. The stakeholder approach on the other hand, like Kaplan-Norton's Balanced Scorecard, is a tool to help managers understand what creates this value. The system therefore is best described not as a scorecard but as a *dashboard* or instrument panel (Jensen, 2010, p. 40).

Coming back to the first issue, Jensen (2010) criticizes the stakeholder approach and states that managers in an organization need to define what is better and what is worse which forms the basis of making decisions. Therefore, Jensen (2010) argues that a single-valued objective function is a needed for purposeful behavior by any organization, which the stakeholder approach lacks. The stakeholder approach (such as the Balanced scorecard) lacks such function. Regarding the second issue, Jensen chooses the firm value as measure but explicitly states that the logic does not specify what the objective function should be.

Concluding: the PAS Design System has one overall performance measure which enables the decision makers to choose the best alternative. However, which overall performance will be used is determined and discussed respectively in paragraph 3.1.7 and 3.1.10.

3.1.4 Definitions of problems, goals and value as applied in PAS

Design problems and *design goals* are key elements of the design-structure of PAS Design System. And the problems and goals are interconnected. They are the basis of PAS as a goal-oriented design system.

"A problem cannot exist without a goal and both goal and problem are subjective" as De Leeuw (2002, pp. 35-38; 279-280) states[18]. De Leeuw indicates that this is not a common viewpoint. A problem is often described as a difference between an existing situation and desired situation and he indicates that the objection to this description is that it does not explicitly state that problems are not objective properties of phenomena. In De Leeuw's approach to problem solving[19] it is necessary to explicitly state who has the problem; the so-called problem holder. De Leeuw (2002, p. 36) defines a problem as follows: "A problem is a situation of subjective discomfort of a stakeholder mixed with a desire to do something about it[20]. This feeling of discomfort arises from a combination of three factors: goal (the subjective wishes), perception (the reality through the eyes of the problem holder) and reality". As is shown in **Figure 3.1** (De Leeuw, 2002)

The key concepts are defined as follows:

- "The *reality* is the concrete system relevant to problem-solving, as defined by the problem researcher" (De Leeuw, 2002, p. 36);
- "The *goal* refers to the goal of the relevant problem holder: the situation as the problem holder wishes"(De Leeuw, 2002, p. 37);
- "By *perception*, the reality is meant as the problem user sees it. Perception (perceived reality) is determined by reality, by the goals of the problem holder and by his general view of things. It is the perception framework or the Real Life System (RLS) of the problem holder. This RLS or the world view of a person is the set of assumptions and views that together form his or her (obviously subjective) reality" (De Leeuw, 2002, p. 38).

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18 Note that, this corresponds with the facilitated mode in OR where problems are seen as socially constructed entities and subjectivity in a problem situation is unavoidable (see 3.1.2).

19 De Leeuw indicates that management as problem solving is useful to formalize the methodological side of (the approach to) management.

20 De Leeuw (2002, p. 282-284) distinguishes three types of problems; perception-, objective- and reality-problems. Reality-problems are problems for which solutions need to be found by altering the reality and are the focus in this research.

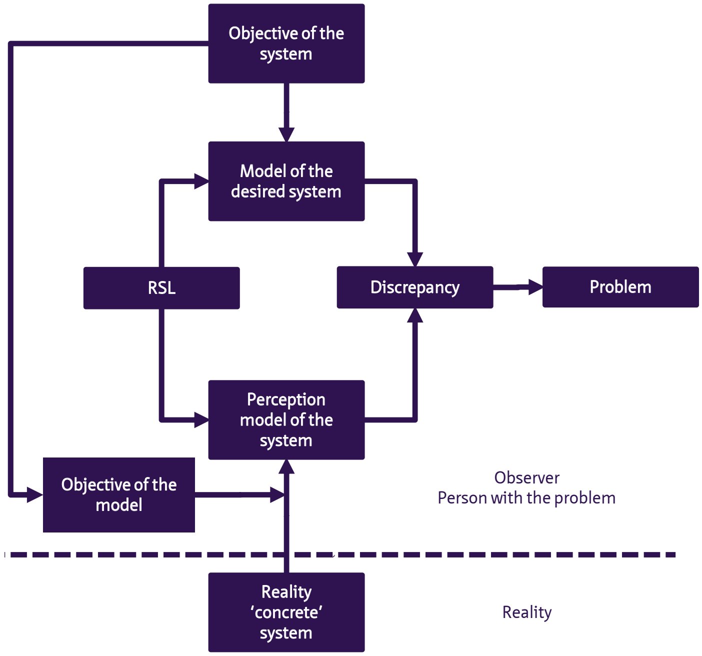

FIG. 3.1 Problem origination Note adapted from De Leeuw, 2002, p. 36

In order to further clarify this, De Leeuw explains that in certain management literature it is usual to refer to a 'problem owner': this person (has been given the assignment) to solve the problem. It is clear that this does not refer to the person that has the problem, as referred to above, because the subjectivity and personal connection to the problem is not central. This means that there cannot be a problem without a problem holder. A problem can be related to an actual situation or a future situation. In the latter, the problem holder expect that an undesired situation will occur De Leeuw (2002, pp. 34, 35, 285).

Problems are, as stated above, not objective properties of phenomena. Objective is opposite to subjective, objective is (formal) "existing outside the mind as something real, not only as an idea. A subject is one who perceives or is aware; an object is the thing perceived or the thing that the subject is aware of"[21]. When looking at the technical definition of tangible in the Longman dictionary online it is "if something is tangible, you can touch or feel it' whereas 'intangible things have value but do

21 https://en.wiktionary.org/wiki/subjective#Etymology

not exist physically – used in business' an intangible quality or feeling is difficult to describe exactly".

In general, in architecture qualities of products may be classified under two general categories that in practice often interrelate and overlap as explained by Volker (2010, p. 17):

- "Technical, physical, hard, functional, objective or tangible qualities;
- Perceptual, soft, subjective, judgmental or intangible values".

"Intangible characteristics refer to a personal response to built form, people's perception of space, texture, color and light, the meanings and associations attached by people to places or the way by which people assign aesthetic qualities to their surroundings" (Bártolo; Vitruvius & Morgan, in Volker 2010). According to Gerritse (2008) intangibles are vital to architectural design but often suppressed in discussion about the realization of a building.

Similar, criteria or values play a role in CRE alignment. De Vries, Van der Voordt and Arkesteijn (2004) also divide values (i.e. criteria) into tangible versus intangible value but add the distinction of financial versus non-financial value (see **Table 3.2**). Many other valuable categorizations also exist (for example Appel-Meulenbroek, 2010; De Vries, 2007; Den Heijer, 2011; Riratanaphong, Van Der Voordt & Sarasoja, 2012). In the 'Added value of facilities management, concept, findings and perspectives' Jensen, Van der Voordt, Coenen (2012) they are elaborated upon and compared.

TABLE 3.2 Value matrix Note from De Vries et al., 2004 visualized by Van der Zwart, 2014, p. 219

	financial	non- financial
tangible	A tangible financial value	A tangible non-financial value
intangible	B intangible financial value	B intangible non-financial value

Van der Zwart (2014) dedicated in his dissertation a chapter to the concept of value and added value in CRE management and concluded that the concept of adding value is usually linked to various lists of possible real estate strategies that could contribute to the organizations objectives and organizational performance. He concluded after comparing different lists of added values that nine added values are mentioned most: (1) reducing costs; (2) improving productivity; (3) increasing user satisfaction; (4) improving culture; (5) increasing innovation; (6) supporting image; (7) improving flexibility; (8) improving the financial position and; (9) controlling risks.

In addition sustainability was found to be often mentioned as an added value. Value is a multidimensional construct, playing diverse roles, and interpreted in different ways by different people (De Chernatony & Harris, 2000; Jensen, Van der Voordt, & Coenen, 2012) that can be defined as the (subjective) appreciation in achieving stakeholders' overall goals and purposes. He defines value as the performance of a product or service that contributes to the achievement of the goals set by the stakeholders. 'Adding value by real estate' includes stakeholders' valuation and therefore stakeholders' perspectives on real estate should be the starting point for the design and management of the accommodation. Added values of real estate have to be defined in advance (ex-ante) to enable the goals of the stakeholders to be established and also to enable testing afterwards (ex-post) of the design or the building-in-use. As a consequence, generic added values have to be translated into sector specific definitions (Van der Zwart, 2014, pp. 217-218, 236).

Concluding, as basic concept in the PAS System a design goal and a design problem are subjective and linked to a specific problem holder. A problem cannot exist without a goal; a problem is the difference between the 'model of the desired system' and the 'perception model of the system'. In PAS it must be possible that all types of values that stakeholders can be interested in can be taken into account. However, it will prove that the current categorizations can be confusing and are not needed.

3.1.5 Multiple criteria as applied in PAS

Design criteria are key elements of the decision structure of PAS. Criteria give the possibility to make choices. They structure PAS as a multi criteria decision system.

Multiple Criteria Decision Analysis (MCDA) also referred to as Multi Criteria Decision Making (MCDM) is described by Belton and Stewart (2003, p. 2) as "a collection of formal approaches which seek to take explicit account of multiple criteria in helping individuals or groups explore decisions that matter". Decisions matter, to them, when the level of conflict between criteria or different stakeholders assumes proportions that intuitive decision making is no longer satisfactory. MCDA is "an aid to decision making, a process which seeks to: Integrate objective measurement with value judgement and Make explicit and manage subjectivity" (Belton and Stewart, 2003, p. 2).

Concluding: a basic concept for PAS is the multi criteria decision making approach.

3.1.6 Specification and modeling of design problems in PAS

To model an accommodation strategy design problem in PAS is the clarification of design objectives and constraints and the establishment of metrics for objectives. To specify functions of the future accommodation methods of engineering design are applied.

Design engineering from Dym and Little (2004) and business management from De Leeuw (2002) stress the importance of understanding the client statement. Dym and Little (2004, p. 50) explain that "… it is important to understand the client's problem and to develop an engineering definition of the problem. A clarification by the designer is important according to them, because the stated objective by the client can be prone to errors, bias and implied solutions. Errors may include incorrect information, faulty or incomplete data, or simple mistakes regarding the nature of the problem. Biases are presumptions about the situation that may also prove incorrect because the client or the users not fully grasp the entire situation. Implied solutions, that is, the client's best guesses at solutions, frequently appear in problem statements. While implied solution offer some usefull insight into what the client is thinking, they may restrict the design space and sometimes fail to actually solve the problem".

A clarification can be reached by asking questions and presenting the answers in a list of attributes. Mostly these statements are different because they relate to different intellectual objects. The attributes consist of objectives, functions, constraints and implications.

- ***Objectives*** describe what the designed artefact will be like, that is, what the final product will be and what qualities it will have. As such, objectives detail attributes and are usually characterized by present particles such as 'are' and 'be'. Objectives or goals are the design tries to achieve and are given in the clients language (Dym and Little, 2004, pp. 8, 52, 87);

- ***Constraints*** are limits that a design must meet to be acceptable. Constraints enable us to identify and exclude unacceptable designs. Constraints are restriction or limitations on a behavior or a value or some other aspect of a designed object's performance. They are typically stated as clearly defined limits whose satisfaction can be framed into a binary choice (Dym and Little, 2004, pp. 8, 52, 59).

- ***Functions*** are the things a design is supposed to *do*, the actions that it must perform, with a particular focus on the input-output transformations that the artefact or system will accomplish and are usually characterized by active verbs. Functions are the language of the engineer in which the objectives are translated into terminology

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that helps the designer(s) realize those needs and measure how well we meet them (Dym and Little, 2004, pp. 53, 87)';

- ***Implementations*** or means are ways of executing those functions that the design must perform. These are the items on the attribute list that provide specific suggestions about what a final design will look like or be made of, so they often appear as 'being' terms. Implementations are very much solution dependent (Dym and Little, 2004, p. 53).

Mapping the problem is very important, because one needs to determine who has which objectives and what the goals exactly mean. Therefore, he has included the diagnosis phase as the first phase in his so-called DAC model. In this phase problems are made explicit preferably by appointing performance indicators (also referred to as indicators, criteria or target vectors or characteristics). He distinguishes between instrumental and functional judgments that are connected as cause and effect. It is very important to distinguish between, on the one hand, goals and / or performance indicators and, on the other hand, variables that are believed to promote performance. In this view, performance measurement systems are implicitly or explicitly based on the system approach and can be seen as input-output system. This is shown in **Figure 3.2** (De Leeuw, 2002, p. 303). The difficulties of performance measurement can be explained using this black-box. Pure output measurement has two difficulties, as De Leeuw explains. The first concerns the extent to which you actually measure the target achievement and the second that the degree of goal achievement is not only dependent on one's own effort, but also on environmental influences that cannot be influenced. A measure of performance that is preferred in many cases relates to both input and output and is expressed in the term *added value*. If no valid output indicators, throughput variables can be used, but that only makes sense if a reasonable statement about the goal achievement can be made (De Leeuw 2002, pp. 288, 303, 304).

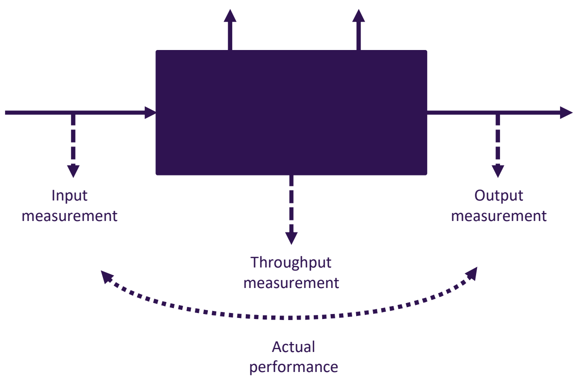

FIG. 3.2 Performance measurement as input-output system Note adapted from De Leeuw, 2002, p. 303

Concluding: as a basic concept goals will be translated into well-defined criteria by dividing them into objectives and constraints and if needed functions and implementations. Furthermore, stakeholders can use both output, throughput and input indicators.

3.1.7 PAS as a multi actor design-decision-management system

In PAS a number of designers/decision makers (the *actors* belonging to a number of different organizations) all pursuing different goals, discuss *interactively* alternative accommodation strategies and form together a design for an strategy which will be followed by de corporation.

In a multi-actor situation a hierarchic relation between actors exists, meaning that they come from the same organization. In an inter-actor approach actors of different organizations are involved. The starting point in PAS is the multi actor situation, however, with blurring boundaries between organization's a multi-actor situation can be extended into inter-actor situation.

This multi-actor approach in combination with the subjective view on problems coincides with the so-called paradigm of the multi-mind systems (Gharajedaghi, in De Leeuw 2002, p. 217). "Problems in this setting are referred to by Ackoff as a 'mess' a system of problems and problem holders" (De Leeuw, 2002, p. 285).

As basic concept, multi stakeholders are involved but they have a more specific role than in regular MCDA processes. The actors are seen as designers and decision makers. Van Loon interpreted the terms *designer* [decision maker], *group* and *optimum result* more broadly than is common in established design [decision] methodology:

- A designer is anyone who has an impact on a design (whether professional or not);
- The group of designers therefore also includes non-professionals; they decide together when their result is optimum;
- A design is a proposal for the use of resources (ideas to be applied) selected from a collection of available resources (applicable ideas) (Van Loon, 1998).

Van Loon (1998) thereby consciously distances himself from the position adopted by many professional designers who believe that professional group optimization must be regarded distinct from, and a necessary prerequisite for, social group optimization. Van Loon (1998, p. 306) therefore defines that "There

is an optimum interorganization al design when several designers cooperating on an interorganization al basis have selected a design solution in an explicit group procedure; this solution is part of alternatives that the designers have drawn up; and this collection lies within the permitten solution space of those concerned."
His interorganizational design and decision making is based on four principal fundamental principles: methodological individualism; Pareto's criterion; concept of collective action and parallel decision making positions.

Whereas Van Loon indicates that it is impossible to distinguish between professionals and non-professionals, De Leeuw (2002, p. 260) has a similar conclusion: 'a strict division of roles between decision makers, decision preparation and implementation is fiction because on the one hand many decisions are made in governmental preparation of decisions and on the other hand it is not realistic (proved) that all government officials are neutral in all cases'.

Concluding, PAS is a multi-actor approach were the actors are as individual and as group 'designers' and 'decision makers'.

3.1.8 PAS as a prescriptive mathematical decision system

The core of PAS is a *mathematical multi actor design decision model*. The model is based on a complex of relationships between mathematical quantities, specified as different categories of variables and parameters and represents the accommodation strategy design problem in a logically consistent way.

Mathematical decision modeling is part of the hard systems approach and is used to choose the best or satisficing alternative. When referring to models it needs to be clear what kind of models are meant in this thesis. In this thesis, the following definition of a model is used.

– "A model is a system that (over a period of time) is an image of aspects of another system that is used in a given situation and whose similarity relates specifically to those aspects which, given the purpose of use, are relevant" (De Leeuw, 2002, p. 125).

De Leeuw (2002) explains that models are systems that are used as a tool to study other systems. This is done in order to make systems simpler, more accessible or manageable than the original system and yet appear to be sufficiently similar. This means that models are disposable articles. The models, that are used in this thesis, are abstract models of a concrete system (De Leeuw 2002, p. 136) and in particular mathematical decision models.

Mathematical decision modeling as basic concept is used because indicates, it has four benefits (i.e. characteristics). Firstly, similar to De Leeuw, a model is a simplified version of the object, making it unnecessary to model the entire object. Secondly, making a model is less expensive than the entire object and makes it possible to avoid costly mistakes. Thirdly, in a model information can be delivered more timely than in a real-world counterpart. And lastly, the most important one a model helps to improve decision making by gaining insight and understanding about the object (Ragsdale, 2008). A mathematical model:

– “uses mathematical relationships to describe or represent an object or decision problem.” (Ragsdale, 2008, pp. 1, 4).

There are different types of mathematical modeling techniques. Ragsdale (2008, pp. 6-7) distinguishes three different categories: prescriptive, predictive and descriptive models (see **Table 3.3**). The *prescriptive* models tell the decision maker what actions to take, and this type of model is characterized by known and well-defined functions between the variables, and the value of the independent variables is known or under the control of the decision maker’s. For the *predictive* models however, the functional form might be unknown and must be estimated (hence predicted). In *descriptive* models, the decision problem has a very precise and well-defined functional relationship between the independent variables, but there might be great uncertainty about the exact values that will be assumed for one or more of the independent variables. In Ragsdale (2008) positions linear programming and goal programming as prescriptive models and simulation as a descriptive model.

Concluding: following Ragsdale’s classification, the basic concept for PAS is a prescriptive model. It is prescriptive because the form of f(*) is known and well-defined (see basic concept goals oriented system approach and preference measurement) and the values of the independent variables are under the decision maker’s (i.e. all stakeholders) control.

Although PAS as a design and decision methodology is prescriptive, this is not the case for the mathematical theories used in the approach. Binnekamp (2010, p. 29 based on Barzilai 2010, pp.11-12) explains that “… Von Neumann and Morgenstern’s utility theory, as well as its later variants, are mathematical theories and since mathematical theories do not dictate assumptions to decision makers, there is no basis in mathematical logic nor in modern utility for the claim that utility theory is normative or prescriptive”.

TABLE 3.3 Categories and characteristics of management science modeling techniques Note from Ragsdale 2008, p. 6. From Ragsdale. Managerial Decision Modeling, Revised, International Edition (with Student CD-ROM, Microsoft Project Management 2007 and Crystal Ball Pro Printed Access Card), 1E. © 2008 South-Western, a part of Cengage, Inc. Reproduced by permission. www.cengage.com/permissions

Category	Model characteristics		Management science techniques
	Form of f(*)	Values of Independent variables	
Prescriptive models	Known, well-defined	Known or under decision maker's control	Linear Programming, Networks, Integer Programming, CPM, Goal Programming, EOQ, Nonlinear programming
Predictive models	Unknown, ill-defined	Known or under decision maker's control	Regression Analysis, Time series Analysis, Discriminant Analysis,
Descriptive models	Known, well-defined	unknown or uncertain	Simulation, Queuing, PERT, Inventory models

Note that there is a difference between a good decision and a good outcome (Ragsdale, 2008, p. 110). A good decision does not always result in (and cannot guarantee a) good outcomes.

3.1.9 Preference measurement in PAS

The selection of the best (most preferred) accommodation strategy out of a set of alternative strategies in PAS is done by means of a mathematical preference measuring model.

The foundation of decision theory is preference measurement. Preference is synonymous to choice as we choose those objects that we prefer. Barzilai (2010) states that the mathematical foundations of social science disciplines, including economic theory, require the application of mathematical operations to non-physical variables. A non-physical variable such as preference[22] describe psychological or subjective properties (Barzilai, 2010).

22 In this thesis, preferences are stated preferences, also referred to as espoused preferences. Stated preferences are opposite to revealed preferences or preference-in-use and "It should be noted that what people say they their preferences are – their espoused preferences – may be different from what they actually are as can be inferred from their observable behaviour – their preference –in-use" Binnekamp, et al. (2008, p. 281). Revealed preference theory (Samuelson, on Wikipedia, n.d.) is a method of analyzing choices made by individuals [they] assume that the preferences of consumers can be revealed by their purchasing habits.

Barzilai (2010) explains the purpose of mathematical modeling of measurement in current terminology as follows:

The purpose of modeling the empirical system (E) by the mathematical system (M) is to enable the application of mathematical operations on the elements of the mathematical system M. To clarify what is meant by 'the mathematical modeling of measurement' some terminology is required. By an empirical system E we mean a set of empirical objects together with operations (i.e. functions) and possibly the relation of order which characterize the property under measurement. A mathematical model M of the empirical system E is a set with operations that reflect the empirical operations in E as well as the order in E when E is ordered. A scale s is a mapping of the objects in E into the objects in M that reflects the structure of E into M. The *Principle of Reflection* is an essential element of modeling that states that operations within the mathematical system are applicable if and only if they reflect corresponding operations within the empirical system. In order for the operations of addition and multiplication to be applicable, the mathematical system M must be:

1. A field if it is a model of a system with an absolute zero and an absolute one;
2. A one-dimensional vector space when the empirical system has an absolute zero but not an absolute one;
3. A one-dimensional affine space, which is the case for all non-physical properties with neither an absolute zero nor absolute one.

Errors have been revealed at the foundations of preference measurement by Barzilai because "Addition and multiplication are not applicable in von Neumann and Morgenstern's utility model, which underlies utility theory, because its axioms are not the axioms of a one-dimensional affine space. This is also the case for later formulations of utility theory" Barzilai (2010).

The next step Barzilai (2010) made was to reconstruct the foundations. In order for the operations of addition and multiplication to be applicable on *preference scale values* the mathematical system must be a one-dimensional affine space. Based on this, Barzilai developed a theory of (preference) measurement, a practical evaluation methodology for constructing proper preference scales, Preference Function Modeling, and a software tool that implements it, Tetra.

Concluding: PAS is based upon Barzilai's proper preference scales and the practical methodology PFM. This enables decision makers to take into account both *physical* and *nonphysical* variables. Following Barzilai, all physical properties are translated into non-physical properties (i.e. preference) and aggregated into one overall preference score. This core concept will be explained more in-depth in paragraph 3.2.

Recall, that in the section definitions of problems, goals and value a matrix is presented with value categorizations (tangible and intangible; financial and non-financial). In PAS decision makers should be able to incorporate any of those four values types in their decision making. In mathematics this distinction into these four types or any other categorization is not necessary. Barzilai (2010) separates properties of objects into *physical* or *non-physical* properties of an object.

3.1.10 The overall preference score as performance measure in PAS

Barzilai's proper preference scales and his Preference Function Modeling in PAS made it possible to calculate an overall preference score. This score is able to include all types of values and all stakeholders.

In the shareholder approach as discussed by Jensen (2010) (see paragraph 3.1.3) value maximization is used as financial performance measure. The objections towards financial measures are discussed.

A fundamental objection towards any monetary measure is that price is not a property of a physical object (Barzilai, 2015, 2016). Barzilai (2016, p. 1) explains this by comparing the demand theories of Marshall's and Hicks: "Demand quantities are determined in Marshallian demand theory under the assumption that consumers maximize their utility while satisfying a budget constraint. In contrast, Hicksian demand quantities are determined under the assumption that consumers minimize their expenditure while keeping the value of their utility function constant. The fact that these contradictory assumptions produce different demand quantities raises obvious questions: Which of these demand theories is the correct one? Are consumers Marshallian or Hicksian?". Barzilai (2015) shows that theory can be simplified and he uses an example of buying goods at the market "As is well known, the value of money is different from money. Both Marshall's and Hicks's theories (and the intermediate ones as well) take into account consumers' preferences for tomatoes and cucumbers but ignore their preference for money. This is an elementary error in current economic theory". He further explains that "when consumers buy tomatoes and cucumbers they exchange money for goods. They must- and they do – take into account their preference for money in addition to their preference for the goods. Contradictions are avoided and the theory is simplified when this transaction is viewed as (i) an exchange of goods, (ii) with money being one of the goods, and (iii) preference for all goods is taken into account".

Disadvantages of social cost and benefit analysis

Some other disadvantages of monetary or quantified measures are discussed by Mouter (2012) in his study into social cost-benefit analysis[23] (SCBA) as it is used in the Netherlands. This form of SCBA has specific advantages with respect to the MCA (see paragraph 3.1.3) because it strives to measure all relevant aspects of prosperity of a project and convert it into a quantitative unit (monetized or not)[24].

In this study improved transparency is one of the main advantages of the SCBA. Both the choice situation becomes more transparent for the decision maker and it makes decisions by decision makers more transparent and therefore more transparent for other stakeholders. Two disadvantages are especially relevant in this research. Firstly, that the ideal of the SCBA to include all the prosperity effects of a project is not feasible in practice (a.o. Odgaard et al.; Mackie, in Mouter, 2012). Secondly, that an inherent limitation of the application of this SCBA in practice is that one effect can be more difficult quantified / monetarized than the other effect. The result of this is that the difficult to quantify / monetarize effects are presented in an unbalanced manner. Mouter (2012, p. 10) explained this phenomenon by referring to Mishan's 'horse and rabbit stew problem': "if you take one horse and one rabbit, no matter how you combine them the taste of horse dominates the stew. Similarly, if you take one set of quantifiable impacts and one set of non-quantifiable impacts in an appraisal, one set will dominate" (Mouter, 2012).

Mouter (2012) also notes the fundamental aspect that was discussed above by Barzilai. One of the ethical aspects he found to be of importance is the fact that the SCBA assumes 'willingness to pay' and does not take into account the difference in 'capacity to pay'.[25]

Concluding: in PAS, all physical and non-physical criteria are expressed in preference, also the preference for receiving and spending money. By doing so, the restrictions as formulated by Barzilai and others, are avoided.

23 abbreviated in Dutch as MKBA

24 In this SCBA the basic information is standardized so that the prosperity effects can be compared and the discussion is about specific figures but differences in methodological visions can be avoided (Mouter, 2012, pp. 5-6).

25 Note that this related to the former objection that price is not a physical property of an object.

3.1.11 PAS as a problem solving system

By viewing a designed accommodation strategy (generated by PAS) as a solution for an organization 's strategic accommodation problem PAS is a *problem solving system*. Design as problem solving leads to an instrumental view on the management of the design process.

One is not only concerned with understanding reality but also on the basis of that understanding intervening in that reality. Intervening in reality is steering and (re) designing that reality. De Leeuw (2002, p. 215) uses the following descriptions of a design and designing:

- "A design is a model of a future (realizable) system that exhibits the required behavior in the concerning future environment. That model is mostly abstract, but can also be concrete;
- Designing is a systematic and creative process of activities with the aim of creating a model of a future system that delivers the desired performance taking into account the preconditions (functional process)."

"A design process is a transformation of a problem situation into a solution" as De Leeuw (2002, p. 216) states. This approach is concretized and visualized in a generally usable scheme of management as problem solving and designing. De Leeuw (2002, p. 217) calls this approach the diagnosis, design and change-model [26] (see **Figure 3.3** (De Leeuw, 2002)).

Designing according to De Leeuw (2002) is often *redesigning* because usually there already is something else, i.e. an organization. This is similar to CRE alignment where an (large) organization always starts with the CRE portfolio that already exists.

Whereas, De Leeuw approaches and defines design from a management perspective, a deeper understanding of design can be obtained by looking at design engineering.

- "Design engineering is the systematic, intelligent generation of specifications for artifacts whose form and function achieve stated objectives and satisfy specified constraints" (Dym and Little, 2004, p. 6);
- "Or expressed in more colloquial terms design engineering is the organized, thoughtful development and testing of characteristics of new objects that have a

26 In Dutch the model is called Diagnose – Ontwerp – Verandering, abbreviated as DOV. Note that in this thesis the last phase 'change' process is outside of the scope.

particular configuration or perform some desired function(s) that meet our aims without violating any specified limitations” (Dym and Little, 2004, p. 7).

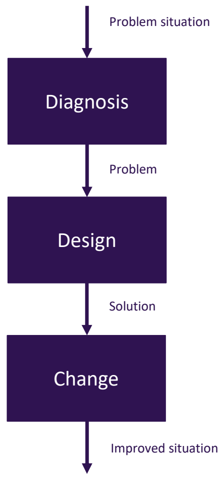

FIG. 3.3 Diagnosis-design-change-model Note adapted from De Leeuw, 2002, p. 217

Design engineering as perspective is chosen because it is a prescriptive process that focuses on how to generate designs. Dym and Little (2004, p. 21) state that ‘some design processes are descriptive, that is, they attempt only to describe the elements of the design process’. It can be noted that such processes compare to the procedural rationality approach as discussed in paragraph 3.1.1. While simple descriptive design processes have the virtue of simplicity, Dym and Little (2004, p. 21) indicate that they are so abstract that they provide little useful advice on how to do a design. Therefore, they converted a descriptive process into a five-stage prescriptive model of the design process that styles the design process as a linear sequence of artifacts (need and final design) and design phases, within which 10 design tasks are situated (see **Figure 3.4**). The five stages are problem definition, conceptual design, preliminary design, detailed design and design communication. However, they emphasize that it is not a linear process at all by adding feedback and iteration to the design process. In this prescriptive model Dym and Little define what is done in each stage; each stage requires an input, has design tasks that must be performed and produces an output or product together with sources of information, methods and means. Note that the output of each stage serves as the input to the following stage.

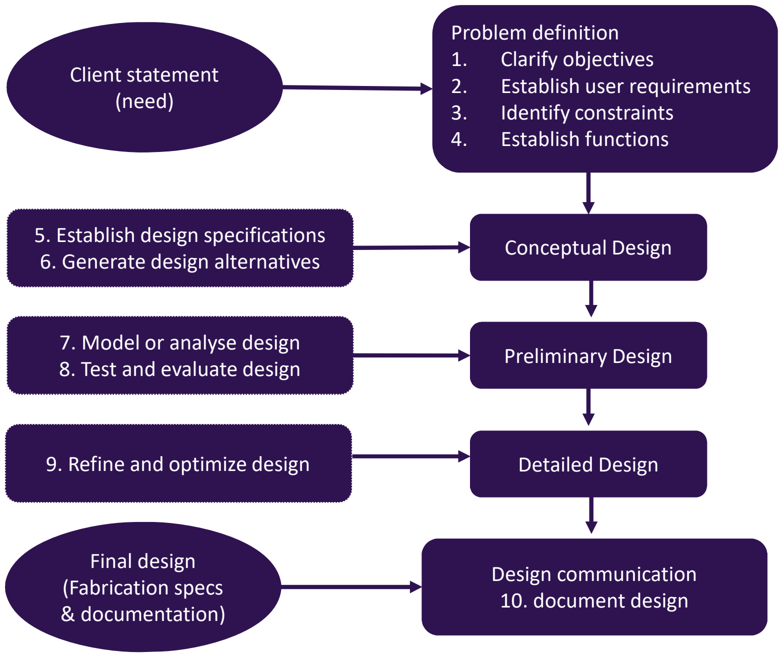

FIG. 3.4 Prescriptive design process © Dym, C., & Little, P., (2004), Figure p. 24, Engineering Design: A Project-Based Introduction, Hoboken. In: NJ.: John Wiley & Sons Inc. Note Used with permission.

Note, that both De Leeuw and Dym and Little emphasize problem structuring as part of the process similar to the importance of goal setting in the soft system approach. De Leeuw refers to this as the diagnostic phase and Dym and Little as the client statement (task 1 to 4) ending in the design specifications (task 5).

Concluding: by seeing PAS as *problem solving system,* De Leeuw defines a design process as a transformation of a problem situation into a solution. Following Dym and Little, PAS uses a prescriptive approach towards design.

3.1.12 PAS as an operational representation of the design (solution) space

In PAS all preferences and constraints of all actors involved are integrated in one overall model which then represents the *design solution* space for the new to design accommodation strategy.

The design space can be defined as a mental construct of an intellectual space that envelops or incorporates all of the potential solutions to a design problem according to Dym and Little. It reflects the number of possible design solutions and the number of design variables. A design space can be large or small. In a large design space either the number of potential designs is very large, perhaps even infinite, or the number of design variables is large, as is the number of values they can assume. In a small design space either the number of designs is limited or small, or the number of design variables is small, and in turn can take on values only within limited range. A large design space is complex because of the combinatorial possibilities that emerge when hundreds or thousands of design variables must be assigned. A well-known approach in design to cope with complexity of decomposing the problem into sub problems and reassembling them. This recomposition of feasible solutions is important (Dym and Little, 2004).

In order to generate potential design ideas and thus *expand the design space* in a goal-directed design Dym and Little state that two main means that can be used: (1) using already available design information (like in handbooks or patents) and (2) team brainstorming. In order to *organize the design space*, i.e. the potential design, in ways that make exploration easy the design space needs to be limited to a useful size. Next to available technologies and external constraints, the main way is to the use the *clients' needs*. The morphological chart (often visualized as a table) is a useful aid to organize the design space; in this chart for each function (rows) that is needed a list of means (columns) is build. The design space is then determined by the combinatorics; any single means for a specific function is combined by the remaining means in all of the other rows (i.e. functions). Next step is to *prune the design space* by identifying and excluding infeasible alternatives. The design space is limited by applying constraints, freezing the number of attributes, impose an order and be realistic Dym and Little (2004).

Design space in linear programming

The design space is also expressed in a mathematical model. The use of linear programming (LP) in the field of architecture has arisen from the basic design problem, being that multiple design alternatives offer a solution to the design

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problem. LP offers a technique where the design alternatives do not need to be known a priori, which is the case in architecture. The design alternative is represented as a set of all the relevant design variable values. LP then maximizes an objective function (representing one decision variable) that is subject to a number of constraints (Binnekamp, Van Gunsteren, Van Loon, et al., 2006). The standard form of the LP problem is formulated as follows (Binnekamp et al., 2006, p. 30):

$$\text{Maximize } Z = \sum_{j=1}^{n} c_j x_j \qquad \text{(Objective function)}$$

$$\text{Subject to} \sum_{j=1}^{n} a_{ij} x_j \leq b_j \qquad \text{for i = 1,2, ….., m (Constraints)}$$

$$and\ x_j \geq 0 \qquad \text{for j = 1,2, ….., m (Non-negativity constraints)}$$

Design space in linear programming with negotiable constraints

Van Loon (1998) made a distinction between 'hard constraints' and 'soft constraints': hard constraints are fixed, whereas soft constraints are negotiable and can thus be used to broaden the design space (see **Figure 3.5**). In LP this means that the mathematical outcome 'infeasible' can be changed to 'feasible' by altering the soft constraints. The use of soft, i.e. *negotiable constraints* makes LP suitable for group decision making. The LP model is used to create a solution space in which the ultimate solution (=joint goal) can be found (Van Loon, Heurkens, Bronkhorst, 2008, p. 11).

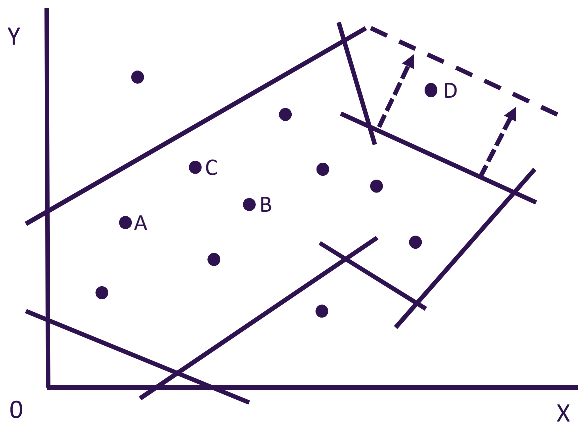

FIG. 3.5 Design space in LP with negotiable constraints Note from Van Loon et al., 2008, p. 11

Concluding, in PAS the design space is a basic concept and will be expressed in a mathematical model, while linear programming will only be used partially (see next section).

3.1.13 The Preference-Based Design method as applied in PAS

To 'solve' the accommodation design problem PAS uses the Preference-Based Design method. And PAS is structured around this method.

The PBD method (Binnekamp, 2010) uses the optimization framework of linear programming (LP) and uses Barzilai's new methodology, Preference Function Modeling , for measurement, evaluation, and decision making by a single decision maker or a group. The first means he uses constraints for expressing each decision maker's interests or criteria in terms of allowed decision variables value ranges and relationships between decision variables in order to define all feasible alternatives. A *design alternative*[27] is then a combination of decision variable values and its feasibility is defined by the constraints and allowed decision variable value ranges (Binnekamp, 2010, p. 3). The second means he uses PFM to order these alternatives on overall preference in order to find the alternative with the highest overall preference rating.

This methodology (Binnekamp, 2010, p. 85) thereby 'removes the limitations that were encountered in group design decision making problems using LP models. The fundamental limitations in these models are that they:

1. only allow single objective optimization thus satisfy only one interest of one decision maker thereby not extending to group decision making, and
2. the constraints divide all possible solutions into either feasible or infeasible ones. This leads to 'black' (excluded) or 'white' (included) situations, where a design is either feasible or not, i.e. no 'grey' situations exist which could eventually be acceptable to decision makers. This means this technique poorly reflect a decision maker's preferences.

The PBD removes all limitations of using either LP, Goal Programming (GP) or Multi objective linear optimization (LMOP) as it removes the harsh division of solutions into

27 This definition is taken from the LP technique

feasible or infeasible and the linearity requirement by introducing curves to represent how decision variable values relate to preference ratings. It enables optimization on multiple objectives by selecting the best design alternative based on the decision variables. PBD also removes the weighted sum limitation by including the PFM algorithm to yield an overall preference scale. Furthermore, it removes the harsh distinction between feasible or infeasible solutions. A solution is only infeasible if it does not meet the design constraints.

Thereby, PBD methodology removes the two limitations as, being built upon PFM, it extends to group decision making (limitation 1) and has a sound mathematical foundation for measuring preference (limitation 2). The PBD methodology is successfully applied to cases at a building and area level, but, as of now, has not been applied at a portfolio level.

Concluding, as second core concept in PAS the PBD methodology is used to design alternatives. This core concept will be explained more in-depth in paragraph 3.3.

3.1.14 PAS as a design management system

The procedural and structural aspect systems of PAS give the opportunity to use the system as a *design management* (steering) system focusing on managing the strategic accommodation design formation process.

'Management as steering' is a collection of ideas about steering and about the way in which these can be used to make representations and models for analysis and design. The starting point is the assumption that it is possible and useful to approach reality in this way (De Leeuw, 2002, p. 150). Thereby, De Leeuw defines steering as any kind of directional influence. This a broader view on steering which is often interpreted more restrictively.

De Leeuw (2002, pp. 152-153) explains his view as follows:

1. Completeness, explicitness, measurability and consistency of goals is not required in order to apply steering;
2. Steering does not have to succeed to be named accordingly;
3. Steering includes change of structures and goals;
4. Not steering is also steering;
5. The prevention of change is also steering;
6. There is a distinction between the manager (driver) and steering.

Management as steering is based on the systems approach. De Leeuw (2002, p. 151) states that "In the case of steering, always at least two subsystems are involved: the system that is steered, i.e. the steered system, in short (SS) the steering unit (SU)." The SU influences the SS with one or more steering measures and the SS provides information to the SU. In this SU/SS system there is also an exchange of steering measures and information with the environment of the system (see **Figure 3.6**).

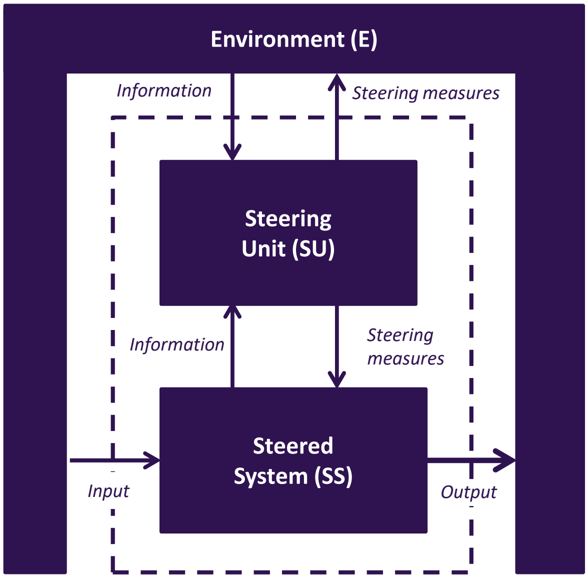

FIG. 3.6 SU/SS system Note adapted from De Leeuw, 2002, p. 155

De Leeuw explicitly mentions in his definition of steering that this is possible regardless the success of the steering measures. A measure is called effective (De Leeuw, 2002, p. 157) if the measure has the intended effect and is called efficacy if it helps in the right direction.

Concluding, in PAS management is seen as steering and steering is any kind of directional influence. In this basic concept it is assumed that it is possible and useful to approach reality in this way.

3.1.15 PAS as Human Activity System

All actors involved in the accommodation design process act within PAS. They make choices, they propose sub solutions, interact and evaluate. PAS is as such a human activity system.

PAS is based on both the hard and soft systems approach with primarily the facilitated operations research mode as foundation (see paragraph 3.1.1). The soft systems approach enables the decision makers to set goals, i.e. to determine which goal(s) need to be achieved. Recall, that in the soft system approach (often linked to the interaction perspective) the unanalyzed problem situation is the starting point. The human activity system (HAS) is a main concept of the *soft systems approach,* according to De Leeuw (2002).

A HAS is a goal-oriented system of human activities that bring about a transformation process (based on Barnard, Miller & Rice and Checkland in De Leeuw, 2002, p. 219). The essence of the transformation process becomes concise from a functional perspective (what the system does or produces) in the root definition. A root definition describes the essential transformation process of an HAS by filling in a so-called CATWOE. Checkland's CATWOE is an acronym that stands for *clients, actors, transformation, weltanschauung, owners* and *environment*. De Leeuw (2002, p. 221) also explains that in his experience it is not always necessary to use all elements of the CATWOE. He adds that a HAS has multiple aggregation levels and therewith the structure of a hierarchical system. A HAS usually includes several managed systems and a steering unit that controls the resources available to the HAS. It is essential that there are more (sometimes even many) different perceptions of a HAS in which the so-called Weltanschauung (compare real life system (RLS)) is expressed.

Concluding, the stakeholders in PAS are seen as designers and decision makers and are part of a human activity system. The essential transformation processes are described in a root definition using CATWOE.

3.2 Preference measurement

In the PAS design and decision method preference measurement, based on Barzilai's proper preference scales and preference function modeling, is a core concept (as explained in paragraph 3.1.9.). In this paragraph this core concept will be explained more in-depth. First of all, the measurement of psychological properties and related problems are discussed. Secondly, the mathematical foundations of preference measurement are explained. Thirdly, the steps of Preference Function Modeling (Tetra) are given. This paragraph is based on Barzilai (2010) and Binnekamp (2010, pp. 23-29).

3.2.1 Measurement of psychological properties

The foundation of decision theory is preference measurement. Preference is synonymous to choice as we choose those objects that we prefer. Barzilai (2010, p. 57) states that "The mathematical foundations of social science disciplines, including economic theory, require the application of mathematical operations to *non-physical variables,* i.e. to variables such as preference that describe psychological or subjective properties".

Barzilai (2010, p. 58) has revealed errors in the foundations of preference measurement and quotes "As Campbell eloquently states ([1920], pp. 267-268) 'the object of measurement is to enable the powerful weapon of mathematical analysis to be applied to the subject matter of science'". In current terminology, Barzilai (2010) explains the *Principle of Reflection* and the purpose of mathematical modeling of measurement as follows[28]:

The Principle of Reflection is an essential element of modeling that states that operations within the mathematical system are applicable *if and only if* they reflect corresponding operations within the empirical system. In technical terms, in order for the mathematical system to be a valid model of the empirical one, the mathematical system must be homomorphic to the empirical system (a homomorphism is a structure-preserving mapping). A mathematical operation is

28 To clarify what is meant by the mathematical modelling of measurement some terminology might be required. http://www.scientificmetrics.com/downloads/publications/Barzilai_2006_On_the_Mathematical_Modeling_of_Measurement.pdf

a valid element of the model only if it is the homomorphic image of an empirical operation. Other operations are not applicable on scale values.

By *The Principle of Reflection,* a necessary condition for the applicability of an operation on scale values is the existence of a corresponding empirical operation (the homomorphic pre-image of the mathematical operation). That is, *The Principle of Reflection* applies in both directions and a given operation is applicable in the mathematical image only if the empirical system is equipped with a corresponding operation (Barzilai, 2010, p. 5). See **Figure 3.7**.

The task of constructing a model for *preference* measurement is addressed by von Neumann and Morgenstern [1944, paragraph 3.4] indirectly in the context of measurement of *individual* preference. While the operation of addition as applies to *length* and *mass* results in scales that are unique up to a positive multiplicative constant, physical variables such as *time* and *potential energy* to which standard mathematical operations do apply are unique up to an additive constant and a positive multiplicative constant. (If s and t are two scales then for *time* or *potential energy* $t = p + q \times s$ for some real numbers p and $q > 0$ while for *length* or *mass* $t = q \times s$ for some $q > 0$) Barzilai (2010, p. 59).

Barzilai (2010) explained that Von Neumann and Morgenstern's as well as Stevens made a classification based on scale uniqueness, whereas, the classification should be based on the mathematical operations that are applicable instead.

It might be claimed that the characterization of scale uniqueness by implies the applicability of addition and multiplication to scale values for fixed scales, but this claim requires proof. There is no such proof, nor such claim, in the literature because this claim is false … Barzilai (2010, p. 60).

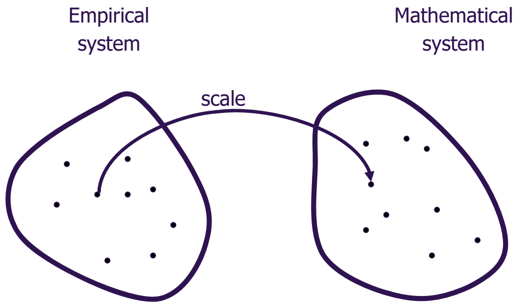

FIG. 3.7 A scale is a mapping of the objects in the empirical system into the objects in the mathematical system Note from Binnekamp, 2010, p. 25

An ordinal empirical system E is a set of empirical objects together with the relation of order, which characterize a property under measurement. A mathematical model M of an ordinal empirical system E is an ordered set where the order in M reflects the order in E. A scale s is a homomorphism from E into M, i.e. a mapping of the objects in E into the objects in M that reflects the order of E into M. In general, the purpose of modeling E by M is to enable the application of mathematical operations on the elements of the mathematical system M and operations that are not defined in E are not applicable in M. In the case of ordinal systems the mathematical image M of the empirical system E is equipped only with order and the operations of addition and multiplication are not applicable in M. In other words, since, by definition, in ordinal systems only order is defined (explicitly — neither addition nor multiplication is defined), addition and multiplication are not applicable on ordinal scale values and it follows that the operation of differentiation is not applicable on ordinal scale values because differentiation requires that the operations of addition and multiplication be applicable Barzilai (2010, p. 62).

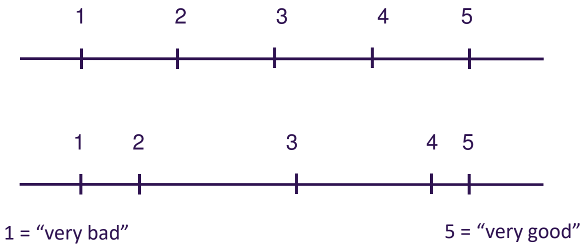

FIG. 3.8 Two example of an ordinal scale; since only order is determined both scales are the same regardless the exact position of digits 2,3 and 4.

This important in our field, because in CRE alignment ordinal scales (see **Figure 3.8**) are frequently used to measure psychological or subjective properties.

3.2.2 Mathematical foundations

The purpose of measurement is to enable the application of mathematical operations to the variables under measurement (Barzilai, 2010). Barzilai therefore, classifies measurement scales by the mathematical operations that are enabled on the resultant scales and scale values. Proper scales are scales to which the operations of addition and multiplication (including subtraction and division) are applicable. Those proper scales that enable order and the application of the limit operation of calculus are termed strong scales. All other scales are termed weak.

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Barzilai reconstructed the foundations of preference measurement as follows:

In order for the operations of addition and multiplication to be applicable, the mathematical system M must be:

1 A field if it is a model of a system with an absolute zero and an absolute one;
2 A one-dimensional vector space when the empirical system has an absolute zero but not an absolute one;
3 A one-dimensional affine space, which is the case for all non-physical properties with neither an absolute zero nor absolute one.

This implies that for proper scales, scale ratios are undefined for subjective variables including preference Barzilai (2010, p. 81).

The mathematical systems are visualized in **Figure 3.9**.

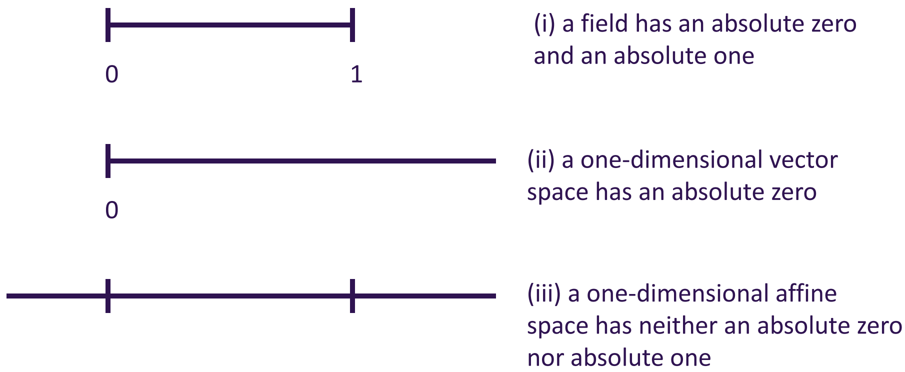

FIG. 3.9 Mathematical systems

Since preference and all non-physical properties neither have an absolute zero or absolute one, the mathematical system must be a one-dimensional affine space in order for the operations of addition and multiplication to be applicable on preference scale values.

… the one-dimensional affine space, is the algebraic formulation of the familiar straight line of elementary (affine) geometry so that for the operations of addition and multiplication to be enabled on models that characterize subjective properties, the empirical objects must correspond to points on a straight line of an affine geometry. In an affine space, the difference of two points is a vector and no other operations are defined on points. In particular, it is important to note that the ratio of two points as well as the sum of two points are undefined. The operation of addition is defined on *point differences*, which are vectors. Multiplication of a vector by a scalar is defined and the result is a vector. In the one-dimensional case, and only in this case, the ratio of a vector divided by another non-zero vector is a scalar … (Barzilai, 2010, p. 76).

The expression $\frac{(a\text{-}b)}{(c\text{-}d)} = k$, where *a, b, c, d* are points on an affine straight line and *k* is a scalar, is used in the construction of proper scales. The number of points in the left hand side of this expression can be reduced from four to three (e.g. if *b* = *d*) but it cannot be reduced to two and this implies that pairwise comparisons cannot be used to construct preference scales where the operations of addition and multiplication are enabled (Barzilai, 2010, p. 81). This is visualized in **Figure 3.10**.

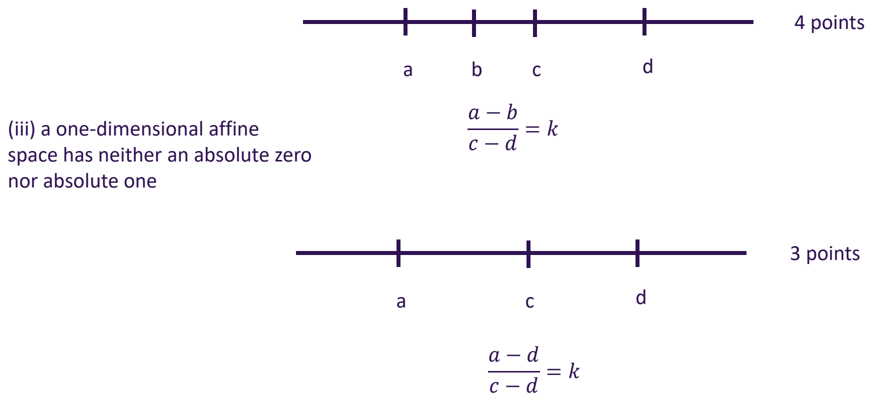

FIG. 3.10 Points on a straight line

Reducing the number of points to two (as is done in the case of pairwise comparison) violates the principle of reflection and is a modeling error. The modeling error is that the axioms of the one-dimensional vector space are used in M while E requires the axioms of the one dimensional affine space.

Binnekamp compared PFM with two other value function methods: Multi Attribute Value Function and Analytical Hierarchy Process (AHP) and with two most prominent outranking approaches, the Elimination Et Choix Traduisant la REalité (ELECTRE) family of methods, developed by Roy and associates at Laboratoire d'Analyse et

Modélisation de Systèmes pour l'Aide à la Décision (LAMSADE), University of Paris Dauphine, and Preference Ranking Organization METHod for Enrichment Evaluations (PROMETHEE) and concluded that none of the scales used by these methods enable the operations of addition and multiplication (Binnekamp, 2010, pp. 37-81).

3.2.3 Preference Function Modeling

Based on his new theory of (preference) measurement, Barzilai developed PFM, a practical evaluation methodology for constructing proper preference scales, and Tetra, a software tool that implements it.

The process of utilizing PFM (single decision maker) is (Binnekamp, 2010, pp. 31-32):

1. Specify the alternatives;
2. Specify the decision maker's criteria tree;
3. Rate the decision maker's preferences for each alternative against each leaf criterion as follows:
    a. For each criterion establish reference alternatives. The most preferred alternative is rated at 100, the least preferred alternative is rated at 0.
    b. Rate the preference for the other alternatives relative to these reference alternatives on the scale established;
4. To each leaf criterion assign decision maker's weight;
5. Use the PFM algorithm to yield an overall preference scale.

In the Tetra Quicktart Guide (Scientific Metrics, 2002-2016) the process is shown extensively with an example.

3.3 Preference-Based Design methodology

In this paragraph the Preference-Based Design methodology, which has been introduced in paragraph 3.1.13, is explained in depth. The first paragraph explains the objective and foundations of the methodology. The second paragraph explains the concept of the PBD methodology and places it in the context of MCDA techniques. The third paragraph explains the PBD procedure in detail combined with the definitions that are relevant to this thesis. In the fourth paragraph the tests Binnekamp have done with the methodology are summarized and in the fifth paragraph his conclusions and recommendations are given, while in the sixth and last the PBD procedure is compared to DAS.

3.3.1 Objective and foundations of the Preference-Based Design methodology

Binnekamp explains that "design in the domain of architecture is a complex process where success or failure depends on overcoming many difficulties." According to him "a substantial amount of these difficulties relates to two prominent characteristics of choice making in architecture:

1. multiple designs can fit into one intended purpose, which raises the question: how to choose the design that fits best, and;
2. a multitude of decision makers have a say in the design process, which is the problem of group choice making. And choice making is about determining the best choice."

The main objective of the Preference-Based Design methodology that Binnekamp developed in his thesis is the *challenge of properly integrating preferences in the so-called Open Design methodology*. Rather than following the classical theory of decision making and integrating preference in Operations Research (OR) techniques, the Open Design group uses Linear Programming (LP) models to solve design problems in the domain of architecture (Binnekamp et al., 2006).

Preferences were not mathematically modelled in the open design methodology before, because Van Loon (1998, p. 84), chose the Paretian approach towards preferences using the following motivation "The Paretian approach is eminently suitable for optimization in interorganizational design. It avoids utility measurement, which is difficult to perform, but does not lapse into the subjective evaluation of utility." At that time, avoiding preference measurement was a valid motivation as classical methodologies for measuring preference lack a mathematical foundation. Binnekamp was able to integrate preference properly by using Barzilai's theory (2004, 2005). Barzilai's theory is Binnekamp's *second foundation* because this theory enables preferences to be taken into account properly, this means in a mathematically correct way. He wants to integrate preferences properly because he states that (Binnekamp, 2010, p. 85) "Design is, for a large part, a process of making choices. Choosing between the possible options for a given design question is fundamentally an issue of preference. As such, methods of preference measurement and preference-based selection should be applicable to design."

Binnekamp's (2010, p. 31) main question for his research is:

"How to select the design that meets all decision makers' interests best taking into account each design's attributes". Binnekamp argues (2010, p. 81) that he therefore needs a methodology that:

1. "Extends to group decision making;
2. Has a mathematical foundation for measuring preference."

The survey Binnekamp (2010, p. 81) conducted into current multi criteria decision analysis approaches "has shown that none of the discussed goal, aspiration or reference level methodologies extends to group decision making. This leaves us with value measurement and outranking methodologies which, with the exception of PFM as shown by Barzilai, all lack a correct mathematical foundation".

3.3.2 Design concept of the Preference-Based Design procedure

Binnekamp therefore proposes a design methodology in which design choices are preference based. As already explained in paragraph 3.1.4 in the design methodology Binnekamp (2010, p. 85) uses

1. "Only the design optimization framework of LP;
2. Preference Function Modeling to incorporate preferences."

The first means he uses constraints for expressing each decision maker's interests or criteria in terms of allowed decision variables value ranges and relationships between decision variables in order to define all feasible alternatives. Binnekamp (2010, p. 3) uses the following definition "A *design alternative*[29] is a combination of decision variable values and its feasibility determined by design constraints and allowed decision variable value ranges". The second means he uses PFM to select from these the alternative with the highest overall preference rating. This methodology

29 This definition is taken from the LP technique

thereby “removes the limitations that were encountered in group design decision making problems when the Open Design group tried to solve these using Linear Programming (LP) models. The fundamental limitations in these models are that they

1. Only allow single objective optimization thus satisfy only one interest of one decision maker thereby not extending to group decision making;
2. The constraints divide all possible solutions into either feasible or infeasible ones; black or white, no grey which could eventually be acceptable to decision makers thereby poorly reflecting a decision maker’s preferences” (Binnekamp, 2010, p. 85).

This tendency to extreme values is a typical feature of linear programming formulations, making it difficult to find compromising solutions.

3.3.3 Preference-Based Design procedure

Binnekamp’s methodology aims to find the design that is both feasible and most preferred by all decision makers. The procedure (Binnekamp, 2010, pp. 121-122) consists of six steps:

Step 1. Specify the decision variable(s) the decision maker is interested in.

Step 2. Rate the decision maker’s preferences for each decision variable as follows:

(a) For each decision variable establish (synthetic) reference alternatives which define the endpoints of a cubic Bezier curve:

(i) 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 origin endpoint of the curve, (x_0, y_0).

(ii) 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 destination endpoint of the curve, (x_3, y_3).

(b) Rate the preference for alternatives associated with the other decision variable values relative to these reference alternatives by manipulating the two control points (x_1, y_1) and (x_2, y_2).

Step 3. To each decision variable assign decision maker’s weight.

Step 4. Determine the design constraints.

Step 5. Combine decision variable values to generate design alternatives and use the design constraints to test their feasibility.

Step 6. Use the PFM algorithm to yield an overall preference scale of all feasible alternatives.

This procedure incorporates in the second step the use of Bézier curves to relate decision variable values to preference ratings proposed by Binnekamp (2010, pp. 4-5, 115) to offer a design methodology. A practical example of the PBD is displayed in appendix C.

Binnekamp considers *decision variables* to be synonymous to criteria or design variables or properties (Binnekamp 2010, p. 90).

Binnekamp (2010, pp. 55-56) uses "Zeleny [1982, pp. 225-226] to describe the conceptual and technical differences between constraints, goals, and objectives:

- a *constraint* is a fixed requirement which cannot be violated in a given problem formulation. Constraints divide all possible solutions (combinations of variables) into two groups: feasible and infeasible;
- a *goal* is a fixed requirement which is to be satisfied as closely as possible in a given problem formulation;
- an *objective* is a requirement which is to be followed to the greatest extent possible (either by minimization or maximization) given the problem's constraints".

A *design space* based on Dym and Little (2004) (see paragraph 3.1.5).

A *synthetic alternative* is an alternative associated with a value for a single decision variable value, regardless of other decision variables and regardless of its feasibility (Binnekamp, 2010, p. 89).

3.3.4 Preference-Based Design applications

Binnekamp applied the PBD in three cases. In the Table 3.4 these cases are summarized.

TABLE 3.4 Summary of cases Binnekamp (2010)

	Case 1 Airport Schiphol and region	Case 2 Stedelijk museum Amsterdam	Case 3 Tilburg area development case
level	Urban	Building	Urban
Type of case	"simulation"	Real	Real
# stakeholders	Role play 4 colleague experts	2	1
# variables	4	12	6
Type of curve fitting	n.a.	3 segment predetermined Bezier curve	5 segment predetermined Bezier curve
Weights per criterion	Assumed equally	Assumed equally	Assumed equally
Intra-stakeholder weights	Not taken into account	Assumed equally	Assumed equally
Constraints	2	4	2
# alternatives	36 feasible alternatives	67 108 864	46656
Overall preference rating of best alternative	59 (second table) (first table 80,144)	46	68.343
Results accepted by stakeholders	Not applicable		Outcome considered to be plausible and satisfactory
Evaluation	Before the model was introduced, design decisions were made that turned out to be either infeasible or unacceptable for the museum staff.		The Tilburg urban development case shows that the Bézier curve is easy to work with and appeals to the decision makers concerned.

3.3.5 Preference-Based Design methodology conclusions and recommendations

Binnekamp (2010, p. 145) concluded that the PBD proposed fulfils both requirements. PBD is built upon Preference Function Modeling (PFM) and extends to group decision making (requirement 1) and has a sound mathematical foundation for measuring preference (requirement 2). It also removes all limitations of using either linear programing, goal programming or Linear Multi Objective Programming because it avoids single objective optimization and it removes the harsh division of solutions into feasible or infeasible and the linearity requirement by introducing curves to represent how decision variable values relate to preference ratings. It enables optimization on multiple objectives by selecting the best design alternative based on the decision variables.

PBD also removes the weighted sum limitation by including the PFM algorithm to yield an overall preference scale. Furthermore, it removes the harsh distinction between feasible or infeasible solutions. A solution is only infeasible if it does not meet the design constraints. For the decision variables, each score on the Bézier curve is considered to be feasible.

Binnekamp (2010, p. 145) concluded that PBD reflects the decision makers' preferences more accurately than was done by LP, based on applications in architecture and urban planning. This PBD methodology is successfully applied to cases at a building and area level, but, as of now, has not been applied at a portfolio level.

Binnekamp (2010, pp. 145-146) indicates two recommendations in his work:

1. A drawback of using a limited amount of Bézier curves is that they, because they are pre-determined, do not purely reflect a decision maker's preferences. Future research aimed at devising a user friendly interface so that the decision maker can directly shape the preference curve is desirable;
2. A limitation of the PBD procedure is that it requires generating alternatives by combining *all* values for *all decision variables* and then filtering from these the feasible alternatives using the design conditions. This makes it a 'brute force' approach. As the number of possible combinations equals the number of decision variable values to the power of the number of decision variables, the number of combinations will be very large for more complex problems as these normally have a greater number of decision variables. … Therefore, given the control and end points of all Bézier curves and PFM's algorithm, an optimization algorithm can be used to directly compute the best design (at least approximately). We then have a design methodology which takes into account each decision maker's preferences. Recall that in fact the 'design' part of the LP process is due to its optimization step.

3.4 Foundations in different scientific fields

In the previous paragraphs, basic concepts and definitions from different scientific fields have been explained. The consequence of this is that there are different names for similar concepts. In order to show these similarities, Dym and Little's prescriptive design process, De Leeuw's DDC model, Barzilai's PFM, and Binnekamp's PBD are compared to DAS which has been introduced in chapter 2.

In DAS the primary vocabulary is *demand, supply and match* or *mismatch* (**Figure 3.11**). Demand is also referred to as *need* and supply as *alternatives* or *solutions*. Although, *added value* is the main concept in DAS, it is not visualized as such in the framework. Added value in DAS is represented by the *match* or *mismatch*.

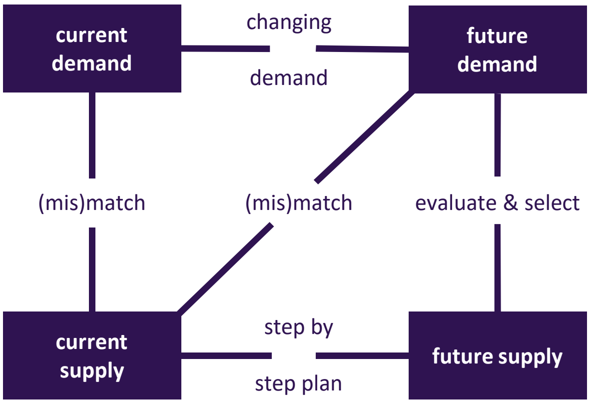

FIG. 3.11 DAS simplified visualization Note simplified DAS adapted from De Jonge, et al., 2009, p. 36), Van der Zwart et al., 2009, p. 3. and Den Heijer, 2011, p. xv

The main concepts as used in design engineering by Dym and Little (2004) are compared to the DAS (see **Figure 3.12).** What stands out is that they do not distinguish between current and future demand. *Demand* is expressed as *client statement* (*need*) or *problem definition*, using concepts as objectives, requirements, constraints, functions which are consolidated in design specifications. *Supply* is expressed primarily as *design* or *design alternatives*.

De Leeuw (2002) on the other hand uses the DDC- model which is a more abstract concise framework. His phase of *diagnosis* is similar to DAS task 2 (future demand matching current supply), while the *design* is similar to future supply (see **Figure 3.13**).

Barzilai uses a finer grain terminology in preference function modeling and Tetra (Scientific metrics 2002-2016) compared to DAS (see **Figure 3.14**). Demand is subdivided into *stakeholders, criteria* and *weight* with no overarching name for these terms. In his evaluation methodology foremost *actual alternatives* (i.e. current supply) are used. For step 6 it is explained that in some decision making situations, an *evaluation plan* is set up for the purpose of assessing *future alternatives*. Since the *actual alternatives* are not known when the evaluation plan is set up, *hypothetical alternatives* must be used to define the reference objects for each criterion (Scientific metrics 2002-2016, pp. 8-9).

Binnekamp (2010) in his PBD uses different terminology than in DAS and slightly different terminology than Barzilai. Preference and design are the two main terms of his methodology. Similar to Barzilai, demand is specified by defining decision variables, preferences, weights and constraints (see **Figure 3.15**). Future supply is referred to as a design alternative, which Binnekamp (2010, p. 3) defines as a combination of decision variable values and its feasibility determined by design constraints and allowed decision variable value ranges. Design variables are design attributes and he considers decision variables to be synonymous to criteria or design variables or properties. He also uses alternative and solution as synonym.

One important remark needs to be made, because the word value is used in two different ways. Firstly, as the equivalent of preference. Secondly, in the description of a design alternative Binnekamp refers to decision variable values. In the latter, value is different from the first, where value is technically equivalent to preference. Value[30], according to the Longman dictionary, is “an amount, which is countable, and technical: a mathematical quantity shown by a letter of the alphabet or sign”.

30 This definition is the seventh definition of value from the Longman dictionary (https://www.ldoceonline.com/dictionary/value)

This means that the following concepts are similar and are used interchangeably in this thesis.

- *Demand* – needs- requirements - diagnose

- *Supply* – alternatives– design – design alternative– solution – situation
  - Current supply – current situation – current design
  - Future supply - alternatives– design – design alternative– solution
  - All feasible alternatives = design space

- *Match/mismatch* = value = preference
  - Value is technically equivalent to preference, therefore the value of an alternative is expressed as overall preference score.
  - Value - overall preference score – overall score – overall preference rating - overall preference scale

- *Evaluate and select alternative* = select or choose best alternative
- Best or satisficing alternative – final design –alternative with most added value, i.e. highest overall preference score
- Added value will be calculated as:
  (overall preference score current supply) – (overall preference score future supply)

- The terms are sometimes intermingled (like demand and alternative or requirements and alternatives) but often the following duo's are used:
  - demand – supply (economics)
  - requirements – design (design)
  - problem – solution (managerial problem solving)
  - (multi-)criteria – alternatives (decision making)

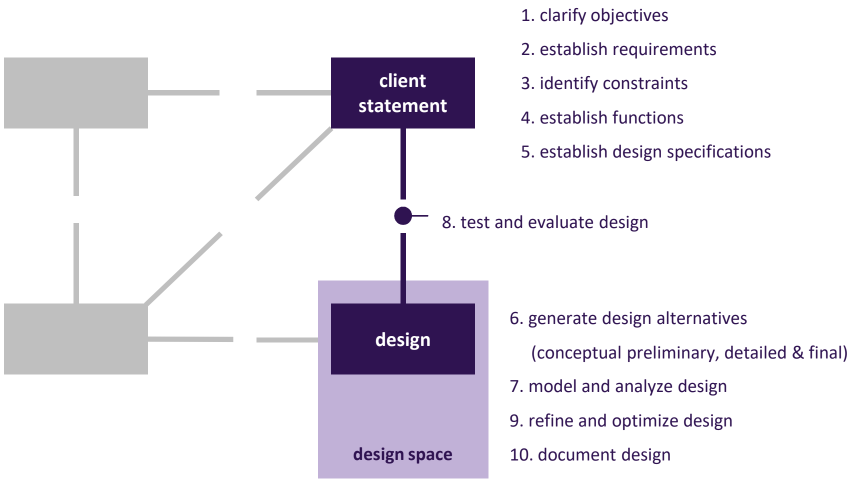

FIG. 3.12 Dym and Little's steps compared to DAS Note simplified DAS adapted from De Jonge, et al., 2009, p. 36), Van der Zwart et al., 2009, p. 3. and Den Heijer, 2011, p. xv

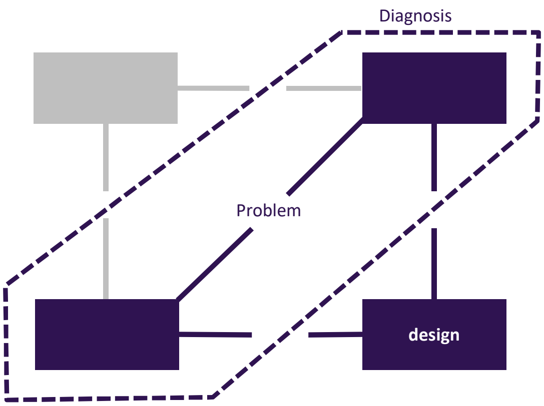

FIG. 3.13 De Leeuw's DDC model compared to DAS Note simplified DAS adapted from De Jonge, et al., 2009, p. 36), Van der Zwart et al., 2009, p. 3. and Den Heijer, 2011, p. xv

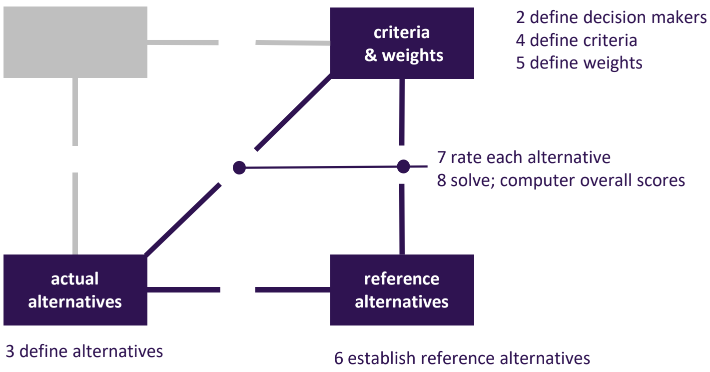

FIG. 3.14 Barzilai's PFM and Tetra compared to DAS Note simplified DAS adapted from De Jonge, et al., 2009, p. 36), Van der Zwart et al., 2009, p. 3. and Den Heijer, 2011, p. xv

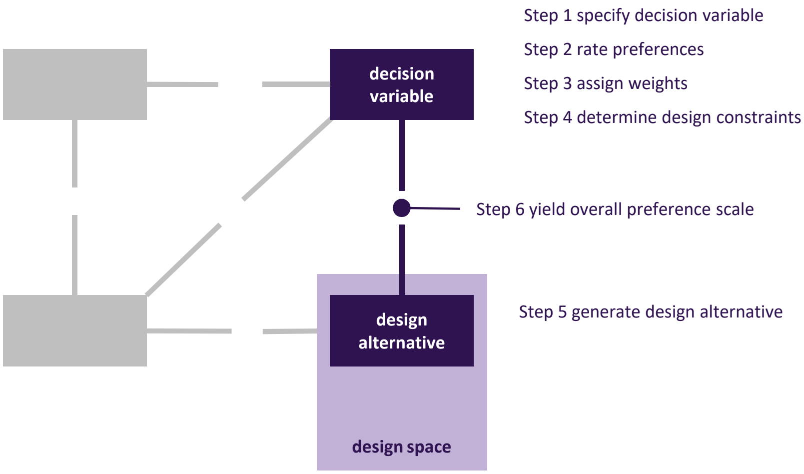

FIG. 3.15 Binnekamp's PBD compared to DAS Note simplified DAS adapted from De Jonge, et al., 2009, p. 36), Van der Zwart et al., 2009, p. 3. and Den Heijer, 2011, p. xv

3.5 Conclusion and comparison

The fifteen basic concepts and definitions from management science, decision theory and design methodology are the methodological aspects, characteristics and features of PAS. By using the fifteen concepts and definitions, past experience benefits the development of PAS.

In PAS all three rationalities are used to open the black-box of decision making in CRE alignment. The *substantive rationality* enables the decision maker to choose an alternative based on the bounded rationality perspective. The *procedural rationality* enables the decision maker to take into account the time perspective when selecting an alternative and the *structural rationality* enables that more than one decision maker is involved. These three rationalities are also used to structure the PAS approach. Next to the three rationalities, Preference measurement and Preference-Based Design are the two core concepts.

Extensive research into existing CRE alignment models has shown that these models still fall short in a number of ways. Eight assessment criteria were logically formulated that would enable CRE manager to do so. These criteria were grouped as follows: selecting an alternative, designing supply and formulating demand. Below, the criteria are compared to the fifteen concepts.

Selecting an alternative

In chapter 2, it was shown that most problems in CRE alignment occur when *selecting an alternative*; none of the models have an overall performance measure that incorporates both quantitative and qualitative criteria, and use correct measurement. These requirements were referred to as respectively, indisputable and correct. PAS is based upon Barzilai's *strong scales* and the practical methodology preference functional modeling. PFM has an *overall preference score* that is able to incorporate all types of values: both financial and non-financial, tangible and intangible, quantitative or qualitative. From a mathematical point of view this or other value categorizations in CRE alignment are unnecessary; in PAS Barzilai only *physical* and *non-physical* criteria are distinguished. Following Barzilai, all physical properties are translated into non-physical properties (i.e. preference), including the preference for receiving and spending money, and aggregated into one overall preference score. By doing so, the restrictions as formulated by Barzilai and others, are avoided.

In order to select an alternative, PAS is based on the hard facilitated goal-oriented

systems approach. The basis is Ackoff and Sasieni's (1968) notation U = f (Xi,Yj) that displays the structure of a generic decision making problem where U stands for utility and represents the goal that one wants to achieve. *In* CRE alignment, *the goal is* to achieve *an optimal added value.* In this thesis, *value* is technically equivalent *to preference* and expressed in an overall preference score (see Figure 3.16).

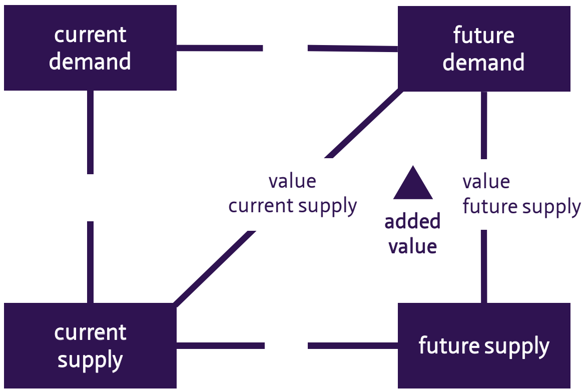

FIG. 3.16 Added value visualized in DAS frame Note simplified DAS adapted from De Jonge, et al., 2009, p. 36), Van der Zwart et al., 2009, p. 3. and Den Heijer, 2011, p. xv

Using the hard goal-oriented systems approach does not mean that the original rationality concept of the 'homo economicus' is used. This rationality concept has been far stretched by Simon's *bounded rationality;* human decision makers are not perfectly informed and also have a limited capacity of information processing. They are not looking for maximum but satisficing alternatives.

This means that, PAS has the ability to be *indisputable* by having one overall preference score and *correct* by using Barzilai's strong scales.

Designing alternatives

In chapter 2, most CRE alignment formulate alternative CRE strategies at visionary level, which than are mostly translated to well-defined criteria. Often, however, they are not translated to the corporate real estate itself, i.e. to the portfolio and building level. It remains unclear how new alternative real estate portfolios are made.

By seeing a designed accommodation strategy (generated by PAS) as a solution for an organization 's strategic accommodation problem, PAS is a *problem solving* *system*. Design as problem solving leads to an instrumental view on the management of the design process because one is not only concerned with understanding reality but also on the basis of that understanding intervening in that reality. *Designing* is a systematic and creative process of activities with the aim of creating a model of a future system that delivers the desired performance taking into account the preconditions (functional process).

In this design process, the design space can be defined as a mental construct (Dym and Little, 2004, p. 97) of an intellectual space that envelops or incorporates all of the potential solutions to a design problem. It reflects the number of possible design solutions and the number of design variables

PAS uses the Preference-Based Design procedure to 'solve' this accommodation design problem. PBD (Binnekamp, 2010) uses the optimization framework of linear programming and Barzilai's methodology, Preference Function Modeling, for measurement, evaluation, and decision making by a single decision maker or a group. Where, PFM evaluates existing alternatives, PBD is able to design alternatives. A *design alternative* is then a combination of decision variable values and its feasibility is defined by the constraints and allowed decision variable value ranges (Binnekamp, 2010, p. 3). The PBD has removed all limitations of using linear programming as it removes the harsh division of solutions into feasible or infeasible and the linearity requirement by introducing curves to represent how decision variable values relate to preference scores. This means that for all criteria, decision variable values are linked to a preference score. Only for criteria that cannot be expressed in a measurable unit preference is rate directly. PAS is structured around the PBD method.

This means that, with these basic concepts and definitions PAS has the ability to iteratively, design an alternative with optimal added value.

Formulating demand

In chapter 2, it became clear that, when formulating demand, most CRE alignment models take a similar approach. The models authors' indicate that all relevant stakeholders need to be involved to formulate an set of well-defined explicit (qualitative and quantitative) criteria to measure their real estate strategy/vision/objectives. Next to that, they state that stakeholders need to be involved, However, it is not clear how the stakeholders are included; whether they set their own criteria and are involved throughout the process.

PAS uses a soft systems to enable the decision makers to determine which goal(s) need to be achieved. PAS is a multi-actor approach were design goal and a design (reality) problem are subjective and linked to a specific problem holder. In PAS these problem holders are the stakeholders and seen both as individual and as group as ‘designers’ and ‘decision makers’. They express their goals into well-defined decision variables in the PBD methodology. While doing this, objectives can include output, throughput and input criteria.

This means that, with these basic concepts and definitions PAS has the ability to explicitly formulate demand that is personal and integral.

Managing the formation of an accommodation strategy

In PAS, management is defined as steering and steering as any kind of directional influence. The stakeholders are designers and decision makers in PAS and part of a human activity system. The essential transformation processes are described in a root definition using CATWOE. This means that, with these basic concepts and definitions, PAS can be represented as a management system. By doing this, PAS is described from the perspective of the organization that executes the process. This is contrary, to the other concepts and definitions where either design or decision making is central.

Different terminology

The consequence of using basic concepts and definitions from different scientific fields in PAS is that there are different names for similar concepts. In this thesis, the following concepts are similar and used interchangeably:

- Demand – needs- requirements - diagnose
- Supply – alternatives– design – design alternative– solution – situation
- Match/mismatch – (added) value - preference
- Evaluate and select alternative - select or choose best, satisficing or optimum alternative