The role of a conceptual model in data analysis: a study of the determinants of utilisation of antenatal services by migrant women in Belgium

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Summary

This paper considers the ways in which a conceptual model served to guide the analysis and interpretation of data arising from a study of the utilisation of antenatal services by Turkish migrant women in Belgium.

Models in general are discussed, and the relationships between theories, causal and statistical models are explored. The data are then analysed using a general multiple regression approach. The conceptual model is used to examine and interpret the model fitted in this way. An alternative method of analysis - the structured analysis - is then presented, in which the modelling procedure itself is suggested by the conceptual model. Finally suggestions are given that could make the conceptual model even more useful in the analysis and interpretation of data.

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1. Introduction

This paper is concerned with the ways in which a conceptual model can guide in the analysis and interpretation of data arising from a study of the utilisation of antenatal services by Turkish migrant women in Belgium.

A conceptual model for the utilisation of antenatal services by Turkish women was proposed by da Silveira et al (1987), using the technique developed by Beghin et al (1988). The conceptual model aims to organise in a structured manner the major determinants affecting the utilisation of antenatal care, and was developed as follows: a multidisciplinary team held a series of meetings or "brainstorming sessions", through which a number of iterations of the model was produced. The final model is a schematic representation of the determinants of the takeup of antenatal care which is constructed in a "top down" approach, starting with the response variable (here this is the utilisation of antenatal care) and moving downward from the explanatory variables with a direct influence to those with a less direct but still important effect on the dependent variable. Direct hypothetical links between variables are indicated by straight lines.

The causal model for the utilisation of antenatal care is shown in Figure 1 below.

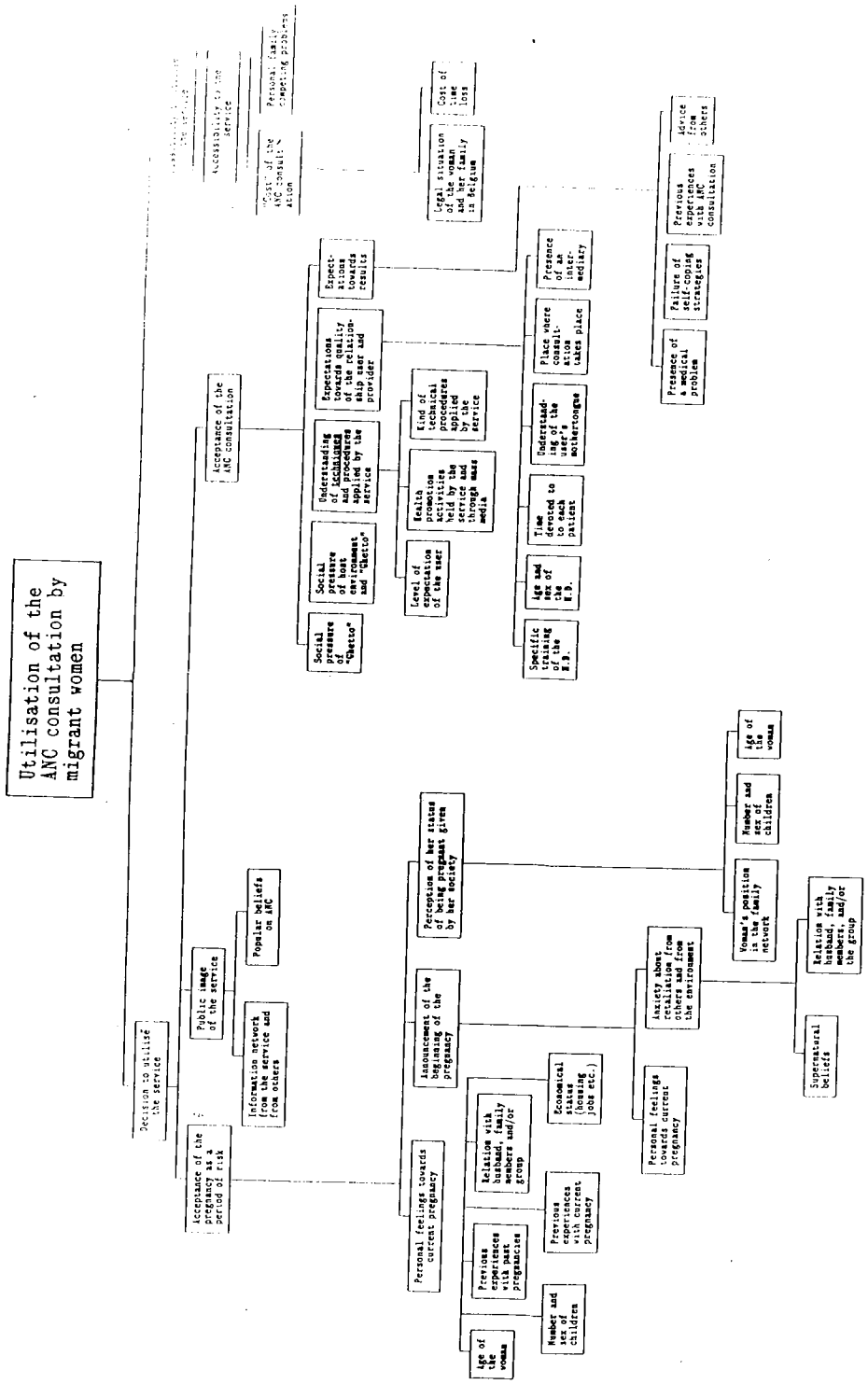


Figure 1: Conceptual Model for ante-natal care take-up by migrant women

After the development of the conceptual model, two questionnaire instruments were developed for a survey of pregnant Turkish women: the model identified factors to be investigated by a factual questionnaire, and by an attitude questionnaire, which aimed at finding the women's opinions about pregnancy, childbirth and the family. The attitude questionnaire also drew on work in Timmerman (1987).

The survey was then carried out on a sample of 74 recently-delivered Turkish women who had given birth between the 15th and 30th of September 1987 in 3 maternity hospitals - Sint Franciscus (Zolder), Sint Etienne (Brussels) and Middelheim (Antwerp) - that are frequently used by the migrant population. The interviews were conducted in Turkish by Turkish females who had been specially trained for the job - outside the normal visiting hours, i.e. in the absence of any one familiar with the interviewee, and they took about 60 minutes. None of the selected women refused participation.

The next stage of the study was the analysis of the data. Here the crucial question is the extent to which the conceptual model can aid in data analysis. In order to examine this we first consider in more detail what is involved in various types of models.

2. Theories, causal, and statistical models

A model is a simplification of reality which aims at aiding understanding of a given set of phenomena. Obviously, models can vary from very simple to fairly complex ones which aim to give an accurate representation of reality. Palloni (1987) discusses the relationship between theories, models and causal inferences. He defines a theory as an organised set of propositions reducing a particular set of phenomena to an abstract network of concepts, created with a causal language that makes explicit the existence of causal factors and causal mechanisms.

In order to draw valid inferences about causal relationships, firstly the theory is translated into a model which expresses in a synthetic form the main relations and concepts involved. At this stage the researcher chooses to emphasise certain aspects of the theory and de-emphasise others, and may also decide to simplify the relations implied by the theory. The model is then translated into a mathematical or statistical model which consists of a set of formal relations between factors which includes assumptions about the explicit functional form of the relationship and the nature of any 'departure' or 'error' terms.

Palloni emphasises the importance of preserving the distinction between the causal model derived from theory and the statistical model, since the latter must explicitly include considerations that arise from the study design.

One example of this process would be the study of the path of a projectile fired from a cannon as a function of the angle of the cannon and initial velocity of the projectile, a well known problem in classical physics . The theory involves Newton's laws of motion. When translating this into a causal model the effect of air resistance would be assumed to be negligible and the model would translate into a mathematical model involving a differential equation. In this case the causal mechanism is well understood and is explicitly included in the mathematical model through the differential equation.

Many statistical models on the other hand involve a "black box" approach. An observation of the response variable is decomposed into a random part and a systematic part i.e. that part which can be directly attributed to the effect of given "explanatory" variables. The systematic part is then related to the explanatory variables. Often very little thought is given to the actual mechanisms involved. Typically the systematic part is taken to be a linear function of the explanatory variables, with the vague justification that this linear function will serve as a useful approximation to the true underlying relationship between the response variable and the explanatory variables. This widely used class of models - the general linear model - can be extended to allow for nonlinear terms of the form x^2 , x^3 as explanatory variables, and also for interactions between explanatory variables. These and several other extensions are discussed by Bibby (1977).

Competing statistical models are judged according to one or more well defined criteria e.g. the coefficient of multiple determination R^2, which measures the proportion of the variation in the response variable accounted for by the explanatory variables. Roughly if two models have the same number of explanatory variables we prefer the model with a higher value of R^2, and we add a term to the model if it significantly improves R^2. Palloni (1987) points out that a statistical model may be consistent with many theories, some of which may be totally contradictory with each other. A conceptual model such as that developed for the utilisation of antenatal care by Turkish women, is closer to a theory than a statistical model, since it seeks to describe and explain causal mechanisms. In this sense a causal model is a "better model" of reality than a statistical model. However, a statistical model can be useful assessing whether the data are in agreement with the conceptual model, or whether the conceptual model needs to be modified.

In the study of antenatal care uptake by Turkish migrant women, the conceptual model was first used in the design of the survey instruments. The data scrutiny and analysis stage then highlighted areas in which the questionnaires could be improved, and this will be implemented in a proposed forthcoming study on the utilisation of antenatal care by Moroccan women.

Secondly, the conceptual model can serve as a guide in the choice of statistical model. It is often said that choice of regression model should be based on prior knowledge of the explanatory variables and their relationship to the response variable - the conceptual model provides a means of doing this.

A regression model developed in this manner is discussed below. One method of analysis often proposed for causal models is path analysis (see e.g. Kendall and O'Muircheartaigh (1977) and MacDonald (1977)). However, there are problems, both general and specific with the application of path analysis. In general there are many statisticians who question whether path analysis actually aids understanding of the underlying causal mechanism - Bibby (1977) contends that "the concepts of path analysis are at best redundant and at worst confusing". In particular, the concepts of path analysis require the analyst to feed in ideas about causality, but offer little guidance on how to do so in a structured way. In most cases the path analysis models given as examples in the literature are considerably simpler than the conceptual model for the utilisation of antenatal care.

Further there is no one-to-one correspondence between concepts in the boxes of our causal model and variables measured in the questionnaire, and our conceptual model explicitly allowed variables to appear in different places in the conceptual model. Therefore an actual path analysis was not carried out - however an analogue of path analysis was carried out and this is also discussed below in section 4.

Bibby (1977) points out that a residual analysis not only is necessary in order to check on the assumptions of our statistical model, but also can be useful in interpreting the data. In our present study this suggests that we can try to explain why the actual utilisation of antenatal care by certain women differs from that predicted by the statistical model, by reference to the conceptual model. Some indication of how this can be done is given below.

Furthermore in our study there were 5 women excluded from the analysis, because they had "missing values" on one or more of the potential explanatory variables. The conceptual model, in conjunction with the statistical model, can be used to predict the utilisation of antenatal care of these women on the basis of the non-missing values, and then to compare the predicted usage with the actual usage. Again this is done below.

3. The analysis of the data on the utilisation of antenatal care: the general approach

The main aim of the data analysis was to determine which covariates significantly influenced the utilisation of antenatal care. This was firstly done using multiple regression modelling, without making use of the causal model. As a measure of utilisation of antenatal care a compliance score was developed as follows:

If the woman had no medical consultation in the first trimester of her pregnancy, she was given a score of -3, otherwise she was given a score of 1. For the second trimester, no visit was given a score of -2, and each visit earned a score of 1 up to a maximum of 3. For the third trimester, no visit was given a score of -1 and each visit earned a score of 1 up to a maximum of 8. The compliance score was then defined as the sum of the scores for the three trimesters, and thus lay between -6 (for a non-complier) and 12 (for an excellent complier). It was recognised that there was a degree of arbitrariness in this definition of the compliance score, and a slightly different score was tried. Since the resulting model was very similar it was decided to use the original compliance score as our response variable.

The potential explanatory variables came from both the factual questionnaire and the attitude questionnaire. On the attitude questionnaire 17 items were assessed each based on statements from four women:

Ayse (who represented very conservative attitudes),
Fatima (who represented fairly conservative attitudes),
Güler (who represented fairly modern attitudes), and
Mektap (who represented very modern attitudes).

Respondents had to give their reactions to the speakers' statements on a five-point scale. For each statement the respondent gave a score:

+2	for strongly agree
+1	for agree
0	for neither agree or disagree
-1	for disagree
-2	for strongly disagree

For each item, a composite attitude score was then calculated as

-2 x (score for Ayse) -1 x (score for Fatima)
+1 x (score for Güler) + 2 x (score for Mektap).

A conservative person would tend to agree with Ayse and Fatima and disagree with Güler and Mektap and hence get a negative score, while a modern person would tend to get a positive score. In this way we produced 17 attitude variables X_1 to X_{17}, which could all be considered as potential regressors. However, a principal components analysis run on the 17 attitude variables showed that the first principal component accounted for over 95% of the total variation between subjects.

Hence the 17 attitude variable were highly correlated with each other and this would lead to serious problems of multicollinearity if all were considered as potential regressors. For this reason we used a composite attitude score, XALL which was the sum of the seventeen attitude scores. As reported in Wilson et al. (1989), it was found that of the 74 subjects 63 had values in the range 60 to 170, 7 had values in the range
-70 to -40, and 4 had values in the range -170 to -140.

Thus we found it useful to characterise the 63 women with positive scores as "modern" and the 11 with negative scores as "traditional". The composite attitude score was not clearly related to potential explanatory factual variables such as age, place where childhood was spent (i.e. Turkish village, Turkish city or Belgium) or educational level. Whether or not a woman was "traditional" was also considered as a potential covariate.

In summary, the following variables were considered as potential regressors;

(a) variables from the factual questionnaire:-

COMHOS - means of communication with doctor
CURACTMA - current activity of the man
CURACTWO - current activity of the woman
EDLEVWO - educational level of the woman
HAPPRE - was the woman happy when she found out about the pregnancy?
KNOWWEL - knowledge of a Western language
LIVSIT - actual living situation
NUBO - number of boys born to the woman
NUGI - number of girls born to the woman
NULOS - number of children lost
NUMISC - number of miscarriages
PART - relationship to partner
PLCHIL - place where the woman spent most of her childhood
PLOR - place where the woman was born
USEPRC - was it useful to follow antenatal care?
YARRWO - year the woman arrived in Belgium
YBIRWO - year of birth of the woman

(b) variables from the attitude questionnaire:-

X_4 - *"Vécu de la Grossesse"*
X_5 - *acceptance of pregnancy as a period of risk*
X_6 - *attitude towards status of being pregnant given by society*
X_7 - *popular beliefs of antenatal care*
X_{15} - *supernatural beliefs*
XALL - overall attitude score
TRAD - whether or not the woman was traditional

Despite the high degree of multicollinearity amongst the attitude variables, X_4, X_5, X_6, X_7 and X_{15} were considered as potential regressors because of their importance in the conceptual model, in addition to the general attitude variable XALL and the indicator for traditionalism, TRAD.

The regression modelling was carried out using the statistical modelling program GLIM. It was decided that regressor variables which showed some influence on the compliance score (i.e. lowered the residual mean square of the fitted model) should be included, even if the improvement to the model on fitting such variables was not statistically significant at the 5% level. A well-known result of using such a procedure is that the standard errors of parameter estimates will be inflated (see e.g. Montgomery and Peck (1982)). This is reflected in the results shown. However, the main aim was not to find the "best regression model", but to relate the statistical model to the conceptual model, and this dictated that as many regressors as possible be included. The following covariates were included in the model:

KNOWWEL - on average the compliance score was 2,45 points higher (s.e. 1,63) for women who spoke a Western language well than for those who had no knowledge of a Western language.

NUMISC / NULOS - there was some evidence that the compliance score increased by about 0,5 points for each extra child either miscarried or lost.

NUGI - the compliance score decreased by 1,74 points (s.e. 0,47) for each extra girl that the woman had had.

NUBO - the compliance score decreased by 0,94 points (s.e. 0,61) for each extra boy that the woman had had.

YBIRWO - as the age of the woman increased the compliance

score increased by 0,26 points (s.e. 0,11) per year.

HAPPRE - the compliance score was higher for the women with levels indicating happiness with pregnancy than for those women indicating unhappiness with the pregnancy. It is difficult to quantify this as *Happiness with pregnancy* was measured on an ordinal rather than an interval scale.

CURACTMA - the compliance score was better for women whose husbands were working or were disabled than for those whose husbands were unemployed at home.

CURACTWO - the compliance score was better for women who were working than for those who stayed at home.

In addition there was an interaction between the effects of the activity of the man and the activity of the woman. If the woman alone was working then compliance was good, or if the man alone was working then compliance was good. However, if both the man and the woman were working, compliance was not as good as would be expected from the added effect of the man working and the woman working. We should be cautious about placing too much importance on this interaction since it is based on only two subjects for whom both the woman and her husband were working.

We can check in general whether the results of our statistical modelling are consistent with the conceptual model. Some of the important variables appear explicitly in the conceptual model e.g. *Number and sex of other children* and *Age of the woman*, while others can be interpreted in terms of "boxes" in the conceptual model e.g. *Number of children lost and miscarried* could influence *Acceptance of the pregnancy as a period of risk*.

Finally the outliers can be examined i.e. those women for whom the predicted score differs substantially from the observed compliance score, to see if their behaviour can be explained by the conceptual model. We consider observations with a standardised residual (defined by the difference between the predicted and observed values divided by the square root of the residual mean square) greater than 2 in absolute value.

The following woman was an "outlier":-

Woman	Observed Score	Predicted Score	Std. Residual
26	103	47	2,30

This woman has a low predicted score because she has no knowledge of a Western language and she was born in 1969 and is therefore very young. Factors that could have contributed to her higher than expected compliance score are:-

(a) she took an interpreter with her to consultations and thus perhaps minimised the effect of not speaking a western language. Further work may need to be done on the mechanism through which knowledge of a western language affects utilisation of antenatal care.

(b) despite her youth she had already had a miscarriage and thus perhaps there were medical reasons for her consulting regularly. Since the medical information was not made available, any modelling exercise suffers from not being able to distinguish general utilisation of antenatal care from consultations for medical reasons.

We can also look at how the statistical model predicts the compliance score for those women who were excluded because they had missing values on one or more of the potential regressor variables. The results for these women are given below, together with general comments.

Woman 14 had a missing value for knowledge of a western language. Her compliance score was 9. She was born in 1951 and was thus relatively very old which might imply a risky pregnancy and regular consultations. Her compliance score is consistent with the information available.

Woman 19 had a low compliance score of 2. She had a missing value for year of birth. She had no knowledge of a Western language, had neither lost children nor had a miscarriage and had one boy and a girl, which are factors that might suggest a low compliance score.

Woman 36 had a compliance score of 8 - she had a missing value for the current activity of the man. She had no knowledge of a Western language, but was born in 1961 which would imply fair compliance because of her age.

Woman 39 had a compliance score of 5 - she had a missing value for knowledge of a Western language and was born in 1959. As with women 36, she had lost no children and had had no miscarriage. Both had 3 previous children. The model thus doesn't provide an easy explanation of why women 36 had a better compliance score than women 39.

Woman 50 had a compliance score of 9. She had a missing value for *Happiness with being pregnant*. She had a good knowledge of a Western language, and had only one girl and no boys, which are factors which could account for good compliance.

Thus the conceptual model can help us interpret and explain the observed data by means of the prior causal framework. However, there will always be some data that cannot satisfactorily be explained, and there might be many alternative causal models that could explain the data as well or better. Thus we cannot use the data to "validate" our causal model. The data may however lead to our making some improvements to our causal model, by illustrating mechanisms that need a better explanation, showing parts of the causal model which do not seem to be valid or highlighting variables that need to be collected in subsequent studies.

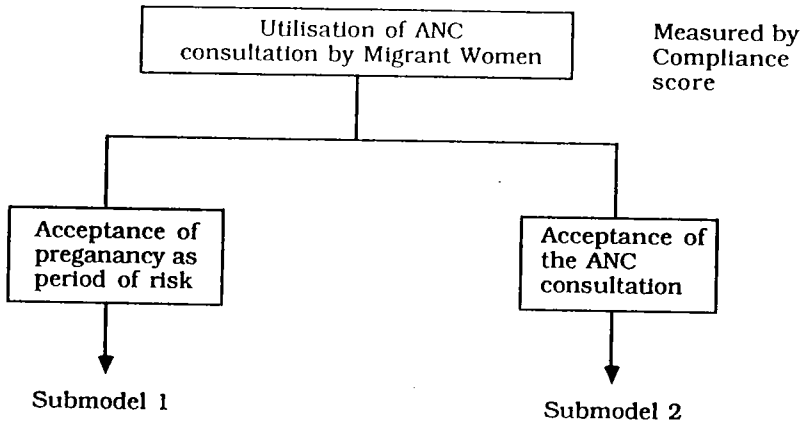
4. Structural analysis of the data using the conceptual model

As has been mentioned in section 2, the use of path analysis was considered and rejected. However, a path analytic type of approach was used in breaking down the conceptual model into a series of submodels with the "top box" of each submodel being considered as the response variable for that submodel, and the lower boxes suggesting the potential regressors for that submodel. The submodels were then combined upwards to create the final model.

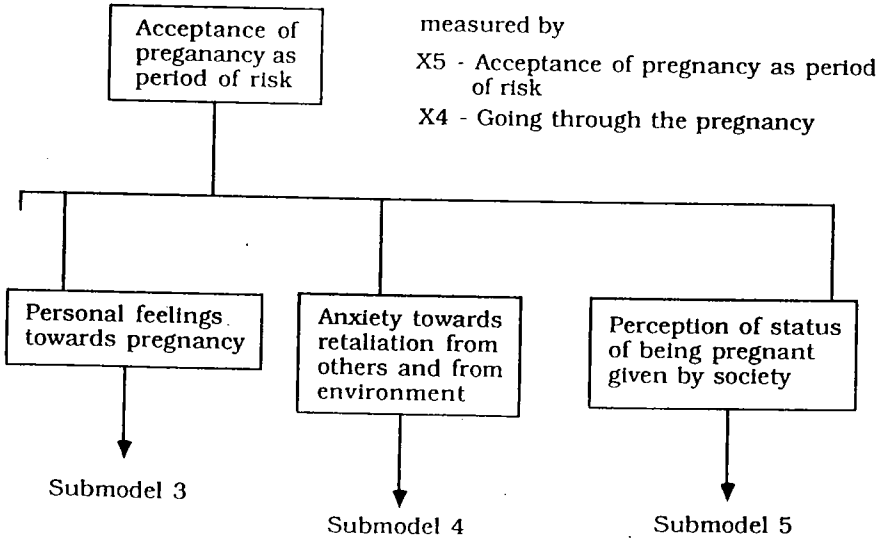
The effect of this was that variables which were not considered simultaneously in the general approach due to multicollinearity, might now enter the final model through different branches. The breakdown of the causal model into submodels is shown in Figure 2.

Figure 2: Breakdown of the Causal Model

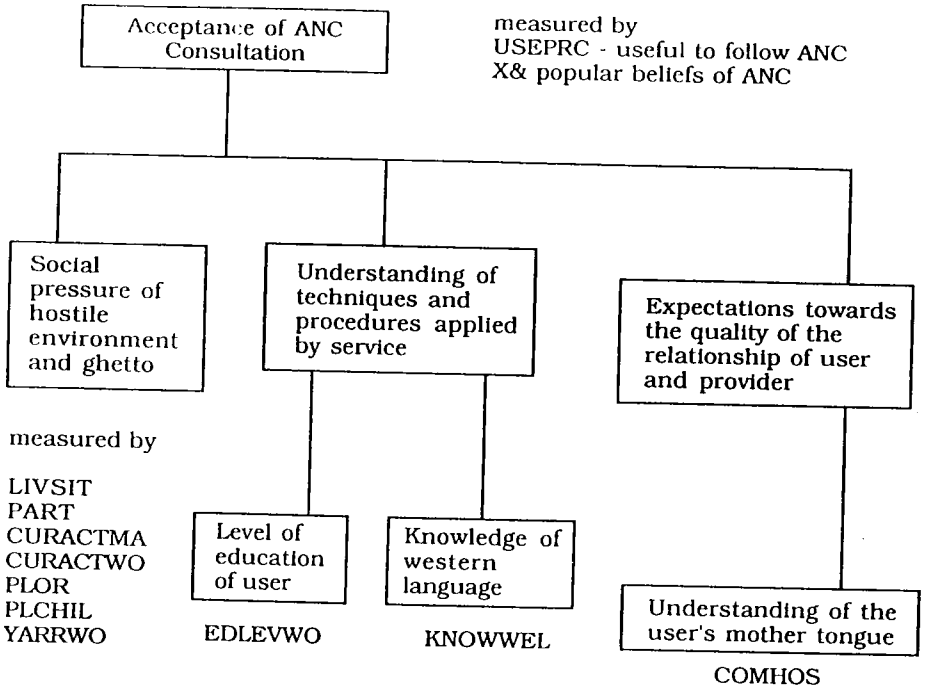
(a) Top Level



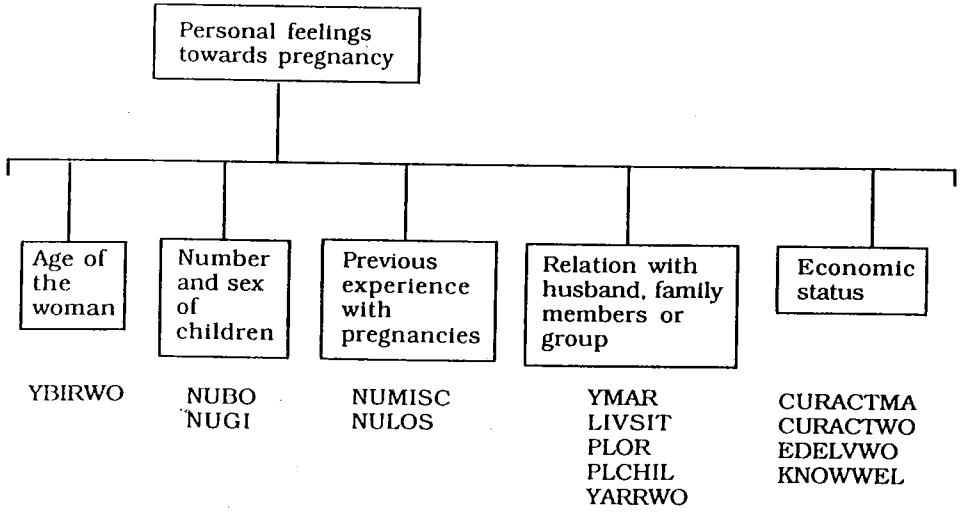
(b) Submodel 1



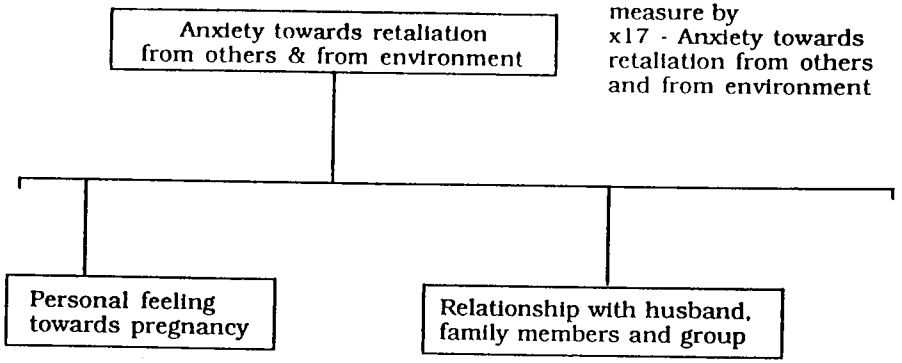
(c) Submodel 2



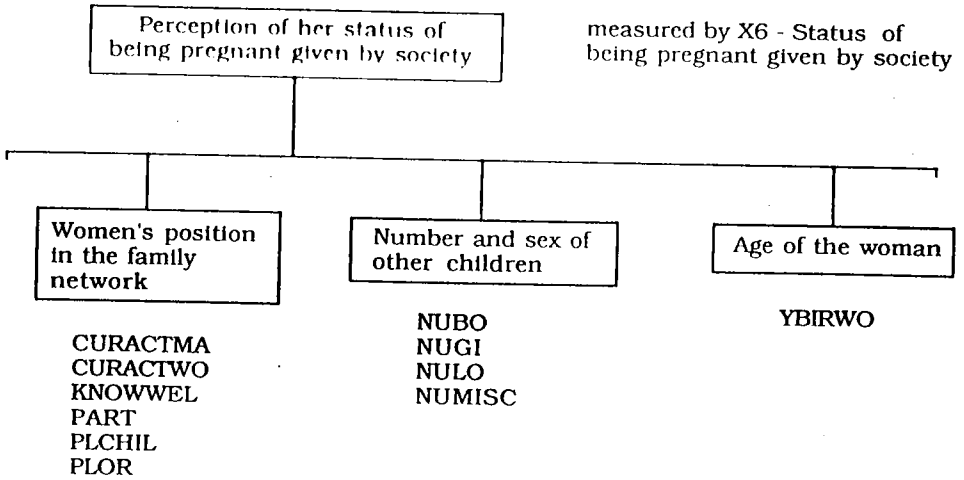
(d) Submodel 3



(e) Submodel 4



(f) Submodel 5



The submodels were then analysed from the "bottom up", identifying the important covariates from the candidate variables, with the variable in the top box of the submodel being treated as the new response variable. This response variable and the selected covariates were then included among the potential regressors for the next model up, continuing until the top model was reached.

For example, in submodel 5 the response variable was taken to be X_6 - *Status of being pregnant given by society* and the important covariates were found to be *KNOWWEL, CURACTMA, CURACTWO the interaction CURACTMA x CURACTWO, NUGI* and *NUMISC* and *NULOS*. These were all then included, together with X_6, among the candidate regressors for submodel 1.

In this way a "structured" statistical model giving the most important determinants of the utilisation of antenatal care was derived. The variables found to have the greatest influence on the compliance score were:

KNOWWEL - On average the compliance score was 2,06 points higher (s.e. 1,57) for women who spoke a Western language well compared to those who had no knowledge of a Western language.

YBIRWO - As the age of the woman increased the compliance score increased by 0,23 points (s.e. 0,11) per year.

NUGI / NUBO - As before the compliance score decreased for each extra child, decreasing more for each extra girl than for each extra boy.

PLCHIL - place of childhood. The compliance score was higher for women who had spent their childhood in a Turkish city, than for those who had spent their childhood in a Turkish village or in a Belgian city. Since the origin of many Turkish women in Belgian cities is a Turkish village, this may be considered as a City versus Village effect.

HAPPRE - happiness with pregnancy. The compliance score was highest for women who were happy with their pregnancy.

NULOS / NUMISC - as before the compliance score increased by about 0,8 points (s.e. 0,45) for each extra child either lost or miscarried.

EDLEVWO - as the educational level of the woman increased, the compliance increased.

CURACTMA / CURACTWO - the compliance score depended on the current activities of man and woman as described in the general model.

Thus the final model chosen by the structured approach is very similar to that chosen by the general approach. It differs in including the covariates *EDLEVWO* and *PLCHIL*, and describes slightly more of the variation in the data (68% versus 67,8%). It excluded all attitude variables. As before, this model could be evaluated with reference to the causal model as was done for the general model. Since the structured model is very similar to the general model, it is not surprising that there is only one outlier, woman 26. The discussion of her behaviour in terms of the conceptual model would be identical, as would be the discussion of the women with missing values.

5. Discussion and Conclusions

As has been pointed out above, the model chosen by the structured analysis is very similar to that chosen by the general approach. The marginally higher value of R^2 for the structured analysis model should not be taken to mean that the structured model is statistically "better" than the general model, since in both cases we were using regression analysis as a descriptive tool, rather than trying to find the "best" regression model. Specifically this meant that we tried to include variables which were thought to be important from prior knowledge, and we included variables which "seemed to be important" (i.e. which reduced the residual mean square of the fitted model) even when this improvement was not statistically significant. A similar criterion was used when filtering out variables in the structured analysis.

Future analyses might benefit from adopting a slightly less arbitrary approach e.g. only including variables which are in fact significant as regressors at the 5% level. Here we were more interested in exploring the methodology of causal and structured modelling than in proposing a well defined method of analysis.

The causal modelling approach offers many advantages for statistical modelling:

(a) It enables us to identify variables that should be measured in the study. In particular the exercise of decomposing the causal model into a sequence of submodels helps to clarify this and to point out areas of the causal model for which we do not have any data.

(b) It offers us a structured way of carrying out a modelling exercise of multiple regression type in the presence of a large number of inter-correlated regressor variables. There is still a problem of multicollinearity in the structured model, but this is a lot less severe than for the general approach.

(c) It enables us critically to examine any observations with large residuals, and any observations for which we have missing values.

(d) The interpretation of the statistical model forces us critically to reappraise the conceptual model and perhaps to modify it. However, it should be borne in mind that it is impossible to use the data to validate the causal model, and that, as we discussed in section 2, the same statistical model could result from very different, and perhaps even contradictory, causal models.

(e) In our study, there was a lack of structure in the questionnaire. In a future study we could impose more structure on the survey instrument. We would foresee even more advantage in the structured analysis if there was more structure in the survey instrument.

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