A SPATIAL ANALYSIS APPROACH TO SIZE AND LOCATION OF AUSTRALIAN WOOL SELLING CENTRES

D. C. Ferguson and W. O. McCarthy*

"*When people have clear cut criteria to go by, criticism and self-criticism can be conducted along proper lines and these criteria can be applied to people's words and actions to determine whether they are fragrant flowers or poisonous weeds.*"

Mao Tse-Tung

This study is concerned with determining the number, size, and location of selling centres for Australian wool so that transport and selling charges are minimized. A plant location model incorporating transhipment assumptions was used. It was found that substantial cost savings could be made by rationalizing wool flows and establishing integrated selling centres. Of fourteen existing centres five were eliminated, and relative throughput at the remainder changed markedly.

1 STATEMENT OF THE PROBLEM

The Australian wool industry has for some time been preoccupied with finding solutions to economic problems which it faces. As indicated by the first Interim Report of the Wool Board Advisory Committee[1] some of these problems revolve around the cost of transferring wool from the grower to the mill door, which includes charges for transport, storage, selling, rehandling, and shipping. The question of wool complexes (integrated wool handling and selling facilities) is also involved. It has been suggested that the establishment of a pattern of complexes would permit cost economies, partly through replacement of labour by capital intensive handling techniques and partly through optimum location and size of such facilities. The first integrated complex is being built at Yennora in Sydney and its capital cost is estimated to be around $15-$20 million[2]. In order that the cost of these complexes be minimized, it is essential to determine their optimal size and location.

Such problems fit well within the framework of an analytical mathematical model designed to minimize aggregate transport and selling costs of the Australian clip. Properly, an investigation along these lines should be long term in the sense that present locations, wool flows and

---

*University of Queensland. The authors wish to acknowledge the help provided by the Development Division of the Australian Wool Board throughout this study.

[1] Australian Wool Board, *First Interim Report of Australian Wool Board Advisory Committee submitted to Australian Wool Board July*, 1970. (Melbourne, Australian Wool Board.)

[2] *Australian Financial Review*, 16th September, 1969, p. 1.

institutional restraints are ignored. It should also be dynamic in that it assumes different levels of wool supply and places confidence limits on the resulting locational patterns. These latter aspects are best handled within a probability framework. The authors view such problems as falling into a two stage study. First, we derive an optimum solution assuming completely inelastic supply and demand for wool (i.e. data for a recent "typical" year) ignoring present locations and varying assumptions about institutional restraints. This is a relatively simple case, and provides immediate answers to current pressing problems such as wool complexes. This is the study reported here. Second, we will rework the analysis within a probability framework. This study is presently being worked on and will be reported later.

Future possibilities of sale of wool by pretested sample or by a single authority does not invalidate the analysis because the only factor subject to change is the nature of the confrontation between buyer and seller.

2 THE METHOD OF APPROACH

2.1 CHOICE OF MODEL

The application of spatial equilibrium theory to location problems in agriculture has been exhaustively reviewed by Weinschenck *et al*[3]. Cassidy *et al*[4] provide a recent Australian empirical example. The appropriate model for this study is the "plant location" type developed

	1 2 3	1 2 3	Supply k_i+A
1	Submatrix 1	Submatrix 2	K_1+A
2	Wool shipment	Wool shipment plus selling in centre j	K_2+A
3	(Unit = 1 bale)		K_3+A
1	Submatrix 3	Submatrix 4	A
2	Not relevant	Shipment of sold wool to demand regions	A
3			A
Demand r_j+A	A A A	r_1+A r_2+A r_3+A	

FIGURE 1: *Matrix format of a three region "plant location" model*

---

[3] G. Weinschenck, W. Henrichsmeyer and F. Aldinger, "The Theory of Spatial Equilibrium and Optimal Location in Agriculture: a Survey", this *Review*, Volume 37, No. 1 (March, 1969) pp. 3–70.

[4] P. A. Cassidy, W. O. McCarthy, and H. I. Toft, "An Application of Spatial Analysis to Beef Slaughter Plant Location and Size, Queensland", *Australian Journal of Agricultural Economics*, Volume 14, No. 1 (June, 1970), pp. 1–20.

by Logan and King[5] and Hurt and Tramel[6] from the work of Kriebel[7] and Orden[8]. The model matrix consists of four sub-matrices as indicated in figure 1. A three region example is assumed.

Each sub-matrix is of dimension $M \times M$ ($M = m + n$; where m is the number of supply regions, n is the number of demand regions). The individual cost elements in sub-matrix 1 are the costs of shipping one unit (bale) of wool from each supply region i to j the selling centres. Sub-matrix 2 includes the costs of sub-matrix 1 plus the unit costs of selling at j. Sub-matrix 3 is not relevant to the wool problem and sub-matrix 4 includes costs of shipping from j to final demand regions K. The A's represent artificial inventory or stockpile constants added to rows and columns to allow transhipment within sub-matrices 1 and 4 if this is necessary for a minimum cost solution. The model allows for changing costs of selling as the volume of throughput changes. Initially, selling costs are set at the lowest point on the average cost curve. The resulting pattern is ascertained and the model then rerun with more appropriate costs at individual centres until no further adjustments are required. "Dropped" centres are prevented from re-entering by specification of a high selling cost. In the final solution (obtained through use of the conventional transportation algorithm) sub-matrices 1, 2, and 4 respectively specify regional supply of wool, quantity sold at each selling centre and quantity shipped to various destinations within Australia or exported.

2.2 SELECTION OF SUPPLY AND DEMAND REGIONS

To facilitate collection of data on annual wool production, the Australian Wool Board divides Australia into 140 Wool Statistical Service (WSS) areas. These form the basis of the supply regions of this study. However, Logan and King have noted that total assembly, processing and distribution costs may be lowered by combining the supplies of a group of small supply regions at one central point, thus utilizing a larger plant. Hence aggregation of the WSS areas was considered and was found appropriate. A total of thirty-two supply regions was de-limited. These were based mainly on geographical considerations, with each supply region producing around 150,000 bales (except in Tasmania). Adjacent WSS areas were not combined without recognition of possible wool flows. Thus wool from WSS areas 35, 36, and 37 in Victoria (Gippsland) was included in the area around Melbourne rather than Wangaratta as it is unrealistic to assume

---

[5] S. H. Logan and G. A. King, "Size and Location Factors Affecting California's Beef Slaughtering Plants", *Hilgardia*, Volume 36, No. 4 (1964), pp. 139–88.

[6] V. G. Hurt and T. E. Tramel, "Alternative Formulations of the Transhipment Problem", *Journal of Farm Economics*, Volume 47, No. 3 (August, 1965), pp. 763–73.

[7] C. H. Kriebel, "Warehousing with Transhipment under Seasonal Demand", *Journal of Regional Science*, Volume 3, No. 1, (1961), pp. 57–69.

[8] A. Orden, "The Transhipment Problem", *Management Science*, Volume 2 (1956), pp. 276–285.

wool will move over the Victorian Alps. Existing wool flows have been ignored as these are conditioned by the location of existing wool selling centres.

Determining raw product demand for each region was more difficult. The only official statistics available were aggregate data on annual domestic consumption. The location of this demand was determined by a mail survey of wool scourers and carbonizers using a list obtained from the Wool Scourers, Carbonizers and Fellmongers Federation of Australia. Export demand was treated as a residual which equated production and domestic consumption.

Throughout this study, data for the 1967-8 season are used. The quantity of wool produced and sold in this year is typical of recent years[9].

2.3 CHOICE OF REPRESENTATIVE BASING POINTS

The model assumes regional supplies and demands occur at discrete but representative locations in space (a point trading model). As well, these basing points are assumed to be transhipment points—that is they can act as selling centres. Generally the largest centrally located town in each region was chosen. However in some cases the basing point was located at a port and therefore on a regional boundary. This is not inconsistent from the regional demand point of view and may not seriously violate the "representative" criterion[10].

On the supply side, thirty-two basing points have been chosen. These include all fourteen existing selling centres with the exception of Ballarat[11]. Demand for greasy wool is confined to relatively few centres in Australia. The model's demand basing points cover all existing selling centres except Warrnambool in Victoria which however is included in the Portland demand region. The addition of "export" gives thirty-three demand basing points. Regional supplies and demands and region basing points are included in Table 1.

2.4 POINT TO POINT PER BALE TRANSPORT COSTS

The per bale rates for movement of wool between all basing points were determined from appropriate authorities. The rates took account of institutional restraints and concessions. For example in N.S.W. it is not possible to move wool intra state by road for more than 50 miles since a State Government permit is required and none are issued. Hence rail has to be used and this involves higher freight rates.

---

[9] Annual average 1964–5 to 1966–7 4·74 million bales; 1967–8 4·85 million bales.

[10] More precisely the sum of squares of deviations of distance of units of supply from the basing point should equal zero.

[11] Ballarat holds two sales each year. In the last 5 years the average quantity sold was 1,510 bales.

TABLE 1

Regional Basing Points and Regional Supplies and Demand

Basing Point	Demand	Supply
Launceston*	24,656	53,285
Hobart*	—	54,874
Naracoorte	—	130,266
Adelaide*	113,846	184,602
Pt Augusta	—	181,566
Coonalpyn	—	102,792
Yalgoo	—	132,818
Koorda	—	176,932
Albany*	—	217,401
Fremantle*	139,824	183,395
Portland*	8,086	154,856
Geelong*	1,663	134,698
Melbourne*	317,771	170,210
Wangaratta	—	130,077
Horsham	—	153,301
Avoca	—	148,910
Ivanhoe	—	162,381
Walgett	—	137,650
Dubbo	—	175,928
Armidale	—	155,730
Warialda	—	144,608
Newcastle*	—	177,042
Sydney*	165,572	137,908
Parkes	—	160,327
Goulburn*	—	165,993
Young	—	157,152
Albury*	—	180,406
Hay	—	148,751
Brisbane*	74,437	134,698
St George	—	165,411
Charleville	—	161,339
Longreach	—	173,957
Export	4,003,409	—
Total	4,849,264	4,849,264

* Existing selling centres

2.5 ESTIMATION OF THE LONG RUN AVERAGE COST CURVE FOR WOOL HANDLING, SELLING, AND DUMPING

Methods of estimating long run average cost curves are discussed by Smith[12] and Walters[13]. The "synthetic" method is used here. Costs curves were derived by utilizing data collected from existing wool stores (many of which are obsolete) together with estimated costs of running

[12] C. A. Smith, "Survey of the Empirical Evidence on Economies of Scale", in *Business Concentration and Price Policy—A Report of the National Bureau of Economic Research* (Princeton: Princeton University Press, 1955).

[13] A. A. Walters, "Production and Cost Functions: An Econometric Survey", *Econometrica*, Volume 31, Nos 1–2 (January-April, 1963), pp. 1–66.

integrated complexes such as that envisaged at Yennora. Some of the necessary information was provided on a confidential basis by brokers and the Australian Wool Board.

The main assumptions inherent in the cost curve are:

(a) The pattern of wool receivals over the season for all hypothetical store sizes is based on present Sydney receivals (Receivals peak in spring and autumn so that there is excess capacity at other times of the year. This influences overhead costs.)

(b) Sixty-six per cent of all wool sold is dumped and containerized at the stores before disposal.

(c) Rehandling (bulk classing before sale) costs have been ignored. These are small and difficult to estimate accurately.

(d) Brokers' charges vary with the size of throughput. These charges are determined from the LRACC. This assumption implicitly requires brokers to forego the present uniform charging policy for all centres. Figure 2 is derived the long run average cost curve[14].

2.6 PER BALE TRANSPORT COSTS FOR SOLD WOOL

Domestic demand is assumed to be satisfied by movement of undumped wool. Intrastate movement in South Australia and Tasmania and all interstate movement is assumed to be by road transport, which is cheapest. Legislation ensures that intrastate movement in N.S.W., Victoria, W.A., and Queensland (normally) is by rail.

Transport costs for export wool to point of export are also required for model input. Seventy-four per cent[15] of export wool is assumed containerized and can only be shipped through feeder or terminal[16] ports which are Brisbane, Newcastle, Sydney, Melbourne, Geelong, Portland, Launceston, Hobart, Adelaide, Melbourne, and Fremantle. Part of the agreement ensuring uniform freight rates for overseas cargo from all Australian ports required the container consortia to bear the cost of centralizing cargo from feeder ports to terminal ports. Hence the model assumes zero charges for wool already located at the above ports. The charge to point of export from all other hypothetical selling centres is the lowest cost of moving sold wool from the centre to a feeder or terminal port. Rail transport is considered to be the most satisfactory method because—

---

[14] The main costs involved include receiving wool into store, preparation of showfloor wool, remarrying of bulk and shown bales, catalogue preparation etc., administrative and supervision charges, dumping and containerization costs.

[15] Sixty-six per cent of total store throughput was assumed containerized. Of the remainder, half satisfies domestic demand and half is exported through external dumps.

[16] A feeder port is defined as one which accepts containers for shipment to other Australian ports. A terminal port is one in which container ships used for overseas trade berth. Feeder ports may or may not be terminal ports. Thus Brisbane is a feeder port for European trade but a terminal port for Japanese trade.

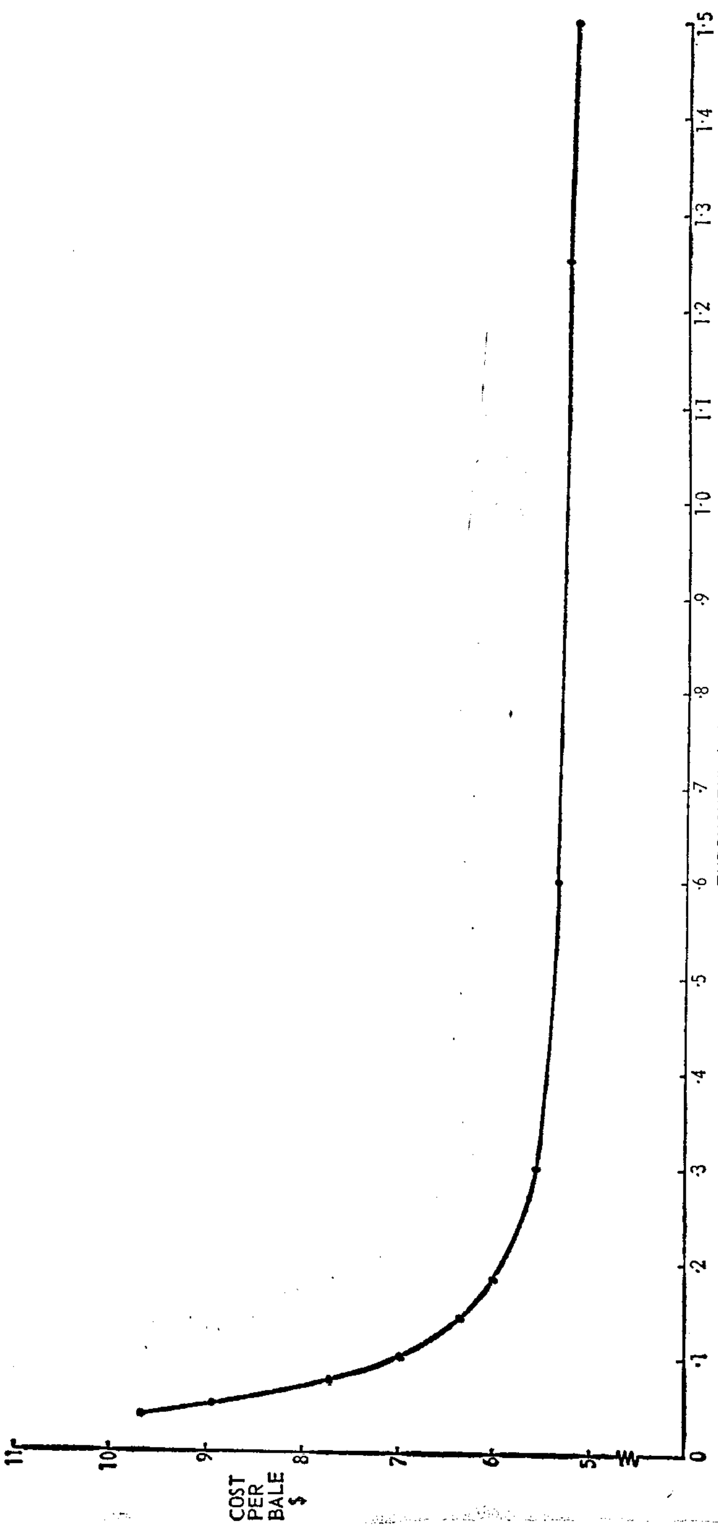

FIGURE 2: *Long run average cost curve for wool handling, selling, and dumping*

(a) A road truck can carry one 20 ft container (average 60 bales) of containerized wool to give an all up weight of 22,150 lb. The capacity of road trucks assumed in this study exceeds this figure and would result in per bale costs around thirty per cent higher than for rail.

(b) It is assumed unlikely that existing legislation would be relaxed to allow wool to go by road where it now must go by rail.

(c) Empty containers must be moved from ports to selling centres.

Few container rail rates have been struck, but general policy (e.g. N.S.W.) is to charge the commodity rate by weight and carry empty containers free. Effectively this means that normal per bale rates apply for this study.

3 RESULTS

3.1 GENERAL

Because the problem involves a nonlinear average cost curve, solution by conventional linear programming is replaced by an iterative technique[17]. All possible locations are first included assuming minimum average processing cost for all, and a location pattern is then obtained. In subsequent iterations more realistic costs are assumed for each store (depending on throughput in the previous solution) until a stable pattern is reached.

Two cases are examined in this study. In Model 1 a location pattern is determined which takes account of existing legislation in each State regulating road and rail transport of wool. Model 2 assumes that restrictive legislation does not exist and wool moves by the cheapest method. Both models take no account of existing wool selling facilities.

3.2 MODEL 1

Table 2 includes the results of Model 1. These are also presented in Figure 3.

The first iteration assumes lowest possible per unit costs so that a decentralized selling centre pattern would be expected. This is confirmed, and sixteen selling centres are indicated (compared with fourteen existing at present). The results are not particularly meaningful but are presented because they show that, even under conditions most favourable to decentralization, two existing inland centres (Albury and Goulburn) do not enter the suggested pattern.

Further iterations were run each of which assumed costs reflecting throughputs of the preceding solution. The model reached stability after the fourth iteration. Nine selling centres are indicated as being

---

[17] Known as heuristic programming and outlined by Logan and King, *op. cit.*

TABLE 2.

Optimum location of selling centres and throughput of Australian wool 1967/8 season (existing rail/road legislation)

Selling Centre	Throughput (bales)	Supply region	Demand
		MODEL 1: First iteration	
Launceston	53,285	Launceston	Launceston, Launceston export.
Hobart	54,874	Hobart	Hobart export.
Adelaide	599,226	Adelaide, Naracoorte, Pt Augusta, Coonalpyn	Adelaide, Adelaide export.
Yalgoo	132,818	Yalgoo	Fremantle export.
Koorda	176,932	Koorda	Fremantle export.
Albany	217,401	Albany	Albany export.
Fremantle	183,395	Fremantle	Fremantle, Fremantle export.
Portland	154,856	Portland	Portland, Portland export.
Geelong	134,698	Geelong	Geelong, Geelong export.
Melbourne	979,227	Melbourne, Albany, Ivanhoe, Parkes, Young, Hay	Melbourne, Melbourne export.
Wangaratta	130,077	Wangaratta	Melbourne export.
Horsham	153,301	Horsham	Melbourne export.
Avoca	148,910	Avoca	Geelong export.
Newcastle	177,042	Newcastle	Newcastle export.
Sydney	479,829	Sydney, Dubbo, Goulburn	Sydney, Sydney export.
Brisbane	1,073,393	Walgett, Armidale, Warialda, Brisbane, St George, Charleville, Longreach	Brisbane, Brisbane export.
		MODEL 1: Final iteration	
Hobart	108,159	Hobart, Launceston	Hobart export, Launceston.
Adelaide	599,226	Adelaide, Pt Augusta, Coonalpyn, Naracoorte	Adelaide, Adelaide export.
Albany	217,401	Albany	Albany export.
Fremantle	493,145	Fremantle, Yalgoo, Koorda	Fremantle, Fremantle export.
Portland	154,856	Portland	Portland, Portland export.
Melbourne	1,722,141	Geelong, Melbourne, Albury, Wangaratta, Horsham, Avoca, Ivanhoe, Dubbo, Parkes, Young, Hay	Melbourne, Melbourne export.
Newcastle	177,042	Newcastle	Newcastle export.
Sydney	303,901	Goulburn, Sydney	Sydney, Sydney export.
Brisbane	1,073,393	Walgett, Warialda, Armidale, Brisbane, St. George, Charleville, Longreach	Brisbane, Brisbane export.

Total cost Model 1: First iteration $31,478,276
Final iteration $32,697,071

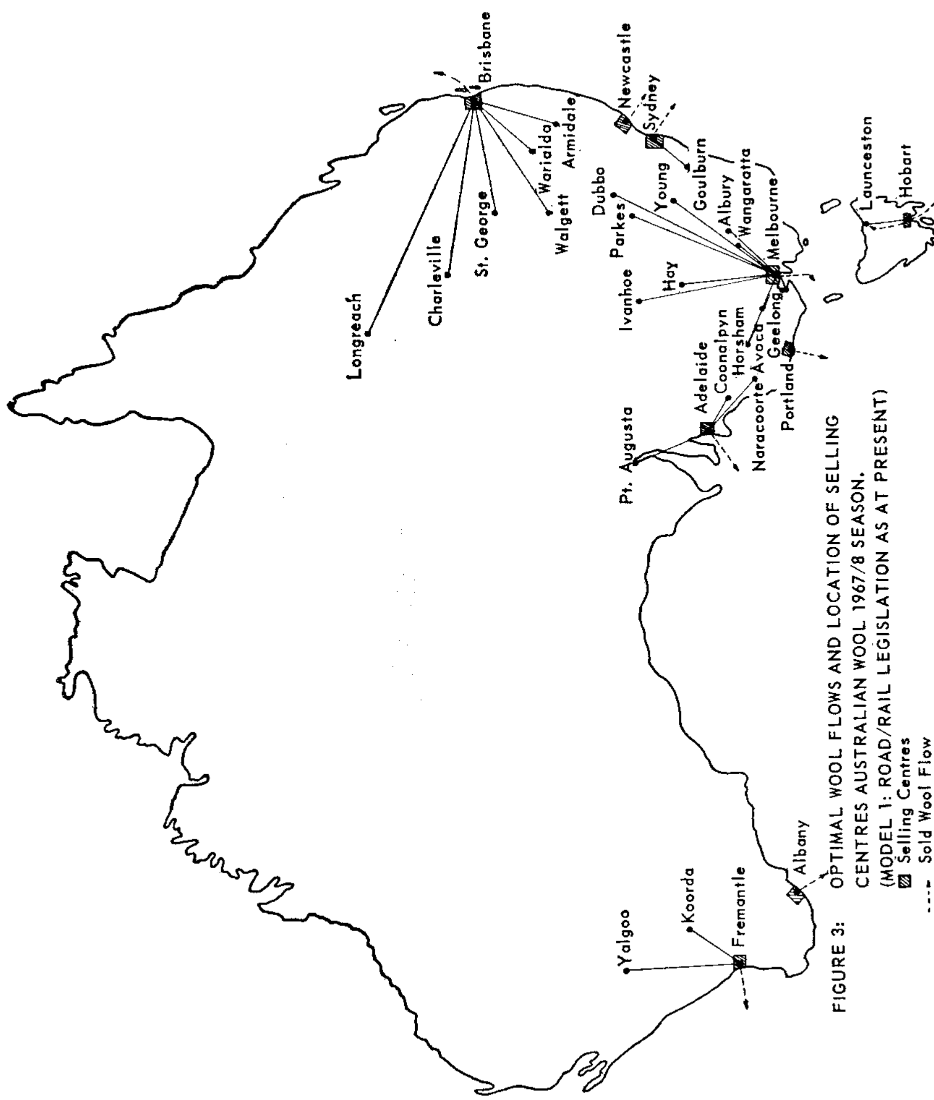

FIGURE 3: OPTIMAL WOOL FLOWS AND LOCATION OF SELLING CENTRES AUSTRALIAN WOOL 1967/8 SEASON.
(MODEL 1: ROAD/RAIL LEGISLATION AS AT PRESENT)
▨ Selling Centres
---- Sold Wool Flow
—— Unsold Wool Flow

optimal. Five existing centres have been dropped. These are Launceston, Goulburn, Geelong, Albury, and Ballarat. Together these accounted for 14·5 per cent of sales in 1967–8.

The final cost for Model 1 is \$32,697,071. This is slightly higher than the cost for the first iteration because more appropriate average costs are assumed as the solution proceeded.

3.3 MODEL 2

Model 2 is similar to Model 1 except that it is assumed that restrictive road and rail legislation is rescinded and wool is transported to selling centres by the least costly method. Table 3 and figure 4 include details of the final solution.

TABLE 3.

Optimum location of selling centres and throughput of Australian wool 1967/8 *season (rail/road legislation rescinded)*

Selling centre	Throughput (bales)	Supply region	Demand
		MODEL 2.	
Hobart	108,159	Hobart, Launceston	Hobart export, Launceston.
Adelaide	599,226	Pt Augusta, Adelaide, Coonalpyn, Naracoorte	Adelaide, Adelaide export,
Albany	217,401	Albany	Albany export.
Fremantle	493,145	Yalgoo, Koorda, Fremantle	Fremantle, Fremantle export.
Geelong	591,765	Geelong, Portland, Horsham, Avoca	Geelong, Geelong export, Portland.
Melbourne	791,825	Melbourne, Wangaratta, Albany, Ivanhoe, Hay	Melbourne, Melbourne export.
Newcastle	615,030	Walgett, Armidale, Warialda, Newcastle	Newcastle export.
Sydney	797,308	Dubbo, Sydney, Goulburn, Parkes, Young	Sydney, Sydney export.
Brisbane	635,405	Brisbane, St George, Longreach, Charleville	Brisbane, Brisbane export.

Total cost Model 2: $30,101,203

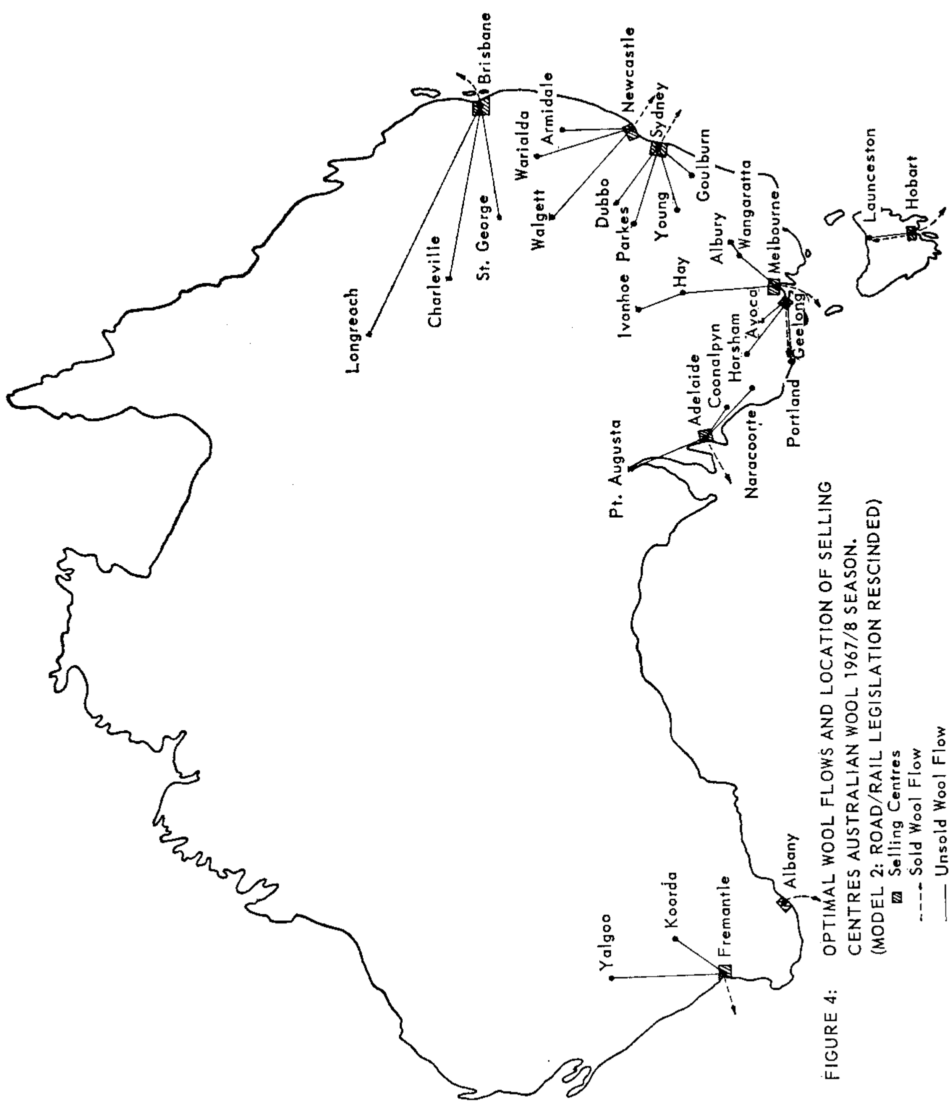

FIGURE 4: OPTIMAL WOOL FLOWS AND LOCATION OF SELLING CENTRES AUSTRALIAN WOOL 1967/8 SEASON. (MODEL 2: ROAD/RAIL LEGISLATION RESCINDED)

Nine selling centres are stipulated. Five existing centres, Launceston, Goulburn, Albury, Portland, and Ballarat are eliminated. Compared with Model 1, wool is more evenly distributed among selling centres. Total cost for Model 2 is $30,101,203 which is $2,595,868 less than for Model 1. In effect this is the "cost" to the wool industry of State Government legislation restricting the mode of wool transport.

4 DISCUSSION

Because around 80 per cent of Australian wool is exported, transhipment oriented (i.e. port locations) rather than production oriented selling centres would be anticipated. The analysis confirms these expectations. In both models the inland centres of Goulburn, Albury, and Ballarat are eliminated. Also wool previously sold at Launceston goes to Hobart because unit selling costs are reduced by the larger volume and total transport charges for Tasmanian wool slightly favour Hobart. Portland replaces Geelong and vice versa depending on the assumptions regarding road and rail transport legislation.

Model 1 is probably the more realistic since it assumes continuation of existing road-rail legislation. Figure 3 illustrates the effects of the latter. Because N.S.W. rail rates are higher than would be possible under open competition, a proportion of N.S.W. wool is moved interstate by road (under Section 92) to Brisbane and Melbourne. In 1967–8 18 per cent of N.S.W. wool was sold in these centres. However under the assumptions of Model 1 this proportion increases to 75 per cent. If the legislation is rescinded (Model 2), the percentage falls to 27 per cent.

Model 1 indicates that if present transport and selling costs are to be minimized, the existing selling pattern must alter markedly. As well as elimination of the five centres already mentioned, Melbourne and Brisbane increase their shares, selling 36 per cent and 22 per cent of the total respectively compared with 15 per cent and 14 per cent at present. The throughput at Albany rises by 74 per cent while that of Fremantle falls by 16 per cent. The most spectacular change is Sydney which is currently the largest selling centre (18 per cent in 1967–8). This falls to 6 per cent under Model 1. Newcastle falls from 8 per cent to 4 per cent. The growth of Melbourne and Brisbane results from high N.S.W. intrastate freight rates which encourages interstate movement and from the lower per bale cost incurred by selling through larger complexes. Consequently competition for N.S.W. wool presently sold at secondary centres is likely to come from Melbourne and Brisbane as well as Sydney.

However, if a uniform charging policy continues, a different higher cost location pattern will be generated. The higher cost occurs because sites with locational advantages are not able to exploit this advantage fully. A major policy implication therefore is that a minimum cost solution cannot be achieved with the present uniform charging policy for broking services.

Similarly, the projected throughput of the Yennora complex of 1·25 million bales[18] is quite unrealistic if the uniform charging policy is not followed. It could only be achieved by seriously distorting the pattern of wool flows at lowest transport cost to other selling centres, and would thus further increase growers' costs. Capital invested in such a centre as Yennora could earn a higher return in complexes elsewhere. The long run average cost curve of figure 2 indicates that integrated complexes have achieved most of the economies due to scale at around 400,000–500,000 bales. Yennora should be planned with such figures in mind as well as allowing for future increases in wool supply

---

[18] G. M. Pemberton (Personal communication).

from the relevant supply regions. Also state government future transport policy would be important. Model 2 indicates that if road-rail legislation was rescinded, optimum throughput at Sydney would rise from around 300,000 to 800,000 bales.

Annual cost savings to the industry if Model 1 was adopted are large. Estimates of the present cost of selling the Australian clip (from farm gate to shipside for export or to local users) were derived by two methods. Firstly data of Westerman and others[19] were used. Here, shipping costs were subtracted from total costs to all destinations (farm gate to mill door). A range of from \$77m to \$101m was obtained. Secondly actual wool flows of the 1967–8 clip were costed using transport and wool store charges collected in the course of this study. This estimate was \$53m. It is suggested that these figures form a reasonable range. Thus the Model 1 cost of \$32m represents a substantial saving. The model does however imply that selling centres would have to be modernized or replaced with integrated complexes which would require further heavy capital investment. This would likely be guaranteed by Federal Government as at Yennora.

It is true that the results of this study are based on wool supplies and demands for the 1967–8 season only. Hence if total supply or the pattern of production changes markedly, these results may be invalidated. Toft *et al*[20] outline a technique for testing the sensitivity of static solutions (i.e. the range of individual selling centre throughputs for which the location pattern remains optimal). However, as indicated earlier, the preferred approach in this study is to rework the problem within a probability framework, and this is currently proceeding.

---

[19] Sir Alan Westerman *et al* in *Workshop on Wool Transport Conference August* 24–25 1967. (Department of Trade and Industry, Department of Primary Industry), p. 2, p. 11, pp. 19–21.

[20] H. I. Toft, P. A. Cassidy, and W. O. McCarthy, "Sensitivity Testing and the Plant Location Problem", *American Journal of Agricultural Economics*, Volume 52, No. 3 (August, 1970).