Searching for Tools to Predict the Past; the Application of Predictive Modelling in Archaeology

Hans Kamermans

Faculty of Archaeology, Leiden University

Introduction

Archaeology tries to extract human behaviour from the material culture that people in the past have left behind. Archaeologists are not only interested in the objects as such but also in their location - in the patterning of the material. This is why spatial analysis, and in particular the analysis of human site location, has always been an important topic in archaeology. Over the years the application of predictive modelling has made some major contributions to this study.

One of the first definitions of predictive modelling is by Kohler and Parker (1986: 400): "Predictive locational models attempt to predict, at a minimum, the location of archaeological sites or materials in a region, based either on a sample of that region or on fundamental notions concerning human behaviour".

Nowadays the two main reasons for applying predictive modelling in archaeology are:

- To predict archaeological site locations to guide future developments in the modern landscape; an archaeological heritage (AHM) or cultural resource management (CRM) application.
- To gain insight into former human behaviour in the landscape; an academic research application.

2 History

Predictive modelling was initially developed in the USA in the late 1970s and early 1980s, where it evolved from governmental land management projects (Kohler 1988). It is possible that this was inspired by one of the final remarks in Ian Hodder and Clive Orton's book *Spatial Analysis In Archaeology* (1976: 244): "Our final point concerning the value of the application of spatial analysis in archaeology is less apparent and its relevance is uncertain". Then they continue: "The possibility exists that the methods and models could be used ultimately to predict the location of undiscovered sites".

In the USA Ken Kvamme was the main advocate of the technique (Kvamme 1985 is an early example). Today it is widely used in the USA (various examples in Wescott and Brandon 2000), Canada (Dalla Bona 2000) and some countries in Europe (e.g. Deeben *et al.*

2002; Münch 2003). The first published application in Europe came from the Netherlands, and was inspired by applications in the USA. It is a collaborative effort between Ken Kvamme and local archaeologists (Brandt *et al.* 1992).

From the start the application of predictive modelling gave rise to considerable academic debate. The material deposits of this debate can be found in articles in conference proceedings and scientific journals (see e.g. Carr 1985; Church *et al.* 2000; Ebert 2000; Harris and Lock 1995; Kamermans and Wansleeben 1999; Kamermans *et al.* 2004; Kohler and Parker 1986; Van Leusen 1995, Lock and Harris 2000; Savage 1990; 1996; Verhagen *et al.* 2000; Wheatley 2003), but also in conference proceedings devoted entirely to the subject (Judge and Sebastian 1988; Wescott and Brandon 2000; Kunow and Müller 2003; Van Leusen and Kamermans 2005; Mehrer and Wescott 2005).

3 Technique

The technique of predictive modelling is quite easy to explain. From the definition mentioned in the introduction it is apparent that there are two basic approaches to predictive modelling, an inductive (or inferential) and a deductive (or behavioural) one. With the inductive approach a model is constructed on the basis of correlations between known archaeological sites and attributes that are predominantly taken from the current physical landscape. These attributes will often stem from a soil map, a geological map or a geomorphological map. We speak of a *predictive* model when the observed correlations are extrapolated. The models can only be tested with an independent archaeological data set from the same area. These extrapolation models are most commonly used in AHM archaeology, but may also have their use in scientific research, e.g. to analyse anomalies in the observed settlement pattern.

The other approach is the deductive one in which the predictive model is constructed on the basis of prior anthropological and archaeological knowledge, and all the known sites are used afterwards to evaluate the model. This approach is relatively rare (cf. Kamermans 2000; Whitley 2002).

The introduction of GIS in Archaeology in the 1980's, with its powerful combination of a database that can handle spatially referenced data, and a statistical package, greatly simplified the application of predictive modelling.

4 Problems and solutions

As a result of an evaluation of the application of predictive maps in the Netherlands, six major problem areas were identified that need to be better understood in order to guide the future development of predictive modelling (Kamermans *et al.* 2004, Van Leusen &

Kamermans 2005). These problems all have implications for the quality, applicability and reliability of the current predictive maps:

- Quality and quantity of archaeological input data
- Relevance of the environmental input data
- Lack of temporal and/or spatial resolution
- Use of spatial statistics
- Testing of predictive models
- Need to incorporate social and cultural input data

Many of these problems were points of discussion immediately after the introduction of predictive modelling in archaeology. Sebastian and Judge wrote in 1988 on the first page of the first chapter of their book *Quantifying the Present and Predicting the Past* (Judge and Sebastian 1988): "One of the more interesting developments in the field of archaeology in the recent past is the emergence of predictive modeling as an integral component of the discipline. Within any developing and expanding field, one may expect some initial controversy that will, presumably, diminish as the techniques are tested, refined, and finally accepted. We are still very much in the initial stages of learning how to go about using predictive modeling in archaeology,…." (Sebastian and Judge 1988: 1).

More than 15 years later we are not in the initial stages anymore but this quote still seems to describe the present situation. The controversy continues and we are still refining and testing the technique. Predictive modelling is far from universally accepted. But are we making progress in the problem areas mentioned above? Some recent attempts are worth mentioning here.

The first theme to discuss is the quality and quantity of archaeological input data. The sample used for predictive modelling comes in general from an existing sites and monuments record. Not only does the database often contain significant errors, in most cases it is also not a representative sample from the material culture of the past.

A second problem is that very often modellers are only using material from surface sites. In 1992, Brandt *et al.* (1992: 278) already warn that "great caution is necessary when using archaeological models as planning tools because a rich and equally important resource base exists beneath the surface which deserves equal attention".

Wheatley (2003) points out another problem with the use of existing records: "If a predictive model is generated on the basis of known sites and then used to influence where we look for undiscovered archaeology, we will have created a self-fulfilling sampling strategy".

The early conclusion that, for inductive predictive modelling, a probabilistic sample that reflects the diversity of the archaeological heritage in a region is a necessity (Kohler and Parker 1986: 403), still stands.

In many countries archaeologists are working hard to improve the quality and quantity of archaeological input data and to make these data available in a digital format. Examples are various excellent local and national databases in the UK, the national archaeological database of the Netherlands Archis (e.g. Deeben *et al.* 2002), VIVRE, a similar project in Luxembourg, various initiatives in Germany (e.g. Ducke and Münch 2005; Münch 2003, 2006) and comparable facilities in many other Western countries.

An example of more fundamental research into the quality of input data is by Philip Verhagen (Verhagen 2005a; Verhagen and Tol 2004) who discusses the role of augering in archaeological prospection to establish without any doubt the presence of archaeological sites.

The second theme that needs attention is the relevance of modern environmental data. Often modern data are used where palaeoecological data are more suitable. Not clear is what the influence of environmental data is on site location in the past and also the role of environmental change is frequently underestimated.

On the topic of the third theme, Kohler and Parker (1986: 406) are already stressing the point that in areas with a long temporal scope of prediction it is important to distinguish temporal and functional subsets of sites. Also Brandt *et al.* (1992: 297) list as one of the areas of improvement "that each archaeological period will be analyzed separately in future efforts, and a distinct model will be generated for each period". Nowadays almost all archaeologists employing predictive modelling are convinced of the importance of introducing a temporal and spatial resolution in predictive models but only few are doing so (e.g. Peeters 2005, 2006; Verhagen and McGlade 1997). The problem with this approach in heritage management is the higher costs of this type of research.

The next theme, the use of spatial statistics and the testing of predictive models, has been discussed for more than 20 years (e.g. Kvamme 1988, 1990; Parker 1985; Woodman and Woodward 2002). The most common way to test the statistical correlation between site location and attributes from the landscape is still logistic regression (c.f. Kvamme 1988). Others have suggested some form of simulation (cf. Kamermans 2000), but many researchers do not test the correlation at all.

Also the resulting predictive model must be tested before being used for AHM purposes. Brandt *et al.* (1992: 276) describe the situation in the Netherlands as follows: "Given the numerous difficulties and data limitations that confront archaeological model development in the Netherlands, together with many simplifications and assumptions that one must make, it is imperative that sufficient tests be performed before any serious consideration of a model is undertaken". According to Wheatley (2003) however, most practitioners of predictive modelling make no attempt at all to find out how well their models perform. The first step to test an inductive model is to collect more archaeological

data but that is, in most cases, an activity people are trying to avoid. The reason for building the model is that it is a cheap and easy way to say something about the distribution of archaeology in a region, while surveying is expensive and time consuming.

So we still can make a lot of progress in this field. Some researchers think that the use of a Bayesian approach in spatial statistics looks very promising (Van Dalen 1999; Millard 2005; Verhagen 2005b), others believe that using the Dempster-Shafer theory will solve at least some of the problems that we have in predictive modelling with uncertainties (Ducke 2006; Ejstrud 2003, 2005).

The last topic, the need to incorporate social and cultural input data, is a difficult one. Predictive modelling, especially when performed with the aid of a GIS, has been accused of environmental determinism (Gaffney and Van Leusen 1995; Kvamme 1997; Wheatley 1999, 2003). For years almost all archaeologists have been agreeing that you cannot study past human behaviour in purely ecological/economical terms and that social and cognitive factors determine this behaviour to a large extent (e.g. Binford 1983; Carlstein 1982; Ellen 1982; Jochim 1976). Kohler and Parker (1986: 401) admit that "subtle social determinants of location are probably at work in all settlement systems, and that inability to take such factors into account is one sense in which predictive models are simplifications of reality". These factors should therefore be additional predictors in the process of predictive modelling (Verhagen *et al.* 2006). Modern landscape archaeology gives us much insight into human social and cultural behaviour in the landscape (Bender 1993; Tilley 1994), but to incorporate these variables into models is a different question. Examples are given by Ridges (2005), Stančič and Kvamme (1999) and Van Hove (2006). Most promising is the work by Thomas Whitley, who recently published a number of papers addressing the more fundamental aspects of 'cognitive' predictive modelling (Whitley 2002, 2003, 2004a, 2004b, 2005a, 2005b,2006). One major problem however, is that most examples of the incorporation of social and cognitive variables have an ethno-historical and not an archaeological origin.

5 Conclusion

The first researchers to apply predictive modelling in archaeology were very optimistic about the possibilities of the technique (e.g. Parker 1985; Kohler and Parker 1986; Judge and Sebastian 1988). It was originally expected that predictive modelling would allow "a broad range of potential constraints on human settlement decisions to be evaluated for their importance: subsistence, constructional, psychological, social and other factors" (Carr 1985: 117). This was seen as a major step forward from previous decision-making analyses of prehistoric settlement choice (e.g. Binford 1980; Jochim 1976; Keene 1981), since they have been limited to "the investigation of potential causal factors in the subsistence domain"(Carr

1985: 117). Sebastian and Judge (1988: 4) thought that the "emphasis on descriptive models will and should eventually be replaced by an emphasis on models that are derived from our understanding of human behavior and cultural systems, models with *explanatory* content".

But already in the early days Kohler and Parker (1986: 440) sketched a problematic picture of the use of predictive modelling: "(the) use of inappropriate sampling techniques, failure to differentiate significant temporal and functional subsets of sites, failure to consider how proxy variables really contribute to locational decisions, low spatial resolution, inappropriate statistical tools, and little consideration for model validation have often weakened the usefulness of these models for both management and research".

Recently Dave Wheatley (2003) concluded that correlative predictive modelling will never work because, among other things, archaeological landscapes, especially in Europe, are too complex. The reason why it is used in AHM anyway is that there are insufficient financial resources to conduct archaeological fieldwork everywhere. Wheatley's solution would be to forget predictive modelling and focus on well-designed and properly implemented sampling strategies.

Finally Thomas Whitley's (2004a) article Causality and Cross-Purposes in *Archaeological Predictive Modelling* explains the nature of the conflict between some of the basic underlying assumptions of certain kinds of predictive models and the purposes for which they were originally intended. His conclusion is that in many cases it is too costly or even impossible to do an inductive (or in his terminology correlative) predictive model and that ultimately the resulting model does not provide better insight into site placement processes than intuition.

It looks as if in the last twenty years progress has been made on details but that we have not been able to solve the major problems. Instead of dealing with the difficulties and trying to improve the technique, the models were more and more simplified to a point where they lack any methodological or theoretical basis. In my mind there is no doubt that predictive modelling, if well considered, can be a valuable tool for academic archaeological research. It can give insight into human behaviour in the past in general and in past land use in particular. But we should be more critical about the use in current archaeological heritage management.

Now two conclusions are possible. If you are looking at the technique from the AHM perspective one can stress the positive points and conclude that predictive modelling is a cost-effective alternative to large-scale archaeological prospection. Developers are not interested in the theoretical considerations behind a predictive archaeological map, but they do need a clear advice on how to deal with archaeology in spatial planning. A predictive map, used wisely, can then be a very powerful and useful instrument for the protection of the archaeological heritage (Verhagen *et al.* 2005).

But the observation that, certainly in Europe with its complex archaeological record, predictive modelling is not a good tool for identifying areas with a high archaeological 'value', is also valid. The current models are neither methodologically nor theoretically sound, their performance is poor and to improve them (if at all possible) would make them too costly for archaeological heritage management purposes. So the other conclusion could be that predictive modelling is not a useful tool for archaeological heritage management. The models should then not reach land managing officials and certainly not the planners. Their only role should be in an initial phase, to aid archaeologists to stratify an area in order to plan various forms of archaeological prospection on the basis of a good sampling design.

It is a difficult dilemma and, as an academic researcher, my choice is an easy one, but seen from a society whose main priorities are not the study and management of our archaeological heritage, I am afraid the daily practice will be a different one. Money will be the decisive factor and predictive models, although they do not work very well, are still a lot cheaper than thorough archaeological prospection fieldwork. This means that AHM, and subsequent scientific research will suffer. This all despite the fact that the very first paragraph of the *European Convention on the Protection of the Archaeological Heritage* (commonly known as the Treaty of Valetta) reads as follows: The aim of this (revised) Convention is to protect the archaeological heritage as a source of the European collective memory and as an instrument for historical and scientific study.

Acknowledgements

I would like to thank the other members of the research group "Strategic research into, and development of best practice for, predictive modelling on behalf of Dutch Cultural Resource Management" Jos Deeben, Daan Hallewas, Martijn van Leusen, Philip Verhagen and Paul Zoetbrood for their work and for the stimulating discussions. The conclusions expressed in this article are solely mine, and not necessarily those of the group.

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過去を甦らせる手法を求めて:
考古学における予測モデル分析

ハンス・カマーマンス

ライデン大学考古学部

考古学は、過去の人々が残した物質文化から、人類行動の復元を試みるものである。考古学者は、色々な物そのものばかりではなく、その空間的位置のパターンにも興味をもっている。ここに人類遺跡の空間的位置の解析が、考古学の重要なテーマであり続ける理由がある。

予測モデル分析とは、ある地域における遺跡の存在を、観察されたパターンや、人類行動に対する推定に基づいて、予測する手法である。予測モデル分析は、まずアメリカにおいて1970年代末から1980年代初めにかけて、土地管理プロジェクトから発展した。そして現在は学術研究と考古文化財管理（AHM）の両分野で活用されている。1980年代における考古学へのGISの紹介は、予測モデル分析の実施を著しく容易にした。北米とヨーロッパの多くの国において、予測モデル分析は今日、現在得られている景観をさらに発展させていく上において、重要な役割を果たしている。

予測モデル分析の適用には議論の余地があり、その最初の適用の段階から、かなりの学術論争を引き起こしてきた。その批判には、理論的なものと実践的なものの二つがある。

ここでは、予測モデル分析の経緯を述べて、その手法を説明し、いくつかの問題点を明らかにするとともに、その解決の方向性を示す。そして最後に、予測モデル分析が考古文化財管理（AHM）にとって有効な手法であるか、という問いに答えたい。