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Invited Review

Sales force deployment models

R.S. Howick * and M. Pidd
Department of Operational Research and Operations Management, Gillow House, Lancaster University, Lancaster LA1 4YX, England, UK

Abstract: This paper reviews models which address one or more of the sales force deployment decisions of sales force size, time–effort allocation and territory alignment. Reasons for model usage are given together with a discussion of the technical content of models within each category. Finally, ideas for future research and guidelines to assist OR practitioners to tackle sales force deployment problems are provided.

Keywords: Allocation, resource, marketing, sales force

1. Introduction

For many companies a field sales force forms an integral but expensive part of the marketing mix. A recent survey (Temperley, 1987) found the average cost of keeping a salesperson in the field in Great Britain to be £26 000 p.a. In the USA, Sales and Marketing Management's 1988 Survey of Selling Costs found the median cost of a sales call to the consumer, industrial and service sectors to be \$152, \$207 and \$193 respectively. Therefore, many firms have considered alternative forms of buyer–seller communication such as telemarketing and direct mail. In the United Kingdom grocery sector, a further stimulus has been the rapid growth of multiples which negotiate at national level and ban salespeople from visiting individual stores. Gwyther (1989) highlights Heinz's UK sales force which has decreased from several hundred to about seventy.

One might therefore expect widespread use of quantitative models to help reduce the risk inherent in sales force deployment decisions. However, the opposite may be the case (see, for example, Fisher and Hirst (1973) and Howick (1987)). This review aims to provide OR practitioners with ideas for approaching sales force deployment problems and also suggests areas worthy of further academic research.

2. A typology of sales force deployment models

Three basic and inter-related decisions are addressed by sales force deployment models (Cravens, 1979):

* Sales force size.
* Time–effort allocation.
* Territory alignment.

Analysing each inter-related decision separately may lead to sub-optimisation. Much recent research has thus integrated different models so that several deployment decisions are addressed together within a single multi-stage framework (LaForge, 1980). This review considers models which address each separate deployment decision and then considers some of the attempts at integration. Detailed comments about models within multi-stage frameworks are made in the appropriate separate deployment decision sections.

* Now with CCN Marketing (O.R. Group), Talbot House, Talbot Street, Nottingham, NG1 5HF, UK.
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Rather than provide an exhaustive list of references for each section the review aims to compare and contrast the main thrust and applicability of different solution approaches.

3. Sales force size / budget

3.1. An overview

Combining and extending the classifications of Churchill et al. (1985) and Dalrymple and Thorelli (1984) produces the following:

* Adjustment of the previous year's expenditure.
* Percentage-of-sales approach.
* Breakdown method.
* Build-up (or workload) method.
* Incremental method.
* Other methods.

3.2. Adjustment of the previous year's expenditure

The sales force budget may be set by simply adjusting the previous year's expenditure whilst allowing for such factors as inflation. Although easy to implement, this method has several disadvantages. First, the extrapolation of previous figures may be unreliable. Second, the method does not allow for major changes in promotion strategy. Third, call norms are not set for different types of customers and prospects meaning that call effort may be badly targetted.

3.3. Percentage-of-sales approach

A second approach is to define the sales budget as a reasonable percentage of sales revenues. Whilst keeping costs at an affordable level this assumes that the budget, and, thus, sales force size, is a function of sales revenue. Since selling effort generates orders, causality may actually be in the opposite direction. Tactical requirements may also be overlooked. For example, Kotler (1984) stresses the important role that salespeople can play during product shortages. The expected loss of revenue during such a period may imply that larger sales force cuts should be performed than is actually advisable.

3.4. Breakdown method

This method can be stated mathematically as

$$N = s/p, \tag{1}$$

where

N = number of salespeople required,
s = forecast of total sales volume,
p = the estimated productivity of one (average) salesperson unit.

Causality may again have been assumed in the wrong direction. Also, the reliance on average values does not take variation in salesperson productivity into account.

3.5. Build-up (or workload) method

This is one of the most popular methods for determining sales force size (Talley, 1961).

It assumes that each salesperson should perform an equal amount of work. Churchill et al. (1985) state that the method consists of the following steps:

* Classify all the firm's customers into categories.
* Determine the frequency with which each type of account should be called upon and the desired length of each call.
* Calculate the workload involved in covering the entire market.
* Determine the time available per salesperson.
* Apportion the salesperson's time by task performed, for example, selling, administration and travelling.
* Calculate the number of salespeople required using the formula

$$N = W/T, \tag{2}$$

where

N = number of salespeople required,
W= total selling time required,
T = selling time available to an average salesperson.

The method is easy to understand, allows for customer heterogeneity through varying call frequencies and lengths, and uses inputs which should be readily available to most companies.

However, it does not guarantee an optimal allocation of call time to accounts because sales response functions are not explicitly considered. Also, a lower bound for the number of salespeople is obtained meaning that modifications may be required to allow successful detailed call scheduling (Howick, 1990).

3.6. *Incremental method*

This is based on the 'decreasing returns' principle that salespeople should be added to the sales force as long as the expected increase in profit exceeds the expected increase in costs.

Semlow (1959) uses the following simple formula to determine the effect of adding a salesperson:

$$Sp - C > 0, \tag{3}$$

where

S = sales volume that each additional salesperson will be expected to produce,
p = the expected profit margin on this sales volume,
C = the total cost of maintaining the salesperson in the field.

To determine the increase in sales volume that an extra salesperson will produce, Semlow (1959) plots sales volume per 1% of potential against the percentage of potential per territory. That is (Weinberg and Lucas, 1977),

$$S_i/P_i = f(P_i), \tag{4}$$

where

P_i = percent of total potential in territory i,
S_i = total sales volume.

The total sales expected for various numbers of equal-potential territories can then be calculated and the estimated profit obtained (equation (3)).

Semlow (1959) recognises the importance of model simplicity as a factor aiding implementation. He also defends the use of averages by stating that "adjustments can be made for... variances by management's seasoned judgement".

Unfortunately, although the incremental method is conceptually correct, Weinberg and Lucas (1977) note a technical flaw in Semlow's application due to the inclusion of the variable P_i on both sides of equation (4).

Also, unless subjective estimation is used (Barker, 1985), a company must employ sufficient salespeople to provide enough data for statistical analysis. In particular, Semlow (1959) found that more accurate results were obtained for larger sales forces. He also assumes that any company should not hold a dominant market share which may be in conflict with the previous requirement.

Both Beswick and Cravens (1977) and Barker (1985) use a modification of the incremental approach to determine sales force size in their multi-stage frameworks.

3.7. *Other methods*

Two other methods were found in the literature. Rangaswamy (1985) presents a model which identifies and analyses the consequences of restructuring a single sales force into several speciality sales forces.

Arora and Cavusgil (1987) present micro-computer software, based upon a earlier paper by Fogg and Rokus (1973), which uses Lotus 1-2-3 macros to decide upon the 'best' combination of direct (company-owned) salespeople and independent agents. Break-even analysis is used to find the account potential above and below which different types of sales force should be employed.

Perhaps the main inadequacy of Arora and Cavusgil's (1987) approach is the neglect of sales response functions. However, they state three benefits of using such a decision support tool. First, it can be used for learning purposes. Second, it allows the user to understand complex interrelationships between decision variables. Third, and perhaps most importantly, it has the capability to allow 'what-if' analyses to be quickly and easily performed. Importantly, they note a lack of micro-computer programs to analyse sales force deployment decisions.

4. Time–effort allocation

4.1. *An overview*

The general problem addressed by these models is the allocation of the limited resource of call time or effort amongst a number of sales entities such as customers and prospects (Zoltners and Sinha, 1980).

LaForge et al. (1986) provide a two-step procedure to help management decide which approach is most appropriate for their situation. They classify the approaches for allocating selling effort to accounts as follows:

* Single factor approaches.
* Portfolio model approaches.
* Decision models.

Several decision models have also been produced which allocate effort across products or markets (Davis and Farley, 1971; Montgomery et al., 1971; Tapiero and Farley, 1975; Lodish, 1980).

Single factor and portfolio model approaches do not require the development of one or more explicit mathematical relationship(s) linking changes in selling effort to market response (sales response functions). Instead, they use one or more simple factors as a basis for effort allocation. In contrast, decision models do require the development of one or more sales response functions.

4.2. Single factor approaches

These use a single factor as a guideline for effort allocation (LaForge et al., 1986). For example, customers may be classified according to previous turnover. Selling effort can then be subjectively assigned to each category by management. At its most detailed level, the assignment will contain the frequency and length of call to all customers within each category as in the build-up method to determine sales force size.

Single factor approaches have a high probability of implementation because they are simple to understand, cheap to operate and use readily available data. Their use is most appropriate when a firm has a low analytical orientation and when sales are felt to unresponsive to changes in effort (LaForge et al., 1986).

4.3. Portfolio model approaches

LaForge and Young (1985) describe a portfolio model consisting of the following two dimensions:

* Account opportunity (high, low).
* Strength of business (strong, weak).

A portfolio grid can then be constructed which consists of four segments. An account attractiveness score is obtained by summing values for variables within each dimension and multiplying these two totals together. Clearly, the method is attractive to implement on a micro-computer.

Desired call effort is calculated using the formula

$$\mathrm{Call}_{ij} = \left(\mathrm{Att}_{ij}/\mathrm{TotAtt}_j\right) \cdot \mathrm{TotCall}_j, \tag{5}$$

where

Call_{ij} = Recommended sales calls to account i in segment j.
Att_{ij} = Account attractiveness score for account i in segment j.
TotAtt_j = Sum of account attractiveness scores for all accounts in segment j.
$\mathrm{TotCall}_j$ = Total number of sales calls to be made to all accounts in segment j (determined by management).

Unfortunately, the subjective determination of $\mathrm{TotCall}_j$ means that accounts which just fall into a segment of the portfolio grid may be unjustly penalised or rewarded.

However, since they consider several factors and allow direct calculation of call effort, portfolio models are more complete than single factor models. They also do not require the same degree of analytical expertise as decision models (LaForge et al., 1986) and can thus be particularly useful when a company has little technical know-how but an adequate data base is available or can easily be obtained. The similarity of portfolio models to traditional SWOT analysis (see Kotler, 1984, p. 285) which management may already be familiar with, may also enhance the probability of implementation.

4.4. Decision models

Decision models are most apt if a company has a high analytical orientation and sales are felt to be reasonably responsive to selling effort (LaForge et al., 1986). They typically consist of two structural components (LaForge et al., 1983):

* Sale response function(s).
* Allocation technique(s).

Comer (1979) and Cravens (1979) discuss issues involved in formulating appropriate sales response functions. For example, few models consider lag effects (see Comer, 1974).

Two classes of decision models can be identified according to the method used to parameterise the sales response function(s). These are (LaForge et al., 1986):

* Empirical models.
* Judgement-based models.

Generally, judgement-based models consist of one micro-level sales response function for each account or group of homogeneous accounts whilst empirical models consist of a single macro function to represent the average sales response relationship across all planning and control units.

Empirical models. In these, the sales response function is generally parameterised by applying multivariate statistical techniques to a data set obtained from experimentation or historical records (LaForge and Cravens, 1985).

Only one example of experimentation could be found (Brown et al., 1956). Its lack of use more recently can be attributed to risk, cost and inconvenience (Montgomery and Urban, 1969, p. 253).

In contrast, historical data has been used in several studies. For example, Beswick and Cravens (1977) consider several sales response functions using both multiple linear regression on logarithmic transforms and nonlinear least squares analysis.

Ryans and Weinberg (1979) question Beswick and Cravens' (1977) results for two reasons. First, management felt that the function originally obtained was not responsive enough to selling effort. The elasticity of sales response to selling time was thus arbitrarily raised by nearly 40%. More formal methods for combining subjective estimates with empirical data would appear to be required. Second, the product of two of the explanatory variables appears to give sales in the previous year which may explain the high value of R^2 obtained.

Two, more general, comments can also be made concerning the development of empirical sales response functions. First, problems may occur if the data available covers a limited range of experience. Ryans and Weinberg (1979) note how "deployment methods based on equalizing potential, workload or span of control can 'design out' the opportunity to measure the impact of these variables".

Second, in most studies, response parameters have been assumed to be constant over time. Ryans and Weinberg (1987) examined this by repeating their 1979 study and concluded that parameters did remain stable for their data set. Obviously, more studies need to be performed before the above can be generalised.

Various allocation procedures have been used with empirical models (see Zoltners and Sinha (1980) for a complete listing).

Brown et al. (1956) state that prospects should be visited at the point where expected conversions per hour of effort is at a maximum. The 'principle of equal profitability' is then recommended to determine the effort required to 'hold' existing accounts.

In ALLOCATE, Comer (1974) uses separate heuristic rules for each of four groups of accounts.

Another method is dynamic programming (Beswick and Cravens, 1977). Unfortunately, this can only be used with some functions. Beswick (1977) states that "if strong evidence of S-shaped response is available then heuristic solution procedures for allocating selling effort may be desirable."

Calls have thus been made for research into more widely applicable allocation procedures (LaForge et al., 1983; Zoltners et al., 1979).

Usage of empirical models varies considerably. Brown et al.'s (1956) experiment used 18 salespeople each assigned 36 customers. Not surprisingly, given the volume of data input, Comer's (1974) testing of ALLOCATE only involved 2 sales territories. Beswick and Cravens (1977) describe an application for 38 sales territories divided into 232 trading areas. Their model predicted a sales increase of \$830 000 for 38 salespeople and an increase of \$1 400 000 for 42 salespeople.

Importantly, none of the above articles describes the repeated use of any model.

Judgement-based models. In these, 'knowledgeable' people (salespeople or managers) are 'interrogated' to provide estimates of sales response for a small number of effort levels. Various curve-fitting procedures are then used (LaForge and Cravens, 1985).

Generally, questions about sales response are asked via interactive on-line computer programs (see, for example, Armstrong, 1976; Lodish, 1971) with an exception being the multi-stage model proposed by Barker (1985).

Much of the interest in judgement-based models can be attributed to a pioneering article by

Little (1970) introducing the concept of a decision calculus. He states that model builders should adhere to the following criteria to increase the probability of implementation. Models should be:

* Simple.
* Robust.
* Easy to control.
* Adaptive.
* As complete as possible.
* Easy to communicate with.

Apart from the above, the main attraction of the approach is that people who will be affected by the model's output are directly involved in the parametrisation process.

Judgement-based models have several drawbacks however (Naert and Weverbergh, 1981). First, they generally ask the user to provide the smallest amount of information possible to parameterise the functional form specified. Thus, unlike empirical models where a value such as R^2 can be calculated, no measure of goodness-of-fit is obtained. An exception is the model proposed by Glaze and Weinberg (1979) which uses least squares analysis.

Second, deterministic sales response functions are generally constructed. If a stochastic function is required then many more subjective estimates may have to be made (see Armstrong, 1976) possibly resulting in errors because of fatigue or because of unfamilarity with probabilities.

Third, good quality data is a prerequisite for good parameterisation. Problems may arise if the supplier of estimates is not knowledgeable enough to provide accurate judgements due to, for example, high staff turnover (Xardel, 1983).

Fourth, experimentation by Chakravarti et al. (1979) has shown that managers subjective judgements may be subject to systematic bias. Little and Lodish (1981) counter this by questioning the limited amount of information that Chakravarti et al. (1979) supplied to their subjects for estimating sales response. They argue that a typical manager will have a much greater knowledge base, gained from a variety of sources, than the few data points available to the experimental subjects.

Finally, users may deliberately input biased judgements to influence model results. One method to deter this is to regularly rotate product managers (Montgomery et al., 1971). Little (1970) considers such abuse to be unlikely since data and assumptions are explicit.

Although it is easy to question the accuracy and validity of such an approach, Lodish (1974) points out that it is better to be 'vaguely right' than to restrict a model to 'hard data' and be precisely wrong. Little and Lodish (1981) state that "in fact, a central idea of decision calculus is to tap multiple sources of information. If the calibration task is really to analyze a single data set, the manager is in the econometric business and, as such, has no differential advantage over a management scientist with a computer. We would surely recommend the latter."

Several allocation techniques have been used with judgement-based models, the most common being incremental analysis heuristics on piecewise-linear approximations of objective functions (Barker, 1985; Lodish, 1971; Parasuraman and Day, 1977). Parasuraman and Day (1977) originally used linear programming but noted that "because the mathematical programming procedures were rather tedious, a simpler alternative was sought".

Zoltners et al. (1979) present an integer programming (IP) formulation which uses a branch and bound solution procedure. Two IP formulations are used simultaneously to solve realistic problems in a fraction of a second (on a CDC 6000 computer).

The most common level of application of judgement-based models has been limited testing for a small number of territories (Armstrong, 1976; Montgomery et al., 1971; Parasuraman and Day, 1977). Results are generally presented in terms of *estimated* productivity improvements (see LaForge et al. (1986) for details).

Two models have been used repeatedly. Zoltners et al.'s (1979) by "several large US firms". Their method's applicability for small to medium-sized companies is thus unknown. Fudge and Lodish (1977) describe an experiment using 10 pairs of closely matched salespeople. One salesperson in each pair used CALLPLAN (Lodish, 1971) whilst the other acted as a control. They found that after 6 months the average CALLPLAN salesperson had *actual* sales 8.1% higher than his matched counterpart. Clearly, testing other sales force deployment models in this manner could prove to be a very productive area of research. By 1982, at least 25 sales forces had used CALLPLAN. In particular, the interested reader should refer to a case study which uses a CALLPLAN-style model to allocate effort across products and market segments and thus determine sales force size (Lodish et al., 1988).

5. Territory alignment

5.1. An overview

Zoltners and Sinha (1983, p. 1238) state that "the sales territory alignment problem may be viewed as the problem of grouping small geographic sales coverage units (SCUs) into larger geographic clusters called sales territories in a way that the sales territories are acceptable (or optimal) according to a managerially relevant alignment criteria".

Examples of SCUs are zip codes and counties in the USA and the various levels of Postcode Geography and Plumbley Bricks within the UK. Each SCU can consist of one or more attributes such as workload and sales potential. Generally, the value of an attribute within a territory is obtained by adding the values of that attribute from its constituent SCUs.

Zoltners and Sinha (1983) describe four properties of a good sales territory alignment:

(P1) *Single assignment of SCUs.* Each SCU is assigned to exactly one sales territory.

(P2) *Attribute balance.* Sales territories are 'almost' balanced relative to one or more territory attributes.

(P3) *Contiguity.* Sales territories are contiguous.

(P4) *Geographic considerations (accessibility).* Sales territories are compatible with geographic considerations such as motorways and non-traversable objects including mountains and rivers.

In addition, this review defines three dimensions along which territory alignment models can be classified:

(D1) *Single/multiple criteria.* If a model attempts to balance only one attribute then it is a single criterion model. Otherwise, it is a multiple criterion model (Zoltners, 1979).

(D2) *Travel/distance measure.* Most territory alignment models attempt to produce territories which salespeople can cover effectively. Various travel and distance measures have been used.

(D3) *Fixed centre/centre-seeking alignment.* Territory centres can either remain fixed during the course of a model or they can be allowed to change as territory configurations are updated.

Slightly altering Zoltners and Sinha's (1983) classification of territory alignment models produces the following:

* Criterion models.
* Heuristic (local improvement) models.
* Mathematical programming (MP) models.

In some cases the distinction may not be clearcut. For example, MP models may have solution procedures which can be termed heuristic in the sense that they do not guarantee optimal solutions (see Hess and Samuels, 1971). Conversely, heuristic models can sometimes be formulated as an MP (Zoltners, 1979). Nevertheless, it is hoped that the above reflects the main emphasis within each set of models.

Table 1 summarises (P1)–(P4) and (D1)–(D3) for each model surveyed. Note that in the table the following notations are used:

(P1) *Single assignment of SCUs.* Y = Yes, R = Reassignment/Rounding, ? = Unknown.

(P2) *Attribute balance.* If given:

(1) Range = Highest territory attribute − lowest territory attribute, where the average territory has a attribute value of 1.00. For multiple criteria results the *most important* attribute is quoted. Fleischmann and Paraschis' results include 26 split SCUs. (Values are approximate.)

(2) Territories in case study or example. Results for Hess and Samuels (1971) and Zoltners and Sinha (1983) refer to an experiment conducted in the latter paper for 3 sets of 13 territories. Results for Howick (1990) refer to an experiment conducted for 10 sets of 9 territories using Version 3 of his model which contains a contiguity check and uses Euclidean distance as a compactness measure; else, ? = Unknown.

(P3) *Contiguity.* Y = Yes, N = Not guaranteed, R = Reassignment.

(P4) *Geographic considerations (accessibility).* Y = Yes, N = No, ? = Unknown.

(D1) *Single/multiple criteria.* S = Single criterion, M = Multiple criteria.

(D2) *Travel/distance measure.* N = No, NC = Not explicitly considered.

d^* = Estimate of travel time within SCU.
d_{ij} = Euclidean distance between SCU j and territory i.

Table 1
Summary of properties and dimensions of sales territory alignment models

Model		(P1)	(P2)		(P3)	(P4)	(D1)	(D2)	(D3)
			(1)	(2)					
Criterion									
Talley	(1961)	Y	?	5	Y	Y	S	NC	NC
Lodish	(1975)	Y	?	4	Y	Y	S	NC	NC
Beswick and Cravens	(1977)	Y	?	38	Y	Y	S	NC	NC
Heschel	(1977)	Y	64%	8	Y	Y	S	NC	NC
Barker	(1985)	Y	?	20	Y	Y	S	d^*	NC
Heuristic									
Easingwood	(1973)	Y	5%	5	Y	Y	S	NC	NC
Deckro	(1977)	Y	18%	5	Y	N	M	N	NC
Hopkins and Kirk	(1980)	Y	20%	35	Y	N	S	N	NC
Ronen	(1983)	Y	20%	7	Y	N	S	d_{ij}	FC
Howick	(1990)	Y	17%	9	Y	Y	M	d_{ij} & t_{ij}	FC
MP-Models									
Set-partitioning									
Shanker et. al.	(1975)	Y	1%	3	Y	Y	M	d_{ij}	FC
SCU-assignment									
(i) *LP-based*									
Hess and Samuels	(1971)	R	26%	13	N	N	S	d_{ij}^2	CS
Segal and Weinberger	(1977)	R	?	12	N	Y	S	d_{ij}^*	FC
Glaze and Weinberg	(1979)	R	?	3	N	N	S	d_{ij}	CS
Richardson	(1979)	?	?	?	N	Y	M	d_{ij}^2	?
Zoltners	(1979)	?	21%	7	N	?	M	d_{ij} & d_{ij}^2	?
Marlin	(1981)	R	20%	18	N	N	S	d_{ij} & d_{ij}^2	FC
Fleischmann and Paraschis	(1988)	R	20%	168	N	Y	S	d_{ij}^2	CS
(ii) *Subgradient optimization*									
Zoltners and Sinha	(1983)	Y	10%	13	R	Y	M	t_{ij}	FC

d_{ij}^* = Shortest path (straight line segments) between SCU j and territory i.

t_{ij} = Travel time between SCU j and territory i.

(D3) *Fixed centre / centre-seeking alignment.*

NC = Not explicitly considered in the mathematical formulation.

FC = Fixed centre.

CS = Centre seeking.

? = Unknown.

5.2. Criterion models

Zoltners and Sinha (1983) define such models to be 'totally heuristic'. This may be misleading since they do not satisfy Nicholson's (1971) definition of a heuristic as a procedure "... for solving problems by an intuitive approach in which the structure of the problem can be interpreted and exploited intelligently to obtain a reasonable solution". Rather, such models provide management with input data and an objective but do not give a procedure to get from the former to the latter. For example, Talley (1961, p. 9) states that "summaries by county were found to be the most convenient bases for designing sales territories. Counties were accumulated until the total call frequencies approximated 750 calls per year."

Not surprisingly, such models are too vaguely defined to guarantee good solutions. Property (P2) may thus not hold. Also, the lack of a precise formulation means that travel times or distances from each territory centre (D2) and fixed or movable territory centres (D3) are not explicitly considered. An exception to this is Barker (1985) who includes an estimate of travel time within each SCU in his workload measure.

Criterion models can be time consuming to use if management wish to consider many alternatives. They are probably most applicable in situations where minor alterations are required.

Finally, none of the models surveyed use multiple alignment criteria (D1) (Zoltners and Sinha, 1983). Although this could be done, in practice the requirement for management to 'keep an eye on' two or more criteria whilst assessing alternative alignments would only exacerbate the problems described above.

However, the use of maps and manual evaluation of alternatives make it impossible to obtain disconnected territories (P3) and easy to include geographic considerations (P4). Also, their simplicity leads to a high probability of implementation.

5.3. Heuristic (local improvement) models

Several heuristic methods were found in the literature (Easingwood, 1973; Deckro, 1977; Hopkins, 1980; Kirk, 1980; Ronen, 1983; Howick, 1990).

All of these have the same general structure:

(1) Construct a first feasible solution (FFS) or use existing territories as a FFS.

(2) Find the worst (or best) territory according to a selected criterion.

(3) Perform a realignment to improve the overall criterion by which territories are judged (iteratively improved solution (IIS) or local improvement stage).

(4) Check for convergence: If Yes, Goto (5). If No, Goto (2).

(5) Stop.

Only Deckro (1977) and Howick (1990) present multiple criterion models (D1). In the former each criterion is ranked in order of importance. If a local improvement decision cannot be made with reference to the primary criterion then at least one lower order criterion is considered. In the latter, criteria are given user-defined weights within a function to be minimised. The user can thus change the relative importance of criteria for different runs of the model.

The number of territories required cannot be explicitly stated in Deckro's (1977) model making its use questionable for an existing sales force. For example, the number of territories changed from 5 to 6 when the primary criterion was changed from sales potential to workload.

Unfortunately, several of the heuristics (Easingwood, 1973; Deckro, 1977; Hopkins, 1980; Kirk, 1980) do not *explicitly* consider a distance measure from each territory centre to each assigned SCU (D2). Visually unacceptable territories may thus be created (P4). For example, Hopkins (1980) notes that "territory shapes changed... into almost 'S' or 'horseshoe' shapes".

Another disadvantage is that 'cycling' of SCUs from one territory to another and back again may occur (see Hopkins and Kirk (1980), and Ronen (1983)). Ronen (1983) states that his "program detects and breaks such cycles" whilst Hopkins and Kirk's (1980) heuristic allows manual intervention to stop this effect. Another way to prevent 'cycling' is to have a function associated with each territory configuration and to only allow a realignment if the function will decrease as a result of this (Howick, 1990).

Advantages of heuristic (local improvement) models are as follows. First, SCUs are always considered as complete entities to be assigned (P1).

Second, all of the models address the issue of contiguity (P3). Perhaps the most interesting approach is taken by Deckro (1977), Hopkins and Kirk (1980), and Howick (1990) who keep a record of which SCUs are contiguous to each other SCU. Deckro's (1977) decision rule of adding districts (of one or more SCUs) together ensures contiguity whilst Hopkins and Kirk (1980) and Howick (1990) check that each proposed swap will not create a discontiguous territory. Of course, in any application the time needed to construct the 'SCU adjacency matrix' must be considered.

Each author describes results from testing which tend to confirm that resultant attribute(s) are reasonably balanced between territories (P2). In particular, Ronen (1983) compares his algorithm to optimal linear programming (LP) and integer programming (IP) solutions and finds that his results agree closely, especially when the attribute balance (upper bound/lower bound) is allowed to vary between 1.3 and 1.5. Ronen (1983, p. 505) notes that "the heuristic algorithm is much faster and can be easily converted to a micro-computer".

Only Howick (1990) gives evidence of testing using multiple data sets. He conducts experiments on four model versions using data obtained from a soft furnishings manufacturer (120 SCUs) and from a brewer (275 SCUs). Unfortunately, none of his results have been implemented making it impossible to assess actual benefits.

5.4. Mathematical programming (MP) models

Zoltners and Sinha (1983) identify two types of MP models:

* Set-partitioning models.
* SCU-assignment models.

The only set-partitioning model found in the literature (Shanker et al., 1975) was described as "cumbersome and computationally unattractive" (Zoltners and Sinha, 1983, p. 1239). In Shanker et al.'s (1975) case example the allocation of 500 customers to 3 salespeople resulted in 129 feasible candidate territory designs being generated for *each* salesperson raising doubts over its applicability to 'real-life' problems.

Several SCU-assignment models have been proposed (Hess and Samuels, 1971; Segal and Weinberger, 1977; Glaze and Weinberg, 1979; Richardson, 1979; Zoltners, 1979; Marlin, 1981; Zoltners and Sinha, 1983).

These are generally formulated as 0–1 (IP) assignment problems, where

$$x_{ij} = \begin{cases} 1 & \text{if sales territory } i \text{ includes SCU } j, \\ 0 & \text{if sales territory } i \text{ does not include SCU } j. \end{cases}$$

Exceptions to the above are the models produced by Glaze and Weinberg (1979), Marlin (1981) and Fleischmann and Paraschis (1988). In these, x_{ij} is immediately defined as the *proportion* of the j-th SCU assigned to the i-th territory.

Zoltners (1979, p. 363) offers the following general formulation for a single criterion model (SCM):

$$\min. \quad \sum_{i=1}^{m} \sum_{j=1}^{n} \text{dist}_{ij} x_{ij} \tag{6}$$

$$\text{s.t.} \quad l_i \leq \sum_{j=1}^{n} a_{ij} x_{ij} \leq u_i \quad \text{for } i = 1, 2, \ldots, m, \tag{7}$$

$$\sum_{i=1}^{m} x_{ij} = 1 \quad \text{for } j = 1, 2, \ldots, n, \tag{8}$$

$$x_{ij} = 0 \text{ or } 1 \quad \text{for } i = 1, 2, \ldots, m, \quad j = 1, 2, \ldots, n, \tag{9}$$

where

dist_{ij} = a distance measure associated with the assignment of SCU j to territory i,
l_i, u_i = lower (upper) bound for attribute in territory i,
a_{ij} = value of attribute in SCU j if assigned to territory i (the attribute can thus be *centre dependent* if required).

Hess and Samuels (1971) define

$$\text{dist}_{ij} = a_j d_{ij}^2,$$

where

a_j = attribute value for SCU j,
d_{ij} = Euclidean distance between the centre of SCU j and the centre of territory i.

Note that Hess and Samuels (1971) replace a_{ij} with a_j in (7) since the attribute is *centre independent*. Hess and Samuels' (1971) objective function tends to force any SCU with a *large attribute value* to be assigned to its nearest territory centre. Such an approach can be described as being '*distance weighted*'.

The formulation can be extended to a multiple criterion model by including a constraint (7) for each of k attributes (see Zoltners, 1979, p. 365).

SCU-assignment models can be classified into two types depending upon the solution procedure used. These are:

* LP-based.
* Subgradient optimisation.

Most of the SCU-assignment models have LP-based solution procedures. Generally, the 0–1 constraint on x_{ij} is relaxed to obtain an LP formulation. Typical solution procedures have been linear transportation algorithms (Hess and Samuels, 1971; Glaze and Weinberg, 1979; Fleischmann and Paraschis, 1988) and the Ford and Fulkerson out-of-kilter algorithm (Segal and Weinberger, 1977; Marlin, 1981).

However, such approaches can have several shortcomings (Zoltners and Sinha, 1983).

First, the use of a LP relaxation means that SCUs may be split between territories (P1). Various rounding procedures have been used to resolve this with the most elaborate being a 3-phase heuristic devised by Fleischmann and Paraschis (1988). Unfortunately, if more than one segment of a split SCU contains a large value for any attribute then reassignment of all of the SCU may significantly alter the territorial attribute balance resulting in a poor solution (P2). Fleischmann and Paraschis (1988) circumvent this by allowing some split SCUs to remain even after their reassignment heuristic has been applied. In their case study, approximately 1.9% of the total SCUs remained split.

Second, noncontiguous territories may be produced (P3). This is because no model formulation explicitly records which SCU is contiguous to each other SCU during the Territory Alignment procedure. Segal and Weinberger (1977) come closest to this by accounting for adjacency during their preliminary procedure of calculating distances between territory centres and other SCUs.

Zoltners (1979) calls the creation of noncontiguous territories the "donut phenomenon". He feels that it is most likely to happen in areas where there is a large variation between SCU attribute values. For example, where a city borders a rural area. Balanced territories may then be produced by adding a (high value) city–centre SCU to a territory containing many rural (low value) SCUs. Zoltners (1979) recognises that two methods can be used to discourage this:

* Assign a very large distance from an SCU to its previously assigned centre to discourage this assignment.
* Use SCUs of little or no attribute variation.

As Segal and Weinberger (1977) note, the second method also allows greater freedom to be enjoyed by any clustering process used. However, in many cases, it is difficult to obtain SCUs exhibiting such features because a suitable data base does not exist.

Third, most of the LP-based models use distance measures instead of travel time in their formulations (P4). Hess and Samuels (1971), Richardson (1979) and Fleischmann and Paraschis (1988) use d_{ij}^2 in their objective functions where

d_{ij} = the Euclidean (straight-line) distance between the centre of SCU j and the centre of territory i.

Cloonan (1972) argues that d_{ij} provides a better measure of territory compactness than d_{ij}^2 in terms of both size and shape since it more accurately reflects travel costs. Such a measure has been used by Zoltners (1979) and Marlin (1981). Glaze and Weinberg (1979) also use d_{ij} but multiply it by a constant scale factor to obtain travel time. Unfortunately, this does not account for differences in speed between road types.

Segal and Weinberger (1977) use a shortest path algorithm to find the distance between a territory centre (SCU) i and any SCU j to be possibly assigned. The distance between any two *adjacent and traversable* SCUs is defined to be the straight-line distance between their centres. Whilst this measure encourages the creation of accessible territories it does not guarantee it (Zoltners and Sinha, 1983).

Richardson (1979) and Fleischmann and Paraschis (1988) also attempt to account for accessibility. Richardson (1979) specifies troublesome territories a priori (Zoltners and Sinha, 1983) whilst Fleischmann and Paraschis (1988, p. 533) state that the user should "define a list of forbidden assignments". Both of these approaches could call for considerable management effort if used to design territories in an area where communications are poor.

Fourth, five of the LP-Based models only allow a single attribute to be balanced (D1) (Hess and Samuels, 1971; Segal and Weinberger, 1977; Glaze and Weinberg, 1979; Marlin, 1981; Fleischmann and Paraschis, 1988).

Finally, Hess and Samuels' (1971) model uses a centre-seeking alignment approach (D3) making it difficult to use for territory realignment if strong preferences have been expressed about home locations. However, the model may prove useful if new sales territories are being created and no sparsely populated areas exist. Glaze and Weinberg (1979) and Fleischmann and Paraschis (1988) also use this approach but allow centres to remain fixed if required.

All authors of LP-based models describe their application. For example, Hess and Samuels' (1971) paper is based on experience gained from 7 studies. One of these called for the realignment of approximately 400 sales territories in 40 districts. Hess and Samuels (1971) found the maximum deviation from the average territorial attribute value to be less than 10% in 95% of the 126 district plans considered.

Marlin (1981) investigates the use of various model formulations. Perhaps his most interesting experiment compares the use of d_{ij} with d_{ij}^2 in the objective function. Use of the latter produced compact segments of disconnected territories which he postulates are because a fixed rather than centre-seeking formulation had been used.

Only one subgradient optimisation model has been cited in the literature (Zoltners and Sinha, 1983).

The most important difference from previous models is the use of a hierarchical SCU-adjacency tree for each potential territory centre. Each tree starts with a centre at level 0 and then lists immediately adjacent SCUs at level 1 and so on. A shortest path algorithm is used to ensure that each set of 'branches' represents the quickest *travel time* (D2) between the *road network* connecting each SCU (P4). Unfortunately, a disadvantage of this is that routes which are perfectly acceptable may be overlooked. Whilst stating that additional (alternative) routes can be supplied by experienced sales management, Zoltners and Sinha (1983) do not say how time-consuming this process could be.

Zoltners and Sinha's formulation is as follows:

$$\text{min.} \quad \sum_{i=1}^{m} \sum_{j=1}^{n} a_{ijk^*} \cdot x_{ij} \tag{10}$$

$$\text{s.t.} \quad l_{ik} \le \sum_{j=1}^{n} a_{ijk} x_{ij} \le u_{ik}$$

$$\text{for } i = 1, 2, \ldots, m,$$

$$k = 1, 2, \ldots, h, \quad k \ne k^*, \tag{11}$$

$$x_{ij} \le \sum_{p \in A_{ij}} x_{ip}$$

$$\text{for } i = 1, 2, \ldots, m, \quad j = 1, 2, \ldots, n, \tag{12}$$

$$\sum_{i=1}^{m} x_{ij} = 1 \quad \text{for } j = 1, 2, \ldots, n, \tag{13}$$

$$x_{ij} = 0 \text{ or } 1 \quad \text{for } i = 1, 2, \ldots, m,$$

$$j = 1, 2, \ldots, n, \tag{14}$$

where

k = index for the h design attributes,

a_{ijk} = k-th attribute value for SCU j if it is assigned to territory i.

l_{ik} = lower limit for k-th attribute for the sales territory centred at i.

u_{ik} = upper limit for k-th attribute for the sales territory centred at i.

Set A_{ij} ($i = 1, 2, \ldots, m$; $j = 1, 2, \ldots, n$) is the set of SCUs which immediately precede SCU j on any branch of the hierarchical SCU-adjacency tree for territory centre i.

Note that the use of a_{ijk^*} allows a distance-weighted model to be used if required. For example, in their experimentation Zoltners and Sinha (1983, p. 1249) define $a_{ijk^*} = a_j d_{ij}$.

This is a multiple criterion model (D1). Also, note how the value of any SCU attribute(s) can be *dependent* upon the centre to which the SCU is assigned.

Zoltners and Sinha's (1983) solution procedure insures that no SCUs will be split (P1) but it requires that the contiguity constraints (12) are dropped. Any noncontiguous SCUs from the solution to a Lagrange relaxation of the problem have to be reassigned to their closest contiguous centre using the hierarchical SCU-adjacency tree. Of course, this suffers from the same problem as reassignment of split SCUs since the territory attribute balance may be significantly disrupted. If many noncontiguous SCUs are created, or any noncontiguous SCU has a large attribute value, then several iterations of the subgradient search may be required in order to achieve the desired attribute balance.

Zoltners and Sinha (1983) state that their model "has been used to develop sales territory alignments for several companies". In particular, they compare results for one implementation, using a single criterion, territory centre-independent formulation, with those produced using an LP-based approach. A summary of results is given in Table 2. Note that in the table, (1) figures refer to 3 test problems, each with 13 salespeople and between 204 and 280 SCUs, and (2) range is the difference

Table 2
A summary of the results from Zoltners and Sinha's (1983) comparison of an LP-based territory alignment approach with a subgradient optimisation approach

Property	LP-based	Subgradient optimisation
P(1): Split SCUs	10–12	0
P(2): Average range	26%	10%
P(3): Contiguity	Yes	Yes
P(4): Geography	–	More practical than LP-based

between highest and lowest territory attribute values where the average territory = 1.00 For example, 1.20 − 0.80 = 0.40 = 40%.

Although it satisfies (P1), (P2), (P4) and uses reassignment to satisfy (P3), Zoltners and Sinha's (1983) model has one major disadvantage. The construction of a SCU-adjacency tree outside of the model may be over-complicated and wasteful. Fleischmann and Paraschis (1988, p. 523) note that "this approach can be very cumbersome for large-scale problems". In particular, the question arises of how many adjacency levels to consider. If this is too low then clustering will be inhibited. On the other hand, the specification of too many levels may waste valuable user effort.

Finally, Zoltners and Sinha (1983) recognise that even sophisticated models such as their own cannot accommodate the qualitative features of sales territory alignment. Since it is possible that such features may be dominant this is clearly an area worthy of further research. In particular, an investigation into the role that expert systems could play could prove fruitful.

6. Multi-stage frameworks

Sophisticated multi-stage frameworks to analyse several sales force deployment decisions have only been developed since the mid-1970s. As Barker (1985) recognises, an important advantage of such frameworks is their ability to allow management to gain an understanding of the overall picture of sales force deployment decisions.

All of the approaches consist, essentially, of linking a time–effort allocation model to a territory alignment model (Zoltners and Sinha, 1983). Table 3 provides a classification of the types of model used within each framework. Note that models in italics are mentioned in articles but not used within a case study or example.

Lodish (1975) first stated that in order to maximize profit, territories should be aligned so that the marginal profit value in each was approximately equal. He achieved this by using a CALLPLAN-style (Lodish, 1971) model to allocate effort to SCUs whilst placing a constraint on the *total time* available to all salespeople. A territory alignment model was then used to produce territories of balanced workload.

As Table 3 shows, most authors recommend the use of a judgement-based decision model for time–effort allocation. This may be problematic if sales response is felt to vary according to the salesperson allocated and territorial boundaries are to be substantially altered since time may have to be spent developing new sales response functions to allow for between-salesperson differences (see Step 4 of Lodish's (1975) procedure). LaForge et al. (1986) feel that empirical decision models are more convenient for across-territory analysis because such differences can easily be accounted for by changing the values of explanatory variables (see Stage IV of Beswick and Craven's (1977) procedure).

Only Beswick and Cravens (1977), Barker (1985) and Howick (1990) consider the decision of sales

Table 3
A classification of multi-stage frameworks

Paper	Type of time–effort model	Type of territory alignment model
Lodish (1975)	Decision model: Judgement based	Criterion model
Shanker et al. (1975)	Decision model: Judgement based	Generate n_j of best solutions followed by set partitioning
Beswick and Cravens (1977)	Decision model: Empirical	(i) Criterion model (ii) *MP model: LP based*
Glaze and Weinberg (1979)	Decision-model: Judgement based	MP model: LP based
Zoltners and Sinha (1983)	*Decision model:* (i) *Judgement-based* (ii) *Empirical*	MP model: Subgradient optimisation
Barker (1985)	Decision model: (i) Judgement based (ii) *Empirical*	(i) Criterion model (ii) *MP model: LP based*
Howick (1990)	Single factor	Heuristic model

force size explicitly within their frameworks. Other models require several runs for different numbers of salespeople to be considered.

Also, only Howick (1990) considers the interaction between sales force deployment decisions and call scheduling in any detail.

Barker (1985) recognises that model complexity may hinder implementation in small and medium sized companies. He champions the use of the "evolutionary model-building concept in order to fit the model to the needs of the firm". His multi-stage framework is thus sufficiently general to allow for varying degrees of model sophistication with his case study being solved manually.

Finally, it is important to note that approaches based on complex formulations (for example, Shanker et al. (1975)) appear to have only been used on very small test problems.

7. Conclusions

Methods to analyse the sales force deployment decisions of size, time-effort allocation, and territory alignment have been reviewed together with sophisticated multi-stage frameworks addressing two or more of the above decisions.

Several avenues for further academic research have been identified. In particular, there is a need for the repeated testing of many of the models proposed. Experiments comparing the performance of two or more approaches on standard problems would be welcome (see, for example, Zoltners and Sinha, 1983) as would results detailing *actual* improvements in deployment resulting from model usage (see, for example, Fudge and Lodish, 1977). This is particularly necessary to examine the practical worth of models which have previously only been tested using artifically small problems.

There is also a need to develop models capable of examining resource allocation between the sales force and other forms of communication such as direct mail and telesales. The use of expert systems to allow for the more qualitative aspects of sales territory alignment should also be explored. Finally, the deficiency in the number of personal computer (PC) based models available has only been addressed in recent years. Opportunities exist to convert previously defined models to a PC format as well as defining new models solely for use on a PC.

Several points can also be made which, I feel, will help the OR practitioner who is attempting to solve one or more sales force deployment problems. In particular, the similarity of some of the recommendations to Little's (1970) notion of a decision calculus should not be overlooked.

First, to enhance the probability of implementation, models should be kept as simple as possible whilst incorporating all important issues. The applicability of territory alignment problems to analytical methods coupled with the high probability of existing territories being unevenly balanced suggests that this is a good area to attack if a single model is to be built. One way to achieve the correct balance between simplicity and completeness may be to employ an evolutionary model building process in which the modelbuilder errs initially on the side of simplicity before gradually adding more detail. This approach may be particularly important for organisations who have little previous experience of using analytical techniques.

However, whilst recognising the above, the importance of multi-stage frameworks, which allow more than one sales force deployment decision to be analysed, should not be underestimated. These are vital in allowing management to gain an understanding of the complex interactions between decision variables as well as helping to reduce the sub-optimisation achieved by using single decision models.

Second, models should be easy to communicate with. The growth in use of personal computers which devolve computing power to management and allow conversational input and output via menu-driven programs has helped enormously in this respect. If programs are well-designed then inputs can easily be changed and answers to 'what-if' questions quickly obtained. The model can thus act as a tool by which a manager can learn about the system under review and provide support to him in his decision making process.

Third, the data which is to be input to any model should be carefully considered. For example, in the sales territory alignment problem the definition of an SCU is vital. Too coarse a level of geography will prevent reasonable clustering from taking place whilst too fine a level will result in unnecessarily long run times. Model builders should also not be afraid of complementing 'hard data' sets with subjective estimates obtained from salesmen or other 'knowledgeable' people. If possible, data should be collected using questions posed in operational terms. Such methods are likely to be of most use in areas where the collection of sufficient empirical data is likely to be troublesome. The development of sales response functions is a good example of this.

Finally, the model builder should recognise that one of the most important functions of this model may be the detection of areas in which data collection is not currently sufficient. The role that modelling effort can play in this area should not be underestimated since the creation of an efficient sales force reporting system can be seen to be central, not only to future modelling efforts, but to sales force, and thus company, success as a whole.

References

Armstrong, G.M. (1976), "The SCHEDULE model and the salesman's effort allocation", *California Management Review* 18/4, 43–51.

Arora, R., and Cavusgil, S.T. (1987), "A micro-computer software for salesforce structuring", *Journal of Sales Management* 4/2, 21–24.

Barker, A.T. (1985), "Implementing a multistage salesforce model in a small company", *European Journal of Marketing* 19/5, 32–41.

Beswick, C.A. (1977), "Allocating selling effort via dynamic programming", *Management Science* 23/7, 667–678.

Beswick, C.A., and Cravens, D.W. (1977), "A multistage decision model for salesforce management", *Journal of Marketing Research* 14/2, 135–144.

Brown, A.A., Hulswit, F.T., and Kettelle, J.D. (1956), "A study of sales operations", *Operations Research* 4/3, 296–308.

Chakravarti, D., Mitchell, A., and Staelin, R. (1979), "Judgement based marketing decision models: An experimental investigation of the decision calculus approach", *Management Science* 25/3, 251–263.

Churchill, G.A., Ford, N.M., and Walker, O.C. (1985), *Sales Force Management: Planning, Implementation and Control* (2nd. edition), Richard. D. Irwin Inc., Homewood, IL.

Cloonan, J.B. (1972), "A note on the compactness of sales territories", *Management Science* 19 (Part I) 469.

Comer, J.M. (1974), "ALLOCATE: A computer model for sales territory planning", *Decision Sciences* 5/3, 323–338.

Comer, J.M. (1979), "Toward a theoretical construct: Salesforce effort allocation", in: *Sales Management: New Developments from Behavioral and Decision Model Research*, R. Bagozzi (ed.), 344–359, Marketing Science Institute, Cambridge, MA.

Cravens, D.W. (1979), "Salesforce decision models: A comparative assessment", in: *Sales Management: New Developments from Behavioral and Decision Model Research*, R. Bagozzi (ed.), 310–324, Marketing Science Institute, Cambridge, MA.

Dalrymple, D.J., and Thorelli, H.B. (1984), "Sales force budgeting", *Business Horizons* 27/4, 31–36.

Davis, O.A., and Farley, J.U. (1971), "Allocating sales force effort with commissions and quotas", *Management Science* 18/4 (Part II) 55–63.

Deckro, R.F. (1977), "Multiple objective districting: A general heuristic approach using multiple criteria", *Operational Research Quarterly* 28/4 (Part II) 953–961.

Easingwood, C. (1973), "A heuristic approach to selecting sales regions and territories", *Operational Research Quarterly* 24/4, 527–534.

Fisher, R.W., and Hirst, M. (1973), "Marketing models in British industry", Pamphlet number 39, Centre for Industrial Economic and Business Research, University of Warwick.

Fleischmann, B., and Paraschis, J.N. (1988), "Solving a large scale districting problem: A case report", *Computers and Operations Research* 15/6, 521–533.

Fogg, C.D., and Rokus, J.W. (1973), "A quantitative method for structuring a profitable sales force", *Journal of Marketing* 37/3, 8–17.

Fudge, W.K., and Lodish, L.M. (1977), "Evaluation of the effectiveness of a model based salesman's planning system by field experimentation", *Interfaces* 8/1 (Part 2) 97–106.

Glaze, T.A., and Weinberg, C.B. (1979), "A sales territory alignment program and account planning system (TAPS)", in: *Sales Management: New Developments from Behavioral and Decision Model Research*, R. Bagozzi (ed.), 325–343, Marketing Science Institute, Cambridge, MA.

Gwyther, M. (1989), "Death of the salesman", *The Independent Magazine* 26, 34–37.

Heschel, M.S. (1977), "Effective sales territory development", *Journal of Marketing* 41/2, 39–43.

Hess, S.W., and Samuels, S.A. (1971), "Experiences with a sales districting model: Criteria and implementation", *Management Science* 18/4 (Part II) 41–54.

Hopkins, P. (1980), M.A. Dissertation, Department of O.R., University of Lancaster.

Howick, R.S. (1987), "Results from a questionnaire on grocery sales force deployment and marketing trends – A report", Working paper, Department of O.R. and O.M., University of Lancaster.

Howick, R.S. (1990), "A multi-stage framework to analyse sales force deployment decisions", PhD thesis, University of Lancaster.

Kirk, J. (1980), M.A. Dissertation, Department of O.R., University of Lancaster.

Kotler, P. (1984), *Marketing Management: Analysis, Planning and Control* (5th edition), Prentice-Hall, Englewood Cliffs, NJ.

LaForge, R.W. (1980), "Salesforce decision models: Trends in the 1970s, directions for the 1980's", in: *Evolving Marketing Thought for 1980*, J.H. Summey and R.B. Taylor (eds.), 41–45, Southern Marketing Assoc., Carbondale, IL.

LaForge, R.W., and Cravens, D.W. (1985), "Empirical and judgement-based sales-force decision models: A comparative analysis", *Decision Sciences* 16/2, 177–195.

LaForge, R.W., and Young, C.E. (1985), "A portfolio model to improve sales call coverage", *Business* 35/2, 10–16.

LaForge, R.W., Cravens, D.W., and Young, C.E. (1986), "Using contingency analysis to select selling effort allocation methods", *Journal of Personal Selling and Sales Management* 6/2, 19–28.

LaForge, R.W., Grove, S.J., and Pickett, G.M. (1983), "Sales management research: A call for integration", *American Marketing Assoc., Educators Proceedings* 49, 212–216.

Little, J.D.C. (1970), "Models and managers, the concept of a decision calculus", *Management Science* 16/8, 466–485.

Little, J.D.C., and Lodish, L.M. (1981), "Commentary on 'Judgment based marketing decision models' ", *Journal of Marketing* 45/4, 24–29.

Lodish, L.M. (1971), "CALLPLAN: An interactive salesman's call planning system", *Management Science* 18/4 (Part II) 25–40.

Lodish, L.M. (1974), " 'Vaguely right' approach to sales force allocations", *Harvard Business Review* 52/1, 119–124.

Lodish, L.M. (1975), "Sales territory alignment to maximize profit", *Journal of Marketing Research* 12/1, 30–36.

Lodish, L.M. (1980), "A user-orientated model for sales force size, product, and market allocation decisions", *Journal of Marketing* 44/3, 70–78.

Lodish, L.M., Curtis, E., Ness, M., and Simpson, M.K. (1988), "Sales force sizing and deployment using a decision calculus model at Syntex laboratories", *Interfaces* 18/1, 5–20.

Marlin, P.G. (1981), "Application of the transportation model to a large-scale 'districting' problem", *Computers and Operations Research* 8/2, 83–96.

Montgomery, D.B., and Urban, G.L. (1969), *Management Science in Marketing*, Prentice-Hall, Englewood Cliffs, NJ.

Montgomery, D.B., Silk, A.J., and Zaragoza, C.E. (1971), "A multiple-product sales force allocation model", *Management Science* 18/4 (Part II) 3–24.

Naert, P.A., and Weverbergh (1981), "Subjective versus empirical decision models", in: *Marketing Decision Models*, R.L. Schultz and A.A. Zoltners (eds.), North-Holland, New York.

Nicholson, T. (1971), *Optimization in Industry, Vol 1, Optimization Techniques*, Ch. 10, Longman Press, London.

Parasuraman, A., and Day, R.L. (1977), "A management-oriented model for allocating sales effort", *Journal of Marketing Research* 14/1, 22–33.

Rangaswamy, A. (1985), "Sales force organization: A modelling approaching", PhD thesis, Northwestern University.

Richardson, R.J. (1979), "A territory realignment model – MAPS", presented at the ORSA/TIMS Meeting, New Orleans, May 1, 1979.

Ronen, D. (1983), "Sales territory alignment for sparse accounts", *OMEGA* 11/5, 501–505.

Ryans, A.B., and Weinberg, C.B. (1979), "Territory sales response", *Journal of Marketing Research* 16/4, 453–465.

Ryans, A.B., and Weinberg, C.B. (1987), "Territory sales response models: Stability over time", *Journal of Marketing Research* 24/2, 229–233.

Segal, M., and Weinberger, D.B. (1977), "Turfing", *Operations Research* 25/3, 367–386.

Semlow, W.J. (1959), "How many salesmen do you need?", *Harvard Business Review* 37/3, 126–132.

Shanker, R.J., Turner, R.E., and Zoltners, A.A. (1975), "Sales territory design: An integrated approach", *Management Science* 22/3, 309–320.

Talley, W.J. (1961), "How to design sales territories", *Journal of Marketing* 25/3, 7–13.

Tapiero, C.S., and Farley, J.U. (1975), "Optimal control of sales force effort in time", *Management Science* 21/9, 976–985.

Temperley, J. (1987), "What every sales director needs to know about sales training", *Business Graduate Journal* 17/1, 12–14.

Weinberg, C.B., and Lucas, H.C. (1977), "Letter to the Editor", *Journal of Marketing* 41/2, 146–147.

Xardel, D. (1983), "The changing role of the sales force in France", *Interfaces* 13/6, 105–109.

Zoltners, A.A. (1979), "A unified approach to sales territory alignment", in: *Sales Management: New Developments from Behavioral and Decision Model Research*, R. Bagozzi (ed.), 360–376, Marketing Science Institute, Cambridge, MA.

Zoltners, A.A., Sinha, P., and Chong, P.S.C. (1979), "An optimal algorithm for sales representative time management", *Management Science* 25/12, 1197–1207.

Zoltners, A.A., and Sinha, P. (1980), "Integer programming models for sales resource allocation", *Management Science* 26/3, 242–260.

Zoltners, A.A., and Sinha, P. (1983), "Sales territory alignment: A review and model", *Management Science* 29/11, 1237–1256.