Cities Made of Boundaries

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CHAPTER 7
THE EMPIRICAL PROCESS OF MAPPING BLTs: TWO CONTRASTING CASES

Introduction

At this stage all preparations have been put in place to advance a method that is both conceptually commensurate and appropriate for the radical comparative social study of the inhabited urban built environment on the basis of boundaries. This chapter therefore serves to introduce the processes of data acquisition, preparation, and BLT identification. The latter is executed as a mapping practice, BLT Mapping, in a GIS environment. This leads to a specific data structure that can be visualised, questioned and analysed (shown in Chapter 8). To make the operationalisation of boundary conceptualisations easier to understand, the processes will be demonstrated via two test cases. A rationale for their selection will be provided. This chapter adds depth and explanatory detail to the line of argument developed in Vis (2014b).

Legacy data as a starting point

To start, the onsite acquisition of original material-spatial (urban layout) data is not the scope of the processes that will be discussed here. It could be argued that now having exact knowledge about what is needed to apply a boundary approach might inform an effective and original data acquisition process in the field. Instead, I emphasise a contrary argument. The fact that pre-existing or ‘legacy’ datasets can be used is a particular strength of the workflow presented. Considering that at the basis
of BLT Mapping is always an urban survey resulting in a large-scale town plan, legacy data compatibility implies the immediate applicability to a large number of existing town plans of all regions and time periods. This is especially significant with regards to accruing a body of data to support radical comparisons and syntheses across urban examples over time. Moreover, for most projects a new comprehensive urban survey onsite is practically unfeasible. Requiring one to do so would severely limit the potential merits of the method. This applies almost equally to the often arduous tasks of archaeological surface surveys and excavation, the laborious process of historical town plan reconstruction, and the comprehensive walking and mapping of the material specificities of present-day urban built environments. Remote sensing could offer an effective alternative when accepting the restrictions on the material information this makes available.

A research practice capable of working on legacy data, then, creates the greatest immediate versatility and flexibility. It also enables revisiting urban landscapes that were studied previously, thereby promoting scientific progress with debates and multimethod approaches. Nonetheless, the use of any pre-existing map – inevitably produced for different purposes and conventions (see Wood 1992; Monmonier 1996; MacEachren 2004; Lilley 2011a, 2012; Hutson 2012; Beisaw & Gibb 2013) – presents its own challenges. The technical challenge of digitisation (exemplified in this chapter) is integral to the legacy data research process, because many maps only exist as physical documents. Using legacy city plans causes inevitable dependence on the mapping processes and professional skills that produced them. In archaeological cases we rely on surveyors and/or excavators. In historical cases we rely on historians and historical geographers. In contemporary cases we typically rely on the relevant mapping agency (public and crowdsourced mapping forming exceptions).

To demonstrate the comparative capabilities of this methodology, the two test cases have been deliberately selected to represent two very different situations. Therefore, I will first present the rationale for selecting these test cases. Because the overarching aim of this book is the development of a methodology, the test cases are used throughout the following chapters to demonstrate processes and possibilities. Therefore to refer to the case work in this book as test cases is deliberate. They are limited in extent and used to emphasise the explorative and diverse nature of cities, and the associated analytical and interpretive opportunities. In articulating a methodological journey, this book is not the appropriate
stage for full-fledged case studies, but my focus is on demonstrating how casuistic social interpretations can be developed and supported.  

**Selecting test cases**

Considering urban traditions to compare

In order to demonstrate the methodological capacity to carry out radical comparisons, the selection of two appropriate test cases needs to ensure that contrast between them is maximised, while striving for potential parity of data throughout. My greatest personal experience of urban contexts (The Netherlands and UK) is part of what can be generalised as the contemporary urban tradition of the western world (e.g. contributions in Slater 1990). This makes it a convenient place to start, because familiarity will result in greater *a priori* understanding of the structure of such urban tradition. Furthermore, there are many examples of cities for which medieval or even earlier origins have been studied in both the UK and The Netherlands. This creates the opportunity for a test case demonstrating historical development. A western urban tradition is thus used to test diachronic comparative ability next to cross-cultural comparisons. So decided, my search became limited to UK or Dutch cities for which data are available and/or could be compiled as appropriate for a test case.

Next to a western historical-to-contemporary example, it is paramount that BLT Mapping is demonstrated on an archaeological case to maximise applicability throughout the variety of patterns produced by urban development in the long-term. In Classical and Near Eastern archaeology, several urban settlements have been mapped to a sufficient extent. Accepting Europe as the heartland of the western urban tradition in both archaeology and geography (respectively, see Storey 2006; Slater 1990), we should consider the relational historical developments that nurtured it. The processes that grew a European urban tradition arguably start with Ancient Greece and the urbanism of conquest that changes the existing tradition in the Hellenic Near East. Here a model is introduced that is continued and perfected by the Roman Empire and

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1. It must be conceded that applications on cases that comprise more comprehensive data on urban development or, indeed, a fuller extent of the city, will advance the analytical relevance and sophistication of interpretation. Full-fledged casuistic work should also be justified and designed to exert control over possible sampling biases. The preliminary outcomes in Chapter 9 should not be taken as grand claims to understanding each case, but careful statements on early stage evidence that could have impactful future consequences.
exported to their provinces (Butzer 2008: 82–86). Notwithstanding each case’s idiosyncrasies, viewed historically, most potential cases could either be considered a close precursor or direct neighbour of the contemporary western example to be selected.

Several contributions in Marcus & Sabloff (2008; also Storey 2006) highlight the meeting of independently developed urban traditions, emphasised by juxtaposing the archaeology of the so-called Old and New World. In ancient encounters between urban traditions, we can nonetheless recognise that there are many aspects of elementary similarity between cities across time and space. Renfrew (2008: 36–49) approaches this similarity as transformations of the same phenomenon, which is explained by a shared morphogenesis. That is, the shape and occurrence of certain traits in cities embodies a similar solution to a similar problem. At the same time, similarity in shape should not be confused with the conclusion that these cities were inhabited in a socially similar way (cf. Fletcher 2010; Chapter 1). In fact, within the similarity of urbanism broadly as well as within cultural regions, there is much internal variation (Butzer 2008). Ultimately, to test BLT Mapping’s comparative compatibility it would be most advantageous to select a truly dramatic contrast. Taking an example from both the Old and New World assures long-term developmental and cultural independence. The sharp difference among urban traits is particularly borne out in the lower population densities that are projected for examples of Maya urbanism (Nichols 2006; Rice 2006; Hansen 2008; Hutson 2016: 41–55).

The dispersal of the material settlement pattern that relates to lower population density estimates, especially found in tropical regions of the world, seems quite alien to our western perception of the city. The western urban tradition – not unlike Near Eastern and Islamic cities in this regard (Butzer 2008) – tends to be characterised by a high intensity of built volumes that readily relate to the prevailing urban planning paradigm of densification today. Therefore, the dispersed and often seemingly irregular urban landscapes that belong to what Fletcher (2009, 2010, 2012) labels ‘low-density urbanism’ would offer a suitable contrast to test the comparative ability of BLT Mapping.

Among these traditions, Maya urbanism fosters the best available variety of archaeological city plans. This is not least aided by the relative preservation of surface remains resulting from a protean developmental history that involves abandonment (rather than collapse, see e.g. Aimers 2007; Turner & Sabloff 2012; McAnany et al. 2016). Fletcher’s loose classification contextualises the foregoing debates on the ‘urbanness’ and ‘strangeness’ of Maya cities (in Chapters 1 and 6 respectively). This preceding discourse
heightens the interest in foregrounding morphogenetic similarity as a lens through which to study how Maya cities function socially. Furthermore, I should acknowledge a personal research history, along with ties to the research community that add background knowledge and convenience to choosing an example of the Maya urban tradition as a test case.

Western urban tradition

The availability of large-scale contemporary city plans was deemed a non-discerning factor. Selecting a test case with historical depth, however, requires the acceptance of some basic facts from cartographic history. The production of city plans in the western world was exceedingly rare till the later sixteenth century. Likely the most notable publication is the *Civitates Orbis Terrarum*, consisting of six volumes published between 1572 and 1617. This work brings together 546 images or prospects of cities from across the world. Not all of these are city plans – there are various orthographic views as well – and those we recognise as a city plan in no way reflect the mapping standards we know today. The *Civitates Orbis Terrarum* was edited by Georg Braun and primarily engraved by Franz Hogenberg, though it combined the work of many different artists and cartographers (Historic Cities Center n.d.). Two pioneer cartographers, Jacob van Deventer (1505–75) and Joris Hoefnagel (1542–1600), produced many of the city plans contained in these volumes.

Jacob van Deventer maintained a meticulous working method. A ‘minuutkaart’ formed the overview of the entire city plan, based on measurements and sketches combined into a whole. The ‘netkaart’ displays the city’s surroundings, sometimes accompanied by a ‘bijkaart’ depicting the city’s major features in the centre, including defences, streets, and significant buildings (for more detail on Van Deventer, see Vannieuwenhuyze & Lisson 2012). A comprehensive town mapping effort in the UK, after those included in the *Civitates Orbis Terrarum*, was carried out by John Speed (1552–1629), published between 1610 and 1611. Little mapping of cities generally took place between Speed’s efforts and the Ordnance Survey maps of the nineteenth century (Carter 1972).

Archived historical plans may be the most direct sources on the historical situation of the built environment when historical or archaeological evidence is lacking, and little of the historic city is preserved in the current urban tissue. However, Lilley (2011a) stresses that historical maps are typically the result of artistic interpretation of the built environment. Furthermore, these maps do not follow contemporary projection systems. Because of their nature, Lilley says, historical maps are almost
impossible to geo-rectify. Even if this is done successfully, the results might be futile as mapped features might not correspond to what was actually there. It is not till the nineteenth century that mapmaking reaches the conventional and scientific standards upon which current standards are built. Therefore, urban morphological studies (Chapter 6) usually begin with the earliest appropriate nineteenth-century city plan. For detailed studies of the urban built environment beyond the nineteenth century, critical historical and geographical reconstructive mapping is pertinent.

The Historic Towns Atlas project (HTA), comprising editions in both the UK and The Netherlands among others, forms an initial port of call for finding out about relatively well-studied examples of historical cities (Lobel 1969; Speet 1982, 1983; Doornink-Hoogenraad 1983; Visser et al. 1990). However, because these atlases do not reproduce the historical stages of the built environment beyond the nineteenth century, their usefulness for research purposes has been questioned (e.g. Slater 1996; Rutte 2008). During the preparatory research for this book, it was found that there is potential for historically reconstructed maps to be produced on Dutch cities, but none were available. Notably, the city of ‘s-Hertogenbosch boasts an appropriate basis were such effort to be made (Rutte pers. comm. 2011; Van Drunen pers. comm. 2011). Undertaking such integrative and reconstructive work has the making of a separate project in its own right, so therefore it was not feasible to serve as a test case location.

Within the UK the medieval New Towns of Wales have been the subject of historically reconstructive mapping (Lilley et al. 2005, 2007), but Lilley (pers. comm. 2011) advised that otherwise knowledge is limited and the cities have probably remained too small over time to have seen major change and development into the present. It transpired that only Chester (Vetch et al. 2011; Lilley 2011a) and Winchester (Keene 1985) had comprehensively been the subject of historically reconstructive

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3. The other Dutch atlases of Amersfoort, Venlo and Bergen op Zoom were not readily available to me for consultation at the time of writing, but follow a similar set-up to the ones cited here.
4. Relatively speaking, many urban archaeological projects have been carried out over the years (for an overview, see Bossche Encyclopedie n.d.). Van Drunen keeps a GIS with the architectural historical surveys of some 3000 buildings, including 1700 buildings within the old expanded city walls. A space syntax approach on the medieval street pattern’s topology incorporating information on the location of professional occupations can be found in Craane (2009). This approach requires less built environment detail (see Chapter 6).
5. Although this book limits itself to testing and demonstrating BLT Mapping principles, the potential to upscale the selected test case to incorporate the whole city as an illustrative and interpretive case study at a later date was deemed important upon selection.
or sequence mapping (Chapter 6). The more recent effort on Chester only produced a time-slice for the situation of around 1500. The inclusion of archaeological evidence and the use of GIS mapping techniques could have created an easier basis for initial testing. Yet, the availability of three medieval time-slices on Winchester (1550s, 1417, 1300s), therewith setting the benchmark for historical work on city environments for long after its appearance (Bisschops pers. comm. 2011), proved persuasive. Thanks to this benchmarking potential for greater time-depth⁶ in future research, Winchester was selected as a test case.

Winchester (close to the UK’s south coast), like Chester, is a typical historical English (and western European) example of a densely settled urban landscape based on a persistent medieval pattern with Iron Age and Roman antecedents (cf. Conzen 1960). Winchester’s mappings completely result from a historical research process (see Keene 1985), therefore exemplifying the opportunities offered by digitising historical legacy data – notwithstanding that these could be improved upon by incorporating available, if dispersed, archaeological records (e.g. Scobie et al. 1991). As it stands, Winchester’s test case can demonstrate the relevant differences between using results from purely historical and archaeological mapping; the two disciplines that crucially expand the source material for the comparative social study of inhabited urban built environments.

Finally, it should be noted that none of these reconstructive mapping efforts reach the level of individual buildings’ fabric. Historic records, and regressive urban morphology in tandem, usually refer to the building plot rather than what occupied it. This means that for the purposes of BLT Mapping, additional ‘working conjectures’ are necessary to rectify this absence of material evidence. This will be part of the method described later in this chapter.

Maya urban tradition

The selection of the Maya case study has been informed primarily based on the intensity of mapping and thus the availability of archaeological data. Recent technological progress – specifically airborne Light Detection and Ranging’s (LiDAR) ability to digitally strip forest canopies

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⁶ Keene’s (1985) work was preceded by Biddle’s (1976) volume on early medieval Winchester. The plans contained in this volume, due to the restrictions of fragmentary historical and archaeological evidence, could not be prepared on the same plot level of detail as Keene’s plans and thus would not be suitable for this research method.
to produce ground surface Digital Elevation Models (DEM) – is advancing the availability of increasingly detailed and comprehensive archaeological city plans (see Evans et al. 2007; Marcus & Sabloff 2008; Sinclair et al. 2010; Chase et al. 2011a, 2011b, 2016). Nevertheless, readily accessible (i.e. published) Maya city plans still concern the results of traditional topographical surface surveys of visible remains (Peiró Vitoria 2015). The nature of tropical archaeological remains – usually badly deteriorated by years of overgrowing reforestation and erosion, and therefore difficult to access and measure – implies that a comprehensive plan of the full extent of a city on the level of detail required may not exist, despite some large-scale long-term archaeological mapping projects.7

The increased visibility of archaeological remains in the dry northern Maya lowlands on the Yucatán peninsula means better mapping has been possible there. This preselection revealed two likely candidates to provide a test case. The first is Mayapan, originally mapped in the 1950s (Pollock et al. 1962). Since then, the Economic Foundations of Mayapan Project (PEMY) (n.d.), directed by Marilyn Masson, has been improving the city plan by integrating several additions, notably including Russell’s (2008) extramural areas and estimates (see Hare & Masson 2012). This last project is also adding the results of a complementary LiDAR survey of the area (Hare et al. 2014).

Mayapan happens to be known as a relatively unusual site. It was one of the latest major centres of the Maya culture area to thrive. Furthermore, it is known for featuring a high density of architectural structures in comparison with other Maya sites, and is also uncommon in being walled (for context see Hutson 2016). Few defensive walls are known in the Maya culture area (Ek Balam is a notable well-documented exception), especially after recent doubt was cast on the existence of such defence works in Tikal (Webster et al. 2007; Silverstein et al. 2009).

Due to the quality and availability of the early comprehensive map of the walled city (Pollock et al. 1962), some spatial analysis has already been tried on Mayapan. Pugh (2003) studied specified building type configurations and associated cluster analysis on ritual or ceremonial architectural assemblages. Brown & Witschey (2003) conducted fractal

7. No comprehensive overview of the research on, and mapping of, Maya urban sites exists. This tentative conclusion was reached after conducting my own search of Maya site surveys, consulting both literature and several Mayanists for their opinion. Soon after, Peiró Vitoria’s (2015) research reproduced and assembled the greatest collection of Classic period urban centre plans in a single volume, in the process basically confirming this assessment.
analysis on Mayapan to support interpretive arguments for the existence of administrative self-organising subunits. Hare & Masson (2012) extend such studies, especially based on a variety of basic metric density analyses, acknowledging that there may be several political or societal models at play. By looking at the density of ‘elite building types’ (cf. Folan et al. 2009), in relation to other features and specifically wanting to connect polity administrators to local populations, Hare & Masson attempt to understand the neighbourhood structure of Mayapan (see also Adánez Pavón et al. (2009) for a spatial modelling of political catchment areas on the basis of plaza groups). Then, Hare et al. (2014) expand the urban context by placing the city in a wider settled landscape. The existence of a thoroughly evolved and digitised city plan and previous spatial analyses would have been an effective foundation for a Mayapan test case. However, as the PEMY project had not made the comprehensive city plan accessible at the time of preparing this book, data provision proved an issue.

The other site featuring a detailed and extensive city plan is Chunchucmil, located in the northwest of the Yucatán peninsula (see Fig. 7.1). Scott R. Hutson kindly agreed for me to use this material (courtesy of the Pakbeh Regional Economy Program) even though the full city plan was then still awaiting publication.\(^8\)

Thanks to its Classic period apogee of occupational remains – generally considered ca. 200–900 AD, in Chunchucmil fifth–early seventh century AD (Hutson et al. 2008) – Chunchucmil bears stronger temporal relevance to the prominent Maya urban centres of what is traditionally regarded as the pinnacle of the Maya culture area (e.g. Tikal, Calakmul, Palenque, Caracol, etc.; see e.g. Sharer & Traxler 2005; Andrews 1975; cf. the approach of Peiró Vitoria 2015). Nonetheless, Chunchucmil is also noted for featuring a relatively high density of architectural structures over a relatively large core (cf. Mayapan). This leads it to be designated the most densely occupied Classic Maya city over a sustained area (Magnoni et al. 2012) by current population research principles (cf. Rice & Culbert 1990; Sharer & Traxler 2005), despite its unfavourable natural environment. At the same time this mapped density of remains could simply reflect the good visibility across the site (Hutson \textit{pers. comm.} 2011–2013), and the scarcity of synthesised results from comparably intensive and comprehensive mapping surveys (though for initial adaptive synthesis see Hutson 2016). Furthermore, its density of

\(^8\) Just before finalising the manuscript of this book, Hutson and Magnoni (2017) published a final version of the full Chunchucmil map as part of an edited volume on the city.
architectural structures is not distantly unparallelled even for the Classic period, and the derived population estimate might only be somewhat lower than Postclassic Mayapan’s intramural core (cf. Barnhart 2005; Hutson 2016).

In addition, Classic period Chunchucmil is unique in the extensive occurrence and persistence of structural patterns of *albarradas* (Magnoni et al. 2012). *Albarradas* are often defined as dry stone houselot walls, which are more usual in the Postclassic period (Hutson et al. 2007; Hutson et al. 2008; Hare & Masson 2012). However, their use appears to be much more diverse in Chunchucmil and across the few Classic period sites where they have been found (see Fletcher 1983; Magnoni et al. 2012). Nevertheless, it has been suggested that the divisive principle of *albarradas* might have been much more widespread, but simply not preserved – assuming perishable materials could have been used for their construction instead of stones (Becker 2001). As
a consequence of their preservation (stone and rubble construction), Chunchucmil visually offers what seems to be a much more complete picture of the social reality of the built environment. At the same time, one should remain aware of the probable ample use of perishable materials to complement the archaeologically preserved built environment with e.g. internal activity arrangements (cf. e.g. Fletcher & Kintz 1983; Manzanilla & Barba 1990; Becker 2001; Hutson et al. 2007, 2008; Magnoni et al. 2012; Hutson 2016).

Chunchucmil has been subject to some spatial analysis, too. Magnoni et al. (2012) conducted a preliminary analysis on the house group assemblages and house lot areas, within a GIS with limited functionalities (Hutson pers. comm. 2013). Hutson & Welch (2016) utilise the superior visibility, detail and extent of the Chunchucmil map to hypothesise a neighbourhood structure based on the large-scale pattern of the pathways left open by the albarradas. This results in a hub-and-spoke motif, where routes into the centre ‘spoke clusters’ are structured in wedges dividing the city. They continue to support this argument, adding in evidence on a more micro-scale, strongly suggesting Chunchucmil’s appropriateness for a BLT test case. Considering the general expectation that developing mapping technologies and rapid data acquisition (see Chase et al. 2016) will promote the availability of equally extensive and detailed maps of (Classic) Maya urban centres, makes Chunchucmil an especially significant example.

Final words of caution should be dedicated to the assumption of contemporaneity within Maya city plans. Because Maya cities tend to have been abandoned (yet usually show some extent of continued population or resettlement) (Aimers 2007; Turner & Sabloff 2012; McAnany et al. 2016), the archaeological built environment remains on the surface likely date to various periods. Initially this seems in keeping with the inevitable palimpsest of the urban landscape (Chapter 6), but the archaeological argument for approximately simultaneous occupation across an entire built environment complex is less straightforward to make than the premise of accumulated historical development.

Fortunately, at Chunchucmil, the artefact assemblages roughly indicate consistency for Classic period occupation across the whole settlement, including finger extensions (Hutson et al. 2008; Hutson pers. comm. 2011). Only few of the architectural groups may not have been occupied during the sixth century (Magnoni 2007; Hutson 2016). While there is a central barricaded portion that indicates Terminal Classic and even later reuse of the monumental core (Dahlin 2000; Hutson et al. 2008), Hutson assured me that the assumption
that the entire mapped layout was once roughly in synchronous use is relatively safe to make. In preparing the data, however, some decisions on poorly preserved or apparently truncated structures may need to be made to maintain one contiguous configuration for which occupation can be assumed.

Preparing the datasets of Winchester and Chunchucmil (1)

From here on, this chapter mainly follows the workflow of mapping practice that creates BLT data. Progress is tracked by the bracketed numbering in the headings. This workflow can be summarised heuristically in the following steps:

1. Preparation of datasets: acquiring, assembling, digitising and converting the source materials to the same format (usually concerns pre-existing or legacy spatial data and/or maps);
2. Mapping (tracing) the outlines of major occupiable subdivisions of the built environment as represented in the source material to create equivalent spatial information as the foundation of the outline base plan;
3. Case-specific conjecturing to resolve any remaining data gaps and ambiguities (data needs to be spatially contiguous), and subsequently revising the resultant outline base plan to ensure equivalent spatial data with topological integrity;
4. Identifying the BLTs by remapping (tracing) the outline base plan with conceptually validated individual data entries (polylines), while also revising and correcting the resultant spatial data structure to assure topological integrity.

In practice it can be expected that these steps, while presented discretely, bleed into each other reflexively (especially steps 2–3 and 3–4). This will be referred to in my report below on how these general steps play out in case work.

The initial stage of preparation means converting the mapped data to an equal and appropriate digital format across all datasets. This technical format needs to be achieved before the further steps are taken, in order to ensure that the datasets will basically represent the same level of conceptual detail and ultimately follow the same conventions to convey information. Chapter 6 highlighted the methodological and
integrative potential of GIS software. Here ESRI’s ArcGIS, version 10, was used as the primary GIS environment to conduct all methodologically specific mapping. ArcGIS was selected because of its widespread use in academic contexts, both in geography and archaeology, as well as its versatility in handling topological information in vector data (i.e. lines, points, and polygons. Lines and their connections are of paramount importance here). Nonetheless, for digitisation and data conversion other software packages were used and will be named when relevant.

The following account is provided with the aim of enabling those pursuing a similar workflow. The four steps are somewhat simplified. When working with increasing familiarity on each particular case and each individual data source, rules of thumb pragmatically emerge in the data creation processes that resolve ambiguities, uncertainty, and confusing data situations with certain degrees of subjective judgment. For our two cases and their data sources, the rules of thumb that emerged in this research are submitted at the end of this chapter. Besides such case-specific particularities, the general steps of the workflow can be pursued as stated. In this account the technical details are kept concise, and generic information on digital work is omitted. I will focus on the sequence of work and decisions for data preparation that produced usable results in the variety of situations that my test cases comprise. It can be expected that various software-based work sequences will be superseded by software updates. That means that the principles are more important than my precise actions within the software. Where instrumental for the results, the processes will be described.

Winchester maps

The Winchester city plans used consist of both the present-day situation and historical situations. The contemporary situation is based on the current large-scale mapping standard of the British Ordnance Survey, called MasterMap (from here on: MM). MM is a digital product of the Ordnance Survey (from here on: OS), updated up to every six months. The version for Winchester used was downloaded at the end of October 2011 (University of Leeds academic license for EDINA services) with the OS providing the complementary OS Imagery Layer (OS official aerial photography) and OS Address Layer (version 2) on disc in April 2012. The first historical time-slice is based fully on the first edition of the large-scale (1:500) OS city plan published between 1871 and 1872 (from here on: OS1872) (University of Leeds academic license for EDINA’s Historic
Digimap). This is in keeping with common practice established by urban morphology (Chapter 6). The additional time-slices are sourced from the reconstructed plans for the later medieval period by Derek Keene (1985), respectively for around 1300, 1417 and 1550. Within the confines of testing the methodology the Winchester case does not revert further than the period around 1550 (from here on: 1550s), which demonstrates the same principles as would apply for the processes required to use the two further possible time-slices. Future research could also consider making the temporal resolution between time-slices more fine grained.9

To emphasise, the three city plans thus used are each of a different nature. MM is a born-digital plan, fully enabled to convert into GIS formats and visualisations, and represents the best British national mapping standards of accuracy. OS1872 is, while produced to be accurate, essentially a historical document. It is acquired in geoTIFF format (i.e. TIFF image files with a basic level of georeferencing: projecting, locating, and scaling it), containing the digital scans of original sheets. Finally, 1550s is a historically reconstructed map, dependent on the academic cartographic and historical research practice producing it.10 Interestingly, the mapping standards of OS1872 feature more detail than MM. In contrast, the burgage plot based historical research of Keene (1985) to produce 1550s provides only a basic level of detail, especially omitting the architectural morphology that would give us building outlines. Regardless, before any data standardisation can take place, OS1872 needs vectorisation and georeferencing to MM, while 1550s needs digitisation and vectorisation to be geospatially linked to the other two.

Starting with 1550s: the Keene plans of medieval Winchester needed digitisation. Keene (1985) reproduces them at a 1:2500 scale, separated out in numerous small sections. While these could be scanned from the books and digitally stitched together, the match errors of so many seams would compromise the quality of the resulting plan.

9. Between the OS1872 and 1550s, Winchester’s 1750 Godson survey was also considered as the basis for an additional time-slice. A digitisation was commissioned, compiled from the two four-sheet copies held by the Bodleian Library and trialled for georeferencing in GIS. The effort was abandoned as the combination of geographical discrepancies caused by the historical survey technique, style of depiction and imprecise edge matching of the printed sheets would not yield the required detail and generate a host of topographical ambiguities. For effective interpretations of the spatial properties of individual representations of topographic features, substantive original historical research would be required. Furthermore, throughout the twentieth century various detailed city plans have been published which could serve as additional time-slices.

10. Keene (1985) prepared his plans in reference to the then current OS city plans of the 1970s, which used planimetric technology closer to present standards (Keene pers. comm. 2012). In addition the 1872 OS plan and the 1750 Godson survey were used as points of reference for shaping features in the built environment.
Therefore the originals were tracked down at the Winchester Research Unit (curated by Martin Biddle and Katherine Barclay), which stores them in the depot of the Winchester City Museum. These originals consist of large sheets of film on which the line drawing of the map was draughted. These sheets display the medieval city in only five parts: the walled area; and the north, east, south, and west suburbs. Their large-scale as well as their less fragmented and unannotated nature would likely increase the quality and direct usability of the digital end product tremendously.\(^{11}\)

To avoid photographic lens distortions, digitisation was carried out using roller scanners. These scanning machines scan large physical documents in flatbed fashion. The large high quality 400–600 dpi resolution raster images needed cleaning and filtering to remove digital noise and original blemishes on the films, enhancement for contrast and definition, and stitching together to compose one entire city plan.\(^{12}\)

Accepting MM as the standard of accuracy, georeferencing and georectification of the historical time-slices are carried out in direct relation to MM. This is alternative to a practice where a proper set of control points are set up onsite with dGPS (differential GPS, cf. Lilley 2011a). GPS error margins could cause unwanted discrepancies between the points taken and MM, which would require superfluous rectifications of MM in addition to the historical layers. Instead, assisted by Keene (pers. comm. 2011), historically persistent points in the current built environment were identified and photographed onsite for future reference. These historically persistent locations and photo directions were then documented as a GIS layer on top of MM as point data (the photographs themselves show little context). According to expectations of urban development, fewer points persisted from the 1300s than each more recent time-slice. The historically persistent points were all in relatively good condition, but there is no accounting for any errors resulting from 40 years of ageing of the carrying material (Biddle pers. comm. 2011).\(^{11}\)

Proprietary functions in Adobe Photoshop were used for these processes. Photoshop puts a cap on the maximum pixel count (30,000) in either of the two dimensions of raster files. This may inhibit the use of very large files, requiring one to reduce resolution before processing. The first roller scans were produced at 400 and 600 dpi, courtesy of Geoff Denford, Winchester City Council. Additional scans of oversized documents were made at the University of Portsmouth by Katherine Barclay at 500 dpi on a larger roller scanner. The quality of definition on the 500 dpi scans was intrinsically superior, possibly due to other technology in the machine, but their lower resolution determined the quality of the final stitched scans. Sharp, full plans were finally produced at a manageable 400 dpi. All scans were visually improved by image processing in Photoshop, thus ensuring readable solid lines, suitable for semi-automated vectorisation (see below). The precision of the plans is inevitably somewhat compromised by the stitching process, which relies on an intuitive visual weighting of matching errors between the seams of each sheet using proprietary graphical processing tools in Photoshop. ArcGIS offers an alternative to match edges of vector files, which would be possible if the separate scans were vectorised first.\(^{12}\)

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11. The film sheets were all in relatively good condition, but there is no accounting for any errors resulting from 40 years of ageing of the carrying material (Biddle pers. comm. 2011).
12. Proprietary functions in Adobe Photoshop were used for these processes. Photoshop puts a cap on the maximum pixel count (30,000) in either of the two dimensions of raster files. This may inhibit the use of very large files, requiring one to reduce resolution before processing. The first roller scans were produced at 400 and 600 dpi, courtesy of Geoff Denford, Winchester City Council. Additional scans of oversized documents were made at the University of Portsmouth by Katherine Barclay at 500 dpi on a larger roller scanner. The quality of definition on the 500 dpi scans was intrinsically superior, possibly due to other technology in the machine, but their lower resolution determined the quality of the final stitched scans. Sharp, full plans were finally produced at a manageable 400 dpi. All scans were visually improved by image processing in Photoshop, thus ensuring readable solid lines, suitable for semi-automated vectorisation (see below). The precision of the plans is inevitably somewhat compromised by the stitching process, which relies on an intuitive visual weighting of matching errors between the seams of each sheet using proprietary graphical processing tools in Photoshop. ArcGIS offers an alternative to match edges of vector files, which would be possible if the separate scans were vectorised first.
In addition, the GIS record of listed buildings and monument sites was obtained from the Winchester City Council (courtesy of Ian Scrivener-Lindley and Tracy Matthews). These polygon and points were prepared on the basis of MM and so would relate exactly to the contemporary source. Because heritage listings serve a policy purpose (protecting and managing current sites), their shapes could not be trusted to convey any historical reality. In Winchester these heritage records followed unclear dated standards, which had not been fully integrated across the recording systems in operation over the years, and exclude archaeological excavation plans. Aided by online resources such as Heritage Gateway (n.d.) and National Heritage List for England (n.d.), only limited and very cautious use could be made of these records. Where possible, then, Keene’s (1985) accounts on the plots concerned were prioritised, but the records did indicate plausible historically persistent features for the 1300s through to the nineteenth century.

For unclear reasons, the less permanent command ‘Update Georeferencing’ did not function on the OS1872 files, requiring a definitive transformation directly. A backup of the original raster image in combination with saved link tables makes sure the process can be repeated and corrected if necessary.

### Table 7.1 Results of georectification for the OS1872 time-slice.

<table>
<thead>
<tr>
<th>Plan</th>
<th>No. of Points Used</th>
<th>Warp</th>
<th>RMS error</th>
</tr>
</thead>
<tbody>
<tr>
<td>OS1872</td>
<td>74</td>
<td>Adjust</td>
<td>0.03241</td>
</tr>
</tbody>
</table>

The low RMS error is not a reflection of visual precision, but could be explained by the combination of local and global correctives that the operation ‘Adjust’ uses, which corresponds with the much higher density of control points within the walled city as opposed to the suburbs.

Although OS1872 is delivered with a basic level of georeferencing, to achieve a closer geographical match with MM these control points were used on that time-slice also.

Initial georeferencing of OS1872 using these control points enabled me to pick out a series of additional points across the time-slices that clearly related to specific corner and intersection locations in MM. Employing ArcGIS proprietary higher order georectification warps, through an iterative and visual process of selecting appropriate points and warps, such additional points improved the relative accuracy of each time-slice. In the georeferencing process errors cannot be avoided (see the result in Table 7.1). An additional error is introduced as an effect of OS1872 consisting of multiple sheets. The sheets of OS1872 were published separately over two years, while the city was developing at a rapid rate, causing imperfect matches (see Fig. 7.2). The rectification can be fixed by transforming the raster file (most effective is saving to TIF with LZW compression), which creates a new raster dataset.

13. In addition, the GIS record of listed buildings and monument sites was obtained from the Winchester City Council (courtesy of Ian Scrivener-Lindley and Tracy Matthews). These polygon and points were prepared on the basis of MM and so would relate exactly to the contemporary source. Because heritage listings serve a policy purpose (protecting and managing current sites), their shapes could not be trusted to convey any historical reality. In Winchester these heritage records followed unclear dated standards, which had not been fully integrated across the recording systems in operation over the years, and exclude archaeological excavation plans. Aided by online resources such as Heritage Gateway (n.d.) and National Heritage List for England (n.d.), only limited and very cautious use could be made of these records. Where possible, then, Keene’s (1985) accounts on the plots concerned were prioritised, but the records did indicate plausible historically persistent features for the 1300s through to the nineteenth century.

14. For unclear reasons, the less permanent command ‘Update Georeferencing’ did not function on the OS1872 files, requiring a definitive transformation directly. A backup of the original raster image in combination with saved link tables makes sure the process can be repeated and corrected if necessary.
incorporating the warp. On this basis vectorisation takes place. Since
for OS1872 this immediately entails extracting the base plan, this is
described later.

Taking into consideration the intensity of the mapping processes to
carry out initial methodological tests for diachronic comparisons, a small
test area (approx. 175x200m, Fig. 7.3) was selected to proceed work on
Winchester. This area was deliberately chosen to include an intramural
and extramural part of the city where the city wall has been removed, so it
would show clear contrasts between persistence and change. The eastern
part of the city centre, around the former East Gate and bridge, offers good
diversity of spaces within a historically well-developed suburb of the city.
Nonetheless, note that a small section could never incorporate the full var-
ety of spatial morphology within the urban built environment concerned.
For the next historical time-slice, 1550s, the approach differs from OS1872. As original scans, after image processing (cleaning, enhancing and stitching) the file is as yet completely ungeoreferenced. Since the image file contains an unannotated line drawing (similar in nature to Fig. 7.2, without text), classification in two value classes only (i.e. a bitalonal image) would make it susceptible to automated vectorisation. Thus prioritising vectorisation, I established separate feature classes (geodata files) to distinguish Keene’s (1985) own original historical conjectures from urban features he deemed certain at the time. On this basis, 1550s was vectorised before georeferencing and georectification, thereby significantly improving the manageability of the file size in the ArcMap environment.

Gregory & Ell (2007) warn that although in principle the historical researcher’s best friend, automated vectorisation is not sufficiently effective in practice to take over vectorisation. The extent of manual editing afterwards would be equal to the manual vectorisation process. In spite of several years of development, even on the very clear line-drawn 1550s map I had to decide that fully automated vectorisation could not be trusted. Issues occurring include: undue cessations along thinner lines,
directional confusion along thick lines and unintended disorder along dashed lines (the software does not recognise drawing conventions). However, *ArcGIS*'s ArcScan tools provide a semi-automated form of vectorisation, which significantly speeds up the manual tracing of the original image with polylines. This process still requires human intervention to avoid improper ruggedness in the shape of polylines derived from thicker originally scanned lines. The upside is, however, that one has direct control over the data produced, significantly reducing the aforementioned errors from automation.

Confusingly, the geoprocess akin to georeferencing raster image files is called ‘spatial adjustment’ in *ArcGIS* when it concerns geographically relating vector data to another dataset (here the vectorised 1550s layer to MM). Fortunately, spatial adjustment operates on very similar principles and thus ends up being quite intuitive for those familiar with raster georeferencing. Because in spatial adjustment snapping exactly onto vector data nodes is enabled, much more accurate placement can be achieved (directly connecting the node within 1550s with the respective node in MM). When the internal scale between the vector datasets is equal, the remaining error should come out nought between co-located nodes (i.e. in the exact same geographical location across layers). Where one is certain a selected node is identical between the two vector layers, these can be fixed as a geolocated connection (hammering in a virtual nail to join both layers) called an ‘identity point’. Now, in subsequent geoprocessing to warp the dataset, this point cannot move from its position (contrary to control points in georeferencing). This warp process is called ‘rubbersheeting’, which entails the stretching of vector data between the identity points based on additional control points added locally to achieve a more precise match. Determining 42 identity points in total over an area of approx. 600x600m, encompassing the test case area, proved sufficient for the successful processing of the data assisted with locally added control points. No residual error is produced in this process.

**Chunchucmil map**

In contrast to the Winchester plans, the Chunchucmil map results from an original archaeological topographical surface survey. This intensive process entailed pacing from the corners of a 20x20m grid system with a compass to map archaeological remains. This grid system was based on a pre-existing grid left by henequen cultivation expanded with additional grids using theodolite measurements, and connecting them up using high precision GPS (Hutson *pers. comm.* 2012). The archaeological plan was
acquired directly from Scott Hutson (courtesy of the Pakbeh Regional Economy Program) in digital format. Hutson directed and completed the mapping project on Chunchucmil, taking over from Bruce Dahlin. Frequent contact with Hutson was invaluable to preparing the GIS, and using and interpreting the plan. Being the product of an archaeological survey, it contains the interpretations and professional judgments of the mappers. In mapping archaeological remains the result comprises a representation of an empirical material situation as encountered onsite. At the same time, the exact condition of the onsite empirical situation cannot be conveyed just by the lines composing the map. In order to better understand why the mapped lines appear as they do, i.e. their characteristics as lines rather than what the legend tells us they convey, contact with Hutson was indispensable.

As said, for Chunchucmil’s archaeological plan I will assume the synchronicity of ca. sixth-century occupation. The map cannot serve for diachronic comparisons. The abandonment of the city left traces of a maximum phase of occupation covering a large area contiguously. No large Maya site has ever been excavated in its entirety, and investigations into earlier phases of development is typically confined to monumental architecture in the centre and individual buildings (Fash 1998). Such research indicates that monumental architectural successions often consist of superposing a new phase onto the preceding one. Andrews (1975) shows the hypothetical evolution of a ‘quadrangle group’ of buildings, in which the group increasingly clots together with elaborate architectural volumes from several related but separate buildings. Ultimately, we know precious little about the development of cities on a settlement scale. In the case of Chunchucmil work done on the chronology of the settlement, based on limited excavations, suggests a ‘filling in pattern’ that maximised the system of albarradas (Stanton & Hutson 2012). The finger or corridor extensions leading to outlying satellite centres of settlement appear to have been actively occupied during roughly the same period as the rest of the city (Hutson et al. 2008). Only additional archaeological research could enable efforts towards reconstructing earlier phases of the urban built environment.

The main purpose of the Chunchucmil test case is to demonstrate the compatibility and effectiveness of applying BLT Mapping to archaeological data, revealing radically different urban traditions. To account for the relative unfamiliarity with this urban tradition and the lower density of built features, a considerably larger area was selected to conduct the test case at Chunchucmil. On Hutson’s (pers. comm. 2012) advice, a test case area was selected on the northwest side of the monumental core.
The approximate location and extent of the test case area indicated within the archaeological map of Chunchucmil. Please note that in this overview map the detail of the archaeological survey has been simplified. (Base map courtesy of the Pakbeh Regional Economy Program with help from Scott Hutson.)

(see Fig. 7.4), where consistent observations during mapping raised the expectation that preservation is slightly better than for other parts of the site. The test case area covers approximately a square kilometre north-west from the site’s mapping centre, overlapping a small section of the monumental core. This represents almost a tenth of the total contiguously mapped area of the city and is intended to contain a reasonable proportion of the spatial morphological variety of the built environment.  

15. This area does not stretch far enough to also include the more dispersed settlement mapped farther away from the monumental core.
an eye to up-scaling the test case to a full-blown case study in the future, the whole map was subjected to the initial data preparation.

The mapping of Chunchucmil took place over a period of 12 years, during which many team members were involved in the work. Contrary to more recent archaeological practice, it was early on decided that the city’s plan would be drawn up in Adobe Illustrator (.ai extension). This is not software with GIS capabilities, but visually oriented graphic software, albeit functioning in vector format. This means that although the Chunchucmil plan concerns born-digital data, none of that data is geospatially stored. Therefore the data had to be converted to an ArcGIS proprietary format, and geospatially located and projected before further work could commence. Unfortunately the .ai format could not directly be imported in ArcGIS.

This inability necessitated a laborious conversion process for legacy Adobe Illustrator data, which was originally set out by Wunderlich & Hatcher (2009). This process could roughly be followed, but software updates make the processes here slightly different. Most of the process takes place in Adobe Illustrator itself, which serves to prepare the data for conversion to other formats and to avoid conflicts or corruption at that stage. Since software is constantly changing, this process is not reproduced in full. The generally important steps include the separation of all image layers, especially to separate out different kinds of digital information (e.g. lines, text, fills). To preserve the shape of automatic visual renders (e.g. curves) of drawn features, the distribution of the anchor points (vertices) needs to be densified. This way the locations of points giving a polyline its more precise shape can be maintained in other formats. Adobe Illustrator can then export the separate layers to AutoCAD formats.

Following Wunderlich & Hatcher (2009), a hereditary AutoCAD exchange format was used (the 2000/LT2000 version for .dxf), which is assumed to store information in a simpler and more stable way than newer versions. Interestingly, no stage of the process requires the operation of a version of AutoCAD software itself (although one might want to check the condition of the data). ArcGIS is then able to import .dxf files, but for unclear reasons the ArcGIS proprietary conversion tools produced grossly compromised results, beyond easy repairs. Through trial and error it was found that MapInfo Professional’s Universal Translator tools produce reliable results. Here the file converts first from .dxf into Mapinfo’s proprietary .tab, and subsequently from .tab the same tool can convert to .shp (i.e. shape file) developed for ArcGIS and other GIS packages. These shape files, finally, can be loaded in ArcGIS.
without issue (text annotations still remained unsuccessful throughout this conversion).

In addition to converting the .ai data to sufficiently reliable .shp format, the .ai map was converted to PDF, and in turn in Adobe Photoshop converted to TIFF. Since the originally shared map only showed a partial grid around the site’s centre, the same was done for the PDFs (provided at a later date) containing the 10 gridded blocks with labelling in which the site plan was organised. These blocks provide coded references for mapped features to improve navigation and referencing across the city plan. Adding a raster image layer of the whole city plan as a dataset in ArcMap enables essential visual checks for the integrity of the converted vector data, and shows the annotations (labels) that did not convert well in the earlier process, aiding interpretive work. After assigning the correct projection to the imported raster data, using the coordinates for the site’s centre point, the TIFF containing the entire plan could be georeferenced. Knowing the partial grid across the centre consists of 250x250m blocks, the georeferencing could be scaled (using five points on the grid in quincunx fashion). This can subsequently be extended to include the grids of the 10 label blocks by using the four extreme corners of each grid. The results of this georeferencing process can be found in Table 7.2.

Next, the generated shape files containing the vector data of the original plan were imported as layers in the GIS. Using the spatial adjustment tools as described for Winchester, referring to the four extreme corners of the partial centre grid (this grid was included as part of each separate .ai vector layer before), each layer could be displaced and scaled exactly (i.e. literally without processing error) onto the corresponding coordinates. With the vector layers overlaying the raster images, the quality and integrity of the vector data conversions could be checked for each detail as well as for overall completeness. On inspection, only few minute details seemed to be missing (likely due to visual rendering techniques). As relatively easy manual edits could resolve any issues in subsequent processes preparing data parity (below), the data were deemed fit for use.

16. Now, fully integrated versions of the map can be downloaded at Hutson & Magnoni (2017) in .jpg format.
17. (Projection system (in metres): UTM>WGS 1984>Northern Hemisphere>UTM zone 15n). Although several GPS points were recorded across the whole of Chunchucmil, the inherent errors of GPS geolocation technology would add unnecessary uncontrollable errors in contrast to using the regularity of the calculable coordinates across the grid system.
Making outline base plans and resolving data gaps (2, 3)

The next stage for both test cases is to prepare an outline base plan, which as an end product upholds the standard of spatial equivalent information decided on for the study. Making an outline base plan actually involves two separate steps: mapping major occupiable subdivisions (2), and complementary conjecturing (3) to resolve data gaps. While two distinct processes, it is pragmatically more convenient and efficient to consider both steps when scrutinising each section of urban space. The principle of the outlines of major occupiable subdivisions composing the built environment and what they convey is explained in Chapters 4 and 5. The comparative information standard depends on the resolution and purposes of the research, and the researcher’s judgment on separating the interior and exterior domains (cf. Hillier & Hanson 1984; Chapter 6). This standard determines the level of detail on which features of the built environment are designated a proper outline. Prior knowledge of the

<table>
<thead>
<tr>
<th>Raster file (coverage)</th>
<th>RMS error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chunchucmil’s entire plan</td>
<td>0.01945</td>
</tr>
<tr>
<td>Block 0</td>
<td>0.00543</td>
</tr>
<tr>
<td>Block 1</td>
<td>0.00952</td>
</tr>
<tr>
<td>Block 2</td>
<td>0.00339</td>
</tr>
<tr>
<td>Block 3</td>
<td>0.00887</td>
</tr>
<tr>
<td>Block 4</td>
<td>0.00030</td>
</tr>
<tr>
<td>Block 5</td>
<td>0.00072</td>
</tr>
<tr>
<td>Block 6</td>
<td>0.00274</td>
</tr>
<tr>
<td>Block 7</td>
<td>0.00574</td>
</tr>
<tr>
<td>Block 8</td>
<td>0.00605</td>
</tr>
<tr>
<td>Block 9</td>
<td>0.00329</td>
</tr>
</tbody>
</table>

The errors have been kept low by closely zooming in on the relevant intersections of the grid in each raster image, then entering the calculated (thus accurate) coordinates manually into the link table.
BLT definitions, which will eventually be applied, can sometimes guide particular decisions on which lines to include or exclude as outlines. It is important that for comparative purposes the same standard can be achieved across all datasets intended for comparison. The ultimate aim is to lay a basis for equivalent spatial data with the same internal consistency and detail.

Winchester base plan

Preparing an outline base plan on the basis of MM is less straightforward than its contemporary pedigree suggests. MM as a mapping product aims to satisfy policy and legal use requirements, as well as depicting the physical layout of the built environment. MM omits entrances to buildings, while many separate single buildings are represented by several polygons. How these polygons construct a comprehensive building remains unspecified. This contrasts sharply with the way material information is conveyed by archaeological mapping. Here the OS Address Layer (version 2) will give an indication of the location and number of addresses at an approximate location, which helps the interpretation of the physical and social reality. Nonetheless, it cannot securely serve to generate the aggregates of polygons that represent each building completely. Furthermore, MM keeps a record on the development of features (extensions, adjustments, etc.), which adds further polygon confusion, preventing one from grasping empirical reality. MM also offers very basic and generalising land use classifications, and will often (but not always) indicate the provenance of a feature as either ‘natural’ or ‘man-made’. Yet, most man-made open spaces are merely described as ‘multi surface’ or ‘general surface’, which does not reveal much of the empirical reality that is actually mapped.

This demonstrates that even when working on contemporary maps, pragmatism (rules of thumb) is an absolute necessity to map a base plan. Given that MM records the contemporary situation, further information sources can be used to interpret the empirical situation represented. These sources are Google Street View, Google Maps, Bing Maps, and the OS Imagery Layer (vertical aerial photography). Although this can clarify much of what is represented in MM, including revealing minor discrepancies with on-the-ground reality, still various aspects of the built environment are largely inaccessible to us. This restriction mostly concerns the backs of buildings and their gardens, small alleyways, or legally and

18. Online mapping and imaging resources can be updated without prior notice. The work on Winchester took place between May 2012 and April 2013.
functionally censored areas. When absolute certainty is required, only a dedicated urban survey might be able to fill in the gaps left after cross-referencing various sources.

So, creating outlines based on MM involved intensive cross-referencing of various sources – photographic sources being the most intuitive – to select those lines which, firstly, convey physically existing outlines only and, secondly, are not part of internal design or composite functions within an occupiable subdivision. In exceptional instances, original MM lines received minor amendments to more precisely convey the actual physical difference on the ground and represent the topological connections accordingly. The greatest ambiguity is associated with separating buildings by internal divisions (e.g. adjoining or terraced housing) and, likewise, with complex plots, and open areas around the back. Ceteris paribus the general assumption across the whole was that in inaccessible areas all lines of MM would be physically recognisable onsite. Therefore, in principle, all features could potentially be used as outlines. Although MM itself is topologically integrally developed by the OS in GIS format, the tracing of lines is a manual process, using ArcGIS editing tools to produce original data. The result of determining outlines in MM is shown in Fig. 7.5.

Likewise, OS1872 introduced its own interpretive difficulties and ambiguities. Some ambiguities are created by its two-year publication period, showing the city in development (see Fig. 7.2). Because the preparation of the base plan is a manual editing process, any mismatches were intuitively weighted to retain more or less continuous regular shapes (see Fig. 7.6). The image resolution and definition, as well as some detailed use of symbology, made OS1872 unsuitable for using the semi-automated raster tracing with ArcScan. Therefore, the vectorisation entailed a manual redrawing of the lines intended for the base plan.

Digitally delivered historical OS plans do not come with a legend explaining the symbology and abbreviations used. Although Oliver (1993) mentions the existence of coloured versions of OS1872, these were not available via EDINA’s Historical Digimap services – hence, the simple black-and-white line drawing shown in Figs. 7.2 and 7.6. This often makes it ambiguous as to what kind of (physical) distinction is represented by each single solid line. Coloured plans normally convey differences between built-up areas and open areas, as well as to a degree the materials used (Oliver 1993). Nonetheless, relatively accurate reading of OS1872 can be achieved through intensive study alongside consultation of other maps of the same era at the same scale (see
OS1872 clearly attempts the comprehensive representation of the physically present features of the city. The general resolution for detailing was 15cm on large-scale city plans (Oliver 1993), which displays greater architectural details than MM. In addition, functional furnishings of the city were often included. Strangely, contrary to Oliver’s supposition, gates and doorways are not consistently featured on OS1872, while archways (in walls) do appear.

Vectorising towards an outline base plan thus involves selections and interpretations (e.g. excluding the furnishings and some architectural details, see Fig. 7.6). Similar to MM, accuracy cannot be guaranteed for areas around the back of buildings or within larger building
complexes. These are too compositely mapped to make secure inferences on what each line conveys. Likewise, separately mapped extensions were interpretively incorporated or divided into discrete buildings with internal divisions. Outbuildings are particularly complex as a great variety was used in the Victorian city. Instead of including each feature separately, clusters of outbuildings were given a single outline. Already having the outlines of MM to refer to, in manually vectorising OS1872, features that are tantalisingly close to MM lines were traced directly, so these become consistent data through time. When the shape and direction changes in OS1872, the MM lines were deviated from.\textsuperscript{19}

\textsuperscript{19.} The Winchester City Council records mentioned earlier could only rarely (at the frontage) be trusted to convey a feature that could be historically projected into the past for OS1872 or 1550s.
1550s was vectorised at the previous stage of the process. This vectorisation comprises the merged data of the adjusted plot-based and conjectural mappings of Keene (1985). Due to the historically self-selective reconstructive mapping process responsible for the creation of this data and its coarse plot level of detail, 1550s includes no unnecessary or confusing detail. The challenge for producing a base plan here is rather the reverse. The limitations of topographical reconstruction on the basis of the historical records (see Keene 1985; cf. Bisschops 2012) may cause unaffordable gaps preventing it from serving as an outline base plan. As mentioned, most conspicuously, buildings are not included (except for those with public and administrative functions). Importantly, as the plans are based on property records, little certainty exists on the physical empirical reality of the lines. Moreover, beyond the surface of a single property, no physical subdivisions are mapped. Keene’s (1985) abstracts of compiled historical records on each property in his gazetteer are used to detect clues about the possibility of multiple buildings, plots or gardens forming part of a single property. Oftentimes evidence for what was on a property is scant or even entirely absent (which also causes some of Keene’s own conjectures). This implies a rather crude level of conjectural mapping to add the missing built environment features as the following step, which then merge into a comprehensive outline base plan.

Keene’s (1985: Fig. 155) smaller-scale plans, indicating the built-up and probable built-up frontages along the streets, provide an additional source in aid of building conjectures onto property plots. This information is used to decide that a building needs to be conjectured. However, there is no pretention that the shape of a building reflects reality. Lewis et al.’s (1988) book Medieval Hall Houses of the Winchester Area depicts three examples of shops surveyed in the city of Winchester, which were between approx. 10 and 15m in length. These dimensions are taken as a rough maximum for typical buildings in the test area, alongside the more detailed knowledge of smaller separate properties along the High Street area. Without readily usable direct sources to ground morphological intervention, ensuring the base plan includes topological distinctions is deemed more important than the appearance of buildings and garden plots.

20. As opposed to archaeology (mapping all material remains) or remote sensing technology (detecting all physical features of the actual situation), historical reconstructions are self-selective due to being restricted to a preconceived level of detail that is available in, and taken from, the sources.
To illustrate the coarse effect this practice has, Fig. 7.7 shows the clear difference between the west and east sides of the northern end of current Chesil Street. The west features large subdivisions on sizeable plots, because no evidence was available beyond the suggestion that this area could have hosted a few substantial medieval buildings. The east, however, has been subdivided into smaller built environment features according to plot sizes. The one historical building still in existence (The Old Chesil Rectory) was indicated to feature two tenements with a probable communal arched entrance (Keene 1985). The neighbouring plots in that sequence feature frontages (probably built-up, according to Keene) with comparably dividable dimensions (4 or 5m each). On the

Fig. 7.7  Crude conjectural effects in the 1550s outline base plan.

The effect of crude conjectures based on scarce information on the material situation within the test case area. Dark grey depicts the lines based on Keene’s original plan, pink the building and plot conjectures added. (Image prepared on originals, reproduced courtesy of the Winchester Research Unit.)
opposite corner, towards the north, there is an indication that at some point during the late medieval period there could have been six shops occupying this site. In these cases, the open areas behind the buildings are not subdivided as they could well have been shared. Open areas are only subdivided if prompted by Keene’s (1985) discussion of the records.

Although these conjecturing efforts ensure the same level of detail on a conceptual level – restricted by the self-selectiveness of historical reconstructions, fragmented archaeological records or even the different nature of geographically representative city plans (e.g. MM vs. OS1872) – true equality in actual detail cannot be guaranteed. It would be a gross over-interpretation to start conjecturing absent outbuildings or architectural details. As a consequence, comparative analysis wishing to include more detailed sources should justify the simplified composition of other sources accordingly.

**Chunchucmil base plan**

Since the Chunchucmil plan originated as vector data, the process of creating a base plan is predominantly limited to tracing the appropriate lines with ArcGIS editing tools, as was the case for MM. Because by their very nature archaeological remains are fragmentary, straight away regular editing tools were used for conjecturing any apparent gaps in information. First, however, tracing those lines determined to be outlines revealed structural issues with the digital data and the topological integrity of composed features. The compromised data structure most probably results from the initial Adobe Illustrator drawing technique.

Visually presentable figures revealed line constructions that were unsnapped or simply did not match the features’ geometry in minute detail (Fig. 7.8). Effective tracing requires continuous (non-interrruptent) lines. Despite measuring no more than a few centimetres or millimetres in geographical space, copying these errors by tracing would compromise the topological usability of the outline base plan. Therefore the tracing process required additional editing to clean up and sometimes completely redraw features, ensuring a proper topological structure for the outlines, which are always conveyed by a single polyline. Similarly, mapped features within and across different classification

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21. Little is known about the actual (physical) subdivisions of open areas associated with buildings in the medieval period. Archaeologically there could have been fences, paths and hedges (cf. Becker’s (2001) perishable albarradas), all used to section off small bits of space. In any case, it seems likely the medieval city saw a variety of plot divisions and shared open areas (Dean pers. comm. 2013), which is also suggested throughout the properties in Keene’s (1985) gazetteer.
layers (e.g. architecture and *albarrada*) can come conspicuously close to connecting – yet virtually never do these features truly connect. As a rule of thumb, detached mapped features of equal or different classifications would be connected (as snapped polylines) immediately within the outline base plan GIS layer if approximately under 50cm of width. Any larger yet analogous or conspicuously positioned gaps would be connected in a separate conjectural layer.

After having traced all originally mapped features that designate outlines, conjectures were also used more progressively. These more progressive conjectures are intended to fill in the inevitable data gaps due to fragmentary archaeological preservation. Both to respect the theoretical foundation (Chapters 3 and 4) and to enable topological spatial analyses, it is required that all the integral subdivisions composing the built environment are included as a base layer of information, avoiding any data gaps. To date, no other Classic Maya city is known to manifest such a constellation of elaborate house groupings, pathways and boundary walls in the areas outside of the monumental centre (Hutson et al. 2008;
Magnoni et al. 2012), so conjecturing analogically is largely unfeasible. Therefore I decided to follow a bold but distinctive approach to conjecturing.

First, fragmented buildings would be finished continuing the shapes suggested in the observed remains. Second, fragmented boundary walls are completed exclusively with straight lines (without crossing any others), directly connecting two ends of mapped lines of the same class or onto another feature, using parallel and perpendicular alignments (see Fig. 7.9). In the highly irregular and curving urban form of Chunchucmil, straight lines will emphasise that these conjectures are not intended to represent informed reconstructions of the actual features’ shapes. Instead, they complete the spatial data by restoring a close approximation of the expected topological

Fig. 7.9  Extract of Chunchucmil’s base plan with conjectures.
This extract consists of traced outline features (in grey) and minor and coarse conjectures (pink). (Image prepared upon original data, courtesy of the Pakbeh Regional Economy Program with help from S. Hutson.)
relations that would have existed between subdivisions. While this unavoidably affects the morphological integrity of the data, suggesting actual morphological knowledge of the features amounts to over-interpretation. Conjectured information can always be retrieved as this is kept as a separate data layer (see Fig. 7.9). Naturally, if no suggestive archaeological remains at all were mapped, no additional conjectures are invented.

These crude conjectures are a requirement of the conceptualisations behind this boundary approach (as based on outlines of discrete subdivisions, Chapters 4 and 5). It is not suggested here as general archaeological practice, and is not a necessity for each form of analysis and interpretation on the basis of the plan (as demonstrated in Magnoni et al. 2012; Hutson & Welch 2016).

To ensure critical evaluation, the complementary conjectures went through three iterations. The initial phase concerned the coarse connecting up of features on screen. Then these were revised based on the principle that directly or indirectly all spaces within an urban environment must be accessible to partake in the socio-spatial inhabitation of the city. This comes down to: how is one able to traverse the site respecting the actual physical barriers mapped? As a shorthand to revealing possible accessibility patterns, open surfaces and alleyways affording movement, flow, and access to building complexes were drawn on a semi-transparent sheet over a high-resolution printout of the test case area. The conjectures were then adjusted accordingly to better facilitate or enable traversing where necessary. The final revision is a side-effect of the actual process of BLT identification (see below). This process highlights any subdivision where a specific discrete outline was intuitively expected, but absent. The particular relationship between virtual boundaries (Chapter 5) and conjectures is discussed later in this chapter.

In keeping with outline logic, furnishings and internal arrangements as indicated by archaeological artefacts, stelae and quarries are excluded in the base plan. A quarry could only be (partially) included when its shape suggests incorporation as part of a built boundary. Querns or *metates* (grinding stones) within gaps breaking up the course of walls are taken as an indication of a probable passage way, because the arduous task of grinding in all probability had a social element to it (Hutson *pers.

22. All conjectures can be retrieved by directly comparing the traced data with the original plan. It is likely that more means and information will become available to improve and correct the conjecturing (or even a comprehensive reconstruction) when additional archaeological research is carried out. This would not just lead to revisions, but also requires adjusting any subsequent analysis accordingly.
Bedrock, however, is included as these outcrops of the natural substratum would have impeded thoroughfare and are often incorporated in boundary walls and even minor architecture.

It is a common expectation that various structures within groups of buildings could have been perishable (Becker 2001; Magnoni et al. 2012; Hutson 2016). The *chich mounds* (low piles of rubble) mapped on the original Chunchucmil plan have been suggested as having formed the foundations of (perishable) buildings (Magnoni et al. 2012). Indeed, regular placement in association with building groups of (circular) chich mounds conspicuously resembles the round architecture mapped onsite. Ancient Maya buildings do not typically straddle *albarradas* (Magnoni et al. 2012) and therefore, in revised iterations of the base plan, chich mounds with dimensions similar to round architecture and placed detached from *albarradas* are included in the base plan assuming they carried a structure. Chich mound outlines are excluded in the rare instances where they are located along (*albarrada*) margins or their shape seemed illogically irregular for an occupiable structure, though a partial edge may coincide with another outline.

Magnoni et al. (2012) offer a population estimate which is partly based on the count of residential structures (the method of Rice & Culbert 1990). The boundary approach is based on only material-spatial information and cannot consider functional links between structures par-taking in a building group. Becker (2001) gives a good overview of possible structures’ functions, but also how few of them are systematically identifiable.

There are also ambiguities such as the ‘screen walls’ connecting structures in building groups in various Classic sites, mentioned by Becker (2001; Tourtellot III 1988). These could easily be confused with remnants of communal platforms and do not often form a discrete subdivision. In such cases, the mapmakers’ expertise is a cautious guide for where they indicate a group (or platform) on the plan (with block annotations). In addition, various fragments of *albarradas* can also be found ‘dangling’ inside house-group-lots. Rather than creating actual subdivisions, these dangling lines may form part of internal arrangements in concordance with the activity areas and perishable boundaries mentioned above.

To enable a critically reflexive research practice, all ambiguous features are initially traced as part of the base plan (see Fig. 7.10). Where a feature is clearly truncated by another feature, in the sense of being subject to later modification of any type or having become obsolete, only
the feature that appears responsible for the truncation (supersedes) is taken into account. There is too little knowledge about these architectural palimpsests on the basis of the survey alone to know the correct order or composition.

The stage of identifying BLTs is an interpretive process on top of the base plan. The BLT identification process may indicate where or how conjectures would be expected in order to complete a discrete subdivision. With this in mind, all dangles or incomplete subdividing features that remain after BLT identifications can be removed from what then would become the actual ‘final base plan’. The researcher should always be mindful of the possibility that, consciously or subconsciously, readily perceived or concealed, subjective patterns could emerge from the

Fig. 7.10  Another example of the Chunchucmil base plan with conjectures (in pink).

The green arrows indicate incomplete subdivisions (possible screen walls), while the red arrow indicates what currently looks like a real dangle. How both situations are treated will need to be settled during BLT identification. (Image prepared from original data, courtesy of the Pakbeh Regional Economy Program with help from S. Hutson.)
Topography checks for outline base plan and BLT identifications (3, 4)

After creation of the outline base plan, we must consider checking the quality of this new standardised spatial data. Despite using GIS tools throughout, making the base plan is a manual and interpretive process and thus prone to imprecision and human error. Problems similar to the ones depicted in Fig. 7.8 would inhibit the usability of the base plan data. BLT identifications in turn are based on manual tracings of the base plan, and thus require continuous lines in contiguous connections. This means that for the base plan to support this work effectively, one must ensure topological integrity throughout the dataset. Similarly, the BLT data after identification must maintain topological integrity. To this end ArcGIS has developed the ‘topology toolbar’, which can carry out several data checks based on a predetermined topology rule set. Carrying out topology checks are therefore a necessary technical step in both step 3 and 4 of BLT data creation.

To apply the tools in the topology toolbar, all separate layers (if any) making up the base plan are best merged into one comprehensive dataset. Then, within ArcCatalog, any feature class (layer), stored as a so-called geodatabase, can be subjected to a topological rule set. When the rules are validated, any found errors can be inspected and corrected within ArcMap. The first step of constructing topology rules is to set a cluster tolerance to simplify the data structure (i.e. any features below a measured threshold are regarded the same). Then the rules themselves are selected from pre-given options. Options include rules that help to make sure the data does not contain: unintended dangles; unsnapped vertices or nodes; intersections; unwanted duplication or coverages; unconnected polylines, etc. Table 7.3 shows the four relevant topology rules selected to check the base plan and, later, to subject BLT data to (step 4, described below).

23. Of course automated simplification is not ‘intelligent’. Though the accuracy is maintained to the resolution specified, at very large scales, some shapes will manifest counterintuitive alterations: e.g. right angles might have become slightly flattened and curves less smooth. Unwanted changes can be manually edited. Simplification will have a small mitigating effect on the earlier densification of anchor points in Adobe Illustrator (for Chunchucmil).
Despite technical limitations, this semi-automated process will speed up subsequent work and immediately improves the quality of any derivative data. When checking the errors found upon validation, any unfinished but ambiguous subdivisions intentionally kept in the base plan to inform the BLT identification stage, as well as all ‘edge effects’ (incomplete subdivisions truncated by the maximum extent of the test area), can be marked as exceptions in the correcting process. Genuine errors are resolved by manual editing or automated fixes.

The cluster tolerance should be a measure commensurate with the precision achieved in the mapping resolution. For Chunchucmil, 10cm was specified, which might be smaller than the actual mapping resolution achieved onsite, but would retain most of the interpreted shapes (e.g. curves) as originally mapped. For Winchester, the cluster tolerance was specified as 5cm, which reflects the higher level of detail and precision in MM, as well as the features generated in the vectorisation processes of the other time-slices directly in GIS.

Since all boundary mapping is based on outlines, its GIS layers will always consist of polyline feature classes. The essential difference with the data structure of the outline base plan and each separate layer conveying a BLT (see below) is that each polyline feature in the BLT

<table>
<thead>
<tr>
<th>Topology rule</th>
<th>Outline base plan</th>
<th>All BLTs (except Type 2, Type 4, and V)</th>
<th>Type 2, Type 4, and V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Must not have dangles</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Must not self-overlap</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Must not self-intersect</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Must not overlap</td>
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<td>X</td>
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</tbody>
</table>

24. Topology rules appear unable to handle composite rules regarding more than one feature class (layer) at once. However, they can run multiple questions simultaneously, each treating a single layer. Complementary coverages can be checked by using tools for selecting on location. It is also possible to set topology rules before mapping and check up on data created in a (semi) live way, during data editing. This could be more efficient if most eventualities are known upfront. Likewise topological rule sets can be adjusted if it is found that the rules do not adhere to the intended logic.
layers must convey a BLT identification in its entirety. In contrast, for the base plan it is only truly important that all lines that shape outlines are included, always maintaining topological integrity. If the data resulting from the BLT identifications are intended to undergo further computation for visualisation, spatial analysis or conversion into other formats, then it is paramount that not only the outline base plan, but also the BLT feature classes are checked against an appropriate topology rule set (see Table 7.3). Types 2, 4, and V are distinct from other BLTs in that they do not circumscribe a space in isolation.

The flexible polyline format enables a further visual data check. *ArcGIS* offers a tool to generate polygons from polylines by closing them. These then visualise as filled areas in *ArcMap*, which cannot happen if the lines are not continuous or the ends not snapped. (Vice versa, the interpretive intricacies of the BLT data structure cannot automatically be generated from polygons.) One should remain mindful, however, that in complex data errors are easy to overlook. Besides, generating polygons automatically lacks human understanding, so inner and outer BLT designations lead to separate polygons. So, despite offering an additional visual check, to serve alternative (analytical) purposes (cf. Magnoni et al. 2012), the generated polygons require a degree of manual editing to remove intellectually unwarranted polygons.

**Identifying BLTs (4)**

Identifying BLTs is the final and most analytical stage in the data creation or mapping process. For each instance a BLT is successfully recognised within the outline base plan, according to Chapter 5’s definitions, an individual segment of line is traced entirely. This is a manual editing process in *ArcMap*, using the tracer in the editing tools. Each data entry (i.e. each polyline) created at this stage is a complete and meaningful empirical identification of the material socio-spatial reality of a boundary operation occurring at the (historical) moment represented by the city plan. For each BLT (Table 7.4 lists the BLTs with name and number), a separate layer (feature class) is created. This improves clarity whilst conducting the accumulatively complex identifications, but it also enables immediate visualisation of each BLT separately and can visually approximate combinations of them. In addition, if the boundary method would at any stage be combined with other methods or data, each separate meaning carrying data entry can be retrieved and further information can be attributed in the spatial database.
Although the exact order in which BLT identifications are carried out is not prescribed, there is a logical starting point following the ontological primacy of seclusion. Chapter 5’s formulation of the ontology of types commences from the ability to close off (make impermeable) a bounded space (subdivision) towards undisruptive interaction from the outside, i.e. a strong seclusion emphasised from within and shielding ‘intrusive’ interactions from without. In its simplest form this creates a ‘cell’ with a relation to its outside (cf. Hillier & Hanson 1984): here represented by buildings’ impermeable material properties. Initial BLT identification thus reads the outline base plan to find these materially closable outlines of an occupiable surface (not negative). In identifying Type 1s, such socio-spatial systems are, as it were, extracted from the goings-on in their environment. This is not to say that Type 1s are a pre-requisite for other BLTs to occur (see Chapter 5) (even though an urban built environment without Type 1s would be extraordinary) as the BLT ontology of types does not fully define relations between types.

There is, however, the ontological necessity for Type 1s to require at least one Type 2 in order for the Type 1 to partake in the socio-spatial configuration and not become a negative void. A Type 1 without a Type 2 would become a Type 11 (negative), as its inside is not accessible for occupation. Because BLT Mapping is intended for built environments, especially urban settlements, the identification of any BLT implies the existence of others specifying its socio-spatial context. Hypothetically speaking, a configuration of only one Type 1 plus 2 would also be designated a Type 13 for the undeveloped surface area surrounding it (or the limits of the selected area of data coverage).

Table 7.4  List of all BLTs with name and number.

<table>
<thead>
<tr>
<th>Boundary Line Types</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
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<th>6</th>
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<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Closing boundaries</td>
<td>Closing</td>
<td>Facing</td>
<td>Associative</td>
<td>Extended</td>
<td>Directing</td>
<td>Disclosing</td>
<td>Enclosing</td>
<td>Mutual</td>
<td>Opening</td>
<td>Neutral</td>
<td>Man-made</td>
<td>Not man-made</td>
<td>Not man-made</td>
<td>Virtual</td>
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<td>Mutual boundaries</td>
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<td>Facing boundaries</td>
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<td>Extended facing boundaries</td>
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<td>Directing boundaries</td>
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<td>Disclosing boundaries</td>
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<td>Enclosing boundaries</td>
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<tr>
<td>Virtual boundaries</td>
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For abridged definitions of all BLTs, please consult the supplementary BLT table towards the back.
The singular seclusion of Type 1s (dominants) thus becomes the first identifiable point of reference in an outline base plan, from where increasingly their environment is inspected to identify further BLTs (see Fig. 7.11).

Fig. 7.11  A sequential representation of stages in BLT mapping.
A composition of six consecutive images (left to right, top-down) of the same configuration showing BLT identification starting with (A) outline base plan, then (B) Type 1 (brown), (C) Type 2 (light green), (D) Type 3 (red), (E) Type 4 (dark green), (F) Type 5 (blue) and Type 9 (pink). (Derived from OS MasterMap. © Crown Copyright 2013. All rights reserved. An Ordnance Survey (EDINA) supplied service.)
It is clear that, beyond the rugged line morphology of the outline base plan, a degree of (material) knowledge is required to identify the properties of a building (in Winchester’s MM supported by aerial photography and online mapping products). This initial stage resembles mapping a figure-ground diagram (see Trancik 1986; Fig. 7.12), as one essentially separates the built volumes from the open spaces (see Fig. 7.13). Such a figure-ground plan approximation can aid readability of the boundary visualisations.

From here on, there is an augmentative quality to the overall order of identifying BLTs that initially roughly pertains to the order of presentation in Chapter 5. In Fig. 7.11, Type 2 first qualifies the Type 1s. Then associative boundaries (Type 3) naturally encompass Type 1s, which in

Fig. 7.12  Example of diachronic figure-ground diagrams of Cincinnati.
(Image source: Scheer & Ferdelman 2001: 22, reproduced by kind permission of Jeremy Whitehand, editor of Urban Morphology.)
turn are made accessible by Type 4s. Then on a larger scale a Type 5 and Type 9 tie this configuration together.

Fig. 7.11 reveals several things worthy of note, which apply to BLT Mapping in general:

- First, the consequence that no single BLT identification can fully define the material reality that a boundary line represents means that all BLT identifications overlay each other. Situation F thus contains six BLT layers (once the BLT identification process is completed the outline base plan is no longer necessary);
- Second, the entrances (Type 2 and 4) are partly conjectured, based on (aerial) photographic sources and the shape and size of the
outlines. With such large buildings one expects more than a single entrance and entrances connecting the building with the shape of its immediate environment. Only onsite surveying can confirm how correct these conjectures are;

- Third, Type 3s encompassing Type 1s (or indeed any BLT encompassing another BLT) bound a space with an inner and an outer boundary that do not meet. That means that the two polyline features are part of (caused by) a single Type 3 identification. However, they do not concern the same boundary line. Once applied, the abstract character of BLT definitions reconfirms that in isolation they cannot capture empirical reality. The inner Type 3 coincides with the Type 1, while the outer Type 3 coincides with other Type 3s, Type 5, and Type 9 respectively (disregarding the Type 2s and 4s). The combinations alone fully describe each unique boundary;

- Fourth, this composition shows a situation in which more architectural structures are outlined than only the main building. These associated auxiliary structures (outbuildings, follies, garages, sheds, garden houses, and further functional varieties in other cultures or different historical periods, etc.) add a layer of subjectivity which commands the expert judgment of the researcher, who must decide on the auxiliary nature of such structures and apply the appropriate BLT consistently thereafter. The more pronounced and unambiguous a 'material recording' (as in archaeology) and one's knowledge of the recording process in the field, the more work can be done without any socio-cultural background knowledge. Though accuracy in the decision can increase with additional knowledge or prior familiarity with an urban tradition, the interpretive decision which outline(s) is (are) 'dominant(s)' (Type 1s) is precarious.

There would have been several ways to approach the conundrum that building groups pose (see Figs. 7.14 and 7.15). So why decide to identify the auxiliary buildings as Type 3s? I used the descriptive term ‘auxiliary’, already suggesting a relation of dependence. Indeed what this alludes to is the idea that a building is predominantly occupied by a socio-spatial system that may extend into several associative boundaries. Some additional Type 3s are strongly marked thanks to their architectural construction. When preserving these structures’ outlines as a successive Type 3 arrangement, future research wishing to distinguish architectural building types and/or functions could still be done. The current
absence of evidence (within standardised comparative boundary data) is not evidence of the eternal absence of properties allowing such further distinctions.

Nonetheless, in many cases the relation of dependence is not so clear, e.g. agricultural and industrial complexes or special design clusters of equally large or elaborate volumes. In such cases, the seclusions are validly deemed equivalent: all are identified as Type 1s. This changes the relation between BLTs. Instead of a successive Type 3 arrangement, this would become a Type 8 (Fig. 7.14: A). Without additional knowledge this distinction will always remain somewhat arbitrary, often evolving as a practice-based rule of thumb as one accustoms oneself with the patterns occurring in an urban tradition or within a case. For example, the internal comparison of material

Fig. 7.14  BLT mapping options for building groups.
A: all buildings are a Type 1, thus the open area a Type 8. B: one building is designated Type 1, the rest remains unknown. This causes impossible data gaps. C: all buildings within a group function distinctively. This requires hierarchical and/or functional information beyond (comparative) reach in spatial-material data. D: one building is designated Type 1, the rest discarded. This would mean losing a lot of architectural information.

Fig. 7.15  Chosen solution to mapping building groups as shown in Fig. 7.11.
This solution for mapping building groups retains architectural detail, while restricting specialist judgment to a more comparative binary distinction between structures (e.g. large and smaller; central and peripheral).
properties could lead to the conclusion that a farm house still bears closer resemblance to a town house than a farm shed.

The basic consideration described here makes an important contribution to comparative work. The alternatives – such as introducing a full hierarchy or functional distinctions between structures to create distinct interrelated ‘dominant complexes’ – sound attractive, but introduce false certainty (over-interpretation) about how structures are related. This could only result from the availability of equivalent additional information across datasets. Notwithstanding its interpretive nature, the chosen solution (Fig. 7.15) retains morphological detail, while only making one main binary judgment on building groups without the pitfalls of Fig. 7.14: B–D.

Maya settlements are characterised by a high frequency of grouped architectural structures. Although some might actually serve several specific functions that are associated with e.g. a house separately, extensive research also suggests that building groups would have been occupied by multiple nuclear families (Johnston & Gonlin 1998; Magnoni 2007). In Chunchucmil, for example, virtually all groups contain more than two buildings, meaning that with greater confidence these likely contain more than one Type 1. The associated open areas in either case comparably end up as a Type 3 or a Type 8 constellation, resulting from one-to-one or one-to-many building(s) relationships.

Allowing the existence of successive Type 3s (or Type 8s elsewhere) creates sequences of the same adjacent BLT identifications. Such distinctions could otherwise have been discarded as internal arrangements. Retaining this empirical reality at identification gives the researcher greater flexibility later. One could choose to disregard configurative complexes of interconnected Type 3s (or Type 8s), or one could focus part of the analysis or interpretation on specific differences they convey.

This brings me to a final point. From a purely intellectual perspective, the BLTs that do not circumscribe a subdivision but qualify the relation between two subdivisions, i.e. Type 2 and Type 4, should be traced twice, creating two polylines. Ultimately, each entrance of a boundary is a qualifying part of each co-located BLT (e.g. the reciprocity of any passage or doorway). This would therefore duplicate identifications in such instances. However, for both visual and analytical purposes this would introduce unnecessary complexity in the data structure. The length, construction and location of any such boundary is immediately recognised and utilised from the single identification. The same applies to virtual boundaries.
Virtual boundaries

Virtual boundaries (V) were introduced in Chapter 5, following from junctions where Type 5s meet (i.e. usually street crossings). Vs are an intellectual construct that chimes with everyday understanding and interaction within the built environment, but which cannot be empirically observed directly. Contrary to all BLTs, a V denotes an implied presence. This presence is implied contextually at certain positions in the empirical material reality of built boundaries: a ‘virtual extension’ is required to connect up boundaries to create discrete subdivisions. That means that in the sense of Smith & Varzi (1997, 2000; Smith 2001), Vs are a fiat presence in a bona fide material world. They are restricted by the empirical configurative context and thus less volatile than completely imagined boundaries. In Chapter 4 it was already indicated that the gaps in built boundaries serving as (closable) passage ways (usually Types 2 and 4) would be closed as feature outlines to create discrete subdivisions. When any open boundaries meet, they might be traversable via gaps where the surface material simply continues (no differentiation). The circumscribing built boundaries that leave the gap(s) morphologically suggest an experiential distinction (e.g. grass fields with intermitted fencing). This resembles the way marked space gives way to subdivisions of space (see Chapter 3).

In contemporary maps it cannot always be determined whether lines convey gaps instead of materially articulated or demarcated boundaries. In archaeology the number of Vs can be much greater, as gaps are mapped (perishable materials used for fences or doors etc.). Archaeologically, then, Vs likely become overrepresented. This starts a dialogue between conjectures and virtual boundaries. Basically a conjecture should fill in a missing material built boundary, but at BLT identification it sometimes becomes apparent that a V is more sensible, or even necessary, to traverse the configuration effectively. Vs can resolve numerous dangles remaining within the outline base plan. Especially within archaeological situations they reflect some interpretive contention also.

In Chunchumil’s case, it would be a logical expectation that there were (possibly closable) openings in albarradas which allowed people to access the areas they circumscribe. When conjecturing, boundary lines could have been created where such openings did originally exist. There is no way to distinguish on the basis of the mapped material remains whether any opening was intended, destroyed, deteriorated, caused by decayed perishables (e.g. incorporated cacti or trees), removed (by
animals or humans) after abandonment, etc. (Hutson *pers. comm.* 2012; concurring Becker 2001; Demarest 1997). At the same time, no wall or material distinction must complete a circumscription contiguously. Indeed, in Chunchucmil several platforms tying building groups together gradually descend into the ground, creating a slight ramp facilitating unimpeded access (Hutson *pers. comm.* 2012). Vs are used to mark-up situations in which missing physical differentiation would not have detracted people from experiencing the spatial distinction in the context of that location. This enables further discrete subdivisions to be mapped (Fig. 7.16). Note, however, that Vs denote places of unimpeded access,
but entrances (Types 2 and 4) do not require virtuality, nor do Vs only occur based on previous conjectures.

The dialogue between boundary line conjectures and Vs is a clear example of how BLT identification can cause changes to the original outline base plan. The Vs connecting up actual gaps in boundary lines, or marking where Type 5 circumscriptions meet, would not have been included in the outline base plan. Therefore, it is a mistake to assume that the outline base plan must already contain all the lines on top of which all BLT identifications occur. Only merging all BLT identification layers together (including Vs) will give a ‘final base plan’ copy of the BLT morphology.

**Mapping practice and the research process**

It should now be beyond dispute that BLT Mapping is also a highly interpretive process, looking beyond the formal BLT definition. The nature of each case and data source requires specific preparation, selection, and creation processes. The four-step data creation process maintains a level of iterative reciprocity (e.g. the outline base plan anticipates BLT identification and is revised by it). As I referred to previously, in mapping practice and with increasing case familiarity, rules of thumb emerge to resolve ambiguities, uncertainty and confusing data situations when preparing data in anticipation of BLT identification, and while identifying BLTs itself. A good reflexive subjective research practice must carefully document and report the (arbitrary) rules of thumb that were consciously applied in data creation. How are the rules of thumb positioned in this research process?

Let us briefly reconsider the research process so far. The BLT ontology of types serves the specific purpose of the study of the socio-spatial significance of material presence to the inhabitation of urban built environments. Therefore disparate ontologies of the built environment might be necessary when one intends to study other aspects of its existence. BLT Mapping declares and articulates its own analytical and interpretive limits through its critical realist research design, theoretical framework and resultant conceptualisations. One could immanently critique the theoretical premise of BLT definitions or the reasoning that subsequently forms its research concepts. Once applied, one could contest and demonstrate fault with instances of the identification of BLT definitions. Progressing empirical research on any city could in time also lead to commensurate revisions of both the outline base plan and resultant BLT identifications.
Furthermore, in keeping with critical realism (Sayer 1981, 2000; Yeung 1997), the BLT ontology of types itself could be improved and expanded through iterative abstraction. The iterative abstraction process then ensures that unexpected empirical situations encountered during the process of identification (i.e. flawed practical adequacy, Chapter 2) will be accounted for by revising the BLTs. In addition, correlative research might gain from retaining the specific data structure produced in this process (see Chapter 8) by combining it with other information directly using spatial database attributes. Such correlations alone could enable the asking of disparate or more detailed (socio-culturally specific) questions than the current radically comparative remit allows.

The rules of thumb in mapping practice, then, give rigour to the subjective remit of interpretive leeway that the researcher permits to account for imperfect knowledge of the source material, and the socio-spatial empirical situation that is documented by the source material. Such rules could be critiqued for inconsistent application, being overly ambiguous, or simply confront differences in professional opinion. The following explanatory lists omit comprehensive illustration of the issues described. Such illustrations would duplicate the preliminary analytical and interpretive explorations in Chapter 9.

**Rules of thumb**

**Mapping practice at Winchester**

(1) The first aspect demanding attention is particular to Winchester as a diachronic test case. In instances where the boundary line remains in exactly the same location through time (e.g. differentiations spatially close enough to justify copying back in time from later phases), any *concurring* BLT identification on that location must be identical to the more recent phase(s). So doing helps to keep the data clean by eliminating confusing insignificant differences in spatial morphology. Most instances where this applies concern historical building frontages, retaining the same doorway(s). Unsurprisingly, due to data preparation processes such as scaling and georeferencing (see above), outline base plans rarely end up in the exact same position. The upscaling of 1550s to MM alone causes a scanned line thickness of 50–60cm in geographical space (see Fig. 7.17).
(2) Due to the same line style dominating OS1872, it is not until BLT identification forces the researcher to disentangle what these lines convey that the appropriateness of outline base plan selections is revealed. Similar to the iterative revisions of conjectures in Chunchucmil, the OS1872 outline base plan revisions are more impactful during the BLT identification process than is the case for either MM or 1550s. At the same time, only OS1872 offers extra certainty for conjecturing entrances thanks to additional details on architecture, furnishings and park or garden design.
(3) Because the back of buildings cannot be satisfactorily assessed, there is little secure information on back entrances in each time-slice. The general assumption is made that back entrances are necessary for structures which have a plot around the back. Unless the shape and mutual orientation of the outlines and further identified BLTs suggests differently, the back entrance is conjectured broadly opposite to the front entrance. Only for elaborate architecture, complex contexts, or on the basis of additional factual information could more entrances be designated. It should be noted that because many entrances are conjectured (cf. Chunchucmil below) their dimension is less relevant than their topological existence. The width of entrances is at best indicative.

(4) Working on an urban tradition that is familiar to the researcher means that there is a greater immediate understanding of what built elements could be expected. This applies especially to outbuildings, garages, sheds, follies, etc. as mentioned before. In contrast to Maya settlements, where groups of buildings are justifiably identified as Type 1s, outbuildings are typically understood as auxiliary to, and under the intended influence of, the ‘main structure’ of the constellation (i.e. the extension of a single socio-spatial system). It seems detrimental to go against that a priori understanding. This would have the consequence that most gardens become the socio-spatially distinct Type 8, despite experiential knowledge that there is a single Type 1 determining the configurative complex. Outbuildings in MM and OS1872 are thus treated as sequential occurrences of Type 3s or 8s, disregarding instances where their material properties are impermeable akin to closable solid dominants. This leaves the choice of how to treat configurative complexes thus defined for later, as deemed appropriate for the comparative analysis at hand (e.g. matching coarse and fragmented historically or archaeologically derived maps). Indeed, this may be necessary for certain diachronic analyses comparing with 1550s, which lacks outbuildings altogether. Moreover, it removes the need to repeat the interpretation process entirely if specific outbuilding information is later desired.

(5) On MM, boundaries of unoccupiability (Type 11 or 12) are primarily based on MM’s own ‘natural’ or ‘man-made’ classifications. On OS1872 they are based on the symbology appearing on the original scans, and on 1550s they are limited to bodies of water only, because reconstructive self-selection means no additional physical information is included in the test area (see note 20 above).
(6) Garden plots situated like housing plots, without maintaining a direct association with a building, are quite particular to the medieval period. Though justifiably identified as opening boundaries (Type 9s), they are something of an oddity. Their open character logically makes these gardens a Type 9, but the known function is quite distinct from parks or other open areas. This difference is similar to distinguishing an agricultural field from a park, which resonates well considering that garden plots could have been used to grow crops rather than to serve modern leisure functions. Besides built-up frontages, Keene (1985: Fig. 155) identifies likely ‘open ground’, which seems to indicate land without any particular identified use. Occurrences roughly follow the general plot pattern. The current BLT ontology prevents such functional differentiation. Functionally, Type 9s thus have a protean referral record, somewhat reflecting the elaborate differentiations in urban studies (Stanley et al. 2012; M.L. Smith 2008). Although from a social perspective (outside the realm of spatial-material evidence), ambiguity due to the lack of a predominant socio-spatial occupation could justifiably render any unused space a Type 10 (e.g. fallow).

Mapping practice at Chunchucmil

(1) The first rule of thumb concerns building entrances (Type 2). Because the archaeologists mapping Chunchucmil estimated the extent and rough shape of structures from piles of rubble and debris, it is typically not possible to define entrances based on archaeological evidence. This leads to conjecturing entrances firstly based on the analogical assumption that buildings face each other (directly and indirectly). This pattern preference is found throughout the Classic period in the Maya area in plaza, patio and platform groups, as well as civic and ceremonial quadrangle groups (e.g. Becker 2001, 2004). Conjecturing additional entrances may depend on boundaries in their direct configurative complex (e.g. facing outward to open space) or to allow access to monumental or palatial architectural types (e.g. Andrews 1975; Parmington 2011; Jones 2015). Alternative locations for entrances are identified when the spatial morphological context displays a persuasive measure of orientation elsewhere rather than building groups facing each other. Hutson (pers. comm.)
2012) suggested that small structures in the middle of plaza groups could have been entered from any side as they could have served as elevations to address audiences.

(2) As previously mentioned, all mapped architectural structures (usually located in groups) have been identified as Type 1s (see also Fig. 7.13). This might include a proportion of what in western and globalised cities would be considered (functional) outbuildings associated with a residence (although many actual outbuildings could have perished also). This leads to an abundance of associated Type 8s and relatively few Type 3s, which is believed to reflect Chunchucmil’s particular Classic Maya socio-cultural nature.

(3) Regarding extended facing boundaries (Type 4), it could generally be assumed that platforms are accessible from all angles as they are low enough to mount without too much trouble. Similar to encountering a low front garden fence, however, it would be logical that there are preferred places to access a platform. In many cases the platforms have been mapped to gradually descend into the ground on one or more sides. Such access design was confirmed by a detailed excavation of a platform group (Hutson pers. comm. 2012). Caution is indispensable, as a discontinuous platform outline could have a number of other causes besides intentional architectural construction. When subsiding platform sides have conspicuous locations this is regarded as an indication for places to ascend onto and access the platform. In instances where a full outline is mapped (possibly including a conjunction with albarradas), a wider opening between buildings or orientation towards the surrounding configuration is accepted as an indicator for an access way.

(4) Architecturally, albarradas are regarded to be materially impermeable (although Hutson (2016) claims they tend to be lower than the human field of vision). Yet, they are usually open boundaries due to the conspicuously fragmented and often virtual nature over their course, which occurs even in well-preserved areas. Impermeability is then permanently mitigated by probably wide and/or multiple passages. Only albarradas mapped over a complete circumscription could become identified as (closable) Type 7s (i.e. enclosing boundaries). The same is considered for rarely occurring high platforms with an outer outline formed in conjunction with structures, circumstantially leading to a probable formal entrance.

(5) The parallel definition of Type 5 is applied in a flexible sense, sometimes including mirroring line directions and contextually derived directionality. This means that two boundary lines
forming a relatively narrow (in context) but irregularly shaped corridor in a mutual linear orientation (broad parallelism) are likely to be identified as a Type 5. Type 5s running long contiguous courses are rare in Chunchucmil (few formal streets exist). Deciding between a Type 5 or a Type 9 is subjective to the degree that one needs to judge when the observed general parallel structure is sufficiently lost.

(6) Though Type 6 depends on opening out onto several Type 1s, it is set apart from Type 8 because of its integration and sense of local centrality. It would seem that plaza and some platform groups make good candidates for Type 6s, but usually their bounded area is spatially removed from the ‘open’ flows of traversing the site from anywhere within the spatial system. Generally identifying a Type 6 is closely associated with nearby or connected Type 5s and Type 9s, along which Type 8s, in contrast, would often be placed laterally.

Taking BLT mapping forward

By conducting the processes this chapter discusses, the result is an intricately layered GIS of immediately visualisable BLT data. Within the confines of this developmental project this has only been done for the small test case areas as defined. This BLT Mapping could be seen as a formal redescription of the urban built environment in socio-spatial terms. On top of already complex morphology and topology, however, their profound complexity is only revealed when focusing on small areas at once to find out which BLT combinations each space is composed of, and connect and embed it in the built environment. In order to create better visualisations and greater insight, appropriate tools are needed to rework and (re)order the data thus created. To devise functional tools, the data structure that emerges through BLT Mapping needs to be better understood. Moreover, we must reflect on which analytical measures and selections could provide meaningful results. So, before I turn to a closer inspection of the specificities of the test case areas and what we may learn from such redescription directly, Chapter 8 will explain the data structure and the opportunities for spatial analytical measures this enables.