KM 14(1984)
pag 164-181

Testing vehicle scheduling programs for milk collection

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Abstract

A case study is presented of a company selecting vehicle scheduling software for milk collection. No satisfactory software is found. It is argued that attention of academia and the software industry should be focussed not so much on saving planned costs as on saving planning costs. This can be achieved by building flexible, user-friendly, interactive, cheap, but not necessarily near-optimizing, software.

1. Introduction

This case study shows a company - a so-called end user - in action selecting software for vehicle scheduling of milk collection. Software programs are eliminated as soon as there is sufficient reason to do so - and none remain. What is needed is more flexible, interactive software allowing of marginal, non-optimal revisions of previous schedules.

The order of presentation is as follows. Section 2 describes the problem environment; section 3 defines the problems the company has both with planning by hand and with the software package VSPX; section 4 describes the elimination procedure actually applied; section 5 summarizes and concludes.

2. Problem environment

The co-operative dairy concern DMV-Campina processes about one third of the Dutch milk production (figure 1). Its 450,000 cows deliver about 500 dairy products, ranging from cheese to pharmaceutical fillers, all over the world (figure 2). Sales revenues were Dfl.2.8 billion in 1982.

DMV-Campina reminds one of the Yugoslavian organizations of associated labour which, if we converge to communism, bears promises for the future. The concern is owned and governed by its 9000 co-operating farmers, who choose a council of 325 representatives, who choose a board of 25 directors, who supervise three executive directors managing five divisions and 15 firms.

If we take a long-term look at the present-day DMV-Campina area, we observe a history of change (table 1, figure 3). DMV-Campina itself resulted in 1979 from a merger between DMV and Campina; the latter was formed in 1976 by five constituting co-operations; and so on. In the thirty-five years between 1948 and 1983 milk produced in the area increased five-fold or by 4.6% per year. This did not result from land use extensification - every bit of soil has been used in the Netherlands for ages - but from land use intensification, feeding and breeding. Meanwhile, the number of dairy farmers in the area dwindled from 41000 to 9000 and the number of dairy firms from 119 to 14. Where two trends work in opposite directions, ratios are squared; for instance, the average amount of milk produced per farmer increased 22-fold and the average amount of milk processed per firm 41-fold. It is expected that such trends and changes will continue in the future.

A relict of nature in this large-scale development is a seasonal pattern in milk production (figure 4). Summer milk quantity lies about 30% above winter quantity (and qualities are different).

This paper is concerned with milk collection. The horse-carts of old times collecting milk-cans twice a day for the local dairy factory have been gradually replaced by road-tankers, visiting
the farms once every three days, pumping the milk from cooling-tanks and dispatching it at unloading pits of ever fewer factories at increasing distances.

The visiting scheme currently in use is called the "6-6-6-6-4 scheme" (table 2). In every area assigned to a given firm, farmers are divided into two groups, each of which is visited in a two-week cycle four times

after three days and once after two days, leaving the Sundays and Wednesdays free. The figures in the name "6-6-6-6-4" indicate the number of milking times that are collected, since milking takes place twice a day - though there is a beginning trend towards milking three times a day.

DMV-Campina has available in 1983: 118 15-ton tankers, 130 10-ton tankers and 8 20-ton trailers.The drivers are in part employees, in part independent, but they are all feather-bedded in that they cannot be dismissed nor even moved to other work.

The amount of money involved with milk collection was Dfl. 32.5 million in 1981, of which 50% was used for drivers' wages, 33% for tanker fixed costs and 17% (Dfl. 5.7 million) for tanker operating costs. Hence a one per cent saving on operating costs would amount to Dfl. 57000. If one planner could be spared, this would amount to about twice as much.

The total costs of milk collection are determined by the organizational set-up, the scenario, in the first place. A scenario is determined by factors like:

- working only between 8.00 and 17.00 hours, or day and night;
- working on Sundays, or not;
- has all milk to be taken at a visit, or is partial collection allowed;
- life-time of tankers;
- replacing 10-ton by 15-ton tankers;
- feather-bedding or possible dismissal of drivers;
- concentrating and closing down factories;
- future developments of volumes and prices.

In fact, the influence of such factors has been analyzed in a simulation study of 86 scenarios over ten years, with sensitivity analysis, and important influences have been determined [1], but we will not dwell on them in this paper.

Within the context of an organizational scenario, benefits may be obtained from good vehicle scheduling and this leads us to the definition of our problem.

Figure 1. The cooperative dairy concern DMV-Campina processes about one third of Dutch milk (in the shaded area) from 450,000 cows of 9000 farmers in 14 firms. Firm locations indicated by dots, for names see table 3.

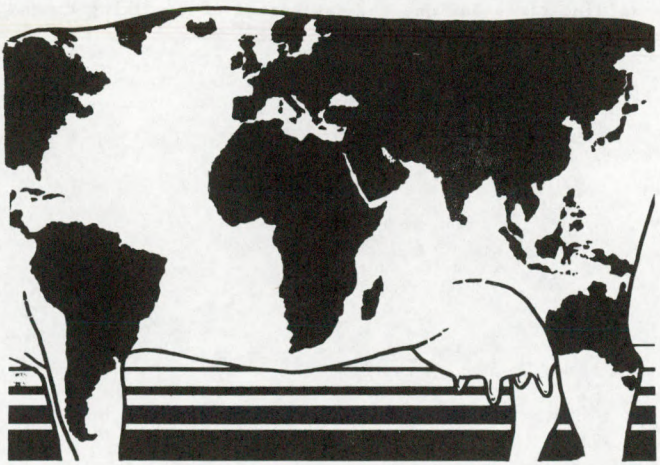

Figure 2. The Dutch cow delivers about 500 dairy products all over the world

Table 1. Number of dairy farms and dairy firms, milk production and ratios between them in the present-day DMV-Campina area

Year	Number of farms (1)	Number of firms (2)	Milk production ($\times 10^6$ kg) (3)	Farms/ firms (1):(2)	Milk/ farm ($\times$1000kg) (3):(1)	Milk/ firm ($\times 10^6$ kg) (3):(2)
1948	41 000	119	483	345	12	4.1
1953	40 000	100	608	400	15	6.1
1958	36 000	85	727	424	20	8.6
1963	33 000	75	977	440	30	13.0
1968	27 000	55	1157	491	43	21.0
1973	17 000	36	1531	472	90	42.5
1978	11 000	24	1912	458	174	79.7
1983	9 000	14	2360	643	262	168.6

Table 2. The "6-6-6-6-4 scheme" of milk collection currently in use leaves Sundays and Wednesdays free and consists of four 3-days periods of 6 milking times and one 2-day period of 4 milking times in a 2-week cycle

Day	Group 1	Group 2
Monday	6	
Tuesday		6
Wednesday		
Thursday	6	
Friday		6
Saturday	4	
Sunday		
Monday		6
Tuesday	6	
Wednesday		
Thursday		6
Friday	6	
Saturday		4
Sunday		

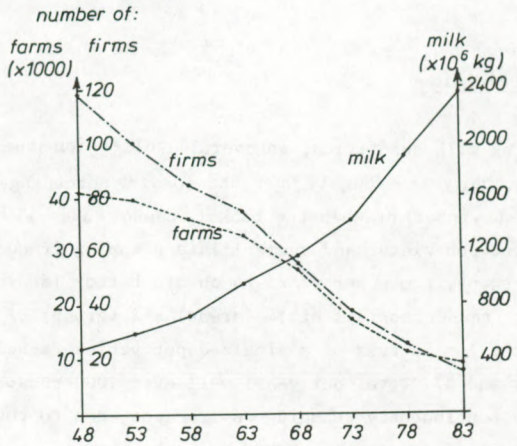

Figure 3. Development 1948-1983 of dairy farms, dairy firms and milk production in the present-day DMV-Campina area.

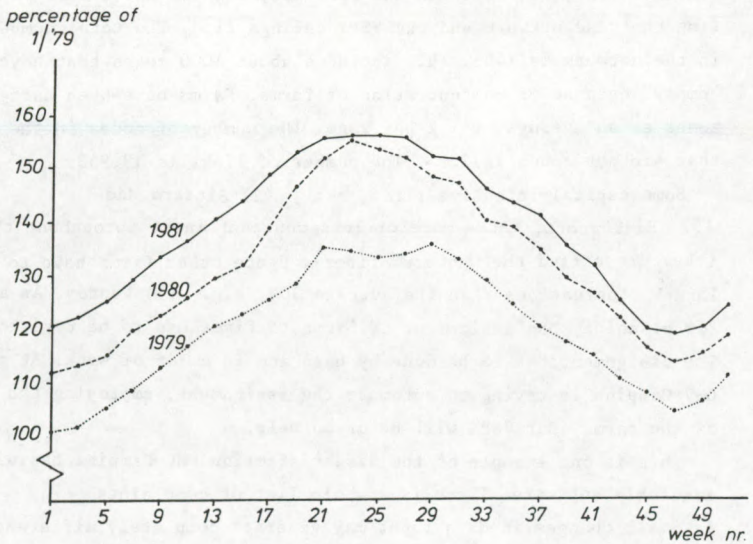

Figure 4. Milk curves 1979-1981; production of first period of 1979 = 100; summer high is about 30% above winter low; overall growth is about 4.6% per year.

3. Problem definition

Due to changing milk quantities, an overall collection schedule is now made about ten times per year - roughly when the loading percentage falls below 90% (between summer and winter) or when the tankers cannot take all the scheduled milk some times (between winter and summer). This planning frequency could be increased to twenty times per year to obtain better loading percentages. Each planning round consists of 14 (areas) × 2 (groups of farmers) × 2 (period lengths) = 56 runs of a single-depot vehicle scheduling program (cf. tables 2 and 3). Total per year: well over 1000 runs.

Within the continuously changing environment, due to the permanently increasing scale of operations, DMV-Campina has been introducing IBM's Vehicle Scheduling Program Extended (VSPX) for milk collection planning since 1975. Some characteristics of the fourteen planning areas are given in table 3. The fact that seven areas are still planned by hand is a matter of time. These areas became part of the concern by the DMV-Campina merger in 1979.

Since 1979, one full man has been busy for two and a half years constructing the road network and the VSPX "savings file". The total number of "zones" in the network is 7465. This includes about 1000 zones that have become "empty" because of concentration of farms. Farms have been assigned to zones at an average of 1.2 per zone. The number of nodes in the network that are not zones is 2295. The number of links is 13,953.

Some capital-intensive firms, e.g., (2) Sittard and (9) Rijkevoort, get a more or less constant input throughout the year (they are called the "square" firms). Hence other firms have to absorb larger fluctuations than the average 30%, e.g., (8) Venray. As a consequence for planning, the assignment of farms to firms has to be revised regularly. The assignment has to be done by hand and is a lot of work. At present, DMV-Campina is trying to automate the assignment, employing the post-codes of the farms. But VSPX will be of no help.

This is one example of the dissatisfaction DMV-Campina has with the available software. There is a whole list of complaints:

1. Small changes in data input may generate completely different routes. This is not acceptable. There should be a certain "rest" in the schedules. Farmers cannot be visited at different hours of the day all the time. Hence small changes in the data should lead to marginal changes in the

schedules. Either the software could take care of this, or the planner could achieve this if he could make changes interactively from an "initial starting base".

2. Only a maximum of three trips per day can be assigned to tankers. In fact, tankers make up to eight trips per day. The important consequence is that trips and arrival times at the firm have to be scheduled by hand. Waiting times at the unloading pits ensue.
3. The assignment of farms to firms mentioned above.
4. VSPX cannot schedule mobile trailer depots. Tankers cannot visit farms with trailers, but they can leave trailers on the main road and use them as mobile depots. A simulation study has shown that this pays if the distance of the trailor depot from the firm is more than 27 kms.
5. There are disturbing inaccuracies in the computer results due to rounding. These can be overcome by scaling, but this is user-unfriendly and causes human errors.
6. Some routes are evidently illogical, e.g. farms belonging to the same "zone" are scheduled at random. This causes loss of goodwill with the drivers.
7. VSPX tries to minimize time, not costs.
8. VSPX is written in Assembler, hence very inflexible.
9. VSPX is no longer supported by IBM.

The problem definition is, then: within the environment sketched in the previous section, find a satisfying vehicle scheduling program.

Table 3. Some data for the July 1983 high and the February 1983 low period for the fourteen dairy firms of DMV-Campina

Nr.	Location of firm	Planning method in 1983	Quantity of milk (× 1000 kg/week)		Number of farms*		Number of vehicles**	
			high	low	high	low	high	low
1.	Maastricht	VSPX	1694	1620	348	469	7.5	9.1
2.	Sittard	VSPX	903	938	228	306	5.3	5.7
3.	Weert	VSPX	4797	4276	954	963	21.0	20.6
4.	Asten	VSPX	1076	1044	173	184	3.4	3.9
5.	Bergeyk	VSPX	4973	4031	760	720	17.9	17.0
6.	Eindhoven	VSPX	1618	1818	358	415	6.8	9.5
7.	Helmond	hand	1274	1008	230	213	4.3	4.1
8.	Venray	hand	3488	2222	580	435	12.2	9.4
9.	Rijkevoort	VSPX	4481	4468	790	920	15.8	19.8
10.	Boekel	VSPX	4187	3578	740	733	14.5	15.2
11.	Den Bosch	hand	5885	4714	1170	1040	24.0	22.2
12.	Tilburg	hand	3355	3094	595	572	12.0	12.7
13.	Breda	hand	751	838	146	186	3.0	4.2
14.	Zevenb.Hoek	hand	10760	8170	2114	1918	46.3	43.0
	Total		49242	41819	9186	9074	194.0	196.4

*About a hundred farmers have a second cooling-tank, which they use in summer only, and which are counted as separate "farms".

**Full-time, 15-ton tanker equivalents. Drivers work 44 hours per week at high season, and 38 hours per week at low season.

4. Testing programs by elimination

It was decided to proceed by elimination. After a preliminary stock-taking, a program would be eliminated as soon as there was sufficient reason to do so. The "cheap", apparent criteria would be applied first. Only in the end, expensive test runs of the remaining programs would be made. Thus, no scientific comparison but a practical selection was envisaged.

Developments, both in theory and in software of vehicle scheduling have been very fast in the past few years. For a survey of the state of the art, see [2]; for a tutorial, see [4]. Most software packages make use of the savings algorithm invented by Clarke and Wright in 1964 [5], with extensions, e.g. [6]. For a number of years, only VSPX and Routemaster were available in the Netherlands. At present, many programs scramble for a market share.

Table 4 presents the list of programs, in reverse order of elimination.

Hand planning (10) was discarded off-hand in favour of VSPX, because in spite of its short-comings, VSPX was experienced to be an improvement, not so much because of savings in operating costs but because of savings in planning costs. Hand planning is difficult; good planners are scarce; the company is more vulnerable if it depends on human planners than on computers.

Multitour (9) is one example of a package that has been overlooked. Not surprisingly, there have been others. Except for VSPX and Routemaster, none of the listed programs at the time of the study had been on the market for more than a few years. Some other packages, e.g., Scicon's "VANPLAN", PE-Consultants' "Paragon", were not (yet) sold in the Netherlands.

Logitrans (8) is another typical example: when it was tried to contact it at a certain address in Paris, the address was wrong and Logitrans could not be retrieved.

For the remaining seven packages, table 5 gives a survey of some "cheap", apparent characteristics by which four programs were eliminated. The relative importance attached to the different criteria is determined by the problem environment.

For Transeconomy (7), sufficient reason for casting it out was its high price.

For Routemaster (6), its bad reputation with respect to support and flexibility turned the scale.

Trucks (5) was eliminated because it can only be run in service at Control Data and DMV-Campina does not wish to become dependent of their service.

TOPAS (4) was considered more closely. Its price was attractive, but the sweep algorithm on which it is based [7] was forbidding. The idea of the sweep algorithm can be compared to radar. For testing purposes, a whole new data file would have needed to be constructed, specifying the locations of farms in terms of distances as the crow flies and angles. Apart from the work, this would have caused unacceptable inaccuracies.

Thus only MOVER (3) and BLS (2) remained for making test runs in comparison with VSPX (1). The area of Rijkevoort was selected as a representative test area. Figure 5 shows the road network of the Rijkevoort area. Test runs were made for one group (443 farmers), one type of tanker (15-ton), without time windows, for both the three-day and the two-day periods.

Table 6 gives the test results for MOVER compared to VSPX. MOVER took one and a half hours computing time per run for its "optimizing" branch and bound algorithm with a parameter setting of two per cent from the optimum. This alone is prohibitive. Moreover, MOVER gave less than one per cent improvement in total trip time. Exit MOVER.

Table 7 gives the test results for BLS compared to VPSX. The reason that the VSPX results of tables 6 and 7 are not identical is that a few measures had to be taken to achieve comparability. Even with the post--optimization option, by which a required loading percentage is specified, BLS gives no improvement.

With BLS, also different kinds of savings were tried, the so-called π- and λ-savings [6], without improvement.

The conclusion is that if nothing else than the test run is wanted, one might just as well stick with VSPX. Of course, more is wanted. DMV-Campina wants software that will obviate the complaints they have about VSPX. Hence it will be necessary to develop new software. Probably BLS can be a starting base, an important consideration being that support is close at hand. The interactive VANPLAN [8] may be worth imitating.

It has been stated that saving planning costs offers more perspective than saving planned costs. However, new software may also improve vehicle scheduling. One aspect one should be careful about is planning loads close to tanker capacity. If planned loadings are increased, actual quantities

may exceed tanker capacity. Hence extra trips have to be made to collect all milk, jeopardizing planned savings.

Figure 6 illustrates this. In this figure, the troubles and vagaries of reality are underestimated because only scheduled trips that were actually executed are shown. Schedules are based on milk quantities collected one week prior to the first scheduled week. A study to improve forecasts of quantities to be collected based on individual farmers' time series of one year has been unsuccessful. The shifting mean could be more easily taken account of than the dispersion. With a standard deviation of 4 per cent, it may be unwise to plan loadings at much more than 92 per cent of tanker capacity.

Table 4. Vehicle scheduling programs considered, in reverse order of elimination

Nr.	Package	(Full name) Supplier, Documentation
1.	VSPX	(Vehicle Scheduling Program Extended) IBM World Trade, "Vehicle Scheduling Program Extended VSPX Education Guide", 1971. VSPX is no longer supported by IBM.
2.	BLS	(BLS-RPS, BLS-Route Planning System) Business Logistics Systems, Geldropseweg 303, Eindhoven, Netherlands (joint venture of DAF Trucks, Van Gend & Loos and Philips). No user manual.
3.	MOVER	(Modelling and Optimisation of Vehicle Routing) ORES Operational Research and Management Science Consultancy, Koninginneweg 83, Amsterdam, Netherlands. Designed by Christofides, Mingozzi and Toth, based on state-space relaxation techniques. User manual is confidential.
4.	TOPAS	(Maschinelle Tourenplanung am Dialog-Computer) Dr. Waltmann und Partner GmbH, Hessenring 64, 6380 Bad Homburg v.d.H., Germany.
5.	Trucks	(Trucks Vehicle Scheduling Package) Deltran Analysis Ltd, Clemence House, Mellor Road, Cheadle Hulme, Cheshire SK8 5AT, U.K. User manual, 1980.
6.	Routemaster	(Routemaster Distribution Planning) Analytical Systems Ltd, 58/59 Margaret Street, London W1, U.K. User manual, 1983.
7.	Transeconomy	Transeconomy Software de Routage, 122 av. des Champs Elysées, 75008 Paris, France.
8.	Logitrans	31 rue Saint Lazare, 75005 Paris, France.
9.	Multitour	Battelle, Am Römerhof 1, Frankfurt, Germany
10.	hand	(procedures for planning by hand) DMV-Campina.

Table 5. Apparent characteristics of vehicle scheduling programs*

Characteristic	VSPX	BLS	MOVER	TOPAS	Trucks	Routemaster	Transeconomy
Hardware	IBM	IBM	Gould	CTM	CDC (service)	IBM	several
Algorithm	savings	savings + "optimizer"	savings + branch & bound	sweep + heuristics	savings + area subdivision	savings + "look-ahead"	savings + "alfa-param"
Objective**	T,V	T,D	T,D,V,C,N	T,D,C	T,D,V,C	T,V	T,D,V
Language	Assembler	Cobol	Fortran	Basic	Fortran	Fortran	Fortran
Flexibility	0	++	+	+	+	0	+
Information system	0	++	+	++	+	0	0
Interactivity	0	+	0	++	+	0	0
Accuracy	0	++	++	+	++	+	+
Options							
- multitrip	no	yes	yes	yes	yes	no	yes
- time windows	0	+	+	0	+	0	+
- trailer depots	no	yes	yes	no	yes	yes	yes
- multidepot	no	yes	yes	no	yes	no	yes
- delivery points	no	yes	yes	no	yes	no	no
Costs/year (Dfl)***	0	25,000	110,000	10,000	20,000	35,000	130,000
Benefits****	0	+ 5%(?)	+ 10%(?)	+ 2%(?)	+ 20%(??)	0	0
Support	0	++	+	+	++	0	0

*Legend: 0 = same level as VSPX; + = better; ++ = much better; - = worse than VSPX (does not occur).

**Legend: T = time; D = distance travelled; V = number of vehicles; C = costs; N = number of non-visited customers (excluded in our case).

***Rough estimate of software costs only.

****First, rough suggestion.

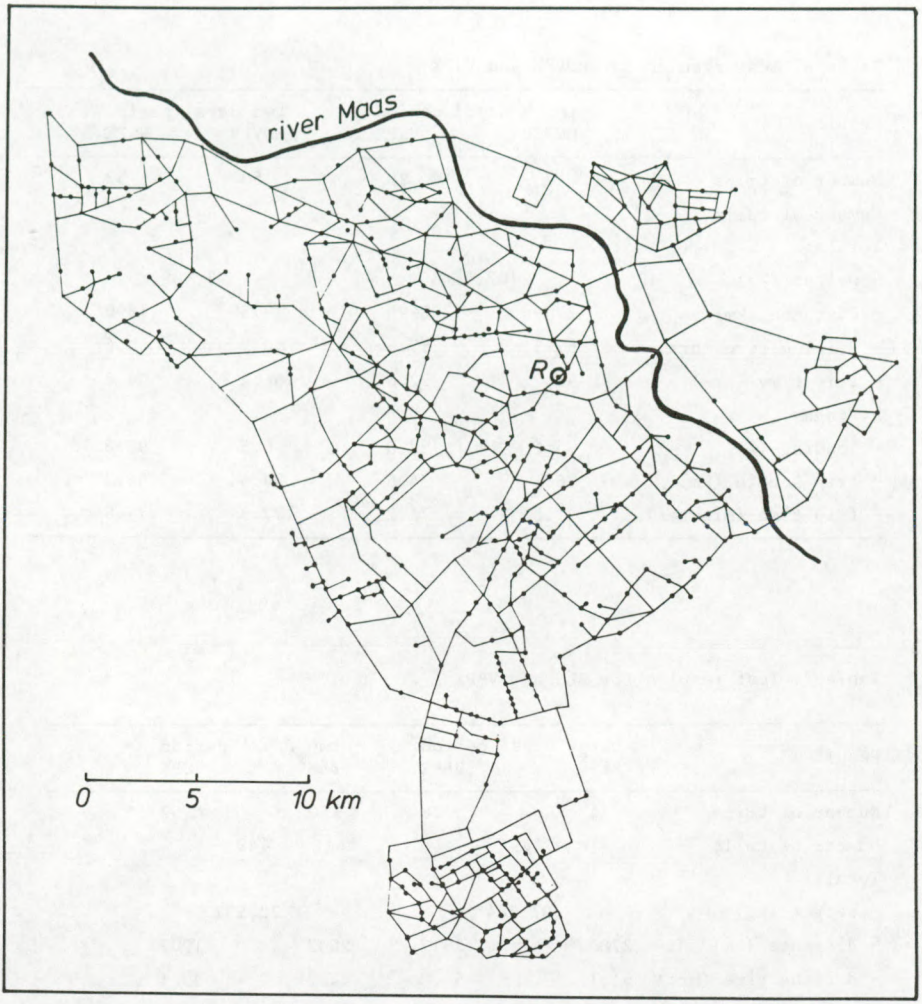

Figure 5. Road network of test area of Rijkevoort. The circle at R indicates the firm at Rijkevoort. Dots indicate zones where one or more farms (average 1.2) are located.

Table 6. Test results for MOVER and VSPX

Result	three days' period		two days' period	
	MOVER	VSPX	MOVER	VSPX
Number of trips	75	78	50	52
Number of calls	443		443	
Totals:				
- weight (kg)	107,584		72,409	
- distance (km)	2709	2695	1875	1890
- driving time (hrs)	57.3	57.6	40.2	40.6
- trip time (hrs)	92.2	92.6	64.4	64.8
Averages:				
- loading (%)	95.6	92.0	96.5	92.8
- trip length (km)	36.1	34.5	37.5	36.3
- trip time (minutes)	73.8	71.2	77.3	74.8

Table 7. Test results for BLS and VSPX

Result	three days' period		two days' period	
	BLS*	VSPX	BLS*	VSPX
Number of trips	74	78	50	52
Number of calls	449		449	
Totals:				
- weight (kg)	107,584		72,537	
- distance (km)	2780	2712	2002	1907
- driving time (hrs)	61.1	54.8	44.2	39.1
- trip time (hrs)	97.0	90.8	68.4	63.5
Averages:				
- loading (%)	96.6	92.0	96.7	92.8
- trip length (km)	37.6	34.8	40.0	36.7
- trip time (minutes)	78.6	69.8	82.1	73.3

*Use was made of the option of post-optimalization; without this option, results were identical.

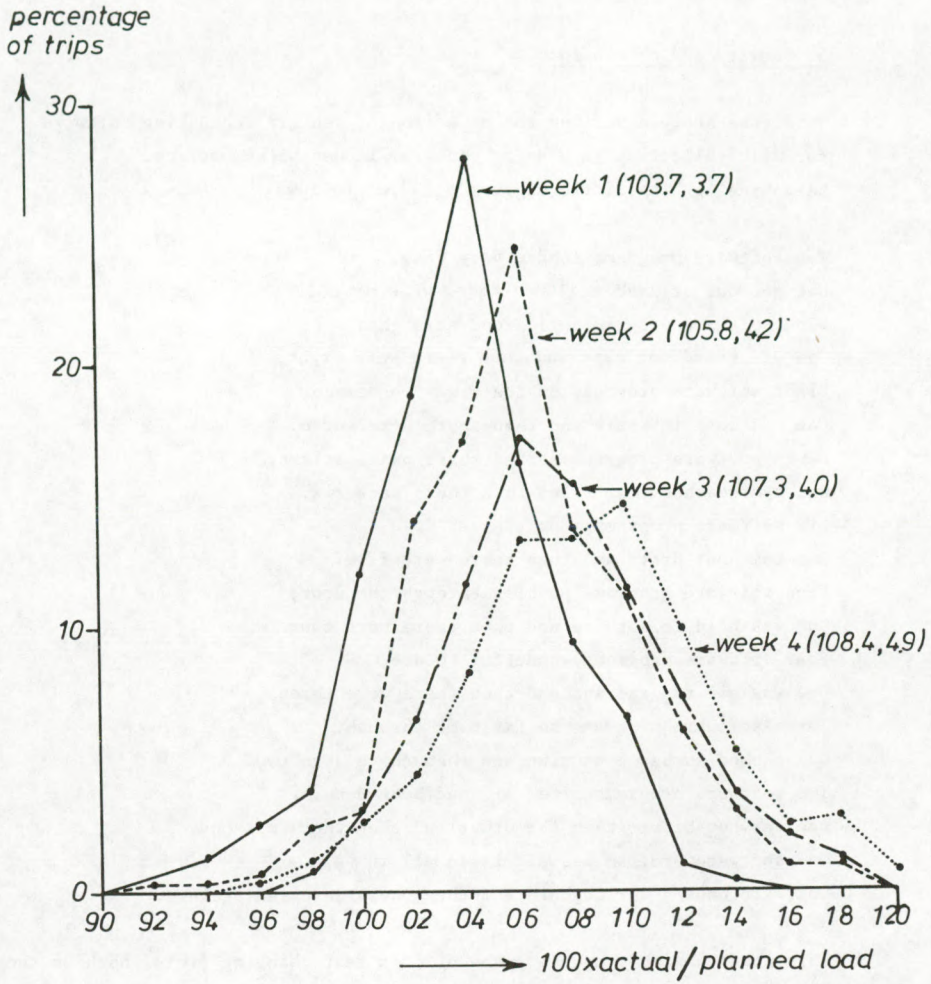

Figure 6. Percentage distribution of actual loadings as a percentage of planned loadings (rounded to the nearest even number) in a sample of 117 scheduled tanker trips in the Rijkevoort area that were executed 8 times during a period of 4 weeks starting 12 December 1983; 41 other scheduled trips not executed 8 times in the 4-week period were excluded from the sample. Figures between brackets give means and standard deviations.

5. Summary and conclusion

This case study described the selection of vehicle scheduling software for milk collection in a dairy concern. It can be summarized, paraphrasing "Ten little niggers" [3], as follows:

Ten software programs looked very fine,
One got out of hand and then there were nine.
Nine software programs all stood straight,
One was heard nor seen and then there were eight.
Eight software programs on their way to heaven,
One was lost in Paris and then there were seven.
Seven software programs raised their price sticks,
One overreached itself and then there were six.
Six software programs took a great dive,
One came out dirty and then there were five.
Five software programs pushing through the door,
One was held in service and then there were four.
Four software programs wonderful to see,
One was all too radiant and then there were three.
Three software programs so far came through,
One choked number-crunching and then there were two.
Two software programs after all had been done,
One was not better than the other and then there was one.
One software program was dismissed all in vain,
Software houses worked hard and then there were ten again.

This study has only been a snapshot of a fast changing field, both on the "supply" side of software manufacturers and on the "demand" side of the dairy industry. We conclude that software developments do not always go in the right direction. Software makers should focus not so much on saving planned costs, as on saving planning costs. There is a need for flexible, user-friendly, interactive and cheap vehicle scheduling software for milk collection. Improvement of the optimization procedure is less urgent.

Acknowledgement

Thanks are due to J.M. Stevens of DMV-Campina for his active monitoring and participation during the nine months, November 1982-July 1983, that the first author worked on his Master's thesis project, and to DMV-Campina for permission to publish the results.

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Ontvangen: 23-2-1984