Determining the optimal policy for a home delivery milk retailing: A simulation approach*

BEREND WIERENGA
AAD VAN TILBURG
University of Wageningen

Summary

A food retailing firm operates in a complex situation where its economic result is influenced by a large number of variables: own marketing variables, characteristics of customers and area of location and the nature of competition.

This paper demonstrates how all these influences can be integrated into a model and how this model subsequently can be used to find the optimal policy of the retailing firm under various conditions. The specific application in the paper is home delivery milk retailing in the Netherlands.

1. Introduction

The economic outcome of a retailing firm is the result of the effect of a large number of variables. First there is the marketing policy of the retailing firm itself with, as important variables: point(s) of location, operating periods, product line, price, advertising, promotion and service.

Secondly, the characteristics of the customers and of the area in which the firm operates are of interest. Here we are thinking of such variables as age distribution of customers, family size, the extent to which housewives work outside the home, degree of urbanization of the area and social class.

* Revised version of a paper presented at the Fifth Annual Meeting of the European Academy for Advanced Research in Marketing, Fontainebleau, 22–23 April, 1976.

In the third place, the level of competition and the marketing policy of the competitors are important for the result of a retailing operation.

This paper describes a modelling approach in which the effects of the different variables and their interactions are described by a set of equations. The equations, after estimating their parameters, are used together in a simulation model. Such a simulation model can then be used to evaluate alternative policies of the retailing firm for different circumstances with respect to characteristics of customers, area and competition. Main emphasis is put on the marketing policy which affects not only sales but also the operating costs of the firm. The ultimate goal is to optimize the total policy of the retailing firm with the economic result as objective variable.

The specific application in this paper is to home delivery milk retailing in the Netherlands. In this type of retailing, variables like service and frequency of delivery are of major importance. Nevertheless, it is felt that the simulation approach as such has a much broader applicability than just to this specific type of retailing. The paper is organized as follows. First a brief description is given of the situation with respect to the Netherlands milkmen. The next section sketches the policy model to be constructed and its major submodels. Subsequently the specification of the equations, available data and estimation results are discussed. Then the simulation model is described and its application in the evaluation of alternative policies is demonstrated. Some discussion points conclude the paper.

2. **Empirical setting**

In the Netherlands there are two types of home delivery milk retailers (milkmen). A traditional milkman operates a delivery van or truck, carries a full line of milk and milk products and some additional products such as beer, soft drinks and margarine. Mostly he also sells a small selection of grocery products. Besides the traditional milkmen there are mobile shops. A mobile shop is a covered van, 8 to 12 meters long, carrying milk and milk products and a good selection of other products that are frequently purchased (food as well as non-food). The total number of products ranges between 500 and 1000. The housewife is supposed to enter the mobile shop, choose the products she wants from the self-service system, and pay at the check-out.

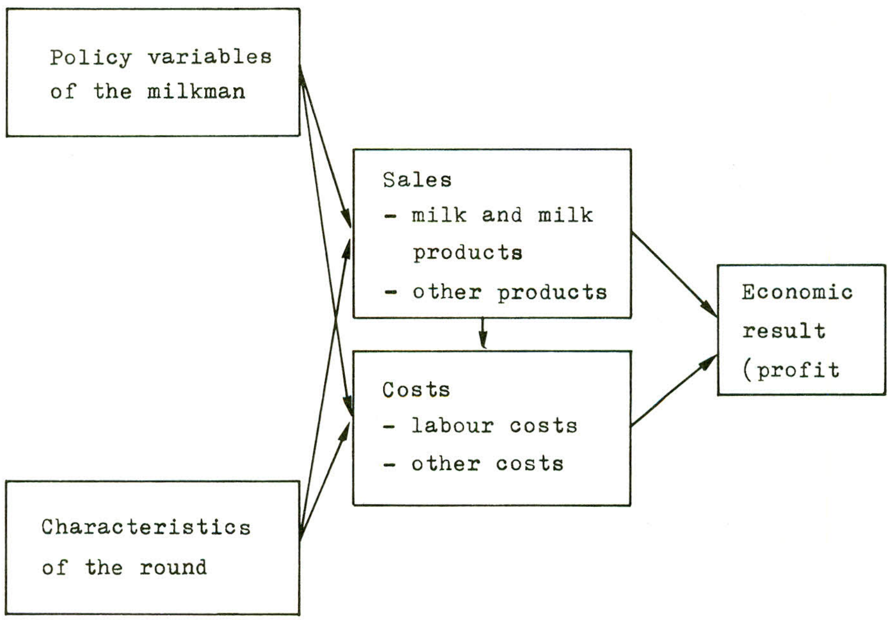
Currently the Dutch milkmen are in economic trouble. This is mainly due to the fact that over the last 10 years almost all supermarkets and other foodstores have adopted milk and milk products in their product lines (formerly this was forbidden by government regulation). The purpose of the research described here – which is part of a larger study project subsidized by the government – is to determine how the milkmen should respond to this new situation and how they should operate under different conditions. The report on the complete project is given by Meulenberg et al. (1976).

3. Sketch of the model

This section gives a global description of the model that links together the policy variables of the milkman and the characteristics of the round into a total policy model. This model, the simulation model, predicts the outcome for each combination of policy variables and round characteristics for an 'average' milkman.

Figure 1 depicts the major relationships that determine the economic result of a milkman.

Figure 1. *Basic relationships that determine the economic result of the milkman*



Important policy variables of the milkman are: frequency of delivery, amount of service offered, price, product-line, type of vehicle used, etc.

Important round characteristics are: degree of urbanization, type of dwelling (houses or flats), composition of the population with respect to family size and age, degree of competition from supermarkets, etc. (Because of a regulation from the Dairy Retail Trade Board there is no competition between milkmen; every milkman has his own round.) Note that the characteristics of the customers, those of the dwellings in the round, as well as the level of competition are together labelled under characteristics of the round.

Sales are affected both by the policy variables of the milkman and the characteristics of the round. For example sales will be higher, the higher the frequency of delivery (milkman variable) and the lower the degree of urbanization (round characteristic). Costs are influenced in the first place by the level of sales, which in turn are affected by milkman variables and round characteristics. Besides there are direct effects on costs of the latter type of variables. For example, total costs are influenced by the vehicle used (milkman variable) and by the intensity of traffic (round characteristic). The economic result is simply the difference between sales and costs.

The policy model is constructed according to the relationships in Figure 1. The two major dependent variables in this figure are sales and costs. Accordingly the model contains a sales model and a cost model as submodels.

3.1 *Sales model*

From Figure 1:
(1) Sales = f (policy variables of the milkman, characteristics of the round).

The dependent variable in equation (1) is the amount spent on products from the milkman. The milkman sales can be divided into:
- sales of milk and milkproducts;
- sales of other products.

The latter category is subdivided in turn into:
- other regular products, i.e., products that are carried by (almost) every milkman, such as beer, soft drinks, margarine;
- specific products, which are carried in varying quantities: fresh products (like bread, fruits and vegetables) and grocery products.

3.2 *Cost model*

According to the accounting survey to be discussed shortly, by far the most important component in the total costs[1] of the milkman is labour costs (78%). The next most important item is vehicle costs (10%), then follows administration (5%), buildings (3%), interest (2%) and advertising (2%).

For reasons of conciseness, of the various cost items in this paper only the labour costs model is dealt with. The models for the smaller cost items are not explicitly treated. They are incorporated in the simulation model though. The interested reader can find them in Meulenberg et al. (1976).

According to Figure 1:
(2) Labour costs = f (policy variables of the milkman, sales, characteristics of the round).

Labour costs, which are expressed in working hours, are divided into two categories:
- delivery hours;
- hours required for loading, unloading and administration.

After this brief outline the model will be treated in more detail in the next section.

4. **Data available, specification and estimation**

4.1 *Data available*

Equations (1) and (2) are specified in interaction with the data available. Therefore, these data are discussed first. There were three sets of data available:

(i) *Consumer panel data.* The quantities of milk, milk products and other products purchased from the milkman by each of the 2000 households of the Dutch Attwood consumer panel during the 4-week period: May 18 to June 14, 1975. Because of certain requirements (e.g., the households without a milkman in the street had to be disregarded) only 1062

1. Not taken into consideration: purchasing costs.

households could be used. For these households a number of socio-economic characteristics were known, together with information on shopping habits, about each household's milkman (e.g., his frequency of delivery, type of vehicle etc.) and about competition (distance to nearest supermarket).

(ii) The results of a survey among milkmen, containing information from a sample of 283 different enterprises with 501 rounds in total (many enterprises have more than one round). This survey contains sales figures, subdivided into (a) milk and milk products, (b) other products for a specific week: September 29 to October 5, 1974. For the same week delivery time per delivery day and total working time spent for loading, unloading and administration were recorded. Also some more general variables were given: type of vehicle, frequency of delivery, composition of product-line, characteristics of the round, etc. This data set is referred to as: the milkman survey.

(iii) The accounting figures of a sample of 100 home delivery milkman retailers for the year 1973. These figures were collected by the Economic Institute for Medium and Small Scale Business Enterprises.[2]
Besides total sales and rather detailed information on cost factors these data also contain some information with respect to the policy of the milkman and the characteristics of his round(s). This data set is referred to as: the accounting survey.

After this description of the data, specification and estimation results are discussed separately for the sales model and the cost model.

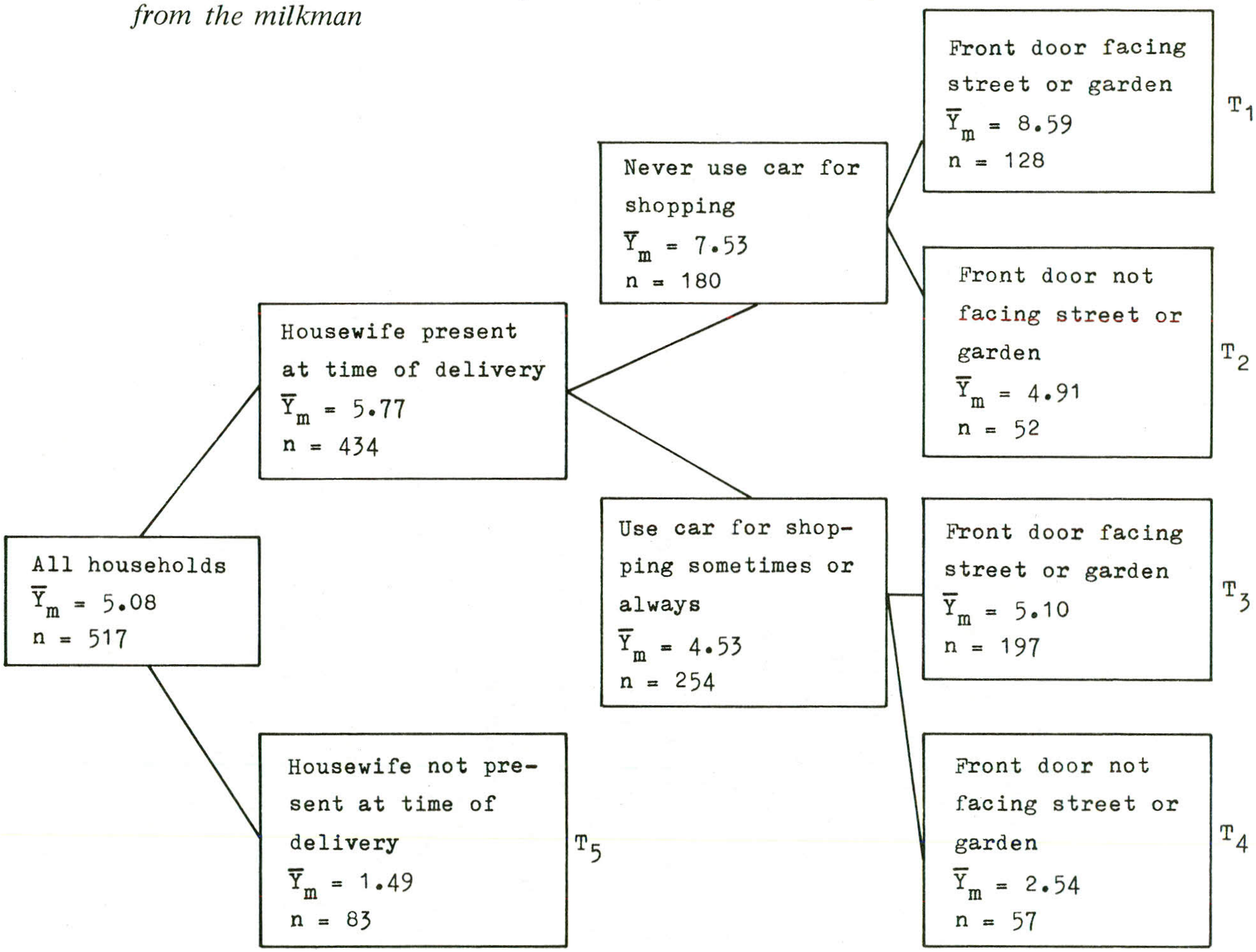
4.2 *Sales model*

The characteristics of the round (mentioned in equation 1) are for the greater part the socio-economic variables and shopping habits of the households. The most detailed information in this respect is provided by the consumer panel data. These data also contain information with respect to each household's milkman (policy variables). Therefore for the specification of the sales functions the consumer panel data were taken as the starting point. (Purchases of consumers are sales for the milkman.)

Two separate sales models are considered: for milk and milk products and

2. In Dutch: Economisch Instituut voor het Midden- en Kleinbedrijf, E.I.M.

Fig. 2. *First part of AID-tree for the purchase of milk and milk products from the milkman*



for other products. In the first model the dependent variable is:

y_{mi} = total amount of milk and milk products per capita purchased from the milkman by household i during the 4-week observation period (in guilders).

y_{mi} is to be explained by the socio-economic and shopping habit variables of household i and by the policy variables of household i's milkman.

Since the consumer panel data contain a great many of variables (28 in total) and the presence of interactions between some of these variables was quite probable, first a search procedure was carried out to select the variables to be inserted in the equation. For this purpose the AID-technique (Automatic Interaction Detector) was used (Sonquist and Morgan, 1970). This method splits the sample into two subsamples according to the variable that explains most of the variation.

It is then tried to split the subsamples again, etc. The method detects the major variables and interactions between variables that should be inserted in the equation, to explain as much variation as possible. Since this is a procedure of fitting the equation to the data it is important to split the original data set into an analysis sample to which AID is applied and a validation sample to check the results. This has been done in the case reported here: a random split produced an analysis sample with $n = 517$ and validation sample with $n = 545$.

The first part of the AID-tree for the analysis sample is shown in Figure 2.

The most important factor that determines the intensity of purchasing from the milkman is the presence of the housewife at the time of delivery. For the group of households with housewives absent, no other variable could be found that explained enough variation to justify a further split. For the other group, car-use for shopping is the next important variable. Apparently housewives often utilize the car to buy the relatively bulky milk and milk-products in the supermarket. Further, when the front door is not on the ground-floor or when the door is in the corridor of an apartment building, purchases from the milkman are considerably lower.

With this AID-tree as a starting point a regression model was set up with, for each of the 5 end branches of the tree of Figure 2, 1 – 0 variables to indicate whether a household is or is not in that branch. Interactions with a number of other variables were considered and in addition some more general variables (such as degree of urbanization) were included in the model.

In the estimated sales function only variables significant at the 10% level are included. Table 1 gives the estimation results. (The exact definition of all

Table 1. *Sales equation, dependent variable is* Y_{mi}: *Sales of milk and milkproducts*

Independent variable	Brief description[a]	Coefficient	T-value (abs.)	Significance level[b]
constant		−1.771		
T_2	(T_i = AID-branch T_i ($i = 1, \ldots 5$), see Figure 2)	4.120	1.79	xxx
T_3		7.778	3.64	xxx
A	age of housewife	1.445	2.04	xx
DT	delivery time	1.642	2.59	xxx
U	degree of urbanization	0.208	2.88	xxx
D_1	district	1.924	3.21	xxx
D_2	district	1.192	1.86	xx
FS	family size	−0.334	2.14	xxx
$T_1 \times W$	W = outdoors working housewife	6.893	9.48	xxx
$T_3 \times 1nFr$	Fr = frequency of delivery	−2.734	1.95	xx
$T_4 \times OD$	OD = other deliverers	1.682	2.58	xxx
$T_4 \times S$	S = service	2.221	1.75	xx
$T_5 \times OD$	OD = other deliverers	0.888	1.30	x
MS	mobile shop	−1.267	2.54	xxx
	$R^2 = .242 \quad n = 517$			

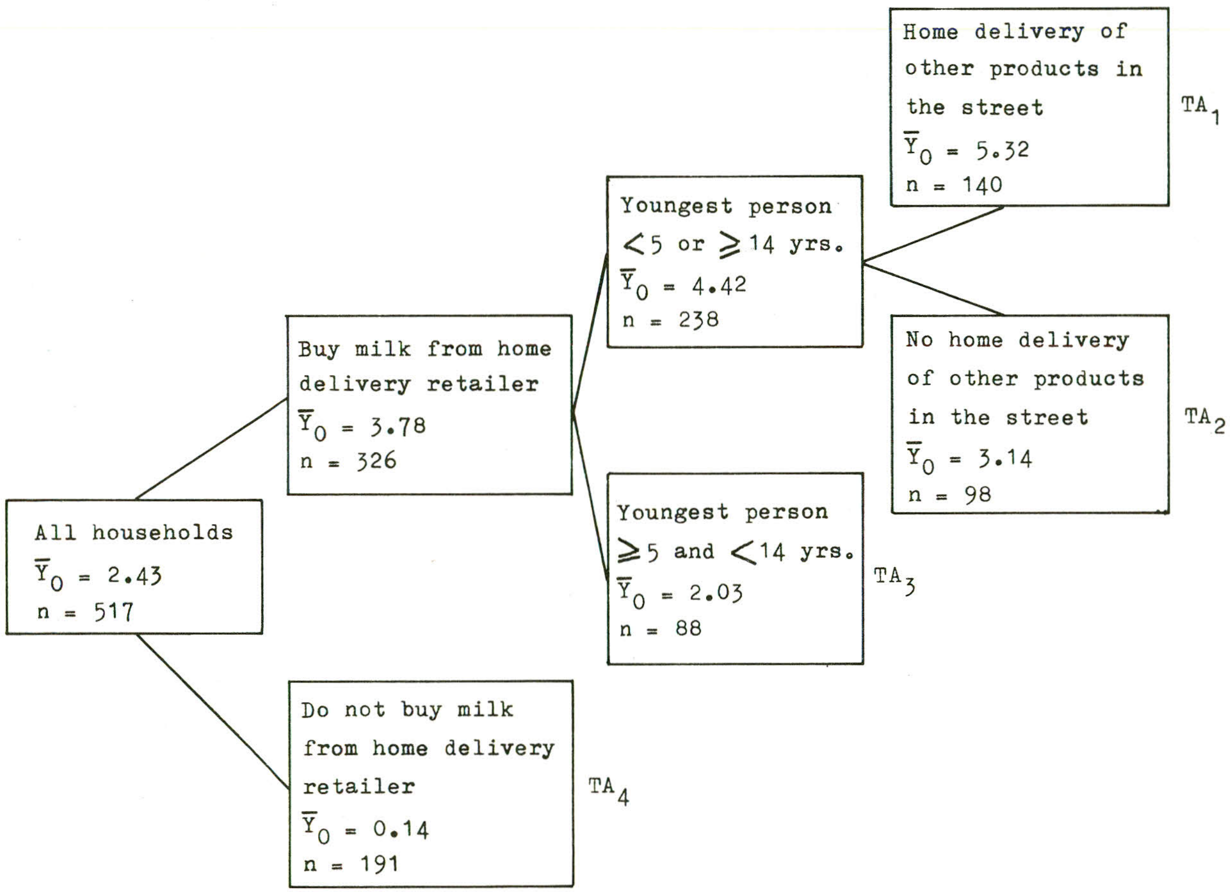
a. For exact definitions of the dependent variables in this equation and the equations to follow, see Appendix A.

b. xxx = sign. when $\alpha = 0.01$;
x = sign. when $\alpha = 0.10$.

variables in this equation and in the equations to follow are given in Appendix A.)

Although quite a number of significant factors were found, R^2 (0.242) is of modest size, which is not so surprising since we try to explain purchases of individual households. Apart from the effects of the variables T_1 to T_5, the purchases of milk and milk products from the milkman are positively influenced by: older age of the housewife, delivery before 4 p.m., a low degree of urbanization, other home delivery retailers in the street and delivery at the customer's door. Negative factors are: a bigger family size, a housewife working outdoors, a round in the south of the country and delivery with a mobile shop. Purchasing intensity seems also to be lower, the higher the

Figure 3. *First part of the AID-tree for the purchases of other regular products from the milkman*



frequency of delivery. This is a doubtful result, possibly due to measurement errors. The competition variable 'distance to nearest supermarket selling milk' does not have a significant influence on the sales of milk and milk products. It does have an effect on the purchases of other products from the milkman though.

In the model for the products other than milk and milkproducts, the dependent variable is:

Y_{oi} = total amount of other products per capita purchased from the milkman by household i during the 4-week observation period (in guilders).

Here other products refer to other regular products defined in section 3. Purchases of specific products were not recorded by the consumer panel.

The first part of the AID-tree for other products is given in Figure 3.

The most important factor for the purchases of other products turns out to be whether or not the household is a customer of the milkman for its milk and milkproducts. The demand equation, estimated consecutively, is given in Table 2.

Apart from the effects of the variables TA_1 to TA_4 (corresponding with the branches of the AID-tree), negative factors for the purchases of other products are: the use of the automobile for shopping and a big family size.

Table 2. *Sales equation, dependent variable is Y_{oi} : Purchases of other products*

Independent variable	Brief description	Coefficient	T-value (abs.)	Significance level[a]
constant		0.276		
TA_1	(TA_i = AID-branch TA_i (i = 1, . . . 4), Figure 4)	4.663	4.33	xxx
$TA_1 \times Au$	Au = car use for shopping	– 3.413	3.02	xxx
$TA_1 \times FS$	FS = family size	– 0.410	1.53	x
$TA_1 \times S$	S = service	1.348	1.67	xx
$TA_2 \times Dis$	Dis = distance to supermarket	0.975	4.36	xxx
$TA_3 \times MS$	MS = mobile shop	2.390	3.03	xxx
Y_m	sales of milk and milk products	0.105	2.73	xxx
	$R^2 = 0.237$ $n = 517$			

a. See Table 1, fn. b.

Positive factors are: delivery at the front door, a long distance to the nearest supermarket and a mobile shop as milkman's vehicle. The positive influence of the mobile shop is due, of course, to its much wider selection of other products. The same specification applied to the validation sample produced a R^2 of 0.166.

The reader will have noticed that in the equations given the variable price is missing as explanatory variable. The reason is that the data were not sufficient to include this variable. This is a drawback; the results that follow are now conditional on a constant price difference between milkman and supermarket. After a turbulent period, during which supermarkets used the price of milk as an incentive to draw customers, partly due to a minimum price regulation imposed by the government the price situation is more stabilized now. So we believe that the assumption of a constant price difference is not too restricting.

In the equations discussed the expenditures on advertising are also missing. On this item, which is of minor importance in the current marketing policy of the milkman, no sufficient data were available either.

The sales functions so far have been derived from the consumer panel data. The milkman survey contained a number of variables not included in the consumer panel data, for which it is important to know the effect on the sales of milk and milk products. Moreover with these data it was possible to check the effect of frequency of delivery, for which the consumer panel data produced doubtful results. For these reasons the sales function for milk and milk products was also estimated from the data of the milkman survey. Only some specific regression coefficients, of interest for the simulation model to be built, are given here. It appeared that – taking into account the effect of other variables – per capita purchases of milk and milk products every 4 weeks were 0.471 higher when the frequency of delivery was high (more than 4 times a week), compared with a low frequency. Furthermore per capita purchases were 0.494 higher when the milkman gave credit to his customers and were 0.170 lower for each other fresh product the milkman carried besides milk and milk products (these can be bread, fruits, vegetables, etc.).

In the milkmen survey the sales of specific products were also recorded. These were missing in the consumer panel data. From the milkmen survey, therefore, an equation could be estimated explaining the sales of specific products as a function of sales of other regular products, fresh products, type of vehicle and regional area. This equation is also used in the simulation model.

4.3 *Labour cost model*

In the labour cost model variables were inserted according to equation (2). The equations were estimated from the data of the milkmen survey.

First the delivery time equation was estimated. There the dependent variable is defined as:

U_D = number of delivery hours per delivery day in the round.

The milkmen were separated into two groups: milkmen with a high efficiency level and milkmen with a low efficiency level; this was done on the basis of the number of hours spent for loading, unloading and administration per *f* 100 sales. Since it was desirable to have a normative working time model, the estimation was done for the data from the milkmen with a high efficiency level. Table 3 gives the model and estimation results.

The estimation result in Table 3 implies the following model:

$$U_D = 0.542\,(HD)^{0.347}\,(Z_1)^{0.126}\,(Z_2)^{0.124}\,(Km)^{0.099}\,(e^S)^{0.044} \times$$
$$(e^V)^{0.063}\,(e^{MS})^{0.054}\,(e^{Fr})^{0.090}\,(e^{TH})^{0.064}\,(e^{D_2})^{-0.053}\,(e^C)^{0.028}$$

Table 3. *Labour cost equation, dependent variable is ln U_D: Delivery hours per delivery day (ln transformation)*

Independent variable	Brief description	Coefficient	T-value (abs.)	Significance level [a]
constant		– 0.612		
ln HD	HD = number of house doors	0.347	11.73	xxx
ln Z_1	Z_1 = sales of milk and milk products per door	0.126	14.30	xxx
ln Z_2	Z_2 = sales of other products per door	0.124	6.24	xxx
S	S = service	0.044	1.35	x
ln Km	Km = length of round in kilometers	–0.099	6.56	xxx
V	delivery van	0.063	2.39	xxx
MS	mobile shop	0.054	1.42	xx
Fr	frequency	0.098	4.09	xxx
TH	type of dwellings	0.064	2.48	xxx
D_2	district	–0.053	2.12	xx
C	credit	0.027	1.31	x
	$R^2 = 0.514$ $n = 379$			

a. See Table 1, fn. b.

This multiplicative model turned out to give a much better fit than an additive model. Since there are evident interaction effects (e.g., additional working time per additional house door will depend on the sales level per door), this is not surprising. The multiplicative function implies: (i) decreasing additional delivery time per additional door as the number of doors in the round increases, (ii) advantages of specialisation, either in milk and milk products or in other products.

Factors that increase delivery time are: number of housedoors, use of delivery van (the traditional milkman can either operate a delivery van or a truck), use of mobile shop, predominantly houses instead of flats in the round and the giving of credit. Factors that decrease delivery time are a high frequency of delivery and a round in (the more quiet) northern and eastern parts of the country.

The second type of labour costs is cost for loading, unloading and administration. The dependent variable is:

U_L = number of hours required for loading, unloading and administration per week.

Table 4 gives the model and estimation results.

Total sales, type of vehicle, giving credit and some additional variables are important for the total time spent on loading, unloading and administration.

Table 4. *Labour cost equation, dependent variable is U_L: Hours spent for loading, unloading and administration per week*

Independent variable	Brief description	Coefficient	T-value (abs.)	Significance level[b]
constant		6.519		
SO	sales[a] of other products	0.179	6.18	xxx
NR	number of rounds per enterprise	1.895	2.29	xx
V	delivery van	3.575	1.80	xx
MS	mobile shop	1.606	1.39	x
C	credit	3.121	1.82	xx
EP	number of employees	3.482	1.95	xx
SM × *CC*	sales of milk × collective cold storage	−0.092	2.57	xxx
(SM+SO) × *V*	total sales × delivery van	0.118	2.76	xxx
(SM+SO) × *C*	total sales × credit	0.074	2.47	xxx
	$R^2 = 0.455$ $n = 198$			

a. Sales × Dfl. 100. b. See Table 1, fn. b.

For the estimation result of Table 4 each milkman's enterprise represented one data point, while in Table 3 each round was a data point. This explains the difference in sample sizes.

5. The simulation model: MILSIM

The sales and cost equations discussed previously were integrated into a simulation model. This simulation model, called MILSIM (milkman simulation), is a computer program that can be used to simulate a round. The user provides input variables which are of two different types: (i) characteristics of the round, and (ii) policy variables of the milkman. The program generates sales, costs and economic result. Thus MILSIM works according to the diagram given in Figure 1. The input variables are described in Appendix B.

After the input variables have been provided the program starts with generating the purchases of milk and milk products, using the equation described in Table 1. This equation is slightly adapted. Since the frequency effect found was doubtful, it was replaced by the coefficient (0.471) indicating the effect of high versus low frequency as found in the milkman survey data. In addition the coefficients for the effect of giving credit (0.494) and the effect of other fresh products (0.170) were incorporated. Of course, the constant term had to be adapted accordingly. This transplantation of coefficients raises some questions. However with not too much intercorrelation the possibility of including the variables in the model in our opinion outweighs the disadvantage. By using the equation described in Table 2, the purchases of other products are generated subsequently. After some normalization figures for the sales per house door per week are produced which are then used in the labour cost equations (Tables 3 en 4) to compute the required delivery time per delivery day and the required additional working time.

Finally all numbers are converted to annual figures, the various other cost functions (not given in this article) are used to estimate vehicle, administration, building costs, etc., and then net profit and income can be obtained. It is clear that it is implicitly assumed that the 4-week observation period of the consumer panel and the one-week observation for the milkman survey are representative for the whole year. Further the time differences between the 3 data sets (which are from 1975, 1974 and 1973) are neglected.

Example

For a round with 500 doors, average degree of urbanization, 3 times delivery per week with a delivery van, delivery at the van (not at the door), no credit given, no other fresh products carried, no employees, with three-quarters of all customers served before 4 p.m., where the milkman has 2 weeks vacation a year and his gross margin is 18% (all other variables set at default values) the result produced by MILSIM is given in Table 5.

In this case the coverage level[3] is generated by the model, using a relationship between coverage level and round characteristics estimated from the milkman survey data. Alternatively if the coverage level for a round is known it can directly be used as an input variable.

Labour costs in Table 5 were computed by using a standard amount for the hourly costs.[4] When the work is done by the milkman himself his income is: labour costs + net profit.

Table 5. *Sample output from MILSIM for a specific round described in the text*

(1)	Number of doors		500
(2)	Sales of milk and milk products	per week	Dfl. 2356
(3)	Sales of other products	per week	Dfl. 1405
(4)	Coverage level[a]		80.3%
(5)	Delivery hours per day		9.4
(6)	Loading, unloading, administration hours per week		9.9
(7)	Total working hours per week		38.0
(8)	Total sales per year		Dfl. 188,063
(9)	Gross margin		Dfl. 33,851
(10)	Labour	costs	Dfl. 22,256
(11)	Administration	costs	Dfl. 1890
(12)	Interest	costs	Dfl. 1038
(13)	Buildings	costs	Dfl. 1335
(14)	Vehicle	costs	Dfl. 4234
(15)	Advertising	costs	Dfl. 487
(16)	Net Profit		Dfl. 2611
(17)	Income of the milkman (Economic result)		Dfl. 24,868

a. Number of milkman clients divided by number of house doors.

3. Percentage of all house doors in the round that are customers of the milkman.

4. This standard amount is computed by the E.I.M., see footnote No. 2.

5.1 *Testing the model*

A possibility to test the model partially was presented by the accounting survey data. The sales figures in this survey may be considered as fresh data. Besides total sales for each enterprise in the survey the following information is available: number of house doors, district, degree of urbanization, type of vehicle of the milkman, frequency of delivery and whether credit is given by the milkman or not. Thus for a subset of the input variables of MILSIM (see Appendix B) the information is known. For technical reasons only the data for the enterprises with one round could be used (74 enterprises in total). For each of these enterprises total sales were computed using MILSIM, where the unknown input variables were set at default values.

First the absolute levels of computed and actual sales were compared. Average sales per enterprise as computed by MILSIM are *f* 169,808. The actual average is *f* 186,911. So the simulation model tends to underestimate true sales by about 10%, probably because of underreporting in the consumer panel that produced the data for the estimated sales functions.

Secondly it was examined how well MILSIM reproduced the variation in the sales among the enterprises. For that purpose sales per house door were considered, which is the crucial variable in the simulation model. The correlation coefficient between computed sales per house door and actual sales per house door over the 74 enterprises turned out to be 0.55. This is when the coverage level is generated by the model. Using the true coverage level for each enterprise, the correlation coefficient increased to 0.71. This implies a reasonable performance of the simulation model, especially when it is taken into account that only a limited subset of the input variables were available for the rounds under study.

MILSIM can be of help when for an individual round the optimal policy of the milkman, vis-à-vis the specific circumstances of the round, has to be determined. Since MILSIM is constructed from the data for a great many enterprises it represents a reference case.

If for a specific round a specific estimate can be made with respect to the effect of a variable, which differs from the average effect, this can be incorporated into the model. By computing through a great many alternatives a checklist was developed which enables an analyst to get a quick indication of the sales potential of a round without having to actually run MILSIM.

The simulation model can also be applied to develop general recommendations on specific points of the milkman's strategy, and to determine the optimal size of a round under different conditions. This will be illustrated in section 6.

6. Examination of policy alternatives using MILSIM

6.1 *Frequency of delivery*

MILSIM can be used to examine specific policy variables of the milkman. Two examples will be discussed: frequency of delivery (this section) and amount of service provided to the consumers (next section). Section 6.3 deals with the question of the optimal size of a round.

With respect to frequency, two alternatives were considered: delivery every other day – which amounts to 3 times a week – and daily delivery, which because of one off-day means delivery 5 times a week. Since it is likely that different round types give different results a segmentation was performed in which 4 different round-types were distinguished:

(i) A round in a city with mainly flats and apartments.
(ii) A round in a city with predominantly houses.
(iii) A round in an area of average degree of urbanization: urbanized countryside.
(iv) A round in the countryside.

For each round-type the various input variables for the round characteristics were set accordingly. For example in the countryside not only the degree of urbanization is low, but also the distance from the average customer to the supermarket is large, all houses have a front door facing the street or garden, generally there are more deliverymen for other products, etc.

The simulation model was used as follows. For each frequency alternative the size of the round (= number of house doors) was increased until either the total delivery time per delivery day was 10 hours or total working time per week (= delivery time + time for loading/unloading/administration) was 50 hours. The results are given in Table 6 where, besides the 4 round-types, 2 different vehicle types are distinguished: delivery van and mobile shop. Except for the variables that define round-type and vehicle-type and the variables frequency and number of house doors all input variables of MILSIM were set at default values. Table 6 shows that – except for one combination – the low frequency alternative produces a higher income in less working time. This higher income results from the somewhat lower sales per house door with low frequency being more than compensated by the bigger number of house doors that can be served. The exception is the situation of a delivery van in a city area of multi-storey buildings. Although the income there is about *f* 2000,– higher with frequency 5, this is achieved by an additional working time of 15 hours a week. Even then the total income is only about *f* 16,000 (modal income in the Netherlands currently *f* 25,000).

Table 6. *Effect of frequency of delivery*

Type of round	Type of vehicle					
	Delivery van			Mobile shop		
	Income[a]	Hours	Doors	Income	Hours	Doors
City, flats						
Frequency = 3	12984	32.7	900[b]	27908	45.2	900
Frequency = 5	16222	48.1	900	15334	49.5	525
City, houses						
Frequency = 3	26561	39.7	675	24883	43.9	525
Frequency = 5	22774	50.4	525	14017	49.6	325
Urbanized countryside						
Frequency = 3	28651	40.7	575	29961	44.8	500
Frequency = 5	22696	49.5	425	16186	49.3	325
Countryside						
Frequency = 3	30342	41.2	475	28328	43.8	400
Frequency = 5	23488	49.6	350	16022	49.2	250

a. Income = annual income (Dutch Guilders).
Hours = total working hours per week.
Doors = total number of house doors in the round.

b. It was felt by practical milkmen that a round of more than 900 households is beyond their possibilities. Accordingly this limit was set for the number of doors.

Thus a frequency of 3 is much more attractive than a frequency of 5. In a sensitivity analysis this conclusion remains valid when the frequency effect (= additional sales generated by the higher frequency) is twice as big as the average effect. An analysis for a specific case showed that the frequency effect has to increase to 7 times the average before a delivery frequency of 5 produces a higher income.

The conclusion that a frequency of 3 is generally more attractive than a frequency of 5 is important, because currently the frequency of delivery is 5 or 6 in 66% of all rounds.

6.2 *Amount of service*

A major policy variable of a milkman with a traditional vehicle is the place of delivery. He can stop in the street and announce his presence by ringing a bell. The housewife is then supposed to walk to the van and is served there. The other possibility is that the milkman rings at the door of every individual customer and delivers the demanded products at the house door. These two alternatives were analysed with MILSIM, in the same way as was done with frequency of delivery before. Since the housewives are supposed to enter a mobile shop, for this vehicle delivery at the house door is no proposition. Delivery at the house door is practically impossible in a round through an area of flats. So this case is excluded too. Table 7 compares the two alternatives. Here the frequency of delivery is set at 3.

Delivery at the house door has a positive effect on the sales of milk and milk products and other regular products (Tables 1 and 2). On the other hand it has a negative effect on the sales of specific products and it increases total delivery time.

Table 7. *Effect of delivery at house door*

Type of round	Delivery van		
	Income	Hours	Doors
City, houses			
Delivery at van	26561	39.7	675
Delivery at house door	24873	38.7	675
Urbanized countryside			
Delivery at van	28651	40.7	575
Delivery at house door	26774	40.6	500
Countryside			
Delivery at van	30342	41.2	475
Delivery at house door	26839	40.2	400

Table 7 shows that, on the average, delivery at the house door cannot be recommended. The lower sales of specific other products and the increase in delivery time implying that less customers can be served within a certain time apparently outweigh the positive effects of delivery at the house door. Currently 74% of all customers are served at the house door. When a round is specially sensitive to delivery at the house door (which is the case with older people and people of higher social class) delivery at the door can be a good strategy, however. A sensitivity analysis showed that when the additional sales caused by delivery at the house door are twice as high as average, both service alternatives lead to about the same results.

In an analogous way MILSIM was used to examine the effects of the policy variables: (i) giving credit to customers, and (ii) carrying other fresh products besides milk and milk products. It was concluded that giving credit is generally not advisable whereas carrying other fresh products can be recommended.

6.3 *Optimum size of the round*

MILSIM was also used to determine the optimum size of the round. Here round size is expressed in the number of house doors in the round (multiplied by the coverage level this gives the total number of customers).

The optimal round size was determined as follows. For each round-type/vehicle-type combination the number of doors in the round is increased until either total delivery time per delivery day is 10 hours or total working time per week is 50 hours. Frequency of delivery is set at 3. With respect to the other policy variables two strategies were distinguished: (i) an intensive strategy, aimed at maximizing total sales per house door. In this strategy credit is given, other fresh products are carried and the customers are served at the house door. Although it was seen before that some of these variables generally can be better set at the opposite level, if a milkman does not have the opportunity to make his round big enough, an intensive policy can be sound strategy; (ii) an extensive strategy with the variables mentioned in (i) set at the opposite level.

Table 8. *Optimal size of round in numbers of doors*

Type of round	Type of vehicle					
	Delivery van		Mobile shop		Coverage	Current situation
	Extensive policy	Intensive policy	Extensive policy	Intensive policy		
City, flats	900[a]	900	900	825	64	370
City, houses	675	525	525	475	70	377
Urbanized countryside	575	425	500	450	80	348
Countryside	475	350	400	350	87	285

a. See Table 6, fn. b.

Table 8 presents the resulting round sizes for different round-type/vehicle-type combinations. Also the coverage levels are given for each round-type. The extreme right column of Table 8 contains the actual average number of doors for each round type.

The actual round size is much below the optimal size. This is the case even when the intensive policy is followed (which mostly is suboptimal). Under the extensive policy the discrepancy is most severe. Further the discrepancy between optimal and current round size tends to be more severe when the round is situated in a more urbanized area. For a mobile shop the optimal size is lower than for a delivery van.

7. Discussion

In the previous sections, sales and cost functions have been estimated from empirical data and were subsequently used to examine specific policy alternatives of the milkman. Of course, this type of approach has its limitations. The following can be mentioned:

(i) Not all relevant factors could be included in the model. For example with respect to competition (supermarkets mainly) of which the price level for milk is very important, no sufficient information was available. Another important variable that could not be measured is the personality of the milkman.

Especially high percentages of unexplained variations were encountered in the sales functions for individual households. This is not too disastrous, because at the level of the round much variation of individual households is cancelled out. As an example the sales of milk and milk products in Table 5 can be considered. The expected weekly purchases by an individual family are *f* 4.71 with a standard deviation of *f* 4.25. For a round of 500 families expected total sales are *f* 2356 with a standard deviation of $\sqrt{500} \times f\,4.25 = f\,95$. So total sales will be in the range: *f* 2166 – *f* 2546. The recommendations are, of course, for the average milkman. Because of the unexplained variation sales and costs levels may differ for individual milkmen.

(ii) The functions were estimated from cross-sectional data and were subsequently used to examine the effects of policy variables for individual rounds. The effect for an individual round can be different from the average effect, however. For this reason it is important to perform sensitivity analysis (as was done here) to examine the sensitivity of a conclusion with respect to changes in the parameters concerned.

(iii) The data are collected at a certain point in time (1975 for the greater part). So the estimated relationships are valid for this point in time. In the years ahead these relationships might change.

Notwithstanding these limitations it was felt that insights could be obtained with this approach. The recommendations with respect to round size, frequency of delivery, amount of service, the giving of credit and the carrying of other fresh products, were adopted by the steering committee mentioning the research and measures will be taken to implement them.

Appendix A: Dependent variables in sales and cost functions

A = age = 1 housewife > 29 years
0 housewife $\leqslant 29$ years

Au = auto = 1 if (almost) always the car is used for shopping
0 otherwise

C = credit = 1 credit given to customers
0 otherwise

CC = cold storage = 1 if there is a collective cold storage (exploited by different milkmen together)
0 otherwise

Dis = distance to nearest supermarket selling milk

DT = delivery time = 1 before 4 p.m.
0 after 4 p.m.

D_1 = District 1 = 1 western part of the country
0 otherwise

D_2 = District 2 = 1 northern or eastern part of the country
0 otherwise

EP = number of employees
FS = family size (number of persons)

Fr = frequency of delivery (number of times per week)
HD = number of house doors in the round
Km = length of round in kilometers driving
MS = mobile shop =
  1 if the vehicle is a mobile shop
  0 otherwise
NR = number of rounds per enterprise =
  1 if the enterprise has > 1 round
  0 otherwise

OD = other deliverers = number of home delivery retailers for other products that appear in the street
OF = number of other fresh products (e.g., bread, fruit, vegetables) carried by the milkman

S = service =
  1 delivery at the door of the household
  0 delivery at the vehicle (in the street)
SM = sales of milk and milk products in the observation week
SO = sales of other products (regular + specific) in the observation week
T_i =
  1 if the household is in branch T_i of Figure 2 ($i = 1, \ldots, 5$)
  0 otherwise
TA_i =
  1 if the household is in branch TA_i of Figure 3 ($i = 1, \ldots, 4$)
  0 otherwise
TH = type of dwellings in the round =
  1 predominantly houses
  0 otherwise

U = degree of urbanization 1 = big city

12 = countryside

V = vehicle type =
  1 if the vehicle is a delivery van
  0 otherwise (truck or mobile shop)

W = working = 1 housewife does not have a job; 0 housewife has a part-time or fulltime job

$Z1$ = sales of milk and milk products per house door (in the observation week)

$Z2$ = sales of other regular and specific products per house door (in the observation week)

Appendix B: Input variables for MILSIM

Table B1. *Input variables for the characteristics of the round*

Variable		Default value[a]
(1)	Number of house doors (households)	343
(2)	Distance to nearest supermarket selling milk (3 min walking = 1, . . . 15 min = 6)	2.21
(3)	Fraction of housewives that always use the car for shopping	0.11
(4)	Fraction of housewives that never use the car for shopping (of the housewives present at delivery time)	0.41
(5)	Fraction of housewives, present at delivery time	0.84
(6)	Number of home delivery retailers for other products in the round	0.85
(7)	District (1 = Amsterdam, Rotterdam, The Hague, 5 = South-Netherland)	5
(8)	Fraction of houses with house door facing street or garden	0.71
(9)	Predominantly houses (yes = 1, no = 0)	1
(10)	Fraction of families with > 4 persons	0.19
(11)	Fraction of families with < 3 persons	0.42
(12)	Fraction of families with youngest person < 5 or ⩾ 14 years	0.73
(13)	Number of kilometers driving per day in round	12.60
(14)	Fraction of housewives > 29 years	0.87
(15)	Degree of urbanization (1 = big city, 12 = countryside)	5
(16)	Fraction of housewives with no job outdoors	0.83
(17)	Quarter built after 1964 (yes = 1, no = 0)	0
(18)	Coverage level is generated by the model (1) or given as input (0)	1

a. Average values or modal values computed from the data.

Table B2. *Input variables for the policy variables of the milkman*

Variable		Default value
(1)	Number of other fresh products carried (such as bread, fruit, vegetables)	2
(2)	More than one round (yes = 1, no = 0)	0
(3)	Frequency of delivery (days per week)	5
(4)	Collective cold storage (yes = 1, no = 0)	0
(5)	Credit given to customers (yes = 1, no = 0)	0
(6)	Gross margin as fraction of sales	0.18
(7)	Delivery at the house door (yes = 1, no = 0)	0
(8)	Vehicle is mobile shop (yes = 1, no = 0)	0
(9)	Vehicle is delivery van (yes = 1, no = 0)	0
(10)	Number of vacation weeks per year	2
(11)	Number of employees	0
(12)	Fraction of customers which are served before 4 p.m.	0.88
(13)	Labour costs per hour	Dfl. 11.26

REFERENCES

Meulenberg, M. T. G., van Tilburg, A. and Wierenga, B. (1976). *Onderzoek naar de mogelijkheden voor de bezorgende melkdetailhandel.* Den Haag: Bedrijfschap Detailhandel in Melk en Melk- en Zuivelprodukten.

Sonquist, J. A., and Morgan, J. N. (1970). *The detection of interaction effects.* Ann Arbor (MI): The University of Michigan.