Ancient Roads, Modern Mapping
Evaluating Chaco Anasazi Roadways Using GIS Technology

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The study of roads can provide archaeologists with information on prehistoric cultures that often cannot be discovered by digging in ruins or analyzing artifacts in a laboratory. Ancient roadways were the ties that bound societies together (Fig. 1). Food and valuables were transported over them from village to village. People traveled on them to attend trade fairs, participate in regional ceremonies, and visit one another. Many road systems served as material manifestations strengthening social and political relationships, while others symbolized ancient cosmologies laid out on the landscape. The discovery and analysis of prehistoric road systems therefore provide an unparalleled opportunity to reconstruct the structure and function of ancient societies.

Over the past few decades, the study of ancient roads has made an important contribution to our understanding of the Chaco Anasazi, a cultural tradition that emerged in the northern American Southwest between AD 900 and 1150. Over 100 related communities have been identified on the periphery of the arid San Juan Basin (Fig. 2), making the Chaco Anasazi one of the largest and most complex cultural traditions to emerge in North America. Chaco communities typically consisted of numerous small habitations, monumental masonry “great houses” that probably served as town halls (Fig. 3), and circular subterranean “great kivas” where religious activities occurred. Scholars believe that Chaco Canyon, located in the center of the San Juan Basin, exercised considerable influence and perhaps control over these communities. Evidence for this includes the concentration of massive architecture and valuables in Chaco Canyon; most outlying communities exhibited small great houses and few valuables, suggesting that Chaco Canyon possessed greater control over resources in northwestern New Mexico. Additional evidence includes the large number of prehistoric roads that appear to emanate from the canyon and extend over the San Juan Basin. These wide roadways are most often shallow linear depressions bounded by low earthen berms or masonry walls (see Fig. 1); a few sections are excavated directly into bedrock. Many Chaco roads seemingly follow straight lines, especially over level terrain, while obstacles such as cliffs are often traversed by masonry ramps or staircases cut into the sandstone (Fig. 4). As archaeologists pursue field investigations of Chaco communities, more and more of these prehistoric road segments are being identified.

The purpose of roadways in a society without pack animals or wheeled vehicles has long been a mystery. Because projections of these roads seem to connect surrounding communities with Chaco Canyon, many scholars have argued that the thoroughfares served a regional economic function. The system of roads would have reduced the cost of moving food, pottery, construction materials, valuables, and people between far-flung Chaco communities (Judge 1993; Mathien 1991). More
**Fig. 1.** This aerial photograph of Haystack, oriented northeast, shows a maze of clearly visible modern roads that contain the ancient roadways that may extend from one of the great houses (shown in top center of photo). The eroded roadways extending southwest of the ruins (arrows) is the most visible, but two more short segments also extend northwest and east of the great house. This photo was taken in the early morning, when the long shadows enhance the visibility of the roadways. Photograph courtesy of John Roney, Bureau of Land Management.

**Fig. 2.** The Chaco Anasazi occupied a large area centered on Chaco Canyon in northern New Mexico from AD 900 to 1150. This map illustrates some of the major Chaco communities and a few of the longer prehistoric roads. The lengthy North Road and South Road appear to be atypical; most Chaco roads are only a few kilometers in length. Drawing based on Pecos 1984-54.

**Fig. 3.** The great house in the community of Casamero was excavated in the 1960s. Its diminutive appearance seems to belie its label, but like other great houses, the one in Casamero exhibits multiple stories, and a larger interior and much more massive masonry than the small habitations that surround it. A wide but shallow circular depression located a few meters away marks the burial remains of a subterranean great kiva.

**Fig. 4.** Chaco Anasazi roads often negotiate rough terrain using stairs cut out of sandstone or built of masonry. This example, located in Chaco Canyon, is cut directly into the cliff face, allowing travelers to quickly ascend to the canyon rim.
Anasazi habitations occupied during Pueblo II (AD 900–1100), with most located in about a dozen communities on the northern and southern sides of a large plateau known as Lobo Mesa. Great houses and great kivas similar to those seen in Chaco Canyon are found in each of the communities in the study area (Kanute 1996). Numerous roads have also been identified, although most are only short sections that may or may not have once been longer (Nials, Stein, and Roney 1987).

My research has attempted to evaluate the proposed functions of the road segments by modeling the routes that the roads should have taken if the theories commonly used to explain their existence are correct. Because of the demanding computational requirements of this kind of research, I use a computerized spatial database and analytical tool known as a "Geographic Information System" (GIS). This technology, which is increasingly being used in archaeological research (e.g., Aldenderfer and Maschner 1996), allows the rapid manipulation and analysis of enormous quantities of spatial data. The techniques I am using (see box on Methodology), in which complex three-dimensional prehistoric landscapes are repeatedly generated and analyzed, were not possible even a decade ago. They allow us to create idealized "cost-paths" between two points—the routes that would take the least amount of time or energy to traverse—and compare them to the actual prehistoric roads (Fig. 5). The following sections

FIG. 5. HOSTA BUTTE, shown in the background, is a prominent geologic feature that is visible as far away as Chaco Canyon.

The GIS-based study suggests that several roadways were built to provide access to Hosta Butte. Large circular masonry structures known as berradales are situated at several points along these roads, such as the example being mapped here. Their function is unclear, but they may have served as resting stops or shrines for travelers.

Photograph courtesy of John Keeney, Bureau of Land Management

Methodology

To evaluate the models of Chaco road function, data on all cultural features in the study area were assembled in a "geographic information system" (GIS) spatial database using ESRI's Arc/Info software. In a GIS, each type of data forms a separate layer of spatial and attribute information that can be either manipulated and analyzed internally or compared with other data layers. Although constructing a GIS database requires a considerable investment in resources and time, the advantage of the technology is its ability to facilitate the analysis of large volumes of spatial data.

For this study, a "cost-surface" was generated for the entire study area using the GIS software. First, Digital Elevation Models (DEMs) were acquired and entered into a new layer in the GIS. Each DEM consists of a grid of points that record elevation at 30-meter horizontal intervals. Using these data, a new grid of points was generated in ArcInfo using the following formula:

\[ T = D/(46 \exp (3.5 \times \sin(\theta) - 0.032)) \]

This formula, known as the "hiking function," is an empirical model that represents the time it would take for someone to cross a given amount of space with a given slope. This function was originally developed by geographer Waldo Tobler and has been successfully evaluated using both archaeological and ethnographic data (Gorenflo and Bell 1991).

Application of the hiking function to the raw DEM produced a cost-surface grid indicating the amount of time it would take to cross each 30-meter cell. This was then used to evaluate the three models of road function. Based on expectations for each model of where roads in the study area should begin and end, idealized "cost-paths" were generated and compared with the actual road segments. For example, a common interpretation of the roads is that they facilitated economic exchange and foot travel between Chacoan communities (e.g., Wilcox 1993; Windes 1991). Using the cost-surface, the GIS software could select the paths that minimized travel time between all of the communities. The resulting cost-path network (Fig. 6) could then be compared with other GIS layers containing information on the prehistoric cultural features to see how closely the modeled paths fit the actual routes of the Chaco Anasazi roads.

Was the GIS necessary to effectively perform this study? Clearly, the various models of road function would have been much more difficult to evaluate without the GIS's ability to generate the cost-paths, especially since the cost-surface of the study area consisted of over 3 million cells! The GIS was especially useful since all that now remains of the prehistoric roads are short segments whose origins and destinations may have eroded away long ago. At the same time, the GIS facilitated the identification of other unexpected patterns that contribute to the issue of road function and intercommunity interaction in the northern Southwest. The GIS-generated cost-paths can also guide future archaeological investigations seeking to identify prehistoric roads in the field. All of these benefits make a GIS extremely valuable for this type of research.

An important issue that still needs to be addressed is the best way to evaluate the fit between the idealized cost-paths and the actual road segments. One potential method is to generate concentric gradients that represent movement away from a point of origin. These gradients can facilitate a qualitative sensitivity analysis. For example, the variable gray backgrounds in Figures 7 and 8 represent increasing costs as a traveler moves away from certain key locations in the area of Kin Ya'a (Fig. 8), the road extending south from the great houses at one point temporarily veers away from the idealized cost-path, only to rejoin it later on its route to Hosta Butte. The gradient shows that the cost of following the prehistoric road was almost identical to the cost of following the cost-path, supporting the contention that the modeled path and the actual roadway corresponded fairly closely. Further research should investigate additional methods to more objectively evaluate the fit between modeled paths and the actual prehistoric roads.
Fig. 6. The study area consists of 13 Chaco communities located on the north and south sides of Lobo Mesa. The thick black line represents the computer-generated network of cost-paths that minimize travel time between the communities, while the solid lines indicate a few of the longer prehistoric road segments. The variable gray background is derived from the Digital Elevation Model, the darker the gray, the lower the elevations.

Fig. 7. The road segments extending from the Muddy Water community do not align with any of the computer-generated cost-paths between communities. The evidence instead suggests that the prehistoric roadway extending to the southwest facilitated travel to a nearby spring. Note the presence of a small great house southwest of Muddy Water that is situated within 100 meters of the two cost-paths leading to communities on the south side of Lobo Mesa. The variable gray background in this figure represents increasing travel costs as one moves away from Muddy Water; as the gray becomes lighter, the travel costs are increasing.

Look at the expectations of each of the major theories of Chaco Ancestral Pueblo road function and then compare them with the results of my GIS-based analyses.

ECONOMIC EXPLANATIONS

Since the 1970s, many archaeologists investigating the Chaco Ancestral Pueblo have argued that the prehistoric roads served an economic function. These explanations are rooted in general theories about the development of a codependent regional economy in which widely dispersed and undependable resources were distributed among Chaco Ancestral Pueblo communities. For example, one theory suggests that Chaco Canyon served as a central point for redistributing agricultural products from areas with plentiful harvests to those communities whose crops had failed (e.g., Powers 1984; Tainter and Plog 1994). A system of roadways emanating from Chaco Canyon would have expedited the transportation of these goods. This conclusion has provided the foundation for several studies employing geographic models to reconstruct the economic and political structure of the Chaco Ancestral Pueblo (e.g., Ebert and Hitchcock 1988; Wilcox 1993).

Recent investigations that challenge economic explanations are based on ground surveys that have attempted to verify the presence and antiquity of roads originally identified through aerial reconnaissance (Nials, Stein, and Roney 1987). These studies indicate that some roads once thought to extend for many kilometers have huge gaps or simply do not exist. Others have turned out to be the remains of historic roads. Few roads visible today actually extend more than a kilometer or two beyond their point of origin (Roney 1992). However, several researchers have also noted that natural forces such as erosion or alluviation may have destroyed or buried portions of some prehistoric Chaco roads. Therefore, since we cannot be certain that we are identifying the original terminus of these road segments, the GIS-based spatial analysis provides an effective way to assess their function.

For this study, the economic model of road function was evaluated by determining how closely the visible road segments corresponded with optimal cost-paths that the GIS predicted should exist between communities. If the economic explanations are correct, the computer-generated cost-paths should closely align with the roads. The results are fairly unequivocal: virtually none of the road segments in the study area come even close to aligning with the idealized cost-paths. Figure 7 illustrates this quite clearly. Dashed lines represent cost-paths between the community of Muddy Water and every other community in the study area. The prehistoric road segments do not align with any of these projected routes, suggesting that they were not constructed to facilitate economic interaction. In fact, out of the 17 roadways in the study area, only 2 may fit the economic model. The first is the famous South Road that originates in Chaco Canyon and enters the community of Kin Ya'a (Figs. 6, 8). This road may have served a regional economic role, but because it extends out of the study area, cost-paths for evaluating its function could not be generated. The second example is a short segment near Blue J that does align with cost-paths connecting several communities. Whether this is a coincidental alignment is difficult to ascertain, but the poor fit between all the other road segments and idealized cost-paths suggests that it may be.

The evidence demonstrates that the majority of Chaco roads in the study area do not fit well with explanations that contend that these features served regional economic functions. However, while the roads may not have served to facilitate intercommunity exchange, at least one may have served a localized economic role. A road segment originating in Muddy Water leads to the cliffs at the base of Lobo Mesa where a spring is believed to have once existed (Fig. 7). Archaeologists have identified numerous pot fragments along the road and suggested that these vessels were used to obtain water (Nials, Stein, and Roney 1987:140-41; Windes 1991).

RELIGIOUS EXPLANATIONS

In recent years, several archaeologists investigating the Chaco Ancestral Pueblo have focused on cosmographic and religious explanations for the prehistoric roads. Their models usually take one of two perspectives. In the first, roads are seen as symbolic representations of Chaco cosmology. Proponents of this perspective have focused on the alignment of roads with cardinal directions, the axial oppositions the roads form with one another, and the role of Chaco Canyon as a “middle place” from which all roads emanate. Roads to prominent geographic features with assumed cosmographic roles are also seen as important. Cosmographic roads are believed to be completely straight, with no consideration for minimizing either the effort to construct the road or the costs of traveling on them. The most commonly cited example is the North Road, oriented to the north and in approximate opposition to the South Road (Fig. 2) (Sofer, Marshall, and Sinclair 1989).

This model of road function is difficult to evaluate without a clear idea of the possible cosmographic expressions that the Chaco Ancestral Pueblo might have symbolized. None of the roads in the study area are axial opposites of one another, and none align with any of the cardinal directions. Even the so-called South Road,
Fig. 8. Like most Chaco roads in the study area, none of those associated with Kin Ya'a correspond with any of the GIS-generated cost-paths that minimize travel between communities. The segments instead appear to be part of the famous South Road, which originates in Chaco Canyon and then passes through the community of Kin Ya'a on a direct path to Hosta Butte. The variable gray background represents increasing travel costs as one moves away from Kin Ya'a; as the gray becomes lighter, the travel costs are increasing.

Fig. 9. The roads emanating from Andrews appear to align with cost-paths that meet the expectations of both the religious and integrative models. The road extending northwest aligns with a computer-generated cost-path leading to Hosta Butte, an important feature in the cosmography of contemporary indigenous inhabitants, while the road segments to the southwest connect with a small cluster of habitations and a great kiva.

which originates in Chaco Canyon, has stayed significantly from a perfect southerly projection by the time it enters the prehistoric community of Kin Ya'a (Fig. 2). However, at least three road segments do appear to be directed towards Hosta Butte, a prominent geological feature visible as far away as Chaco Canyon (Fig. 5). The most interesting example is the South Road (Fig. 8). This road aligns with a GIS-generated cost-path between Kin Ya'a and Hosta Butte, and it also corresponds well with a straight alignment connecting these two points. An identical pattern is found for a road segment emanating northwest from the Andrews community (Fig. 9). Hosta Butte is an important feature in the cosmography of indigenous groups currently living in the area, and small shrines with offerings have been found on top. The road segments suggest that the mesa was also a significant point on the prehistoric religious landscape.

Other scholars have focused on religious explanations that relate the roads to the more immediate ritual landscape around Chaco communities (Fowler and Stein 1992). Archaeologists espousing this perspective note that almost all roads lead to great houses or great kivas, both of which are believed to have served religious functions. The identification of some roads that run between non-contemporaneous great houses has led to the popular concept of “roads through time.” These features are believed to have symbolically linked religious structures from different time periods, perhaps in an attempt to legitimize new great houses by physically relating them to the established religious authority of older buildings (Fowler and Stein 1992:116-118).

Many of the roads in the study area do in fact support the hypothesis that they symbolically connected architectural features on the local religious landscape. In a few cases, idealized cost-paths generated between great houses and great kivas correspond with prehistoric roads, such as in the community of Andrews, where a segment extending west from the great house appears to connect with a nearby great kiva (Fig. 9). Another short segment in Tse Bee Kintsoh exhibits the same pattern (Fig. 10), as do roadways in the communities of Blue J and Coolidge. However, at least in the case of Tse Bee Kintsoh, the architectural features at either end of the roadway were occupied at the same time, suggesting that not all thoroughfares of this type served as “roads through time.”

Integrative Explanations

Archaeologist John Roney (1992) has recently proposed that Chaco Anasazi roads functioned to integrate local Anasazi populations over small areas. His model is based on the scarcity of road segments longer than a kilometer or two, as well as on the fact that a great house or great kiva is found at one end of most
Chaco road segments. According to Roney (1992:139), this pattern suggests that the function of roads must have been closely tied to the function of the related architectural features. By assuming that great houses served to locally unify communities, Roney (1992:130) hypothesizes that the road's directed attention, both symbolically and physically, towards this integrative architecture. In essence, this view sees roads as drawing people from surrounding areas and guiding them towards a particular great house.

These theories receive considerable support from the GIS-based analyses of prehistoric roads in the study area. The majority of segments appear to fit with optimal cost-paths generated between great houses and habitation clusters, or "neighborhoods," found in the Chaco communities. For example, a road segment extending west from Andrews corresponds with the cost-path between the community's great house and a nearby cluster of habitations (Fig. 9). Similarly, in the community of Tse Bii Kincinnati (Fig. 10), a road segment may go around a small mesa to connect one of the great houses to a large concentration of dwellings on the east side of the community. In a few cases, such as at Casasero, roads extend beyond community boundaries and connect with isolated clusters of habitations known as "hamlets."

Although the pattern of short road segments emanating from great houses and leading to nearby habitation clusters is common in the study area, what this actually signifies is not as clear. In general, scholars investigating the Chaco Anasazi have seen great houses and associated architecture as serving to locally integrate communities, and if this is true, the roads likely served a similar function. However, other research suggests that great houses may have also been arenas of political competition, with local leaders maintaining specialized architecture to impress followers and upstage potential competitors (Kehoe 1996; Seilhan 1992). From this perspective, short road segments may have been designed not so much to unify groups of people, but rather to augment the influence and prestige of local political entrepreneurs and extend their authority over local populations. Determining the intended purpose of the Chaco roads in these cases will require additional archaeological research focused on the roles of great houses and great kivas in Anasazi communities.

**Figure 11.** An unexpected pattern identified in this study was the close association between small stone circles and the computer-generated cost-paths that minimize travel between Chaco communities. This association suggests that a network of paths for traveling between communities in the study area once did exist, even though no prehistoric roads were built along these cost-paths. Apparently, the routes between communities did not merit the labor investment that was reserved for the formalized roadways, where, in addition to the construction of the roads themselves, large masonry *herraduras* were built.

**Figure 12.** Small stone circles appear in greater numbers along the roads from Chaco communities located on the northern side of Lobo Mesa. In this example, stone circles are associated with each of the cost-paths that connect the communities of Kin Ya'a and Muddy Water. These small stone circles appear along ridges that physically separate the communities, as if they served as boundary markers along commonly used footpaths.

**The majority of road segments appear to fit with optimal cost-paths generated between great houses and habitation clusters.**

**Unexpected Patterns**

As is common in archaeological research, some of the most intriguing patterns identified in this study were not predicted by existing models. Of particular interest are patterns that were revealed through the computer-based generation of cost-paths, especially those minimizing travel between Chaco communities. These unexpected patterns include the close association between unusual stone features and the cost-paths connecting communities, the appearance of small hamlets at points where several of these cost-paths cross, and the placement of small isolated great houses on routes between communities. These examples illustrate how GIS-generated networks can provide potential explanations for previously mysterious features of the cultural landscape.

In the study area, there are two major types of small stone features that clearly served unique functions for the Chaco Anasazi. The first consists of small stone circles, with diameters of 3 to 5 meters, that are associated with Anasazi ceramics. These are often referred to as "shrines," perhaps because they lack any obvious purpose, but there is no evidence to confirm that they served a religious function. The other feature type, the *herradura*, includes larger (6 to 10 meter) oval or circular masonry structures that appear to be more formalized versions of the smaller circles. This study found that the clear majority of small stone circles were situated close to the computer-generated cost-paths linking communities together (Fig. 11). This pattern was especially prominent north of Lobo Mesa, where virtually all small stone circles were closely associated with cost-paths (e.g., Fig. 12). In contrast, almost none of these stone circles were found along visible prehistoric roadways. Instead, all but one of the *herraduras* in the study area were situated along these roads (e.g., Fig. 8).

These patterns suggest that the computer-generated cost-paths correspond with the actual routes that Chaco people used for traveling between communities. According to this perspective, the small stone circles may have been built along commonly used footpaths to serve as boundary markers or resting places. Perhaps these features even once had walls and roofs made of brush and other organic materials. However, recalling
that none of these cost-paths align with the prehistoric road segments, apparently intercommunity interaction was not formalized through the construction of roads and hereditary. Paths for traveling between communities in the study area apparently did not warrant the substantial investments in labor and material needed to create formal roadways.

The second unexpected pattern identified in this study focuses on the few points where several of the cost-paths connecting communities cross one another. In many of these locations, small clusters of habitations appear (e.g., Fig. 13). All of these hamlets are considerably smaller than the named communities, and none exhibit specialized architecture such as great houses or great kivas. All appeared after AD 1050, late in the Chaco Anasazi prehistoric period, and most are located on Lobo Mesa at elevations that would have made agriculture challenging. A related pattern is the association of two isolated great houses along major GIS-derived cost-paths that minimize travel across Lobo Mesa (e.g., Fig. 7). Unlike most great houses, which appear within the heart of Chaco communities, these two structures are situated some distance from habitation areas, and both are exceptionally small. Like the small hamlets on Lobo Mesa, these isolated great houses were constructed after AD 1050.

The late appearance of hamlets on top of Lobo Mesa and the construction of isolated great houses in the study area have always been difficult to explain. However, the results of the cost-surface analysis may provide some insight since we can now see that the location of these features was not necessarily random. Perhaps the intensity of regional interaction was increasing after AD 1050, stimulating the development of hamlets that took advantage of increasing economic exchange between Chaco communities. Similarly, the isolated great houses may have been resting stops that accommodated increasing quantities of goods and people moving between communities. These new patterns warrant further attention and will undoubtedly provide new information important for explaining the development of the Chaco Anasazi.

CONCLUSIONS

The evaluation of the three general models of Chaco road function suggests that the roads in the study area did not economically integrate the region. With the possible exception of the South Road between Chaco Canyon and Kin Kletso, virtually none of the road segments align even closely with the computer-generated cost-paths. In contrast, almost all roads appear to fit more closely with explanations that see the roads as having served localized religious or integrative functions (Fig. 14).

Determining the relative accuracy of religious and integrative explanations of road function is a more difficult challenge. In a few cases, roads fit the expectations of both models. For example, one road segment in Andrews connects the great house with a nearby cluster of dwellings that also includes a great kiva (Fig. 9), thereby meeting the expectations of both the religious and integrative models. Additional lines of evidence will be needed to test the validity of each theory, although it is probable that different Chaco communities built roads for different reasons. Future models of road function will need to consider combining aspects of both of these interpretations.

Despite the potential for improving the models and methods used in this study, the results already provide some conclusions regarding the function of prehistoric roads used by the Chaco Anasazi. Few roads seem to have facilitated or symbolized regional interaction, with most apparently constructed to serve localized functions. This suggests that the mere presence of roads in Chaco communities should not be used to determine either the spatial extent of Chaco Canyon’s authority or the intensity of regional travel and exchange. Perhaps roads were a general Anasazi phenomenon that Chaco Canyon manifested at a larger scale through the construction of a few longer roads such as the North and South Roads. Meanwhile, the majority of communities in the northern Southwest continued to construct shorter roadways that physically linked people with their local religious and social landscape.