DETERMINING ALTERNATIVE LOCATIONS FOR PLANT PROCESSING FACILITIES: A METHOD FOR GUIDANCE OF POLICYMAKERS

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"But, fill me with the old familiar juice
Methinks I might recover by-and-bye."
Omar Khayyam

A method is outlined which augments and modifies the Logan and King optimum solution of the processing plant location problem to give a number of near optimum solutions. Policy-makers can then consider jointly the comparative costs of alternative locations and their comparative non-economic benefits. A Western Australian example involving the location of wool assembly and sampling centres is used to illustrate the method.

1 INTRODUCTION

A recent paper of Ferguson and McCarthy [3] reported the results of research into the optimum size, number and location of Australian woolselling centres. The study was prompted by the decision to replace the existing Sydney wool stores with one integrated complex at Yennora. It was also envisaged that such complexes would be progressively built in several other capital cities. As the capital cost of these complexes was substantial, and as minimizing transport and handling costs of the Australian woolclip was critical it was considered necessary to undertake such research. The reported study had three major shortcomings.

Firstly, the technique resulted in a single cost minimizing spatial pattern. While such a simple solution may be satisfactory for a firm locating new plant it is unsatisfactory for a large industry such as wool, wishing to locate numerous facilities. Because of Government involvement, various externalities need to be taken into account. These include considerations such as decentralization or employment policy. Hence, for a public policymaker, cost minimization alone is too naive an objective

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The authors benefited from discussion with Clarrie Higham.

function. A range of solutions each showing the cost divergence from the least-cost optimum is more satisfactory as these differences can then be set against non-economic benefits of alternative locations.

Secondly, the study was essentially *ex post* in that many of the investment decisions concerning Yennora had been made when the study began. However, economists perhaps contribute most to policymaking when they anticipate innovation and technical change and are able to advise what should be, rather than what could have been.

Thirdly, further use of the Logan and King [4] model by the authors indicated that the supposed least-cost optimum was in fact not unique and could be improved on.

This paper attempts to take account of these factors. The general area of study is the same as before, namely, transport and handling costs of the Australian woolclip. However a new element has recently been introduced into woolhandling and distribution. This is the packing of wool into large, dense bales weighing about 450 kg. Because it appears to offer significant cost economies it is taken into account here. Meantime, attention is confined to Western Australia because of its suitability in developing a methodology for application to the whole of Australia. Its wool production is geographically isolated so interstate wool flows are not significant. Further, the State has areas of dense wool production as well as large tracts where production is sparse, thus testing generality of the model.

Many of the assumptions (particularly in regard to overseas shipping) are realistic in the longer term but are inapplicable in the short-term. They have been included to stress scope of the model and provide as much information as possible about its flexibility.[1]

The envisaged Australian study will include assumptions likely to obtain over the next 4 to 5 years.

2 THE PROBLEM

The sale of wool by sample with objective specification is rapidly gaining acceptance and in the future is likely to be the basis of sale of the major proportion of the Australian woolclip.[2]

Divorcing the point of sale from the location of the stored wool allows the development of radically new handling systems. One such system under evaluation by the Australian Wool Board entails the packing, at selected locations, of similar types of greasy wool into large dense units

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[1]For this reason the implications of the results reported in this paper should be treated with care.

[2]The *Australian Financial Review* 28th July, 1972, p. 33, reports the National Council of Wool Selling Brokers as estimating that over 500,000 bales of wool are expected to be sold under objective measurement this season and this method will be extended as facilities become available.

of approximately 450 kg prior to sampling and coring. The initial cost analysis associated with this process is favourable, as the additional cost of packing wool into the larger bale is more than offset by:

the growers ability to reuse conventional wool packs for several seasons.

the elimination of coring as a specific operation; this is done in the wool press.

the elimination of dumping prior to shipping.[3]

the reduced transport costs. The larger unit utilizes existing transport capacity more effectively.

the reduced handling costs because the larger units are more suited to mechanised handling. Also, because of its regular shape and higher density, more wool may be stored per unit of storage space.

As the reaction of mills to large bales has been favourable, and if the savings indicated by the Wool Board's pilot study are confirmed in practice, the industry will be faced with determining the optimum location of these pressing and sampling facilities. Our study investigates aspects of this problem. More precisely, it is concerned with determining the size, number and location of these facilities for Western Australia so that costs of transport, pressing and packing from farm to overseas mill are as low as possible. However, instead of a single, lowest cost solution, a set of almost lowest cost solutions are presented. Policy-makers can then choose the "best" based on their own criteria.

3 METHOD OF APPROACH

3.1 CHOICE OF MODEL

The model chosen in the study is essentially a modification of the Logan and King model used in the previous study of Ferguson and McCarthy. These modifications which are discussed later, enable the generation of a number of near optimum solutions.[4]

The study is long-term in the sense that present wool centre locations, wool flows and institutional restraints, such as the present pattern of shipping, are ignored. The model assumes completely inelastic supplies and demands for wool.

3.2 SUPPLY AND DEMAND REGIONS

Using Australian Wool Board data on production in their defined Wool Statistical Service (W.S.S.) areas, fifteen wool producing regions in

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[3]Dumping is an additional pressing process which reduces the volume of a conventional bale by up to two-thirds.

[4]The Logan and King model used previously only generated one solution.

Western Australia were delimited.[5] In several cases large W.S.S. areas were divided up into as many as four subregions. This was done to introduce as many basing points as possible and thereby reduce the magnitude of the transport cost for the movement between the individual production units and the basing point.

Determining demand was more difficult as domestic consumption of greasy wool is not normally available by region. However, this information was obtained from an Australian Wool Board customer identification study. Export demand is a residual and is allocated to the six assumed overseas demand destinations in proportion to the 1970–71 destinations of Australian greasy wool exports.

Throughout this study, data for 1970–71 (the latest available) are used. During this year it is contended there were no unusual factors which were likely to make the distribution of production in Western Australia a typical for planning purposes.[6]

3.3 CHOICE OF BASING POINTS

As the model is a point-trading type it requires that regional supplies and demands occur at discrete but representative locations in each supply region. These representative points are the potential locations of production oriented processing facilities. In general, Western Australian State legislation does not permit the movement of wool by road when rail is practicable. Accordingly, where possible, the largest centrally placed town on a rail line was chosen as a regional basing point.

On the demand side seven destinations—six overseas and one local demand—were specified. As the model considers overseas shipping from Western Australia to export demand centres, it must allow transhipment through all possible ports, not just those used at present for wool shipment. Four ports are judged to be appropriate for wool shipment. These are Perth/Fremantle and Albany which are existing wool ports and Geraldton and Bunbury. These ports represent the potential location of transhipment oriented processing facilities.

The six overseas destinations, Japan, U.K., Northern Europe, Southern Europe, U.S.A. and a residual export demand centre are potential (though unlikely) sites for consumption oriented processing facilities.

Regional supplies, demand, basing and transhipment points are

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[5]In the wool selling centre location model previously reported there were 32 supply regions. However, in that model, minimum centre size was about 150,000 bales. In the present case, minimum feasible press throughputs are considerably lower, hence the model allows greater disaggregation.

[6]The paper "Sensitivity of Plant Location Solutions to Changes in Raw Product Supplies", by W. O. McCarthy, D. C. Ferguson and P. A. Cassidy, *Review of Marketing and Agricultural Economics*, Volume 39, No. 3 (September, 1971), pp. 36-42, discussed a method of using randomly generated regional supplies to provide an indication of the stability of an optimal plant location.

TABLE 1

Regional Supplies, Demands and Basing Points, Western Australian Model

Basing Points*	Demand	Supply
	(100 conventional bales)	
1. Roy Hill (RH)	0	198
2. Mt Magnet (MM)	0	530
3. Gascoyne Junction (GJ)	0	496
4. Mullewa (ML)	0	715
5. Southern Cross (SC)	0	662
6. Koorda (KD)	0	662
7. Moora (MO)	0	604
8. Wubin (WB)	0	603
9. Brookton (BK)	0	721
10. Narrogin (NG)	0	721
11. Quairading (QA)	0	721
12. Boyup Brook (BB)	0	898
13. Katanning (KT)	0	898
14. Jerramungup (JR)	0	898
15. Ravensthorpe (RT)	0	898
16. Geraldton (GD)	0	0
17. Albany (AB)	0	0
18. Perth/Fremantle (PT)	1320	0
19. Bunbury (BY)	0	0
20. Japan (JP)	2962	0
21. United Kingdom (UK)	831	0
22. Northern Europe (NE)	2627	0
23. Southern Eurpoe (SE)	1026	0
24. U.S.A.	303	0
25. Other destinations	1156	0

*1–15 Origins
16–19 Ports
20–25 Destinations.

summarised in table 1. Figure 1 illustrates the spatial relationships of the locations in Western Australia. For computational ease, units of 100 conventional bales are used throughout.

3.4 PER BALE TRANSPORT COSTS FOR WOOL PRIOR TO PROCESSING

As previously indicated, Western Australian legislation forces wool to move on State-owned railways whenever practicable. Therefore, transport linkages between basing points have been costed assuming rail transport. These rates were obtained from the published Western Australia Railways rate book adjusted for any concessions.[7] Where

[7]For example, the 50 per cent reduction on the conventional bale rate on all wool consigned to Albany from sidings south of Narrogin. This concession became effective from August, 1971.

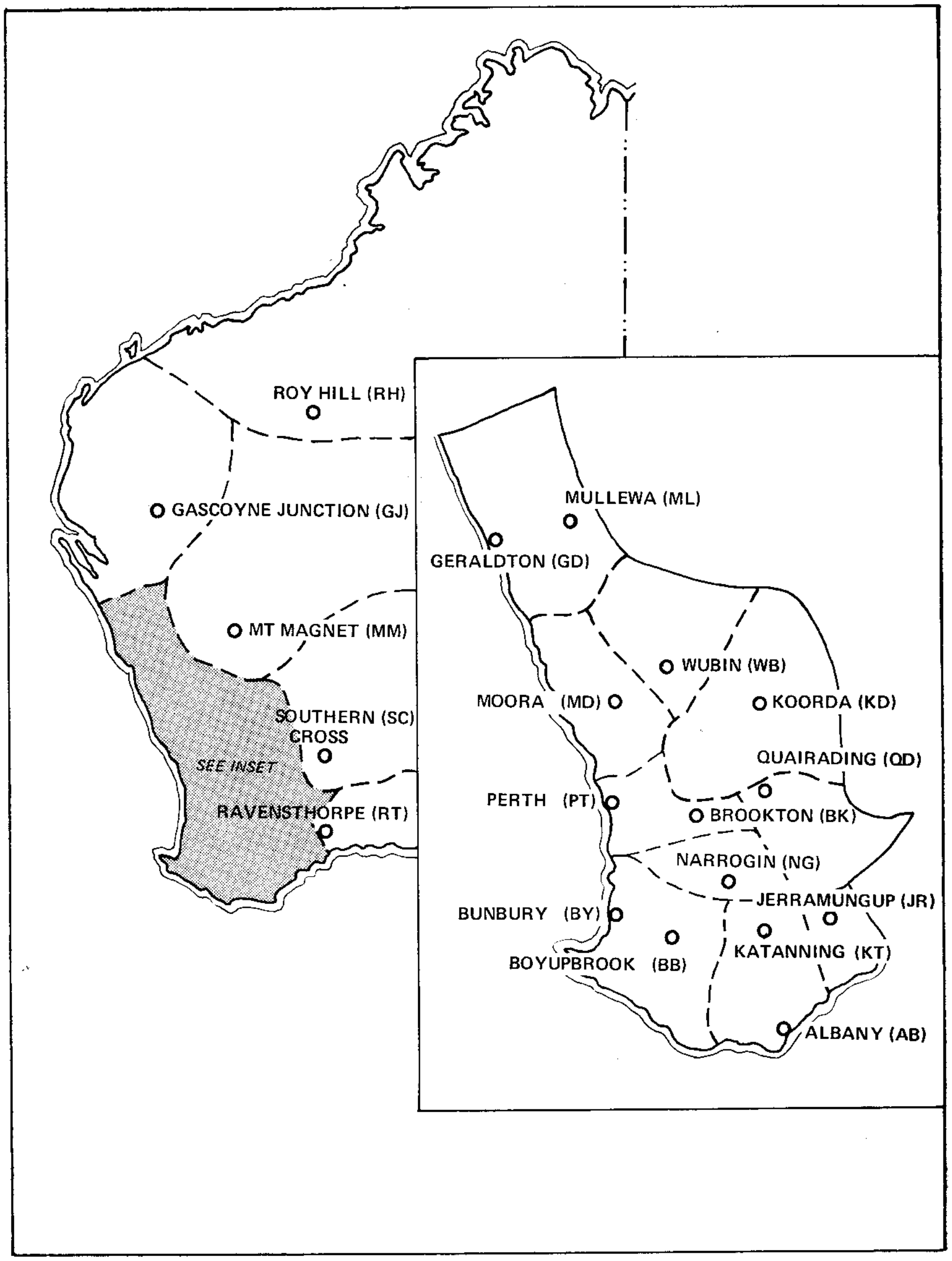

FIGURE 1: *Supply regions basing points and ports, Western Australian model.*

rail transport is impractical, rates from road haulers have been sought,[8] or calculated using road transport costs. Allowances are made for available back loading following the method of Ferguson [2]. As the model evaluates the movement of units of 100 conventional bales the transport costs have been expressed in these terms.

3.5 ESTIMATION OF THE LONG RUN AVERAGE COST CURVE FOR REBALING INTO LARGER BALES AND CORING

Of several methods of determining the LRACC discussed by Smith [5] and Walters [7], the "synthetic" method is the most appropriate here. The cost curve components were derived from the studies on big baling carried out under approximately commercial conditions by the Australian Wool Board. The main assumptions used in the preparation of this curve are:

On-farm storage of conventional bales to ensure continued operation of the central presses throughout the year and to minimize the provision of storage at the pressing facility.

Adoption of special clip preparation procedures to minimize the need for amalgamation of lines to ensure adequate wool for conversion into larger bales[9].

The utilization of capital equipment for two shifts per day for a 230 working day year.

Hourly press throughput of about 15 big bales per hour[10].

The charges for big-baling at a given press vary with the annual throughput of that press. These charges are determined from the long run average cost curve.

Allowing for all such factors the synthesized cost curve used is as follows:[11]

$$Y = 447{\cdot}708 + \frac{123{,}331}{X}$$

where Y = pressing cost per 100 conventional bales.
X = annual press throughput in 100 conventional bales.

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[8] *Wool transport in Australia.* Development Division, Australian Wool Board, August, 1971.

[9] Special clip preparation involves the use, in the field, of objective research which indicates that within any merino flock, the variation in fibre diameter between sheep is within acceptable processing limits. Such procedures result in the preparation of longer sale lines than under conventional classing procedures.

[10] This rate includes an allowance for press maintenance and idle time.

[11] Because most of the input data were prepared after a limited number of trials and as some of the critical assumptions are feasible but not yet attainable, the absolute position of the cost curve (but not its shape) must be treated with some caution. However, sensitivity testing of solutions with respect to the absolute position of the cost curve has indicated that errors in the specification of the curve are unlikely to influence the spatial pattern derived.

3.6 PER BALE TRANSPORT COST FOR PRESSED WOOL TO PORT SIDE AND DOMESTIC DEMAND LOCATIONS

As there is no reason to expect that the movement of wool in large bales would be exempt from existing transport restrictions, rail transport is assumed to predominate.

However, the uniformity and greater density of the larger bale results in better utilization of existing road and rail transport capacity. Also, large bales reduce terminal charges. Consequently, in this study the cost of moving large bales over a given route is estimated to be 70 per cent of the equivalent conventional bale rate.

3.7 PER BALE COSTS OF MOVING WOOL FROM PORT SITES TO OVERSEAS DESTINATIONS

At present most Australian wool is shipped from the various Australian ports in Conference Line vessels. A uniform rate applies for wool consigned to a given destination from any port. This uniform shipping rate distorts the distribution of wool production by preventing areas with locational advantage gaining the benefits of that advantage.

This model uses hypothetical freight rates, which reflect the locational advantages of various ports with respect to a particular demand area; synthesized from confidential data provided by various shipping companies. This assumes that the types of wool available to supply a port with a particular location advantage with respect to a given user, are acceptable to the user. While not precisely correct, this assumption is sensible for the bulk of wool production.

The types of vessels suited to each of the four ports vary. All the ports are suited to conventional unit load vessels and roll-on roll-off vessels.[12] However, Fremantle alone of the four ports has shore facilities for container vessels. Bunbury is a major port for the export of mineral sand by bulk vessel to the U.K., Northern and Southern Europe and the U.S.A. Mineral sands constitute an ideal base cargo for wool shipment.[13] However, it is doubtful that roll-on, roll-off vessels would call at Bunbury for wool if they were servicing Fremantle. Also, it is unlikely that bulk ships would load at Bunbury with sand and sail to Fremantle to load wool. Consequently, only bulk ships are assumed to load at Bunbury.

The per pound sea freight between port and destination for large bales was assumed to be reduced by 25 per cent, when compared with the hypothetical conventional rate over the same route.[14] The sea costs

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[12]For a discussion of vessel flexibility see the UNCTAD report "Utilization of Cargo", New York, 1970.

[13]This is illustrated by the discussion on the 10,000 bale shipment in the Norwegian bulk ship *Brunes* in January, 1972, see *Australian Financial Review*, 25th January, 1972, page 1.

[14]Considerable raw data were available from a continuing project on wool shipping by the Development Division of the Australian Wool Board. These hypothetical rates were corroborated by some ship owners.

account for only a part of the total freight cost. Other costs include counter marking, unitizing in the case of roll-on, roll-off vessels, transport to ship side, shore labour and equipment. These are included to give a complete transport cost from port of origin to discharge at the wharf area of the destination port.

Unlike previous studies such as Whan [8] and the Bureau of Transport Economics [1], the authors consider that the risks inherent in scheduling wool from country locations to ship side without short-term transit storage are unacceptable.[15] Therefore, a transit storage cost is included in the freight rate. Still, because of the very high storage densities possible with big bales the cost of provision of this storage for periods up to 2 months is not substantial.

4 RESULTS

4.1 INTRODUCTION

Applying the Logan and King method to the data outlined above, a single solution which is a local optimum can be obtained.[16] However, it has been argued that several near optimum spatial patterns should be available for policy decisions. These additional solutions are obtained by a two-phase procedure. First, a Monte Carlo technique is used and then the standard Logan and King model, or a modification of it, is constrained or forced to yield solutions.[17]

The Monte Carlo technique permits the generation of a large number of feasible solutions quickly and cheaply. Only those falling below a specified cost level need to appear on the computer printout.[18] These solutions are inspected and subjective conclusions drawn about what

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[15]The high risks are occasioned mainly by the strong desire of ship owners to have vessels in port for no more than 36 hours, and the difficulty of scheduling wool from diverse locations to meet a given vessel. The risk is further increased by the possibility of shipowners instituting a penalty charge if an agreed uplift is not achieved during the loading period because wool is unavailable.

[16]A global optimum spatial pattern is one in which total cost of any other feasible combination of plant sizes, numbers and locations is more costly. A local optimum is one in which any small change in plant sizes, locations and numbers will yield a higher cost solution. However, while a global optimum must be a local optimum, there is no guarantee that a particular local optimum is a global one. In the absence of a technique which *simultaneously* minimizes assembly, processing and distribution costs (and no such technique is currently available), a global optimum cannot be guaranteed.

[17]Forced in the sense that centres are made to appear or are not allowed to appear in solutions.

[18]Initial assumptions such as the probability of each centre entering a solution or plant size range can be modified on the basis of results obtained and the programme rerun until it is considered sufficient information is available. The authors found that a series of shorter runs, with intermediate data modifications, were more productive than one or two longer runs. In this study about 500 solutions were generated in runs ranging from 30 to 100 but only about 200 were printed out.

centres and combinations of centres could possibly feature in low-cost local optimum solutions.

The second step is to force these centres into solutions generated by the standard or modified Logan and King method. In this paper use is made of a modification suggested by Stammer [6].[19] The forcing technique combined with Stammer's modification yielded most of the low-cost solutions reported here.

4.2 MONTE CARLO TECHNIQUE

The Monte Carlo technique generates a feasible solution by proceeding as follows:[20]

Selecting the centres to enter the solution and the size of the corresponding plant throughputs according to specified probabilities.

Optimizing assembly costs from origins to processing centres using the transportation algorithm.

Optimizing distribution costs from plants to final destinations allowing trans-shipment (via a port) where necessary.

Calculating the total cost (assembly, processing and distribution) of the solution and including it in the printout when such cost is below a specified level.

In addition to the data required by the analytical (i.e., Logan and King and modifications) method, the Monte Carlo approach requires the following to be specified:

The probability of each centre entering a solution.

A plant size range for each selected location.

An exclusive tied vector.[21]

The maximum number of plants allowed to enter a solution pattern.

Table 2 includes selected results obtained by using the Monte Carlo technique.

These data quickly indicated that low-cost solutions favoured port oriented processing. Further, the solutions tended to specify three or four large facilities. Of the port locations, Bunbury (BY) was dominant while Albany (AB) was of least importance. Good solutions were obtained when Perth (PT) did not enter the solution. The likelihood of Geraldton (GD) being included in good solutions was high.

Of the production oriented locations only Jerramungup (JR) entered for the lower cost solutions. At somewhat higher costs Mullewa (ML)

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[19]This requires that processing costs for plants not entering a solution on any particular iteration be left at their previous level while processing costs for plants entering are adjusted in accordance with the quantity processed.

[20]Clarrie Higham was responsible for initial formulation of the method.

[21]Potential processing centres can be tied so that should a certain location be selected others tied to it are excluded from further consideration in the current solution.

TABLE 2

A Small Selection of Monte Carlo Solutions with a Total Cost Below $12.3 *m*

Plant Location*	Throughput '00 bales						
1. RH ..	..	..	..	..	..	..	..
2. MM ..	..	..	..	..	..	..	..
3. GJ ..	..	..	..	..	..	..	..
4. ML ..	..	..	..	2,127	..	1,502	..
5. SC ..	..	..	..	..	..	..	..
6. KD ..	..	..	..	..	..	2,499	2,021
7. MO ..	..	..	..	..	..	..	..
8. WB ..	..	..	..	..	..	..	..
9. BK ..	..	..	..	..	..	..	..
10. NG ..	..	..	..	..	..	..	..
11. QD ..	..	..	..	..	..	..	..
12. BB ..	..	..	..	..	..	..	..
13. KT ..	..	..	..	..	..	..	1,562
14. JR ..	3,091	..	2,483	3,242	..	..	2,753
15. RT ..	..	..	..	..	..	..	..
16. GD ..	2,321	2,995	1,414	..	2,023	..	2,329
17. AB ..	..	..	..	..	1,325	1,496	..
18. PT ..	..	2,379	2,602	..	2,654	..	1,560
19. BY ..	4,813	4,851	3,726	4,856	4,223	4,728	..
Total Cost $m.	12·042	12·069	12·076	12·090	12·124	12·134	12·277

*1–15 Origins
16–19 Ports

Koorda (KD) and Katanning (KT) also entered. A decentralization policy favouring the latter two plus Jerramungup, Perth and Geraldton would raise total costs by $208,000 compared with an exclusively port location of Geraldton, Perth and Bunbury.

4.3 FORCING THE ANALYTICAL MODEL

The Monte Carlo solutions suggested possible low-cost spatial patterns. The second step involved encouraging such patterns using the forcing technique on the Logan and King model (with and without Stammer's modification). Of the very large number of solutions obtained, Table 3 presents ten selected ones in order of increasing cost.

Table 3 emphasizes the tendency of a small number of large processing facilities to occur in the low-cost spatial patterns. These better solutions also show that, despite the reduced transport costs available on wool pressed into big bales in country locations. processing facilities tend to be port oriented. Thus in solutions 3 and 5 processing centres are exclusively at ports.

Consider solution 4. The Monte Carlo solutions of table 2 indicated that Mullewa (ML) was a possibility as a production oriented processing

TABLE 3

Selected Location Patterns in Order of Increasing Cost

Processing Centre*	Solution									
	1	2	3	3	5	6	7	8	9	10
1. RH	..	..	..	..	..	..	..	..	..	..
2. MM	..	..	..	..	..	..	..	..	..	..
3. GJ	..	..	..	..	..	496	..	..	..	..
4. ML	..	..	..	2,542	..	670	..	..	1,939	2,542
5. SC	..	..	..	..	..	..	..	..	662	662
6. KD	..	..	..	..	..	..	..	..	..	662
7. MO	..	..	..	..	..	..	..	..	..	604
8. WB	..	..	..	..	..	..	..	..	..	..
9. BK	..	..	..	..	..	..	..	..	4,032	721
10. NG	..	..	..	..	..	..	721	..	..	..
11. QD	..	..	..	..	..	..	..	..	..	721
12. BB	..	..	..	..	..	..	898	3,492	..	..
13. KT	..	..	..	..	..	..	..	..	..	..
14. JT	2,694	1,796	..	2,896	..	..	2,694	..	3,592	4,313
15. RT	..	..	..	..	..	..	..	..	..	..
16. GD	2,744	1,939	2,542	..	1,939	..	1,939	2,542	..	..
17. AB	..	..	..	..	1,023	1,796	..	..	..	..
18. PT	..	1,703	2,896	..	2,476	2,476	3,973	4,091	..	..
19. BY	4,787	4,787	4,787	4,787	4,787	4,787	..	..	..	..
Total Cost $m.	12·015	12·035	12·041	12·072	12·077	12·169	12·215	12·224	12·392	12·477

*1–15 Origins.
16–19 Ports.

Least cost local optima are as follows:

Logan and King standard	$12·669
Logan and King forcing	$12·041
Stammer modification	$12·052
Stammer forcing	$12·015

centre while still providing a relatively low-cost solution which included ports.[22] Mullewa was therefore forced in.

In small problems such as reported here it is also possible to explore alternative locations with information gained from the dual of the first iteration. This specifies those centres which failed to appear in the solution because the costs were marginally higher. Consequently, such centres could be further investigated by forcing. However, for large models this approach is time consuming.

Solution 4, which has a penalty cost of about 0·5 per cent when compared with the best solution, differs from the best three solutions in utilizing two large production oriented plants and only one port location. The production oriented facilities occur in the north and in the southeast of the study area. The port plant draws wool from the central and southern regions.

Spatial patterns which include a greater number of production oriented plants can be generated but only at a cost penalty. For example, solution 7 with two ports and three inland centres has a total cost about 1·5 per cent higher than solution 1. Solution 10 is a highly decentralized processing pattern. The total cost here is about 3·9 per cent above the optimal solution. This may be considered a relatively small divergence and may be acceptable to policymakers wishing to promote a policy of decentralization.

However, there are two factors to be considered. Firstly, the adoption of the spatial pattern suggested in solution 10 represents an annual cost penalty of about $462,000. This penalty cost approximately represents the contribution paid by the wool industry to the community in general to achieve the policy objectives embodied in solution 10 as opposed to those of solution 1.[23] On equity grounds, it could be argued that payment for community goals should be from the public purse rather than by what is, in effect, a levy on a particular industry. Thus, if solution 10 is chosen on community grounds as a basic plan, a transfer payment equal to the difference in cost between the optimal and the chosen pattern less secondary benefits, should be paid to the wool industry.

Secondly, as well as increased cost, a highly decentralized processing pattern is inherently more riskly. Take for example the suggested processing centre at Moora. The annual throughput is of the order of 60,400 bales which is drawn from regions whose basing point is Moora. If production declined in the short-term by say 10 per cent (and this is not unreasonable in cases of serious but local drought), then the

[22]This is not a particularly easy operation and cannot be done without forcing Logan and King or using the Stammer modification. The standard Logan and King model does not allow ports to enter. This is because ports have a locational disadvantage relative to production regions. Thus when the same unit cost is attributed to all processing centres in the first iteration, ports are excluded and cannot re-enter in subsequent iterations.

[23]If secondary benefits to the farming community through decentralization are ignored.

TABLE 4

Ports of Loading for Wool to Japan for Solutions 1–10 *in Table* 3

Port	Solution									
	1	2	3	4	5	6	7	8	9	10
GD	2,744	1,939	2,542	2,542	1,939	1,166	1,939	2,542	1,939	2,542
AB	218	1,023	. .	420	1,023	1,796	1,023	. .	1,023	420
PT.	. .	. .	420	. .	. .	. .	. .	420	. .	. .

associated decline in throughput would result in a cost increase of 3·5 per cent per unit. However, should the throughput of a large centre, say Geraldton in solution 3, decline by 10 per cent, the unit processing cost would increase by only 1·2 per cent. Also, a 10 per cent decline in the throughput of one facility drawing wool from one region is more likely than a 10 per cent decline in the throughput of a facility drawing wool from a more diverse group of regions.

The favourable rail rates to the Albany woolselling centre also suggest that State Government policy favours the retention of Albany as a wool port. Under the handling system assumed in this paper, Albany's role as a wool export port would be strengthened if a processing facility was located in that centre. Solutions 5 and 6 offer locational patterns which utilize Albany. The divergence from the optimal solution is 0·5 per cent and 1·3 per cent or $62,000 and $154,000 respectively.

4.4 FLOWS FROM PORTS TO FINAL DESTINATIONS

The distribution flows for all low-cost solutions, including those obtained by the Monte Carlo method and those not presented here, are highly stable.

For the 10 solutions of table 3, throughput of Bunbury (BY) is always constant at 4787 units.[24] This wool is shipped to U.K. (831), Northern Europe (2627), Southern Europe (1026), and U.S. (303). The 1156 units exported to "Other Countries" are always shipped from Perth (PT). Residual or domestic demand of 1320 units also goes through Perth. It is only the 2962 units exported to Japan that are subject to variation in terms of the port of loading. Table 4 includes the details. Even here Geraldton predominates, taking the major share in all but one case. Perth enters only twice and for relatively small amounts. There are three pairs of common solutions.

[24]100 bale units.

5 CONCLUSION

This paper reports research of interest to policymakers in that it tests a method permitting generation of a local optimum and a number of near optimum solutions to the classical processing plant location problem. The study differs from previous ones in that it used a Monte Carlo technique to derive quickly a number of promising solutions which were then incorporated into the Logan and King method as modified by Stammer. As a final step a technique developed by the authors to force centres in and out of the pattern was used.

Overall the approach could be termed successful in the sense that feasible solutions were obtained at reasonable research cost. A feature of the results was the comparatively wide range of differing spatial location patterns derived for which costs are not greatly different. The primary purpose of the study, that of giving policymakers a range of feasible plans, was thus achieved.

A more specific implication for wool processing in Western Australia, given the assumptions of the model, is that a policy of decentralization, with its assumed social benefits, would not entail substantial additional costs. True the study ignored the present locational pattern and assumed improved handling and processing techniques not yet in general use. However, conditions similar to those assumed in the model are likely to obtain in the relatively near future. Hazarding a guess, the similarity in costs between centralized locations and decentralized locations is likely to be the outcome of the Australia wide study presently in progress. Thus, decisions to install new woolhandling facilities at portside locations during this transitional period must be examined carefully.

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