APPLICATIONS OF MATHEMATICAL PROGRAMMING IN THE NETHERLANDS

by W.B. van Dam and C.B. Tilanus*

Abstract

Results of an exhaustive survey of mathematical programming in the Netherlands held in 1982 are presented and, where applicable, compared to a survey held in 1976. It appears that the growth rate has levelled off, that about half of the largest hundred industrial firms in the Netherlands now apply MP and that the users are quite satisfied with LP programs except for input, output and documentation.

*Eindhoven University of Technology Department of Industrial Engineering and Management Science Postbox 513 5600 MB Eindhoven Netherlands Telephone 040-473601

A more comprehensive account of this survey will be published in the European Journal of Operational Research.

Free copies are available from the authors.

1. Introduction

In 1976, Müller conducted a survey of linear programming in the Netherlands [1, 2]. One of his findings was that about half of the users had started LP in the last six years. Two questions remained: how many users had quit LP in the last six years and what growth could be expected in the future? A natural consequence was to update and expand the survey about six years later. This has been done in 1982.

This article presents the results of the 1982 survey of mathematical programming users, linear programming models and mathematical programming software in the Netherlands. Where applicable, a comparison is made between the 1982 and 1976 surveys.

2. Organization of 1982 survey

The aim was to make an exhaustive survey of mathematical programming in the Netherlands with two categorical exceptions:

- Universities and other educational institutions were excluded because there MP is an educational end and not a managerial means.
- (2) In the last few years, simple LP software had been introduced in the cattle-fodder industry on a large scale. One package, Bestmix, had already 57 users in the Netherlands. Because the LP applications in the cattle-fodder industry are quite similar, only 6 such firms were included in the survey.

Otherwise, we tried to achieve completeness. To identify MP users, the following means were employed:

- Müller's address list [1];
- In a questionnaire by telephone, 98 per cent of the personal memoership of the Netherlands Society of Operational Research [3] were asked if they applied MP or could name colleagues who did;
- Contact persons in universities and companies were questioned;
- Identified users were asked for names of other users, since MP users rarely work in isolation;
- Computer and software manufacturers were approached, but these would not generally disclose their clients.

In this way, a list of 112 addresses was made up. For a check, the list of the 100 largest companies quoted at the stock exchange, combined with the 75 unquoted, was considered [4]. Of the combined 100 largest, 47 were already on the address list. Telephone calls were made to 15 out of the remaining 53 and only one very recent starter was discovered, whereupon this approach was abandoned. It was concluded that about half of the largest Dutch companies apply MP.

In mail surveys, response rates are generally low, in the order of 30 per cent. In order to get a high response rate, the following steps were taken:

- First, the right person at the user's address was found out and his consent to answer the guestionnaire was obtained by telephone;
- Then, the questionnaire was sent for his personal attention:
- After one month, a first reminder call was made:
- After two months, a last reminder call was made.

Thus, 86 per cent of the questionnaires sent out in May-June 1982 had been returned by the deadline of 1 September (table 1). In 16 cases it turned out that no mathematical programming was used after all - the misunder-standing being that the respondenthad thought that any computer programming with regard to some mathematical problem was Mathematical Programming. The result was 78 usable questionnaires.

Questionnaires sent out	112	(100%)
Returned	96	(86%)
Duplications (same company)	2	
No MP users after all	16	
MP users responding	78	

Table 1. Data about 1982 MP questionnaire

3. Results for MP users

Table 2 gives the main distribution of MP users by type of technique. Note that both MP and LP are interpreted in a wide sense. Of all MP users, then, 86 per cent apply LP, and an unexpectedly high 23 per cent apply nonlinear programming or combinatorial programming techniques. Table 3 gives the distribution by economic sectors. The primary sector, agriculture, is absent. Within the secondary sector (manufacturing industry), the process industry is strong and the assembly and construction industries are weak. The quartary sector accounts for a high 32 percentage of MP users.

<u>Table 4</u> represents the immediate cause for this survey: the gross growth numbers of LP users. Apparently, there is continued growth. But the picture of 1982 looks more similar to the picture of 1976 than really is the case. Of 19 users that professed to have started in the period 1977-1982, three already participated in the Müller survey. After transferring these, we find 16 starters in the period 1977-1982. Two respondents did not answer the question concerned, but participated in Müller's survey. Assigning them to the Müller period, we find 50 starters up to 1976 according to the 1982 survey, and 48 according to the 1976 survey. So far so good, but among the 50, we find 21 new names! Both surveys have only 29 users in common.

What happened to the 19 companies that responded in 1976, but were not included in the 1982 survey? Four of them were nonrespondents in 1982; one could not be contacted; three were anonymous in the 1976 survey, so they may be among the 21 new names; the remaining eleven explicitly confirmed that they had stopped using LP after 1976. Hence about one in four users observed in 1976 stopped after 1976. If the same ratio holds for the users overlooked in 1976, there must have been in fact about $(21-3)\times 4/3 = 24$ overlooked users, of whom 6 stopped after 1976 and were hence not included in the 1982 survey. This gives an estimated 11+6 = 17 who stopped after 1976. On the other hand, recent starters are probably more easily overlooked than longstanding users, hence the 16 starters after 1976 may have been underestimated.

We conclude that, except for the cattle-fodder industry in which there has been strong growth, net growth of the number of LP users after 1976 has been nil or little, and gross apparent growth has been mostly "changing of the guard".

The eleven that had stopped using LP in the last six years were asked for the reason why. The answers were quite elusive and unsatisfactory. They had just stopped. Because LP failed to be a successful tool of management or because the man who did it left the organization?

The sixteen that had started in the last six years were also asked for the reason why. The two main reasons given were:

entrance into the organization of new employee(s) who introduced LP;
financial attainability of hardware/software due to price decreases.

Users of	Number	Percentage		
MP*	78	100	-	
LP**	67	86		
Nonlinear programming	18	23		
Dynamic programming	10	13		
Combinatorial techniques	18	23		
			-	

Table 2. Main distribution of MP users by type of technique

* Mathematical programming is defined as any technique for solving optimization problems in management.

**Linear programming includes the techniques implemented in the standard "mathematical programming" packages with their options of mixed-integer programming, parametric programming, separable programming, etc.

Table 3. MP and LP users by economic sectors

Sector		MP users number percentage		LP users number percentage	
II	Manufacturing industry	31	40	27	40
	(of which process industry*)	(23)	(29)	(21)	(31)
III	Commercial services	22	28	18	27
IV	Non-profit, government	25	32	22	33
		78	100	67	100

*Food, cattle-fodder, chemical and oil industries.

Table 4. When was LP started?

Starting years	Number of LP users that s 1982 survey	tarted according to: 1976 survey
≤ 1960	8	3
1961 - 1965	3	9
1966 - 1970	13	11
1971 - 1976	21	25
1977 - 1982	19	5
	64	48

Table 5 shows that the level of education of MP users has increased further still. Over one half is now university-trained, as opposed to only 3 per cent in the total working population.

Education	Dutch working population	1982 survey MP users*	1976 survey LP users*
University	3	56	46
Higher professional	8	29	34
Other levels	89	15	20
	100	100	100

*People who actually apply MP/LP.

Table & Levels of education (nercentages)

4. Results for LP models

Table 6 gives a specification by problem types of 184 LP models given by 56 LP users. Admittedly, what to count as a model is not well-defined. It was requested to consider all different model variants for one specific problem as one model. One respondent specifying 35 different models was not believed and excluded. Mixing and blending is the most frequent application of LP, especially if one takes account of the fact that the cattle-fodder companies included were limited to six. Production planning holds the second place and long range planning the third.

<u>Table 7</u> is based on characteristics asked from the users about one specific model, viz., the model they were most familiar with. The table compares the sizes of the models in the 1976 and 1982 surveys. The criterion is the number of restrictions, but this is highly correlated with the number of variables [2]. We can cautiously conclude that both the percentage of small models (\leq 50 restrictions) and the percentage of large models (> 500 restrictions) seem to increase.

Problem type	Number of models	Percentage ***
Mixing, blending**	34	18
Production planning	31	17
Long term, strategic planning	24	13
Location, allocation	23	12
Distribution	18	10
Purchasing	16	9
Cutting stock	8	4
Manpower planning	7	4
Investment analysis	7	4
Short term, corporate planning	6	3
Costing, budgetting	6	3
Sequencing, scheduling	4	2
	184	100

Table 6. LP models by problem types*

* Response: 56 users; excluding one respondent specifying 35 models.

**Number of firms in cattle-fodder industry limited to 6.

** Percentages do not add up to 100 due to rounding.

Number of restrictions	1982 survey*	1976 survey**
≤ 50	25	21
51 - 150	11	24
151 - 500	34	34
> 500	30	21
	100	100

Table 7. Size of LP models (percentage distribution)

* Response: 44 models.

**Response: 67 models.

5. Results for MP software

Table 8 compares the non-default options (that have to be explicitly called upon by the user) in 1976 and 1982. There is little difference; perhaps the dominance of the options of initial starting base and mixed--integer programming is reinforced and the unimportance of parametric programming, generalized upper bounds, etc., is protruding.

Table 9, finally, gives a survey of complaints about standard LP software packages. For one reason or another, IBM's MPSX attracts more complaints than other software packages.

Most of the complaints refer to the manuals, the input and the output, not to the solution programs. The programs seem to have stabilized with few serious bugs left, although occasionally weird phenomena occur, like: - an infeasible solution after feasibility has been attained;

- the dual algorithm stops after some iterations because the solution gets worse;
- more iterations with an initial starting basis than without;
- too many equalities cause a "permanent" phase I;
- an integer solution with a higher objective value than the continuous solution.

Nevertheless, the overall number of complaints about the standard LP software packages is so low that it does not seem worth-while to perform the intended analysis and testing of LP packages on criteria derived from users' criticisms. Instead, it looks promising to make a deeper analysis of the input and output sides of LP systems, of matrix generators and report writers, or generator generators, modelling languages, information systems, or by whatever names they may be called, and to study cases of successful or unsuccessful implementation of LP models in the management of organizations.

Option	1982 survey*	1976 survey**
Initial basis	39	37
Mixed-integer programming	32	29
Reduction to smaller problem***	17	10
Parametric programming	14	22
Generalized upper bounds	8	12
Separable programming	3	3
Decomposition methods	2	3

Table 8. Non-default options used (percentage of models)

Response: 59 models.

** Response: 73 models.

***Sometimes implemented as option by default.

Package	MPSX	APEX	Other packages	Total
Number of respondents	18	11	31	60
Number of complaints about:				
- input (organization)	8	5	6	19
- output	8	1	7	16
- user-friendliness	3	2	10	15
- bugs in program	2	1	3	6
- manuals/documentation	12	5	15	32
- user error handling	3	1	3	7
- weird phenomena	6	0	2	8
Total complaints	42	15	46	103
Complaints/respondent ratio	2.3	1.4	1.5	1.7

Table 9. Dissatisfaction with standard LP software packages

6. Summary and conclusions

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Results of a survey held in 1982 of mathematical programming applications in the Netherlands were presented and, where applicable, compared with results of a survey held in 1976. A response rate of 86 per cent was achieved.

The fifty per cent gross growth in users observed in 1976 for the period 1971-1976 seems to have levelled off to about thirty per cent gross growth for the period 1977-1982. However, net growth is estimated at little or nil, almost all apparent growth being mere "changing of the guard".

About half of the 100 largest Dutch companies now use MP. The process industries, like food, fodder, chemicals and oil, are well represented. The quartary sector is also well represented.

The level of education of MP users has still further increased.

The classical short-term application areas like mixing and blending and production planning are still dominating but long-term, strategic, location and manpower studies are running up.

Both small models (up to fifty restrictions) and large (over five hundred restrictions) seem to hold their share.

The only non-default options that are widely used are initial starting basis and mixed-integer programming. If possible, their implementation in software packages should be perfected.

Complaints by users about the standard LP programs proper were few. Their criticisms focussed on the input side and the output side, the documentation, etc. Since LP software packages seem rather stabilized, further study could be devoted to LP model integration in the management of organizations.

References

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