*Exploring Social Dynamics at the Ancient Site of Copán, Honduras*

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**Abstract**
This paper examines social dynamics at the archaeological site of Copán, Honduras, just prior to the Maya "collapse" (AD750-820). It is during this time period that the ancient Maya faced many problems including environmental degradation, warfare and competition, political disruption, and ideological disintegration. ArcGIS 9.1, including its Spatial Analyst and 3D Analyst extensions, was employed to measure changes in access and visibility. These measurements were used to investigate how access and visibility within Copán's urban environment was used to reinforce or actively shift social relationships among the site's various social groups during this ever-changing period. The results indicate that the built environment, comprised of monumental and residential architecture, freestanding monuments, causeways, and the like, was used to control access, manipulate the flow of movement, and influence visual perception and as such, formed part of an indigenous Maya strategy to shape social dynamics.

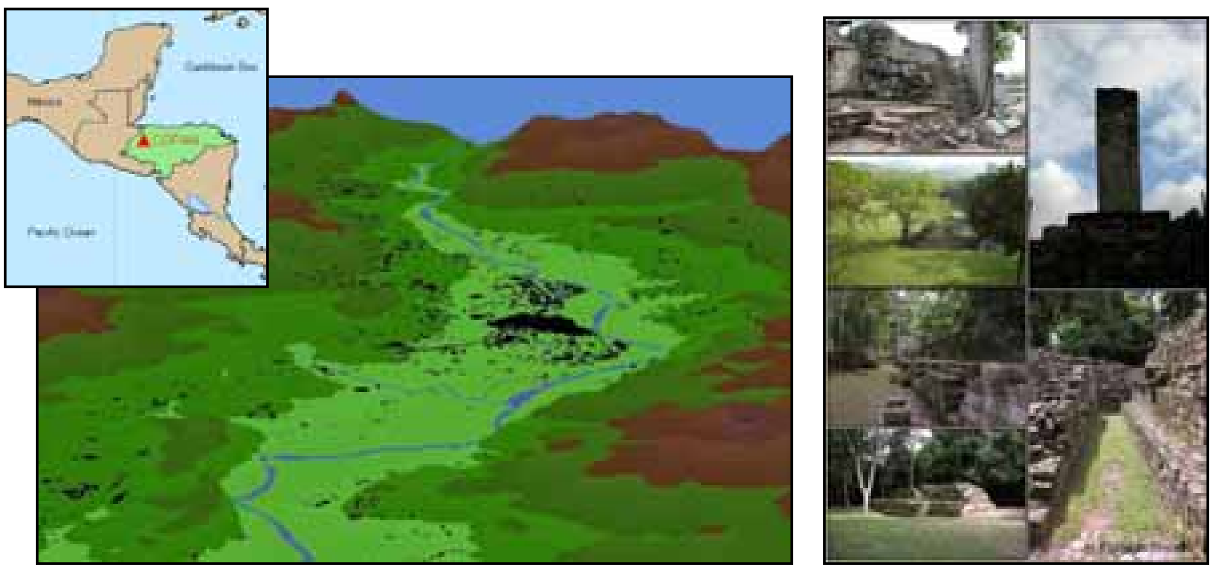


**Figure 1: Location (left) and Archaeological Ruins (right) of Ancient Maya Site of Copán, Honduras**

## Introduction

This paper offers an innovative approach uniting Geographic Information Systems (GIS) with a theory of social semiotics in order to investigate *how* ancient peoples negotiated their physical surroundings, both built and natural. The ancient Maya city of Copán located in the southeast periphery of the southern Maya lowlands is used as a case study (Figure 1). The time period of interest is a seventy-year span at the end of the Late Classic (AD 750-820), just prior to the Maya “collapse”, in which the city’s inhabitants lived in florescence, while simultaneously facing many problems including environmental degradation, warfare and competition, political disruption, and ideological disintegration (Abrams and Rue 1988). As these problems mounted the city’s inhabitants experienced many changes that shifted social relationships and influenced social dynamics, ultimately resulting in a reorganization of the urban landscape that was part of a broader sociopolitical strategy to stave off sociopolitical collapse (Maca 2002; Plank 2004).

This research uses access and visibility to study the influence of urban configurations on the use of space because previous research has suggested that these factors often serve as mechanisms of cultural integration and/or segregation (e.g. Crown and Kohler 1994; Fletcher 1981). Moreover, many scholars believe that ancient Maya sites were intentionally constructed to control access, manipulate the flow of movement, and influence visual perception (Hammond and Tourtellot 1999; Tourtellot et al. 1999; Tourtellot et al. 2003; Stuardo 2003); all factors that can be used to reinforce or actively shift social relationships among a city’s various social groups, and therefore, it is argued that access and visibility influenced *how* Copán’s ancient inhabitants negotiated the ancient landscape (Figure 2).

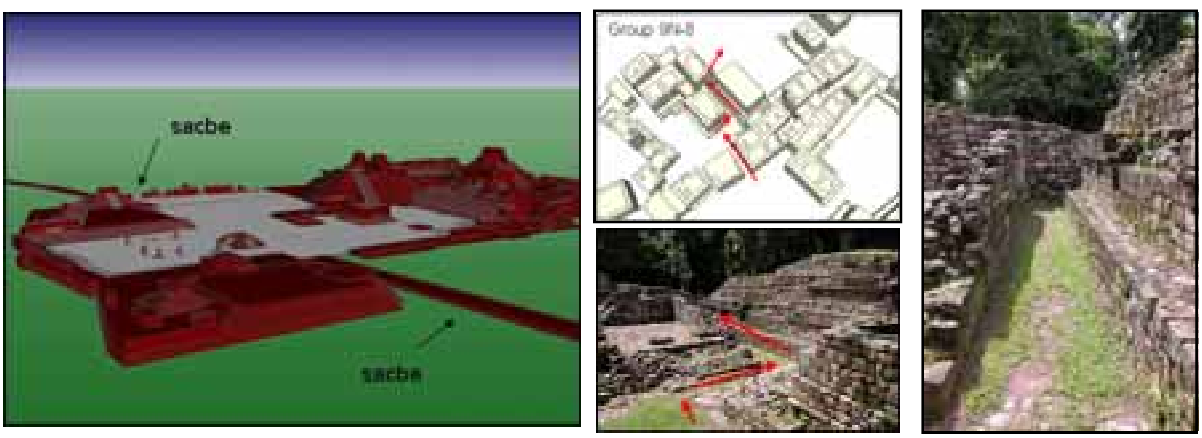



**Figure 2: Sacbe (ancient road) leading to Highly Visible Ceremonial Structures of Principal Group (left) and Narrow Accessways located in Group 9N-8 (Elite Residential Complex) at Copán (right)**

The assumption is made that meanings associated with the urban landscape often varied depending on an individual’s social group and his/her status within that group, and that these meanings would have served to reinforce existing social relationships or have helped to shape new relationships. Understanding the nature of Copán’s social interactions is particularly important at the end of the Late Classic, just prior to sociopolitical ‘collapse’, as current interpretations about the city’s Late Classic sociopolitical organization are varying and somewhat contradictory (Fash 2001; Maca 2002; Plank 2004). However, few approaches exist to study the role the urban planning played in structuring social dynamics in ancient cities.

**Ancient Urban Planning**

Michael E. Smith’s (2007) recent publication in the *Journal of Planning History* sets forth a new model for ancient urban planning. His model does not dichotomize ancient cities as ‘planned’ versus ‘unplanned’; instead, it allows for diversity in ancient urban planning. Using spatial principles and Amos Rapport’s (1988) three levels of meaning in the built environment, Smith offers a way to explore the social and political significance of urban configurations.

Described briefly, his model is comprised of two parts: 1) the coordinated arrangement of buildings and spaces and 2) standardization. The first part, coordination among buildings and spaces, is subdivided into five categories. These include the arrangement of buildings, formality and monumentality of layout, orthogonality, other forms of geometric order, and access and visibility. The second part, standardization, is subdivided into four categories. These include urban architectural inventories, spatial layouts, orientation, and metrology. He uses his model to identify the types of data to collect and then interprets the political and social significance of ancient urban planning using Amos Rapport’s model of levels of meaning in the built environment, which takes into account cosmology (high-level meaning), messages about power, identity, and status (middle-level meaning), and the built environment’s role in manipulating movement and shaping behavior (low-level meaning).

We introduce here an alternative approach to study ancient urban planning that complements Smith’s model. Although similar, our approach is fundamentally different from Smith’s in three ways. First, it focuses explicitly on the relationship between how people negotiate their physical surroundings and how messages of power, identity, and status are constructed. Second, it offers a mixed method approach employing both quantitative and qualitative methods, whose variables are driven by a theory of social semiotics. Third, it employs a GIS is to measure access and visibility and to identify sign configurations in the urban environment.

The theory of social semiotics is useful for studying how people negotiated the built environment because it describes *how* systems of signs are related to their meanings, and as such it offers three ways in which people assign meaning to objects (Gardin and Peebles 1992; Jakobson 1980; Parmentier 1986; Preucel and Bauer 2001). These include: iconic, symbolic, and indexical (Figure 3). Although all three of these are useful, indexicality is particularly well-suited to using a GIS because it suggests that signs are often aggregated and organized into sign configurations (indexes) that convey meaning through adjacency or spatiotemporal context, and a GIS can be used to identify such signs. In the case of urban studies, these sign configurations are comprised of architectural components such as doors, stairs, and sculpture. They influence social interaction by directing individuals in the course of their encounter with them and in doing so they convey messages to specific audiences.

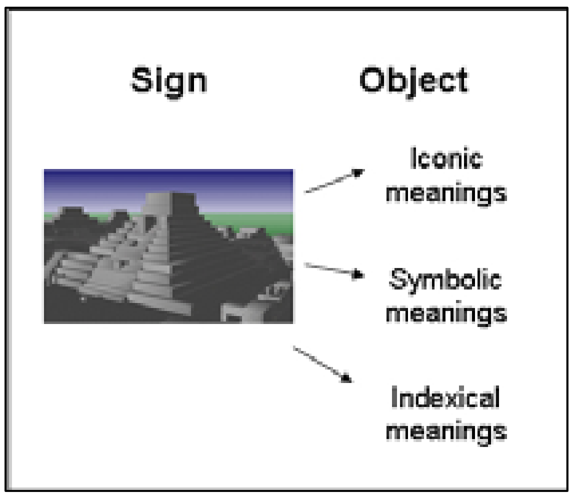



**Figure 3: Three ways in which meaning is ascribed to objects in a theory of Social Semiotics**

For example, previous research by Elizabeth Newsome (2001) on Copán's Great Plaza stelae suggests that the placement of these stelae along with their associated imagery influenced how people moved through the plaza. The result was a ritual circuit comprised of sign configurations that structured the order in which people encountered particular images. A GIS can identify these sign configurations by measuring spatial autocorrelation, i.e. the extent to which attributes are influenced by adjoining or neighboring attributes. In the case of Copán's Great Plaza, the type of imagery sculpted on a particular stela was dependent upon the stela's location relative to other objects within the plaza (Figure 4). Sign configurations represent one way in which to investigate social dynamics. Access and visibility represent another.

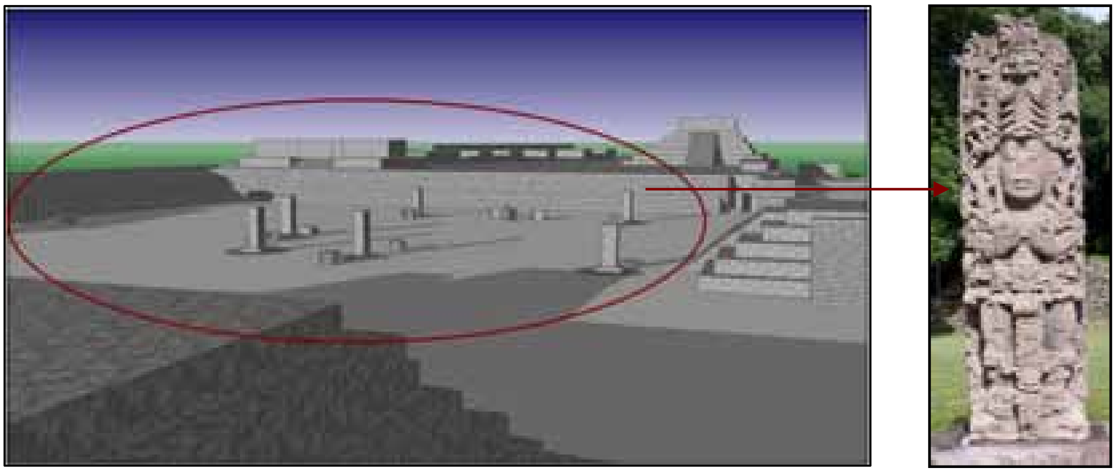


**Figure 4: Stelae Circuit in Great Plaza of Principal Group at Copán (left) and Stela A (right)**

## Previous Archaeological Approaches to Access and Visibility

Several methods have been used to examine access and visibility. One of the most commonly used in archaeology is space syntax, an approach that describes relative connectivity and integration between spaces in order to evaluate access within and among buildings (Batty and Longley 2003; Hillier and Hanson 1984; Hillier 1999; Moore 1996; Stuardo 2003); however, the method has been criticized because it does not adequately take into account visibility (Ferguson 1996). In regards to Maya studies, it has been applied to examine differences and similarities in access patterns within royal compounds across the Maya region.

An example of such work is Stuardo's (2003) comparisons of access between Classic (AD 250-950) royal architecture at the sites of Palenque, Tikal, and Uaxactun in the southern lowlands and Early Postclassic (AD 950-1250) royal architecture at Uxmal, Labna, Kabah, and Sayil in the northern Yucatan. The results of which illustrated simpler access patterns for elite architectural complexes in the northern Yucatan than for those in the southern lowlands suggesting changes in political organization from the Classic to Early Postclassic periods. [1]Stuardo compares these changes to other lines of evidence, which together indicate a departure from Classic forms of rulership to a more decentralized system of governship comprised of a council of nobles in the Early Postclassic (Schele and Friedel 1990).

Stuardo concludes that “although graph analysis [*space syntax*] represents an important tool for emphasizing the similarities and differences among buildings, it does not yield any information about the meaning and use of specific spaces” (Stuardo 2003:199). This noted, he concurs with others arguing that if used in conjunction with other archaeological data (e.g. room dimensions, room function, imagery, and building materials), access studies are an integral and necessary component to studying social interaction (Blanton 1995). This conclusion supports the use of a GIS to carry out access studies as its unique capabilities are tailored to integrating, measuring, and analyzing spatial and attribute (e.g. room function) data.

Traditionally, archaeologists have emphasized the role of access in shaping social interaction; however, recent work on visibility indicates that it also plays a role in social interaction. Archaeological investigations at the ancient Maya site of La Milpa, Belize used viewsheds to investigate the role visibility may have played in how the Classic Maya may have organized large centers located in rugged terrain (Hammond and Tourtellot 1999; Tourtellot et al. 1999; Tourtellot et al. 2003). The viewshed results indicated that two stelae positioned in two nearby smaller sites, *La Milpa East* and *La Milpa West*, were visible from atop a large temple located at the site’s center, *La Milpa Central*. They concluded that the alignment most likely had an ideological function, one that served as a mechanism of cultural integration between *La Milpa Central* and surrounding middle-level sites (Hammond and Tourtellot 1999).

Their investigations are important to this research because they support the premise that visibility may have acted as a vehicle for social integration among the Classic Maya. However, given that their analysis did not take into account accessibility, or potential movement across the landscape, it provides only one step in studying processes of social integration. Although the authors do not explain how or why visibility influences social interaction, following Llobera (1996, 2000, 2006) it is argued that visibility influences the potential for individuals to be drawn to particular locations. In other words, high visibility tends to increase the likelihood that a person will move toward a particular location whereas access influences through which spaces a person will move to arrive at that location.

These examples show that the importance of access and visibility in social organization has been recognized by a number of researchers in different ways. Many scholars contend that access and visibility function to control access, manipulate the flow of movement, and influence visual perception, and although several methods exist by which to test this assumption, they often do so *in absentia* of theory. This research is unique in that it is rooted in a theoretical framework of social semiotics, combining several geospatial methods that help to measure and visualize models of social organization within this theory. By employing such an approach a more holistic understanding of social interaction can be achieved, especially at a site like Copán that experienced many changes in a short time period.

**Archaeological Site of Copán, Honduras: A Case Study**

In the first half of the Late Classic period (AD 650-800), Copán's population nearly quadrupled, but was followed by rapid population loss one-hundred years later circa AD 900-950 (Webster 2005). This rapid population growth and decline over such a short period is one factor that contributed to changing social dynamics in the Late Classic. During this time Copán's inhabitants also saw six dynastic rulers ascend to power (Table 1). The accession and death of each of these rulers resulted in change. One of the most conspicuous of these changes was the repeated configuring and reconfiguring of the site's main ceremonial complex, the Principal Group. These massive construction projects not only transformed the Principal Group, but more importantly they changed the face of the city's entire landscape. Recent research at Copán has raised new questions about the nature, purpose, and meaning(s) of these reconfigurations (Maca 2002; Plank 2004), especially the site's very last reconfiguration, which was commissioned by the site's sixteenth and final dynastic ruler, Y*ax Pasaj*, at the end of the Late Classic.

The debate surrounding Copán's sociopolitical organization focuses on the political strategies of the city's last three rulers (Rulers 14-16), and the crux of the argument is whether or not its sociopolitical system was centralized versus decentralized at the end of the Late Classic. William and Barbara Fash (B. Fash and W. Fash 1991; W. Fash 2001), among others (B. Fash et al. 1992; Stomper 2001), argue that the capture and decapitation of Ruler 13 by the nearby city of Quiriguá in AD 738 marked a turning point for Copán's ruling dynasty. The accession to power of Ruler 13's successor, Ruler 14, was most likely surrounded by uncertainty about the royal lineage's legitimacy; the decapitation sparking questions about royal disfavor with the supernatural. Thus, with his regime marred by not only external strife, but also by internal conflict, several scholars argue that Ruler 14 conceded some of his power to other elite lineages within the Copán Valley. A strategy they believe was followed by his successors leading to a 'dissolution' of centralization at the end of the Late Classic. Advocates of this hypothesis use epigraphic and sculptural data from the Principal Group and outlying suburbs to support their interpretations (e.g. Fash 1989; Riese 1989; Sanders 1989).

| Ruler | Reign | Monuments | Structures |
|---|---|---|---|
| Ruler 11 | AD 578 - 628 | Stelae 7, 18, P; Altar Y | Renewed 10L-26, 10L-11, Ballcourt A |
| Ruler 12 | AD 628 - 695 | Stelae 1, 2, 3, 5, 6, 10, 12, 13, 19, 23, I<br>Altars H'J', K | Major remodeling of Acropolis |
| Ruler 13 | AD 695 - 738 | Stelae A, B, C, D, F, H, J, 4<br>Altar S | 10L-2, 10L-4, 10L-9, 10 (Ballcourt A-III), 10L-22, 10L-26 3rd. first Hieroglyphic Stairway |
| Ruler 14 | AD 738 - 749 | | 10L-22A (*Popul Na*) |
| Ruler 15 | AD 749 - 763 | Stelae M, N | Refurbishes Hieroglyphic Stairway<br>Temple of Structure 10L-26 1st |
| Ruler 16 | AD 763 - 820 | Stelae 8, 11; Altars F', G1, G2, G3, D', O, Q, R, T, U, V, Z, inscribed stone on 10L-22A | 10L-11, 10L-16, 10L-18, 10L-21A |

**Table 1: Late Classic Dynastic Rulers at Copán listing monuments erected or renovated in their reigns**

In contrast, Maca (2002) and Plank (2004) contend that Copán's last royal ruler, *Yax Pasaj* (Ruler 16), used a different political strategy making an effort at centralization through a massive construction campaign that transformed not only the Principal Group, but several structures located in the city's suburbs. They arrived at their conclusions using independent lines of evidence. Plank (2004) used epigraphic and architectural data from the Principal Group and its nearby suburbs, while Maca (2002) focused more specifically on architectural stratigraphy and ceramic data from recent excavations at 9J-5, an elite courtyard group located on the outskirts of the city's proposed urban boundary. Their conclusions suggest that much of the suburban architecture used to support the decentralization hypothesis is misattributed to the city's non-royal elite lineages. They believe that several of the city's suburban structures were intentionally renovated by *Yax Pasaj* as part of a "purposeful and centrally-directed construction project"

(Plank 2004:90). In other words, breaking tradition with his predecessors *Yax Pasaj* broadened his efforts at site reconfiguration beyond the Principal Group, commissioning a large-scale urban renewal project that formed part of a larger political strategy emphasizing centralization.

We believe that these two interpretations are not necessarily mutually exclusive. Following the untimely death of Ruler 13, the royal lineage may have experienced waning power resulting in some degree of decentralization. However, whether or not *Yax Pasaj* tried to curb the processes of decentralization by commissioning a massive construction campaign that extended into the suburbs, the final configuration of Copán's landscape remains the same. It is this configuration that provides data on access and visibility that can be used to investigate *how* the city's inhabitants negotiated the urban landscape, perhaps leaving unanswered the question as to *who* built *what*, but offering some insight on social integration and social segregation that may ultimately shed light on the processes of sociopolitical organization at Late Classic Copán. Thinking along these lines, the question arises as to how to make use of a GIS to measure differences and similarities in access and visibility in Copán's Late Classic landscape.

**GIS Methodology**

[2]Many steps were involved in the design and development of the GIS database; however, only those relevant to measuring visibility and access will be discussed. In order to quantify visibility and access in Copán's urban landscape, two Urban Digital Elevation Models, or Urban DEMs are required – one to calculate viewsheds and the other to calculate least-cost routes. Several steps were involved in creating these two DEMs. The Environmental Systems Research Institute's (ESRI) ArcGIS 9.1 was used to store, create, edit, and analyze the GIS data.

First, scanned maps were georeferenced to the [3]Universal Transverse Mercator (UTM) Projection and then digitized to vector data. These vector data, comprised of natural topography, hydrology, and archaeological features, were then assigned z-values (heights) using data collected from many sources (e.g. Baudez et al. 1983; Hohmann-Vogrin 1982; Hohmann 1995). The topographic data was digitized at 2-meter or 10-meter intervals depending on the availability of data. All known structure heights were manually assigned to an attribute table. A basic trigonometry function taking into account platform height, wall height, wall thickness, and roof pitch was used to calculate unknown heights. The variables were assigned values using the

Harvard Site Typology (Types 1-4), which classifies architectural groups according to social status (Baudez et al. 1983; Willey and Leventhal 1977) [See Appendix A].

After all archaeological features were assigned z-values, their corresponding vector files were converted to a raster format at a resolution of 20cm. The topographic data were converted to a Digital Terrain Model (DTM) and resampled to a common resolution of 1.5 meters. The DTM and Urban DEM were then added together using map algebra to create a high-resolution Urban-View DEM (Figure 5).

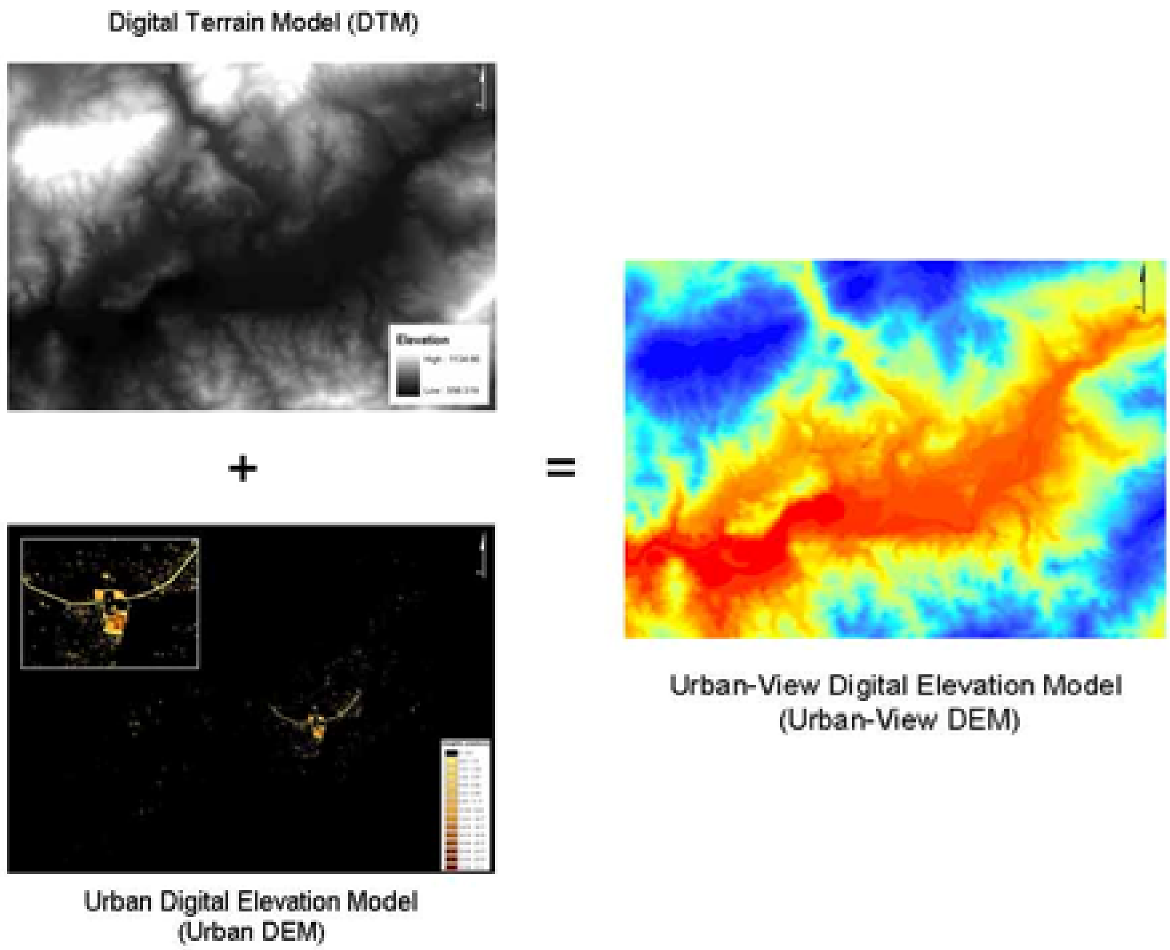



**Figure 5: Urban-View Digital Elevation Model of archaeological site of Copán, Honduras**

This Urban-View DEM was used to create an Urban-Access DEM, which involved creating a FRICTION Surface to take into account impedance (friction), or cost of movement. The

FRICTION Surface was generated by reclassifying the combined structures, causeway, and hydrology vector file into three classes in order to account for areas of no change, barriers, and facilitators. The FRICTION Surface was then multiplied to the Urban-View DEM to generate the Urban-Access DEM (Figure 6).

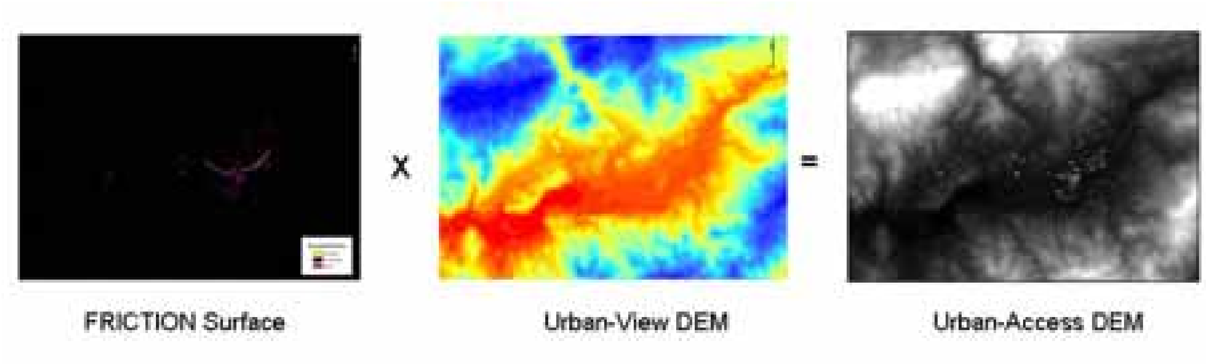



**Figure 6: Urban-Access Digital Elevation Model of archaeological site of Copán, Honduras**

After both Urban DEMs were created, they were employed to measure access and visibility. ESRI's 3*D Analyst* extension was used to generate cumulative viewsheds from the Urban-View DEM in order to identify three things: 1) visible prominence of individual structures, 2) visual prominence of structures classified by social status, and 3) overlap (common areas) of visibility. ESRI's *Spatial Analyst* extension was used to derive Cost Direction and Cost Distance surfaces from the Urban-Access DEM and ASPECT surface in order to create least-cost routes (Figure 7).

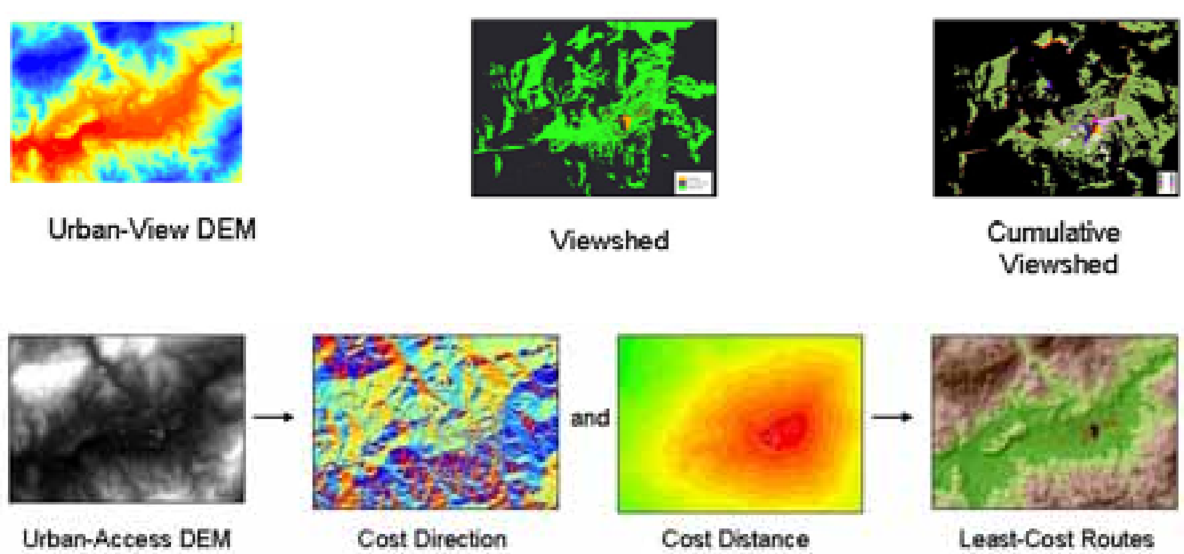
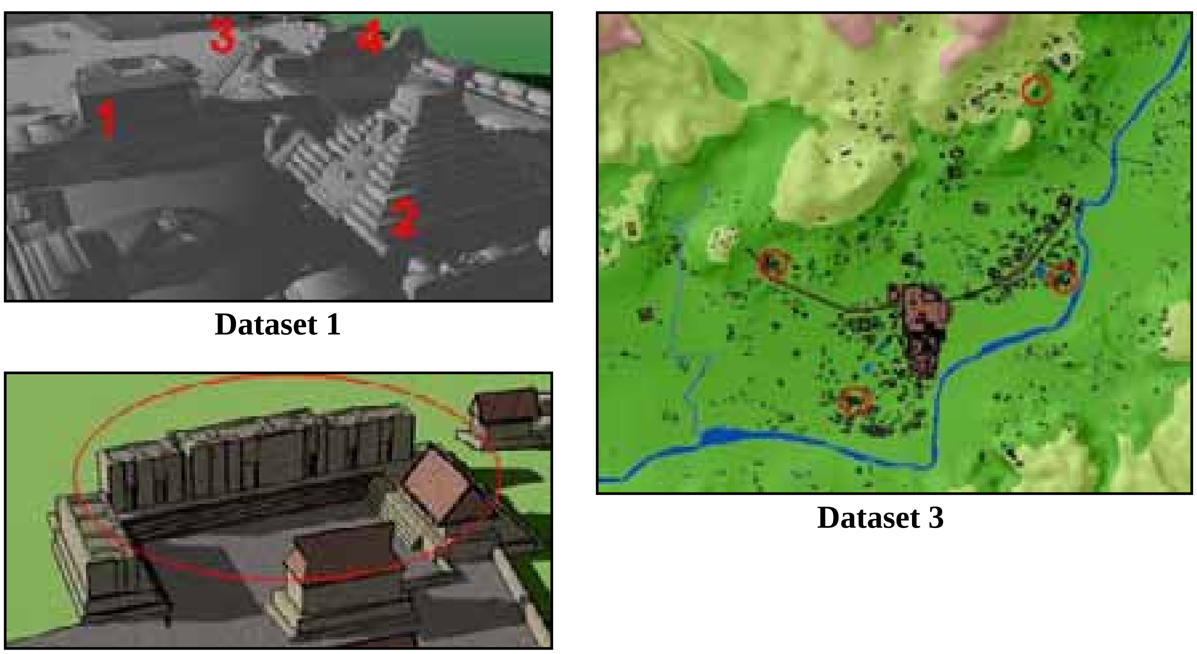



**Figure 7: Processes for Cumulative Viewsheds (top) and Least-Cost Routes (bottom)**

The least-cost routes were calculated using a cost-of-passage function that averaged the cost of traveling from one location to many other locations (Ratti 2005). This is similar to Hillier's (1999) space syntax concept of integration, which uses axial graphs to measure the potential for social interaction to take place (Ferguson 1996; Hillier and Hanson 1984; Shapiro 2005); however, by using an urban DEM rather than axial graphs the process has several advantages, it is somewhat simplified, not limited to line-of-sight measurements, and is easily transferable to other scales.

After these steps were completed, the Copán GIS was used to create the five datasets analyzed in this pilot study (Figure 8). Three datasets served as the source locations and include four ceremonial structures located in the Principal Group (Dataset1), five elite structures/groups identified as *otoot*, or dwelling, structures erected by Ruler 16 (Dataset 2) (Plank 2004), and four elite groups identified as part of a quadripartite design delineating Copán's urban boundary (Dataset 3) (Maca 2002). Two additional datasets were randomly selected to serve as the destinations for the visibility and access analyses. Dataset 4 was comprised of Type 4, or elite, destinations and Dataset 5 consisted of Type 1, or commoner, destinations [See Appendix B].




**Dataset 1**

**Dataset 2**

**Dataset 3**

**Figure 8: Sample Datasets Used in Case Study**

Viewsheds and least-cost routes were generated for Datasets 1-3 using the Urban-View DEM and Urban-Access DEM.  However, further processing of the viewsheds was required to make them useful for my analysis. Cumulative viewsheds were generated for each of the three datasets [See Appendix C]. These are needed to assess visual prominence.  The process of creating these cumulative viewsheds did not involve simply adding together the initial viewsheds rather they were reclassified using three classification schemes. By assigning all non-visible areas a value = 0 and assigning all visible areas unique values that result in values representing unique combinations, the visible areas of the site can be added together to determine not only the most visually prominent features, but also identify, or attribute, visual prominence to both individual features and groups of features. For example, in *Dataset 1* at any locations with a value = 7, a person can see Structures 10L-11, 10L-16, and 10L-22; however, they cannot see Structure 10L-26.  This classification method results not only in identifying visual prominence, but also areas of common visibility, which is critical to any comparative analyses. The Urban-Access DEM did not require further processing to calculate the least-cost routes.

**Preliminary Observations**

Cumulative viewsheds and least-cost routes were created for these datasets and then analyzed in order to make some preliminary observations about visibility and access with the Copán Valley. The focus was on identifying similarities and differences between locations attributed to royal elite, non-royal elite, and commoners. The results of the visibility analysis indicate that the most visually prominent archaeological feature in the Copán Valley at the end of the Late Classic was Structure 10L-16.  Tunneling excavations and architectural reconstructions indicate that the building was renovated during Ruler 16’s reign making it taller than Structure 10L-22, previously the site’s tallest building and the viewshed of Structure 10L-16 indicates that is was visible to 25% of the valley. However, when a larger-scale analysis is carried out reducing the study area from $60km^2$ to $12km^2$ in order to conform to Maca’s (2002) proposed urban boundaries, the results dramatically change.  Structure 10L-16 becomes visible from 64.44% of the urban area compared to only 25% for the valley as a whole making its visual prominence much greater within the city’s urban limits. Given that the structure is not visible from either of the two stelae hypothesized to mark entrance to the valley and delimit Copán’s hinterland, this suggests Structure 10L-16’s immediate audience were the occupants of Copán rather than visitors from other sites (Figure 9). In future analyses, the percentage visibility of Structure 10L-16 and other monumental structures will be correlated to elite and non-elite households (Type 1-4) in order to identify similarities and differences in visual prominence based on social group [See Appendix D].

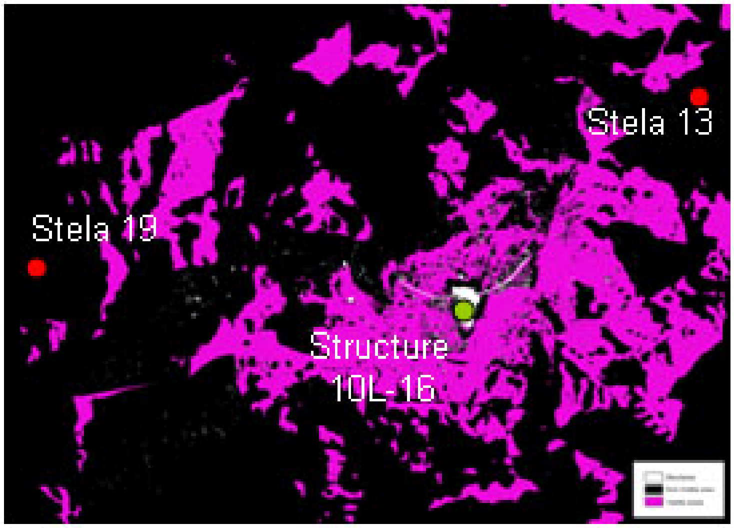



**Figure 9: Viewshed of Structure 10L-16 showing non-visibility of stelae marking entrance to Copán Valley**

The preliminary results of the access analysis indicate that Type 4, or elite structures were more highly integrated with other elite structures than they were with Type 1, or commoner structures. In fact, in most cases, elite structures are almost three times more integrated with each other than with commoner households (Figure 10). However, it must be noted that only a small percentage of known commoner structures in the Copán Valley were used in the analysis and therefore, these results should be considered preliminary. The access data also suggest that the massive structures of the Principal Group appear to have integration values similar to those of elite courtyard groups. That is, they are more highly integrated with elite groups than with commoner households perhaps indicating a greater focus on channeling movement between the Principal Group and persons of elite status rather than between the Principal Group and commoners [See Appendix E].

In general, a couple of observations can be made by integrating the access and visibility results. First, the most visually prominent archaeological feature is Structure 10L-16, commissioned by Ruler 16, Copán's last dynastic ruler. Second, all four of the Principal Group structures analyzed in this study can be seen simultaneously from 20% of the valley and interestingly, although erected by Ruler 12 almost 150 years before the reign of Ruler 16, six of Ruler 12's eight valley stelae fall into this area of common visibility.

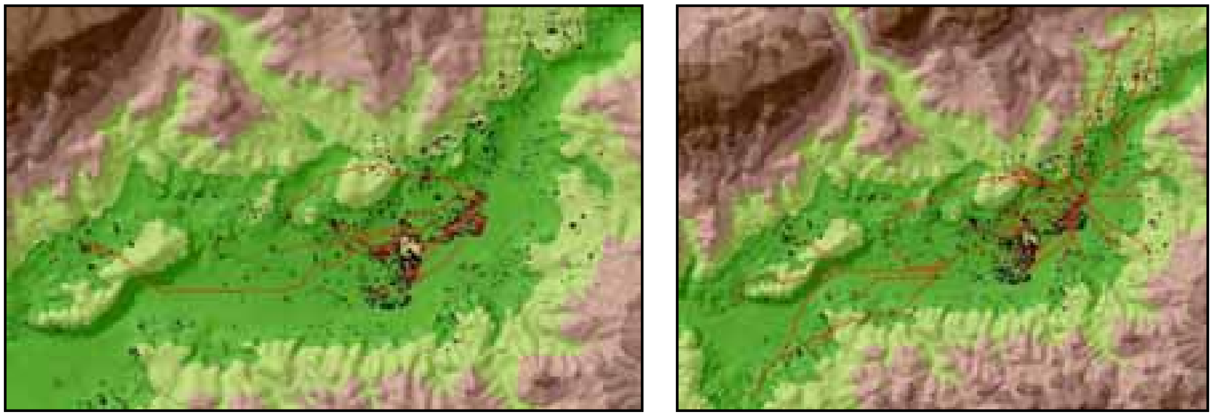


**Figure 10: Least-Cost Routes from 8N-66, an elite structure, to other elite groups (left) and to commoner households (right)**

Third, the four architectural groups (Dataset 3) posited by Maca (2002) to delimit the site's urban boundaries can be seen simultaneously from only 2.95% of the valley; however, all four can be seen from Stela 12, also erected by Ruler 12 (Figure 11). Fourth, there is three time greater integration between the monumental structures of the Principal Group and Elite architectural groups than between the Principal Group and commoner groups. These data possibly support Maca (2002) and Plank's (2004) hypothesis that Ruler 16 commissioned an urban renewal project as part of a political strategy toward centralization. By emulating Ruler 12, who shifted focus toward the Principal Group in what many believe was an attempt to centralize power (Fash 2001), Ruler 16 may have sought to maintain power even as problem's mounted within the valley. These preliminary analyses are provocative; however, given the small sample size, definitive patterns cannot be established until further analyses are carried out and placed within their appropriate historical and social circumstances.

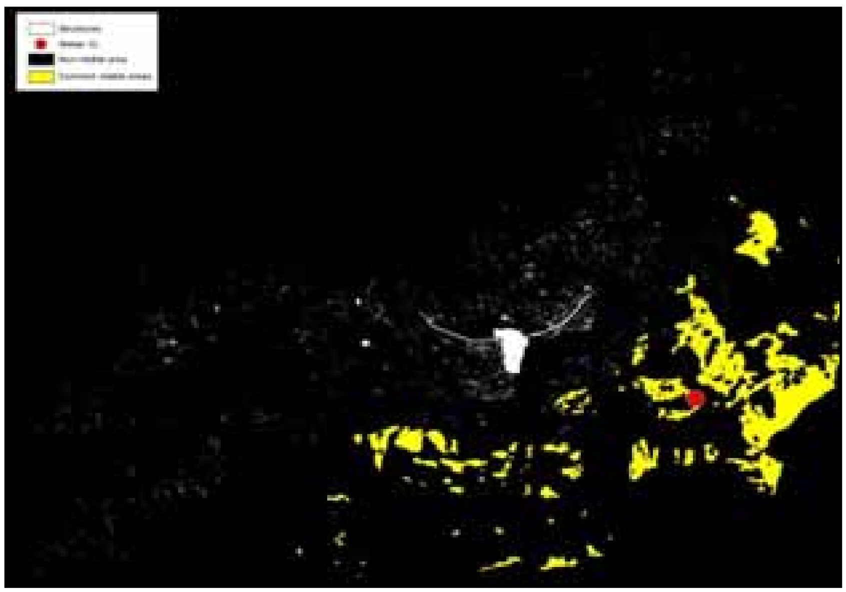


**Figure 11: Visibility of Ruler 12's Valley Stelae from Ruler 16's Structure 10L-16 (top) and Common Visibility of Stelae 12 from Four Architectural Groups Hypothesized to Delimit Copán's Urban Boundaries (bottom)**

## Future Work

The next phase of the project is to continue to collect access and visibility measurements, analyze these data, and then use spatial autocorrelation to identify links between attributes such as sculpture, iconography, or building function and access and visibility patterns. Given that ancient social lives were played out in many arenas and on many spatial scales, a multi-scalar approach will be employed to investigate access and visibility patterns within and between Copán's courtyard groups, 'neighborhoods' (*sian otoots*), the urban core, and the valley (Fash 1983). It is the connections between these various scales that are indicative of social interaction and ultimately illustrate how "small things are connected with the bigger social landscapes in which they are set" (Knowles and Sweetman 2004:7) and will provide us with a better understanding of how the ancient Maya negotiated their physical surroundings. By measuring access and visibility in a GIS we can investigate how ancient peoples negotiated their built and natural environments, and use these data to enrich our understanding of *how* messages were being communicated, to *whom*, and *why*.

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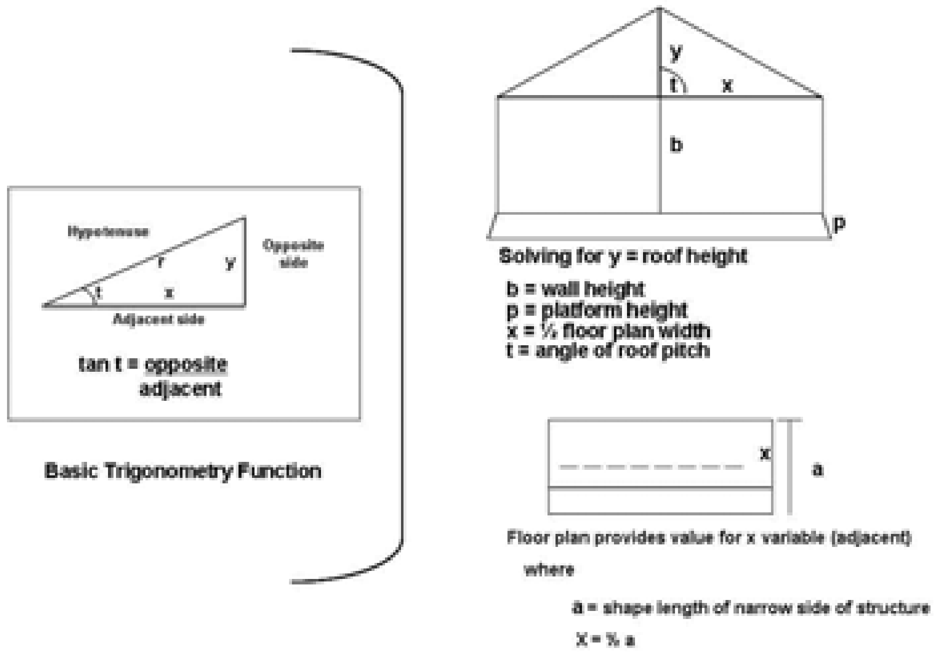
## Appendix A

### Assigning Heights to Unexcavated Excavated Structures, Stelae, and Altars




### Assigning Variable Using the Harvard Site Typology

**Type 1**

height = ((0.5 * shape length) * tan t) + b

where b = wall height
tan t = 45°

height = ((0.5 * shape length) *1) + 2.0
= (0.5 * shape length) + 2.0

**Type 2**

height = ((0.5 * shape length) * tan t) + b + p

where b = wall height
tan t = 45°
p = platform height

height = ((0.5 * shape length) *1) + 2.0 + 0.54
= (0.5 * shape length) + 2.0 + 0.54

**Type 3**

height = ((0.5 * shape length) * tan t) + b + p

where b = wall height
tan t = 45°
p = platform height

height = ((0.5 * shape length) *1) + 2.0 + 0.97
= (0.5 * shape length) + 2.0 + 0.97

**Type 4**

height = ((0.5 * shape length) * tan t) + b + p - w

where b = wall height
tan t = 60°
p = platform height
w = wall thickness

height = ((0.5 * shape length) *1.73) + 2.0 + 1.15 – 2.0

## Appendix B

**DATASET 1-** Four Ceremonial Structures located in the *Principal Group*

| Structure | Urban Sector | Type | Ruler (final phase erected by) |
|---|---|---|---|
| **10L-11** | Principal Group | Ceremonial | Ruler 16 |
| **10L-16** | Principal Group | Ceremonial | Ruler 16 |
| **10L-22** | Principal Group | Ceremonial | Ruler 13 |
| **10L-26** | Principal Group | Ceremonial | Ruler 15 |

**DATASET 2-** Five Elite (otoot) Structures located in suburb of *Las Sepulturas*

| Structure | Urban Sector | Type | Time Period |
|---|---|---|---|
| **8N-66** | Las Sepulturas | Elite (Type 4) | Late Classic (*Ruler 16) |
| **9M-146** | Las Sepulturas | Elite (Type 4) | Late Classic (*Ruler 16) |
| **9M-195** | Las Sepulturas | Elite (Type 4) | Late Classic (*Ruler 16) |
| **9N-82** | Las Sepulturas | Elite (Type 4) | Late Classic (*Ruler 16) |
| **10L-32** | Principal Group | Royal Elite | Late Classic (Ruler 16) |

* Although constructed/renovated during reign of Ruler 16, this does not necessitate that he commissioned the structures.

**DATASET 3-** Four Elite (Quadripartite) Structures delimiting urban boundary

| Structure | Urban Sector | Type | Time Period |
|---|---|---|---|
| **9J-5** | El Pueblo | Elite (Type 4) | Late Classic (*Ruler 16) |
| **11K-6** | El Bosque | Elite (Type 4) | Late Classic (*Ruler 16) |
| **7M-8** | Chorro | Elite (Type 2) | Late Classic (*Ruler 16) |
| **9N-82** | Las Sepulturas | Elite (Type 4) | Late Classic (*Ruler 16) |

* Although possibly constructed/renovated during reign of Ruler 16, this does not necessitate that he commissioned the structures.

**Appendix C**

**DATASET 1**

| Archaeological Feature | Visible Pixels ID (RECLASSIFIED) |
|---|---|
| Structure 10L-11 | 1 |
| Structure 10L-16 | 2 |
| Structure 10L-22 | 4 |
| Structure 10L-26 | 8 |

| Combinations of Archaeological Features | Unique Identifiers |
|---|---|
| 10L-11 + 10L-16 | 3 |
| 10L-11 + 10L-22 | 5 |
| 10L-16 + 10L-22 | 6 |
| 10L-11 + 10L-16 + 10L-22 | 7 |
| 10L-11 + 10L-26 | 9 |
| 10L-16 + 10L-26 | 10 |
| 10L-11 + 10L-16 + 10L-26 | 11 |
| 10L-22 + 10L-26 | 12 |
| 10L-11 + 10L-22 + 10L-26 | 13 |
| 10L-16 + 10L-22 + 10L-26 | 14 |
| 10L-11 + 10L-16 + 10L-22 + 10L-26 | 15 |

**DATASET 2**

| Archaeological Feature | Visible Pixels ID |
|---|---|
| Structure 8N-66 | 1 |
| Structure 9M-146 | 2 |
| Structure 9N-82 | 4 |
| Structure 9M-195 | 8 |
| Structure 10L-32 | 16 |

| Combinations of Archaeological Features | Unique Identifiers |
|---|---|
| 8N-66 + 9M-146 | 3 |
| 8N-66 + 9N-82 | 5 |
| 9M-146 + 9N-82 | 6 |
| 8N-66 + 9M-146 + 9N-82 | 7 |
| 8N-66 + 9M-195 | 9 |
| 9M-146 + 9M-195 | 10 |
| 8N-66 + 9M-146 + 9M-195 | 11 |
| 9N-82 + 9M-195 | 12 |
| 8N-66 + 9N-82 + 9M-195 | 13 |
| 9M-146 + 9N-82 + 9M-195 | 14 |
| 8N-66 + 9M-146 + 9N-82 + 9M-195 | 15 |
| 8N-66 + 10L-32 | 17 |
| 9M-146 + 10L-32 | 18 |
| 8N-66 + 9M-146 + 10L-32 | 19 |
| 9N-82 + 10L-32 | 20 |
| 8N-66 + 9N-82 + 10L-32 | 21 |
| 9M-146 + 9N-82 + 10L-32 | 22 |
| 10L-32 + 9N-82 + 9M-146 + 8N-66 | 23 |
| 10L-32 + 9M-195 | 24 |
| 10L-32 + 9M-195 + 8N-66 | 25 |
| 10L-32 + 9M-195 + 9M-146 | 26 |
| 10L-32 + 9M-195 + 9M-146 + 8N-66 | 27 |
| 10L-32 + 9M-195 + 9N-82 | 28 |
| 10L-32 + 9M-195 + 9N-82 + 8N-66 | 29 |
| 10L-32 + 9M-195 + 9N-82 + 9M-146 | 30 |
| 10L-32 + 9M-195 + 9N-82 + 9M-146 + 8N-66 | 31 |

**DATASET 3**

| Archaeological Feature | Visible Pixels ID |
|---|---|
| Group 9J-5 | 1 |
| Group 7M-8 | 2 |
| Group 9N-8 | 4 |
| Group 11K-6 | 8 |

| Combinations of Archaeological Features | Unique Identifiers |
|---|---|
| 9J-5 + 7M-8 | 3 |
| 9J-5 + 9N-8 | 5 |
| 7M-8 + 9N-8 | 6 |
| 9J-5 + 7M-8 + 9N-8 | 7 |
| 9J-5 + 11K-6 | 9 |
| 7M-8 + 11K-6 | 10 |
| 9J-5 + 7M-8 + 11K-6 | 11 |
| 9N-8 + 11K-6 | 12 |
| 9J-5 + 9N-8 + 11K-6 | 13 |
| 7M-8 + 9N-8 + 11K-6 | 14 |
| 9J-5 + 7M-8 + 9N-8 + 11K-6 | 15 |

**Appendix D**

**DATASET 1:**

| Structure | Urban Sector | % Visibility | Ranking |
|---|---|---|---|
| 10L-11 | Principal Group | 0.20% | **9** |
| 10L-16 | Principal Group | 1.00% | **3** |
| 10L-22 | Principal Group | 0.48% | **6** |
| 10L-26 | Principal Group | 0.16% | **10** |
| 10L-11 + 10L-16 | Principal Group | 0.04% | **14** |
| 10L-11 + 10L-22 | Principal Group | 0.79% | **5** |
| 10L-16 + 10L-22 | Principal Group | 1.4% | **2** |
| 10L-11 + 10L-16 + 10L-22 | Principal Group | 0.10% | **13** |
| 10L-11 + 10L-26 | Principal Group | 0.10% | **12** |
| 10L-16 + 10L-26 | Principal Group | 0.03% | **15** |
| 10L-11 + 10L-16 + 10L-26 | Principal Group | 0.11% | **11** |
| 10L-22 + 10L-26 | Principal Group | 0.25% | **8** |
| 10L-11 + 10L-22 + 10L-26 | Principal Group | 0.35% | **7** |
| 10L-16 + 10L-22 + 10L-26 | Principal Group | 0.81% | **4** |
| 10L-11 + 10L-16 + 10L-22 + 10L-26 | Principal Group | **20.41%** | **1** |

| Structure | % Cumulative Visibility | Visual Ranking |
|---|---|---|
| Structure 10L-11 | 23.06 % | **3** |
| Structure 10L-16 | 25.00 % | **1** |
| Structure 10L-22 | 24.19 % | **2** |
| Structure 10L-26 | 22.20 % | **4** |

**Cumulative Visibility = 26.2 %**

**DATASET 2**

| Structure | Urban Sector | % Visibility | Ranking |
|---|---|---|---|
| 8N-66 | Las Sepulturas | 1.00% | |
| 9M-146 | Las Sepulturas | 0.23% | |
| 9N-82 | Las Sepulturas | 0.25% | |
| 9M-195 | Las Sepulturas | 1.44% | |
| 10L-32 | Las Sepulturas | 0.58% | |
| 8N-66 + 9M-146 | Las Sepulturas | 0.08% | |
| 8N-66 + 9N-82 | Las Sepulturas | 0.11% | |
| 9M-146 + 9N-82 | Las Sepulturas | 0.11% | |
| 8N-66 + 9M-146 + 9N-82 | Las Sepulturas | 0.02% | |
| 8N-66 + 9M-195 | Las Sepulturas | 0.26% | |
| 9M-146 + 9M-195 | Las Sepulturas | 0.15% | |
| 8N-66 + 9M-146 + 9M-195 | Las Sepulturas | 0.31% | |
| 9N-82 + 9M-195 | Las Sepulturas | 0.36% | |
| 8N-66 + 9N-82 + 9M-195 | Las Sepulturas | 0.64% | |
| 9M-146 + 9N-82 + 9M-195 | Las Sepulturas | 1.70% | |
| 8N-66 + 9M-146 + 9N-82 + 9M-195 | Las Sepulturas | 5.6% | |
| 8N-66 + 10L-32 | Las Sepulturas | 0.34% | |
| 9M-146 + 10L-32 | Las Sepulturas | 0.25% | |
| 8N-66 + 9M-146 + 10L-32 | Las Sepulturas | 0.18% | |
| 9N-82 + 10L-32 | Las Sepulturas | 0.78% | |
| 8N-66 + 9N-82 + 10L-32 | Las Sepulturas | 0.59% | |
| 9M-146 + 9N-82 + 10L-32 | Las Sepulturas | 0.09% | |
| 10L-32 + 9N-82 + 9M-146 + 8N-66 | Las Sepulturas | 0.13% | |
| 10L-32 + 9M-195 | Las Sepulturas | 0.14% | |
| 10L-32 + 9M-195 + 8N-66 | Las Sepulturas | 0.10% | |
| 10L-32 + 9M-195 + 9M-146 | Las Sepulturas | 0.28% | |
| 10L-32 + 9M-195 + 9M-146 + 8N-66 | Las Sepulturas | 0.45% | |
| 10L-32 + 9M-195 + 9N-82 | Las Sepulturas | 0.68% | |
| 10L-32 + 9M-195 + 9N-82 + 8N-66 | Las Sepulturas | 0.50% | |
| 10L-32 + 9M-195 + 9N-82 + 9M-146 | Las Sepulturas | 1.18% | |
| 10L-32 + 9M-195 + 9N-82 + 9M-146 + 8N-66 | Las Sepulturas | **5.34%** | |

| Structure | % Cumulative Visibility | Visual Ranking |
|---|---|---|
| **8N-66** | 11.81 % | **4** |
| **9M-146** | 11.32 % | **5** |
| **9N-82** | 14.51 % | **2** |
| **9M-195** | 12.22 % | **3** |
| **10L-32** | 16.60 % | **1** |

**Cumulative Visibility = 23.9 %**

**DATASET 3**

| Archaeological Features | Urban Sector | % Visibility | Ranking |
|---|---|---|---|
| Group 9J-5 | El Pueblo | 4.94 % | |
| Group 7M-8 | Chorro | 2.16 % | |
| Group 9N-8 | Las Sepulturas | 1.74 % | |
| Group 11K-6 | El Bosque | 3.60 % | |
| 9J-5 + 7M-8 | | 0.30 % | |
| 9J-5 + 9N-8 | | 1.60 % | |
| 7M-8 + 9N-8 | | 2.15 % | |
| 9J-5 + 7M-8 + 9N-8 | | 3.00 % | |
| 9J-5 + 11K-6 | | 3.72 % | |
| 7M-8 + 11K-6 | | 0.02 % | |
| 9J-5 + 7M-8 + 11K-6 | | 0.62 % | |
| 9N-8 + 11K-6 | | 1.81 % | |
| 9J-5 + 9N-8 + 11K-6 | | 1.98 % | |
| 7M-8 + 9N-8 + 11K-6 | | 0.18 % | |
| 9J-5 + 7M-8 + 9N-8 + 11K-6 | | **2.95 %** | |

| Archaeological Features | % Cumulative Visibility | Visual Ranking |
|---|---|---|
| **Group 9J-5** | 18.38 % | **1** |
| **Group 7M-8** | 11.38 % | **4** |
| **Group 9N-8** | 14.72 % | **2** |
| **Group 11K-6** | 14.27 % | **3** |

**Cumulative Visibility = 30.7 %**

## Appendix E

### Least-Cost Routes: Sources are Type 4 Groups

| Source Location | Urban Sector | Destinations | Total Cost | Average Cost | Ranking |
|---|---|---|---|---|---|
| Structure 8N-66 | Las Sepulturas | Type 4 Groups | 31,226.47 | 529.26 | **1** |
| Structure 9I-1 | El Pueblo | Type 4 Groups | 33,092.80 | 560.89 | **2** |
| Structure 10L-201 | Principal Group | Type 4 Groups | 33,865.11 | 573.98 | **3** |
| Structure 10L-32 | Principal Group | Type 4 Groups | 34,177.13 | 579.27 | **4** |
| Structure 9M-195 | Las Sepulturas | Type 4 Groups | 34,752.21 | 589.02 | **5** |
| Structure 9J-38 | El Pueblo | Type 4 Groups | 34,973.41 | 592.77 | **6** |
| Structure 9M-164 | Las Sepulturas | Type 4 Groups | 35,428.69 | 600.49 | **7** |
| Structure 9M-146 | Las Sepulturas | Type 4 Groups | 35,810.96 | 606.97 | **8** |
| Structure 9N-82 | Las Sepulturas | Type 4 Groups | 36,059.50 | 611.18 | **9** |
| Structure 9L-104 | Principal Group | Type 4 Groups | 37,084.40 | 628.55 | **10** |
| Structure 11K-30 | El Bosque | Type 4 Groups | 40,069.86 | 679.15 | **11** |
| Structure 7M- 47 | Chorro | Type 4 Groups | 40,989.11 | 694.73 | **12** |
| Structure 8L-74 | Salamar | Type 4 Groups | 42,743.04 | 724.46 | **13** |

| Source Location | Urban Sector | Destinations | Total Cost | Average Cost | Ranking |
|---|---|---|---|---|---|
| Structure 8N-66 | Las Sepulturas | Type 1 Groups | 80,205.42 | 1336.76 | **1** |
| Structure 8L-74 | Salamar | Type 1 Groups | 112,237.5 | 1870.63 | **2** |
| Structure 9N-82 | Las Sepulturas | Type 1 Groups | 112,756.6 | 1879.28 | **3** |
| Structure 7M- 47 | Chorro | Type 1 Groups | 116,225.8 | 1937.10 | **4** |
| Structure 10L-201 | Principal Group | Type 1 Groups | 118,751.9 | 1979.20 | **5** |
| Structure 10L-32 | Principal Group | Type 1 Groups | 118,914.8 | 1981.91 | **6** |
| Structure 9M-195 | Las Sepulturas | Type 1 Groups | 119,323.5 | 1988.76 | **7** |
| Structure 9L-104 | Principal Group | Type 1 Groups | 117,134.7 | 1995.25 | **8** |
| Structure 9M-164 | Las Sepulturas | Type 1 Groups | 120,438.7 | 2007.31 | **9** |
| Structure 9M-146 | Las Sepulturas | Type 1 Groups | 120,651.2 | 2010.85 | **10** |
| Structure 11K-30 | El Bosque | Type 1 Groups | 121,988.1 | 2033.14 | **11** |
| Structure 9J-38 | El Pueblo | Type 1 Groups | 122,722.4 | 2045.37 | **12** |
| Structure 9I-1 | El Pueblo | Type 1 Groups | 127,138.6 | 2118.98 | **13** |

**Least-Cost Routes: Sources are Principal Group Ceremonial Structures**

| Source Location | Urban Sector | Destinations | Total Cost | Average Cost | Ranking |
|---|---|---|---|---|---|
| Structure 10L-11 | Principal Group | Type 1 Groups | 118,135.9 | 1968.93 | **2** |
| Structure 10L-26 | Principal Group | Type 1 Groups | 117,779.7 | 1963.00 | **1** |
| Structure 10L-22 | Principal Group | Type 1 Groups | 118,872.8 | 1981.21 | **3** |
| Structure 10L-16 | Principal Group | Type 1 Groups | 119,479.8 | 1991.33 | **4** |

| Source Location | Urban Sector | Destinations | Total Cost | Average Cost | Ranking |
|---|---|---|---|---|---|
| Structure 10L-11 | Principal Group | Type 4 Groups | 34,919.28 | 591.85 | **1** |
| Structure 10L-26 | Principal Group | Type 4Groups | 36,425.55 | 617.37 | **4** |
| Structure 10L-22 | Principal Group | Type 4 Groups | 35,971.67 | 609.69 | **3** |
| Structure 10L-16 | Principal Group | Type 4 Groups | 35,248.03 | 597.42 | **2** |

## End Notes

[1]Given that this same pattern of decentralization has been argued for Late Classic Copán using iconographic evidence from the Acropolis' *Popul Na* (Structure 10L-22A), or 'Council House', and the 'House of Bacabs' (Structure 9N-82), a study of access can serve as another line of evidence to investigate the site's sociopolitical organization (Fash 2001; Fash et al. 1996; Stomper 2001).

[2]It must be noted that given the lack of readily-available high resolution data for most archaeological sites, any study of ancient urban landscapes requires a large amount of time to collect and coalesce spatial and attribute data, convert these data to vector and raster GIS data, and preprocess them. It is my goal (once the GIS data are in hand) to offer a methodology that is relatively straightforward and transferable to studies of other ancient Maya cities beyond Copán.

[3]The data were georeferenced using the Universal Transverse Mercator (UTM) projection to easily allow for distance measurements in centimeters and meters.

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