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Real estate portfolio decision making

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Abstract: *In the Netherlands municipalities own a substantial number of buildings within their city which have been acquired to serve societal goals. However, some buildings might no longer serve these goals and could be sold or, conversely, buildings that could serve societal goals can be acquired. More than one decision maker decides which intervention to select, choosing the intervention that meets the different goals best is a multi-criteria group decision making problem.*

Multiple Criteria Decision Analysis (MCDA) methodologies enable the aggregation of the performance rating of alternatives on different criteria into an overall performance rating. Alternatives are rated on preference on each criterion. Given that criteria are properties by which to measure the portfolio's performance on a goal MCDA approaches help to find the intervention that meets different goals best.

A survey is carried out on models that help decision makers to align the real estate portfolio to the organizational objectives and to select the best performing portfolio. The methods did either 1) use (preference) scales to which mathematical operations do not apply or 2) not have a well-defined procedure for selecting the most preferred portfolio. See Barzilai (2007) for the requirements for these operations to be applicable.

Binnekamp (2010) devised a Preference-Based Design (PBD) methodology using preference scales to which mathematical operations are applicable enabling group decision making. This paper describes how this methodology has been converted into a Preference-Based Portfolio Design (PBPD) methodology that 1) allows all decision makers to iteratively enter their criteria and preferences and 2) orders all possible portfolios based on the overall preference rating.

Keywords. *Corporate and public real estate management, portfolio level, multi criteria decision making, preference measurement*

1 Introduction

In this paper we show that "… the conditions that must be satisfied in order to enable the application of linear algebra and calculus, …" (Barzilai, 2007, p. 10) are not satisfied in certain models in the field of corporate and public real estate management. Barzilai (2007, p. 10) "established that there is only one model for strong measurement of subjective variables" and he developed an evaluation methodology called Preference Function Modeling (PFM) (Barzilai, 2005) which Binnekamp (2010) transformed into a design methodology called Preference-Based Design (PBD). This methodology is applied to cases at a building and area level, but has not been applied at a portfolio level. This paper describes how this methodology has been converted into a Preference-Based Portfolio Design (PBPD) methodology.

This paper describes (§2) foundational errors and solutions in decision theory and (§3) evaluates whether these errors are made in real estate portfolio decision making. In (§4) the PBDB methodology is discussed. The paper ends (§5) with conclusions, discussions and recommendations.

2. Decision theory foundational errors and solutions

In the domain of architecture we face the problem of multiple stakeholders having to choose the design that best fits their interests as a group. The scientific foundation of selection (choice) is preference measurement. The construction of the mathematical foundations of any scientific discipline requires the identification of the conditions that must be satisfied in order to enable the application of the mathematical operations of linear algebra and calculus (Barzilai, 2007, p. 8). In addition, the mathematical foundations of social science disciplines, including economic theory, require the application of mathematical operations to non-physical variables. "*Value* (or utility, or preference) is not a physical property of the objects being valued, that is, value is a subjective (or psychological, or personal) property" (Barzilai, 2007, p. 2).

The construction of a model for preference measurement is addressed by Von Neumann and Morgenstern (1944 in Barzilai (2007, p. 2). Elaborating upon Von Neumann and Morgenstern's concepts, Stevens (1946, see Barzilai (2007, p. 4)) proposed a uniqueness-based classification of "scale type" and research interest turned from the issues of the possibility of measurement of psychological variables and the applicability of mathematical operations on scale values to the construction of "interval" scales, i.e. scales that are unique up to an additive constant and a positive multiplicative constant. There is no proof in literature that these scales devised by Stevens (or any model based on Von Neumann and Morgenstern's concepts) allow mathematical operations Barzilai (2007, p. 5).

In reconstructing the foundations of (preference) measurement, Barzilai (2007, p. 5) classifies measurement scales by the mathematical operations that are enabled on scale values. He defines *proper* scales as scales to which the operations of addition and multiplication (including subtraction and division) are applicable (Barzilai, 2007, pp. 8-9). Those proper scales that also enable order and the application of the limit operation of calculus are termed *strong* scales (Barzilai, 2007, p. 10). All other scales, including Stevens' "interval" scales are termed *weak*.

In other words, to evaluate the mathematical foundation of any methodology involving preference measurement, we initially only need to look at the scales used for measuring preference. If the operations of addition and multiplication are applied where they are not applicable, the numbers generated are meaningless.

Barzilai (2004, 2005) developed a new theory of (preference) measurement based on measurement scales to which linear algebra and calculus are applicable. Based on this theory, a practical methodology for constructing proper preference scales, PFM, and the Tetra software tool that implements it, have been developed.

In its current form however, PFM is an evaluation methodology, helping decision makers to choose the most preferred design alternative from a set of already existing alternatives. In the domain of architecture a design methodology is needed, where the design alternatives are not known *a priori*. The following Preference-Based Design (PBD) procedure proposed by Binnekamp (2010) offers such a design methodology:

1. Specify the decision variable(s) the decision maker is interested in.
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, (x0, y0).
      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, (x3, y3).
   b) Rate the preference for alternatives associated with the other decision variable values relative to these reference alternatives by manipulating the two control points (x1, y1) and (x2, y2).
3. To each decision variable assign decision maker's weight.
4. Determine the design constraints.
5. Combine decision variable values to generate design alternatives and use the design constraints to test their feasibility.
6. Use the PFM algorithm to yield an overall preference scale of all feasible alternatives.

Within the PDB procedure design alternatives are defined as combinations of decision variable values. These alternatives are defined as follows. For each decision variable a Bezier curve is defined to relate decision variable values to preference ratings. Each curve is then divided into a number of segments yielding a number of points on each curve. Combinations of points on each curve thus represent design alternatives. The x-coordinates of these points represent decision variable values. Design constraints, relating to decision variable values, are used to test design alternatives on feasibility. The y-coordinates represent preference ratings associated with decision variable values. These are used to determine the overall preference rating for combinations of decision variable values that pass the feasibility test.

This PBD methodology (Binnekamp, 2010) is successfully applied to cases at a building and area level, but, as of now, has not been applied at a portfolio level.

3. Evaluating approaches to real estate portfolio decision making

Real estate decision making on a portfolio level is addressed in real estate management (REM). De Jonge et al. (2009, p. 10) distinguish various specialisations in REM, like: *portfolio management*, also referred to as REM by investors; *corporate real estate management* (CREM): REM (steered) by private organisations or businesses and *public real estate management* (PREM): REM by public parties. This research focuses on CREM and PREM, especially on PREM for municipalities.

De Jonge (1994, p. 15) has positioned CREM in terms of a match between business i.e. the demand side and real estate i.e. the supply side, connecting the strategic and operational level. CREM has the objective to optimally attune corporate accommodation to organisational performance, adding value to corporate objectives and indirectly generating income (De Jonge, 1994). Heywood (2011, p. 1) shows that this alignment is “a long-standing issue”.

Van der Schaaf (2002, p. 5) stated that “public real estate portfolios have very specific characteristics and there is clear evidence of political influence on the quality and location of the buildings included in them”. This has a strong influence on how such properties are managed. She defined PREM within governments as “the management of a government’s real estate portfolio by aligning the portfolio and services to (1) the needs of the users, (2) the financial policy set by the Treasury and (3) the political goals that governments want to achieve” (Van der Schaaf, 2002, p. 6).

Municipalities own 42 million square meter gross floor area size in the Netherlands, which almost equals the size of the Dutch office market (Vastgoedmarkt, 2011). The book value of this portfolio is estimated at 15 to 20 billion euro by Teuben et al. (2007), with an estimated market value of 30 to 37 billion euro. Tazelaar and Schonau (2010, p. 6) indicated that the professionalization of PREM for municipalities in the Netherlands currently is important because of three reasons: (1) the need for more efficient use of municipal real estate; (2) the increasing demand for public accountability; and (3) the quality of municipal services.

In the strategic alignment within CREM and PREM “adding value” and “optimally attuning” are central concepts. The specific interest of this paper is in how preference is measured in these models and how the stakeholders' interests are integrated, i.e. how a strategy is selected, i.e. how an optimal solution is determined.

Consider the following example of such a selection process: a municipality acquired a substantial number of buildings within its city to serve societal goals. However, some buildings (might) no longer serve societal goals and could be sold or, conversely, buildings that could serve societal goals can be acquired. More than one decision maker decides which intervention to select. Choosing the intervention that meets the different goals best is in essence a multi-criteria group decision making problem. Multiple Criteria Decision Analysis (MCDA) methodologies enable the aggregation of the performance rating of alternatives on different criteria into an overall performance rating. Alternatives are rated on preference on each criterion. Given that criteria are properties by which to measure the portfolio's performance on a goal we can expect that MCDA approaches help to find the combination of interventions that aligns the portfolio to the organisational objectives.

For these MCDA models within corporate and public real estate management the work of Barzilai (2007) and Binnekamp (2010) is relevant because Barzilai (2007, p. 2) focuses on measuring preference (synonymous to value and utility) and found errors at the foundations of utility theory. Most CREM models use an algorithm-based approach according to Heywood (2011, p. 6) which he defines as a series of defined steps, meaning that although indicated by the terminology mathematical operations are not necessarily used. In order to determine whether these models are based on mathematically sound foundations CREM and PREM models are evaluated. Firstly it is determined if mathematical operations are used and secondly, for the methods using mathematical operations, if strong, proper or weak scales have been used.

Table 1. Evaluation of CREM and PREM models.

Domain	Authors	Use of mathematical operations	Scales used
CREM	Nourse and Roulac (1993)	Yes	Not indicated
CREM	Edwards and Ellison (2003)	No	N.A.
CREM	Osgood (2004)	No	N.A.
CREM	Scheffer et al. (2006)	Yes	Weak[1]
PREM	Brackertz and Kenly (2002)	Yes	Weak
PREM	Wilson et al. (2003)	No	N.A.
PREM	Van der Schaaf (2002)	Yes	Weak

As can be concluded from Table 1 in three of the four models that *use* mathematical operations weak scales were used, which means that the conditions are *not* satisfied in order for the operations of addition and multiplication to be applicable to scale values. For the three models that do *not use* mathematical operations it can be deferred from the models or case descriptions that mathematical operations are performed when evaluating the performance and/or selecting a strategy. However, in their texts it is not explicitly shown how the preferences were measured and how the overall performance rating was determined. Brackertz and Kenley (2002, p. 62) for instance use employee satisfaction and a customer satisfaction ratio as performance measures. Nourse and Roulac (1993) indicate that they use linear programming but do not specify how. Binnekamp (2010, p. 2, 59-61) also found a major problem relating to the use of LP for solving group decision making problems; the end result is a single objective function that aims to reflect the goals of all decision makers. Edwards and Ellison (2004 p. 27-28) indicate that their framework is a heuristic tool and as such should be used to order information and to facilitate understanding of property problems. The selection and implementation of strategies are brought together in

[1] In this model preference is measured indirectly.

general in the framework and addressed through the case studies. In some case studies they refer to 'overall performance rating'.

We conclude that, as yet, no methodology for designing a portfolio exists which incorporates proper preference measurement. We therefore propose the following preference-based portfolio design methodology.

4. Preference-based portfolio design (PBPD)

It is necessary to convert the PBD procedure in two ways in order to be able to use it on portfolio level. Firstly it is important to note that in the PBD procedure (Binnekamp, 2010) each combination of decision variable values defines no more than one alternative. However, with respect to the problem of real estate portfolio decision making, one combination of decision variable values could define more than one alternative. For instance, consider a portfolio consisting of 3 buildings; building A, B and C. Assume that we are interested in the percentage of buildings that serve societal goals. Also assume that building A is the only building within the portfolio serving societal goals. This means that removing building B or C would both result in a portfolio having 50% of buildings serving societal goals. Conversely, setting this decision variable to 50 would define two alternatives (portfolio with building A and B and the portfolio with buildings A and C), not just one.

To resolve this problem all possible portfolios need to be generated using the number of buildings in the current portfolio and the number of allowed interventions. Given i interventions and j buildings a total of i to the power of j combinations are possible. In this experiment the portfolio consists of 15 buildings and 3 interventions (remove, keep, renovate) are considered. A building can be removed from the portfolio for instance if it is demolished or sold. The total number of possible portfolios is the number of interventions to the power of the number of buildings (3^{15}=14,348,907).

Secondly, approaching the generation of portfolios this way means that the performance of each portfolio is determined *a posteriori*. Going back to the previous example, removing building B is an example of a generated portfolio. Only after this portfolio has been generated it is possible to determine the number of buildings that serve societal goals with respect to the total number of buildings within that particular portfolio consisting of buildings A and C.

However, within the original PBD procedure, the Bezier curve was divided in segments yielding a number of points on each curve. The x-coordinates of these points represented the performance of the alternative with respect to that design variable *a priori*.

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

The above changes mean that the original PBD procedure needs to be changed as follows.

2. Rate the decision maker's preferences for each decision variable as follows:
   a) Establish (synthetic) reference alternatives which define 2 points of a Lagrange 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 first 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 second point of the curve, (x_1, y_1).
   b) Rate the preference for an alternative associated with an intermediate decision variable value relative to the reference alternatives. This defines the third point of the curve (x_2, y_2).

5. Generate all design alternatives (using the number of buildings and allowed interventions). Then use the design constraints to test their feasibility.

In order to evaluate this converted PBPD procedure a case simulation is generated based on the prototype Public Real Estate system under construction (Arkesteijn et al. 2010) for the municipality of Rotterdam.

Step 1: Specifying the decision variable(s)

The following six decision variables for the specified stakeholders within this municipality are used. (1) Policymaker: the percentage of buildings within the (new) portfolio serving societal goals. (2) Policymaker: the percentage of buildings within the (new) portfolio having an overall preference rating of 40 or more on the criterion 'user satisfaction'[2]. (3) Technical manager: the percentage of buildings within the (new) portfolio having an overall preference rating of 40 or more on the criterion 'technical state'. (4) Asset manager The percentage of buildings within the (new) portfolio for which the rent covers the cost. (5) Users: The gross floor area of the (new) portfolio and (6) Policymakers: The additional yearly rent due to renovation.

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

Table 2 shows for each decision variable value the 3 points that relate decision variable values to preference ratings. These 3 points define a Lagrange curve (example for decision variable 1 is given in Figure 1).

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

Table 2. Decision variables and associated decision maker's preference ratings.

Decision variable	x0,y0	x1,y1	x2,y2
1. Percentage of buildings serving societal goals	40,0	80,50	100,100
2. Percentage of buildings scoring ≥40 on user satisfaction	0,0	50,70	100,100
3. Percentage of buildings scoring ≥40 on technical state	20,0	50,60	100,100
4. Percentage of buildings for which rent covers costs	0,0	50,60	100,100
5. Gross floor area	1794,0	1709,100	1628,0
6. Additional yearly rent due to renovation interventions	0,100	30k,40	60k,0

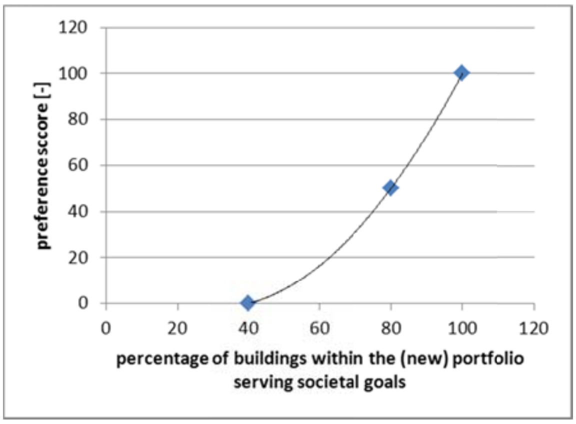

Figure 1. Lagrange curve relating preference rating to the percentage of buildings within the portfolio serving societal goals.

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

Table 3 shows for each decision variable value the weight assigned by the associated decision maker.

Table 3. Decision variables and assigned decision maker's weights.

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

Step 4: Determining the design constraints

For this experiment no design constraints are used.

Step 5: Generating all design alternatives

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

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

Table 4 shows the top 10 of portfolios ordered on associated preference ratings. It also shows the overall preference rating of the current portfolio (keep all buildings). In this case, without strict financial limitations, the highest rated portfolio shows a possible overall performance improvement of 57.9.

Table 4. Top 10 of portfolios sorted on overall preference rating (0=remove, 1=keep, 2=renovate)

Portfolio	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Rating
9388514	1	2	2	1	2	2	2	2	2	1	2	1	2	0	2	75.6
9388502	1	2	2	1	2	2	2	2	2	1	2	1	0	2	2	75.6
9387773	1	2	2	1	2	2	2	2	1	1	2	1	0	2	2	75.5
9387785	1	2	2	1	2	2	2	2	1	1	2	1	2	0	2	75.5
9033491	1	2	1	2	2	2	2	2	1	1	2	1	2	0	2	75.4
9033479	1	2	1	2	2	2	2	2	1	1	2	1	0	2	2	75.4
8857073	1	2	1	1	2	2	2	2	2	1	2	1	2	0	2	75.2
8857061	1	2	1	1	2	2	2	2	2	1	2	1	0	2	2	75.2
8856344	1	2	1	1	2	2	2	2	1	1	2	1	2	0	2	75.1
8856332	1	2	1	1	2	2	2	2	1	1	2	1	0	2	2	75.1
Current	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	17.7

5. Conclusions, recommendations and discussions

We conclude that, as yet, no methodology for designing an portfolio exists which incorporates proper preference measurement. We recommend that more than seven models will be evaluated.

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

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

Despite these limitations, we see the proposed PBPD procedure and associated model as a proof of concept for applying it in practice. Currently work is being carried out to find the search algorithm. The next step will be to evaluate the PBPD procedure in practice.

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