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A Group Decision Support Approach to Budget Allocation for the Horticulture Program of the Department of Agriculture Western Australia

Mohammed Quaddus

Nazrul Islam

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Mohammed Quaddus
Graduate School of Business
Curtin University of Technology
78 Murray Street, Perth, WA 6000, Australia
E-mail: quaddusm@gsb.curtin.edu.au

Nazrul Islam
Department of Agriculture Western Australia
3 Baron-Hay Court, WA 6151, Australia
E-mail: nislam@agric.wa.gov.au

Abstract

Budget allocation to competing projects is an age-old problem in any organisation. Due to funding cuts and other socio-economic priorities budget allocation in public sectors is even more difficult where the norm now a days seems to be doing more for less. Traditional approaches to budget allocation are therefore inadequate to address the myriads of problems. This paper presents a new computer based group decision support system (GDSS) and process for budget allocation. The system called ALLOCATE and the group decision support process called Decision Conferencing for budget allocation are described in details. Their application in the Horticulture program of the Department of Agriculture WA is then presented. The results indicate that the process and system of budget allocation is integrated nicely and new insights are thus generated which lead to effective budget allocation.

Keywords: Group decision support, decision conferencing, budget allocation, resource allocation.

1. Introduction

In recent years, as budgets tighten in all levels of government, the Department of Agriculture Western Australia (DAWA) has had to face the challenge of achieving its goal under increasingly tight budget conditions. Moreover, as there is now increased emphasis on accountability and transparency and the application of competition principles in public sector business activities the agency is in fact under pressure to do more with less. Given its vital role as a leader in agricultural research, development and extension activities for the benefit of all Western Australians, it is important therefore for the agency to identify those R&D and extension projects which should receive funding priorities for efficient allocation of its limited budget. To identify such projects it is essential to develop and apply a methodological framework consistent with the mission and objectives of the agency by analysing and providing a maximum possible information to the decision makers.

At present the process and criteria applied in the allocation of budget in DAWA are as follows (Agriculture Western Australia, 1997). The agency's budget working group rely on several assessment criteria. Industry program managers (PM) are informed about these criteria and judgments about desirable funds allocation. In formulating such judgments the PMs are provided with some key questions to justify their budget bid. The questions are mainly related to the issues of market failure, competitive advantage, government's commitments, agency's objectives, contribution to the State's economy, and productivity gains.

Based on responses to these questions and on several discussions with the PMs two broad principles are used by the working group in recommending budget allocation. The principles are *precedence* and *strategic merits*.

In the principle of precedence, the previous year's budget allocation is used as a guide for the current allocation. In the principle of strategic merit the PMs' budget bids are assessed to ensure that they are consistent with the strategic plan of each program and are consistent with the agency's broad strategic directions. However, wherever necessary strategic merit is supported or restricted by the consideration of: (a) legislative, contractual, and tied obligations; (b) community services obligations; (c) ministerial imperatives; and (d) equity issues.

Although rigorous in process, the current practice does not consider the competitive budget bids in an objective manner with respect to multiple criteria and multiple stakeholders in a participative environment. This paper presents a budget allocation process which addresses this gap. Our process considers multiple conflicting criteria of agency and program in an explicit way via an interactive computer based system called ALLOCATE. It also allocates the budget with respect to various wants and demands of the multiple stakeholders following a structured group decision process called Decision Conferencing (Quaddus *et al.* 1992; Quaddus and Siddique, 2001). We apply this process of budget allocation in the Horticulture Program of the Department of Agriculture Western Australia.

In the next several sections we first describe the ALLOCATE model. The group decision process called Decision Conferencing for the Horticulture program is then described which uses the ALLOCATE system as the backbone. The results of budget allocation in the Horticulture program are presented next. Finally, conclusions are presented.

2. The ALLOCATE Model

The ALLOCATE model is essentially a Multiple Attribute Decision Modelling (MADM) type benefit-cost model (Hwang and Yoon, 1981). It emphasizes a widely known process, called Decision Conferencing (Quaddus *et al.* 1992; Quaddus and Siddique, 2001) to develop the model structure. ALLOCATE uses a hierarchical structure to develop the model by interacting with the DMs. Although hierarchical structure is most popular in MADM, there is a general lack of agreement on the exact form of hierarchical representation in the MADM literature (Belton, 1985, 1990). Figure 1 shows the hierarchical structure used in the ALLOCATE model.

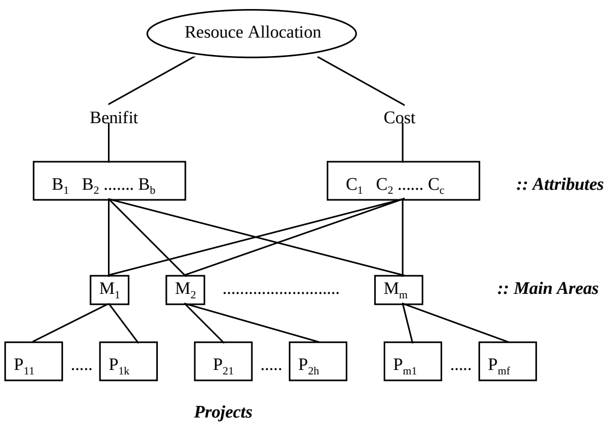


Figure 1. Hierarchical Structure of the ALLOCATE Model.

It is observed from Figure 1 that the global attributes of the ALLOCATE model are benefit and cost, which are then sub-categorised into specific benefit and cost type attributes. The projects are grouped into various main areas. Depending on the problem domain these main areas could be manufacturing, human resources etc. ALLOCATE uses a simple value elicitation approach. It also uses a simple additive model of MADM. Mathematical model of the above hierarchical structure is as follows:

$$\text{Maximise}[\text{Satisfaction}\{V_i(\overline{B}), V_i(\overline{C})\}]$$
$$i \subset p$$
$$\text{Subject to } V_i(\overline{B}) = \sum_{B} W_{MB} W_B P^B_{iM}$$
$$V_i(\overline{C}) = \sum_{C} W_{MC} W_C P^C_{iM}$$

Where,
- p = number of projects
- $B \subset \overline{B}$ = set of benefits attributes
- $C \subset \overline{C}$ = set of costs attributes (one of which is the $cost)
- $M \subset \overline{M}$ = set of main areas
- $V_i(\cdot)$ = additive value function for project *i*
- W_j = normalised swing weight of attribute *j* (benefit or cost)
- W_{Mj} = normalised swing weight of the main area *M* with respect to the attribute *j* (benefit or cost); and
- P^j_{iM} = preference score for project *i* w. r. t. attribute j within the main area *M*

It is observed from the above model that Decision Maker's (DM's) "satisfaction" with respect to the benefit and cost values is maximized over all the projects. This is done by displaying the efficient frontier and extensively interacting with the participating DMs. It is also noted that the value functions are additive in nature. Stepwise procedure of the ALLOCATE system of resource allocation is as follows:

Step 1. Problem structuring:
The ALLOCATE tree is developed.
Step 2. Project preference scoring:
P^j_{iM} scores are obtained by interacting with the stakeholders.
Step 3. Determining the weights W_{Mj}:
Theses are called "within" weights, i.e. within each of the benefit or cost criterion j. Found by interacting with the stakeholders.
Step 4. Determining the weights W_j:
Theses are called "between" weights, i.e. between the criteria j (benefit or cost). Found by interacting with the stakeholders.
Step 5. Finding the satisfactory solution:
The efficient frontier is explored in an interactive way. Both graphical and text displays are used as required.

2.1 The Decision Conference for Budget Allocation

Decision Conferencing (DC) is characterised by a problem solving environment which recognises that it is always a top level *group* in the organisation that makes decisions based on judgment – in particular uncertainty, preference, and trade-off (Phillips, 1989; Quaddus *et al.* 1992). As budget allocation must deal with uncertainty, preferences of the stakeholders and trade-off, DC is an appropriate process in this domain. In DC, the owners of the budget allocation problem participate in a single day problem-solving session that features on the spot computer modelling, aided by a facilitator and an analyst. The analyst uses a computer and appropriate software to build models and capture information. In the budget allocation process for the Horticulture program the ALLOCATE software is used. The facilitator works directly with the group to help it to structure and focus discussions, to think creatively about the problem, and to address the full range of issues involved. Information technology supports the activities of the DC by enhancing the efficiency of information flow and transfer.

Although every decision conference is different, the process consists of some common broad stages. These are: (i) structuring the problem; (ii) assessing the parameter; (iii) running the sensitivity analyses; and (iv) planning the implementation (Phillips, 1989). The decision conference for the budget allocation process was carried out as detailed below. It is noted that another software called EXPERT CHOICE was used primarily for benefit assessment (Expert Choice Inc., 1995).

Pre-conference Stage

(i) Identify the stakeholder group from the Horticulture program.
(ii) Identify the projects for budget allocation.
(iii) Collect data via survey to assess project benefit; and
(iv) Assess the project benefits by EXPERT CHOICE software, for each individual stakeholder and also for the group.

Decision Conference

(i) Revisit the group benefit assessment by survey and fine tune the pairwise comparison data in a face-to-face environment.
(ii) Recalculate the project benefit for the group and perform a range of sensitivity analyses.
(iii) Find the final benefit ranking for the projects to be used in the ALLOCATE model.
(iv) Populate the ALLOCATE system with cost and benefit data as obtained from above; and
(v) Allocate budget as suggested by the system and as chosen by the group. Perform sensitivity analyses to achieve the final budget allocation.

3. Results of Budget Allocation

This section presents results of budget allocation exercise for projects in the Horticulture program of the Department of Agriculture WA. Both the pre-conference and the decision conference stages are described in details. It is noted that the pre-conference stage was dominated by the questionnaire-based survey to collect relevant data to assess the project benefits. The decision conference stage then fine tuned this data and dealt with the actual budget allocation in a group environment.

3.1 Assessment of Benefit

To assess the project benefits, a hierarchy of objectives has been developed from various Horticulture documents. Figure 2 shows this hierarchy. Level 1 of the hierarchy contains the program goal, which is: “A profitable, sustainable and growing industry supplying safe quality products to domestic and world markets”. To attain this goal the Horticulture Program has to achieve a number of specific objectives, which are shown in level 2.

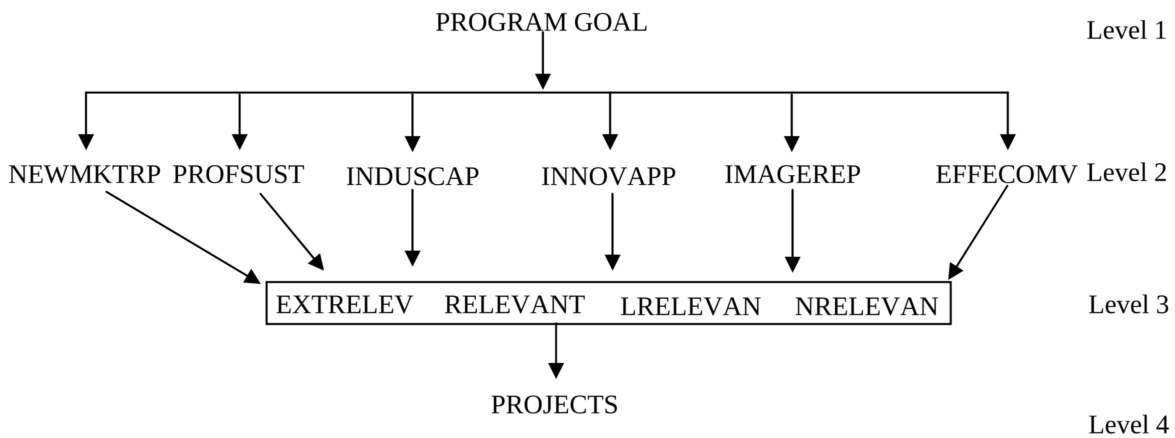


Figure 2. The horticulture program hierarchy of objectives.

Level 3 of the hierarchy provides the intensities (in terms of *extremely relevant, relevant,* etc.) that have been used to evaluate the degree of relevance of the various projects in achieving the program objectives. Level 4 shows the actual projects (25 of them).

Two questionnaires were developed based on the above hierarchy: (i) to **assess the importance or priority weights** of the objectives at level 2 and the intensities at level 3 of the hierarchy; and (ii) to **rank the projects** based on the degree of relevance of each project with respect to the objectives of level 2. The questionnaires were distributed to all the relevant stakeholders of the Horticulture program with detailed instructions to fill them up. Five responses were received by the deadline.

Table 1 presents comparative results of the **relative priority** of the objectives based on the survey, which have been obtained by using the software EXPERT CHOICE. All these values are in between zero and one (0 – 1). The first five columns present the individual responses. The second last column presents the average of the five responses. It is observed that the individual responses vary widely, which is expected. Last row of Table 1 shows the inconsistency ratio of assessment. This ratio indicates the degree of inconsistencies of each respondent in the pairwise assessment of the objectives. In general, if an object A is preferred to B, and B is preferred to C, then one should prefer A to C. Any violation of this indicates inconsistency. EXPERT CHOICE provides a measure of the level of inconsistency in the assessment. One should always expect some level of inconsistency in his/her assessments. But this must be less than 0.1. It is observed from Table 1 that all the inconsistency ratios are less than 0.1. However, respondent 3 has an inconsistency ratio of 0, which is unusual! The relative priority of this respondent is also doubtful! The last column, called Group, will be addressed later.

Table 2 presents the ratings of the projects as obtained from the survey. All the values in this table are in between zero and one (0–1). Note that these ratings indicate the relevance of the projects with respect to the objectives of Table 1 (see also at level 2 in Figure 2 above). As before the ratings by different individuals vary widely. The second last column also shows the average of the five respondents.

3.2 Re-assessment in Decision Conference

The entire assessment process of the hierarchy of Figure 2 was revisited during the decision conference. A group of seven stakeholders participated in the decision conference. Since the group had already gone through the assessment via survey they were more focussed in revising/fine-tuning the assessments. Considerable time was devoted in this part of the decision conference. The group debated various issues, which primarily dominated by the meaning of various objectives of Figure 2. Sometimes the group struggled for meaning and assessment of some objectives. After much discussion the group came up with the required assessment. The last column in Table 1 shows the group consensus assessment for the objectives. Note that the group decided to give a very low priority for the EFFECINV (i.e. to maximise effectiveness of program investment) objective. The group rating of projects is shown in the last column of Table 2. Note that the group ratings are quite different from any other ratings. In fact, the group moved up the ratings of many projects during the assessment process.

The group rating of Table 2 (last column) was used as the assessment of benefits of the projects in the next phase of the decision conference, ie budget allocation. However, before moving on to the next phase some sensitivity analysis of the projects ratings were done. In order to do that the top eight projects from Table 2 (group column) were chosen. Figure 3 shows one such sensitivity graph. It shows the sensitivity of PROFSUST objective (highest group priority) with respect to the eight projects. With its current priority of 0.301 the HAS project (Develop low input wine…) is rated first. If this priority is decreased, there is no change in the rating, unless it becomes less than 0.15 (approximately). However, if it is increased beyond 0.375 a new project (HGD Developing the Cotton Ind …) is rated first. Therefore, for PROFSUST objective there is a range of 0.15 to 0.375 between which the ratings of the projects do not change. This is a very valuable information. Sensitivity analysis, like this, can be done for all the objectives.

Table 1. Relative priority of the objectives

Objectives	**1**	**2**	**3**	**4**	**5**	**Ave 1-5**	**Group**
NEWMKTRP	0.238	0.277	0.200	0.086	0.117	0.180	0.194
PROFSUST	0.179	0.266	0.200	0.430	0.233	0.272	0.301
INDUSCAP	0.123	0.176	0.200	0.238	0.235	0.204	0.135
INNOVAPP	0.101	0.101	0.200	0.033	0.143	0.105	0.129
IMAGEREP	0.090	0.116	0.100	0.174	0.144	0.132	0.220
EFFECINV	0.270	0.064	0.100	0.038	0.138	0.107	0.021
Inconsistency	0.07	0.01	0	0.09	0.09	0.01	0.02

Table 2. Ratings of the projects

Projects	Resp 1	Resp 2	Resp 3	Resp 4	Resp 5	Ave 1-5	Group
1. HBC: Developing an Internationally Competitive WA Potato Industry	0.645	0.345	0.632	0.756	0.250	0.502	0.525
2. HBD: Export Root Vegetables	0.645	0.376	0.519	0.713	0.270	0.546	0.626
3. HBG: Export Development of Brassicas	0.645	0.321	0.519	0.588	0.362	0.514	0.618
4. HHA: Vegetable Industry Development	0.645	0.321	0.607	0.553	0.345	0.515	0.607
5. HAJ: Stable Fly Management	0.193	0.145	0.330	0.257	0.097	0.214	0.442
6. HAK: Sustainable Horticulture on Swan Coastal Plain	0.594	0.276	0.440	0.409	0.728	0.527	0.604
7. HCA: Sustainable Management of Horticulture Pests	0.594	0.329	0.632	0.592	0.253	0.519	0.525
8. HAM: Pot Plant and Amenity Plant Development	0.687	0.367	0.386	0.541	0.227	0.406	0.571
9. HAN: Plant Selection and Breeding	0.687	0.419	0.372	0.802	0.352	0.513	0.623
10. HAP: Floriculture Industry Development	0.539	0.257	0.519	0.692	0.168	0.414	0.543
11. HAR: Develop Quality Control Systems for Wine	0.559	0.363	0.424	0.851	0.092	0.465	0.578
12. HAS: Develop Low Input Wine Grape Production Systems	0.369	0.376	0.745	0.981	0.283	0.554	0.661
13. HBO: Fruit Breeding	0.682	0.293	0.580	0.866	0.270	0.536	0.573
14. HBX: Regional Sustainable Resource Development	0.388	0.321	0.416	0.484	0.221	0.377	0.463
15. HHB: Horticulture Protection Initiatives	0.208	0.367	0.443	0.470	0.475	0.405	0.578
16. HBU: Tropical Fruit Development	0.510	0.333	0.406	0.492	0.092	0.342	0.618
17. HBV: Developing New Fruit Industries in WA	0.524	0.333	0.607	0.460	0.158	0.430	0.546
18. NAN: Developing the Sugar Industry	0.281	0.323	0.413	0.668	0.370	0.411	0.473
19. HGD: Developing the Cotton Industry	0.397	0.624	0.413	0.679	0.490	0.545	0.657
20. HAW: Improve Strawberry Quality	0.523	0.351	0.769	0.541	0.495	0.573	0.575
21. HAX: Expand Table Grape Industry	0.718	0.351	0.467	0.763	0.370	0.572	0.627
22. HBK: Summer Fruit Industry Development	0.349	0.387	0.494	0.702	0.144	0.438	0.590
23. HBP: Pome Fruit Industry Development	0.594	0.321	0.494	0.668	0.182	0.445	0.565
24. HBQ: Citrus Industry Development	0.594	0.321	0.494	0.553	0.192	0.425	0.587
25. HBW: Strategic Market Information	0.706	0.278	0.457	0.333	0.141	0.381	0.448

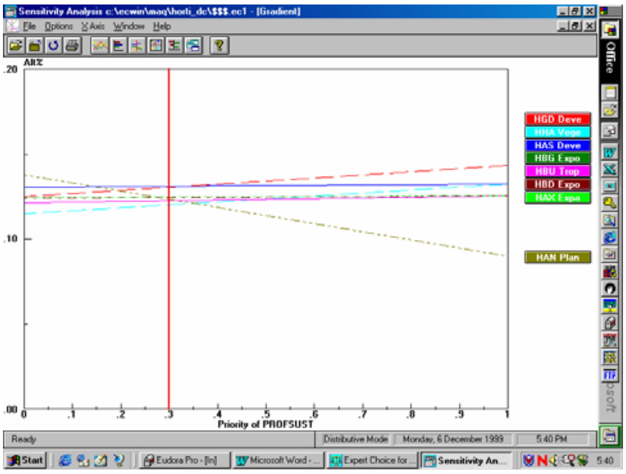
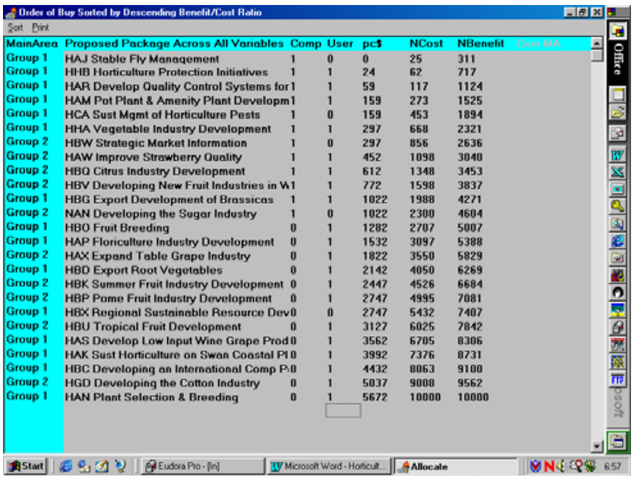


Figure 3. Sensitivity graph from EXPERT CHOICE

3.3 Budget Allocation

The budget allocation process began during the second half of the decision conference. The ALLOCATE software was used for budget allocation. Budget allocation model needs the dollar value of cost and benefit of each project. The group rating of the projects (last column of Table 2) was taken as the benefits of the projects and actual value of cost was taken from the Horticulture program log frame summaries. The ALLOCATE system was populated with these costs and benefits data. Various displays were then presented to the group for discussions, comments and changes, if necessary.

The group was specially alerted of the fact that for some projects the cost is extremely high compared to the benefit. The group was then presented with the "order of buy" display from the ALLOCATE software, which is shown in Figure 4.



Order of Buy Sorted by Descending Benefit/Cost Ratio

MainArea	Proposed Package Across All Variables	Comp	User	pc$	NCost	NBenefit
Group 1	HAJ Stable Fly Management	1	0	0	25	311
Group 1	HHB Horticulture Protection Initiatives	1	1	24	62	717
Group 1	HAR Develop Quality Control Systems for	1	1	59	117	1124
Group 1	HAM Pot Plant & Amenity Plant Developm	1	1	159	273	1525
Group 1	HCA Sust Mgmt of Horticulture Pests	1	0	159	453	1894
Group 1	HHA Vegetable Industry Development	1	1	297	668	2321
Group 2	HBW Strategic Market Information	1	0	297	856	2636
Group 2	HAW Improve Strawberry Quality	1	1	452	1098	3040
Group 2	HBQ Citrus Industry Development	1	1	612	1348	3453
Group 2	HBV Developing New Fruit Industries in W	1	1	772	1598	3837
Group 1	HBG Export Development of Brassicas	1	1	1022	1988	4271
Group 2	NAN Developing the Sugar Industry	1	0	1022	2300	4604
Group 1	HBO Fruit Breeding	0	1	1282	2707	5007
Group 1	HAP Floriculture Industry Development	0	1	1532	3097	5388
Group 2	HAX Expand Table Grape Industry	0	1	1822	3550	5829
Group 1	HBD Export Root Vegetables	0	1	2142	4050	6269
Group 2	HBK Summer Fruit Industry Development	0	1	2447	4526	6684
Group 2	HBP Pome Fruit Industry Development	0	1	2747	4995	7081
Group 1	HBX Regional Sustainable Resource Dev	0	0	2747	5432	7407
Group 2	HBU Tropical Fruit Development	0	1	3127	6025	7842
Group 1	HAS Develop Low Input Wine Grape Prod	0	1	3562	6705	8306
Group 1	HAK Sust Horticulture on Swan Coastal Pl	0	1	3992	7376	8731
Group 1	HBC Developing an International Comp P	0	1	4432	8063	9100
Group 2	HGD Developing the Cotton Industry	0	1	5037	9008	9562
Group 1	HAN Plant Selection & Breeding	0	1	5672	10000	10000

Figure 4. The order of buy.

Figure 4 is an important display. The first column shows two groups of projects, which were arbitrarily created to keep the list of projects manageable within each group. The column "Comp" presents the computer chosen projects, where the relative benefit is more than the relative cost. The next column "User" presents an opportunity for the group to select any project they like. In this case, the group chose to select the top 20 highest benefit projects. Next column shows the total $cost for these 20 projects, which is $5.672 million. Note that total cost to do all the projects is $6.403 million. The last two columns show the normalised total cost and total benefit (normalised to sum to 10000). Normalisation is done by converting both costs and benefits into a common unit of measurement. These normalised values are needed for equitable comparisons. Using this "order of buy" table the group can make the ultimate decision for project selection and budget allocation. The group can use the model prescribed projects as guide for ultimate selection of projects due to other political and non-quantifiable reasons.

After selecting the 20 top projects from Figure 4 the group was provided with the efficient graph as shown in Figure 5. This graph shows how good is the user chosen package of projects. Each dot in the figure represents a package of projects which can be displayed by clicking the corresponding dot. The dotted line running from the bottom left hand corner to the top right hand corner represents the efficient line. Any dot below this line represents an inefficient package of projects. For example, the group-selected package of projects in Figure 4 is shown by the 3rd top dot in Figure 5, which is below the dotted line. This package is inefficient as we can move up towards the dotted line and choose a package which costs the same but gives more benefit (e.g. second dot from top). Or we can move left and choose a package which will give the same benefit but will cost less (e.g. 5th dot from top).

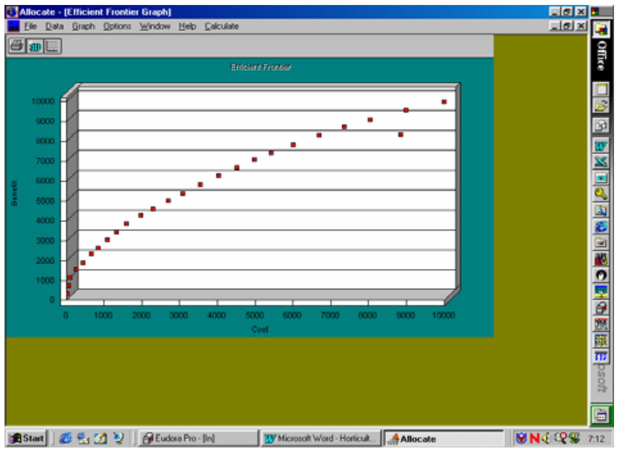


Figure 5. The efficient graph of projects.

The group can move between Figures 4 and 5 a number of times until they are completely satisfied.

In this decision conference the group investigated a number of project packages including the top five projects (fell in the efficient line), the bottom five projects (fell in the inefficient region), and the middle five projects (fell in the inefficient region). This was an eye opener for the group. The group then wanted to populate the ALLOCATE software with the average 1-5 benefits from Table 2. This was done and results similar to above were obtained, although the project packages were different.

The decision conference was concluded with further discussions on how the EXPERT CHOICE and LLOCATE system can be used effectively for future budget allocation in the horticulture program.

4. Conclusions

This paper presents a process of budget allocation in the Horticulture program of the Department of Agriculture WA. Based on the notion of Decision Conference the process uses an ALLOCATE model for the budget allocation. The ALLOCATE model and the Decision Conference process for budget allocation is described in details.

The Decision Conferencing approach to budget allocation offers a number of benefits to the Horticulture Program. The ALLOCATE model prescribes an efficient allocation of the budget. The budget allocation will thus provide an insight into the Horticulture projects and can be used as a vehicle for any future negotiation with the Government for funding. The ALLOCATION model offers different scenarios of efficient projects and the corresponding budget, which can be used for forward planning and negotiation with the external agencies.

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