Research Article

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Urban Success and Urban Adaptation Over the Long Run

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Abstract: One of archaeology's principal contributions to knowledge is its ability to track human actions and social conditions over long periods of time. I describe an approach to operationalizing this insight for the rise and fall of cities and other settlement over time. Cities that survive and thrive are considered successful, and urban success can be measured along three dimensions: persistence, population, and prosperity. Successful cities were those whose leaders, residents, and institutions found ways to adapt to a range of shocks and conditions, including the environment, local institutions, and regional political and economic forces. Urban success is therefore due to processes of urban adaptation that operated over long periods of time. I outline a conceptual and methodological approach to urban success and position the concept with respect to notions of adaptation and time scales in sustainability science and the social and historical sciences more broadly.

Keywords: cities, urban adaptation, prosperity, success, persistence

1 Introduction

One of archaeology's principal contributions to knowledge is its ability to track human actions and social conditions over long periods of time. For cities and urbanism, I call this the "urban trajectory argument"; it is one of the three arguments I have proposed for the broader value of archaeological research on early cities and settlements (Smith, 2023a,b). The other two are the sample size argument (archaeological cases enlarge the sample of known cities) and the laboratory argument (archaeological cases can serve as a "laboratory" specifically for testing explicit models first established for contemporary cities). I elaborate on these three arguments in Smith (2023a,b); Smith (2023a) elaborates on how they relate to the task of identifying similarities and differences between urbanism today and in the past.

In this article, I attempt to move beyond vague claims for the relevance of archaeology's long temporal perspective (Smith, 2021) by proposing a way to operationalize the urban trajectory argument, using concepts from the social sciences and urban sustainability science. Cities or settlements that survive and thrive can be considered successful settlements; those that last for a short time and/or lack prosperity are judged unsuccessful settlements. My concept of urban success is similar to the concept of urban adaptation, or, more precisely, urban adaptedness (Orlove, 2022). I propose three dimensions to measure urban success: persistence, population, and prosperity.

In this article, I explore the realm of urban success, and I focus on the relevant concepts and the structure of argument. I refrain from developing specific material measures of these concepts, putting off the task of operationalization for a future paper. My goal is to set out a structure or an argument for a line of analysis that will help urban archaeologists put our data into a productive framework. Such a framework

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will not only illuminate past cities and urban processes but also provide insights that may be useful in addressing critical urban issues today.

2 Long-Term Change

I begin with a point of convergence between archaeology and sustainability science: a recognition of the importance of considering varying scales of time for studying processes of change (Table 1). The historian Fernand Braudel (1972) identified three scales over which different historical processes operate. Battles, disasters, and the actions of kings play out on a scale of days to years ("events"); demographic and economic cycles – including the rise and fall of states, empires, and cities – develop over decades ("conjunctures"); and environmental change happens over the "longue durée," a scale of centuries and millennia. A number of archaeologists adopted Braudel's scheme in the 1990s (Bintliff, 1991; Knapp, 1992), but it has receded from view in recent years.

Karl Butzer developed a scheme of time scales parallel to that of Braudel, for both environmental archaeology (Butzer, 1982) and geomorphology (Butzer, 2011); he has four instead of three scales in the latter work. More recently, sustainability scientists have proposed similar schemes for studying adaptation to climate change across scales (Chhetri, Stuhlmacher, & Ishtiaque, 2019; Kates, Travis, & Wilbanks, 2012). Not surprisingly, the longest scale of adaptation in sustainability science – transformational adaptation – is the least well understood. It is impossible to study change at this scale into the future; yet, sustainability scientists have been slow to consider research on past urban adaptation as relevant to climate change adaptation today.

Perreault (2019) develops a strong argument that processes operating over long time spans are the only domain for which rigorous scientific results can be generated from the archaeological record. He criticizes anthropological archaeologists for construing archaeology as a kind of ethnology of the past; that is, archaeologists have tried to study processes, known from ethnology, that operate over much shorter time spans. "By focusing on microscale processes, archaeologists have been living beyond their epistemological means" (Perreault, 2019, p. 165); Lyman (2007) makes a similar argument.

If archaeologists are correct in claiming that change over long periods is one of our major contributions to knowledge – particularly given Perreault's claim that this is our only rigorous domain – then we should apply this perspective to the study of past cities and settlements. How did past settlements and settlement systems change over long periods? Why did some survive and others fail? What independent variables account for the successes and failures of past cities? If we can construct reliable scientific knowledge on these and related questions, then our findings might prove useful for understanding urban adaptation to stresses – including climate change – today and into the future. I propose the concept of urban success as an avenue to pursue these issues.

3 Urban Success

My notion of urban success is adapted from the sustainable livelihoods approach in developmental studies. Research in this area relates rural agriculture and other economic strategies to well-being and resilience at both the household and community levels (de Haan & Zoomers, 2005; Scoones, 2009). Osbahr, Twyman, Adger, and Thomas (2010, p. 2) develop a concept of livelihood success based in the literature on resilience:

> Taking resilience theory as a starting point, we define the process of successful adaptation as that which increases system resilience but also, giving explicit treatment to governance, as that which promotes legitimate institutions to generate and sustain collective action.

I translate this approach into concepts that can be operationalized with archaeological data. I define urban success as a composite condition composed of three dimensions: persistence, population, and prosperity.

Table 1: Time scales in different disciplines

Discipline	Author	Time scale		
		Short	Medium	Long
History and social archaeology	Braudel (1972), Knapp (1992)	Event	Conjuncture	Longue durée
Geomorphology	Butzer (2011)	Seasonal stress	Medium-term pulse	Long-term environmental shift
Environmental archaeology	Butzer (1982)	Adaptive adjustment	Adaptive modification	Adaptive transformation
Sustainability science	Chhetri et al. (2019), Kates et al. (2012)	Coping adaptation	Incremental adaptation	Transformational adaptation

This approach to urban success draws on literature in the social and natural sciences, including urban economics, sociology, anthropology, complexity theory, resilience theory, and sustainability science. I attempt to avoid the way some archaeologists use the term urban success without explicit definition or operationalization (e.g., Jackson et al., 2022; Murphy & Crumley, 2022, p. 10).

Success is a continuum, not a dichotomous variable. My basic conceptual model is shown in Figure 1. Cities, as settlements, adapt to various shocks and conditions that arise in the environment, in local institutions, and in regional politico-economic forces. The operation of adaptation processes can lead to success, to failure, or to a range of outcomes in between. The level of success can be evaluated along three dimensions: persistence, population, and prosperity. These dimensions constitute the essential features of urban success, and they can be measured independently. The nature of adaptation processes and their outcomes can change through time. For example, the Classic-period cities of the ancient Maya were highly successful for much of their history. They lasted for many centuries, their populations grew, and by various measures, they were prosperous cities. But, in the ninth century, these successful trajectories were reversed; the Maya collapse signaled a drastic decline in all three measure of success for most Maya cities.

In economics and social history, urban or societal success is typically defined in terms of prosperity (Beyer, 2015). Historian Prak (2011, p. 3), for example, states "successful societies, incidentally, are those societies that produce the greatest amount of prosperity and well-being for their citizens." Economist Glaeser (2010, p. 2) adds population growth to prosperity in his concept of urban success: "Urban economists infer urban success from high local wages, robust real estate prices, and growth in the number of people within an area." In the fields of urban planning and community analysis, success is viewed as an attribute of communities that have a high level of social interactions, leading to social cohesion, collective action, and economic prosperity (Bowles & Gintis, 1998; Brower, 2011; Klinenberg, 2018). Goldstone's (2002) concept of efflorescence provides another way of looking at success. An efflorescence is a period of economic, demographic, and cultural expansion and flourishing that results in a condition of intensive (per capita) economic growth for a city or region for a period of up to a century or two (Campbell, 2016; Ortman & Lobo, 2020).

My innovation is to add the dimension of settlement persistence or longevity to prosperity and population as a marker of urban success. The concept of success is used occasionally in the literature on climate change adaptation (Adger, Arnell, & Tomkins, 2005; Osbahr et al., 2010), where it is typically defined in terms of concepts such as adaptive capacity and resilience. The concept of urban prosperity is often used in the social sciences in the same way I am using urban success (see discussion below). I distinguish them to add persistence and population – not typically seen as independent constituents of prosperity – as components of urban success.

4 Urban Adaptation and Urban Success

Urban success is achieved through processes of urban adaptation (Figure 1). Cities and other settlements are complex adaptive systems in that they have an internal structure, they possess the capacity to adapt,

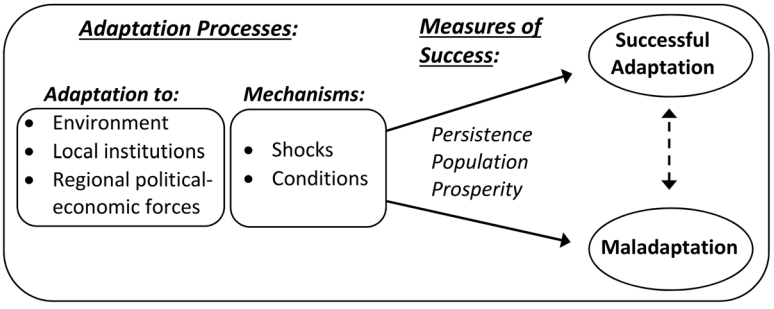

Figure 1: Conceptual model of urban success. Graphic by Michael E. Smith.

and their boundaries are porous and promote interaction with their environment and other systems. Complex adaptive systems are characterized by a variety of dynamic processes, and novel qualities emerge through complex nets of causality (Holland, 2014; Lansing, 2003; Mitchell, 2009; Preiser, Biggs, De Vos, & Folke, 2018). Cities are complex adaptive systems whose properties emerge through both bottom-up, or generative processes operating among residents, and top-down processes originating with political and other authorities (Moroni, Rauws, & Cozzolino, 2020; Smith, 2023b); see further discussion below.

Many archaeologists prefer to focus on the actions of individuals, using the concept of agency, and distrust accounts that infer causality on larger scales, such as cities or polities. To understand cities and urban phenomena, however, a complexity perspective allows the actions of individuals to be contextualized within broader institutions and settings. In line with this observation, the concept of urban adaptation has become a standard part of the scientific literature on urban sustainability today (Kaźmierczak, 2020; Lobo et al., 2023; Neder et al., 2021).

Preiser et al. (2018, p. 5) describe adaptation in complex adaptive systems as follows:

> Complex adaptive systems adapt over time in response to feedbacks from interaction between system elements, and between elements and their environment. The connections between elements and how these relations give shape to the structure and function of a system are sustained by self-generating organizational capacities.

This perspective helps contextualize the concept of adaptation as used in the literature on sustainability today. That literature contains two distinct concepts of adaptation: a narrow concept that has become entrenched in the field of climate-change adaptation and a broad concept within anthropology and development studies. To sort these out, I begin with the original concept of adaptation from evolutionary biology. The adaptation of cities is not a biological process, of course, and I employ the relevant biological concepts as metaphors – not as models – for urban processes. The geneticist Theodosius Dobzhansky defined four adaptation-related terms as follows:

> *Adaptedness* is a status of being adapted, i.e., of being able to live and to reproduce in a given environment. *Adaptation* is the process of becoming adapted. *Adaptability* is an ability to become adapted to a certain range of environmental contingencies. An *adaptive trait*, sometimes also referred to as "an adaptation," is a feature of structure, function, or behavior of the organism which is instrumental in securing the adaptedness (Dobzhansky, 1968, p. 111).

In evolutionary biology, adaptations are evaluated with respect to reproductive fitness. If organisms survive and reproduce, then they are said to have achieved fitness, or a successful adaptation. For cities (and societies), however, adaptation must be evaluated in social terms.

I define *urban adaption* as the process by which a city or settlement adjusts to, or accommodates, features of its natural and social environment. The process of adaptation can have positive or negative outcomes. If a city survives and thrives, then it has achieved – at least for some interval of time – a successful level of adaptedness. If a city declines, collapses, or is abandoned, however, then its processes of adaptation have not been successful. In biology, Dobzhansky suggests that the adaptedness of a population or species can be measured by its population growth rate (Dobzhansky, 1968, p. 114), and I use population size as one of my three measures of urban success.

Urban adaptedness is the condition that urban scholars want to measure and study. It is achieved by processes of adaptation. Biologists agree that adaptation is best viewed as a process through time (Dobzhansky, 1968; Endler, 1986, p. 42; Lewontin, 1978, p. 213). McDonnell and Hahs (2015, p. 262), for example, state that "Ecologists primarily view adaptation as a dynamic evolutionary process that facilitates the survival and persistence of organisms under altered environmental conditions." The process view also characterizes research on adaptation in anthropology and development studies (Eriksen, Inderberg, O'Brien, & Sygna, 2015; Thornton & Manasfi, 2010) and in the field of climate change adaptation (Orlove, 2022). The concept of "an adaptation" – to refer to a specific adaptive trait – is quite common in biology. Because my focus is on the adaptedness and adaptation processes of cities, the concept of "an urban adaptation" seems less useful.

Biological adaptation has been portrayed as the ways organisms or populations respond to problems or challenges: "The modern view of adaptation is that the external world sets certain 'problems' that organisms need to 'solve', and that solution by means of natural selection is the mechanism for creating these solutions" (Lewontin, 1978, p. 213); this view is echoed by biological anthropologists (Jones, Ready, & Pisor, 2021). Shorn of the concept of natural selection, this view is close to the concept of sustainability as described by Tainter and Taylor (2014, p. 175): "Sustainability is a function of success at solving problems." The ability to deal with problems and setbacks is an important component of urban success and adaptation.

The concept of adaptation in the field of climate change science is considerably narrower than the broad notion discussed above. Most definitions require that adaptation processes be deliberate human actions and policies, undertaken specifically to address the effects of climate change. The latest IPCC report (Pörtner et al., 2022) is careful to distinguish adaption in human systems ("adjustment to actual or expected climate and its effects in order to moderate harm"; note 10, page SPM5) from adaptation in natural systems, where intentionality is not part of the definition. Orlove (2022) discusses how this narrow concept of adaptation originated and spread through the sustainability community. He points out inherent ambiguities in the definitions of adaptation in that literature.

The biological and anthropological literatures take a broader view of adaptation. They point out that the success or failure of processes of adaptation can only be evaluated in retrospect. In the words of Mayr (1992, p. 131), "adaptedness thus is an *a postiori* result rather than an *a priori* goal-seeking." Sober (1984, p. 210) has a similar formulation, noting that adaptation "looks to the past, reflecting the kind of history that a trait has had." Development anthropologists Thornton and Manasfi (2010, p. 132) write that "adaptation is often a blind process that can be viewed as 'rational' only in hindsight." They suggest that the narrow, or "planned adaptation" concept in the climate change literature has a "progressivist, 'techno-fix' bias" (p. 133). Jones et al. (2021) discuss this and other differences between the narrow and broad concepts of adaptation.

Few treatments of urban adaptation to climate change discuss how "urban adaptation" may differ from societal adaptation. One of the few such schemes, (Satterthwaite et al., 2020) identifies four broad "urban agendas," of which climate change adaptation is one; the others are climate change mitigation, disaster risk reduction, and poverty reduction through universal provision of services. Although these authors do not use the phrase "urban success," their paper suggests that success is achieved through positive changes in one or more of these agendas. A recent call for the development of a science of urban adaptation to climate change (Lobo et al., 2023) relaxes the requirement that adaptations must be anticipatory and deliberate actions: "We define urban adaptation to climate change as the set of actions by which urban societies adjust, change, and transform their infrastructures, support systems, interactions, and governance mechanisms to mitigate the adverse environmental changes brought about by climate change."

The narrow concept of adaptation is difficult to use with archaeological data. If archaeologists adopt the broader concept, then the process of adaptation, and the state of adaptedness (or success) – like sustainability in general (Costanza & Patten, 1995) – can only be adequately judged in hindsight. Nevertheless, a condition of adaptedness is what allows an entity to continue to survive and thrive into the future.

5 Adaptation Processes

5.1 Resilience, Shocks, and Disturbances

In both ecology and social science, resilience is typically defined as the ability of a system to respond to, or recover from, shocks or changes (Adger, 2000; Holling, 1973; Meerow, Newell, & Stults, 2016). Like adaptedness and adaptability, it is difficult or impossible to measure resilience prior to a shock. One needs to observe one or more shocks or changes and study the aftermath. Climate change is only one of the many types of shocks that have affected cities throughout history. In Figure 2, I have organized urban shocks by their type and their temporal trajectory. The trajectory categories are taken from the field of disturbance ecology.

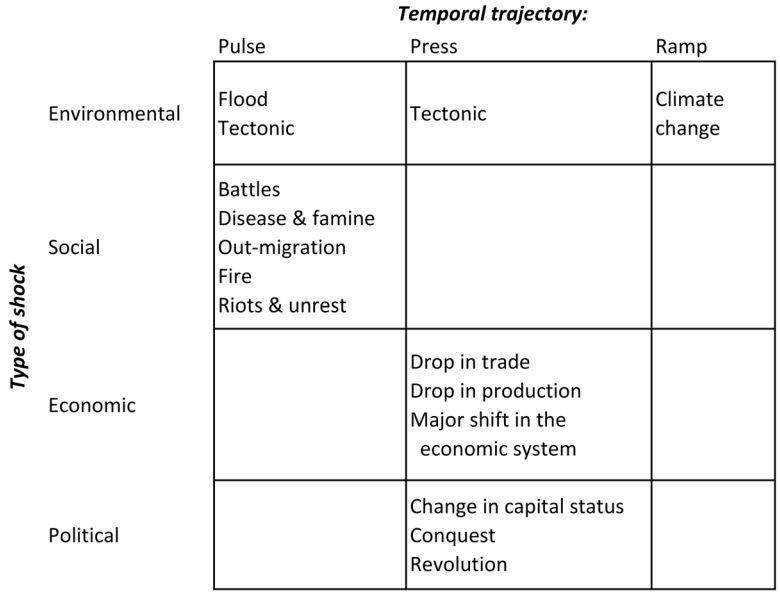

Figure 2: Classification of urban shocks. See text for discussion.

A *pulse* is a short-term and clearly delineated disturbance, such as a battle or a flood. A *press* is a disturbance that grows quickly and then levels off; the conquest of Yautepec by the Teotihuacan empire (see Figure 5 below) was a press type of disturbance. A *ramp* is a steadily increasing (or decreasing) disturbance; see Lake (2000) or Nimmo, MacNally, Cunningham, Haslem, and Bennett (2015). Grimm, Pickett, Hale, and Cadenasso (2017) argue that it is inappropriate to consider urbanization itself as a disturbance to ecosystems, as Nimmo et al. (2015) and others have done, because urbanization and city growth are composed of many subprocesses that in themselves constitute more directly relevant ecological disturbances.

The responses of cities and economies to shocks has become a staple in the field of economic history (Bosker, Brakman, Garretsen, de Jong, & Schramm, 2008; Davis & Weinstein, 2002; Jedwab, Khan, Russ, & Zaveri, 2021). Glaeser (2022) offers a hypothesis on the effects of, and resilience to, different kinds of shocks to cities: "The long view of urban resilience suggests that cities are far more vulnerable to economic and political dislocation than to earthquakes, wars and even pandemics" (p. 2). For Glaeser, cities are able to bounce back from shocks like the COVID-19 pandemic, unless the shock is serious enough to cause major political or economic disruption. Analyzing the responses of past cities to a variety of shocks provides insights that may help understand the likely effects of rising temperature on cities today (van Bavel et al., 2020).

5.2 Types of Urban Adaptation

Processes of urban adaptation can be illuminated by considering adaptation actions as resulting from two intersecting dimensions (Figure 3). The first dimension separates top-down and bottom-up channels for the origin of the plans and actions of adaptation. Top-down channels are plans and actions that originate in governments or central institutions, whereas bottom-up channels mark the actions of people acting independently of central authorities. The second dimension, anticipation, describes planned and spontaneous actions. The limited concept of adaptation common in the urban climate change literature (e.g., Orlove, 2022; Prieur-Richard et al., 2019) fits mostly into the top left quadrant, along with other government-led policy outcomes. Yet, generative, or bottom-up, processes – where individuals and local groups assemble, coordinate among themselves, and act, independently of governments and central institutions – are among the most important processes in cities, today and in the past (Batty, 2013; Bettencourt, 2021; Smith, 2023b).

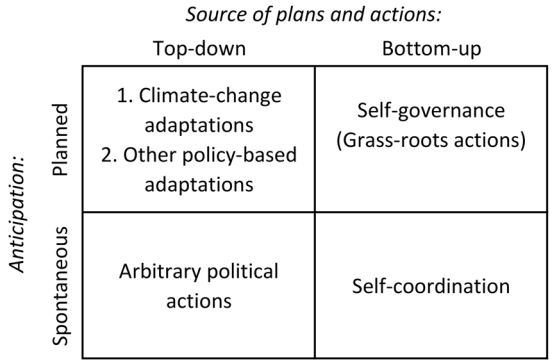

Figure 3: Concepts of urban adaptation arranged by their sources (top-down vs bottom-up) and the nature of anticipation (spontaneous vs planned).

Following Moroni et al. (2020), I distinguish two types of bottom-up, generative process: self-governance and self-coordination.

Self-governance can be defined as "processes of collective decision-making and action undertaken by groups of people sharing common objectives in relatively independence from public actors and institutions" (Moroni et al., 2020, p. 222). Also, called grassroots actions, these are certainly planned actions (that is, they are not random or spontaneous), but they are not planned by central authorities. Many of the urban climate-change adaptations studied by anthropologists (Oliver-Smith, 2016; Thornton & Manasfi, 2010) fit into this category. The growing recognition that local communities can design effective climate-change adaptations (Coger et al., 2022) pertains to this quadrant of the diagram. In the words of Thorn, Thornton, and Helfgott (2015), "Actors do not have to consciously choose to adapt, but rather may do so autonomously, either voluntarily or involuntarily."

"Self-coordination," the second type of bottom-up (generative) process, is not based on deliberate planned activities. People interact socially in myriad ways, in the course of their daily movements, economic tasks, rituals, and many incidental activities. Cities and other settlements concentrate these social interactions in space, which contributes to a series of unintended consequences. One result is the condition that has been labeled *energized crowding* (Smith, 2019a, 2023b), which in turn has three major types of outcome: creation of neighborhoods; economic growth; and negative outcomes, such as stress, crime, and poverty. Given the fundamental role of generative processes within cities, this realm needs to be incorporated into analyses of urban success and urban climate-change adaptation. Failure to do so is one example of how the urban climate-change adaptation literature – with its limited concept of adaptation – can seem naïve to social scientists (Eakin et al., 2017).

6 Three Dimensions of Urban Success

Urban success can be measured along three dimensions: persistence, growth, and prosperity. Persistence refers to the length of time a settlement is occupied; the city of Rome survived longer than the city of Pompeii and, therefore, had greater success on this dimension. Growth refers to the population of a city. A growing population, and a larger population, indicate greater success, in part because they imply a greater capacity to obtain food and resources. And a more prosperous city – whether measured by economic productivity, by quality of life, or by justice and equity – indicates greater success socially in the sense described by the quotation from Maarten Prak above. Processes of urban adaptation can be evaluated by change in these three dimensions.

In this section, I describe the basis for using persistence, population, and prosperity for measuring success. While I provide some examples and make suggestions about measurement, I refrain from

describing specific schemes by which individual cities can be scored on the dimensions. The operationalization of this approach is a separate task requiring more detailed treatment in a separate paper.

6.1 Persistence

Costanza and Patten noted some time ago that "The basic idea of sustainability is quite straightforward: a sustainable system is one which survives or persists... Sustainability, at its base, always concerns temporality, and in particular, longevity" (Costanza & Patten, 1995, p. 193). The persistence of a city or settlement can be defined as the length of continuous use of a specific place of human occupation (Smith et al., 2021b). While promoting a condition of urban persistence is certainly an important goal of climate-change adaptation today, we have no way of knowing how long current cities will last into the future. How long will coastal cities be able to resist rising sea levels? Will shrinking hinterland cities continue to dwindle until they are abandoned? Although persistence is an important part of urban success and sustainability in general, it is insufficient alone as a measure of these phenomena:

> When judged by the length of time for which they were sustained, some of the most "successful" societies were also among the most exploitative, where the abuse of human rights was greatest. These are not societies we would want to "sustain." Development includes strong and explicit social objectives and achieving the development goals within sustainable development demands social change, not 'sustainability' in the sense of 'keeping them going continuously (Mitlin & Satterthwaite, 1996, p. 25).

Research on past settlements has so far yielded little information on the variation of settlement persistence within or between regions, and even less on the drivers of that variation. There are two reasons for these lacunae, conceptual and methodological. The conceptual issue is a continuing obsession with processes of collapse. Both the scholarly and popular literatures are full of accounts of the often spectacular fall of ancient cities and civilizations (Cumming & Peterson, 2017; Diamond, 2004; Middleton, 2017). Although many Maya cities persisted for five and even ten centuries, these jungle settlements are best known for collapsing in the ninth-century CE. An infatuation with the question of why they collapsed has crowded out research on the reasons they survived for so long.

The methodological obstacle to assessing past urban persistence is that current methods of archaeological data collection and analysis employ data structures that are not conducive to tracking individual settlements through time and measuring their persistence. I am part of a research group that has initiated the analysis of archaeological survey data to study past settlement persistence. Our first lesson was that it takes considerable time and effort to convert archaeological databases into a format that permits the analysis of persistence. A preliminary study (Crawford et al., 2023) revealed differences in the median persistence of settlements in seven world regions (Table 2), from a figure of 67 years for the Santa Valley of coastal Peru to 1,000 years for major settlements in northern Mesopotamia. Our initial hypotheses – which we are starting to

Table 2: Variation in median settlement persistence in six survey projects

Survey	Median persistence	# Sites	Date range
Santa Valley, Peru	67	708	3000 BCE to 1532 CE
Southeastern United States	80	473	600 to 1800 CE
Basin of Mexico	185	1,593	1640 BCE to 1521 CE
Southwestern United States	200	5,220	800 to 1800 CE
Central Italy	330	6,892	2300 BCE to 1200 BCE
Yautepec Valley, Mexico	370	394	1640 BC to AD 1521 BCE
Mesopotamia	1,000	132	4000 to 1000 BC

Note: Data are from Crawford et al. (2023).

test – are that the major determinants of settlement persistence within regions are settlement size, local environmental amenities, and institutions, while the major determinants of persistence variation among regions are climate and agricultural productivity (Crawford et al., 2023; Smith et al., 2021b).

Settlement persistence can be measured in several ways. The total duration of a settlement, from founding to abandonment, is the simplest measure, but it is biased in that later settlements cannot last as long as the longest-lasting earlier settlements. Measuring the duration of sites as a proportion of the maximal possible duration for a given time period addresses that bias. A related measure is settlement continuity: the percent of settlements in a given period that continue to be occupied into the following period. A higher level of continuity at a particular time indicates greater persistence compared to other period transitions, and this can be seen a type of urban success.

Figure 4 shows the mean settlement continuity for each period in the Yautepec Valley of central Mexico (Smith, Hare, Montiel, Sherfield, & Huster, 2021a). A notable pattern in these data is that the two intervals with the highest settlement continuity correspond to periods when the Yautepec Valley was integrated as a periphery into large macro-regional systems. The Terminal Formative to Middle Classic interval was when the valley was conquered and incorporated into an empire based at Teotihuacan (Smith & Montiel, 2001), and in the Late Postclassic period (Atlan and Molotla periods), valley polities joined the Postclassic Mesoamerican world system, a network of increased long-distance exchanges of goods and information (Smith & Berdan, 2003). Carballo, Feinman, and López Corral (2022) examine a sample of ancient Mesoamerican cities and find that persistence is correlated with variables, such as the collectivity of governance, shared infrastructure, and elevation.

6.2 Population

Population growth rates are used as a measure of adaptedness and evolutionary success in biology (Dobzhansky, 1968; Peck & Waxman, 2018). Urban economists and historians have related both city size and urbanization level (the percent of the population living in cities) to levels of economic activity (Bairoch, 1988; Jedwab & Vollrath, 2015; Storper, 2013). Davis and Weinstein (2002) use the population of Japanese cities to measure the impact of bombing in World War II on urban activity. The fact that the populations of Hiroshima and Nagasaki were able to rebound within a short period after being largely destroyed by atomic

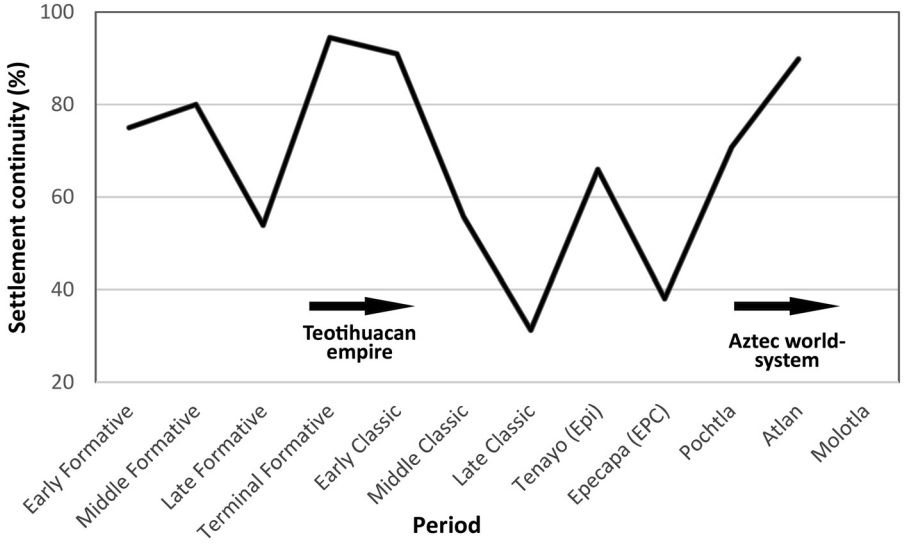

Figure 4: Settlement continuity across periods as a measure of settlement persistence: Yautepec Valley, Mexico (Smith et al., 2021a).

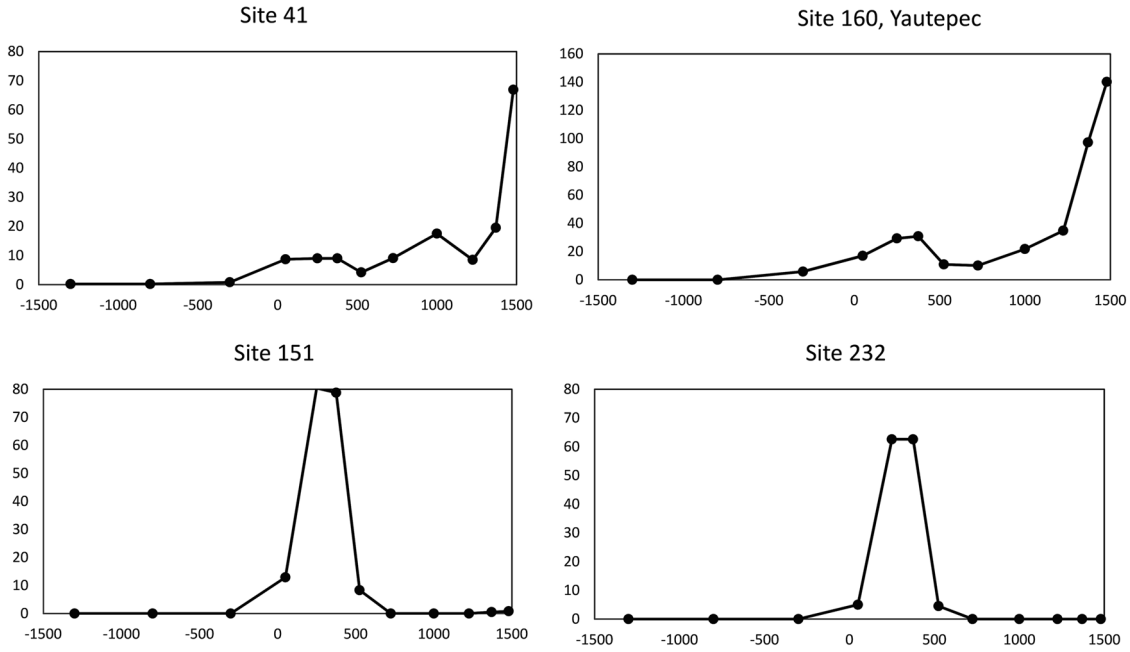

Figure 5: Population as a measure of urban success, four sites in the Yautepec Valley, Mexico (Smith et al., 2021a).

bombs can be considered a striking example of urban success, although those authors do not use the term success. de Long and Shleifer (1993) discuss these relationships and point out that while "urban populations are good measures of preindustrial economic prosperity" (p. 674), this correlation does not work in all contexts. Indeed, Smith and Lobo (2019) suggest that the relationship between economic activity, political activity, and city size differs between what they call "economic cities" and "political cities" (see also, Ades & Glaeser, 1995).

An examination of the demographic trajectories of individual settlements provides some context on the use of population size and growth as measures of the success of cities and settlements. Figure 5 shows the population trajectories of four settlements in the Yautepec Valley across 3,000 years (Smith et al., 2021a). The top two graphs show sites that became successful in the Aztec period, after several millennia of sporadic smaller occupations. Site 160 is the Aztec city of Yautepec (Smith, 2019c). The bottom graphs show sites that were occupied exclusively when the valley was a province of the Teotihuacan empire; these were almost certainly imperial control points, probably functioning to promote the cultivation and transshipment of cotton destined for Teotihuacan (Montiel, 2010). These trajectories illustrate the importance of temporal scale for considerations of urban success. For the two or three centuries of their existence, sites 151 and 232 witnessed rapid population growth and occupational continuity and were therefore successful settlements. But over a longer time frame, they were not successful at all. These sites were strongly dependent on a foreign occupying force, and they disappeared when that force withdrew.

6.3 Prosperity

While persistence and population can be measured for past cities using standard archaeological methods, prosperity is a more complex and diffuse concept that is harder to operationalize. Many archaeologists and historians use the term as a buzzword – often in their titles – without providing a definition or operationalization (e.g., Bintliff, 2014; Dalgaard, Kaarsen, Olsson, & Selaya, 2022; Scheidel, 2019). The general sense of the term prosperity usually refers to "more choices, richer lives, and an improved quality of life" (Budowski, Tillmann, Keim, & Amacker, 2010). In the words of Tim Jackson (2013, p. 107), "The requirements of prosperity go way beyond material sustenance... Prosperity has vital social and psychological

dimensions." This term parallels Amartya Sen's concept of quality of life, which is also composed of two elements: wealth or standard of living, and capabilities (Sen, 1999, 2013).

Archaeologists have made a start on operationalizing a concept of urban prosperity, although we still lack a fully worked out scheme for this. I applied informal (unquantified) measures of community prosperity, based on Sen's capabilities approach, to Aztec provincial sites. I measured wealth by the sum of household wealth levels, and capabilities by collective construction projects, stability of residence, population growth, longevity (persistence), and resilience to external shocks (Smith, 2016, 2019b). Hu and Quave (2020) build on my scheme, and contrast prosperity (they use the term quality of life) with prestige at provincial Inka sites. Richard Blanton and Lane Fargher (Blanton, 2016, pp. 248–259) identified what they call a "coactive causal process" that includes six processes: collective action, commercialization, improved standard of living, urbanization, population growth, and intensification of production. The joint operation of these mutually-reinforcing processes leads to increased prosperity in a society.

The City Prosperity Index ("CPI") created by UN-Habitat (UN-Habitat, 2012) provides a path for creating archaeological measures of the components of prosperity. This scheme has five pillars or dimensions: productivity, infrastructure development, quality of life, equity and social inclusion, and environmental sustainability; see also Abilla (2018), Torres-Meraz and Iracheta (2022) or Wong (2015). Table 3 lists these dimensions, with some potential archaeological indicators. Three of these dimensions also featured in my earlier index of community prosperity. I have removed two of my original measures – persistence and population – from prosperity proper, so that they can serve as separate measures of urban success in the more comprehensive scheme described in the present paper.

1. Productivity. Based on the widespread assumption that economic growth generates prosperity, the CPI scores a variety of measures of growth such as trade, savings, and investment in contemporary cities. This dimension can be measured archaeologically with the quantification of craft production output (Hanson, Ortman, & Lobo, 2017; Kaše, Heřmánková, & Sobotková, 2022) or the quantities of imported or exported goods (Haase & Hammers, 2021; Romanowska et al., 2022).

2. Infrastructure development. On the assumption that prosperity requires adequate infrastructure and housing, the CPI counts the provision of both of these under this dimension. Several types of infrastructure can often be identified and sometimes quantified for past cities. These include amenities within cities, such as streets, or water supply (Klassen & Evans, 2020; Poehler, 2017) and landscape features that have an urban impact, including dams, aqueducts, or roads (Freeman, Baggio, Miranda, & Anderies, 2023; Hanson, Ortman, Bettencourt, & Mazur, 2019). Housing can be used for measuring quality of life and perhaps equity (see below), but for past cities, it is difficult to quantify housing construction as a separate dimension, as done for the CPI.

3. Quality of life. Following UN practice, the quality of life dimension of the CPI measures education, health, social security, and public space. There is widespread support for the notion that the concept of sustainability needs to go beyond conserving resources and planning for the future, to include issues like

Table 3: Dimensions of city prosperity

City prosperity index[a]	Smith (2019b)[b]	Archaeological indicators
Productivity		Craft output
		Imports
Infrastructure development	X	Urban amenities
		Landscape infrastructure
Quality of life	X	Household standard of living
		Stability of residence
Equity and inclusion		Low inequality measures
Environmental sustainability	X	Agricultural output
		Land degradation
		Resilience to shocks[a]

[a]UN-Habitat (2012).
[b]X indicates dimensions that are included in Smith (2019b).

quality of life and justice (Hicks et al., 2016). Amartya Sen expresses this idea as follows: "The overall effect is to integrate the idea of sustainability with the perspective of freedom, so that we see human beings not merely as creatures who have needs but primarily as people whose freedoms really matter" (Sen, 2013, p. 12); see also Sen (1999).

Archaeologists have begun to develop approaches to the measurement of past quality of life. The most common approach focuses on household standard of living or well-being (Hegmon, 2016; Munson & Scholnick, 2022; Pitts & Griffin, 2012). Also, relevant is residential stability, or how long individual households remain in one location. This measure has been found to be associated with quality of life in contemporary cities (Boggess & Hipp, 2010; Desmond, 2016), and I have applied this archaeologically in terms of the temporal continuity of individual houses within settlements (Smith, 2016, 2019b).

4. Equity and social inclusion. This dimension of the CPI focuses on inequality by household and by gender. More inclusive and equity-based urban processes are increasingly seen as important parts of urban prosperity (Castán Broto, 2021; Glaeser & Joshi-Ghani, 2013). A relevant approach in archaeology that could be used here is the measurement of household inequality using the Gini index and other indicators (Kohler & Smith, 2018; Kohler et al., 2017; Munson & Scholnick, 2022), although wealth inequality is not a direct measure of social inclusion or equity.

5. Environmental sustainability. The CPI includes various measures of air quality and indoor pollution. Archaeologists can increasingly measure variables, such as agricultural output, land degradation, and resilience to shocks, but this work has yet to be applied to the question of the prosperity of cities and settlements, and it is hard to envision how this specific dimension can be measured consistently for early cities and settlements.

As is the case with many archaeological indicators, specific measures derived from these five dimensions of city prosperity can be taken for some settlements but not others. The operationalization of urban prosperity will need to balance the social and theoretical components of prosperity as discussed in the literature on cities today, with the available samples of settlements and deposits yielding quantifiable material remains. The key element linking these two disparate domains is the research question. As archaeologists work toward a better understanding of urban prosperity in the past, we will have to solve the problem of operationalization, most likely on multiple analytical levels.

6.4 Interactions Among the Three Dimensions of Success

Persistence, population, and prosperity are interrelated dimensions and they can interact in complex ways. For example, it has been observed that larger cities today last longer than smaller cities (Mulligan, Partridge, & Carruthers, 2012). While there is limited evidence of a similar relationship between persistence and population for past settlements (Crawford et al., 2023), the nature and extent of this pattern has yet to be explored in any detail. By identifying these three dimensions as components of a domain called urban success, it is not necessary to establish that they are orthogonal or independent of one another. To adequately understand these three dimensions, however, relationships like this will need to be explored in more detail.

7 Measuring Past Urban Success

The concept of urban success outlined in this article lends itself to a variety of approaches to measurement and analysis. While it is possible to create a single index of urban success by combining scores on the individual dimensions, analyzing the separate scores on persistence, population, or the dimensions of prosperity will normally be a more informative procedure. Individual settlements can be examined on these measures (as in Figure 5), or scores can be averaged or combined for regions (as in Figure 4 and Table 2).

Simple inspections and comparisons like these can reveal patterns in the urban dynamics within and between settlement systems.

Plotting the population and other variables of settlements (or regional settlement systems) through time can identify regime shifts, which are intervals when the dynamics shift from one kind of trajectory to another. The settlements in the lower graphs in Figure 5 show two obvious shifts in regime: from rapid growth to stability and from stability to rapid decline. Most regime shifts, in social and ecological systems, are more subtle and harder to identify without quantitative methods (Biggs et al., 2012; Scheffer et al., 2012).

The processes that create urban success – particularly over long time intervals – are time-dependent, meaning that a city's levels of population, infrastructure, and other measures at a given time are influenced by its levels at an earlier period. This means that simple statistical comparisons – whether across cities or systems, or through time – will be inadequate to capture the dynamics of a case or system. Therefore, archaeologists need to employ the methods of time series analysis (Alexander, 2014; Box-Steffensmeier, Freeman, Hitt, & Pevehouse, 2014) to model the trajectories of cities and systems through time. Archaeologists are only beginning to use time series analysis (Bevan & Crema, 2021; Kohler, Ellyson, & Bocinsky, 2020; Riris & de Souza, 2021), and it is not yet clear whether time series methods from econometrics and other fields – often based on yearly measurements – can be used successfully with the far rougher chronological control of our data. One approach for archaeology is to use Bayesian chronological refinement methods to increase the number of chronological periods in a given sequence (Fernández-López de Pablo & Barton, 2015; Roberts et al., 2012). Another approach is to use summed radiocarbon probability distributions to refine sequences at sites or regions (Crema, 2022; Price et al., 2021).

8 Conclusion

The adoption of a model of urban success as a way to monitor long-term developments in cities and settlements has several benefits for archaeology and for urban studies generally. First, this approach provides concepts and tools that help archaeologist interpret the urban past. Settlement persistence is a new approach to urban sites (Carballo et al., 2022; Smith et al., 2021b), and it brings a variety of conceptual and comparative tools that can illuminate the trajectories of early cities over time. Prosperity is only starting to be analyzed for the distant past, and having an explicit model of urban prosperity can move this idea beyond its current status as a slogan or buzzword to become a useful analytical concept in archaeology. Population, of course, is a long-standing research theme in archaeology, and the success model provides an additional theoretical context for its analysis.

Flowing from the increased alignment of research on early and contemporary cities is a second benefit of the analysis of urban success: this approach has the potential to generate new findings that allow archaeological research on early cities to make a unique contribution to urban sustainability science (Smith, 2023a; Smith et al., 2021b). Just as paleontology only began contributing significantly to evolutionary theory after its unique contribution – evolution over long periods – was recognized and exploited (Lyman, 2007; Perreault, 2019; Turner, 2009), perhaps archaeological research on early urbanism can begin to contribute to theory and practice in urban sustainability science by developing our own unique contributions in the realm of long-term trajectories of urban stasis and change.

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