ANALYSES OF THE OPERATIONAL PERFORMANCE OF MATERNAL AND CHILD HEALTH (MCH) SERVICES IN HONG KONG*

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Abstract: This study is based on the 35 full-time Maternal and Child Health (MCH) centres in Hong Kong. Cluster analysis is first applied to produce homogeneous groups of MCH centres with a similar level of workload by using hierarchical clustering techniques, followed by a non-hierarchical clustering technique for verification.

Based on the results from the clustering analyses, operational performance of the MCH centres is evaluated by using performance indicators (PIs) as it is useful to compare the performance of centres between and within clusters with similar workload statistics. The nurses' strength of different ranks are also taken into account for operational reasons. This study is helpful for the management in identifying areas in need of in-depth study and possible improvement.

Keywords: Maternal and Child Health Service, cluster analysis, performance indicator.

1. INTRODUCTION

1.1. Background

The Maternal and Child Health (MCH) centres under the Family Health Service of the Department of Health in Hong Kong provide a comprehensive range of promotive and preventive health service for children aged below six and women of childbearing age. The 35 full-time and 11 part-time MCH centres are organized into four distinct regions, spreading out in most districts in Hong Kong. This paper is based on the 35 full-time MCH centres only. These centres provide four main types of services, namely child health, antenatal, postnatal and family planning services.

1.2. Operational Performance

Demand for the four services varies greatly from centre to centre. With one main objective being the grouping of centres with a similar level of workload, the total number of clients and the total attendance divided by the number of sessions for each service are taken as the workload variables. The demand pattern of the four services is also closely related to the number of different ranks of nurses assigned to the various centres. The tree ranks of nurses are Nursing Officers, Registered Nurses and Enrolled Nurses/Mid-wives. Different types of work offered by each MCH service are done by different ranks of nurses. For example, nurses' interviews for child health service are done by either Nursing Officers or Registered Nurses.

Performance Indicators (PIs) offer one aspect of operational performance. Results from the cluster analysis together with data on the strength of different ranks of nurses are incorporated into the evaluation of the operational performance of the MCH services.

1.3. Related Work

Cluster analysis has became a common and useful took in marketing analysis to identify homogeneous marketing segments in order to build tailor-made marketing programs meeting the needs of different target segments [5]. Applying cluster analysis in health care organization is also suggested to improve the management and marketing strategy [6]. In this study, cluster analysis is first applied to produce homogeneous groups of MCH centres with a similar level of workload by using hierarchical clustering techniques such as in [2, 7], based on different definitions of distance measured between clusters. This is followed by a non-hierarchical clustering technique [4] for verification consideration.

Based on the results from this clustering analysis, the operations of MCH centres are evaluated by using performance indicators, as it is then more meaningful

to compare the performance of centres between and within clusters with similar workload statistics. A set of performance indicators (PIs) is suggested to help management in examining the performance of these health organizations [1, 8]. PIs can be some "traditional" efficiency measures (ratios of output to input(s)), but some may relate to the process (such as length of stay). PIs do not relate directly to productivity but they do indicate performance indirectly. The relative position of each health organization can be determined based on each PI. This is helpful for the management in pinpointing areas in need of further study and possible improvement.

2. CLUSTER ANALYSIS

2.1. Methods and Techniques

The main objective of this first part of the study is to produce groups of centres with a similar level of workload. The clustering variables considered are thus the total number of clients, as well as the total attendance, of each of the four services divided by the total number of sessions for each service. Hence there are eight characterising variables stemming from these session averages of service factors.

The determination of the distance between centres is usually affected by the range and the dimensions of the clustering variables used. In our case, there is no dimensional problem, but the ranges of the variables are quite different. For example, the attendance of child-health clients is far greater than that of post-natal clients. Since giving a heavier weight to the variables of child-health clients is actually meaningful, natural and reflects higher external demand for their services, in this study the original values of the variables (with no transformation or standardization of data) are used in carrying out the clustering analysis. Also the most commonly used Euclidean distance is adopted in the procedures.

Five hierarchical techniques are tested in this study. They are the single linkage, complete linkage, centroid linkage, average linkage and Ward's methods. The single linkage method tends to produce long stringlike clusters (or 'chaining'), which is not desirable. The centroid linkage method is quite sensitive to outliers. Contrary to this, the results based on the complete linkage, average linkage and Ward's methods are quite consistent, with clearly observed clusters. This effectively suggests that the data are rather stable, and any one of these three methods could be chosen for the subsequent analysis. We report our findings from Ward's method in the following cluster analysis.

2.2. Clustering Freely Across Regions

As a first analysis (of their natural grouping), all the 35 centres under study are allowed to cluster freely (across regions). The resulting dendrogram is shown in

Appendix 1 and five clear clusters can be formed. They are as given in Table 1.

Table 1.

Cluster	1	2	3	4	5
MCH Centre	1A 1B 1E 4A 4F 4G 4H	1D 2E 3A 3C 3F 3G 3J 3L	2C 2D 2I 4E	1C 2F 2H 3I 4B 4D	2A 2B 2G 3B 3D 3E 3H 3K 3M 4C

2.3. Clustering Regionally

Clustering the 35 MCH centres together simply by their natural grouping is not very practical, because the centres are located and managed in four distinct regions. The management reasonably expects to cluster the centres regionally. Appendix 2 shows the resulting dendogram in this case, in which two clear clusters emerge in each region resulting in eight clusters (which are also the preferred number of clusters from the managerial point of view). This formation into eight resulting clusters is shown in Table 2.

Table 2.

Region	Region 1		Region 2		Region 3		Region 4	
Cluster	1	2	3	4	5	6	7	8
MCH Centre	1C 1D	1A 1B 1E	2C 2D 2F 2I	2A 2B 2E 2G 2H	3B 3D 3E 3H 3I 3K 3M	3A 3C 3F 3G 3J 3L	4B 4C 4D 4E	4A 4F 4G 4H

2.4. Reduction of Variables

The previous clustering analysis in Sections 2.2 and 2.3 are based on the eight variables of the total number of clients per service session and the total attendance per service session, for each of the four services. However, these two types of variables, namely the session averages of the total number of clients and the total attendance, may be highly correlated. One expects the total attendance of clients for a service to vary directly with the total number of clients. The correlation of the total number of clients per service session and the total attendance per service session of each service is thus calculated as shown in Table 3.

The high correlations between the two types of variables of each service are evident from Table 3. Therefore the variables of total attendance per service session of the four services alone may be sufficient to represent the workload statistics (for the purpose of clustering). In subsequent analyses, the 35 MCH centres are clustered

regionally based only on the total attendance per service session of the four services (thus having only four instead of eight variables). The resulting dendogram is shown in Appendix 3 and the formation into eight clusters happens to be identical to those shown in Table 3. More detailed comparisons of the dendograms in Appendices 2 and 3 show extremely minor variations in the formation process itself of, but not the resulting, cluster 6 only. For simplification and reduction of data requirements, only the four variables of total attendance of the clients per service session for each service are deemed sufficient.

Table 3.

Services	Correlation
Child Health Service	0.9677
Antenatal Service	0.9584
Postnatal Service	0.9998
Family Planning Service	0.9597

2.5. Non-hierarchical Clustering Consideration

Sections 2.2 to 2.4 applied only hierarchical clustering methods. One potential disadvantage of hierarchical clustering methods is that subsequent unmerging centres which have been merged together into one cluster in an earlier stage are not catered for. This means that correcting any poor initial merging (due to the input order of data, for example) is not possible. Therefore hierarchical clustering techniques do not guarantee optimal final clusterings. To address such a concern, one non-hierarchical approach, a k-mean method [3], is adopted (for verification). Under non-hierarchical methods, the number of required resulting clusters k is pre-specified and k centres are selected as initial singleton clusters. Centres are then moved and included into the k clusters with the goal of optimising certain clustering criteria. Differences among various methods arise with respect to the ways of choosing the initial clusters and the clustering criteria to optimise. Possible disadvantages of using non-hierarchical methods are: the number k of required clusters has to be specified (it may sometimes be difficult to choose a particular k) and the high computing time for large data sets. For our case, the number of eight required clusters can be rather naturally decided upon from the management's point of view. And the number of MCH centres total only 35 so the data set is modest in size. Hence the k-mean non-hierarchical clustering method has been suitably implemented. To allow for two clusters in each region, two clusters are initially and randomly selected for each of the four regions. Centres are subsequently moved into those eight clusters with the goal of minimising the variability within clusters and maximising dissimilarity between clusters. The results based on four clustering variables are shown in Table 4.

Table 4.

Region	Region 1		Region 2		Region 3		Region 4	
Cluster	1	2	3	4	5	6	7	8
MCH Centre	1C 1D	1A 1B 1E	2C 2D 2F 2H 2I	2A 2B 2E 2G	3B 3D 3E 3H 3I 3K 3M	3A 3C 3F 3G 3J 3L	4B 4C 4D 4E	4A 4F 4G 4H

The results are nearly the same as that from Ward's method (Table 2) except for a small difference in the distribution of one centre (2H) in region 2. In conclusion, it has thus been observed that hierarchical and non-hierarchical clustering methods result in very consistent clusters. This consistency means that the workload statistics of the 35 MCH centres under study can be regarded as stable with respect to natural grouping based on the chosen (four) clustering variables.

3. PERFORMANCE INDICATORS

The performances of the 35 MCH centres are evaluated in terms of various performance indicators (PIs) in this part of the analysis. The PIs used are the ratios of client attendance of each service to the number of nurses per service session. These are straightforward and easily identifiable measures of performance. (The numbers of clients are not considered as noted before because they are highly correlated with the attendance of clients, as shown in Table 3).

3.1. Overall Performance Level of MCH Centres

The four PIs for the individual services (relative to nurse strength) are given by: CH/NURSE, FP/NURSE, AN/NURSE, PO/NURSE,

where CH   = total attendance for the child health service,
       FP   = total attendance for the family planning service,
       AN   = total attendance for the antenatal service,
       PO   = total attendance for the postnatal service,
       NURSE = total number of nurses (being Nursing Officers, Registered
                   Nurses, and Enrolled Nurses/Mid-Wives) on duty.

3.1.1. Comparison between regions

The performances of the centres are firstly compared on a regional basis as shown in Appendix 4. The service-specific effect of each of the four PIs is clear and consistent in every region. The order from highest to lowest PIs is given by

CH/NURSE, FP/NURSE, AN/NURSE and PO/NURSE. The dichotomy of performance can also be detected to be regions 1 and 4 versus regions 2 and 3. Region 1 invariably scores the highest in each PI, followed consistently by region 4.

3.1.2. Comparison between clusters

The performance of the centres is now compared on a cluster basis (according to Table 2 above) as shown in Appendix 5. A similar service-specific effect is also observed, consistently in every cluster, except for cluster 2. The PIs AN/NURSE and PO/NURSE of cluster 2 are higher than expected. Clusters 2 and 8 score higher in all four PIs than the other clusters. For cluster 1, the PIs CH/NURSE and FP/NURSE also appear to be higher than expected.

3.1.3. Comparison within clusters

The performances of the individual centres within a same cluster are compared next. Only the results of clusters 3 and 5 are illustrated in Appendix 6 (6a & 6b). The PIs of centres in cluster 5 are close together with very similar patterns (Appendix 6b). This implies that the performance levels of these six centres with a similar workload are also comparable. In contrast, cluster 3 exhibits a rather different picture (Appendix 6a). For both centres 2D and 2F in cluster 3, the PI CH/NURSE, falls unexpectedly low, showing a rather different pattern than most other centres.

3.2. Performance Level of Various Ranks of Nurses

The next set of PIs here relate to the comparison of nurses. Performing four services, the data on the strength of the three (combined) ranks of nurses lead to the following twelve PIs:

CH/NO, FP/NO, AN/NO, PO/NO, CH/RN, FP/RN, AN/RN, PO/RN, CH/EN&MW, FP/EN&MW, AN/EN&MW, PO/EN&MW,

where   NO   = number of Nursing Officers on duty,

RN   = number of Registered Nurses on duty,

EN&MW = number of Enrolled Nurses/Mid-Wives on duty,

and the services CH, FP, AN and PO are as defined previously.

3.2.1. Comparison between regions

Again the comparison is first made on a regional basis. The performances of each region with respect to the twelve PIs are shown in Appendix 7. The same

ordering of decreasing PIs from CH to PO is clear, as in the case when all nurses are considered together (Appendix 4). It can also be observed that the performances are close except for the much higher service attendance to NO ratios of region 1 relative to the other regions. Indeed all the PIs here for region 1 (with other ranks of nurses as well) are uniformly the highest among all regions.

3.2.2. Comparison between clusters

The performances of individual ranks of nurses on a cluster basis are shown in Appendix 8 (8a, 8b & 8c). A similar performance pattern prevails for each rank of nurses in every cluster except for cluster 2 (and to a lesser extent, cluster 3). Cluster 2 shows exceptionally high PIs relating to the antenatal service (AN for each rank of nurses, Appendices 8a, 8b & 8c). In addition, the four PIs with respect to NO of cluster 2 steer clear from and far above their counterparts of the other seven regions (Appendix 8a). Cluster 3, on the other hand, shows a deviation of somewhat unexpectedly high PIs relating to the FP service (FP for each rank of nurses, Appendices 8a, 8b & 8c).

3.2.3. Comparison within clusters

Here we finally examine more closely the three individual centres in cluster 2, which is chosen for this illustration because of its deviations in various previous settings (Appendices 5 & 8) as discussed before. All twelve PIs of the three centres from cluster 2 are shown in Appendix 9. The first observation here is that the PIs relative to RN for all three centres are quite close together. However, the CH and FP service ratios to the remaining ranks of nurses, NO and EN&MW, of centre 1E are significantly higher than those of the other two centres 1A & 1B. Finally, centre 1B shows across-the-board (over all ranks of nurses) low PIs for its FP service. Hence while centre 1A appears typical, centres 1B and 1E together largely account for the rather atypical PI patterns for cluster 2 taken as a whole, as shown in Appendix 5 (and also Appendices 8a, 8b & 8c).

4. CONCLUDING REMARKS

One natural aspect of operational analysis is the comparison of centres (in our case, MCH) by evaluation with respect to meaningful benchmarks. In practice, this is often achieved by calculating various performance indicators (PIs) such as those we have considered in the previous sections. Detection of relatively ineffective (or sometimes just undesirable) productivity is then feasible, and eventually such individual differences may lead to grouping of centres from an operational management point of view - a segmentation of operational units.

The approach we have taken may be regarded as consisting of two phases. Cluster analysis with workload statistics as characterising variables is first applied, as indicated in section 2, to partition the centres for subsequent performance analyses. The actual PIs are then identified, calculated and results analysed in section 3, on a regional basis, cluster basis and individual centre basis. Thus the analysis by PIs in section 3 builds on the similarity of centres within clusters and the dissimilarity between clusters in section 2. A general picture of the conclusion emerges after these two phases of work that (1) the centres cluster very naturally for the MCH services; and (2) the services perform rather consistently with respect to the chosen (service-to-staff ratio) PIs, although there are individual centres exhibiting atypical patterns (in certain PIs). Such an example is nicely provided by region 1 (always highest in all PIs, see section 3.1.1); cluster 2 of region 1 (AN and PO related PIs higher than expected, see section 3.1.2); and centres 1B in cluster 2 of region 1 (uniformly low FP/nurses PIs, see section 3.2.3.). Such information is useful for the management in considering any future arrangements of the services and/or nursing staff, if, after examining more closely the pinpointed cases, more uniformly observed PIs among groups of similar centres are appropriate.

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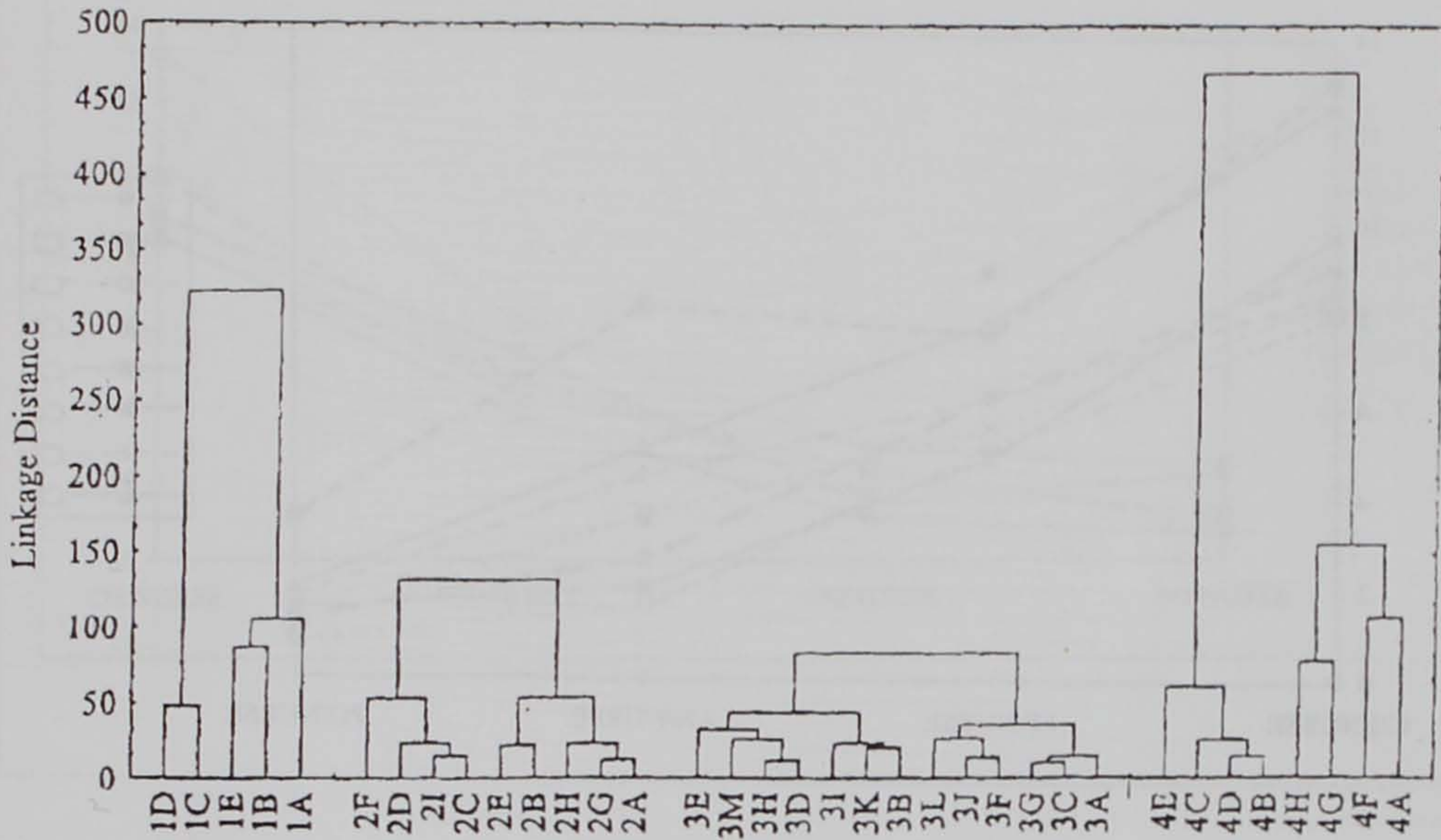
APPENDIX

Appendix 1 - Clustering 35 MCH centres altogether by using Ward's linkage method.
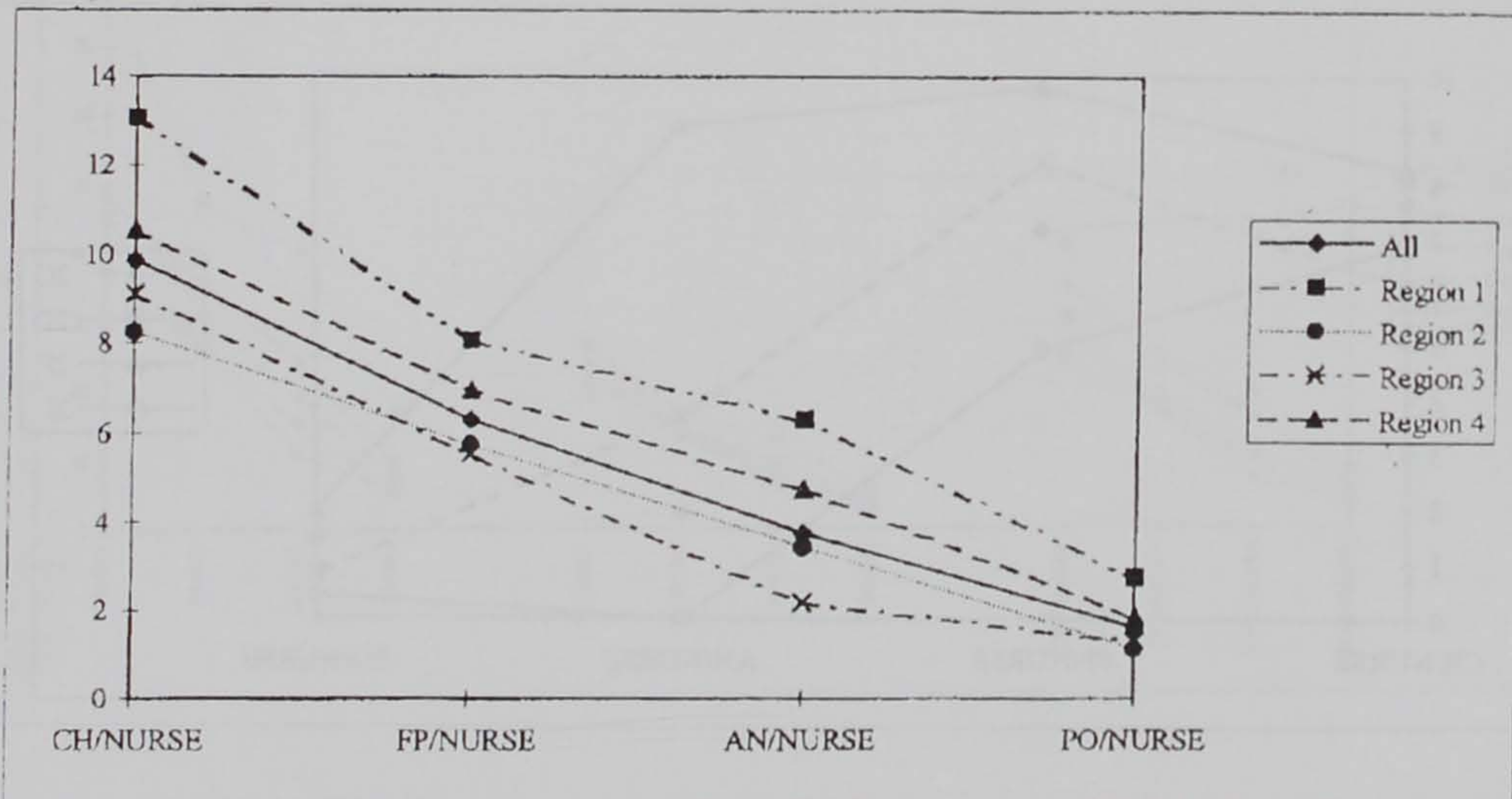

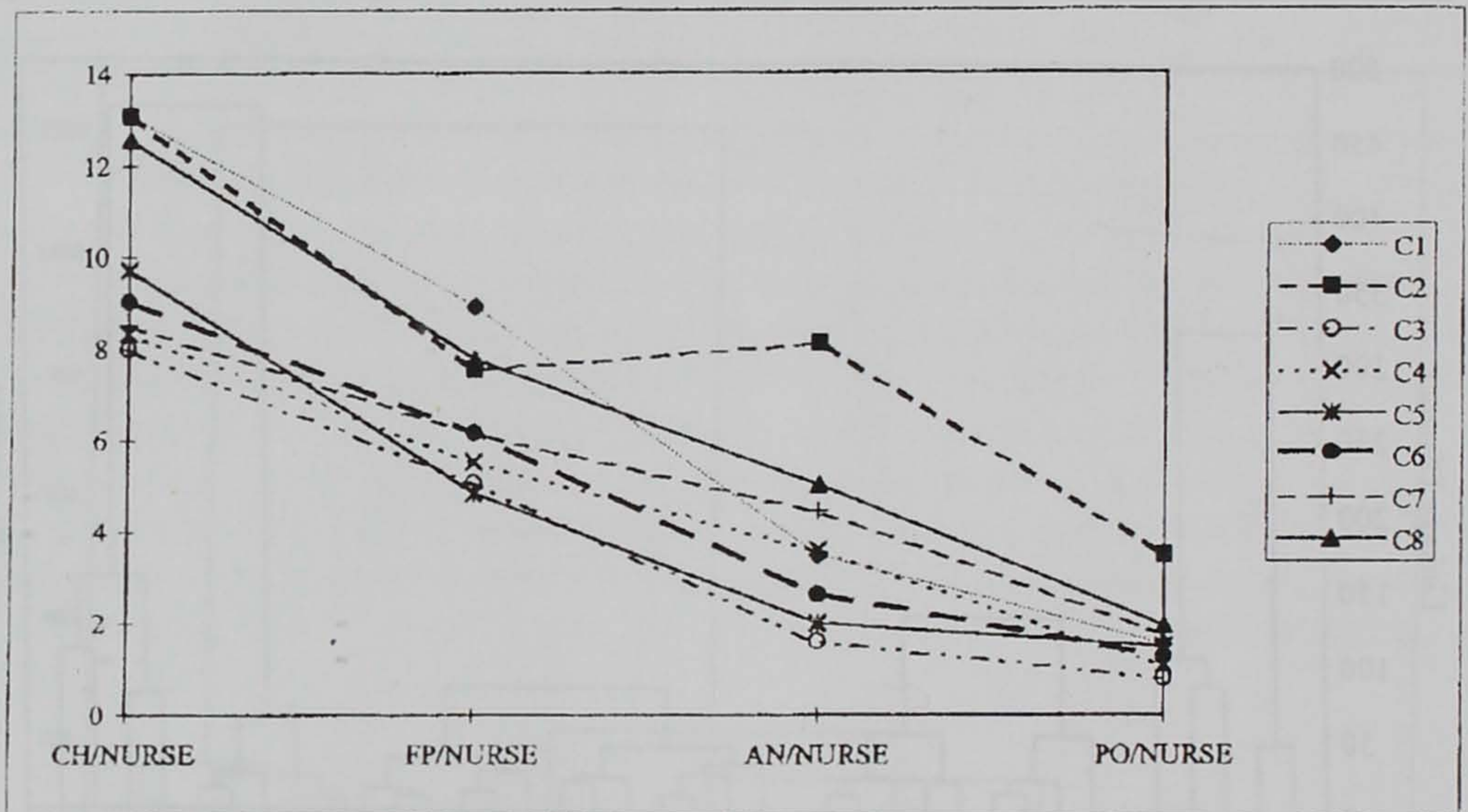**Appendix 2** - Clustering 35 MCH centres regionally by using Ward's linkage method.
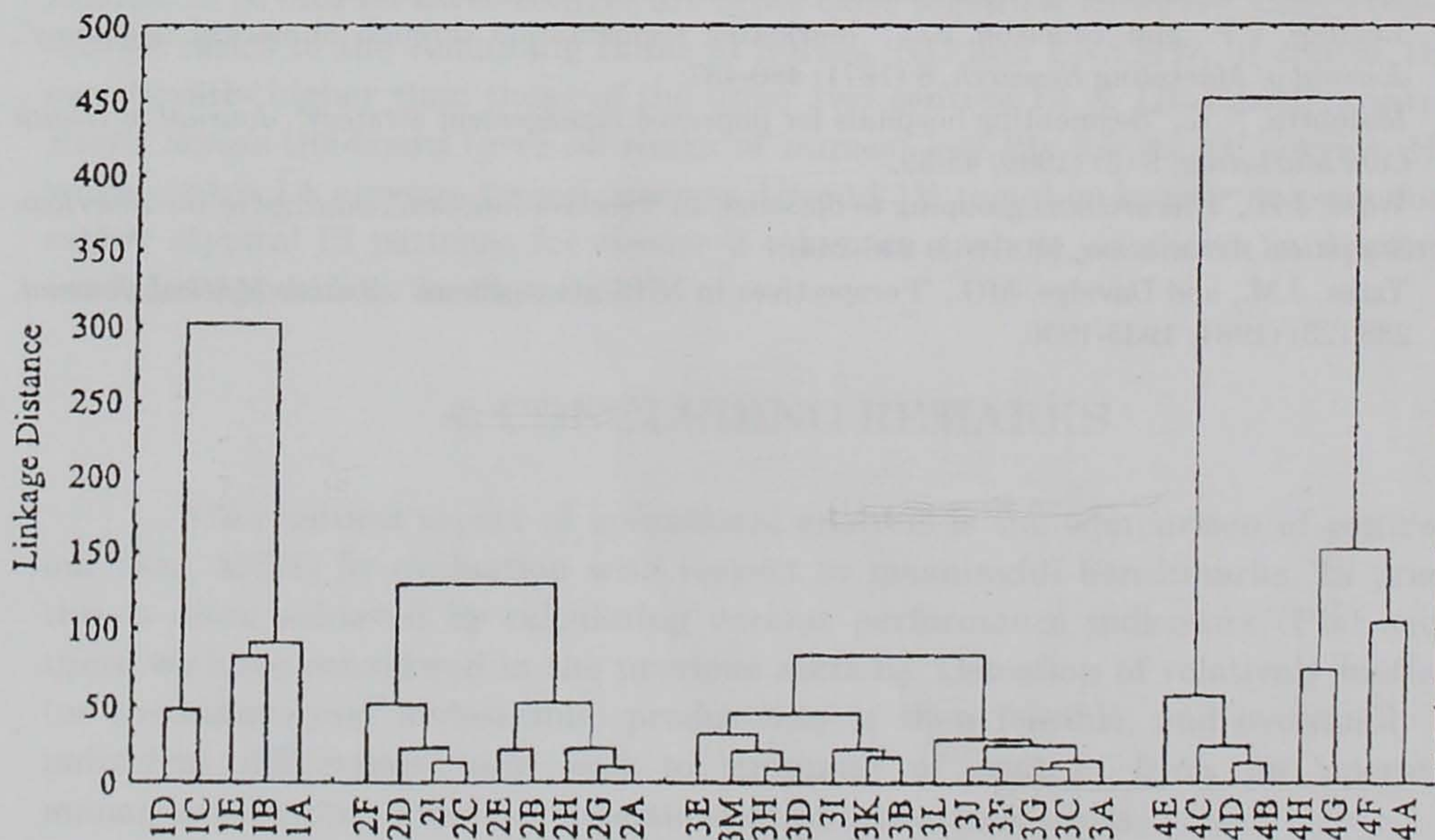
Appendix 3 - Clustering 35 MCH centres regionally based on variables of the total attendance of the clients for four services.
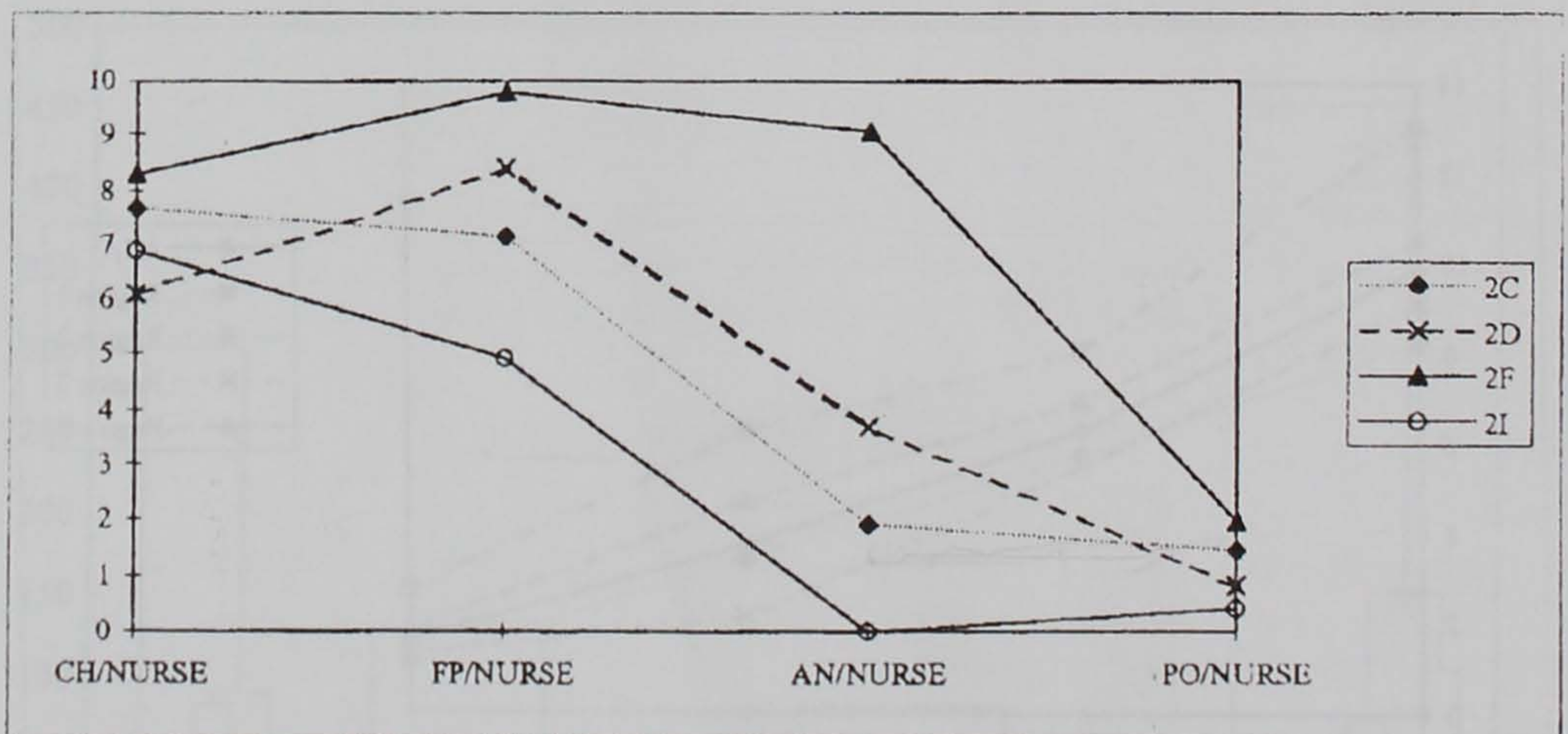

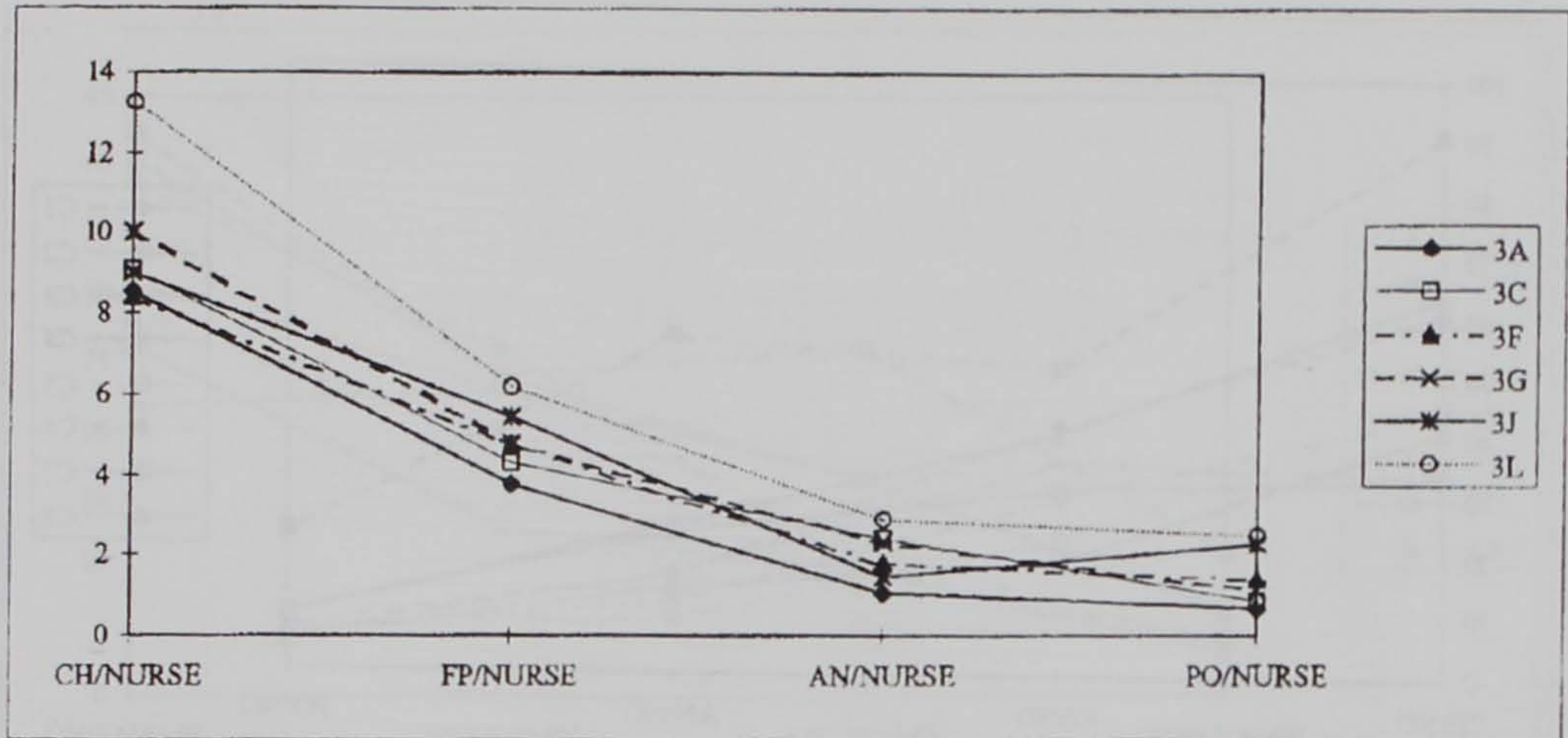**Appendix 4** - Performance lines of four regions.
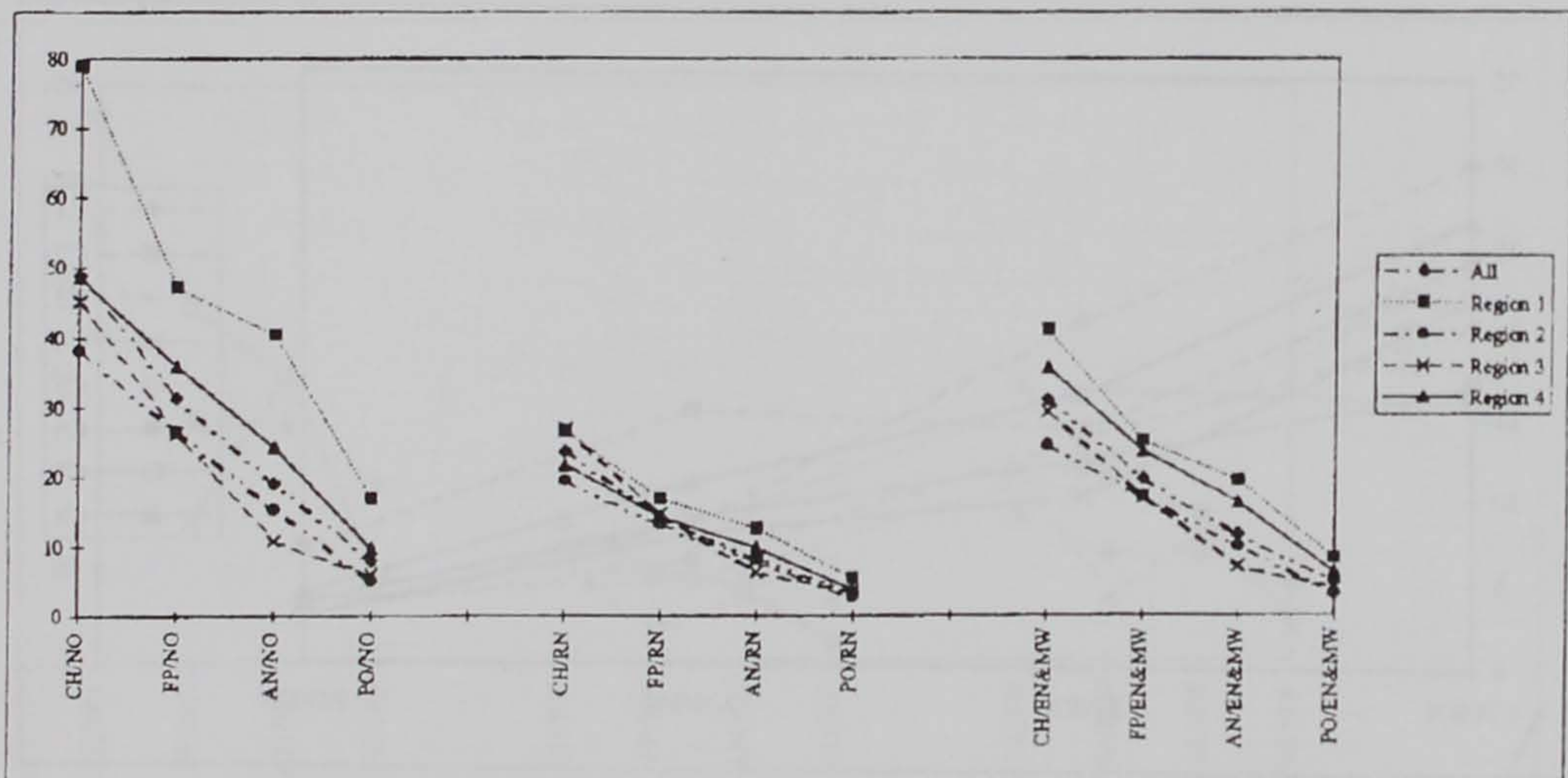
Appendix 5 - Performance lines of eight clusters.

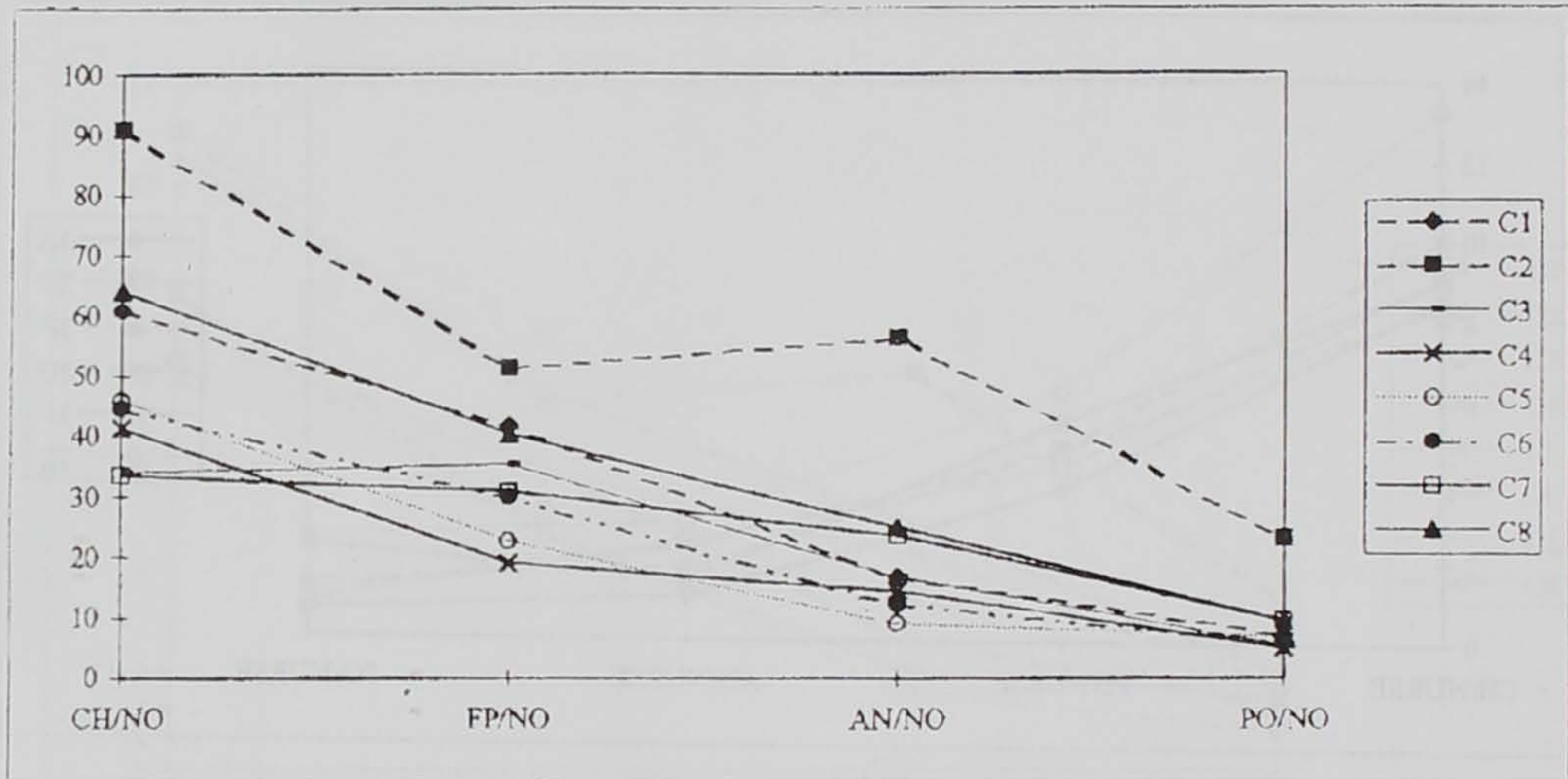**Appendix 6a** - Performance lines of cluster 3.

Appendix 6b - Performance lines of cluster 5.

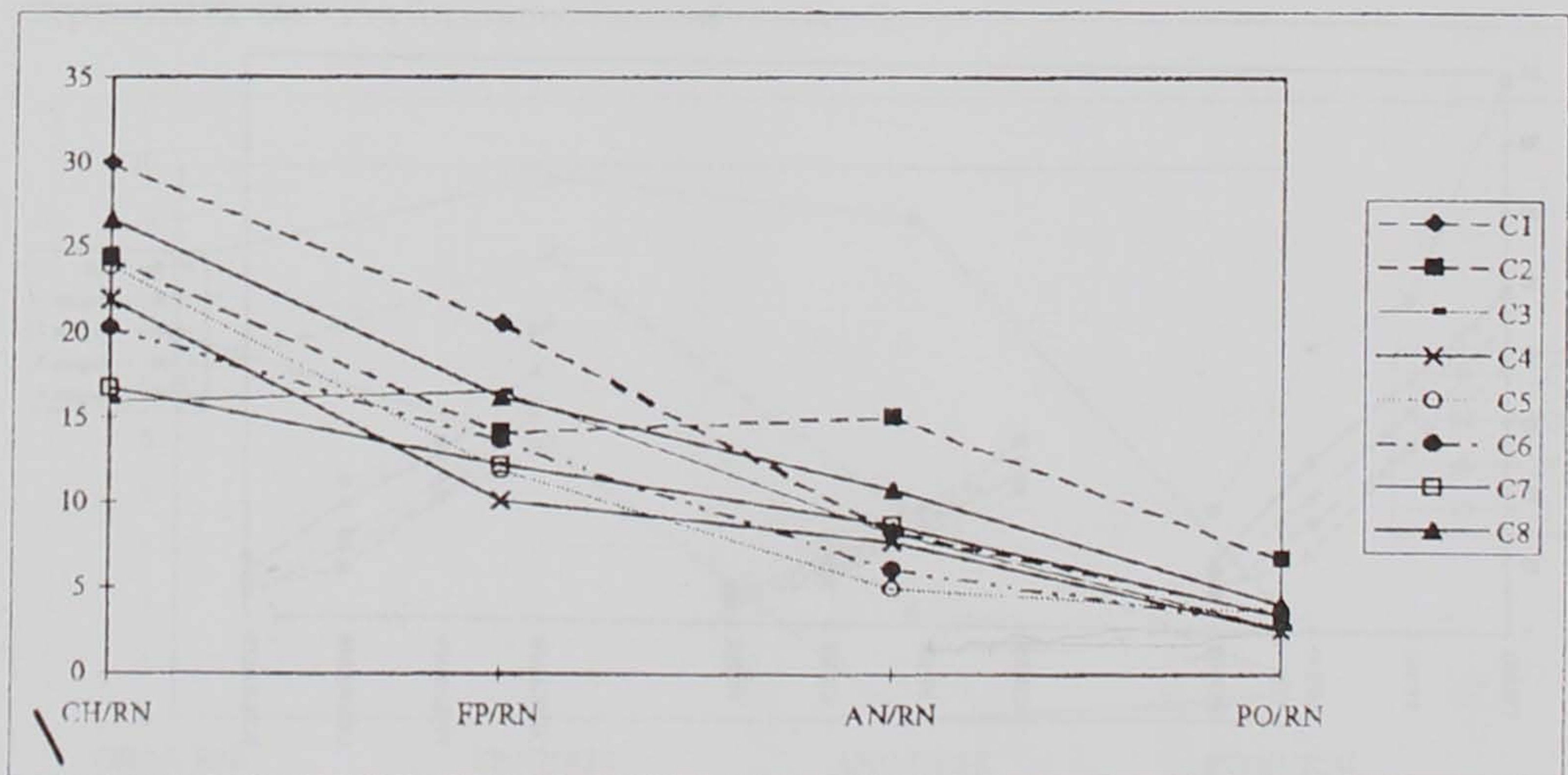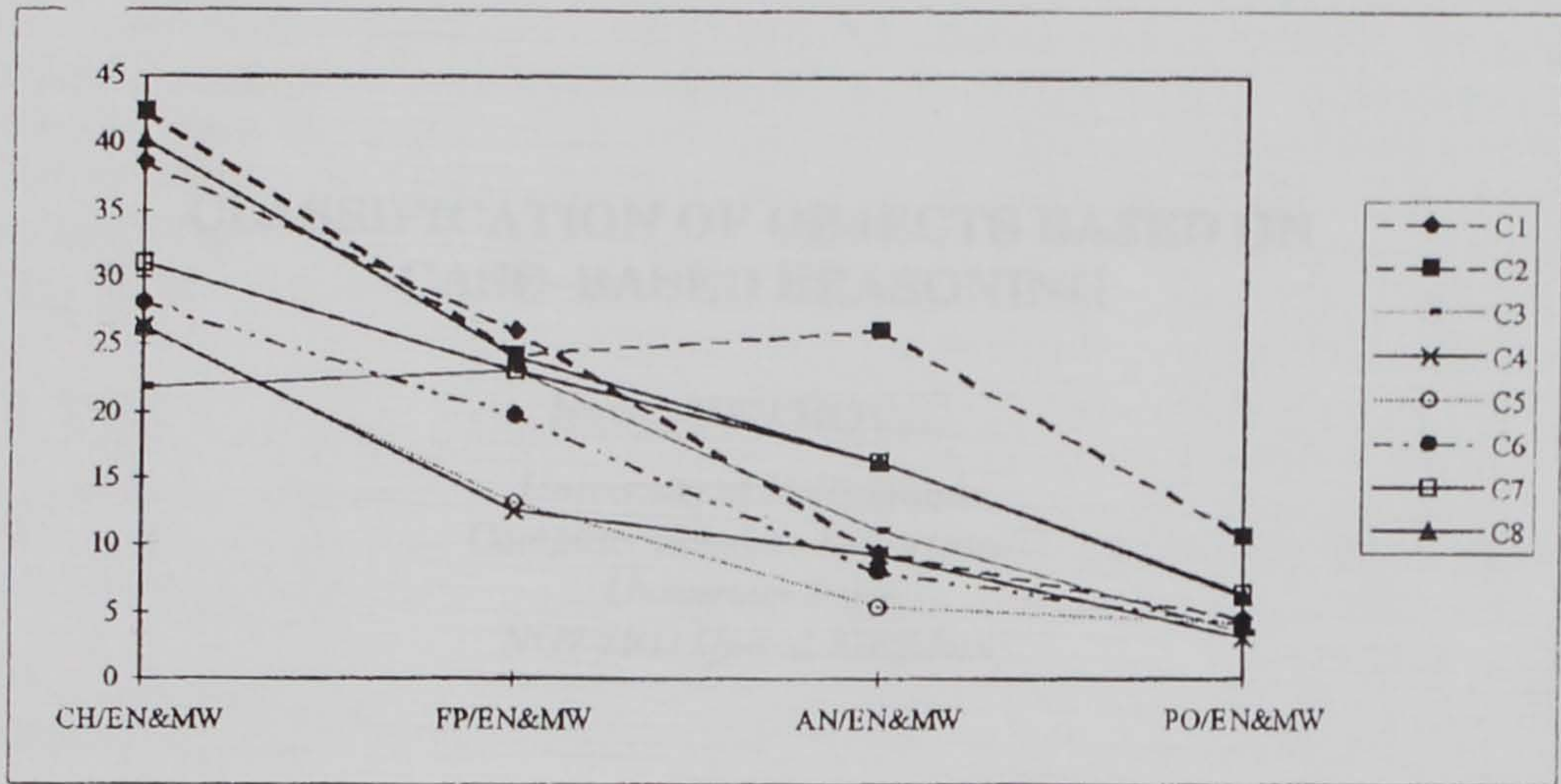**Appendix 7** - Performance lines of every rank of nurses in four regions.

Appendix 8a - Performance lines of NO in eight clusters.

Appendix 8b - Performance lines of RN in eight clusters.

Appendix 8c - Performance lines of EN&MW in eight clusters.

Appendix 9 - Performance lines of each rank of nurses in cluster 2.