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Establishing best practice university research funding strategies using mixed-mode modelling ☆

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ABSTRACT

This paper develops a model representing the university research funding problem under a performance based research funding (PBRF) scheme during the 'lead-up period' using a mixed-mode modelling approach (involving soft and hard models) and suggests a solution heuristic. The resultant model facilitates the development of 'best practice' strategies to assist in raising the level of research quality and participation, thus placing the university (or academic unit) in the best possible position for facing the final hurdle, the formal research assessment process. This assessment process constitutes the 'positioning problem', for which models already exist to assist individual universities to adopt the most favourable strategy. However, the ultimate position of the university depends on the results from the lead-up period. The suggested model facilitates 'research enhancement' strategy formulation, evaluation and revision and actively involves the researchers themselves. Benchmarking, an Expert Panel (operating on panel consensus) and subjective strategy impact evaluation are the key tools used. The suggested methodology relies on the knowledge, wisdom and experience of the researchers themselves and will hopefully facilitate the achievement of an academic unit's research goals over the lead-up period preparing them for the 'positioning problem'. The paper also offers some suggestions as to how to establish and obtain maximum usefulness from the expert panel. Lastly, the suggested solution to the suggested model is user friendly, requiring no more than the use of a spreadsheet.

1. Introduction

With the adoption of performance based research funding (PBRF) models occurring in many countries (the Excellence in Research for Australia [ERA] for example), and already a fact of life in others (the Research Assessment Exercise [RAE] in the UK) many universities are in the process of either changing or refining their strategies for maximizing their research funding. For a more detailed account of the various PBRF schemes in operation, see Guena and Martin [1] and Liefner [2]. In Australia prior to 2008, research funding was essentially based on research quantum, i.e., the larger the number of publications, research grant funding received and research candidates completing, the more the funding received. This 'quantum' system was on an annual cycle, whereas the foreshadowed quality based model is expected to be on a six year cycle similar to the current Research Assessment Exercise (see HEFCE, [3]) in the UK. This change from research quantity to research quality will require some different approaches to managing research activity. In the UK, despite mooted changes to its RAE funding scheme [4,5], the emphasis will still be essentially on quality but with it being assessed more by 'bibliometric' means rather than full assessment panels as was the case in the past.

In the UK and Australia, academic units need to find answers to two major questions. Firstly, what strategies should be followed during the lead-up period prior to the formal research quality assessment process to potentially maximize the opportunities for research funding at the end of the current research quality cycle (*the university research funding lead-up problem*). Secondly, given their research quality and participation levels at the end of the research quality assessment cycle, which of the available research output (and thus participants) should be put forward for the formal government research quality assessment process (*the university research funding positioning problem*). In the UK, a positioning strategy for many (especially the 'new' universities) is to forget about immediate research funding and concentrate on obtaining the highest quality rating possible with small participation. For example, an academic unit might have relatively few experienced researchers who can produce high quality research output, with a majority of the remainder of the academic staff only able to produce low quality research output. Essentially, PBRF models require the highest participation and quality levels

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possible for the final quality assessment and consequential government funding decisions.

This paper suggests a methodology to assist an academic unit (faculties, schools or discipline groupings) in formulating and implementing strategies during the lead-up period in order to best position itself for the formal quality assessment, i.e., achieve the maximum possible research publication quality together with the highest participation by academics in producing this research output. This level is also where the greatest chance of success lies for implementation [6]. The methodology suggested requires direct involvement by researchers and other experts within the academic unit at all stages. The suggested procedures are therefore heuristic and potentially deliver 'best practice' rather than 'optimality'. Further, the suggested procedures for strategy development, implementation and monitoring require nothing more than a simple spreadsheet. The relatively straightforward 'mechanics' of the solution heuristic are hidden and need not be seen by the participants. This makes the approach user friendly.

To better understand the relationship between eventual quality and participation used in the formal quality assessment process (at time T—the end of the assessment cycle) and the resultant research funding, a simple funding model (based on the RAE) is summarised below. There are far more complicated representations of this problem for the interested reader [7].

The research funding allocated to an academic unit as a result of the quality assessment at time T can be expressed as

$$RF_T = f(Q_T, P_T) \tag{1}$$

where RF_T, Q_T and P_T are the research assessment funding received, quality level and the number of academics participating in the quality assessment, respectively, in an academic unit at the formal research quality assessment process at the end of the quality assessment cycle (T). Note that the research output put forward for assessment (and thus the academics producing it) is selected by the academic unit in the case of the RAE (or its replacement). Fig. 1 shows the different weightings given to the different quality levels for funding determination. In Fig. 1, Quality Rating 1 ($QR1$) has zero funding, while Quality Rating 2 ($QR2$) has a weighting of 1 and Quality Ratings 3 and 4 ($QR3$, $QR4$) weightings of 2 and 4, respectively. The level of funding is determined thus:

$$RF_T = \delta_T P_T f \tag{2}$$

where δ_T is the quality weighting factor assigned to an academic unit as a result of the formal research quality assessment process and f is the funds per participant allocated by the assessment.

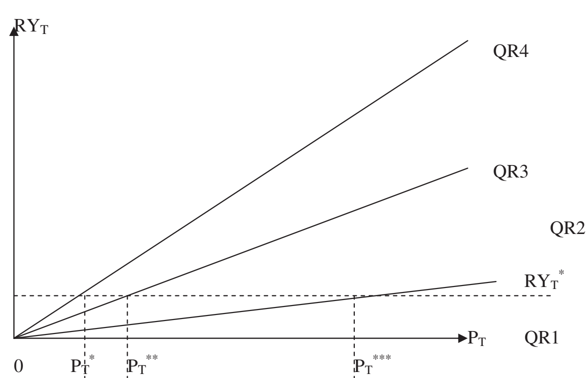


Fig. 1. Quality, participation and research income.

Note that

$$\delta_T = \begin{cases} 0 \text{ iff } QR = 1 \\ 1 \text{ iff } QR = 2 \\ 2 \text{ iff } QR = 3 \\ 4 \text{ iff } QR = 4 \end{cases} \tag{3}$$

Fig. 1 highlights the obvious 'positioning problem'. From Fig. 1 it is apparent that there are three ways (out of many) to generate the same level of funding. Participation levels P_T^*, P_T^{**} and P_T^{***} all yield the same research income RY_T^*. Fig. 1 also highlights the impact that increasing the δ_T and P_T variables will have on funding. This paper aims to develop a means of arriving at strategies that will achieve such increases, leaving the academic unit in the best possible position for the positioning problem at the end of the research quality assessment cycle.

An academic unit will normally aim to maximize its funding at the formal research quality assessment process at the end of the quality assessment cycle (T). This non-linear objective is drawn from (2) and is

$$\text{Max } Z_T = \delta_T P_T f \tag{4}$$

where Z_T is the academic unit's objective function at the end of the research quality assessment cycle. Maximizing δ_T and P_T will require identification and implementation of appropriate strategies during the lead-up period, the prime concern of this paper.

With respect to the lead-up problem, it should be noted that writers such as Talib [8] and Talib and Steele [9] (amongst many) do not totally ignore this issue of strategy development in the lead-up, but when they do refer to it, they generally adopt a very narrow perspective ignoring human resource management and secondary economic issues and concentrate only on budgetary matters. Additionally, their models tend to be complicated and not readily applied by an academic unit. Thus, how an academic unit positions itself for the quality assessment process (i.e., solution to the positioning problem) will therefore depend on how close it is to its targets set in the lead-up problem.

It should be noted that in the Australian situation, the proposed ERA funding scheme [10] will include all academics above a certain level in the assessment unless they are designated "teaching only". There is little room therefore under this scheme for the 'positioning' game to be played at the end of the lead-up period and the lead-up problem becomes even more important. In the UK, the RAE still allows the academic units to select who they will put forward for the assessment—this does not need to occur early on in the lead-up period; thus the lead-up period is a significant planning period for ramping up quality publications, etc.

2. A model of the university funding lead-up problem

Before any model can be developed, simple annual measures of quality and participation are required as well as the development of an objective function encompassing these. The determination of the best practice strategy for maximizing research funding for an academic unit will require evaluation of the direct funding and the secondary economic impact as well as the human resource management implications, on an annual basis throughout the lead-up period.

2.1. A measure of quality

How can quality (or at least an approximation thereof) be measured on an annual basis? A research quality index (Q) has recently been proposed and illustrated by Nicholls [11], which helps answer this question. This research quality index takes into account publication, research grants and higher degree by research activity by an academic unit. It is possible to disaggregate the index so that only one or two of the elements are taken into account, e.g., publications and research grants. For the UK (RAE) and Australia the first element pertaining to publication quality would be the primary component of interest. This index was developed to enable an academic unit to track and benchmark its quality over the period of time in between the assessment cycles (the lead-up period), since it is not feasible for an academic unit to replicate the formal official quality assessment process on an annual basis.

Most PBRF regimes focus on the quality of journal publications (for the RAE 70% in 2008). Consequently, for the purposes of this paper, the research quality index will be limited to this aspect. For research publications, the index uses a surrogate measure of quality, namely, top international journal publications (or equivalent). For research grants, only the highly competitive and prestigious are taken into account and with respect to higher degree by research, the expected completion rate of Ph.D. candidates is used. These attributes of an academic unit (which also take into account the participation by academics) form the basis of the research quality index. The index (Q) is expressed as

$$Q_t = a_1\, PP_t + a_2\, PR_t + a_3\, PCT_t \tag{5}$$

$$a_1 + a_2 + a_3 = 1.0 \tag{6}$$

$$0.0 \leqslant a_1, a_2, a_3 \leqslant 1.0 \quad (t = 1, \ldots, T) \tag{7}$$

where Q_t is the research quality index for an academic unit at the end of academic year t and can take on values from 0 to 1; PP_t the proportion of the industry best (IB) *per capita* publication rate that an academic unit has achieved in academic year t by its *per capita* (using for example Tier 1 journals) publication rate, i.e., the publication quality index; PR_t the proportion of the industry best (IB) *per capita* research income amount that an academic unit has achieved in year t (i.e., the research grant quality index), PCT_t the proportional achievement of the IB that an academic unit has managed in year t associated with higher degree completions (i.e., the higher degree quality index), a_1, a_2, a_3 the weights assigned to each of the component parts of the composite index (e.g., publications quality assessment component in the 2008 RAE is weighted 0.7; therefore one might set $a_1 = 0.7$) and T the end of the current lead-up period prior to the research quality assessment cycle.

Here, industry best (IB) refers to the academic unit that is the recognized leader with respect to the attributes being measured, i.e., quality publications *per capita*, prestigious research grants *per capita* and the Ph.D. completion rate (see Nicholls [11]). Note also that if an academic unit exceeds the *IB*, then it becomes the *IB* with (for publications for example) $PP_i \equiv 1$. Thus, using the index's research publication quality surrogate (i.e., $Q_t = PP_t$ with $a_1 = 1$), an appropriate and measurable indicator of quality is available. Industry best data are available (at least in New Zealand and Australia) through government publications, university websites and academic unit research reports on an annual basis. The expression for PP_t in (5) in proportional terms is

$$Q_t = PP_t = ((J_t/S_t)/p(IB)_t) \quad (t = 1, \ldots, T) \tag{8}$$

where Q_t is the surrogate measure for research publication quality for an academic unit in year t (a proportion); PP_t the proportion of the industry best (*IB*) *per capita* publication rate for Tier 1 journals that an academic unit has achieved in year t (as in (5)); J_t the number of (say) Tier 1 journal articles produced by an academic unit in year t; S_t the number of equivalent full-time academic staff of an academic unit in year t; and $p(IB)_t$ the industry best (*IB*) *per capita* publication rate in year t.

Since this is a model for internal and competitive benchmarking, whether only Tier 1 (A^*) journals or Tier 1 and Tier 2 (A) journals are used is a matter of choice, provided consistency is maintained. In Australia, the Australian Research Council (the organisation that administers the ERA—the PBRF scheme) is developing lists that categorize the journals into tiers making the journal ranking task easier for academic units.

2.2. A measure of participation

A simple measure of participation by academic staff in selected research activities can easily be established as follows:

$$P_t = (AR_t/S_t) \quad (t = 1, \ldots, T) \tag{9}$$

where P_t is the measure of participation in research publication in an academic unit in year t (expressed as a proportion) and AR_t the number of active researchers who contributed to the research publications (as distinct from the total number of equivalent full-time staff) in the academic unit in year t.

2.3. The quality/participation objective

The establishment of the measures of quality and participation permits the specification of an appropriate goal for the academic unit, i.e., the 'objective' (Z_t) using (8) and (9), as follows:

$$\text{Max } Z_t = (J_t(S_t^{-1}/p(IB)_t))(AR_t S_t^{-1}) \tag{10}$$

or

$$\text{Max } Z_t = Q_t P_t \quad (t = 1, \ldots, T) \tag{11}$$

Thus an academic unit will want to adopt strategies that maximize the number of (say) Tier 1 academic journal publications (J_t) in Q_t and the number of academic staff participating in this activity (AR_t) in P_t focusing initially on whichever of these variables has the highest priority for the academic unit.

The objective function has a maximum value of 1 and a minimum of 0 and conveys the double nature of the objective of the academic unit, i.e., to maximize the quality (Q_t) and the participation (P_t) components. An academic unit can maximize the quality measure ($Q_t = 1$) but still see the overall objective function far from its maximum unless the participation element is also maximized ($P_t = 1$). For the IB academic unit, the quality element (Q_t) is by definition 1 but its participation (P_t) needs to be taken into account and therefore its Z_t value may be less than 1 (since $P_t < 1$). The academic unit may set interim 'target' values for Z_t.

The objective function can be tracked over time as the quality and participation values change as a result of the academic unit's research performance. The objective function value (Z_t) as well as the movements of P_t and Q_t can clearly be seen (as shown in Fig. 2), giving an indication as to how the academic unit is progressing towards its goal and whether the movement is either participation and/or quality led (e.g., quality improving faster than participation, participation improving faster than quality or both improving equally). Figs. 2 and 3 illustrate this. In Fig. 2, the isoquants (Z_1, Z_2, etc.) reflect all the possible combinations of P_t and Q_t that yield a given Z_t value. Each Z_t isoquant in this illustrative case represents an academic unit's objective function at a given value and time. Using the P_t and Q_t values, the isoquants *per se* (see Fig. 4) can be identified as well as the *points* on the isoquant (see Fig. 5). The distance from one to the other isoquant indicates the rate of progress towards the goal ($Z_t = 1$) (in Fig. 2 decreasing); moreover, by plotting the actual values of an academic unit's P_t and Q_t for each year on the appropriate

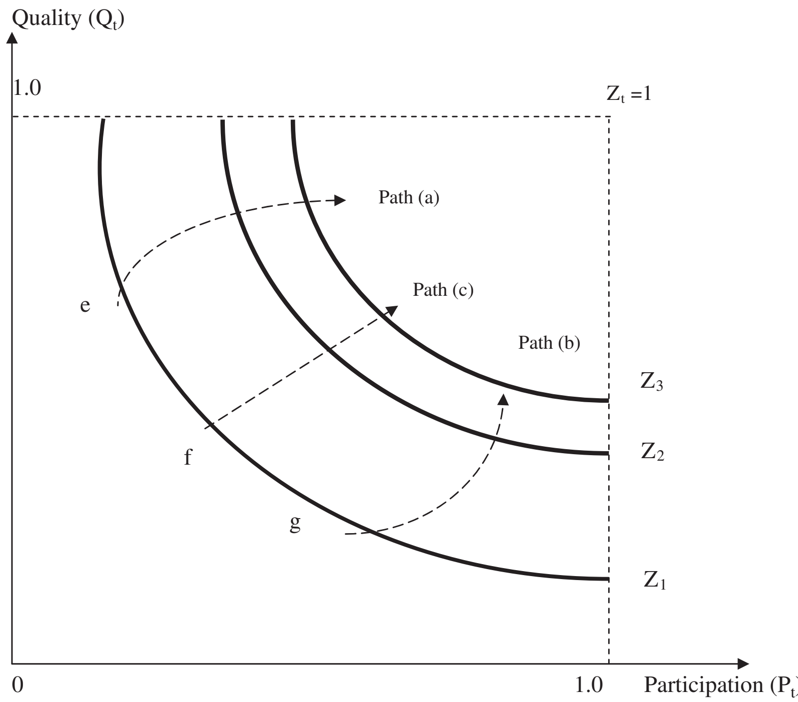


Fig. 2. The $Q-P$ map showing the objective function (isoquants) and potential strategy paths.

isoquant, one can see whether the 'path' towards the academic unit's goal is participation led (path (b) in Fig. 2), quality led (path (a) in Fig. 2) or participation *and* quality led (path (c) in Fig. 2). The '*Z* isoquants' are indicative of the research funding that will flow to the academic unit from the funding authorities (as shown in the model of the PBRF scheme discussed earlier in the paper and illustrated in Fig. 1). Since academic units will have the values for P_t and Q_t, the task of constructing Fig. 2 (and Figs. 4 and 6) will not be great. An illustrative case is given later in the paper.

2.4. A dilemma

Having identified the so-called 'variables', the question is: can they be *directly* influenced, i.e., does an academic unit have direct control over these? The answer is that of course it does not. At best an academic unit will have *indirect* control over J_t and AR_t through various *actions* that they might take during the course of an academic year (i.e., quality and participation are behavioural functions (bf) of actions). An academic unit's influence on these 'variables' is unfortunately indirect as people are involved. Sometimes the actions will be correct and have the right consequences (i.e., they will move the 'variables' in the right direction): other times they will be either incorrect or will not result in the expected magnitude of change in Z_t.

The actions, which in turn affect the variables, will generally have consequences, expected and unexpected. If, for example, an academic unit were to "pay a bounty" on all Tier 1 publications published by its academic staff, it might find that directly it ends up exceeding its budget (a budgetary impact). Alternatively, as a secondary effect, the action may lead to a reduction in teaching time available, since a large number of its academics decided to dedicate themselves to research and therefore reduced teaching time (a secondary economic impact). Further, the action might disengage those academics who are either early career researchers or non-researchers to such an extent (since they cannot participate in the "bounty scheme") that they become disengaged and their effectiveness as teachers diminishes considerably and causes a drop in overall morale (a people management issue). The actions therefore need to be considered carefully in the light of these types of considerations. Hence, in line with the above discussion the actions are subject to a number of constraints: direct (economic, budget), indirect (maintenance of minimum teaching time, etc.) and human resource considerations (e.g., disenfranchisement and loss of morale). These are real world considerations!

An academic unit might also choose a number of actions that are aimed at producing a result that is thematic, i.e., concentrating on an increase in participation (path (b) in Fig. 2) or aimed at increasing the quality of publications (path (a) in Fig. 2). The groups of actions focusing on the themes constitute *strategies*. Strategies are therefore defined as a group of actions ($\boldsymbol{a}$) that are *changes* to current research encouragement activity levels (α) and that *indirectly* influence the J_t and AR_t variables. It is this *indirect (and subjective)* control over the variables through the actions and their human resources implications that requires the problem to be formulated and solved using a mixed-mode modelling approach (discussed later in this paper). The subjective forecasting of the actions' impact on the variables (and thus objective) and the strategy formulation *per se* also reinforce the need for this approach. The determination of the actions and their potential impact on the variables requires input from the academic unit's experts (i.e., expert advice) obtained through an Expert Panel (using consensus) or possibly even a Delphi approach as well as from academic staff through say School meetings. Thus, *subjectivity and/or judgement is an integral part of the solution to the problem*. How this is implemented in practice will be discussed later in the paper.

The indirect relationship between strategies, variables and actions in an academic unit in period t, for the kth strategy may be written as follows:

$$J_{k,t}, AR_{k,t} = bf(a_{k,r,t}) \tag{12}$$

with

$$\mathcal{S}_{k,t} = \{a_{k,r,t}\} \tag{13}$$

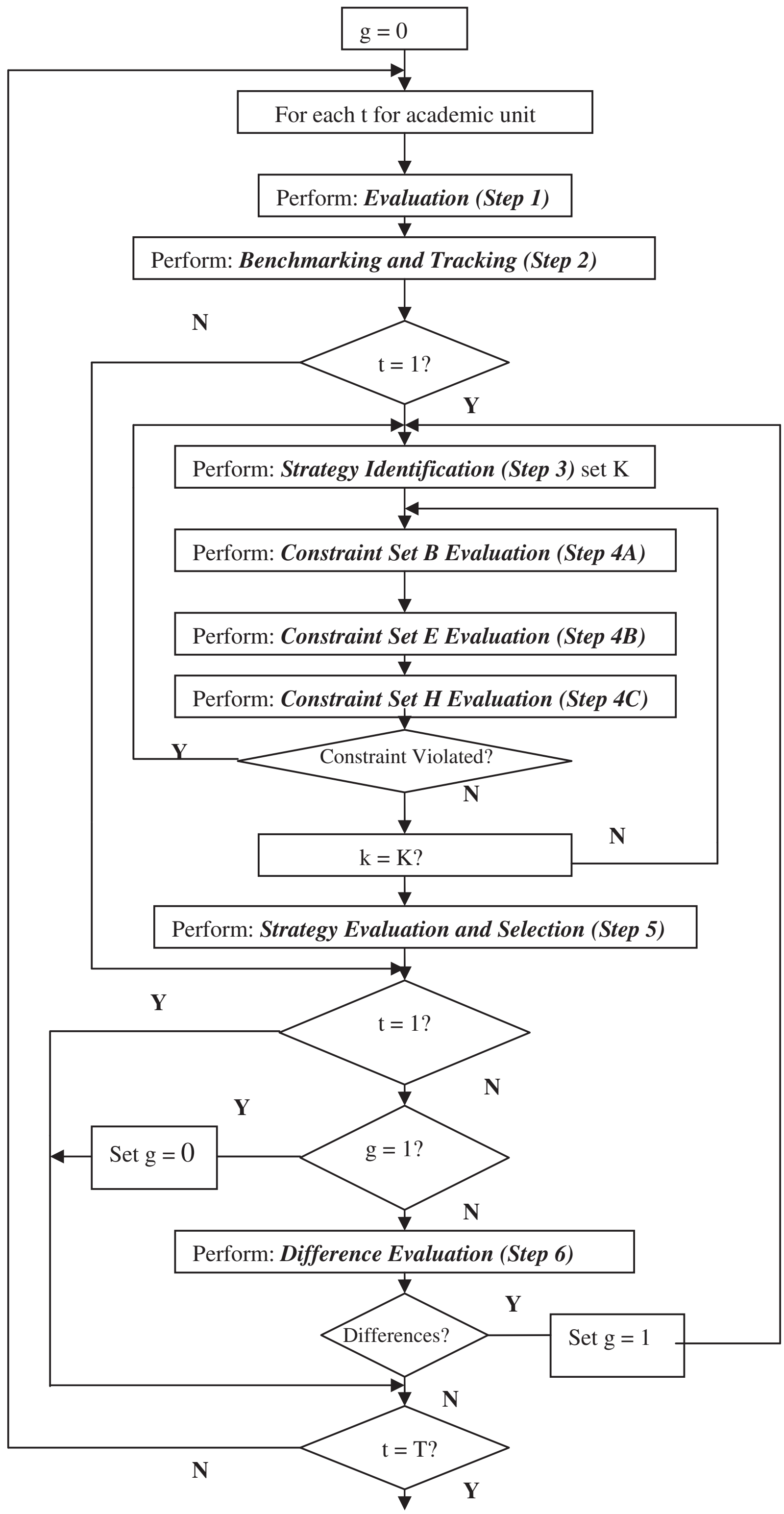


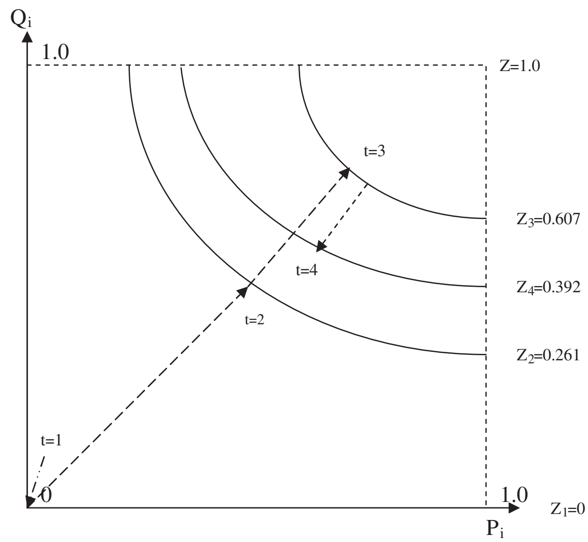
Fig. 3. The mixed-mode modelling solution heuristic

where

$$a_{k,r,t} \geq -\alpha_{k,r,t} \quad (k=1,\ldots,K) \quad (r=1,\ldots,R(k)) \quad (t=1,\ldots,T)$$

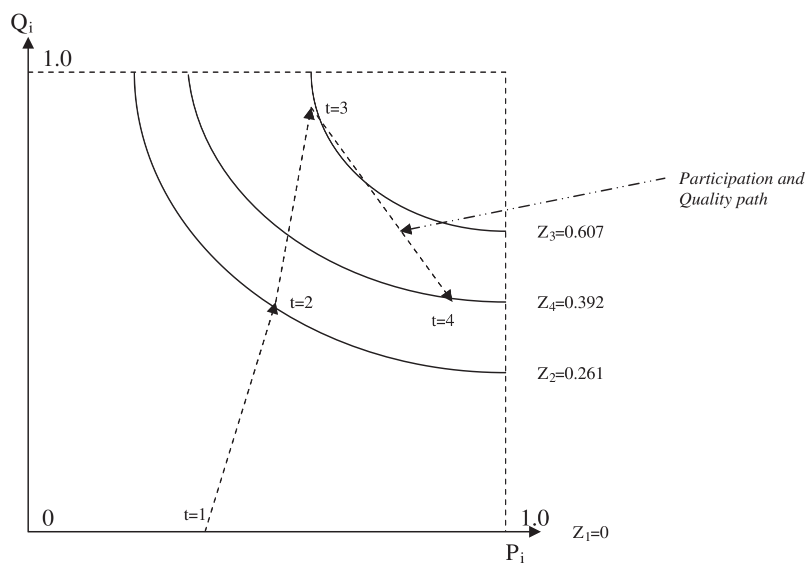
where $J_{k,t}$ and $AR_{k,t}$ are the publication and participation variables for an academic unit arising from the application of Strategy k at time t, $\mathcal{S}_{k,t}$ an academic unit's Strategy k at time t, $a_{k,r,t}$ an academic unit's rth action in Strategy k for time t and $R(k)$ the number of actions making up Strategy k for an academic unit. This is assumed to be the same for $\forall t$ and if an action is not undertaken in a period then it is null and its impact is zero.

Note that $a_{k,r,t}$ might contain activities that require reductions; hence the actions can be negative. (e.g., "reduce non-research intensive staff by six") but the actions cannot reduce levels of activity by an amount greater than their current level $\alpha_{k,r,t}$ (e.g., negative journal output). Each of the Strategies' actions will also involve direct resource (funding), secondary economic



Where Z_1 represents the Z isoquant for the academic unit at time t=1 and arrows indicates the direction of movement of the academic unit across the isoquants – t=4 saw a decline in performance.

Fig. 4. *Z* isoquants ($Q-P$ map) for the academic unit X 2005–2008.



Where Z_1 represents the Z isoquant for the academic unit at time t=1.

Fig. 5. $Q-P$ map showing the participation—quality path of the academic unit X 2005–2008.

impact and human resource management aspects, i.e., constraints. These actions represent changes to existing (or the creation of new) levels of activity; therefore their impact on the various constraints will be *changes* to the level of usage. Consequently, the right hand sides of the constraints used in the strategy evaluation will be the residual resources available (current slack) given the existing level of activities in operation in an academic unit. The constraints for each strategy need to be evaluated separately.

The constraining factors can be categorized under three main headings, namely budgetary, secondary economic impact and human resources management issues. The first two constraint categories are essentially budget and secondary economic impact constraints, which are objective and quantitatively expressed (see Nicholls and Cargill [12] for more discussion). The third constraint category is subjective and human based, i.e., it focuses on human resource matters connected with the actions undertaken. Consequently, this group of constraints is dealt with in a 'soft' manner (i.e., not in an analytical way) within the solution heuristic. Specifically, they are dealt with by an expert panel who has the judgement and experience to reach consensus about whether actions leave the human resources constraints still satisfied or not.

3. The constraints associated with the actions constituting the strategies

The *L* budgetary constraints can be written as

$$\mathbf{B}_k \boldsymbol{a}_{k,t} \leq \mathbf{b}_{k,t} \tag{14}$$

where $\mathbf{B}_k$ represents an $(L \times R(k))$ matrix of budgetary constraint coefficients for an academic unit associated with Strategy k, $\boldsymbol{a}_{k,t}$ an $(R(k) \times 1)$ vector of actions that an academic unit might use for Strategy k in period t and $\mathbf{b}_{k,t}$ an $(L \times 1)$ vector of right hand side residual values (e.g., spare budget capacity for various sub-categories of budgetary constraints) for an academic unit associated with Strategy k at time t. Some of the budgetary constraints include staffing, recruitment costs, research facilitation and training and so on.

The secondary economic impact constraints are quantitative (hard) in nature but are not budgetary. These constraints can relate to issues such as opportunity costs of actions in a strategy (hard). An example might be that the increase in time allocated to research activity to academic staff reduces the time available to undertake the necessary teaching activities. This in turn means that extra teaching capacity must be purchased at an increased cost to the academic unit. There will be limited finds available for these consequential actions and thus they form constraints, but not necessarily of a direct budgetary nature.

The constraints may be written as follows:

$$\mathbf{E}_k \boldsymbol{a}_{k,t} \le \mathbf{e}_{k,t} \tag{15}$$

where for the M secondary economic impact constraints, $\mathbf{E}_k$ is a $(M \times R(k))$ matrix of secondary economic impact coefficients that an academic unit might use for Strategy k and $\mathbf{e}_{k,t}$ a $(M \times 1)$ vector of right hand side *residual* values for an academic unit associated with Strategy k at time t (i.e., limits for various subcategories of secondary economic impact constraints).

The human resources management 'constraints' are simply a list of the areas to be considered *and satisfied* in obtaining a 'solution'. Because these are qualitative, they only need to be satisfied as assessed by the expert panel and hence there is no formal 'right hand side'. This situation is reflected by the notation adopted to represent this class of 'constraints', i.e., (16).

The N human resource management (constraining) issues that an academic unit might use for Strategy k in period t expressed qualitatively can be written as

$$\mathbf{H}_k(\boldsymbol{a}_{k,t}) = \mathcal{S}_{k,t} \tag{16}$$

where $\mathbf{H}_k$ is a list of the N issues and associated information associated with an academic unit's Strategy k that need to be considered and *satisfied*. Here, $\mathcal{S}_{k,t}$ represents 'satisfied'. All the issues are 'soft' ones in this constraint category. Some of the issues include staff morale, staff productivity, change management, industrial matters and support issues. Again, these will be discussed in the next section. An example of such a 'constraint' might be the impact on existing staff (in both productivity and morale terms) of implementing forced redundancies in order to make way for newly recruited high impact experienced and productive researchers.

Additionally, for convenience it is assumed that the coefficients associated with $\mathbf{B}_k$, $\mathbf{E}_k$ and the data associated with $\mathbf{H}_k$ are time invariant. This in reality will not necessarily be true since the cost coefficients associated with academic and general staff will almost by definition change on an annual basis.

3.1. The model of the university research funding lead-up problem

Combining the objective function and constraints developed above, a general representation the two variable multiple actions 'mathematical' model for an academic unit at time t for Strategy k is arrived at. It is not suggested that this can be solved using an analytical approach, but is merely a representation of the problem which is:

$$\mathrm{Max}\, Z_{k,t} = (J_{k,t}(S_{i,t}^{-1}/p(IB)_t))(AR_{k,t}S_t^{-1})$$

s.t.

$$\mathbf{B}_k \boldsymbol{a}_{k,t} \le \mathbf{b}_{k,t} \tag{17.1}$$

$$\mathbf{E}_k \boldsymbol{a}_{k,t} \le \mathbf{e}_{k,t} \tag{17.2}$$

$$\mathbf{H}_k(\boldsymbol{a}_{k,t}) = \mathcal{S}_{k,t} \tag{17.3}$$

$$J_{k,t}, AR_{k,t} = bf(\boldsymbol{a}_{k,t}) \tag{17.4}$$

$$\boldsymbol{a}_{k,t} \ge -\boldsymbol{\alpha}_{k,t} \tag{17.5}$$

$$(k = 1,\ldots,K) \quad (t = 1,\ldots,T) \tag{17}$$

Using (13), the best set of actions (and their magnitudes) will be determined for each strategy. The overall 'best practice' strategy ($\mathcal{S}^*$) is then determined:

$$Z_{k^*,t}^* = \mathrm{Max}_k(Z_{k,t}) \tag{18}$$

In (17), note that (17.3) represents the 'soft' constraints and (17.4) the indirect relationship between the variables and the actions that might alter them. The solution heuristic is discussed and demonstrated in the next section.

4. The heuristic solution to the university research funding lead-up problem

4.1. The use of mixed-mode modelling

The selection of an appropriate methodology with which to both formulate and solve this problem is critical as was observed previously. An approach that allows the subjective/qualitative ('soft') and objective/quantitative ('hard') aspects of the problem and its solution to be fully represented and integrated (not just mixing hard and soft techniques) is needed. The solution to the problem requires the direct participation of the academic unit's staff in formulating strategies, evaluating their likely impact, deciding which one to use and ultimately assessing the actual impact on participation and quality at the end of the planning period (each year). In effect, people and their judgements (iteratively) constitute many of the 'sub-models' in the solution heuristic. Further, the choice of actions and their level have an *indirect* and, *a priori*, a deterministically *unquantifiable* impact on the variables, making a quantitative approach *per se* to the problem inappropriate. Mixed-mode modelling facilitates just such a problem's formulation and solution.

The term mixed-mode modelling has been well explained by Eden et al. [13] as "*….the interaction between qualitative aspects of a problem and the insights that may be provided by quantitative modelling—…* ." (p. 234). Here, the qualitative aspects are represented by soft models and the hard by quantitative models that together make up the solution heuristic. Attempting to solve the lead-up problem without this approach would be difficult. The heuristic solution process arrives at a 'best practice'. As such, it is an *approach* to solving problems (normally) involving direct human participation and is categorised under the heading "soft OR". Soft OR had its origins in the works of Ackoff [14], Checkland [15], Eden et al. [16], Flood and Jackson [17], Midgely [18] and Ormerod [19]. Later Checkland [20] expanded on the concept by focusing on the idea of systems thinking and essentially pursued this through processes rather than mathematical models. See also Friend [21] for an excellent overview on the development of Soft OR. The concept of mixed-mode modelling *per se* has also been added to and explored further by Lehaney [22], Lehaney and Clarke [23] and Mingers and Brocklesby [24] and further extended in Nicholls and Cargill [25] and Nicholls and Cargill [26] (see also Nicholls et al. [27] for a more general exposition of the topic).

The various models in a mixed-mode modelling problem are independently 'solved' using hard or soft solution algorithms/heuristics as applicable, with the results passed on to the next appropriate sub-model which in turn is solved. This interdependence of sub-models is quite common. The end result may well be a number of possible solutions to the problem with the final 'best practice' solution being arrived at iteratively by the expert panel with input from staff in general. In mixed-mode modelling as dealt with in this paper, there is no overall analytical solution technique, no optimality and certainly no single correct answer. Additionally, the solution heuristic may well be set up so that the solution procedure is repeated at regular intervals as new and more accurate information and data is available.

4.2. An overview of the suggested heuristic solution mechanism

The solution heuristic for the general mixed-mode model as summarised by (17) is illustrated by Fig. 3 For each iteration of the solution heuristic, i.e., at the commencement of each year of use in the planning cycle, a full evaluation is undertaken of the quality and participation measures of an academic unit (Z_t for $t=1$ or first time the heuristic is used and $Z_{k,t}$ thereafter since a strategy would have been determined and followed)—*Evaluation (Step 1)*. The values for the variables and objective function evaluated at the beginning of each t ($t>1$) will have been determined (at least to some extent) by the actions of the past. It is only in the next period (t+1) that the actions implemented in year t will be able to be assessed. Following this, the quality and participation measures for the academic unit's competitors are determined using (8) and (9) and benchmarking and progress tracking undertaken—*Benchmarking and Tracking (Step 2)*. At the very beginning of the planning period *($t=1$) or the first time* the academic unit uses this solution heuristic in the current planning period (e.g., the use of the heuristic, say two years after the commencement of the current lead-up period [$t=3$]), an examination of the academic unit's objectives is undertaken and, given their position on the *Q-P* map, various strategies (themed actions aimed at achieving their objectives) are identified—*Strategy Identification (Step 3)*. This step is very significant as it represents the core of the solution heuristic. For convenience in Fig. 3, it is assumed that $t=1$ is also the first time that an academic unit uses the heuristic.

The general strategies (e.g., participation or quality lead) and the actions of each potential strategy are identified. Then for each identified action in a strategy, its magnitude is determined (e.g., recruitment of three high impact researchers *per annum* in the quality lead strategy) as well as its impact, i.e., the *expected change* in the quality ($\Delta 1_{k,r,t}$) through the *expected change* in publications ($\Delta J_{k,r,t}$) and for the *expected change* in participation ($\Delta 2_{k,r,t}$) through the *expected change* in the number of active researchers ($\Delta AR_{k,r,t}$). This then provides the expected change in the objective function measured after the application of the action during the coming year 'guesstimated' at the commencement of period t+1. These expected changes associated with the actions in the strategies are noted beside each action. The Expert Panel is responsible for determining all the above. This process is discussed in detail later. Following on from this *step*, a detailed examination of all the constraints in each constraint type for each strategy is undertaken to determine whether they are met or not. Should at least one constraint be violated for a particular strategy, then a reassessment of (adjustment to) the 'offending' action in the particular strategy will be undertaken and the constraints re-evaluated—*Constraint Evaluation (Step 4A, 4B and 4C)*. With respect to the human resource related constraints H, they are assessed by considering what impact the actions of a strategy might have on the human resource aspects of the academic unit and they are either *satisfied or not* according to the assessment of the Expert Panel (and academic staff).

With the information from the above steps, the identified strategies are then evaluated at the beginning of period t in terms of the expected objective function ($Z^e_{k,t+1}$) as at beginning of the next year (t+1) and the strategy with the maximum value, selected—*Strategy Evaluation and Selection (Step 5)*. Given that $t=1$ or the solution heuristic has been used for the first time in the current planning period, the solution obtained represents the 'best practice' plan for achieving the academic unit's objective and an exit is made from the heuristic.

As indicated, if $t=1$ or this is the first time the academic unit has used the heuristic (as explained earlier), then after performing *Evaluation (Step 1)* and *Benchmarking and Tracking (Step 2), Steps 3, 4* and *5* are carried out. However, since this is the first time through the heuristic, *Step 6* is not undertaken since there are no comparisons yet able to be made. If however, $t>1$ (or it is not the first time the heuristic has been used this planning period by the academic unit) then after performing *Evaluation (Step 1)* and *Benchmarking and Tracking (Step 2)*, a skip is made directly to *Step 6—Difference Evaluation*. The purpose of *Step 6* is to consider all the parameters and inputs of the model such as, for example, costs, performance over the previous year and to determine if anything has changed or if in the case of the soft aspects of the problem, difficulties have arisen. Additionally, for the current period t, the actual objective function value ($Z_{k,t}$) is compared with the expected value estimated last period ($Z^e_{k,t-1}$) and the magnitude assessed. If significant differences are detected (as assessed by the Expert Panel) then a re-evaluation of the strategies and the constraints (via *Steps 3, 4A, 4B and 4C*) is undertaken followed by *Strategy Evaluation and Selection—(Step 5)*. If on the other hand no significant differences were detected and/or the increase in the objective function was acceptable and within expectations, then the same strategy that was selected the previous year is continued. At the commencement of the next year, the procedure is repeated as per Fig. 3.

The iterative application of the solution heuristic during the lead-up period will give the Expert Panel feedback on its decisions of the previous year. This will hone their evaluation skills along the lines experienced in the application of Social Judgement Theory [28]. A detailed specification of each of the steps follows.

4.2.1. Evaluation (Step 1)

In this step Q_t and P_t are evaluated for the academic unit *per se* as well as for the academic units with which the academic unit is going to benchmark against. This is undertaken using (8) and (9) and also allows the evaluation of the objective function $Z_{k,t}$ (11) (i.e., the actual value of the objective function under the adopted Strategy k).

4.2.2. Benchmarking and tracking (Step 2)

The position on the *Q–P* Map (Fig. 2) can then be determined for an academic unit and the positions of the competitor academic units can also be also seen when their Q_t and P_t values are determined. The academic unit can also track the movement of the objective function value over t (providing $t>1$). This information will assist in strategy selection.

4.2.3. Strategy identification (Step 3)

In maximizing the objective function $Z_{k,t}$ through the manipulation of the $J_{k,t}$ and $AR_{k,t}$ variables indirectly though $\boldsymbol{a}_{k,t}$, an academic unit needs to consider what values it should aim to achieve for $J_{k,t}$ and $AR_{k,t}$, for each t, i.e., while both the $J_{k,t}$ and $AR_{k,t}$ variables need to be maximized in order to maximize the objective function, the question is should both ($J_{k,t}$ ($S_{k,t}^{-1}/p(IB)_t$)) and ($AR_{k,t}/S_t$) move towards 1 together, or should one precede the other? This is in effect determining the *themes* of the potential strategies, either a participation and quality, participation or quality led path to T, respectively (three strategies, i.e., $K=3$) and the ultimate objective, $Z_{k,t}=1$ (see Fig. 2).

The selection of the themes then enables the academic unit to undertake the identification of the actions that might constitute these strategies through the use of their Expert Panel. The Expert Panel needs to devise appropriate actions that are relevant to their unit and circumstances and put them together into a coherent group with the common aim of increasing either participation, quality or both. The interdependence that might exist between actions needs to be also taken into account. Several different strategies might be devised to achieve the same objective or, alternatively, participation led and quality led strategies might be established and set up ready for evaluation. Table 1A represents a set of possible actions that might lead to an increase in quality (ahead of participation) in an academic unit. Table 1B represents some possible actions that are primarily participation enhancing. The impact of each of these actions on both quality and participation is then 'guesstimated' by the Expert Panel and placed in the tables (see the process described below). This then allows the overall impact on the variables to be determined before the constraints are evaluated. The problem of possible interdependencies between actions with respect to their impact on P_t and Q_t adds additional complexity. However, since the evaluation of the impact of actions is undertaken by the Expert Panel, these interdependencies can to some extent (if suspected or known) be taken into account. If the approach to solving this problem were deterministic ('hard'), then the difficulty is not so easily dealt with. The other potential problem of actions possibly taking longer than one planning period (year) to reveal their full impact also needs to be recognized. Again, it comes down to the judgement of the Expert Panel as to whether the impact has been fully felt or not.

After the actions that make up each strategy have been identified and their magnitude determined, an assessment of each action's expected impact on the objective function (quality and participation separately) is also undertaken at this stage. In the next period's iteration (t+1), the actual $Z_{k,t}$, $J_{k,t}$ and $AR_{k,t}$ values will be known, allowing the efficacy of the selected strategy to be assessed (*Step 6*). Switching strategies would potentially have some value but only when the objective function is not close to its maximum or where the differences between the strategies are significant (i.e., in terms of $Z_{k,t}$).

Note that if an action is not undertaken subsequently (in later periods) then its value and impact are zero. Some examples of actions are suggested in Table 1A and 1B along with the constraint types that are associated with the actions and the expected effect on the quality and participation elements of the objective function after the action has been implemented over the coming year (designated $\Delta 1_{k,r,t}$ and $\Delta 2_{k,r,t}$ respectively), i.e., what it might be at the commencement of the next year as assessed by the expert panel.

Here

$$\Delta 1_{k,r,t} = (\Delta J_{k,r,t}(S_t^{-1}/p(IB))) \quad (19)$$

$$\Delta 2_{k,r,t} = (\Delta AR_{k,r,t}/S_t) \quad (k=1,\ldots,K) \quad (r=1,\ldots,R(k)) \quad (t=1,\ldots,T) \quad (20)$$

where $\Delta 1_{k,r,t}$ is the expected change in the objective function of an academic unit over the coming year (i.e., anticipated at the commencement of t+1) due to a change in quality occasioned by Strategy k's action r estimated at the commencement of period t, $\Delta J_{k,r,t}$ the expected change in an academic unit's (Tier 1) publications ('guesstimated' by the expert panel) over the coming

Table 1A
Potential actions constituting strategy 1 (quality lead) together with the constraint groups involved and potential impact on the objective function for an academic unit at commencement of year t.[a]

Quality led strategy (k=1)		**Detailed action suggested**	**Constraint group involved**	**Expected impact on objective function elements**	
Broad actions[b]	***r***	**($a_{k,r,t}$)**		**Quality ($\Delta 1_{k,r,t}$)**	**Participation ($\Delta 2_{k,r,t}$)**
Recruitment of high impact researchers	1	Recruit 3 professors in finance and marketing	B, E and H	+0.2	−0.1
Allocation of significant research workload allocations to academic staff	2	Identified research capable staff to receive 80% allocation of workload to research	B, E and H	+0.1	+0.30
Voluntary redundancies of non-researchers	3	Target 8 academic staff for redundancy	E and H	+0.1	+0.2

Notes:
[a]As ascertained from the detailed strategy component by the expert panel.
[b]Thus for k=1; $R(k)$=3.

Table 1B
Potential actions constituting strategy 2 (participation lead) together with the constraint groups involved and potential impact on the objective function for academic unit i^* at commencement of year t.[a]

Participation led strategy (k=2)		**Detailed action suggested**	**Constraint group involved**	**Expected impact on objective function elements**	
Broad actions[b]	***r***	**($a_{k,r,t}$)**		**Quality ($\Delta 1_{k,r,t}$)**	**Participation ($\Delta 2_{k,r,t}$)**
Establishment of a research facilitation unit	1	Recruit appropriate staff (2) initially and provide facilities.	B, E and H	+0.0	+0.15
Adjust the workload allocation model to be more generous to all academic staff	2	Allow a 30% *a priori* workload allowance to all academic staff for research (unless they have a larger one already)	B, E and H	+0.025	+0.2

Notes:
[a]As ascertained from the detailed strategy component by the expert panel.
[b]Thus for k=1; $R(k)$=2.

year (i.e., anticipated at the commencement of t+1) and measured at the beginning of t+1 occasioned by Strategy k's action r estimated at the commencement of period t, $\Delta 2_{k,r,t}$ the expected change in the objective function of an academic unit over the coming year (i.e., anticipated at the commencement of t+1) due to a change in participation occasioned by Strategy k's action r estimated at the commencement of period t and $\Delta AR_{k,,t}$ the expected change in the number of participating academics ('guesstimated' by the expert panel) of an academic unit over the coming year (i.e., anticipated at the commencement of t+1) occasioned by Strategy k's action r estimated at the commencement of period t.

Some of the actions that could potentially make up each of the strategies together with the constraints that impact upon the actions and the expected magnitude of change due to the actions to the quality and participation elements of the objective function are summarised in Tables 1A and 1B.

4.2.4. Constraint evaluation (Step 4)

In this step, the constraints are evaluated as they would normally be for (17.1) and (17.2) and are assessed by subjective judgement (by the Expert Panel) in the case of (17.3) as to whether they are satisfied ($\boldsymbol{S}$) or not. The general evaluation follows thus:

For Strategy k (k=1, …, K)
Set d=0

For Constraint Type B (of which there are L)
Check: $\mathbf{B}_k\ \boldsymbol{a}_{k,t} \le \mathbf{b}_{k,t}$
If for any l (l=1, …, L) $\exists\ \mathbf{B}_{k,l}\ \boldsymbol{a}_{k,t} > \mathbf{b}_{k,l,t}$ then set d=1 and store the value of l

For Constraint Type E (of which there are M)
Check: $\mathbf{E}_k\ \boldsymbol{a}_{k,t} \le \mathbf{e}_{k,t}$
If for any m (m=1, …, M) $\exists\ E_{k,m}\ \boldsymbol{a}_{k,t} > e_{k,m,t}$ then set d=1 and store the value of m

For Constraint Type H (of which there are N)
Check: $\mathbf{H}_k\ (\boldsymbol{a}_{k,t})$=$\boldsymbol{S}_{k,t}$
If for any n (n=1, …, N) $\exists\ \mathbf{H}_{k,n}\ (\boldsymbol{a}_{k,t}) \ne S_{k,n,t}$ then set d=1 and store the value of n

If d=0 and then proceed to *Step 5*
Otherwise go to *Step 3*
Next Strategy

4.2.5. Strategy evaluation and selection (Step 5)

Selection of the best practice strategy for an academic unit in year t is achieved as follows:

$$Z^*_{k^*,t+1} = \underset{k}{\mathrm{Max}}(Z^e_{k,t+1}) \quad (t = 1, \ldots, T) \tag{21}$$

where

$$Z^e_{k,t+1} = \left((J_{k,t}(S_t^{-1}/p(IB)_t)) + \sum_{r=1}^{R(k)} \Delta 1_{k,r,t} \right) \left((AR_{k,t}/S_t) + \sum_{r=1}^{R(k)} \Delta 2_{k,r,t} \right)$$
$$(k = 1, \ldots, K) \quad (t = 1, \ldots, T)$$

Here $Z^e_{k,t+1}$ is the expected value of the objective function at the commencement of period (t+1) for an academic unit as a result of the application of (the $R(k)$ actions of) Strategy k during year t estimated at the commencement of year t, $Z^*_{k^*,t+1}$ the 'best practice'(i.e., maximum value) objective function for an academic unit following Strategy k^* in period t selected from $Z^e_{k,t+1}$ and k^* the best practice strategy.

The *expected* value of the objective function at (t+1) is the actual value of the quality and participation components at the beginning of year t, namely $Z_{k,t}$ from (11), plus their respective expected changes from Tables 1A and 1B incorporated as in (22).

4.2.6. Difference evaluation—Step 6

The purpose of this step is to determine whether there are any significant changes in the parameters associated with (18), and between $Z^*_{k,t-1}$ and $Z_{k,t}$. If there are, then *Step 3* (Strategy Identification), Constraint Evaluation (*Steps 4A, 4B and 4C*) and Strategy Evaluation and Selection (*Step 5*) are repeated. In this way, the strategy initially selected is constantly evaluated and, if necessary, changed or adjusted, according to the prevailing circumstances. If no significant differences have been detected, then the current strategy is maintained. Classifying a change as 'significant' is determined by the Expert Panel. As only the macro change (through J_t and AR_t and other environmental parameters) can be measured, it is not possible to analyse the strategy's performance at the action level for this step. However, Expert Panel will have some knowledge as to which of the actions were successful or otherwise.

5. An application of a precursor approach to the suggested solution heuristic—an illustration

It is not possible to illustrate by case study how the entire solution methodology developed in this paper can be applied. However, a *precursor* of the suggested solution heuristic to the university research funding lead-up problem had been developed and used, providing some insight as to how the solution methodology suggested in this paper could be implemented. In fact, this precursor acted as the incentive to develop something more robust and systematic to replace it—such as the methodology developed in this paper. For obvious reasons, the academic unit in which the precursor solution was applied as well as the industry best (*IB*) academic unit used will remain anonymous. Both the academic unit used (designated hereinafter as academic unit X (AUX)) and the 'industry best' academic unit (*IB*) (a local and prestigious competitor) had very similar missions, courses and academic structure, making them a meaningful comparison.

In the AUX, there was a small number of 'core' (i.e., full-time on-going) academic staff, the only ones recognized by the Government and University for the purposes of the ERA. In the IB academic unit, there is a much larger number of core academic staff as well as a very large number of 'adjunct' staff. AUX was very recently established with staff drawn from existing departments as well as from outside the university. Strategies were developed for encouraging both quality and participation in research publication, research funding and higher degree completions in AUX (with only the research publications being discussed here). The IB *per capita* Tier 1 journal publication rate was determined using publicly available data. The assessment of whether a journal was Tier 1 (A^*) or not was undertaken initially using Harzing [29], (2005), (2006) and (2007) whereas for 2008, when the ERA preliminary journal ranking list was released, this was used. However, in this paper, all journal classifications were standardised using the ERA list for inter-temporal consistency. This standardization resulted in very little difference in classifications.

The Expert Panel was the AUX's Research Committee, chaired by the Research Director together with a very broad School representation. Importantly, the Academic Head of the AUX was on the Research Committee. Additionally, while the Research

Committee assumed the responsibility of developing the actions associated with the strategy and evaluating their likely impact, the actions were also brought before the AUX *per se* (at general meetings) for input and comment. There was a large degree of consensus associated with the process and the decisions made. Assessment of the 'performance' of the strategy at the end of each year was undertaken by the Research Committee and if any revision/changes were required, the same process of consultation specified above was used. The main 'tool' used to measure progress and performance was benchmarks (both internal and external) rather than figures such as 4 and 5. These refinements had not at that stage been developed. Staff found the benchmarking particularly helpful. In Table 2, the essential statistics relating to the research details of AUX are presented along with the calculation of the P, Q and Z values.

Fig. 4 illustrates the Z isoquants for AUX and their increase/decrease over the years 2005–2008. Fig. 5 illustrates the 'path' the AUX followed with respect to progress (a participation *and* quality path). For $t=4$, there was a decrease in performance occasioned by a decrease of one Tier 1 (A^+) publication. With a small academic staff associated with AUX, these anomalous results can occur. Indications are, however, that the following year ($t=5$) will see a resumption of the climb towards the academic unit's objective.

Table 3 describes the actions that were developed for the Strategy and their modification/deletion where assessed appropriate. The evaluation of the potential impact of the actions, the assessment of the economic aspects (e.g., budget and revenues) and the secondary economic impact considerations (e.g., teaching time available etc) as well as the human resources implications of actions were very subjectively assessed by the Research Committee.

Where Z_1 represents the Z isoquant for the academic unit at time $t=1$ and arrows indicate the direction of movement of the academic unit across the isoquants—$t=4$ saw a decline in performance.

Much discussion took place regarding the objectives that AUX wished to achieve. It was decided that an increase in both participation and quality was desirable. This fitted in with the University's objectives in order to best position itself for the foreshadowed ERA scheme. Assessment by the Research Committee suggested that, with some 'exceptions', this was in general being achieved. Additionally, internal University benchmarking with the *per capita* research publications output (i.e., all journals irrespective of rank) was carried out. At the time, this was seen by some internal University research administrators as a 'good measure'. The process used above was nowhere near as structured or as detailed as that suggested in this paper—something that may well have added considerable value. The precursor scheme was nonetheless a valuable tool for the Academic Unit.

Table 2
Summary of participation and quality statistics associated with the academic unit X[a,d].

	2005	2006	2007	2008
Staff (S_i)	11	11	11	11
Journals (Tier 1) (J_i)	0[b]	1	2	1
Active researchers (AR_i)	4	6	7	9
***Per capita* journals (J_i/S_i)**	0	0.091	0.182	0.091
Participation (P_i)	0.364	0.546	0.636	0.82
Quality (Q_i)[c]	0	0.478	0.955	0.478
Objective function (Z_i)	0	0.261	0.607	0.392

Notes:
[a]Academic Unit X established in 2005 but staff published prior to this.
[b]$J_i=0$ for this year reflecting the research environment generally.
[c]IB averages 0.1905 over 2006–2008 with a very small standard deviation. For 2005, an outlier of 0.24 occurred.
[d]The determination of the IB figures for Tier 1 (A^*) journal articles was easily undertaken by accessing the public research record of the academic unit, its staffing list and the publicly available journal ranking source.

6. Concluding remarks

This paper has presented a model that encapsulates the university lead-up research funding problem that exists under a PBRF scheme. It also suggests a means of solving the problem using a mixed-model modelling approach. The solution to the model developed is a heuristic one, leading to 'best practice'. The implementation of the suggested model to develop strategies during the lead-up period can be undertaken with a simple spreadsheet with straightforward input of decisions, actions and the evaluations made by the Expert Panel. There is no need for any of the so-called 'modelling' or 'mechanics' to be explicit at all.

Table 3
Research publication strategy—actions implemented by academic unit X[a]

Strategy actions ($a_{k,t}$)	2005	2006	2007	2008
Action 1	Established a Workload Model (WLM) based on past research output of staff to allocate research time each year	Introduced a modification to the WLM that allowed forthcoming papers to be claimed in the year they were accepted or published. *(Modification to Action 1*[b]*)*	WLM weightings for journal articles (by Tier) altered to emphasise quality. (*Modification to Action 1*)	No change
Action 2	Introduced a conference funding scheme based on refereed conference papers		Conference papers no longer contribute towards determination of research time in WLM. (*Action 2 rescinded*)	No changes
Action 3		Early career researchers scheme introduced		
Action 4		Visiting scholars scheme—providing international mentoring to all researchers		
Action 5				Small grants made available to researchers to assist in starting research projects

[a] One strategy was formulated and agreed to by the Expert Panel but was assessed each year and revised where needed, thus $K=1$. This strategy pertains only to research publications. Other strategies dealt with research grants and higher degree publications. There is insufficient space to specify details of the actions.
[b] These modifications were enacted as a result of careful assessment of the actual impact of the original actions as seen in Figs. 2 and 3 and also as external circumstances altered (e.g., the confirmation of the introduction of PBRF based on quality).

This allows the implementation of the suggested heuristic to be a straightforward process and one that can be participated in by those who will be affected. Another attribute of the suggested solution algorithm is that it causes university research managers and academic unit leaders to focus on the development of appropriate strategies (e.g., quality or participation lead research strategies) as well as on the possible actions that might make up these strategies. The strategy assessment process allows academic leaders to gain an insight into the potential impact if the strategies were implemented. Through the use of this solution heuristic, academic units have a means of systematically moving towards their preferred position in terms of quality and participation in research at the end of the lead-up period.

The potential value of the suggested approach outlined in this paper can be gauged to some extent from its precursor applied in AUX. This has provided a systematic, transparent and participatory means for encouraging research quality and participation to increase within the academic unit and, while not as sophisticated as the suggested model in this paper, it has achieved considerable success. With the greater insight and detail enabled by this paper's suggested model, even greater advances are expected. The precursor process has also increased the level of understanding amongst academics regarding the necessity of increased quality and participation and has harnessed many valuable ideas from them. It has, in effect, 'democratised' research management, a necessary precondition for the still greater increases in quality and participation required in the future (see [30]).

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