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Abstract

World-wide, most global cities are located in coastal zones, but a paradox of sustainability is especially striking for US global cities. This article examines such a paradox, drawn between globalisation-induced development and coastal ecosystems. It focuses on two developmental components found principally in global cities: the agglomeration of foreign waterborne commerce and global business services; and, the accelerated activity and mobility habits of a global professional class. Despite formidable gaps in research, some anecdotal evidence suggests that unique hazards exist for the coastal ecology as globalisation pressures expand a global city's urban footprint.

In the US, only a few coastal cities are global cities, but nearly all global cities are coastal cities. More than 20 per cent of today's US population live in a handful of global cities, but they contain nearly half of those living in coastal zones. Although recognised as core places for the global economy, their comparative impacts on the coastal ecology are seldom the subject of global cities research. Nevertheless, given unique attributes of this form of urban agglomeration, its socioeconomic activities and its coastal location, a global city appears to have different and more problematic impacts on ecological sustainability than other cities. This article is an inquiry into that possibility.

With respect to development pressures commencing after WWII, contemporary globalisation provided global cities with the fuel to be both the engines of economic growth and the principal sources of assault on ecological carrying capacity. With an eye towards global cities, a US National Research Council workshop concluded that

> Urban environments … spur economic development … But, their size and insatiable appetite for growth also mean cities consume resources at prodigious rates, in concentrated areas (Schaffer and Vollmer, 2010, p. 1).

Although 'smart planning' and attendant technologies may enable continued management of this paradox, some seem uncertain about an ability of global cities simultaneously to sustain the developmental benefits

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of globalisation and to sustain ecological integrity over the long run.

Indeed, the paradox raises certain troubling questions. To the extent that global cities have critical attributes distinct from other cities and are located principally in a coastal zone, do they pose different or more problematic issues for sustainability? Is concern for a global city's sustainability simply about urban size or does its composition also warrant special consideration? If composition matters, what factors within global cities act as unique or disproportionately influential sources of impact? If global cities produce different impact vectors than other cities, does this change the stakes of a sustainability paradox?

A sustainability paradox may have always been apparent, but there is risk in seeing an urban/coastal conflict as simply resulting from *longue durée*—the accumulated layers of historical sediment—rather than the work of more recent circumstances. To the extent that post-WWII contemporary forces had disproportionately greater effect on today's global cities than on other urban areas, it may be that more recent events explain differential global city impacts on the coastal ecosystem. Yet, with research lacking, answers remain largely unknown.

There are competing economic and environmental perspectives about sustainability, but this article's analysis is framed by the 'socio-ecological systems' school (for example, Ostrom, 2009) which looks at relationships between human activity and the environment from the angles of energy and materials flow (urban metabolism) and the size and nature of ecological displacement of urban activity (ecological footprint). The analysis revolves around an empirically supported argument about two developmental components found principally (although not exclusively) in global cities—global gateway seaports and a genre of global-aspiring urban professionals. Together, these agents are examined for their particularistic impacts on the coastal ecology and their roles in producing a comparatively higher-stakes paradox for global cities. The inquiry concedes an inability to develop the huge and complex data needed to be definitive, but nevertheless provides evidence supporting a need to investigate further the underlying ingredients of the paradox and its possible resolution.

What Is a 'Global City'?

Scholars frequently argue that global cities around the world (also known as 'world cities' and 'mega cities') share more in common with one another than with other cities with which they share proximity or national identity (for example, Hall, 1966; Friedmann, 1986; Sassen, 2001; Boschken, 2008). Having such affinity, the global city connotes, with varying degrees of clarity, a distinctive multifaceted urban habitat which acts as a portal and stage for world connectivity. As the world's 'global service centres' (Taylor, 2004), their urban habitats are embraced enthusiastically by some but scorned by others. They are often described simultaneously as cosmopolitan, commercially enterprising, congested, socioeconomically polarised, commanding far-reaching world influence and ecologically unsustainable. American global cities are no exception to this variegated characterisation.

Although global cities research often proceeds along the lines of interurban relationships and a focus on mapping a 'world city network' (for example, Timberlake, 2010; Derudder *et al.*, 2010; Alderson *et al.*, 2010; Taylor, 2004), this article pursues another focus which views the global city from an intraurban perspective measured by attributes of place resulting from globalisation. While the two tracks produce nearly identical lists of US global cities (for example, Taylor and Lang, 2005), the intraurban perspective focuses on attributes providing a context more directly related to urban development and its impacts on the coastal ecology.

Although earlier eras of globalisation matter, post-WWII globalisation has been especially crucial to modern global city development. Clark (2004, p. 293) says, for example, that for certain receptive cities that grasped the myriad opportunities, contemporary globalisation has had dramatic cumulative effects involving a post-war, three-stage, partly overlapping sequence of economic, sociological and political transformations. Described in detail elsewhere (Boschken, 2008), these transformations were embodied in: world-scale separation of goods production from locations of product consumption; a massive shift towards international trade flows made possible by a 'container revolution' in shipping; a concentration in strategic cities of global business services firms needed to control and augment these flows world-wide; a revolution in information systems and media technologies; and, a realignment of urban policy-making founded on a 'new political culture' of fiscal conservatism and social liberalism (Clark and Hoffmann-Martinot, 1998). All were unique to the post-WWII period in scale and reach.

These transformations have made contemporary globalisation an essentially postmodern phenomenon, where industrialisation is no longer a central feature of urban life in those cities most affected. Speaking of where globalisation is most evident, some argue that "globalization can be deconstructed in terms of the strategic sites where global processes materialize" (Sassen, 1998, p. 392), and is grounded in what "geographically-situated people do" (Smith and Timberlake, 2001, p. 1657). Yet, not all cities are equally 'strategic'. Most have some global attributes and world connectivity, but global cities are different empirically in that they contain the central agglomerations of globalisation activities. To characterise the US global city, this study draws on previous work (Boschken, 2008) that assembled seven dimensions to distinguish global city status among a sample of 53 large US cities.

Those distinguishing dimensions include

(1) *the size of the urban area*, where size provides a critical mass necessary for holistic global functioning;
(2) an agglomerated *command-and-control platform* for the global economy (Alderson *et al.*, 2010; Taylor, 2004; Sassen, 2001);
(3) a *world entertainment stage* providing globally emulated symbols, amenities and media innovations (Silver, *et al.*, 2010; Markusen and Schrock, 2006; Glaeser and Gottlieb, 2006);
(4) a non-corporate *world research crucible* composed of an agglomeration of university, government and tax-exempt organisations (Matthiessen *et al.*, 2010; Brint, 2001; Kerr, 1963);
(5) a *nexus of multiculturalism* for global social exchange (Sassen, 2004; Nyman, 1996);
(6) a *global gateway* for international transport including air passenger travel (Mahutga, et al, 2010; Derudder and Witlox, 2005) and maritime trade (Jacobs *et al.*, 2011; Verhetsel and Sel, 2009; Boschken, 1988); and
(7) the city as an *integrated and accessible built environment* predicated on effective rail-based mobility systems (Boschken, 2002).

Notably, global city status is not seen as the expression of any one dimension, but rather as a holistic profile that emerges from the synergy and cohesion of these seven dimensions together reflecting a "complex and multifaceted" character (Sassen, 2001, p. 351).

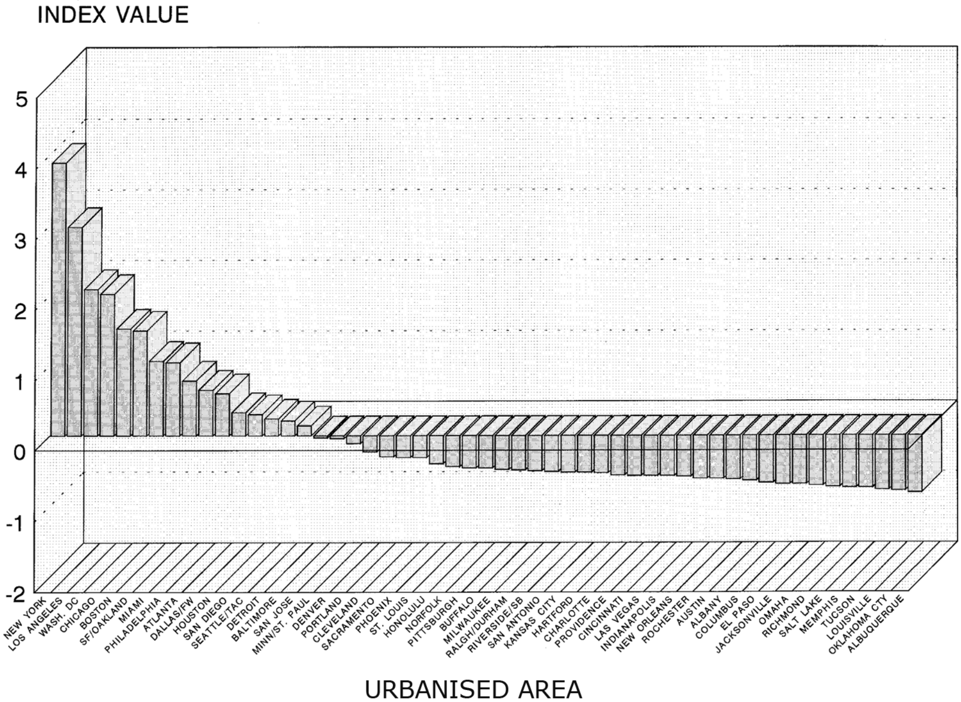

Figure 1. Global, partial-global and non-global cities in the US, year 2000 data: seven-variable index (single factor).

In the Boschken (2008) study of 53 cities, global city status was empirically determined by a two-step procedure. Cities were first located along a scale for each of the seven dimensions and then the dimensions together were factored to produce a composite profile value for each city. In this case, the algorithm produced a composite factor to which all seven dimensions were highly correlated. The factor distribution of those 53 cities is shown in Figure 1.

The factor values were then used in a K-means cluster analysis which distinguished eight cities among the 53 as global cities. The cluster of eight accounted for 15 per cent of the sample and, by order of inclusion, were New York, Los Angeles, Chicago, Boston, San Francisco-Oakland, Washington, DC, Miami and Philadelphia. The figure also shows three urban areas (5 per cent of the sample) that appear to have near-global-city status, but which the dichotomous cluster analysis deemed part of the second grouping of 'other cities'. Except for these, the cluster analysis provides evidence that global cities are measurably distinct from other cities.

Framing the Paradox

Beyond the seven dimensions, a common characteristic of all eight global cities is that they are coastal cities. That is, they exist within 60 miles of a coastline which NOAA (2004) defines as the 'coastal zone' (Chicago is located along a NOAA-designated freshwater coast). Coastal counties in the continental US make up only 13 per cent of the land mass but have 51 per cent of the population (US Census Bureau, 2000; NOAA, 2004; Rappaport and Sachs, 2003). This skewed population distribution is further concentrated in the eight global cities, which combined, represent 40 per cent of the 153 million people residing in US coastal counties (NOAA, 2004). In contrast to bucolic seaside towns and mid-sized coastal cities, the eight global cities represent the dominant form of American coastal urbanisation (with the exception of the three large cities with near-global-city status—Houston, San Diego and Seattle).

The combination of unusually concentrated global activity and dominant urban form points to coastal global cities as central locations for a potentially high-stakes paradox in sustainability (Turner *et al.*, 1996; Marshall, 2005; Baird, 2008). On one side of the paradox are socioeconomic activities and waste-assimilation requirements evidenced by immense building scale, centrality to world-wide economic growth, an elevated consumption culture, a corporate growth orthodoxy and trans-territorial reach. Set against these urban pressures is the coastal zone. As a particularly fragile and biodiverse ecology, it consists of complex interdependent webs of terrestrial, aquatic, marine and atmospheric sub-systems. Its sustainability is made more vulnerable by the invisibility of marine composition beyond the horizon and beneath the surface.

The sustainability paradox in these contrasting observations may be framed by the concept of 'social-ecological systems' (for example, Ostrom, 2009). It holds that sustainability is about relationships between the volume of human activity, dynamic flows of energy and other resources to accommodate that activity and the amount, complexity and diversity of resources that define ecological carrying capacity. Socio-ecological systems are multilevelled and composed of deeply interwoven sub-systems of human activities and dynamic natural ecologies. At various levels, sustainable outcomes are maintained or lost through the interaction of sub-systems, which include resource sub-systems (coastal ecology), resource-user sub-systems (producers and consumers) and governance sub-systems (global city). When resource-user demands outstrip resource sub-system capacities, dynamic balance is lost, such that the sustainability of one sub-system may be sacrificed to another, potentially leading to long-term socio-ecological systemic imbalance. In the case of resource sub-system collapse, the decline is first noticed in persistent pollution and loss of biodiversity.

From this framework, the existence of paradox in coastal global cities appears more troubling than for other cities. On the one hand, the character of global cities (measured by the seven dimensions) is largely moulded by world-wide interurban competition induced by globalisation. On the other, ecological sustainability requires the size and composition of urban sub-systems to exist within the integrity of ecological pathways and long-term carrying capacity limits. The large-area expansion of one and the limits of the other raise a spectre of tightly coupled but essentially incompatible realities at multiple levels.

Ostrom's framework is augmented by two others which help to identify sub-system components and specify the dynamics of sub-system interaction. They are 'urban metabolism' (for example, Wolman, 1965; Haberl *et al.*, 2006; Newman, 1999) and 'ecological footprint' (for example, Rees and Wackernagel, 1996). With more than half the metabolism case literature concentrated on global cities (Holmes and Pincetl, 2012), this model is used to observe flows and transformations of physical mass and energy associated with production and consumption activities within the city. The footprint model introduces a focus on sub-system boundaries allowing for the accounting of resource flows (both linear and circular) and transformations across sub-systems (in this case, tracing impacts from global city resource users on coastal zone resource sub-systems).

These frameworks elicit further concern that the developmental sustainability of global cities and the ecological sustainability of the coastal zone are unlikely to persist in paradox over the long run. Even though technological innovation, resources importation and urban waste export may postpone a paradox resolution, a growth-based strategy for developmental sustainability ultimately forces trade-offs in a finite world that either prohibitively raise the cost of growth or breach carrying capacity.

Observed through impact vectors (such as greenhouse gases, solid waste, sewage, energy utilisation), coastal global cities may house metabolisms more problematic to environmental sustainability than other cities. For instance, even though some argue that "sustainable development is about reconciling 'development' and 'environment'" (McGranahan and Satterthwaite, 2003, p. 244), others argue that in the case of very large social-ecological systems (such as coastal global cities), reconciliation is less likely than paradox resolution involving trade-offs favouring developmental sustainability (Ostrom, 2009, p. 420).

Urban Metabolism of Global Cities

Given that global cities exhibit an attribute profile contrasting with those of other cities (summarised in Figure 1) and have a propensity for coastal locations, how might these characteristics prescribe uniqueness in urban metabolism? Is a global city's metabolism simply a matter of scale or does its composition of production and consumption activities convey uniqueness as well? If the latter, what particular aspects of economic development matter most? In response, attention is placed on metabolism scale (measured by population size) and two metabolic activities that appear quintessential to global city development during the transformative stages of the post-WWII era. The first is about containerised seaport activities and attendant agglomeration of business services. The second has to do with the high-octane lifestyle of a global-aspiring professional upper middle class (UMC) drawn to the global city by its attributes. Both are the result of globalisation; both are indigenous to global cities; and both are resource-user sub-systems contributing to an ecological footprint. The first characterises a production source, while the second characterises a consumption source.

Urban scale is widely researched and needs little introduction. By contrast, the potential significance of post-WWII seaports and a globalised UMC are often understated or overlooked in relevant literatures. Little attention to impacts of urban containerised seaports is found in either the global cities literature (for partial exceptions, see Jacobs *et al.*, 2011; Verhetsel and Sel, 2009) or the environmental sustainability literature (for exceptions, see Cannon, 2008; Boschken, 1988). Impacts from UMC lifestyle have received virtually no attention in global cities research and only marginal attention in environmental sustainability (for exceptions, see Clement, 2010; Wheeler, 2009; McGranahan and Satterthwaite, 2003). Yet, global city seaports and UMC lifestyle, both individually and systemically, would seem to be significantly associated with the paradox and the consequences of an overextended ecological footprint. The next two sub-sections explain why.

Load-centre Seaports and Global Support Services: A Production Source of Impacts

Contemporary globalisation is rooted in the ability to move a huge tonnage of goods swiftly around the world at a scale and efficiency that renders cost per unit of transport minimal or insignificant in the final per-unit cost of goods sold (Boschken, 1998; Levinson, 2006). To make these efficiencies possible, transformational technologies in ship design and seaport terminals emerged in the late 1960s and 1970s that revolutionised maritime shipping by transporting goods in large salt-resistant metal containers (Boschken, 1988).

In the 1970s, the biggest ships (about 300 feet in length) were transporting 2000 containers per load to multiple ports of call. By 2010, newer 'post-panamax' ships (up to a quarter of a mile in length) were handling more than 16 000 units. This dramatic shift in size led to enormous pressures for the emergence of one-stop seaports called 'load centres' (Boschken, 1998) and for certain seaport cities to emerge as principal nodes of foreign-trade activities.

Along with the ability to transfer goods across the sea–land barrier, the load centre concept encouraged agglomeration of advanced producer services (APS) into corporate command-and-control platforms (Jacobs *et al.*, 2011), another central attribute of global cities. Although conventional wisdom holds that a global knowledge economy (Brint, 2001; Romer, 1990) makes proximity and geographical location less important, evidence shows that it reinforces localisation, especially for agglomeration of those business services integral to the global economy (Porter, 1998).

At the dawn of the container revolution in the 1970s, all large American coastal cities were in the competitive mix of maritime shipping routes. After the turn of the century, only a handful of load centre cities remained. The spatial centralisation and agglomeration of global seaport and APS functions were the result of growing scale and complexity in the emerging global economy which produced intense pressures for logistics and command efficiencies. The effect was emergence of a wide disparity in global centrality between coastal global cities and other cities that either were not coastal or were but failed to anticipate the technological, infrastructure and APS requirements of globalisation. Developmentally, a global city's centrality in foreign maritime commerce and related APS boosted its stature and resources in a world city network.

For the paradox in developmental and coastal sustainability, the argument is this: developmental success of global cities is heavily driven by influences of the global economy being directed through maritime load centres and associated APS agglomerations. In the course of this transformation, these resource-user sub-systems were likely to be metabolising more and different marine, terrestrial and atmospheric coastal resources, at least in the form of wastes (for example, heavy metals and greenhouse gases). Specifically, the city's transformed ecological footprint probably involves special demands on ecological sinks to assimilate the resultant stream of by-products associated with load centres and APS.

Upper Middle Class Lifestyle: A Consumption Source of Impacts

Population pressures associated with the scale of urban consumption and a particular post-industrial lifestyle have been cited as principal threats to environmental sustainability (for example, Glaeser and Gottlieb, 2006; McGanahan and Satterthwaite, 2003). Glaeser and Gottlieb, for example, argue two points about urban consumption. First, with a focus on aggregate demand, they point to scale being critical to estimating the impacts of an ecological footprint. Secondly, with reference to lifestyle-related per capita consumption, they note that cities have experienced "a renaissance as places of consumption, not production" (Glaeser and Gottlieb, 2006, p. 1276).

Scale and 'renaissance' lifestyle influences may be interdependent. Being the largest among urban areas in aggregate consumption, global cities are more likely to have achieved critical masses in provision capacity spanning multiple urban services and amenities. Therefore, they are better able than other cities to agglomerate more of globalisation's desirable opportunities and benefits (Porter, 1998; Huggins and Izushi, 2009), which in turn, attract those lifestyles that engender higher per capita activity levels, resource uses and intraurban mobility. One might also expect that a city's size, global centrality and world-wide connectivity may determine how urbanites interact, what activities they pursue, how much they make and spend, and what consumption patterns they exhibit.

Leading this consumption-based 'urban renaissance' (Glaeser and Gottlieb, 2006) is a socioeconomic status (SES) traceable to a highly visible upper middle class. Not to be confused with activities of a stealth upper class, these 'on-the-go' lifestyles reflect the habits of well-educated and well-paid professionals and their cosmopolitan families (Boschken, 2002). Reich (1992) refers to them as 'symbolic analysts' engaged in what Brint (2001) calls a 'scientific-professional knowledge economy'. Not by coincidence, those seeking APS employment act as vectors of knowledge and skills crucial to operating at a global scale (Beaverstock *et al.*, 2010).

Both on and off the job, UMC professionals tend to envision their opportunities, movements and activities in the context of an enriched 'urban field', described by Friedmann and Miller (1965) as holistic cognitive maps of a metropolitan area and containing spatially separated but functionally integrated activity locations. In this context, what does a global city offer UMC professionals that other cities and rural areas are less able to provide? Besides commuting flexibility (which includes the global city attributes of effective transit infrastructure and a global gateway airport), the UMC lifestyle demands venues that facilitate frequent specialised face-to-face meetings (Porter, 1998) outside their workplaces but within an intraurban agglomeration of professional contacts and locations.

Consistent with this characterisation are non-parametric travel patterns spread across the urban field that involve numerous personal chores and professional engagements (including global city attributes of a command-and-control platform, global research centres and world-class entertainment venues). Since UMC status often comes with more proportionally higher dual-breadwinner families (often both professionally employed) than the median family, their work- and leisure-related transport habits also may be magnified. Add to this, myriad elevated activities (jobs and commuting) of others induced by UMC consumption demands for child care, residential maid service and landscapers, private social and recreational clubs, limo and retail pick-up and delivery services, health and cosmetic services.

UMC-inspired consumption also may be heightened in global cities by the genre's 'systemic power' (Stone, 1980) over a broader activity scene (especially non-work-related) by providing a consumption profile that the larger indigenous non-UMC population may seek to emulate (Boschken, 2003). Further, global cities are gateways of travel and temporary stays for global business, research and entertainment purposes and, therefore, attract a larger mix of highly educated professionals from places other than non-global cities (Beaverstock *et al.*, 2010). These non-resident UMC (often with family in tow) may prefer a global city activity scene modulated by the systemic power of an indigenous UMC.

Placing the UMC's potential impacts on ecological sustainability in the context of Ostrom's socio-ecological model, the inference is that UMC lifestyle characterises a particular resource-user sub-system having a high-consumption metabolism which also modulates overall indigenous consumption through its systemic-power effects. Hence, beyond the impacts of urban scale alone, accelerated per capita consumption and mobility may result from a disproportional share of professional UMC in global cities, causing additional and possibly unique impacts on the coastal ecology.

Comparative Methods

The analytical concern here is about two issues: (1) whether global cities stand out from other urban areas according to their urban metabolism, and (2) whether their ecological footprint is sufficiently different to raise the possibility of a unique sustainability paradox. Due to insufficient standardised comparative data, the evidence presented is not intended to 'prove' an argument, but rather to spark a search for new data and to encourage the pursuit of important theoretical and policy questions raised by the insufficiency. Also due to data insufficiency, this study does not calculate detailed consequences (individually or holistically) for coastal sustainability stemming from a city's metabolism and footprint. Instead, the analysis follows a sequence that first addresses the comparative uniqueness of sub-system metabolism (seaports and the UMC genre) and then examines some impact vectors for both.

The comparisons draw from the sample of 53 large US urban areas (exceeding 500 000 in population) identified in earlier global city research (Boschken, 2008). That work classified each city according to the census category: 'urbanised area' (UA). It is defined as a functionally integrated metropolitan area where every location (core and suburb) within it has "a general population density of at least 1000 people per square mile" (US Census Bureau, 2000). MSA data (which contain urban and some rural sub-areas) were used in the comparisons when UA data were unavailable (for example, in the use of NAICS data).

The compiled data came from several sources, most of which used the millennial base year of 2000. Where data were unavailable for this base year, data were compiled for the year closest to the millennial. The bulk of data came from the Census of the Population (US Census Bureau, 2000), Census of Economics, NAICS Basis (US Census Bureau, 1997), urban transport statistics (FTA, 2000; Schrank and Lomax, 2009) and waterborne commerce reports (Port Import Export Reporting Service, 2001). For coastal implications, additional data from NOAA (2004) and other sources were merged with the urban and economic data in SPSS format.

Evidence: Unique Urban Metabolism

In general, the evidence appears to support the argument that a disproportional presence of load centre seaports, APS platforms and UMC lifestyle occurs in global cities and is associated with more and different urban metabolism compared with other cities. Where exceptions exist (individually identified in what follows), they are limited in scope. In cases where one or more of the eight global cities are found outside top-eight rankings, cities displacing them held factor ranks *closest* to the cluster. Moreover, none of the individual exceptions occurs in more than one category.

Regarding seaports as a production source of urban metabolism, Table 1 shows

Table 1. Foreign trade seaports and the global command platform (containerised cargo transshipment and business services, 2000 data)

	Seaport centrality in global trade			
Urban area (listed by 7-dimension factor[a]	*Seaport type*	*Seaport size*[b] *(millions of TEUs)*	*Percentage US foreign waterborne TEUs*	*Global platform (53-city rank)*
Global cities				
1. New York	Primary load centre	2.36	13.0	1
2. Los Angeles	Primary load centre	6.62	36.5	3
3. Chicago	Small, miscellaneous	0.03	0.1	4
4. Boston	Small, container	0.06	0.1	5
5. San Francisco/ Oakland	Secondary load centre	0.96	5.3	6
6. Washington, DC	—	—	—	2
7. Miami	Secondary load centre	0.72	4.0	(16)
8. Philadelphia	Secondary load centre	0.27	1.5	(10)
Eight global cities	–	**11.02**	**61.0**	
Other urban areas				
9. Atlanta (Savannah)	Secondary load centre	0.81	4.5	(50)
10. Dallas/Ft Worth	—	—	—	7
11. Houston	Secondary load centre	0.78	4.3	(11)
13. Seattle/Tacoma	Primary load centre	1.43	7.9	(15)
14. Detroit	—	—	—	8
15. Baltimore	Secondary load centre	0.27	1.2	(18)
25. Norfolk	Secondary load centre	0.91	5.0	(50)
Total US foreign containerised cargo	—	18.12	100.0	

[a]Listed according to global city factor values (see Figure 1 for order).
[b]Measured by the number of '20-foot-equivalent units' (TEUs).
Source: Port Import Export Reporting Service (2001).

an association of the eight global cities with container ports handling foreign trade cargo. Five of the eight global cities contain load centre seaports (Washington, DC, has no maritime port facilities). New York and Los Angeles contain the two largest US container seaports, accounting for 13 per cent and 36.5 per cent of total US containerised foreign waterborne cargo respectively. Combined, the eight global cities (representing 15 per cent of the sample) account for 61 per cent of containerised maritime cargo entering or leaving the US. By contrast, only 5 of the other 45 cities have comparable load centre volume, the largest of which is Seattle/Tacoma.

Table 1 also shows ranking according to the biggest US business services platforms. Six of the eight top global command platforms are found in global cities. Miami and Philadelphia are not in the top eight, but still rank in the top third of the 53-city sample. By contrast, Dallas and Detroit, neither of which has a seaport, are the only two non-global cities with platforms in the top eight ranking. Hence, in combination, foreign-trade cargo and dollar flows for international business services appear to form a concentration in the global city cluster.

Regarding consumption-driven metabolism, urban size and UMC lifestyle appear to be associated with relatively higher metabolism levels distinguishing global cities from others. This is noted in correlations of a size effect and a UMC modulation effect with the global city factor. Using average annual consumption expenditures per household (Bureau of Labor Statistics, 2011) as a base, a size effect on consumption was calculated by multiplying BLS figures for each urban area with households to produce aggregate consumption. The UMC modulation effect was calculated as an interaction of BLS's average consumption per household and an urban area's percentage of UMC professionals in its population.

The results show that, although the global city factor is marginally associated with BLS's average consumption ($r = 0.38$, significant at the 0.05 level), it is more strongly associated with a size effect ($r = 0.91$, significant at the 0.01 level) and the UMC modulation effect ($r = 0.42$, significant at the 0.01 level). Correlation of size and UMC presence shows the two to be independent of one another. Yet, UMC presence is marginally associated with average per household consumption ($r = 0.39$, significant at the 0.05 level), suggesting that Stone's systemic power is marginally in play amplifying general consumption levels.

These influences are also found by comparing individual global cities with other cities included in the top eight ranks. Table 2 shows these according to average consumption per household and the two sources of influence: urban size and UMC lifestyle. Consistent with Glaeser and Gottlieb's (2006) argument that urban size and consumption metabolism are linked, the global city cluster (15 per cent of the sample) accounts for 88 per cent of the top eight rankings for aggregate consumption. The UMC lifestyle effect accounts for 38 per cent of the top rankings. On the surface, no meaningful difference exists between rankings of average consumption and rankings according to UMC influence, but: UMC presence and average consumption appear to be marginally coupled as indicated in the correlation; and, UMC buying propensity alone (excluding the systemic power effect) may be already implicit in average consumption.

Finally, global cities appear to share the highest consumption metabolism with a few other urban areas (13 per cent of the remaining 45 in the sample), but all are located on the factor scale near the global city cluster. Notably, Dallas ranked 7th and 8th for size and UMC lifestyle effects, while four others held top eight rankings for UMC effect.

Table 2. Consumption metabolism: urban size and UMC lifestyle (global city ranks derived from 53-cities sample, 2000 data)

Urban area (rank)[a]	*Per household average annual consumer expenditure*	*Sources of influence*	
		Size effect (aggregate consumer expenditures)	*UMC lifestyle effect (modulated per household average consumer expenditure)*
Global cities			
1. New York	7	1	5
2. Los Angeles	(9)	2	(14)
3. Chicago	(12)	3	(13)
4. Boston	(23)	(11)	(10)
5. San Francisco/Oakland	1	4	2
6. Washington, DC	3	8	1
7. Miami	(17)	6	(26)
8. Philadelphia	(19)	5	(15)
Eight global cities (percentage ranked in top 8)	**38**	**88**	**38**
Other urban areas in top eight rank of 53			
10. Dallas/Ft Worth	5	7	8
11. Houston	6	(9)	(11)
12. San Diego	4	(13)	4
13. Seattle/Tacoma	(11)	(16)	7
17. Minneapolis/St Paul	2	(15)	3
18. Denver	8	(17)	6

[a]Listed according to global city factor values (see Figure 1 for order).
Sources: Data for 53 urbanised areas as reported by Boschken (2008); US Census Bureau (2000); Bureau of Labor Statistics (2011).

In short, even though the highest UMC influences on metabolism are found in some urban areas outside the global city cluster, the results indicate an affinity of UMC for global cities along with higher attendant consumption levels.

Besides raising consumption, size and UMC influences also may be associated with systemic multiplier effects. For example, an apparent relationship exists between UMC activity levels and measures of aggregate mobility demand. Table 3 shows significant correlations between three UMC-populated global platform activity areas (measured by command centre employment, institutional research employment and entertainment receipts) and demand pressures on specific urban mobility modes. With regard to public transit, greater amounts of global platform activities are associated with greater per capita use of public transit (r = 0.79, 0.69, 0.58 respectively). So also are higher levels of urban traffic congestion (r = 0.50, 0.42, 0.54 respectively). Likewise, greater numbers of international airport passengers are highly associated with UMC platform activities (r = 0.76, 0.42, 0.84 respectively).

Table 3. UMC 'systemic power' and mobility pressures (53 US cities: correlations, year 2000)

Mobility demands	*Upper-middle-class activities*[a]		
	Command centre employment	*Institutional research*	*Entertainment receipts*
Transit consumption per capita	0.79	0.69	0.58
Urban traffic congestion index	0.50	0.42	0.54
International airport passengers	0.76	0.42	0.84

[a]Indicators for these activity types are three of the seven dimensions composing the global city factor.
Note: Correlations significant at the 0.01 level.
Sources: FTA (2000); Schrank and Lomax (2009); OAI/BTS (2000).

Although this circumstantial evidence indicates that a global city's activity and mobility levels may be connected and point to a disproportional UMC influence, how might these be tied more directly to the global/non-global comparisons? One area of support is found in a rank order analysis of urban areas according to the three mobility correlates found in Table 3: per capita transit consumption, traffic congestion and international travel flows. The results are reported in Table 4 and show global cities to be most prevalent among those urban areas having the highest UMC-induced mobility levels.

For per capita transit use, 88 per cent of global cities appear in the top eight (Miami is 10th). For highest roadway congestion, 63 per cent of global cities appear in the top eight (New York, Miami and Philadelphia are 19th, 9th and 26th respectively). For international air travel, 75 per cent of global cities hold the highest ranks (Chicago and Philadelphia are at 15th and 10th). By comparison, seven other cities hold limited placement among the top ranks, none of which claims more than one top ranking across the categories. For example, Atlanta holds 6th place in roadway congestion, but is not near the top ranking in other categories. Hence, the analysis seems to show that these three urban mobility indicators are significantly related to specific UMC-populated activities and indicate that metabolism from consumption and attendant mobility is highest in global cities.

Discussion: Ecological Footprint and Vector Impacts

Do global cities possess unique attributes that foster larger or different socioeconomic metabolisms than other cities? With available evidence, the answer appears to be yes. For load centre seaports and a UMC genre, it offers a picture of distinguishable metabolic activities particularly concentrated in the eight US global cities. From the social-ecological perspective, it would be tempting to argue from this that a global city's comparatively higher developmental pressures from globalisation carry heightened risk and compounded negative consequences for ecological sustainability relative to other urban areas. Moreover, as production and consumption metabolisms outstrip local natural resource capacities, the global city footprint holds implications *beyond* its urban confines for natural resources procurement and waste disposal.

Nevertheless, affirming a connection between metabolism and ecological impact is fraught with an insufficiency of scientific data. Mindful of this, researchers overall

Table 4. UMC consumption: mutiplier effect on urban metabolism (rank comparisons derived from 53-Cities Sample, 2000 Data)

Urban area (rank)[a]	*UMC-induced demand on mobility*		
	Transit consumption	*Roadway congestion*	*International air travel*[b]
Global cities			
1. New York	1	(19)	1
2. Los Angeles	3	1	3
3. Chicago	2	7	(15)
4. Boston	7	8	6
5. San Francisco/ Oakland	4	2	4
6. Washington, DC	5	3	8
7. Miami	(10)	(9)	2
8. Philadelphia	6	(26)	(10)
Percentage of global cities in top eight rank of 53	**88**	**63**	**75**
Other urban areas in top eight rank of 53			
9. Atlanta	(9)	6	(14)
11. Houston	(11)	(29)	7
12. San Diego	(12)	5	(47)
13. Seattle/Tacoma	8	(15)	(11)
16. San Jose	(19)	4	(47)
24. Honolulu	(20)	(34)	5

[a]Listed according to global city factor values (see Figure 1 for order).
[b]Ranked according to the percentage of total US international travellers passing through the city's airport. Based on Form 41 Traffic (OAI/BTS, 2000).

are "increasingly aware of the limitations of current knowledge" regarding ecological impacts and outcomes induced by development (NRC, 2011, p. 2). In this study of 53 cities, such limitations include lack of comparability, leaving incomplete or anecdotal evidence as the principal means to draw extensions between metabolism and impact vectors embedded in ecological footprints.

Compounding the limits of knowledge, there is also a counter-argument to the claim that higher or different urban metabolism begets ecological footprints and outcomes unique to global cities. It says that global cities, by virtue of their skewed abundance of human intelligence and creative professional capital (for example, Florida, 2001), have greater capacity to maintain the paradox such that trade-offs in sustainability are minimised and the relationships remain in balance. Specifically, global cities are thought to be enabled simultaneously to engage in economic development and to maintain the coastal ecology because they have a disproportionately larger size to achieve land use efficiencies, a more powerful public-minded 'regime' (Stone, 1987) to mobilise great efforts (leadership), a more enlightened electorate (political culture) and more organisational resources (economic systems). So, even though seaports and a UMC presence may be more conspicuous in global cities, these places are better positioned than other cities to contain or mitigate potential environmental impacts.

Limited knowledge and contrasting perspectives notwithstanding, what evidence in vector impacts might suggest that we are observing either a ‘canary in the mineshaft’ or not? In the case of global coastal cities, the footprint might include such impact vectors as transport congestion across the urban field, harbour and coastal water pollution (from solid waste leaching, chemical spills and intractable toxic wastewater effluents), persistent water resources depletion, acute air pollution and changes in coastal marine composition due to CO_2 emissions and urban waste effluents. We might also be interested in knowing how these interact synergistically to cause systemic impacts. For this quest, some research provides partial clues on probable sustainability outcomes. One thread focuses on coastal and harbour pollution probably related to seaport activities. Another relates to transport emissions in urban areas probably related to UMC mobility. A third speaks to synergistic effects acting systemically.

Regarding the ecological footprint attributable to seaports, a study of water pollutants along California’s coast and harbours compared the presence of methylmercury and PCBs at numerous locations (California State Water Resources Control Board, 2011). Marine water samples were collected in and near the two global cities of Los Angeles and San Francisco, and other cities including San Diego, Santa Barbara and less-urbanised coastal locations.

Using 2009 readings, the report showed a considerable spiking of both contaminants (mercury >440 ppm, PCB >120 ppm) in harbour waters nearest the Los Angeles/Long Beach and San Francisco/Oakland container terminals. While San Diego showed one location near the Navy’s South Harbor berths with high levels of PCB (>120 ppm), the rest of its harbour and coastal waters consistently showed moderate or low levels. All other coastal areas tested much lower for these contaminants. Although the study covered only the California coast, one might expect comparable results on the other US coasts where global cities are present.

Regarding UMC mobility impacts, evidence was examined for urban CO_2 emissions. By extracting CO_2 data from Glaeser and Kahn (2008), the research compared the 53-cities sample according to relative per capita emissions from transport use (auto + transit). As in the California coastal contaminants report, the results speak to both this article’s thesis and the counterclaim. For example, per capita CO_2 is an impact vector and reasonable marker for urban metabolism, but is nuanced by factors largely determined by land use configuration (see also, Brownstone and Golob, 2009).

In order for the counter-thesis to have merit, American global cities would have to share a trait of efficient densities presumably resulting from community-minded leadership and superior human capital (i.e. smarter and ‘greener’ policy-makers and planners) and from their pre-suburbanisation design as older American cities. However, data analysis for the 53 cities and studies elsewhere (Sorenson, 2009) show that neither global nor other cities have common land use patterns. Hence, while CO_2 exhibits a significant inverse correlation with urban density (r = –0.47, significant at the 0.01 level), it has an insignificant relationship with global city status (r = –0.19, significant at the 0.17 level).

Indeed, Table 5 shows global and other urban areas to vary widely in density and per capita CO_2 emissions. Los Angeles exhibits a polycentric and sprawled land use pattern, but census data show it to be the most densely urbanised area in the 53-city sample and near the lowest in transport-sourced CO_2 emissions. Although Los Angeles, New York, San Francisco and Miami are global cities with high density and lower CO_2 emissions,

Table 5. Impact vector: urban configuration and CO_2 emissions (rank comparisons derived from 53-cities sample, 2000 data)

Urbanised area[a]	*Urban density (highest density = 1)*	*Per capita CO_2 emissions (highest emissions = 1)*
Global cities		
1. New York	3	51
2. Los Angeles	1	50
3. Chicago	10	11
4. Boston	41	48
5. San Francisco/Oakland	4	43
6. Washington, DC	16	3
7. Miami	8	16
8. Philadelphia	24	37
Other urban areas		
9. Atlanta	51	4
10. Dallas/Ft Worth	23	15
11. Houston	22	17
12. San Diego	15	47
13. Seattle	26	7
14. Detroit	19	24
15. Baltimore	21	19

[a]Listed according to global city factor values (see Figure 1 for order).
Sources: US Census Bureau (2000); Glaeser and Kahn (2008).

they represent only half of the eight global cities. The other four have density and CO_2 figures that are uncorrelated. Boston has the oddest combination of lower density and lower CO_2. Other urban areas in the sample show similar lack of pattern.

The lack of CO_2 association with the global city dimensional factor is disconcerting, especially when global cities account for 40 per cent of the US coastal population. Given their role as a governance subsystem in the socio-ecological model, urban areas represent the system's policy-making potential. However, even with a global city's unique aggregations and superior intellectual resources, such places do not appear to manage greenhouse gases distinguishably better than other urban areas. Plentiful human capital, deliberate 'green' planning or mitigation attempts have not seemed to alter the mobility impacts on the ecology in a way that favours an argument for superiority of global cities in dealing with the paradox, at least regarding a per capita CO_2 footprint.

How might such outcome failure speak further to systemic impacts? An ocean acidification study (NRC, 2010) raised concern about multiple synergistic pathways of coastal urban wastes and toxics as contributors to the rapidly declining pH (acidification) of shallow coastal waters. Although airborne CO_2 emissions matter most (through direct absorption by oceans and indirectly by global warming on marine temperatures), the study found unique systemic impacts from urban activity. Highlighting "corrosive events" and "dead zones" (p. 51), it concluded that coastal ecosystems are "subject to a diversity of stresses caused by human activities, such as organic matter and nutrient inputs, pollution by toxic organic compounds and metals" along with other ingredients (p. 50). The report pointed to data implicating the largest coastal cities as contributing the highest contaminant concentrations with systemic effects.

Suggesting a 'canary in the mineshaft', anecdotal evidence leaves reason to be concerned that global city development and the coastal ecology may form a uniquely challenging, high-stakes paradox in sustainability. It also urges action for building research capacity to test the proposition that global cities' unique metabolisms have created a footprint of impacts incompatible with limits of the coastal ecology's carrying capacity. One wonders if this proposition might hold world-wide.

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