A critical assessment of key datasets and approaches with which to determine the resource requirements of future urbanisation

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Abstract

It is now generally agreed that in order to avoid the severe threats posed by the "global polycrisis" of climate change, ecological degradation, biodiversity loss, water scarcity, food insecurity, income inequality, poverty and over-consumption of raw materials, a pathway of sustainable development must be found in the 21st century. It is also increasingly recognised that urban areas, where the majority of the people on the planet now live, and where the vast majority of energy and materials are consumed, are not only key contributors to the global polycrisis, but also hold the key to a pathway of sustainable development.

However, with around 2.5 billion people projected to be added to the global urban population by 2050, serious questions need to asked about the sustainability of such urban growth. But nearly everyone in the mainstream urbanisation literature seems to assume that urbanisation will continue unabated, and that somehow the resources will be found to make this happen. Nobody is asking, "what are the resource requirements of future urbanisation?" So, the original goal of this study was to try and find an answer to this vital question.

However, in order to assess the resource requirements of global urbanisation to 2050, three key sets of figures would have to be accepted, namely: estimates and projections of urbanisation, population and urban resource consumption. And, in the analysis of the literature surrounding these data themes, fundamental problems were uncovered. So, the focus of the study was then shifted from trying to assess the resource requirements of future urbanisation, to critically analysing the way in which to do so.

As a result, an extensive literature analysis was undertaken over three chapters, focussing on global urbanisation, population growth and resource consumption. The key findings of these literature analyses are that:

- the inaccuracies, inconsistencies and uncertainties that are imbedded within the urbanisation estimates and projections of the UN are of such a nature that their data must be considered too unrealistic and unreliable to form the basis of a comparative study on global urbanisation;

- in the coming decades, economic factors look set to both impede the decline of Africa's high fertility rates and drive an increase in the fertility rates of low-fertility countries, and, if

this materialises, the combined effect would be a much higher global population by 2050 than any world population perspectives currently projects;

- the domestic material consumption (DMC) indicator that is used in material flows analysis (MFA) studies of cities and countries, does not provide a realistic picture of a city or country's resource consumption, because it does not account for the upstream raw materials that were required to enable the consumption at the final destination.

An alternative perspective to assessing global urban resource consumption is then proposed, which re-defines "urbanisation" from a global socio-metabolic perspective, and uses the raw material consumption (RMC) indicator and a range of population projections in its method.

Opsomming

Sedert die 1960s het die wêreldpopulasie meer as verdubbel, wêreldwye roumateriaalverbruik het meer as verdrievoudig, die wêreldwye stadsbevolking het verviervoudig, en die wêreldekonomie het meer as verviervoudig. Hierdie vinnige groei en ontwikkeling het teen 'n duur omgewingsprys gekom, en in die 21ste-eeu word die menslike beskawing gekonfronteer deur die "globale veelvoud-krisis" van klimaatsverandering, ekologiese degredasie, biodiversiteitsverlies, voedsel- en water-onsekerheid en hulpbronverlies. Dit word nou in die algemeen aanvaar dat indien hierdie bedreigings teen die volhuibaarheid van moderne menslike beskawing oorkom wil word, 'n pad van volhoubare ontwikkeling gevind moet word. Dit word ook al hoe meer herken dat stads- en dorps-areas, waar die meerderheid van mense op die planet nou woon, en waar die oorweldige meerderheid energie- en material-hulpbronne verbruik word, nie net belangrike sleutelspelers is in die bydra tot die globale veelvoud-krisis nie, maar ook die sleutel dra tot 'n pad van volhoubare ontwikkeling.

Alhoewel, met die beraming dat 2.4 biljoen mense nog by die wêreldwye stadsbevolking gevoeg gaan word teen 2050, moet ernstige vrae gevra word oor die volhoubaarheid van sulke stadsgroei. Maar, dit kom voor asof amper almal in die hoofstroom literatuur oor verstedeliking net aanvaar dat verstedeliking net kan aanhou, en dat die nodige hulpbronne op een of ander manier gevind sal word om dit te laat gebeur. Niemand vra, "wat is die hulpbronvereistes van toekomstige verstedeliking?" nie. So, die doel van hierdie studie was om 'n antwoord vir hierdie vraag te probeer kry.

Maar, indien die hulpbronvereistes van wêreld-verstedeliking tot 2050 beraam wil word, dan moet drie data-stelle aanvaar word, naamlik: waarderings en projeksies van verstedeliking, populasie en hulpbronverbruik. En in the analise van die literatuur rondom hierdie drie data-stelle het fundamentele en wyd-rykende probleme na vore gekom. So, die fokus van hierdie studie het toe verander van een wat die hulpbronvereistes van toekomstige verstedeliking wil beraam, tot een wat die maniere om dit te doen krities analiseer.

Om dit te doen was 'n omvattende analise van die literatuur gedoen, met huidige waarderings en projeksies van verstedeliking, populasie-groei en hulpbronverbruik wat geanaliseer word oor drie hoofstukke. Die belangrikste vindings is dat:

- die onakuuraatheid, inkonsekwentheid en onsekerheid wat gekoppel is aan die verstedeliking waarderings en projeksies van die Verenigde Nasies (VN) is van so 'n aard

dat hulle data as te onrealisties en onvertroubaar beskou moet word vir ‘n studie oor wêreldwye verstedeliking;

- binne die komende dekades gaan ekonomiese faktore heel moontlik terselfdertyd die hoë vrugbaarheidsvlak van Afrika verhoed om vinnig te daal en ook verhogings in die vrugbaarheidsvlak van lande met lae vrugbaarheid veroorsaak – en, as dit verwesenlik word, sal die gekombineerde effek ‘n veel hoër wêreldpopulasie teen 2050 wees as wat enige van die huidige wêreldpopulasie-projeksies voorspel;

- die “domestic material consumption” (DMC) aanwyser wat gebruik word in materiaalvloei-analise (MFA) studies van stede en lande lewer nie ‘n realistiese prenjtie van ‘n stad of land se hulpbronverbruik nie, want dit reken nie die bo-stroom rou-materiale in wat benodig was om die eindverbruik moontlik te maak nie.

‘n Alternatiewe perspektief om die wêreld se stedelike hulpbronverbruik te bereken word voorgestel, wat “verstedeliking” van ‘n sosio-metaboliese perspektief her-definieer, en wat die “raw material consumption” (RMC) aanwyser en ‘n wyer verskeidenheid van populasie projeksies in sy metode gebruik.

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List of acronyms and abbreviations

CAR	-	Central African Republic
CH_4	-	methane
CO_2	-	carbon dioxide
CU	-	counter-urbanisation
DE	-	domestic extraction
DMC	-	domestic material consumption
DRC	-	Democratic Republic of Congo
EF	-	ecological footprint
EU	-	European Union
FAO	-	Food and Agriculture Organisation of the United Nations
GDP	-	gross domestic product
GHG	-	greenhouse gas
IEA	-	International Energy Agency
IPCC	-	Intergovernmental Panel on Climate Change
MF	-	material footprint (alternative name for RMC)
MFA	-	material flow analysis
N_2O	-	nitrous oxide
OECD	-	Organisation for Economic Co-operation and Development
RMC	-	raw material consumption (alternative name for MF)
SFA	-	substance flow analysis
SSA	-	Sub-Saharan Africa
TFR	-	total fertility rate
TMC	-	total material consumption
TMR	-	total material requirement
UK	-	United Kingdom
UM	-	urban metabolism
UN	-	United Nations
UNDP	-	United Nations Development Programme
UNEP	-	United Nations Environment Programme
UNESCO	-	United Nations Educational, Scientific and Cultural Organisation
UN-HABITAT	-	United Nations Human Settlements Programme

UNPD	-	United Nations Population Division[1]
USA	-	United States of America
WBCSD	-	World Business Council for Sustainable Development
WPP	-	World Population Prospects (report published by the UNPD)
WUP	-	World Urbanisation Prospects (report published by the UNPD)
WWF	-	World Wildlife Fund for Nature

[1] The full name of this UN body is "United Nations Department of Economic and Social Affairs, Population Division". This was shortened to "United Nations Population Division" or "UNPD", as was done by the Population Reference Bureau (2014).

CHAPTER 1

Introduction

1.1 Background

1.1.1 Our unsustainable development and the global polycrisis

In 1972 the first United Nations (UN) conference on the environment was held in Stockholm, Sweden (UN, 1972), and the "sustainable development" concept was also first introduced to the world by the pioneering work *The Limits to Growth* (Meadows, Meadows, Randers, & Behrens, 1972). Since then global efforts towards the environment and to the sustainable development of modern human civilisation have increased markedly. These efforts got off to a slow start, however, so in 1983 the UN established the World Commission on Environment and Development (WCED) (also known as the Brundtland Commission) to formulate new proposals to deal with the important environmental and developmental issues facing the world (WCED, 1987; Swilling, 2004; Wheeler & Beatley, 2004). The result after three years was a document entitled *Our Common Future*, which is widely known as the *Brundtland Report* (Mebratu, 1998; Swilling, 2004). The *Brundtland Report* famously defined sustainable development as *"development that meets the needs of the present without compromising the ability of future generations to meet their own needs"* (WCED, 1987: 43).

Since the Brundtland Commission was dissolved in 1986, three major UN conferences on the environment and sustainable development have been held[2], and in the 21st century the sustainable development concept finally managed to gain a firm foothold in the global policy arena. This establishment of "sustainable development" as a top priority in the global policy arena was confirmed at the 2015 Sustainable Development Summit in New York, when world leaders replaced the UN's Millennium Development Goals with a new set of global targets, which are now referred to as the "Sustainable Development Goals" (UNEP, 2015).

However, despite this general acceptance by world leaders that our current path of development is unsustainable, and despite all the policies that have been put in place to try and correct this, modern human civilisation is still firmly on a path of unsustainable development. Over the last four decades greenhouse gas (GHG) emissions have only increased (IPCC, 2015), food and

[2] (1) the 1992 UN Conference on Environment and Development (a.k.a. The Rio Earth Summit);
(2) the 2002 World Summit on Sustainable Development (a.k.a. The Johannesburg Earth Summit); and
(3) the 2012 UN Conference on Sustainable Development (a.k.a. Earth Summit 2012, or Rio+20).

water supplies have only become more threatened (FAO, 2011), ecosystems have only become more degraded (UN, 2005), the rate of biodiversity loss has only sped up (SCBD, 2014), global income distribution has only become more unequal (UNDP, 2013), and global consumption of natural resources has continued to grow exponentially (Behrens, Giljum, Kovanda & Niza, 2007; Krausmann, Gingrich, Eisenmenger, Erb, Haberl & Fischer-Kowalski, 2009; Giljum, Dittrich, Lieber, & Lutter, 2014). These environmental and social costs of our unsustainable development has brought modern human civilisation to a point in the 21st century where we are confronted by what can be termed a "global polycrisis" (Swilling, 2012: 68).

The global polycrisis consists mainly of eight global, interconnected threats. A brief overview of each is necessary here to illustrate their individual contribution to our unsustainable development, as well as to illustrate their complex, systemic and interconnected nature:

- **Income inequality:** It is estimated that the 85 richest people in the world today have the same level of wealth as the poorest 3.5 billion people combined (Fuentes-Nieva & Galasso, 2014: 2). Over the last 30 years, income inequality has risen in almost all high-income countries, and in some cases reached historic highs (OECD, 2015), while also rising by 11 percent in developing countries from 1990 to 2010 (UNDP, 2013: 3). This growing income inequality is unsustainable because it weakens the social fabric of our civilisation. Empirical evidence shows that as income inequality increases within societies, so too does social ills such as crime, violence, infant mortality, teenage pregnancy, drug addiction and physical and mental health problems (Wilkinson & Pickett, 2010), while at the same time lowering levels of educational attainment, social mobility and innovation (Wilkinson & Pickett, 2010; UNDP, 2014: 36-39). Income inequality also impedes future development by reducing the tax base of countries, which in turn reduces the ability of governments to invest in public goods, services and protection (UNDP, 2014: 21). Such continuous increases in income inequality shows that the global economic system is only making the rich richer and the poor poorer – and this is clearly not a sustainable trend.

- **Urban poverty:** Nearly a third of the global urban population is estimated to live in slums. Even though the global proportion of urban slum inhabitants have fallen from 39 percent in 2000 to 30 percent in 2014, the total number of urban slum inhabitants have only increased (UN, 2015: 60). It is estimated that the global urban slum population has increased from around 690 million people in 1990 to around 880 million people by 2014 (UN, 2015: 60). The vast majority of the world's urban slum population lives in Africa and Asia, which is also the regions where the majority of population growth to 2050 is projected to occur (UNPD, 2015a). Africa has the largest slum population, with nearly 60 percent of their urban population still residing in slums (UN, 2015: 60). The growing urban slum population is an unsustainable situation for similar reasons to those of income inequality, but there are also other factors that come into play. Overcrowding, unsafe building structures, occupation of hazardous land and lack of water and sanitation all combine to create highly unsafe living conditions, where disease and disasters can easily have large-scale impacts (UN-HABITAT, 2010). With over 2 billion people expected to be added to the urban populations of Asia and Africa by 2050 (UNPD, 2015c: 1), the global urban slum situation is set to get much worse, unless major steps are taken to reduce global income inequality.

- **Climate change:** According to the scientists of the Intergovernmental Panel on Climate Change (IPCC), current concentrations of atmospheric carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) – the three main GHGs – have reached a level that has not been seen for at least 800,000 years, and possibly even for millions of years (IPCC, 2015: 4). It is estimated that human activity has released 555 billion tonnes of carbon into the atmosphere since 1750, with about half of these emissions occurring over the last 40 years (IPCC, 2015: 45). Emissions of CO_2 from fossil fuel combustion and industrial processes contributed nearly 80 percent of all increases in GHG emissions between 1970 and 2010 (IPCC, 2015: 46). Agriculture is also a major contributor of GHGs, contributing about 25 percent of all CO_2 emissions, 50 percent of all CH_4 emissions, and 75 percent of all N_2O emissions (FAO, 2011). GHGs that are not captured in natural "sinks", such as soils, forests, waterbodies or ice, accumulate in the atmosphere and create a greenhouse effect that leads to global warming and climate change (IPCC, 2013, 2015).

  Global warming and climate change poses a severe threat to the sustainability of modern human civilisation for several reasons. Increases in the frequency and intensity of storms, floods, droughts and heatwaves, as well as increasing water scarcity, food insecurity, ecological degradation, species extinction and sea-level rise, will all have major consequences not only for the global economy, but also for human survival (IPCC, 2015; New et al., 2011; OECD, 2012). Urban areas, where most people on the planet are said to now live (UNPD, 2015c), are especially vulnerable – not only due to higher temperatures within cities and larger concentrations of people, but also because many major cities have been built on the coast or in low-lying areas next to major rivers, making them particularly vulnerable to the threats of sea-level rise (Gasper, Blohm, & Ruth, 2011).

  A global target has been set to limit average global warming to 2˚C above pre-industrial levels, in order to reduce the severity of these global environmental effects and to prevent various irreversible tipping points from being reached (IPCC, 2015). But if current global policies do not become far more ambitious soon, the 2˚C goal will likely be exceeded before 2050, and temperature increases up to 6˚C in the second half of the century could become a reality (OECD, 2012: 73).

To put these temperature increases into perspective: with a global-mean warming of 4˚C, scientists expect more than 40 percent of species on Earth to be threatened with extinction (IPCC, 2015); a 3 to 5˚C rise would likely result in the melting of both the West Antarctic Ice Sheet and the Greenland Ice Sheet (OECD, 2012: 87), which would raise sea-levels significantly; and a global-mean warming of 7°C is likely to create areas on Earth where metabolic heat dissipation would become impossible for humans, and thus leave such previously-inhabited areas uninhabitable (Sherwood & Huber, 2010).

- **Food insecurity:** Over the last 50 years the cultivated area on Earth has increased by around 12 percent, while agricultural output has nearly tripled (FAO, 2011: 3). Yet, today almost 800 million people on the planet are still undernourished (FAO, IFAD, & WFP, 2015: 8), and it has been estimated that around 70 percent more food will have to be produced globally by 2050 than there was in 2009 (FAO, 2011: 7). However, a more recent study suggested that 30 to 50 percent of all food produced on the planet is wasted (IME, 2013), so the challenge is not just to produce more food, but also for our global food system to drastically reduce waste.

  The vast majority of the increased food demand will come from developing countries (FAO, 2011), where most of the world's future population growth is expected to occur (UNPD, 2015a). However, the Food and Agriculture Organisation of the United Nations (FAO) estimates that the per capita agricultural land availability in low-income countries is less than half that of high-income countries, and that the suitability of their land for cropping is also lower (FAO, 2011). Also, over one third of the world's soils are either degraded or under degraded land[3], and valuable agricultural land is increasingly being lost to urban expansion (FAO, 2011; Angel, Parent, Civco, Blei, & Potere, 2011). These trends of increasing demand for food and decreasing supplies of arable land combines with the various threats of climate change[4] to create the prospect of severe food insecurity and shortages in the 21st century.

- **Water scarcity:** Fresh water supplies are increasingly being threatened by continued industrialisation, urbanisation and population growth, and now also climate change (FAO,

[3] "Land degradation" looks further than just the soil to include the wider ecosystem (see FAO 2011: 108).

[4] Particularly the threats of more severe droughts, floods and changing rainfall patterns (IPCC, 2015).

2011; UNESCO, 2015). Ever-increasing water use by agriculture, manufacturing and electricity generation are some of the biggest contributors to water scarcity (FAO, 2011; UNESCO, 2015). Groundwater sources, which are the sole source of drinking water for about 2.5 billion people on the planet, and which provides over 40 percent of global irrigation water (FAO, 2011), are also increasingly being diminished, with around 20 percent of the world's aquifers estimated to be over-exploited – particularly around intensely farmed areas and megacities, as well as in arid regions such as the Arabian Peninsula (Gleeson, Wada, Bierkens, & Van Beek, 2012; UNESCO, 2015). Water security is also increasingly threatened by water pollution, which is mainly caused by mining, agriculture, industrial production and untreated urban runoff and wastewater (UNESCO, 2015). Even though our current water-situation is already unsustainable, global water demand from manufacturing, electricity production and domestic use alone is expected to increase by over 50 percent between 2000 and 2050 (OECD, 2012: 208). Adding to this future water demands from agriculture, global water demands in 2050 could easily be double that of the already high demand of today.

- **Ecosystem degradation:** In 2005 the UN released their *Millennium Ecosystem Assessment* report, which was compiled by 1,360 scientists from 95 countries (UN, 2005). The key finding of this global assessment was that over 60 percent of the ecosystem-services[5] on which human civilisation depends for its survival are either degraded or being used unsustainably (UN, 2005). With the global population doubling from 3 billion people in 1960 to 6 billion people in 2000, the ecosystems responsible for these "services" to modern human civilisation have been pushed to or even beyond their capacity. As a result, we are now confronted by increasing problems of soil degradation, desertification, deforestation, over-grazing, habitat loss, ocean acidification, coral reef loss, over-fishing, eutrophication of waterways and "dead zones" where rivers connect to the sea (UN, 2005; WWF, 2014; UNESCO, 2015). This ecological degradation reduces the ability of ecosystems to regulate and restore themselves, and it increases the likelihood of sudden, nonlinear and irreversible changes, where entire ecosystems shift from one state into another state, with dire consequences for all who depend on them (UN, 2005; WWF, 2014; UNESCO, 2015). The main contributors to ecosystem degradation are population growth, industrialisation, urbanisation, agriculture and climate change (UN, 2005; Lewis & Maslin, 2015).

[5] "Ecosystem services" are an anthropocentric term for natural functions performed by ecosystems, such as: air and water purification; pest and disease control; climate regulation; pollination; animal and plant production; ocean fishery production; nutrient cycling; carbon sequestration; erosion and flood prevention; and detoxification (UN, 2005; WWF, 2014).

- **Loss of biodiversity:** Closely linked to ecosystem degradation is the threat of biodiversity loss. The persistent destruction of primary forests, which are some of the richest areas of biodiversity on land, as well as the increasing pollution of waterbodies and loss of coral reefs (the richest areas of biodiversity in the oceans), are having major impacts on the planet's genetic diversity (UN, 2005; OECD, 2012; Rockström et al., 2013; WWF, 2014; Lewis & Maslin, 2015; UNESCO, 2015). Even though extinction can be seen as part of the natural long-term cycles of Earth, the current rate of species extinction is estimated to be up to 1,000 times what could be considered natural, leading some biologists to suggest that we might be facing the Earth's sixth mass extinction event (Barnosky et al., 2011). Presently at risk of extinction are: 13 percent of all birds; 26 percent of mammals; 33 percent of reef-building corals; 41 percent of amphibians; and 63 percent of cycad plants (UN, 2015). A continuation or worsening of current extinction rates would further decrease the resilience and adaptability of ecosystems, and this would pose severe threats to the sustainability of our civilisation, since we are inextricably dependent on these ecosystems for our survival (UN, 2005).

- **Over-consumption of raw materials:** The global economy relies on the constant extraction of raw materials[6] from the Earth's lithosphere, which are processed via production activities before being consumed as finished products (Krausmann et al., 2009; Swilling & Annecke, 2012). Along this metabolic line of extraction, production and consumption, various wastes are created as by-products, which take the form of solid wastes (often ending up in landfills), liquid wastes (often ending up in freshwater bodies and the oceans) and gaseous wastes (such as GHGs – ending up in the atmosphere) (UNEP, 2011). It has been estimated that this global metabolism of raw materials have increased 8-fold between 1900 and 2005, with the steepest increases seen for the non-renewable abiotic categories (namely fossil fuels, construction minerals, industrial minerals and metal ores) (Krausmann et al., 2009). Even though technological advancements have greatly improved material resource efficiencies over the last century (Smil, 2014), continuous population growth has meant that annual global raw material consumption has increased almost every year – and particularly over the last 50 years (Behrens et al., 2007; Krausmann et al., 2009; UNEP, 2011; Schaffartzik et al., 2014).

  With global population growth between now and 2050 expected to increase by about 2.5 billion people (UNPD, 2015a), the finite resources on which the global economy depends are destined to become increasingly depleted, and waste problems (such as CO_2 emissions from fossil fuel combustion) are destined to become much worse, unless

[6] Raw materials can be grouped in the following material categories: biomass, fossil fuels, construction minerals, industrial minerals and metal ores. Other natural resources such as water and air are excluded.

consumption of raw materials is somehow significantly reduced. Under conditions of scarcity related problems such as higher resource prices, resource price volatility and increasing resource conflicts are also likely to get worse, which will further threaten our economic and social sustainability (Swilling & Annecke, 2012; UNEP, 2014).

This overview of the global polycrisis clearly illustrates that is a complex, systemic problem, and that it will require complex, systemic solutions to be overcome (Swilling & Annecke, 2012). Attempting to fix one component with little regard to how it influences the other components could worsen the polycrisis overall. For example, if issues of food security were tackled by simply producing more food in a business-as-usual manner – i.e. with resource- and chemical-intensive, mono-crop, industrial agriculture – then it will only worsen climate change, ecological degradation and water scarcity, and thereby also create a negative feedback loop, further threatening food security. A better approach in this example would be to reconfigure the global food system to eliminate waste, which could not only increase "production" by 30 to 50 percent[7] (IME, 2013), but could do so without increasing resource inputs, GHG emissions, ecological degradation and water consumption – especially if more sustainable agricultural practices were followed alongside.

However, even if such systemic efficiency "solutions" were achieved, we would not be able to overcome the threats of the global polycrisis as long as population growth, industrialisation and urban expansion continues unabated – and as long as the world continues to rely on an economic model that is based on eternal growth. On a finite planet there are limits to growth, and even with significant gains in efficiency, critical planetary boundaries will eventually be crossed if growth continues unabated (Rockström et al., 2009, 2013), and this would inevitably lead to societal collapse (Diamond, 2005).

There are already signs that modern human civilisation has overstepped a critical mark. While life on Earth has gone through many periods of significant environmental change, modern *homo sapiens* only started to thrive during the unusually stable conditions of the last 10,000 years or so (Rockström et al., 2009: 472; Dawkins, 2005), which is known in geological terms as the *Holocene epoch* (Lewis & Maslin, 2015). However, since the start of the Industrial Revolution, the global human population has increased exponentially – from around 1 billion people in the early 19th century to nearly 7.5 billion today (UNPD, 2015b) – and during this time humans increasingly became a primary driver of global environmental change (Zalasiewicz, Williams, Steffen, &

[7] It is estimated that 30 to 50 percent of all food produced on the planet is wasted (IME, 2013), so, if this waste can be eliminated, 30 to 50 percent more food will be available for consumption – without having to produce 30 to 50 percent more food.

Crutzen, 2010). This human-induced change of the Earth's biosphere[8] has increased to such an extent, and has had such an overall biophysical impact, that geologists are currently discussing the creation of a new geological epoch, called the "*Anthropocene*" (Zalasiewicz et al., 2010; Lewis & Maslin, 2015). This is a clear indication that the unsustainable development of modern human civilisation is now threatening the very planetary conditions on which we have evolved to depend.

So, although the global polycrisis and its components are complex and systemic in nature, its message is quite simple: either find a pathway of sustainable development soon, or enter a period of collapse[9]. A number of previous civilisations (many of whom existed for far longer than our current civilisation) have collapsed due to human-induced environmental problems such as we are facing now (Diamond, 2005). Only, this time our environmental impacts and its related threats are on the global scale – and there is nowhere left for us to move. We only have one Earth. And our only way to avoid collapse is to reach a path of sustainable development soon.

1.1.2 The importance of "decoupling" for achieving sustainable development

Of all the components of the global polycrisis, the over-consumption of raw materials arguably plays the most fundamental role. The extraction of abiotic raw materials from the Earth's lithosphere usually requires industrial-scale mining, and this not only causes large-scale ecosystem degradation, but also relies on substantial inputs of energy, water and chemicals, which results in GHG emissions and water pollution (UN, 2005; UNEP, 2011; FAO, 2011; UNESCO, 2015). The extraction of biomass (through farming, fishing and wood harvesting) also causes ecosystem destruction where done in an unsustainable manner – and this is mostly the case where farming, fishing and deforestation happens on an industrial scale (FAO, 2011; UN, 2005; UNEP, 2011; UNESCO, 2015). The production processes of both abiotic and biotic materials also rely on substantial inputs of energy, water and chemicals – which results in further GHG emissions, water pollution and land degradation – and, after the final products are consumed, the remaining materials are discarded back into the biosphere as waste, which often causes further environmental harms (UNEP, 2011). Furthermore, this global socio-metabolic process of extracting, processing and consuming materials, and excreting wastes, is occurring unequally throughout the world, with developed (or "industrialised") countries consuming far more material resources than developing (or "industrialising") countries, and they are also responsible for far more of its related environmental impacts (Krausmann et al., 2009; UNEP, 2011; UNESCO, 2015).

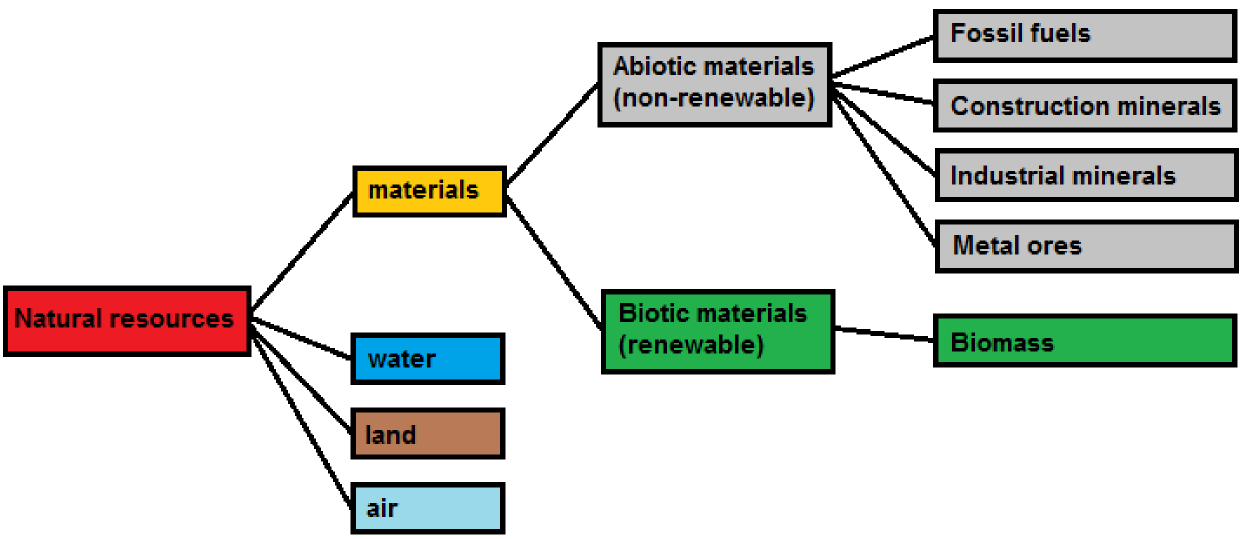
[8] The Earth's biosphere encompasses the atmosphere, hydrosphere, cryosphere, lithosphere and all ecosystems – in other words, the "living zone" of earth.

[9] It must be noted that "collapse" does not mean total destruction or extinction. It is essentially the opposite of growth. In terms of the collapse of a civilisation, it refers to the collapse of the vital systems on which a society depends for its functioning – such as the existing food- or economic-system (Diamond, 2005).

So, in terms of the global polycrisis, when we are talking about income inequality and poverty, we are ultimately talking about inequality in material consumption and a poverty of material resources; and when we are talking about climate change, food insecurity, water scarcity, ecological degradation and loss of biodiversity, we are ultimately talking about the unsustainable and ecologically harmful extraction and waste of material resources. Put another way, and following Goodland & Daly's definition of sustainable development: we are extracting material resources at a faster rate than the biosphere's capacity to renew them, and we are producing wastes at a faster rate than the biosphere's capacity to absorb them (Goodland & Daly, 1996: 1002). This extraction, processing, consumption and waste of materials and their by-products – i.e. the global "social metabolism" (Weisz et al., 2001; Fischer-Kowalski & Haberl, 1997) – is thus at the heart of the global polycrisis. And unless we drastically reduce the material intensity of the global economy, we will not be able to achieve sustainable development.

For the sake of clarity: in the literature the terms "resources" and "materials" are sometimes used interchangeably, so Figure 1.1. illustrates the difference between "natural resources" and "materials" – with the latter being a sub-category of the former. Figure 1.1. also shows that materials can be further broken down into "abiotic materials" (fossil fuels, industrial minerals, construction minerals and metals ores), and "biotic materials" (or "biomass" – which is largely made up of agricultural-, fishery- and forestry-products). Abiotic materials are considered non-renewable[10], and biotic materials are renewable (UNEP, 2011). "Raw materials" simply refers to unprocessed materials – i.e. the form they are in when they are extracted (UNEP, 2011).

Figure 1.1: Illustrating the difference between natural resources and materials

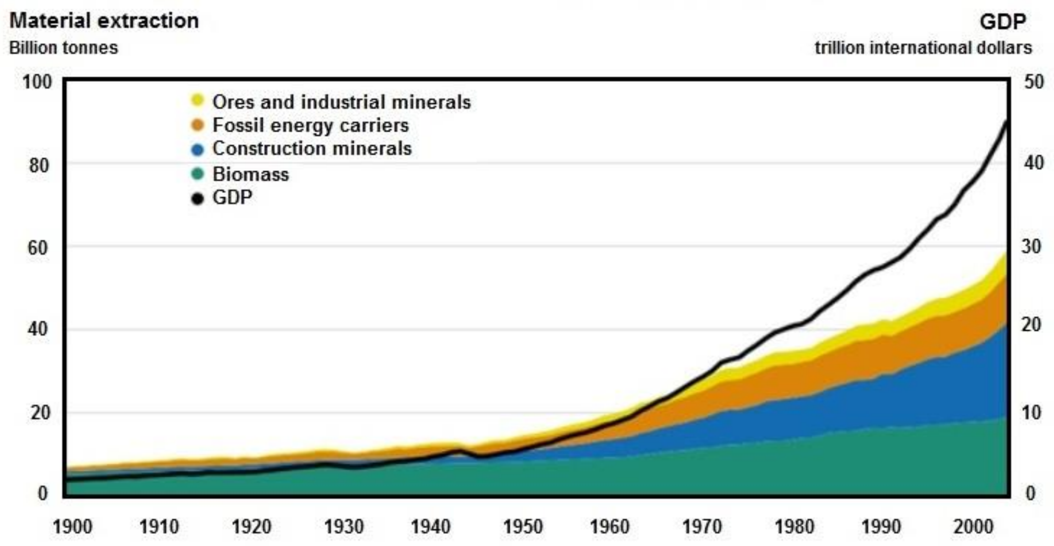


Source: Based on UNEP (2011).

[10] Abiotic materials often take millions of years to form, so they are not renewable in human lifetimes.

In order to deal with the goal of drastically reducing the material intensity of the global economy, the concept of "decoupling" was introduced by the International Resources Panel of the United Nations Environment Programme (UNEP, 2011). Figure 1.2 illustrates the decoupling concept. As can be seen in this figure, where global material extraction was closely linked to GDP for most of the 20th century, increasing as GDP increased, the link between global material extraction and GDP "decoupled" around the 1970s – meaning that the global economy became less material-intensive, requiring fewer raw materials to produce one unit of GDP than it did before (UNEP, 2011). This decoupling has been largely due to various efficiency gains, while the continuous increase of material extraction has been largely due to continuous population growth (Krausmann et al., 2009). In order to reach a path of sustainable development, however, an absolute reduction of annual global material extraction (and of its related environmental impacts) would be necessary, since the illustrated "relative decoupling"[11] still leads to annual increases in overall global material consumption (UNEP, 2011).

Figure 1.2: Global metabolic rate 1900-2005 related to global GDP



Source: UNEP (2011) and Krausmann et al. (2009).

1.1.3 The import role of urban areas for achieving absolute decoupling

Urban areas play a central role in the various components of the global polycrisis, and therefore also play a central role in our quest for sustainable development through decoupling. As highlighted earlier, a significant portion of the world's poor lives in urban slums, constituting around 30 percent of the total global urban population – and the total number of people living in urban slums are increasing. At the same time, even though only about 50 percent of the current

[11] "Relative decoupling" refers to material consumption increasing at a slowing rate relative to GDP, while "absolute decoupling" refers to the absolute amount of material consumption going down while GDP increases (UNEP, 2011).

global population are estimated to live in urban areas (UNPD, 2015c), around 80 percent of global gross domestic product (GDP) is produced here, and around 70 to 75 percent of global energy and materials are consumed here (OECD/IEA, 2008; Hodson, Marvin, Robinson, & Swilling, 2012; Royal Dutch Shell, 2012; UNEP, 2013). So urban areas are both breeding grounds for income inequality and poverty, and the places where the vast majority of GDP is produced and materials and energy are consumed. Furthermore, and also in terms of the global polycrisis, urban expansion plays a central role in the loss of agricultural land, groundwater depletion, increasing water pollution and ecosystem destruction, which makes urban growth one of the main drivers of food insecurity, water scarcity and ecosystem degradation. And, because urban areas are where most materials and energy are consumed, they are also key drivers of climate change.

So, with the UN projecting that the global urban population will increase by around 2.5 billion people by 2050 (UNPD, 2015c) – which practically constitutes all of their projected world population growth to 2050 (UNPD, 2015a) – it becomes critically important that we achieve absolute decoupling at the urban level if we have any hope of achieving it globally. Because, as was illustrated by the overview of the global polycrisis earlier, our current situation (at current levels of world and urban populations) is already unsustainable. With all the technological advancement and efficiency gains that we have made over the last century, we have still only achieved relative decoupling; our overall consumption of materials and energy has continued to increase, even though at a slower pace to GDP. Population growth, and particularly urban population growth, has been largely responsible for this continued growth in global material and energy consumption, because urban areas are where the vast majority of materials and energy are consumed. Therefore, if our goal of absolute decoupling on the global level was to be achieved, it would be imperative to achieve urban-level decoupling first (UNEP, 2013) – especially considering the projected world and urban population growth to 2050. If we fail, material and energy consumption will continue to increase alongside world and urban population growth, and so will their related environmental and social impacts, and a path of sustainable development will not be reached.

As the director general of the 1992 Rio Earth Summit, Maurice Strong, put it:

> *"The battle to ensure our planet remains a hospitable and sustainable home for the human species will be won or lost in the major urban areas"* (Girardet, 2004: 3).

Urban areas are therefore not only key contributors to the global polycrisis, but also hold the key to a pathway of sustainable development. And it is increasingly being recognised that in both cases it is the same key, namely: urban infrastructure (Hodson et al., 2012; Ramaswami et al., 2012; Bulkeley, Broto, & Maassen, 2013; Muller et al., 2013; UNEP, 2013). Urban infrastructures not only embody materials and energy in their physical stocks, but they also conduct the flows of materials and energy through urban areas (Hodson et al., 2012; Muller et al., 2013; UNEP, 2013). The *design* of infrastructure systems for energy, transport, sewage, water, telecommunications, etc., and for buildings, ultimately determines the quantity of materials and energy required for the urban fabric (i.e. the stocks). It also determines the amount of material and energy flows that are conducted through these urban landscapes – and wasted (UNEP, 2013).

The way in which urban infrastructures and buildings have been designed, built and operated until now has essentially been under a set of technical modalities and governance routines that assumes a limitless supply of resources and limitless absorptive capacities of the environmental sinks into which they excrete their wastes (Hodson et al., 2012: 790; UNEP, 2013). In other words, urban infrastructures and buildings have not been designed and built with sustainability in mind, and as a result their wasteful designs are a root cause of our urban and global unsustainability. So, in order to achieve absolute decoupling at the urban-level, it is now increasingly being recognised that it would be necessary to reconfigure the world's urban infrastructures to drastically reduce their material and energy intensity (Hodson et al., 2012; UNEP, 2013).

But, with around 2.5 billion people projected to join the global urban population by 2050, it would not only be necessary to reconfigure existing urban infrastructure, it would also be crucial to not build new urban infrastructure in a business-as-usual manner. This is because urban infrastructure typically lasts between 25 and 75 years, so infrastructure and buildings built today will create a "lock in" effect to 2050 and beyond, dictating urban material and energy flows for decades to come, and preventing their cities and towns from becoming sustainable (UNEP, 2013). Also, the materials and energy embodied in the physical infrastructure and buildings themselves are also of concern – especially with regards to the CO_2 emissions that would be emitted in the production of the urban fabric required for future urban expansion – if these are constructed in a business-as-usual manner (Muller et al., 2013; Angel et al., 2011).

So, ultimately: the extent to which we manage to overcome the global polycrisis, achieve decoupling and reach a path of sustainable development will largely be determined by the extent to which we can achieve urban-level decoupling through redesigning our urban infrastructures. And, critically, the extent to which future urban development incorporate these new designs. Because if future urban growth continues in a business-as-usual manner, using conventional designs and approaches to building urban infrastructures, then such levels of material and energy intensity will combine with future urban population growth and urbanisation to worsen the global polycrisis, and keep us locked-in on a path of unsustainable development.

1.2 Motivation for research

This background of the global polycrisis and our unsustainable urban systems, which largely drives it, was the theoretical source of my research topic. After first releasing a report on the need for decoupling in general (UNEP, 2011), and then focusing on the importance of urban-level decoupling (UNEP, 2013), my supervisor and his colleagues on UNEP's International Resource Panel set their sights on assessing the resource requirements of future urbanisation. Their rationale was that the "second urbanisation wave", which is projected to add around 2.5 billion people to the global urban population by 2050, is likely to pose severe challenges to our goal of reaching a path of sustainable development if our business-as-usual approach to designing and building our urban areas is followed. However, nearly everyone in the urbanisation literature seems to assume that this future urbanisation will happen, and that somehow the resources will be found to build, maintain and operate our future urban settlements. Nobody is asking "what are the resource requirements of future urbanisation?". So, a team was brought together to start considering this question, and I was fortunate enough to have been invited to their first meeting, which took place in Rotterdam in October of 2014.

The original intention was that I would form part of the eventual project to ascertain the resource requirements of future urbanisation, and that elements of this project would then feed into my thesis. I was drawn to the topic because of my education in sustainable development at the Sustainability Institute at Stellenbosch University, which allowed me to make the connections I made in the background section earlier. I am also of the view that it is important to ultimately judge sustainable development from the global perspective. This is because, even though the devil is in the detail, and reaching a path of sustainable development will require that sustainability solutions are found for nearly every product, process and system, these sustainability "solutions" (whether "sustainable cities" or "sustainable energy systems", "sustainable agriculture", etc.) will mean little if we do not overcome all the components of the global polycrisis and reach a path of sustainable development on the global level – and in time. For example, even if 100 cities achieved "zero" carbon emissions, they would not be sustainable unless global carbon emissions come down, because they do not exist in a bubble, and global climate change will still affect them directly. So, both in terms of the background of the original research problem, and in terms of the global perspective taken, the research topic appealed to me, and the critical importance of the research was clear to me.

1.3 Obstacles, and refinement of research problem

Unfortunately the project did not work out as planned, and after a few unforeseen setbacks it was decided to lengthen its schedule. As a result of these developments I found myself in a "change-of-plan" situation about halfway through my thesis period, and I had no other choice but to find my own way of ascertaining the resource requirements of future urbanisation. However, this brought the benefit of taking a more critical look at the underlying data and assumptions of such a study – particularly with regards to the UN's urbanisation projections – and this is what my supervisor advised me to do. He also suggested that I take a look at fertility rates and population projections, since these largely underpin future urbanisation projections. So, my focus then expanded slightly to also ask "are these future urbanisation projections likely to materialise?"

As a result of these changes I shifted my literature focus from only resource consumption and urban metabolism literature to include a deeper focus on the urbanisation literature, as well as literature on fertility rates and population projections, while at the same time reviewing potential methods and models for determining the resource requirements of future urbanisation. This process continued for at least two more months, during which time I finally gave up on finding an existing model to help me calculate the resource requirements of future urbanisation – because none of the models were suitable. I therefore decided to find my own way of doing the calculations, and collected all the data that seemed relevant for me to do so. This included three key sets of data, namely data on urbanisation, population growth and resource consumption. Most of this data was for the country level, since standardised urban-level data is still hard to come by.

However, alongside my struggle do find a way of calculating the resource requirements of future urbanisation, and collecting and analysing the data I felt were necessary to do this, my deeper analysis of the literature continued. And this literature analysis revealed more and more obstacles, which kept forcing me to change my current idea of how to approach the study, and start over again. This process continued until I reached a point where I realised – about two months before my due date! – that the problem was not in the way I was using the data, but with the data itself. I effectively reached a dead-end with my analysis of all three key sets of data, which was due to fundamental problems that underpin these datasets themselves. And in doing so I made it impossible for myself to continue with the study by just taking these datasets at face value. So, my supervisor then suggested that I take a step back, and instead of trying to calculate the resource requirements of future urbanisation, I should rather critically analyse the foundations on which such a study would be built. This meant not only that the focus of my study changed again, but also that the structure of the thesis shifted from including a data analysis, to becoming three interlinked literature analyses, and a proposal of a way forward.

1.4 Research problem and objectives

In light of the global polycrisis and the key role played by urban areas, it must be asked what the resource and sustainability implications of the projected urban growth to 2050 will be. Nobody in the urbanisation literature has tried to tackle this critical question. Scholars such as Orr (1999), Heinberg (2006, 2007, 2011) and Moriarty & Honnery (2015) have considered the limits of future urbanisation, and offered various reasons for why people might start moving back to rural areas one day – which includes considerations of future resource constraints – but these are mainly theoretical assumptions. None of them attempted to actually calculate the resource requirements of future urbanisation. So, this is the problem that still looms over this study: we do not know what the resource requirements of future urbanisation are, and we need to know this if we are to design and build urban infrastructures and buildings today which will not lock us into a path of unsustainable development.

However, after my in-depth analysis of the relevant literature, I established that this research problem could not be addressed if the three key types of data which would underpin such a study were taken at face value, because there are fundamental problems with these datasets themselves. A pre-requisite for a study to assess the resource requirements of future urbanisation would therefore be a study to assess the way in which to do so – with a particular focus on the validity of the most critical data sources. So, the objectives of this study are now to:

- assess the validity of the available data on global urbanisation;
- assess the validity of the available data on global population;
- assess the validity of the available data on global urban resource consumption; and
- propose the best way to assess the resource requirements of future urbanisation.

1.5 Research methodology

In the end, the research methodology for this research product was quite simple. All other approaches and considerations that were taken along the way, and types of data that were collected, are now irrelevant. The final research product, as it is laid out in this thesis, consists of three literature analyses and a proposal derived from my reading and reflections. In the few places where data are analysed, explanations are offered there for how it was done. There was no clear, linear process that was followed for the various literature analyses – it was very much an organic process that evolved as new information came along, and as external factors changed – so an attempt will not be made to explain the sequence of the process.

My investigation of the literature revolved around the three main themes: urbanisation, world population projections and urban resource consumption. However, the focus was not just on the actual data of these themes, but also on the theories underpinning the data, and on the theories based on the data. In my search for literature I always first looked for peer-reviewed journal articles through my university's library, and then looked for reports or books from reputable sources – using both the university library and the internet. Where sufficient academic material could not be found, or where developments were too recent to have resulted in published studies, reputable newspapers and websites were searched.

The only data that was found on global urbanisation was that of the UN, published biennially as their *World Urbanisation Prospects*, which is essentially the dataset that underpins the mainstream narrative on global urbanisation. So, for the analysis of the urbanisation data, no comparisons were made with other urbanisation estimates and projections, and the approach centred around questioning the UN's data. For the analysis of world population projections, the UN's world population projections (which underpin their urbanisation projections) were weighed up against two other sets of world population projections that were found in the literature. So, the analysis of the world population projections was more substantial. Recent developments that were included in the analysis of world population were sourced from reputable newspapers, since these developments are likely to only show up in academic studies and policy reports in the next year or two. The vast majority of my literature investigation revolved around resource consumption, and particularly urban resource consumption, since this was the body of literature I originally planned on tapping into, and it is also the literature containing the largest variety of sources. My focus here was on the urban metabolism (UM) field, particularly on the individual UM studies that have been done, and on the methods and concepts that they use, but the broader resource consumption literature within which UM is embodied was also often consulted.

As mentioned earlier, once the three main bodies of literature were analysed and conclusions were drawn, I found myself in a dead-end with all three, and there was no clear path forward. So, I withdrew from the literature and my laptop to give myself the necessary space and "slowness" to reflect on this complex problem – as suggested by the late complexity philosopher, Paul Cilliers (P. Cilliers, 2006). The process of this reflection, and the questions and insights that arose from it, are detailed in Chapter 5, which contains my proposal for assessing global urban resource use.

1.6 Outline remainder of thesis and core arguments

Chapter 2 will lay out the analysis of the urbanisation literature. The core argument that will be made here is that the inaccuracies, inconsistencies and uncertainties that are imbedded within the urbanisation estimates and projections of the UN are of such a nature that their data must be considered too unrealistic and unreliable to form the basis of a study on global urbanisation.

Chapter 3 will lay out the analysis of the world population literature. The core argument that will be made here is that, in the coming decades, economic factors look set to both impede the decline of Africa's high fertility rates and drive an increase in the fertility rates of low-fertility countries; and, furthermore, if this materialises, the combined effect would be a much higher global population by 2050 than any world population perspectives currently projects.

Chapter 4 will lay out the analysis of the urban resource consumption literature. The core argument that will be made here is that the domestic material consumption (DMC) indicator that is used in material flows analysis (MFA) studies of cities and countries, does not provide a realistic picture of a city or country's resource consumption, because it does not account for the upstream raw materials that were required to enable the consumption at the final destination.

Chapter 5 will then consider an alternative approach for assessing global urban resource consumption, which includes a re-definition of urbanisation from a socio-metabolic perspective. These proposals will be based on the theory of socio-metabolic regimes.

Chapter 6 ends with a brief discussion and conclusions. The significance of the study will be emphasised here, which stretches to all fields who rely on urbanisation, population and resource consumption data. Recommendations for future studies will also be made.

CHAPTER 2

Analysing urbanisation data

2.1 Introduction

One of the key sets of data needed to conduct an assessment of the resource requirements of future urbanisation is urbanisation estimates and projections. Urbanisation estimates would be required to determine the historic and current per capita resource consumption of urban areas (by combining it with resource consumption data), and urbanisation projections would be required to create trajectories for per capita urban resource consumption into the future. These estimates and projections of urbanisation are provided by the UN in their biennial *World Urbanisation Prospects (WUP)* reports (UNPD, 2015c). However, instead of taking the UN's urbanisation estimates and projections at face value, a decision was made to first check the foundations of their data. This involved an analysis of the latest *WUP* report itself, as well as of the wider literature on urbanisation – including critiques of the UN's estimates and projections. It is this analysis of the urbanisation literature that will be the topic of this chapter.

A number of issues were uncovered in the analysis of the mainstream narrative on urbanisation. Issues of semantics were identified in the literature with regards to the terms "city" and "urbanisation", and the way in which their misuse can lead to confusion is discussed. But the most significant critique of the mainstream narrative (and the UN's data that underpins it) comes from scholars who study urbanisation in Africa, and these critiques make up the majority of this chapter. Questions are asked over the contribution of rural-urban migration to urbanisation in Africa, the pace of urbanisation in the region, the accuracy of the UN's estimates and the reliability of the census data on which they are based. These are all highly relevant critiques, since the UN expects around 90 percent of urban growth to 2050 to be contributed by Africa and Asia (UNPD, 2015c). So, what happens in Africa has significant implications for the global urbanisation picture. The chapter ends by investigating another key issue with urbanisation estimates and projections, namely the variety of definitions for what constitutes and "urban settlement". This is found to be a proverbial "joker in the pack", and the profound implications of this urban demarcation problem is discussed.

2.2 The mainstream narrative on urbanisation

2.2.1 Overview of the mainstream narrative on urbanisation

> *"Africa is the fastest urbanising continent in the world – around twice as fast as Latin America and Asia, with an annual urban growth rate of close to 5 per cent"* (Commission for Africa, 2005: 227).

> *"The West African sub-region is projected to have an urban majority just before 2020"* (UN-HABITAT, 2008: 11).

> *"Half of the world's inhabitants – 3.6 billion people – live in cities. The proportion is the highest in mankind's history, and it is growing fast. By 2030, 60 percent of the population – 5 billion people – will be city dwellers. The ways in which cities develop and cope with such rapid urbanisation are of huge importance to citizens"* (McKinsey & Company, 2013: Foreword - no page number).

> *"Although cities only occupy 2% of the earth's land surface, 75% of all natural resources are consumed within cities, and as of 2007 more than half of the world's population lived in cities"* (UNEP, 2013: 26).

> *"For the foreseeable future, rapid urbanisation will be an almost exclusively non-Western affair: about 94% of those who will move to cities in the next few decades will come from the developing world"* (World Economic Forum, 2014: 9).

The excerpts above offer a glimpse of the typical mainstream narrative that can be found in the literature on urbanisation over the last decade. In general, the phrase "rapid urbanisation" is often used, particularly with regards to Africa, and a common statement is also that more than half of the world's population now live in "cities". It is also often implied that this "rapid urbanisation" in Africa is occurring mainly due to people from rural areas flocking to urban areas (Commission for Africa, 2005; UN-HABITAT, 2008). However, when a deeper analysis of the urbanisation literature is done, these claims are found to be erroneous, because they are not supported by the available evidence. Critique of the mainstream narrative on urbanisation has come particularly from scholars who study urbanisation in Africa (which will be analysed further on), but the narrative can also be challenged by simply referring to UN's estimates and projections of urbanisation – which is ultimately the dataset that underpins the mainstream narrative.

2.2.2 The UN's urbanisation estimates and projections

The biennial *World Urbanisation Prospects (WUP)* reports, which has been published since 1988 by the Population Division of the UN's Department of Economic and Social Affairs (from hereon in referred to as the UNPD[12]), has been the main source of estimates and projections of the rural and urban populations in the world over the last three decades. The data from these reports not only underpin the urbanisation narrative throughout the UN (UNFPA, 2007; UN-HABITAT, 2003, 2008, 2011, 2012, 2014; UNEP, 2011, 2013, 2014; UNDP, 2014), but also regularly forms the basis of the urban research and information emanating from other global organisations (World Bank, 1999, 2013, 2015; McKinsey & Company, 2011, 2013; World Economic Forum, 2014), as well as the research of scholars dealing with urban issues (Angel et al., 2011; Bettencourt, Lobo, Helbing, Kühnert, & West, 2007; Cohen, 2006; Moriarty & Honnery, 2015).

According to the 2014 revision of the *WUP* report (UNPD, 2015c), which projects the estimated changes in urbanisation for all countries up to 2050, continuing population growth and urbanisation will result in 2.4 billion people being added to the global urban population by the middle of the century. The global level of urbanisation is expected to rise from 54 percent (in 2015) to 60 percent by 2030 and to 66 percent by 2050 (UNPD, 2015c). Nearly 37 percent of the projected urban population growth to 2050 is expected to come from only three countries: China, India and Nigeria – who are estimated to contribute 404 million, 292 million and 212 million urban dwellers respectively (UNPD, 2015c). Overall, nearly 90 percent of the global urban population increase is set to occur in Africa and Asia, who are currently the two most rural continents in the world, with urbanisation levels of 40 and 48 percent respectively (UNPD, 2015c). Even though the number of megacities[13] are expected to increase from 28 today to 41 by 2030, the fastest growth is expected to occur in the villages, towns and small- to medium-sized cities of Africa and Asia (UNPD, 2015c).

By using the UNPD's urbanisation data, the common mainstream statement that the majority of people on the planet now live in cities can be challenged. Even though the UNPD estimates that around 54 percent of the people on the planet now live in urban settlements, they also make it clear that almost 45 percent of these urban residents live in settlements of less than 300,000 people (UNPD, 2015b: 17). In other words, about 45 percent of the global urban population live in very small cities or towns and villages. Even though the word "city" can be as ambiguous as "urbanisation", the pictures plastered across urban reports – such as those from McKinsey & Company (2013) and the World Economic Forum (2014) – allude to cities as the high-rise

[12] This is not their official abbreviation – just the one used for this thesis, following the Population Reference Bureau (2014b).

[13] "Megacities" are cities with a population of 10 million or more people (C. Kennedy et al., 2015; UNPD, 2015c).

metropolises that many Western people will picture when hearing the term "city". The content of these reports also reflect this modern, Western notion of a city. So, statements such as "half of the world's inhabitants – 3.6 billion people – live in cities" (McKinsey & Company, 2013: Foreword) can therefore easily create the wrong picture of where the majority of the people on the planet now live.

Furthermore, considering the dire slum problem that still exists in much of Africa, and also in parts of Asia, the "more than half of the people on the planet live in cities" phrasing becomes even more misleading. It is estimated that in 2014 there were approximately 880 million people living in urban slums – which constitutes around 30 percent of the global urban population (UN, 2015). The recent Millennium Development Goals report estimated that in SSA nearly 60 percent of the urban population still live in slums (UN, 2015). Also, it is estimated that approximately 40 percent of the people on the planet live in the poor rural areas of Asia and Africa (UNPD, 2015c).

So, considering these substantial rural and slum populations in Asia and Africa, and the estimate that over 40 percent of the global urban population live in settlements of less than 300,000 people, it can be argued that most of the people on the planet do not live in cities, but in villages, towns and slums. And, judging by the suburban sprawl witnessed in many of the developed countries (Stanilov & Scheer, 2004), "and suburbs" could probably be added to this equation of where the majority of the people on the planet live. It would therefore be more accurate to say "more than half of the people on the planet today live in urban settlements", to avoid creating the wrong image of where the majority of people live, and avoid the incorrect focussing of policies.

2.2.3 The misuse of the term "urbanisation"

Moving on from the UN's estimates and projections for now, there is another common problem that was encountered in the mainstream urbanisation literature: the misuse of the word "urbanisation". And this often creates confusion, and could lead to incorrect claims being made about urbanisation. Potts (2009, 2011, 2012b) and McGranahan & Satterthwaite (2014) have highlighted this problem in their work. They found that "urbanisation" is regularly used to indicate, individually or collectively, any of the following:

- physical urban growth (i.e. urban expansion);
- urban population growth;
- rural to urban migration; and/or
- the increase of the urban portion of a given population.

But, according to Potts (2009) and McGranahan & Satterthwaite (2014), the term "urbanisation" refers specifically to the demographic process whereby the urban portion of a population increases over time (while the rural portion decreases) – i.e. the fourth point. The urbanisation rate is then the rate at which the urban share increases. So, for example, if 30 percent of Zimbabwe's population lived in urban areas in 1990, and by 1995 this share increased to 32 percent, then urbanisation has occurred in Zimbabwe – and their urbanisation rate was 2 percent over this period. To illustrate why it then becomes a problem when "urbanisation" is also used to indicate the other three processes listed, and why this discussion should not be seen as semantic nit-picking, consider the following:

> It is possible for physical urban growth and/or urban population growth to occur – even rapidly – without urbanisation taking place; and it is possible for rural-urban migration to occur – even in large numbers – without urbanisation taking place. This is because as long as the rural portion of the total population increases faster than the urban portion of the population (say, due to higher birth rates and/or an influx of people from urban areas or bordering countries), then the urban portion will decrease (referred to as counter-urbanisation or ruralisation). For example, if a country's total urban population increased by 1 million people over 5 years (due to a mixture of natural births and in-migration), they would have certainly experienced rapid urban *population growth*. But, if their rural population increased by 1.2 million people over the same period, due perhaps to much higher birth rates, then urbanisation did not take place – the country would have counter-urbanised, or "ruralised". So, even though urban population growth and rural-urban migration can *drive* urbanisation, these three demographic processes are not the same thing. And urban expansion might in some cases be driven by urbanisation, but it is a separate process – even 100 percent urbanised countries can still experience urban expansion.

It is therefore understandable that misinterpretations can occur in the urbanisation literature, because it is easy to make false statements about urbanisation if the term is not used correctly (or the reader understands it to mean something else). Nevertheless, even when interpreting urbanisation in the correct way, significant discrepancies became apparent when the mainstream narrative on urbanisation and the UN's urbanisation data was measured against the work of scholars who study migration and urbanisation in Africa. In particular, the notion that urbanisation in Africa is occurring "rapidly" has been challenged, and evidence was found of over-estimation of urbanisation in Africa by the UN. The next section will analyse these arguments.

2.3 Challenging the mainstream narrative on urbanisation: The case of Africa

A number of studies have been done over the last 15 years that have challenged the mainstream narrative on urbanisation in Africa, including the estimates and projections emanating from the UN. Scholars who study urbanisation in the SSA region in particular have found evidence which refutes the notion that urbanisation has been occurring rapidly in the region, or the notion that rural-urban migration was the main driver of urbanisation here. They also found evidence of regular over-estimation by the UN.

2.3.1 Signs of slow urbanisation and weak rural-urban migration in Africa

At the turn of the century Beauchemin & Bocquier (2004) conducted a study in West Africa which found that rural-urban migration was contributing only moderately to urban growth in West Africa, and that the rate of urbanisation was slowing in the region. Based on these findings, they argued that the UN's contemporary projection of West Africa being 50 percent urban by 2025 should be "seriously questioned" (Beauchemin & Bocquier, 2004: 2261)[14]. A few years later Beauchemin (2011) used new datasets to establish that the contribution of rural-urban migration to urban growth in Burkina Faso and Côte d'Ivoire has decreased, and, using data from French scholar Zanou (2001, as cited and translated in Beauchemin, 2011), showed that – contrary to UN estimates – counter-urbanisation has in fact occurred in Côte d'Ivoire between 1988 and 1998. Potts (2005, 2012a, 2012b) also found evidence for counter-urbanisation in Côte d'Ivoire during the 1990s, and added Zambia, Mali and the Central African Republic to the list of counter-urbanising countries. A more recent study also found evidence of slow rural-urban migration in SSA during the 1990s, establishing that the average rural-urban migration rate for the region was only slightly above 1 percent per year between 1990 and 2000 (De Brauw, Mueller, & Lee, 2014).

2.3.2 Evidence for over-estimation of Africa's urbanisation by the UN

The UN's simplistic methods of estimating urbanisation was challenged by two studies, who employed a more detailed approach, and found significantly different results. The first study was conducted by French demographer Philippe Bocquier. Bocquier (2005) evaluated the simplistic linear model employed by the UN for estimating urbanisation, and found not only evidence of past over-estimation, but also showed that future urbanisation levels may be greatly over-estimated. By employing a more detailed polynomial method, Bocquier found that the UN may have been over-estimating the global urban population in 2030 by nearly 20 percent (around one billion people), with the over-estimation being more pronounced in developing regions – possibly exceeding 30 percent in Africa (Bocquier, 2005).

The second study that challenged the UN's estimates and projections for urbanisation in Africa was a geo-statistical study conducted by Agence Française de Dévelopment (from heron in referred to as the *Africapolis* study[15]). The *Africapolis* study took place between 2000 and 2006

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[14] The UN's latest estimate for urbanisation in West Africa by 2025 is still 51.4 percent (UNPD, 2015b: 207).

[15] This was the African arm of the GEOPOLIS study (Agence Française de Dévelopment, 2008).

and assessed the level of urbanisation in West Africa by combining satellite imagery with GIS (Geographic Information System) databases, and with all available documentation (such as censuses, “village lists” and other official publications) (Agence Française de Dévelopment, 2008). By taking this more thorough approach, they found significantly lower levels of urbanisation in the West African region than the contemporary UN estimate – particularly in Nigeria, Africa’s most populous country (UNPD, 2015a). The *Africapolis* study estimated Nigeria’s level of urbanisation to be at 30 percent in 2006, while the UN estimated it at 49 percent in the same year (Agence Française de Dévelopment, 2008: 100) – a difference of nearly 20 percent. The *Africapolis* study also projected that West Africa will be 35 percent urbanised by 2020, while the UN at the time predicted the region to be over 50 percent urbanised by 2020 (UN-HABITAT, 2008: 11)[16] – a difference of 15 percent. These findings of over-estimation of urbanisation in Africa by the UN were further corroborated by the work of Potts (2005, 2008, 2009, 2010, 2011, 2012a, 2012b), who also found further evidence of slow urbanisation in the region.

2.3.3 Evidence that urbanisation in Africa has been slow, not rapid

One of the most prominent voices in the challenge of the UN-led mainstream narrative is Deborah Potts from King’s College London, who has been studying rural-urban migration and urbanisation in SSA since the 1980s. She argues vehemently against the idea that rapid urbanisation has been occurring in SSA, and she criticises organisations such as the UN and World Bank for over-estimating urbanisation in the region since the 1970s (Potts 2008, 2009, 2011, 2012a, 2012b).

Even though Potts acknowledges that the UN’s over-estimations of urbanisation in SSA have been mostly due to censuses becoming infrequent, unreliable or unavailable in the post-colonial, she argues that the need to treat their estimates with caution was rarely noted (Potts, 2011). When new, more reliable census data for SSA started becoming available from the 1990s onwards, UN estimations and projections for urban populations started receiving downward revisions (Brockerhoff, 1999; Cohen, 2006; Satterthwaite, 2007, 2010). This, for Potts, indicated a broad acceptance by the UN statisticians that their former projections for SSA were wrong (Potts 2011). However, despite more reliable census data exposing their previous over-estimations, Potts (2011, 2012a, 2012b) argues that the strength of urbanisation in SSA is still being over-estimated by the UN, stating that “the typical message remains that Africa is urbanising rapidly, just not quite as rapidly as before” (Potts 2011: 1383).

[16] The latest *WUP* report (UNPD, 2015c) now state Nigeria’s 2005 level of urbanisation as 39.1 percent (a reduction of around 10 percent from their previous estimate), and they have also lowered their 2020 projection for urbanisation in West Africa to below 50 percent (now 48.3 percent). This implies that they have admitted to overestimating in the past, while still not fully accepting the more detailed *Africapolis* study.

In order to analyse the difference between Potts's research and the estimations of the UN, a comparison of their results are made in Table 2.1. In the left-hand column is presented Potts's analysis of the latest census periods of 17 SSA countries. In the right-hand column is the latest estimates from the UN, which are also mainly based on the results of these censuses[17]. Since the UN present their estimates in 5-year periods, it was not always possible to match the years between their estimations and those of the census periods exactly, so the closest options were selected. This will result in some variance, but this factor is not enough to explain most of the discrepancies between the results. The 2014 national population of each country is indicated in order to provide some context to those not familiar with the relative population size of these countries (and therefore their relative impact on the overall urbanisation picture for Africa). The rates of urbanisation were rounded up to the nearest 1 percent to make comparison simpler. The figures in the "urbanisation rate" column represents the increase or decrease of the level of urbanisation in the period of time indicated, with "CU" representing counter-urbanisation taking place in Potts's column[18].

Table 2.1: Comparison between Potts's analysis and UN estimates for SSA urbanisation

Country	Population in 2014	POTTS'S ANALYSIS		THE UN ESTIMATES	
		Census period	Urbanisation rate	Estimate period	Urbanisation rate
	Millions	*Years*	*% change*	*Years*	*% change*
Benin	10.6	1992 – 2002	1%	1990 – 2000	4%
Burkina Faso	17.4	1996 – 2006	4%	1995 – 2005	6%
Cameroon	22.8	1987 – 2005	11%	1985 – 2005	12%
CAR	4.7	1988 – 2003	CU	1990 – 2000	1%
Côte d'Ivoire	20.8	1988 – 1998	CU	1990 – 2000	4%
Ethiopia	96.5	1994 – 2007	1%	1995 – 2005	2%
Malawi	16.8	1998 – 2008	1%	2000 – 2010	1%
Mali	15.8	1987 – 1998	CU	1985 – 1995	5%
Mauritania	4.0	1988 – 2000	1%	1990 – 2000	4%
Mozambique	26.5	1997 – 2007	1%	1995 – 2005	2%
Niger	18.5	1988 – 2001	1%	1990 – 2000	1%
Senegal	14.6	1988 – 2002	1%	1990 – 2000	2%
Sudan	38.8	1993 – 2008	1%	1995 - 2010	1%
South Sudan	11.7				2%
Togo	7.0	1981 – 2010	1%	1980 – 2010	13%
Uganda	38.8	1991 – 2002	1%	1990 – 2000	1%
Zambia	15.0	1990 – 2000	CU	1990 – 2000	- 5%

Data sources: Potts (2012a, 2012b) and UNPD (2014, 2015b).

[17] The UN sometimes make adjustments to the available census data – for explanation see UNPD (2015a).

[18] Potts did not always make clear by how much a country counter-urbanised, so this indicator was used for her results to avoid misrepresentation.

Since there are a number of 1 or 2 percent discrepancies between the two sets of results – which might seem insignificant – it would be useful at this point to illustrate the power of a 1 percent difference in estimating urbanisation. To do so, consider the following scenario:

> In a (hypothetical) stable population of 10 million people, a 1 percent urbanisation rate over a 10-year period represents the urbanisation of 100,000 people over that period. But, if a rate of 2 percent was incorrectly estimated for the same period (only 1 percent more), it would, statistically, result in 200,000 people having been urbanised – double the actual number of people who moved to urban areas. If this incorrect 2 percent rate is then used to create a future urbanisation rate for this hypothetical stable population (in order to estimate their future level of urbanisation), the difference becomes even more significant. If there was reason to believe that the rate of urbanisation would remain constant over the next three decades, but the incorrect 2 percent rate was then used as a baseline instead of the actual 1 percent rate, then this would result in a projection of 600,000 people being urbanised over 30 years instead of the actual 300,000 – still double the actual amount, but far more people.
>
> So, when we are dealing with a population of 100 million people (about the national population of Ethiopia, and only a portion of the population of Nigeria), or that of 1 billion people (roughly the population of SSA) – and, moreover, these populations are growing at a fast pace, not remaining stable like our example – then a 1 or 2 percent difference starts representing millions to tens of millions of people. For this reason the 1 or 2 percent higher estimates by the UN should not be seen as trivial.

Two deductions that can be made from the comparison in Table 2.1, is that the UN not only tends to have higher estimations than Potts, but also that their data, to an extent, corroborates Potts's argument that urbanisation has been slow in many SSA countries. Some estimations by the UN are only 1 or 2 percent higher, and could be as a result of the comparison periods not always matching exactly, but there are some higher estimations that are clearly detached from the census evidence as analysed by Potts. For Côte d'Ivoire, where both Potts and Beauchemin (2011) showed counter-urbanisation occurred during the 1990s, the UN estimates a 4 percent increase in that decade. The same for Mali, where Potts interpreted counter-urbanisation from the 1987 and 1998 census-period, while the UN estimated a 5 percent increase from 1990 to 2000. For Mauritania both parties used the last 1988 census and a 2000 estimate (the UN did their own – it is not clear if Potts used their estimate or another), but for some reason the UN estimated a 3 percent higher increase. Then there is Togo, where the same two censuses were used as sources (1981 and 2010), but Potts very explicitly found only 0.8 percent of urbanisation to have taken place (Potts 2012a: vi-vii, 2012b: 5), while the UN estimates a 13 percent increase.

Out of the four countries where Potts found counter-urbanisation, the UN only agreed with her on Zambia. Even so, with estimates of no more than 1 or 2 percent increases during the most recent census periods for 10 out of 17 countries, the latest revision of the UN's data seems to support Potts's argument that the rate of urbanisation has been slow in most SSA countries. The latest *State of African Cities* report also acknowledges the work of Potts and the *Africapolis* study, and concedes that urbanisation rates in West Africa are "slowing" (UN-HABITAT, 2014: 98-103). So, the notion that urbanisation has been occurring "rapidly" in Africa seems to be receding.

The fact that only 17 SSA countries are included in this analysis should not, however, give the impression of a weakly supported argument. These countries by themselves represent around 35 percent of the African population. If you add Nigeria, where the *Africapolis* study found a 19 percent lower level of urbanisation than the UN estimate in 2006, the sample would represent 50 percent of the African population (UNPD, 2015a). The other most notable omissions are those of South Africa, Tanzania, Kenya, Ghana, Angola and the Democratic Republic of Congo (DRC), who, if they were included, would have resulted in a 73 percent representation of the African population (and a 90 percent representation of the SSA population) (UNPD, 2015a). South Africa was excluded by Potts because it is already mostly urbanised, while Kenya, Ghana and Tanzania were excluded because their latest census results (for 2009, 2010 and 2012 respectively) were not yet fully available at her time of writing (Potts, 2012b). However, she does use Tanzania as an example of a country where urbanisation has been occurring at a fast pace, while she includes Ghana and Kenya amongst SSA countries that are urbanising, while questioning the proclaimed pace at which this is happening (Potts, 2012a, 2012b)[19]. Nigeria, Angola and the DRC, on the other hand, were not analysed due to unreliable and unavailable census data. And this is a problem that affects a number of countries in Africa, as the next section will explain.

2.3.4 Evidence of old and unreliable census data

As was mentioned earlier, a lack of recent and reliable census data has been a major problem in Africa during the post-colonial era, and this has often been the reason behind previous over-estimations (Potts, 2011; Satterthwaite, 2010). Nigeria, Africa's most populous country, has been conducting censuses, but their results are considered too politically-charged to be reliable (Potts, 2011; Satterthwaite, 2010). Even though the UN uses the census data from Nigeria, they only consider them as "estimates" (UNPD, 2015b: 113)[20]. Angola and the DRC are two other key African countries for whom recent and reliable census data are not available – they have not had censuses since 1970 and 1984 respectively (UNPD, 2015b: 102 & 106). This means that their

[19] The World Bank insists, however, that urbanisation in Ghana has been occurring "rapidly", as can be seen in their recent *Ghana Urbanisation Review* report (World Bank, 2015).

[20] This is likely why the *Africapolis* study found such different results from the UN estimates.

current population and urbanisation estimates amount to little more than guesswork, based mainly on very old census data. And, with their current national populations said to be around 20 million and 70 million respectively, getting it wrong about Angola and the DRC will have a significant effect on the overall picture for Africa.

But, Angola and the DRC are not the only countries in Africa for whom recent and reliable census data are not available. For a number of African countries censuses have not been held for 20 to 40 years. Table 2.2 shows all the African countries for whom recent or reliable census data are not available. This means that these countries' current population and urbanisation estimates are also little more than guesswork, based on linear projections of old (and in some cases very old) census data. So, their real populations could be very different – as can their levels of urbanisation. The table includes the UN's current population projections to 2050 for these countries to give an indication of their contribution to future urbanisation and population growth.

Table 2.2: SSA countries who have no census data for 20 to 40 years

Country	Last census held *Year*	2015 population estimate *Million people*	2050 population projection *Million people*	Population contribution by 2050 *Million people*
Angola	1970	25.0	65.5	40.5
Congo	1996	4.6	10.7	6.1
DRC	1984	77.2	195.3	118.1
Eritrea	1984	5.2	10.4	5.2
Gabon	1993	1.7	3.2	1.5
Guinea	1996	12.6	27.5	14.9
Guinea-Bissau	1991	1.8	3.6	1.8
Liberia	1995	4.5	9.4	4.9
Madagascar	1993	24.2	55.3	79.2
Mauritania	1988	4.1	8.0	3.9
Nigeria	no reliable	182.2	398.5	216.3
Somalia	1975	10.8	27.0	16.2
Totals:		**353.9**	**814.4**	**460.5**

Data sourced from: United Nations Population Division, World Population Prospects 2015 (UNPD, 2015a) and World Urbanisation Prospects 2014 (UNPD, 2015b: 101-119).

There are also two notable high-fertility countries from Asia that can also be added to this list. Pakistan and Afghanistan, who are said to have a combined population of around 220 million people (UNPD, 2015a), have not had censuses since 1998 and 1979 respectively (UNPD, 2015c: 101-119). They are projected to collectively add 144.2 million people to the planet by 2050 (UNPD, 2015a). If these two countries are added to the African countries listed in Table 2.2, there are well over half a billion people included in current world population estimates whose countries have not had a census for about 20 to 40 years. Moreover, this group of countries are projected to have a combined population of nearly 1.2 billion people by 2050 – nearly the equivalent of China's population today – making them very important in the future world population picture (UNPD, 2015a). But, because of this lack of recent and reliable census data, we can say little for certain about their current populations, let alone their future populations.

2.3.5 Reasons for slow urbanisation in Africa

We have established that there has been regular over-estimation of urbanisation rates in Africa by the UN, and that a lack of recent and reliable census data creates even more uncertainty in the region. But we have also established that, regardless of this over-estimation, the rates of urbanisation has been slow in most of Africa. Before we move on to the next section, it is important to note why urbanisation has been slow in SSA. In this regard, Potts offers two explanations in her work.

The first reason Potts gives for slow urbanisation in Africa is their high rural fertility rates. Even though African urban populations have been growing rapidly, their rural populations have largely kept pace, and this has prevented a significant increase in the urban share of their populations (Potts, 2011). According to Potts (2011: 1384), the youthful age structure of the urban population in SSA has resulted in their urban fertility rates falling more slowly than has been the case in other parts of the world, but the future implication of this is that, as urban fertility rates in SSA eventually decline more significantly, rates of urbanisation will further be depressed. So, unless rural fertility rates fall too, a decline in urban fertility rates in SSA – where urbanisation is already slow – could slow urbanisation further, and potentially even lead to ruralisation.

The second reason that Potts offers for slow urbanisation in SSA is the phenomenon of circular migration. In short, circular migration refers to both rural-urban migration and urban-rural migration, and represents the tendency in SSA for people to move to urban areas only temporarily before moving back to rural areas at a later time. Potts (2009, 2012b) argues that this process has deep roots in SSA and that it is closely linked to the ebb and flow of economic opportunities in urban areas (even though it can also be influenced by conflict, droughts and other natural disasters). For example, the counter-urbanisation that occurred in Zambia during the 1980s and 1990s was largely attributed to economic decline, particularly in the country's copperbelt region (Potts, 2005), while the re-urbanisation that seems to have occurred between 2000 and 2010 was driven by an economic upturn on the back of soaring copper prices (Potts, 2012a: xviii). So, the rural areas in SSA still offer a safety net for those in urban areas (Potts, 2012b), which implies that rural-urban migration in the region should not necessarily be seen as a linear process – as the UN's projections do.

There is, however, one more important factor, which throws the urbanisation picture into even more uncertainty: the problem of urban demarcation. This issue will be considered in the next section, before conclusions are drawn in the final section of this chapter.

2.4 The joker in the pack: urban demarcation

It is often noted in the urbanisation literature that there exists no common definition for "urban", and that different countries use different criteria; but the full extent and implications of these differences are rarely communicated.[21] When this issue of urban demarcation is investigated more closely, it becomes apparent that its extent and implications are more serious than is usually implied – which gives the impression that the few scholars who do heed this warning are merely repeating what others have said, instead of analysing the urban definitions themselves.

According to the *WUP* report (UNPD 2015), criteria of what constitutes an "urban" settlement can be based on anything from administrative indicators (such as municipal boundaries), to demographic indicators (such as a certain population threshold or density), to economic indicators (such as the proportion of the population employed in non-agricultural sector), and even infrastructural indicators (such as paved roads, electricity or a sewage system). Even if a common indicator is used, like a population threshold – which most countries use to some extent (UNPD, 2015b: 101-119) – different definitions still make comparisons futile. For example, in Benin, Botswana and Uganda a population threshold is used as one of their main criteria – but these thresholds are 10,000, 5,000 and 2,000 people respectively (UNPD, 2015b: 103 & 118). This means there are a large number of settlements in these countries that would have been counted as either "urban" or "rural" if they were just in a different country – without anything else changing. So, meaningful comparisons between countries become impossible.

On closer inspection of the Beauchemin study (2011), it was noticed that differences in urban classification played a key role in his results differing from those of the UN. Beauchemin (2011: 50) states that the definition of "urban" has changed a number of times in Côte d'Ivoire. Because the UN always adopts the relevant national definition (UNPD, 2015c), this means the UN's estimations for Côte d'Ivoire would have been affected by this reclassification. But Beauchemin based his study on data that kept the definition of urban consistent (which was a population threshold of 5,000), and this is what delivered the results of counter-urbanisation (Beauchemin, 2011). So, this suggests that the 4 percent "urbanisation" that the UN estimated for Côte d'Ivoire between 1990 and 2000 (shown in Table 2.1) was mainly due to reclassification.

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[21] Two of the few exceptions found were Satterthwaite (2010) and McGranahan & Satterthwaite (2014).

Potts also addresses the issue of reclassification in her work (2008, 2009, 2011, 2012a, 2012b), and points out that some of the urbanisation that is occurring in SSA "appears to be increasingly derived from rural settlements being redefined as 'urban', having passed a definitional population threshold" (Potts, 2011: 1383). It is not clear, however, whether she kept the definition of urban consistent in her analysis of the census data, and whether this could be an explanation for some of the discrepancies between her analysis and the UN's estimates. But she does argue that Kenya and Tanzania's "unusual" definitions and re-definitions of what constitutes an urban settlement means that the urbanisation rates reported in their censuses are "extremely misleading" (Potts, 2009: 257).

McGranahan & Satterthwaite (2014: 7) also addresses the issue, and points out that in Mali the 1987 census used a 5,000 population threshold, the 1998 census a 30,000 threshold, and the 2009 census a 40,000 threshold. So, this suggests that if Mali kept their definition for "urban" the same as in 1987, their rate of urbanisation to 2009 would have been far higher. On the other hand, if their definition for urban in 1987 was also 40,000 people (as it was in 2009), then their level of urbanisation might have been seen to stagnate or reverse. So, changing the definition of what constitutes an urban settlement can have a massive impact on the overall urbanisation rate – without anything actually being different on the ground.

However, the problem of urban demarcation is not only an African problem – it affects all the countries of the world. Reviewing the definitions of each country in the latest *WUP* report (UNPD, 2015c), it quickly becomes apparent that, even when using only the common criteria of a population threshold, you are not comparing like with like. For example (UNPD, 2015b: 101-119): Sweden and Denmark uses a population threshold of 200 people, but Albania's population threshold is double that, at 400 people; Laos uses a population threshold triple that of Sweden and Denmark, at 600 people; but Australia's threshold is again much higher, at 1,000 people. But then Argentina and France have a threshold double that of Australia (and ten times that of Sweden and Denmark), at 2,000 people.

And so it goes on, with countries like Belgium and Ghana having a threshold of 5,000 people; Benin, Mauritania, Spain, Switzerland and the UK a population threshold of 10,000 people; Nigeria and the Netherlands[22] one of 20,000 people; and Japan a threshold of 50,000 people (UNPD, 2015b: 101-119). The highest number of countries who share exactly the same definition for "urban" is 10 countries (out of over 230 countries and territories listed) – who all use only a population threshold of 2,000 people. The next highest is a group of 7 countries, who all use only a population threshold of 5,000 people (more than double that of the previous group). This

[22] The Netherlands does not have an official definition of "urban", so this is the threshold applied by the UN.

plethora of definitions for “urban”, and the magnitude of the differences between them, means that comparisons of urbanisation on the global level borders on the absurd. The picture could be vastly different by simply using a different definition of “urban”.

But, it is not only comparisons between countries that become meaningless – a number of countries also change their own definitions of “urban” over time, making comparisons between one census period and another equally difficult. For example, in Uganda the threshold was 1,000 people for their 1991 census, but it was changed to 2,000 people for their 2002 census (UNPD, 2015b). The case of Mali was mentioned earlier, with their threshold being 5,000 people in 1987, but 40,000 by 2009. If India decided to change their complicated criteria (which includes a population threshold of 5,000 people, a requirement for 75 percent of the male working-population to be employed in non-agricultural activities, and a density of at least 400 people per square kilometre), then they could conceivably go from being 32 percent rural to being more than half urban – without anything actually changing on the ground. Similarly, in China the 1999 urbanisation level could have been 24 percent, 31 percent or 73 percent, depending on which definition of urban you used (Liu, Li, & Zhang, 2003; L. Zhang, 2004). Satterthwaite (2010) also pointed out that if China and India decided to change their urban criteria, this could raise or lower the global level of urbanisation by several percentage points.

So, when looking at global levels of urbanisation, it can be argued that the world can either be, for example, around 40 percent urbanised, or around 60 percent urbanised – depending on which criteria you use. Satterthwaite (2010: 3) suggested that we should see the world as 45 to 55 percent urbanised, instead of an exact figure like 50 percent. But, it could also be argued that if all countries used Sweden and Denmark’s threshold of 200 people, the world would be closer to 100 percent urbanised. This massive diversity in urban demarcation criteria, unfortunately, makes the UN’s global urbanisation estimates and projections practically meaningless.

2.5 Summary and conclusion

The mainstream narrative on global urbanisation essentially states that more than half of the world’s population now live in urban areas (or in “cities” according to some), that urbanisation has been occurring “rapidly” in regions such as Africa, and that by mid-century around 2.4 billion people will be added to the global urban population – with around 90 percent of this urban growth set to take place in Asia and Africa. Based on this future urbanisation narrative the initial question was asked, “what would the resource requirements of this future urbanisation be?” But, in order to answer this question, and conduct a realistic assessment of the resource requirements of future urbanisation, you need to have reliable urbanisation estimates and projections. You need urbanisation estimates to determine the historic and current resource consumption of urban areas (by combining it with resource consumption data), and you need urbanisation projections to create trajectories for urban resource consumption into the future. So, an analysis of the urbanisation literature was done to assess the viability of the available data on urbanisation. What became apparent during this critical analysis is that the mainstream narrative on global urbanisation, and the UN's urbanisation data on which it is based, are highly erroneous.

Firstly, the claim by some that more than half of the people in the world today live in "cities" was challenged. According to the UN's data, nearly 30 percent of the global urban population live in slums (UN, 2015), about 45 percent of the global urban population live in urban settlements of less than 300,000 people, and around 40 percent of the total global population live in the rural areas of Africa and Asia (UNPD, 2015c). Considering then also the suburban sprawl witnessed around cities in the developed world (Stanilov & Scheer, 2004), it was argued that most of the people on the planet do not live in cities, but in villages, towns, suburbs and slums. The term "urban settlements" was proposed as an alternative to "cities" to avoid misinterpretation.

Secondly, it was found that the misuse of the term "urbanisation" itself was a source of confusion in the literature on urbanisation. According to Potts (2009) and McGranahan & Satterthwaite (2014), the term "urbanisation" refers specifically to the demographic process whereby the urban portion of a population increases over time (while the rural portion decreases). However, in the urbanisation literature it is also used to indicate rural-urban migration, urban population growth, or even physical urban expansion. And this was shown to easily lead to misinterpretations, and to incorrect statements being made about urbanisation.

Thirdly, empirical studies by scholars who study urbanisation in Africa challenged the mainstream narrative in a number of ways. Not only was it shown that rural-urban migration contributed very little to urbanisation in the region in recent decades, but evidence was also found that the UN has over-estimated urbanisation in the region on a regular basis. In particular, the *Africapolis* study suggested that the UN might have over-estimated the urbanisation level of Nigeria in 2006 by nearly 20 percent. The work of Potts (2005, 2008, 2009, 2011, 2012a, 2012b) also found evidence of over-estimation by the UN, and showed clearly that urbanisation in most of Africa has been slow over the last few decades – not "rapid" as the mainstream narrative suggests.

Fourthly, the UN's urbanisation estimates and projections in Africa were shown to be little more than guesswork in a number of countries, due to a lack of recent or reliable census data. Twelve countries, including the key African countries of the DRC, Angola and Madagascar, have not had a census for 20 to 40 years, with Nigeria's politically-fuelled censuses considered to be too unreliable by scholars. The two Asian countries of Pakistan and Afghanistan were added to this list where censuses have not been held for around 20 years or more, and combined with the African countries they represent around half a billion people on the planet today who are included in population and urbanisation estimates, but for whom there is no recent census evidence. Furthermore, together this group of countries are projected to have a combined population of 1.2 billion people by 2050 (in other words, their combined population are expected to more than double by then), but all of this is based on census data from 20 to 40 years ago that has been projected forward linearly to today – and now another 35 years ahead to 2050.

Lastly, the issue of urban demarcation was investigated more closely, and it was found that there are such a plethora of definitions for “urban” across countries, and that the magnitude of difference between them is so great, that meaningful comparisons of urbanisation on a global level is impossible. Also, with a number of countries changing their definition of “urban” from one census period to another, even comparisons within the same country over time become futile in such cases. Even though population thresholds form part of most countries’ criteria, these were found to range from settlements of 200 people to settlements of 50,000 people. So, even if only a population threshold was used, the world could have, for example, been more than half urbanised a decade ago, or could still be mostly rural – instead of being exactly 54 percent rural as is stated today by the UN (UNPD, 2015c). Satterthwaite (2010) suggested that a range be used instead of an exact figure, such as saying the world is 45 to 55 percent urban instead of saying it is 50 percent urban. However, if we used the population threshold of Sweden and Denmark (200 people), we would probably find the world to be closer to 100 percent urbanised.

So, the analysis of the urbanisation literature makes it clear that little can be said with certainty about current levels of global urbanisation – particularly in the key area of Africa. Evidence of over-estimation, a lack of recent and reliable census data, factors such as circular migration in SSA (which are not accounted for in the linear projections of the UN) and a plethora of definitions for “urban” all contribute to massive ambiguity. It must therefore be concluded that the inaccuracies, inconsistencies and uncertainties that are imbedded within the urbanisation estimates and projections of the UN are of such a nature that their data must be considered too unrealistic and unreliable to form the basis of a comparative academic study on urbanisation – particularly one looking to the distant future. Some broad-brush statements about urbanisation can still be made, however, such as the rough number of people living in megacities, or in settlements of less than 300,000 people, etc., or that most future urban growth is set to take place in Africa and Asia. The available evidence for these trends or statistics seems quite reliable (UNPD, 2015c). So, it is not that nothing can be said about current global urbanisation estimates. But, even these more certain figures will be difficult to project forward reliable if the population projections underpinning them are flawed.

The following chapter will investigate world population projections to 2050, since these are not only fundamental to projections of future urbanisation, but also to the establishment of future resource demand. The significance of population projections, and the fertility rate projections that underpin them, are captured in the following excerpt from the latest *WUP* report, who said about their urbanisation projections that (UNPD, 2015c: xxi):

> *"Realisation of these projections is contingent on the continuation of fertility reductions in the developing world. If fertility were to remain constant at current levels and the pace of urbanisation remained that projected in the 2014 Revision, the world urban population would increase to 7.4 billion by 2050 instead of the 6.3 billion expected when fertility is assumed to continue declining in all developing regions"*.

CHAPTER 3

Analysing world population projections

3.1 Introduction

Population projections are one of the most essential sets of data in environmental, social, and economic studies. Policy-makers and planners around the world need reliable population projections to determine future demand for anything from food and water to healthcare and education (Population Reference Bureau, 2014b). Academics and organisations also rely on population projections to assess potential future demands and developments. For example, in order to make GDP projections, detailed population projections are used to calculate the size of the future labour force (OECD, 2012a; PWC, 2015; Randers, 2012). Academics and organisations who make the critically important calculations of future CO2 emissions and energy demand also depend on population projections (OECD/IEA, 2008; Muller et al., 2013; IEA, 2015b; IPCC, 2015). Furthermore, the UN's *Millennium Ecosystem Assessment* (UN, 2005) and, more recently, the OECD's *Environmental Outlook to 2050* (OECD, 2012b), identified human population growth as one of the biggest contributors to the severe ecological degradation that has occurred over the last century, and identifies future population growth as one of the biggest challenges to our goal of sustainable development. Reliable population projections are, therefore, critical to almost any study that attempts to assess future social, economic and environmental developments – especially if the goal is to make assessments on sustainability.

In terms of assessing the resource requirements of future urbanisation, population projections play two key roles. Firstly, as mentioned in Chapter 2, population estimates and projections underpin estimates and projections of urbanisation. The proportion urban and rate of urbanisation can only be known if the population numbers are known, and, furthermore, future urbanisation projections can only be made if there are population projections to attach the estimated urbanisation rate to (Bocquier, 2005; Buettner, 2014; UNPD, 2015c). Secondly, population growth has been, and still is, one of the main drivers of the exponential increase in resource consumption over the last number of decades (Baccini & Brunner, 2012; Behrens et al., 2007; Krausmann et al., 2009; Smil, 2014; UNEP, 2011). So, population projections are of fundamental importance to studies attempting to assess future resource consumption, and this is evident from its presence in the models and scenarios of such studies (Dittrich, Giljum, Lutter, & Polzin, 2012; Meadows et al., 1972; Meadows, Randers, & Meadows, 2004; Randers, 2012; Schaffartzik et al., 2014; Schandl et al., 2015; UNEP, 2011).

It is no small matter then that the world population projections for 2050 that have been found in the literature range from just under 8 billion (Randers, 2012) to nearly 11 billion[23] (UNPD, 2015b). Seeing that world population was around 6 billion in 2000 (UNPD, 2011), this 3 billion difference represents half the number of people on the planet in 2000 either being added to the total population in 2050 or not, depending on which projection you use. Such a massive variance in global population numbers would clearly result in very different outcomes, and it also indicates a very large degree of uncertainty in population projections to 2050. So, in order to try and find a sound basis from which to assess the resource requirements of future urbanisation, it is necessary to bring population projections under closer scrutiny.

From an analysis of the literature on population projections, three prominent perspectives emerged, which come from three well-respected sources. These are:

- **The United Nations Population Division –** who regularly publish their projections as the *World Population Prospects* (UNPD, 2005, 2011, 2015a);
- **Jørgen Randers** – one of the authors of the pioneering *Limits to Growth* study (Meadows et al., 1972) and its 30-year revision (Meadows et al., 2004), who included a world population forecast in his latest book (Randers, 2012); and
- **Wolfgang Lutz** and his team from the Vienna Institute of Demography, which is affiliated with the International Institute for Applied Systems Analysis (IIASA).

In analysing these three sources it became clear that the differences in their population projections were primarily a result of different assumptions underpinning their projections of fertility rates. The main point of contention between the three world population perspectives were found to be the fertility rates of Africa.

This chapter will start by giving a brief introduction and overview of fertility rates, before the world population projections and underlying assumptions of the UN, Randers and Lutz and colleagues are analysed in the following sections. After the analysis of these three perspectives, a factor which none of them considers will be revealed as a potential joker in the world population pack: the phenomenon of population cycles. Here a specific focus on China, where there are recent signs of change to their one-child policy. The main findings of the chapter will then be summarised and conclusions drawn in the final section.

[23] The latest (2015) high-variant projection of the UN for 2050.

3.2 Fertility rates

According to the Population Reference Bureau (2014b), the growth or decline of any population is essentially determined by the interaction of three dynamic demographic factors: fertility , mortality and migration. In order to make projections of future populations, demographers have to make assumptions about how current rates of births, deaths, immigration and emigration will change in the future, and add these rates onto current population estimations (Population Reference Bureau, 2014b). The need for assumptions in each of these key areas means that there is an inherent degree of uncertainty involved in population projections, and, furthermore, due to compounding effects over time, this uncertainty increases the farther into the future the projections are made (Population Reference Bureau, 2014b; UNPD, 2015a).

Of these three demographic factors, fertility rates usually have by far the most significant influence on population growth or decline (Population Reference Bureau, 2014b; UNPD, 2015a). For this reason it is often the main focus of studies dealing with population projections (Basten & Jiang, 2015; Bongaarts & Casterline, 2013; Lutz, Butz, & KC, 2014; Randers, 2012; UNPD, 2015). Fertility rates, when expressed as "total fertility rate" (TFR), refers to the number of children women in a given population have on average per year. So, for example, if a TFR of 2.0 is attributed to a country, it means that the women in that country had on average two children each per year.

The fertility rate of 2.0 (or 2.1) is commonly known as the "replacement rate" (Basten & Jiang, 2015; Gerland et al., 2014; Population Reference Bureau, 2014b; UNPD, 2015a). This term refers to the two parents replacing their number without increasing or decreasing the size of the succeeding generation. A population will therefore eventually stop growing and decline if its TFR drops to below the replacement level and stays below. It is important to note, however, that the population does not stop growing immediately once its TFR drops to below the replacement level. Countries who have experienced high fertility rates for a number of years could wait decades for their population to start declining, because their young population will first have to grow up and produce children of their own, which will provide momentum for population growth for some time into the future (Population Reference Bureau, 2014b).

According to the latest estimates from the UN, the average global fertility rate currently sits at 2.5 (UNPD, 2015a), but this global average masks significant differences between the fertility rates of the developed and developing world. Most of the countries of the developed world currently have fertility rates below the replacement level (Population Reference Bureau, 2014a, 2014b; UNPD, 2015a), with some countries – such as Spain (1.32), Portugal (1.28), Hungary (1.34), Moldova (1.27) and South Korea (1.26) – being closer to a TFR of 1.0 than 2.0 (UNPD, 2015: 43). In contrast, most developing countries are still experiencing above-replacement level fertility rates

(Population Reference Bureau, 2014b; UNPD, 2015a), with many of these countries – particularly those in Sub-Saharan Africa (SSA) – having a TFR of over 4.0 (Population Reference Bureau, 2014a; UNPD, 2015a). Of the ten countries that were estimated to have the highest fertility rates in the world between 2010 and 2015, nine were from the SSA region – with the Democratic Republic of Congo (DRC) (6.15), Angola (6.20), Chad (6.31), Mali (6.35), Somalia (6.61) and Niger (7.63) estimated to be the highest (UNPD, 2015). There are some exceptions to these trends, however, with Ireland (2.01), New Zealand (2.05) and Israel (3.05) being developed countries with above-replacement level fertility rates between 2010 and 2015, and Brazil (1.82), China (1.55) and Thailand (1.53) being notable developing countries with below-replacement level fertility rates during this period (UNPD, 2015). In China's case, their low-fertility rate can be directly attributed to their one-child policy, which has been enforced since the late 1970s (Basten & Jiang, 2015; Jiang, Li, & Feldman, 2013; Zeng, 2007).

Even though fertility rates are still very high in a number of countries, scholars studying population trends are in agreement that global fertility rates have been declining over the last number of decades, and they all expect this trend to continue until global population eventually stops growing, stabilises and declines (Gerland et al., 2014; Lutz, Butz, KC, et al., 2014; Population Reference Bureau, 2014a, 2014b; Randers, 2012; UNPD, 2015a). What there is considerable disagreement on, however, is the pace and timing of world population growth, stabilisation and decline, and this is largely due to different assumptions informing their fertility rate projections. The focus in the rest of this chapter will be on the different trajectories and underlying assumptions of world population projections from the United Nations Population Division (referred to simply as the UN's population projections), Jørgen Randers, and Wolfgang Lutz and his colleagues from the Vienna Institute of Demography.

3.3 The UN's world population projections

The most widely-used source of population estimates and projections are those of the UN, whose Population Division publishes annual or biennial revisions in their *World Population Prospects (WPP)* reports (UNPD, 2005, 2011, 2015a). Apart from the UN's population estimates and projections being used throughout the UN itself (Alexandratos & Bruinsma, 2012; UNEP, 2011; UNFPA, 2007; UNPD, 2015c; UNESCO, 2015), other prominent organisations regularly use them as a basis for their studies and forecasts, including the Organisation for Economic Co-operation and Development (OECD, 2012b), the International Energy Agency (OECD/IEA, 2008), the World Business Council for Sustainable Development (WBCSD, 2010) and the International Labour Organisation (ILO, 2015). Since the UN's population projections also form the basis of their *World Urbanisation Prospects (WUP)* (UNPD, 2015c), studies who use the UN's urbanisation projections (such as Angel, Parent, Civco, Blei, & Potere, 2011; Angel, 2012; Cohen, 2006;

McKinsey & Company, 2013; Moriarty & Honnery, 2015; Royal Dutch Shell, 2012; World Bank, 2013; World Economic Forum, 2014) are also, indirectly, relying on their population projections.

In recent years the UN have made slight changes to their methods for projecting global population. Until recently the UN calculated their population projections as medium-, low- and high-variants, with the low- and high-variant assuming 0.5 children less or more (than the medium-variant) for every woman in the world (Gerland et al., 2014). However, since 2012 they have supplemented these simplistic variants with a more advanced probabilistic methodology, which allows them to attach levels of certainty to their projections (Gerland et al., 2014; UNPD, 2015a). So, for example, with their latest medium-variant projection for world population in 2050 being 9.7 billion people, they can also say that they are 95 percent certain that it would be between 9.3 billion and 10.2 billion by 2050 (UNPD, 2015a: 2).

Over the last ten years the UN has consistently increased their previous projections for world population in 2050. In the 2004 *WPP* revision their medium-variant projected world population to reach 9.0 billion in 2050 (UNPD, 2005), by 2010 the projection was 9.3 billion (UNPD, 2011) and in the 2015 revision it was 9.7 billion (UNPD, 2015a). In other words, over the last decade the UN have added 700 million people to their world population projection for 2050 – which is roughly the current population of Europe (UNPD, 2015a). Also, while the UN previously thought world population would probably stabilise and decline this century (UNPD, 2005), they now project world population to continue growing throughout, attaching a 95 percent certainty to their projection of having between 9.5 and 13.3 billion people on the planet by 2100 (UNPD, 2015a).

The main reason for the upward-revisions of the UN's world population projections over the last decade has been upward-revisions of their projected fertility rates for Africa (UNPD, 2005, 2011, 2015a). In other words, Africa's fertility rates have come down at a slower pace than the UN previously expected, and, as a result, Africa's population projections – and, therefore, global population projections – had to subsequently be increased. While the medium-variant projection in the 2004 *WPP* revision put the 2050 population for Africa, Asia and the rest of the world at 1.9, 5.2 and 1.9 billion people respectively (UNPD, 2005), the 2015 revision put it at 2.5, 5.3 and 2.0 billion people respectively (UNPD, 2015a) – i.e. an approximate 0.1 billion increase each for Asia and the rest of the world, and an approximate 0.6 billion increase for Africa.

The significance of Africa's high fertility to world population projections becomes even more apparent when the UN's current projections are analysed. The 2015 *WPP* revision's medium-variant projection for world population in 2050 is 9.7 billion people, which, with the current world population estimated at 7.3 billion people, represents an additional 2.4 billion people on the planet by 2050 (UNPD, 2015a). Of this additional 2.4 billion people, more than half is expected to come from Africa (1.3 billion), with Asia expected to contribute most of the rest (0.9 billion), and only a comparatively small portion (0.2 billion) added by the rest of the world (UNPD, 2015). In other words, according to the UN's medium-variant, the equivalent of China or India's 2015 population (both currently at 1.3 billion - UNPD, 2015a) will be added to Africa's population by 2050. Most of this projected growth is contributed by 28 African countries, whose populations are expected to more-than-double in this period (UNPD, 2015a: 9). If these projections materialise, 25 percent of the world population in 2050 will be African (UNPD, 2015a).

It is important to note, however, that the high fertility rates of Africa means there is a significant degree of uncertainty in these projections (Population Reference Bureau, 2014b); and, furthermore, that even higher population increases could materialise. The UN's current population projections for Africa are based on the assumption that fertility rates on the continent will come down from an average of 4.7 in 2015 to 3.1 by 2050 (UNPD, 2015a: 3). This represents a TFR decline of 1.6 over 35 years. But, considering that the ten African countries with the highest TFR in 2013 had a combined average TFR of 6.5, and a combined average TFR of 6.9 in 1970 (Population Reference Bureau, 2014a), i.e. an average TFR decline of 0.4 over 45 years, the UN's revised fertility rate projection for Africa still seems highly optimistic. What they expect to change so drastically over the next 35 years that have not changed much over the last 45 years they do not make clear.

However, the UN does address the uncertainty of their projections for Africa, and points out that slower-than-projected fertility declines would result in "much higher population totals in all subsequent time periods" (UNPD, 2015a: 5). So, since fertility rates in Africa have recently been coming down at a slower pace than previously anticipated (Bongaarts & Casterline, 2013; Gerland et al., 2014), or in some African countries have not come down at all (Population Reference Bureau, 2014a, 2014b; UNPD, 2015a), the possibility of Africa adding more than 1.3 billion people to the planet by 2050 starts looking like a more probable scenario, and therefore also a higher total world population by then.

Even though there seems to be broad acceptance of the UN's projections in the literature, their forecasts of world population growth are not accepted by everyone. In the literature searched for this study, two prominent scholars were found that offered alternative perspectives. The first is Jørgen Randers, who is best known as a member of the Club of Rome team who produced the pioneering *Limits to Growth* forecast (Meadows et al., 1972) and its 30-year revision (Meadows et al., 2004). The second is Wolfgang Lutz and his colleagues from the Vienna Institute of Demography. Both scholars have produced world population projections to 2050 that differ significantly from those of the UN, and in both cases this was due to different assumptions about future fertility rates. Their perspectives will be analysed over the next two sections.

3.4 Jørgen Randers's world population projections

3.4.1 Overview

In his most recent book, *2052: A Global Forecast for the Next Forty Years*, Jørgen Randers again makes a global forecast similar to the *Limits to Growth* studies, which includes a world population projection that stands in stark contrast to that of the UN (Randers, 2012). Even though his population projections are more simplistic than the UN's – only offering one trajectory and breaking it down into only five world regions – his statistical base is similar to theirs, since he uses as his starting point the demographic estimates (births, deaths, total fertility, age structure, etc.) contained in their 2010 *WPP* report (Randers, 2012; UNPD, 2011). He reaches a very different conclusion, however; projecting a world population that peaks at 8.1 billion people in the early 2040s, before starting to decline at an accelerating pace by 2050, reaching 7 billion again by 2075 (Randers, 2012). So, according to Randers, global population will peak this century (and do so quite early), and by 2050 there will be nearly 2 billion less people on the planet in his projection than in the UN's most recent medium-variant projection of 9.7 billion (UNPD, 2015a).

The reason for this considerably lower projection is Randers's expectation that global fertility rates will come down much faster than the UN expects (Randers, 2012). He bases his argument on historic declines of fertility rates, pointing out that the global fertility rate has come down from 4.5 to 2.5 over the last forty years, and he expects this trend to continue over the next forty years, projecting the global fertility rate to approach 1.0 child per woman by 2050. He expects population to peak first in those countries where fertility rates have been declining the most, such the OECD countries, Russia and China, and he expects the rest of the world to then follow these countries' trends of well-below-replacement-level fertility rates, with only parts of South Asia and SSA still having TFRs above the replacement level by 2050 (Randers, 2012).

Randers does not make clear by how much he expects Africa's fertility rate to come down over the next four decades, but from his population projections for Africa's category in his book it can be assumed that he expects a sharp decline. For his "Rest of World" category (consisting of all African countries, minus South Africa, plus all the remaining countries of the world after removing the OECD countries, China and the "BRISE" countries[24]), Randers projects a combined population peak of 3.1 billion during the 2050s (Randers, 2012). To put this in perspective, this is around 500 million less people than the UN's medium-variant projection for the same group of countries in 2050 (UNPD, 2015a: 18-22), which equates to roughly half of Africa's current

[24] Randers's five regional categories are: 1) the USA; 2) China; 3) the OECD countries minus the USA; 4) the "BRISE" countries, consisting of Brazil, Russia, India, South Africa, Indonesia, Mexico, Turkey – even though Mexico and Turkey are OECD countries, so it is not clear why they are included here – Vietnam, Iran, Thailand, Ukraine, Argentina, Venezuela and Saudi Arabia; and 5) the Rest of the World, being all the remaining countries of the world – including all of Africa, minus South Africa.

population either being added to the "Rest of World" countries or not by 2050, depending on which forecast you use. So, judging by this projection, one can assume that Randers's projected TFR for Africa in 2050 is less than the UN's current projection of 3.1 – a TFR which was argued earlier to seem too optimistic already.

Underpinning these staggering global declines in fertility rates are some interesting assumptions about future urbanisation. Randers essentially assumes that urbanisation will continue until the vast majority of people on the planet in 2050 live in cities, and that this urbanisation process will be accompanied by improvements in education and an increase in contraception use, which will then result in the rapidly declining fertility rates and the population peak-and-decline that he projects by 2050 (Randers, 2012). The following excerpt offers an example of Randers's reasoning (Randers, 2012[25]):

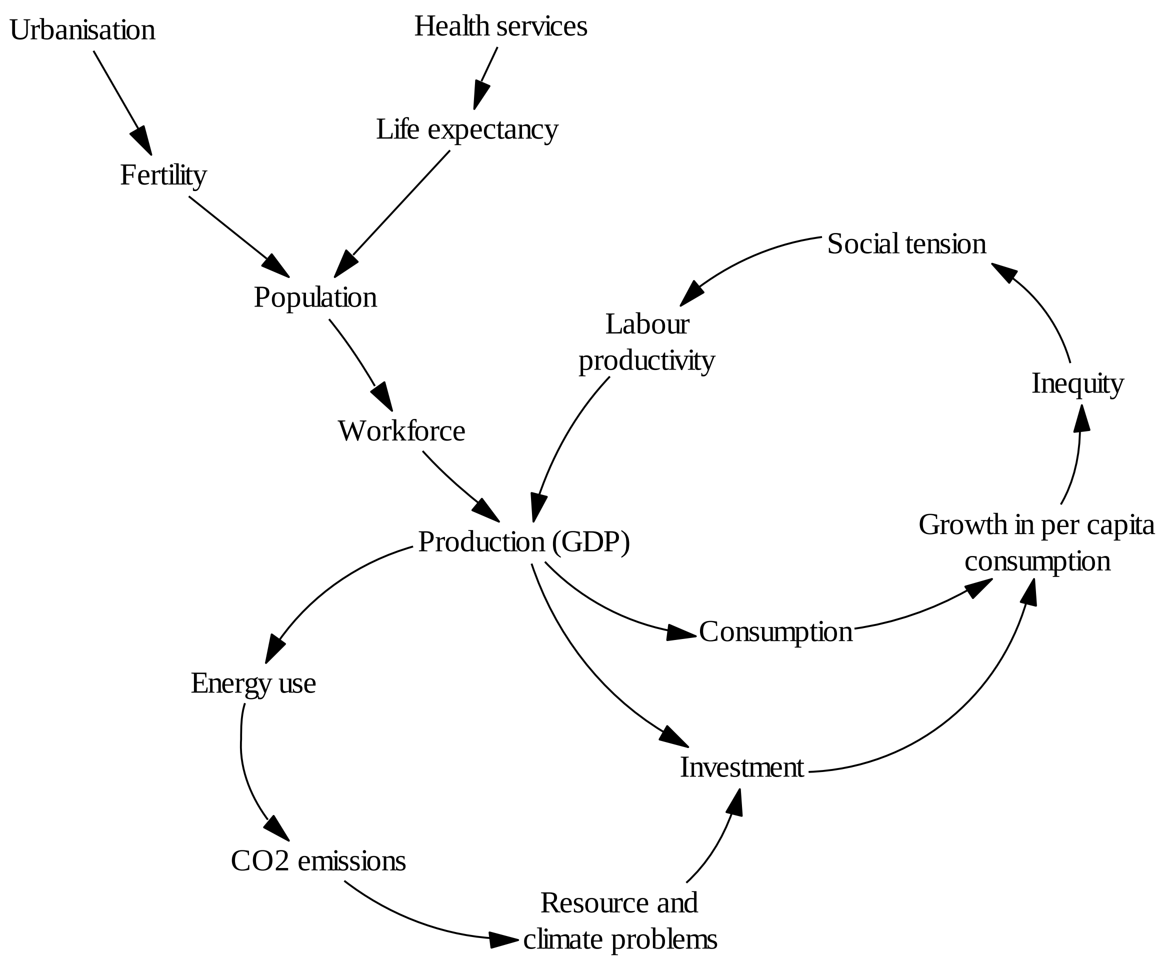
> *"Already more than half the people in the world live in cities, and that fraction will go up with continuing industrialisation in the developing world. Most people will be urban and live in conditions where having many children is not an advantage. The desire to have small families will not be limited to two-career couples in the industrialised world. Billions of poor urban families in emerging economies will make the same choice, in an attempt to escape poverty. The reasoning will be the same everywhere. Families will increasingly be able to have exactly the number of children they want – because of steady improvements in education, health, and contraception. And most will live in settings where another child is a burden. In the crowded megacity one more child is one more mouth to feed and one more person to get through school – not an additional farmhand".*

As can be seen from this excerpt, Randers draws a straight, logical line between urbanisation and declining fertility rates, with the underlying assumption being that most people who move from rural to urban areas will desire fewer children – both for practical and economic reasons – and that this will be the primary driver of declining fertility rates. He essentially bases this assumption on the historic evidence from the OECD countries and Latin America, as well as the developing countries in Asia who have experienced declining fertility rates in recent decades as their levels of urbanisation increased (Randers, 2012). Randers's emphasis on urbanisation as the primary driver of declining fertility rates, and the fundamental role that this plays in his population

[25] Page unknown – retrieved from Kindle edition, which do not give actual page numbers. Can be found in Chapter 4: "Population and Consumption to 2052".

projections (and the rest of his forecasts), is clearly illustrated by the diagram in Figure 3.1 below, which represents what he calls the "deterministic backbone" of his forecasts (Randers, 2012)[26]:

Figure 3.1: The "deterministic backbone" of Randers's forecasts



Source: Randers (2012).

As is made clear by this diagram, assumptions about future urbanisation is what ultimately underpins Randers's projections of fertility rates and world population growth to 2052 – and the rest of his forecasts. So, considering the variety of problems that were uncovered in the analysis of the urbanisation literature in Chapter 2, Randers's projections appear to be built on shaky foundations. Closer scrutiny of his urbanisation assumptions is therefore called for.

3.4.2 Analysing Randers's future urbanisation assumptions

Randers seems to draw most of his assumptions about future developments from a number of expert contributions to his book. His assumptions about future urbanisation seem to come from three expert contributions on the topic of urbanisation, and these will be analysed in this section.

[26] This is a re-creation of the diagram in his book, which can be found in Chapter 3 under the section titled "The Deterministic Backbone".

The first contribution, entitled *Flight to the City*, is written by Thomas N. Gladwell, Professor of Sustainable Enterprise at the University of Michigan (Randers, 2012: Glimpse 5.4). It is not clear where Gladwell sources his information from, because he does not provide references – but it comes across as though he has combined three different perspectives, and this results in some confusion.

Gladwell starts by echoing the UN's contemporary future urbanisation narrative (at that time UNPD, 2010), stating that the global urban population will grow from 3.5 billion in 2010 to around 5 billion in 2040, with most of this urbanisation occurring in Asia and Africa. He also echoes the UN narrative on the urban slum problem in these regions (UN-HABITAT, 2011a), stating that a significant portion of the global urban population increase will occur in slums, with the global urban slum population growing from nearly 1 billion in 2010 to around 1.5 billion by 2030.

However, despite acknowledging this dire urban slum problem in Africa and Asia, where he accepts the vast majority of future urbanisation to occur, Gladwell then shifts to an optimistic economic view. He essentially goes on to argue that "rapid urbanisation" in Africa and Asia will generate "substantial economic growth", and that this economic growth will result in trillions of dollars being spent on infrastructure, education and healthcare between 2010 and 2030, leading to around 0.5 billion urban slum dwellers being uplifted into improved living conditions during this period (Randers, 2012: Glimse 5.4[27]).

But then, again, Gladwell overlaps this optimistic economic perspective with a pessimistic global warming perspective. He continues to argue that various climate-induced catastrophes over the next four decades will "radically alter urbanisation patterns", with people in vulnerable cities moving to safer cities, or entirely new cities (Randers, 2012: Glimpse 5.4). He foresees that cities in the more developed countries (such as those of North America, Europe, Brazil and China) will increase their investment in climate change mitigation and adaption, and he expects high-tech sustainability features and technologies to become commonplace here, but he foresees the opposite for most cities in Africa and Southeast Asia. In these poor regions Gladwell expects a lack of investment for climate change adaption and mitigation, and he believes that "hundreds of millions" of rural people will stream into cities to escape the negative effects of climate change (Randers, 2012: Glimpse 5.4).

Gladwell ends by arguing that, due to this massive climate-induced rural-urban migration, future urbanisation levels will be much higher than current projections, claiming that by 2052 approximately 80 percent of the global population will be living in urban areas – with the

[27] Real page numbers are not provided on the Kindle edition, so the expert contribution number, which Randers refers to as "glimpses", will be given instead.

developed and developing worlds being approximately 90 percent urban and 75 percent urban respectively.

Gladwell's confused view of future urbanisation is questionable for a number of reasons:

- Firstly, in Chapter 2 of this thesis it was shown that little can be said with certainty about current or future urbanisation levels. Besides various issues with estimating and projecting urbanisation in the key region of Africa – such as a lack of recent or reliable census data, evidence of over-estimation by the UN and the phenomenon of circular migration – the added issue of inconsistent urban classification throws global urbanisation estimates and projections into the realm of absurdity. For example, depending on whether Gladwell uses Japan's definition of an urban settlement, which includes a population threshold of 50,000 inhabitants, or Sweden's definition of an urban settlement, which is any settlement of 200 inhabitants (UNPD, 2015c), his results for future global urbanisation levels would clearly be very different. So, Gladwell's projections of urbanisation levels in 2052 are inherently flawed, and neither him nor Randers seems to realise this.

- Secondly, the dire situation of urban slums in Africa and parts of Asia, and the fact that this problem is set to get worse in the near future – as Gladwell admits – calls into question his assumption that "rapid urbanisation" in these regions will now suddenly lead to "substantial economic growth". Turok & McGranahan (2013) have shown that urbanisation will not result in economic growth in the absence of conducive infrastructure and institutional settings – which is a significant problem in most of Africa (World Bank, 2010) – and they argued that economic opportunities tend to drive urbanisation, not the other way around. Potts (2012b) echoed their argument, adding a lack of human capital (such as poor education and skills shortages) as another key factor limiting the economic potential in Africa. So, Gladwell's assumption that future urbanisation will drive economic growth is not supported by the empirical evidence – particularly not for Africa.

- Thirdly, Gladwell's assumption of "rapid urbanisation" in Africa is also not supported by evidence. As the literature analysed in Chapter 2 showed, despite what the mainstream narrative on urbanisation in Africa says, urbanisation in most countries of Africa have been slow or stagnant (Potts, 2012a, 2012b).

- Fourthly, Potts also showed that a large number of the urban poor in Africa still use the rural areas as a safety net, and that this factor results in the phenomenon of circular migration, which she argues to be a deep-rooted migratory culture in the SSA region (Potts, 2005; 2008; 2012b). So, while Gladwell assumes that under catastrophic conditions there would be a one-way stream of rural people into urban areas in Africa, there could be urban people flocking to rural areas, or rural people moving to different rural areas – depending on the location and type of threats.

- And, finally, it is highly questionable whether substantial economic growth would be possible under the catastrophic conditions and mass urban migration Gladwell envisions. Under such desperate conditions one would reasonably expect economies to suffer – so his catastrophic global warming perspective and optimistic economic perspective are contradictory. Slum-living will therefore likely be more of a problem than he expects.

The second expert contribution on urbanisation to Randers's book is entitled *Megacity Living and Externalisation of the Mind*, and is written by Per Arild Garnåsjordet, a researcher and former consultant on urban and regional planning, and Lars Hem, an associate professor of clinical psychology at Aarhus University (Randers, 2012: Glimpse 7.1). What these authors base their current or future urbanisation claims on is also not clear, because they also do not provide references.

Like Gladwell, Garnåsjordet & Hem recognise the presence of slums in their view of future urbanisation, envisioning in the less developed world "cities of gold" being surrounded by "cities of slums" (Randers, 2012: Glimpse 7.1). However, despite this recognition of a continued urban slum problem in parts of the developing world, Garnåsjordet and Hem seem convinced that most people on the planet will be living in internet-based megacities of 10 to 40 million people by 2052 – with permanent internet connection changing our way of life significantly. They argue that by 2052 "the megacity will constitute the social world for the overwhelming majority of people", and that over the next forty years there will be a "parallel evolution of the megacities and the human minds continuously connected via the internet", resulting in a future mentality "profoundly" different from ours today (Randers, 2012: Glimpse 7.1).

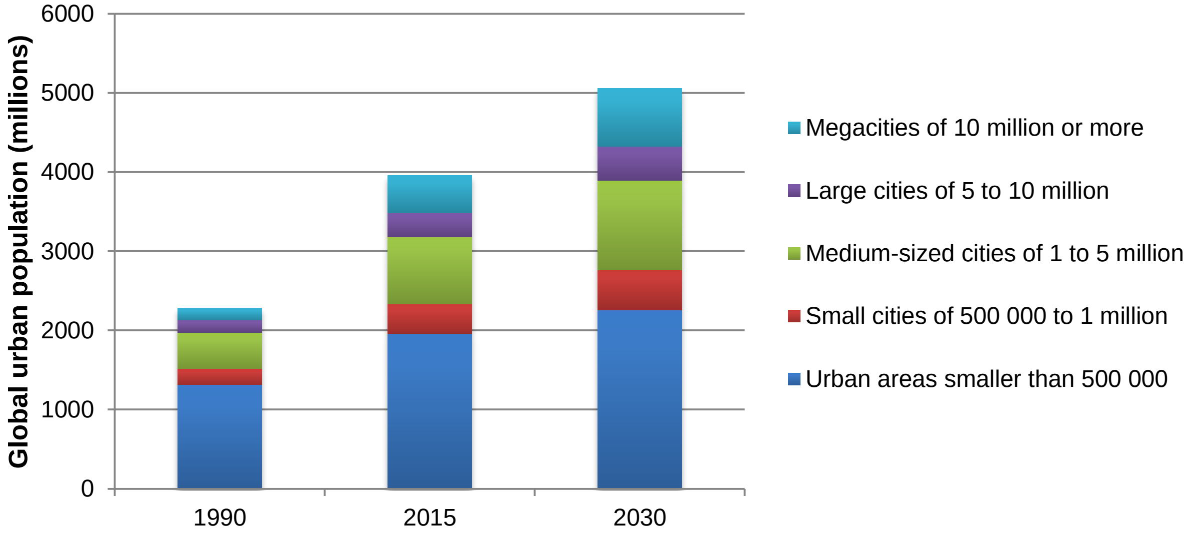
From this short overview of Garnåsjordet & Hem's vision of future urbanisation it should be evident that their perspective seems closer to the plot of a futuristic Hollywood movie than to the academic literature analysed in Chapter 2. Even though it was argued in Chapter 2 that very little can be said with certainty about global urbanisation trends, some general trends seemed to be pretty clear-cut. For one, based on the UN data illustrated in Figure 3.2, it can confidently be argued that:

- the vast majority of the current global urban population resides in small- to medium-sized cities, or towns and villages – not in megacities, or even large cities;

- the vast majority of urban population growth is taking place in small- to medium-sized cities and towns and villages – not in megacities or large cities; and

- by 2050 the majority of the global urban population will more than likely still be living in small- to medium-sized cities and towns and villages – not in megacities, or large cities.

Figure 3.2: Global urban population growth is occurring mainly in towns and small- to medium-sized urban settlements



Data sourced from: World Urbanisation Prospects 2015 (UNPD, 2015c: 474).

Add to these urban figures the towns and villages of the world's rural population, which the UN projects to remain above 3 billion people up to 2050 (UNPD, 2015c: 229), and one can confidently argue that the "overwhelming majority" of people on the planet in 2052 will *not* be living in megacities, but in villages, towns and small- to medium-sized cities. So, Garnåsjordet & Hem's futuristic megacity perspective is clearly contradicted by the available evidence.

The third and final expert contribution on urbanisation to Randers's book is entitled *Slum Urbanism in Africa*, and is written by Edgar Pieterse, who is director of the African Centre for Cities at the University of Cape Town, and holder of the South African Research Chair in urban policy (Randers, 2012: Glimpse 8.3). Pieterse is the only contributor who provides references for his claims and arguments.

Pieterse starts with a statistic from the *African Futures 2050* study (Cilliers, Hughes, & Moyer, 2011), who found that in the 50-year period of 1960 to 2010 the annual per capita GDP in Eastern Africa and Western Africa increased by a mere $150 and $130 respectively, while the annual per capita GDP in Central Africa has remained almost unchanged. Referencing the UN (UN-

HABITAT, 2011b), he states that more than 60 percent of Africa's urban residents currently live in slums, and that by 2052 Africa's population will likely double to 2.3 billion and reach an urbanisation level of 60 percent.

From this background, Pieterse then argues why he believes slum urbanism will remain the predominant form of urbanism in Africa up to 2052. He references a World Bank study, *Africa's Infrastructure: A Time for Transformation* (World Bank, 2010), which found that nearly $100 billion would have to be spent per year in Africa to overcome its infrastructure deficit and cope with future urban growth. Pieterse agrees with the World Bank report who considers a "massive shortfall" of this target to be the most likely scenario (Randers, 2012: Glimpse 8.3). He also argues that Africa is destined to remain on the global periphery in economic terms over the next four decades, citing the *African Futures* projection that Africa is set to contribute less than 5 percent to global trade by 2050 (Cilliers et al., 2011).

Pieterse attributes this economic stagnation to a number of factors, such as Africa's severe infrastructure deficits, governmental inefficiencies, market failures and an inability to build an effective trading system across the continent. And, since Africa is set to remain on the periphery of the global economy, Pieterse argues that the formal part of the urban economies in Africa will remain small, and that the tax base will therefore remain small, which will mean large-scale public investments in infrastructure would be difficult, and which in turn would mean economic growth in the region will remain stunted (Randers, 2012: Glimpse 8.3).

This prospect of slow GDP growth, continued income inequality and "systemic political dysfunction" are some of the reasons why Pieterse believes that slum-living will remain the predominant feature of African cities up to 2050. He does, however, end on a semi-positive note, saying that he expects self-organisation to become a more common feature amongst the urban poor in the coming decades, pointing to the NGO "Slum Dwellers International" as a shining example (Randers, 2012: Glimpse 8.3).

Of the three expert-contributions on future urbanisation, Pieterse has the most well-supported and coherent argument, and he exposes contradictions and fundamental flaws in the arguments of the other contributors. For example, his economic forecast for Africa stands in stark contrast to that of Gladwell, who believes that rapid urbanisation will automatically lead to substantial economic growth and investments in infrastructure, education and health. Furthermore, Pieterse's well-supported argument that slum urbanism will likely remain the predominant form of urbanism in Africa exposes the empirical weakness of Garnåsjordet & Hem's argument, which claims that the "overwhelming majority" of people on the planet in 2052 will live in futuristic megacities. There are, therefore, significant contradictions between the three expert contributions on future urbanisation to Randers's book.

This contradiction and lack of consensus between the three expert-contributions means that Randers would have had to decide which expert opinions to value and which to disregard. Judging by academic focus alone, Pieterse seems to be the best qualified on African urbanism, and his arguments are also the best supported academically – which gives his perspective more weight. Considering this, and the fact that Africa is such a key player in both the global urbanisation and population pictures, one would expect Randers to place the most value on Pieterse's opinion, or at least recognise the contradictions and fundamental flaws of the other two contributions, which Pieterse's argument so clearly expose. But, this is not the case. After Pieterse's contribution, Randers ends up picking out only the positive note offered by him – being his expectation of an increase in self-organised slum movements – concluding that, "this provides another example of the bottom-up solutions that will characterise our always-connected future" (Randers, 2012: Glimpse 8.3). In other words, Randers ends up using only a side-note in Pieterse's contribution, and he uses it only to support Garnåsjordet & Hem's internet-based megacity perspective, which claimed that there will be a "parallel evolution of megacities and human minds continuously connected via the internet" (Randers, 2012: Glimpse 7.1). Randers ignores the rest of Pieterse's argument, even though it clearly explains why this kind of high-tech megacity future that Randers settles on is a completely unrealistic scenario for the African context over the next forty years – and therefore why it could not be considered a likely global norm.

This disregard of Pieterse's perspective – and favouring of Gladwell and Garnåsjordet & Hem's perspectives – can be illustrated by Randers's comments in Chapter 7 of his book, in the section entitled "Megacity Environment". Here he states that:

> *"…there is one thing most global citizens will have in common, and that is urban living. Life will no longer be village life in contact with land, animals and nature. Home life will be largely conducted in high-rise apartments in big cities. Work life will be in an office, shop, or care centre. And recreation will be increasingly virtual… …The fact that 80% of the world's population will live in cities will have an impact on the political agenda, which increasingly will focus on the problems of the urban dweller: traffic, air quality, noise, sewage, water, and power"* (Randers, 2012: Chapter 7).

So, as is evident from this excerpt from Randers's book, and the one from earlier, Randers ends up basing his future urbanisation assumptions on the contributions of Garnåsjordet & Hem and Gladwell – i.e. the two contributions that were found to be contradicted by academic literature. Randers had an indication from the contribution of Pieterse that his assumptions about future urbanisation might be flawed, and that they should be questioned, but he did not pay heed. Had Randers consulted the academic literature on urbanisation, he might have realised that his assumptions about future urbanisation were misguided.

But it is not just Randers's assumptions about future urbanisation that are misguided, but also his assumption about the effect of urbanisation on fertility rates. Randers seemingly assumes that urbanisation will automatically result in declining fertility rates – as if increasing education and contraception-use is an intrinsic part of the urbanisation process. But this assumption is also challenged by the academic literature.

As highlighted in Chapter 2 of this thesis, Potts found that urban fertility rates across SSA have fallen more slowly than has been the case in other parts of the world, with urban birth rates staying nearly as high as rural birth rates in many countries – a trend which she attributes mainly to the youthful age structure of their urban populations (Potts, 2011: 1384). But other factors are also likely playing a role in the urban birth rates in SSA falling more slowly than elsewhere. Lutz (2014) highlighted the important role of cultural norms in high fertility rates, and he argued that these often take a long time to change – and usually only through the improved education of women. The Population Reference Bureau echoes this line of argument, stating that "fertility does not decline automatically, as assumed in projections, without investments in areas such as family planning, health, and education of women and girls" (Population Reference Bureau, 2014b: 4). And, furthermore, investments in family planning, health and education can only occur if economic growth makes available the necessary investment capital, and if competent governments then prioritise and implement these improvements.

So, it is clearly not as simple as drawing a straight line between increasing urbanisation and declining fertility rates – there are other conditions that have to be in place for fertility rates to come down. Practical reasons, such as no longer needing an "extra farmhand", or economic reasons, such as affordability, are not sufficient grounds for fertility rates to fall.

Randers also does not consider the potential depressing effect of declining urban fertility rates on urbanisation. As Potts pointed out, a significant decline in urban fertility rates in SSA would depress the rate of urbanisation in the region even more (Potts, 2011: 1384), because, as discussed in Chapter 2, urbanisation in most of Africa have been slow or stagnant. So, if urban fertility rates decline while rural fertility rates remain at the same high level, the urban portion of the population will grow at a slower rate (or pause, or decline – depending on the extent of the urban fertility decline), and this will lead to even slower urbanisation, and potentially ruralisation. Therefore, even if urban fertility rates in Africa or other high-fertility regions decline significantly, as Randers imagines it will, it would depress the rate of urbanisation or result in ruralisation if the rural fertility rates do not come down significantly too. This would mean that Randers's main driver of fertility declines – urbanisation – would weaken or even disappear.

3.4.3 Dismissing Randers's world population projections

The analysis of Randers's assumptions about future urbanisation and the relationship between urbanisation and fertility declines has exposed a number of problems. Randers was found to be misguided in the following four areas:

- **The predominant urban form:** Randers believes that megacities will be home to the majority of the people on the planet by 2050. But the available evidence for global urbanisation clearly contradicts this assumption.

- **The extent of urbanisation:** Randers believes that the world is currently over 50 percent urbanised and will be around 80 percent urbanised by 2052. But, as was argued in Chapter 2, very little can be said for certain about global levels of urbanisation – with the main reason being the plethora of definitions for urban settlements across countries. By just using a different definition for "urban", the world could currently be 40 percent urbanised or nearly 100 percent urbanised – and the same is true for future urbanisation.

- **The effect of urbanisation on fertility rates.** Randers believes that as urbanisation increases, education levels and contraception-use will go up, and fertility rates will come down – as has happened in most countries of the world. However, the literature suggests that this is not the "package deal" it seems to be. Other factors – such as age structure, cultural norms, economic growth, good governance and investment in education – all play a key role in bringing down fertility rates. And these are all areas where SSA is different.

- **The effect of fertility rates on urbanisation.** Randers focusses on the effect of urbanisation on fertility rates, but does not consider the potential depressing effect of declining fertility rates on urbanisation. As Potts pointed out (Potts, 2011), declining urban fertility rates can slow or even reverse the rate of urbanisation if rural fertility rates remain higher than urban fertility rates. So, in high fertility countries with large rural populations, this is a significant factor to consider – but Randers does not.

Based on these fundamental problems in the assumptions underpinning the fertility projections of Randers, his world population projections must be dismissed as unfounded and unrealistic. His projections of a global population peak of 8.1 billion people in the early 2040s and a global TFR of close to 1.0 by the 2050s are based on assumptions about future urbanisation that are starkly contradicted by the academic literature. The extent and nature of the contradictions means that his projections should be considered much too low.

3.5 Lutz and colleagues' world population projections

3.5.1 Overview

The third and final set of world population projections that were analysed are those of Wolfgang Lutz and his colleagues at the Vienna Institute of Demography. Like Randers, Lutz and his colleagues also believes that the UN has been over-estimating future fertility rates, and they also believe that world population will peak, stabilise and start declining this century (Lutz, Sanderson, & Scherbov, 1997; Bruckner, Giljum, Lutz, & Wiebe, 2012; Lutz, Butz, KC, et al., 2014; Lutz, Butz, & KC, 2014). However, they estimate a significantly higher and later population peak than Randers.

In their recent book *World Population and Human Capital in the Twenty-First Century* (Lutz, Butz, KC, et al., 2014), Lutz et al. projects world population to peak at 9.4 billion people by 2070 before starting a slow decline. Like the UN, Lutz et al. makes use of more than one population variant and they also employ a probabilistic methodology. Their medium variant, which they consider to be the most likely scenario, projects the world population to reach 9.2 billion by 2050, and they attach an 80 percent certainty to there being a peak and decline in world population this century (Lutz et al., 2014: 525-526). This projection is much higher than that of Randers, who projected the global population to decline to below 8 billion by 2050 (Randers, 2012), but it is also significantly lower than the latest UN medium-variant projection of 9.7 billion people by 2050 (UNPD, 2015a). They are also openly challenging the UN (see the journal letter: Lutz, Butz, & KC, 2014), who attached an 80 percent certainty to their projection that world population will continue to grow throughout the century (Gerland et al., 2014; UNPD, 2015a).

The reason for the lower population projections of Lutz and colleagues is also, like Randers, an expectation that fertility rates will come down faster than the UN projects – only, they see improvements in education as the main driver of faster fertility declines. Their projection of 9.2 billion people on the planet by 2050 is based on the projection that global TFR will decline to 2.0 by then, which represents a decline of 0.5 over 35 years from the current TFR of 2.5 (UNPD, 2015a). This TFR is 0.25 less than the UN's projection of 2.25 by 2050 (UNPD, 2015a), so Lutz et al. expects global fertility rates to come down at double the pace than the UN projects. They premise their argument for faster TFR declines on the well-established theory that fertility rates come down as levels of female education increases (Baker, Leon, Smith Greenaway, Collins, & Movit, 2011; Gerland et al., 2014; Hirschman, 1994; Lutz, 2014; Population Reference Bureau, 2014b; UNPD, 2015a: 5), and their main assumption is that there will be continuous expansion and improvements in education in the coming decades, which will continuously drive down the TFR everywhere – including in high-fertility countries (Lutz, Butz, KC, et al., 2014).

The UN also consider education levels in their projections, but they assume a continuation of existing education policies and reform efforts (Gerland et. al. 2014). On the other hand, Lutz and his colleagues assumes a path of education expansion based on the average rate that other, more advanced countries have experienced. They essentially assume that all countries will experience continuous improvements in education, and they base their projection for each country's education improvements on what the countries on a higher level of development than them have historically achieved (Lutz, Butz & KC 2014). So, in short, the reason for their world population projections being lower than that of the UN is an assumption that education will expand and improve more significantly than the UN expects, and that this will drive down fertility rates faster than the UN projects.

This fundamental assumption of Lutz and his colleagues about future education expansion has the most significant effect in Africa, which is also where their projection differs the most from the UN's. According to Lutz et al.'s medium-variant projection, Africa's population will reach 2 billion by 2050, which is 0.5 billion less than the UN's medium-variant projection of 2.5 billion (Lutz, Butz, KC, et al., 2014; UNPD, 2015a). Since Lutz et al.'s projection for global population by 2050 is also 0.5 billion less than the UN's projection (with the former putting it at 9.2 billion and the latter at 9.7 billion), it is evident that a difference in the projection for Africa is essentially what stands between the two world population projections. So, since Africa's fertility rates are the main point of contention, a closer look at Lutz et al.'s underlying assumptions for Africa is called for.

3.5.2 Analysing Lutz and colleagues' assumption of education expansion in Africa

A quick scan of Lutz et al.'s assumptions about Africa's future fertility immediately reveals a contradiction, and some familiar empirical weaknesses. Firstly, even though they acknowledge at one point that poor political governance, low levels of education and slow economic growth means that rapid declines in Africa's fertility is unlikely in the near future (Lutz, Butz, KC, et al., 2014: 214), they then end up contradicting this view by projecting rapid declines in Africa's fertility anyway. The reason for this contradiction might be the large number of contributors to their project, because besides the various scholars who contributed to the book, a number of experts were also consulted in the process. And the acknowledgement of the challenging economic and political reality in Africa was made by the writers of the section on high fertility countries, but the future fertility declines in the high-fertility countries were apparently decided by the experts who were consulted (Lutz, Butz, KC, et al., 2014: 214). And these experts made the assumption that a continuous spread of women's education, family planning and "rapid urbanisation" will occur in

Africa over the next few decades, and that this will drive down their fertility rates (Lutz, Butz, KC, et al., 2014: 214).

Now, from the literature analysis done thus far we know this assumption about rapid urbanisation in Africa to be erroneous. So, at the risk of becoming repetitive, this response will be kept short. Firstly, their assumption about rapid urbanisation in Africa is refuted by the empirical studies of Potts that were analysed in Chapter 2 (for example: Potts, 2012a): urbanisation in Africa has been mainly slow or stagnant, or even reversed in some cases, and there is no reason to believe that the immediate future will be any different. Secondly, in the analysis of Randers's population projections in the previous section, the link between urbanisation and fertility declines was argued to be weak: urbanisation by itself will not drive down fertility rates – other factors such as cultural norms, education levels, economic growth and good governance all play pivotal roles in bringing down fertility rates. This is a fact that Lutz and his colleagues actually acknowledge in other parts of their book (Lutz, Butz, KC, et al., 2014: 214), and that Lutz discusses in his other work (Lutz, 2014), so why they then allow their experts to assume otherwise is not clear.

When the factor of "rapid urbanisation" is removed from the equation, it leaves the perspective of Lutz and his colleagues with assumptions about continuous educational improvements and increased family planning as the reasons for why fertility rates in Africa will come down faster than the UN projects. However, these assumptions about educational expansion and increasing contraception-use in Africa are also problematic when considering the African context.

As was argued by Pieterse in his contribution to Randers's book (Randers, 2012: Glimpse 8.3) – an argument that he based on comprehensive academic studies (Cilliers et al., 2011; World Bank, 2010) – the economic and political situation in Africa is not likely to improve significantly in the coming decades; mainly due to a chronic lack of conducive infrastructure, institutional capacity and good governance. This is an argument that Lutz et al. essentially made themselves elsewhere in their book, where they said about Africa that "*the socio-economic conditions in many countries in terms of political governance, low levels of education, and under-performing economies do not favour rapid future declines in fertility*" (Lutz et al., 2014: 214). Why, then, they ended up accepting their experts' view that a continuous spread of women's education and family planning will occur in Africa within the next few decades is also not clear. But the result is that, ultimately, their projections are just as flawed as those of Randers, because they too are based on empirically unfounded assumptions about "rapid urbanisation" in SSA, and they too end up making the underlying assumption that the economic growth and good governance needed for continuous educational expansion will materialise – and to such an extent that Africa's fertility rates will come down at twice the speed of the UN projection.

In this regard, the UN pays closer heed to the unique African context than Lutz and colleagues. In the introduction of their 2015 *WPP* report (UNPD, 2015a: 4), the UN reminds us that global population growth is concentrated in the poorest countries, particularly those of Africa, and that these countries face other, far more critical problems – such as poverty, hunger, malnutrition and severe health problems – which all compete with education for the limited financial resources that are available. So, even if economic growth does occur in these poor, high-fertility countries over the coming decades, and even if their governments are determined to improve education, they are not likely to have sufficient financial resources left for substantial educational expansion after spending on matters of life and death.

3.5.3 Dismissing Lutz and colleagues' world population projections

It must, therefore, be concluded that Lutz and his colleagues' projections for fertility declines in Africa seems, like those of Randers, too optimistic, and that their projection for world population in 2050 is also probably under-estimated. Even though their central argument about the effects of education on fertility rates are theoretically sound, their assumptions about major education expansion in the poor, high fertility countries of SSA in the near future are unrealistic. Since Africa is destined to remain on the global economic periphery until 2050 (Cilliers et al., 2011) and is destined to suffer from severe infrastructure deficits during this time (World Bank, 2010), the substantial and continuous economic growth that would be necessary for substantial and continuous improvements in education levels are unlikely; especially if one considers that the highest fertility rates are in the poorest countries, where the least resources are available, and where education has to compete for investment with issues of life and death. A slower decline of Africa's fertility rates should therefore be expected, and a higher global population number in 2050 than the 9.2 billion Lutz and his colleagues projects.

So, out of the three perspective analysed thus far, the UN's current medium-variant projection for a world population of 9.7 billion people in 2050 seems the most likely. But the debate about world population growth to 2050 needs to be taken further than these three perspectives, because there is another important factor that came to light during my analysis of the literature, which is not considered by any of the three perspectives. Yet, it is a potential game-changer in the world population picture.

3.6 The joker in the pack: population cycles

What became apparent during my analysis of the population projections of the UN, Randers and Lutz and his colleagues, was that they all make one key underlying assumption. They all assume that the TFRs of every country in the world will continue to come down and eventually stabilise below replacement level, leading to world population stabilisation and decline; they just disagree over when this will happen. But there are reasons to believe that this fundamental assumption is built on shaky foundations, and that world population in 2050 could be significantly higher.

A recent study argues that there is little scientific basis for this “decline and freeze” perspective on fertility rates, and that history shows populations have always gone through cycles of growth and decline (Livi-Bacci, 2015). This perspective is supported by the work of Hirschman (1994), who originally challenged simplistic fertility theories with an analysis of historic trends, which highlighted the complexity of fertility changes. Even though Livi-Bacci agrees that we are heading towards a slowdown-phase of world population growth, he questions whether the world will stabilise around homogenous parameters, and he argues that this is not likely to be the end of population cycles (Livi-Bacci, 2015). As he puts it (Livi-Bacci, 2015: S27):

> *“demography is not independent of external constraints (natural, economic, social, political) and there are no reasons to believe that in the future these will be less variable than those of today”*.

Well, considering very recent developments in a number of low-fertility countries of the world, these words of Livi-Bacci might turn out to be prophetic. The most significant of these developments have occurred in China, and they will be the focus of this section.

My analysis of the three sets of world population projections revolved mainly around Africa, because this is the region that has been identified as the most important to world population growth, and it is also the central point of contention between the three perspectives. However, being a population billionaire, China is another major player in the global population picture. The reason China has been ignored thus far is because there is little disagreement between the three world population perspectives over China’s fertility trends. There is some disagreement over when China’s population will peak and decline, but all three perspectives accept, due to China’s one-child policy, and a fertility rate well below the replacement level, that their population will peak and start declining before or by 2030 (Lutz, Butz, KC, et al., 2014; Randers, 2012; UNPD, 2015a). All three projections assume that China’s TFR will remain below the replacement level to 2050.

But, recent developments in China challenges these assumptions. For more than three decades China has strictly been enforcing their one-child policy, but in late 2013 signs of change started to appear. At the Third Plenary Session of the Eleventh Central Committee of the Communist Party of China, which took place during November 2013, the Chinese government decided that all couples in which one person was an only child would from then on be allowed to have a second child (Basten & Jiang, 2015). Even though some expected that this significant relaxation of the one-child policy would lead to a baby-boom, there has been only a small number of applications for a second child thus far (Basten & Jiang, 2015; Denyer, 2015). Nevertheless, the Chinese government seems intent on increasing fertility rates, with Premier Li Keqiang stating in March 2015 that further changes will now be considered (Khan, 2015). And, as Basten & Jiang notes, China plans on recruiting and training 1.45 million social workers by 2020 (Xinhua, 2013: in Basten & Jiang, 2015), and they state that *"one should not underestimate the capacity of the Chinese state to implement ambitious social policies"* (Basten & Jiang, 2015: S101). Experts are suggesting a universal or even mandatory two-child policy (Jiang et al., 2013; Khan, 2015).

What is important to note, because it is relevant to all countries who experience long-term low fertility, is that the reasons for this ideological U-turn in China's fertility policy are mainly economic concerns. The problem centres around what is commonly known as the "dependency ratio" (Zeng, 2007; Cai, 2010; Jiang et al., 2013; Basten & Jiang, 2015), which is the relation between the part of the population who are of working-age (i.e. the potential labour force) to those who are of non-working-age (i.e. the dependent part: young people and old people) – and it indicates the pressure (dependency) on the productive population. As a population's age structure changes over time, the dependency ratio changes as well, and it is this shift in China's dependency ratio that is forcing the shift in their fertility policy.

During the early stages of China's low-fertility regime, they achieved a "demographic dividend" by simultaneously reducing their youth-dependency ratio and increasing the working-age portion of their population, which raised their per capita income (Jiang et al., 2013; Zeng, 2007). It has been estimated that this demographic dividend was responsible for 15 to 25 percent of China's economic growth between 1980 and 2000 (Wang, 2011). But, this demographic dividend is only a window of opportunity, because eventually a low fertility rate will lead to an ageing population and thereby result in a negative dependency ratio, and China have now reached the end of their window of opportunity (Basten & Jiang, 2015; Jiang et al., 2013; Wang, 2011; Zeng, 2007). Where a positive dependency ratio once helped boost economic growth in China, a negative dependency ratio from an ageing population is now slowing it.

The implications of these recent developments in China are far-reaching. Not only because a rise in China's fertility rates would contribute to a higher world population by 2050, but also because the economic reasons behind their desire for a higher fertility rate suggests that countries who have below-replacement level fertility rates would not want to stay there for long. Other low-fertility countries might also take measures to raise their fertility to the replacement-level or above. And countries who still have above-replacement level fertility rates – such as the other population billionaire, India – might take steps to try and slow their fertility declines, based on the economic challenges currently faced by China.

This might seem like pure speculation, but besides the recent developments in China there have also been strong indications this year from other low-fertility countries that they plan on raising their fertility rates. The governments of Japan (Reynolds, 2015), South Korea (Lee, 2015), Singapore (Chia, 2015) and Iran (De Bode, 2015) have all shown signs that they are now actively pursuing higher fertility rates – and there have also been indications from Denmark (Diebelius, 2015), France (Smith, 2015) and the rest of Europe (Kassam et al., 2015) that they too are pursuing fertility rates closer to the replacement level. So, considering these recent developments, it seems less like speculation and more like the latest global trend for low-fertility countries. It seems, therefore, that Livi-Bacci was right when he said: "*demography is not independent of external constraints (natural, economic, social, political) and there are no reasons to believe that in the future these will be less variable than those of today"* (Livi-Bacci, 2015: S27). A new population cycle, where low-fertility countries now enter a period of rising fertility rates, might be starting – with the driver being the usual suspect: economic growth.

The question now is, what is the most likely future population scenario for China, and the world? This is a difficult question to answer. The Chinese government's discussions are still ongoing and the process of change has only just begun. But, as Basten & Jiang (2015: S102) argues, the recent reforms shows that the encouragement of childbearing has now entered the policy discourse in China. And this should serve as a clear indication that there is now a desire by the Chinese state to raise the country's fertility levels. It therefore seems probable that China's fertility rates will be going up again – so the question should perhaps not be if, but when, and by how much? There are too many variables to consider here, so it is hard to say – and also outside the scope of this study to consider. But a study by Zeng (2007) suggested that if a two-child policy was implemented in China, it could result in 200 to 300 million more people by 2050 than if the contemporary policy was continued with.

So, with this population increase for China alone, the UN's medium-variant projection for global population in 2050 would have to be pushed up from 9.7 to 9.9 or 10 billion people, and Lutz et al.'s projection from 9.2 to 9.4 or 9.5 billion. If India then decided to slow its fertility declines, to avoid the negative demographic dividend now faced by China, and their TFR did not decline to below the replacement-level by 2050 as all three world population perspectives expect (Lutz, Butz, KC, et al., 2014; Randers, 2012; UNPD, 2015a), then they could easily add another 100 million or more people to the world population by then. And if the low-fertility European countries, Japan, South Korea, Iran and others succeed in their efforts to raise their fertility rates, an even larger number of people are set to join us on the planet by 2050.

Whatever the number, these recent developments strongly challenges the assumption that all countries' TFRs will fall below the replacement-level eventually, and then stay there, and it suggests that a much higher global population in 2050 seems more likely than even the UN's current medium-variant projection. A world population of closer to 11 billion people by 2050 is now starting to look like a very real possibility[28].

3.7 Summary and conclusion

Population projections are some of the most widely-used and essential sets of data in social, economic and environmental studies. It is used by policy-makers, planners and scholars to determine anything from future demand for energy, food, water, healthcare and education, or to formulate future projections such as GDP, ecological degradation or CO_2 emissions. In terms of assessing the resource requirements of future urbanisation, population projections play two key roles: they underpin projections of future urbanisation, and also largely determine potential future consumption of resources.

The main source of population projections are those of the UN, which are published regularly as the *World Population Prospects* (UNPD, 2015a). These are also the population projections which underpin their urbanisation estimates and projections (UNPD, 2015c), and therefore any study on current or future urbanisation that uses these. Even though there seems to be broad acceptance of the UN's population estimates and projections, two alternatives from prominent scholars have emerged within the last five years – those of Jørgen Randers, one of the lead authors of the *Limits to Growth* studies (Meadows et al., 1972, 2004), and from Wolfgang Lutz and his colleagues from the Vienna Institute of Demography (Lutz, Butz, & KC, 2014).

Out of these three alternative sets of world population projections, the lowest projection for 2050 is that of Randers, who expects the world population to peak at about 8.1 billion people in the early 2040s and then decline just below 8 billion people by 2050. The highest projection is that of the UN, whose current medium-variant for 2050 is 9.7 billion people, with their high-variant being nearly 11 billion people. Due to this large discrepancy in world population projections, and the significance of these projections for future urbanisation and resource consumption, this chapter set out to analyse the three perspectives on world population to 2050 to establish which one offered the most realistic perspective.

It was found that the main point of contention between the three perspectives was the future fertility of Africa. Over the last decade, the UN was found to have increased their projection for world population in 2050 by around 700 million people – the equivalent of the current European population. The reason for these upward-revisions over the last decade was found to be almost exclusively due to Africa's fertility rates coming down slower than was previously expected. On

[28] Two days before the submission of this thesis the Chinese government announced that all couples in China will now be allowed to have two children (Rajagopalan & Qing, 2015), which supports this likelihood.

current medium-variant projections, Africa is expected to add the equivalent of China's current population (1.3 billion people) by 2050, which would mean that, if other projections also held true, 25 percent of the people on the planet in 2050 will be African. But this enormous population boom is still reliant on Africa's TFR coming down from its current 4.7 to 3.1 by 2050; a steep decline which was argued to seem very optimistic considering that the TFR of the ten African countries with the highest fertility have only come down by 0.4 over the last 45 years.

Yet, Randers was found to project that the TFR of African countries, and the rest of the world, will come down even quicker than the UN projects, resulting in his very low forecast of just under 8 billion people on the planet by 2050. But, in analysing Randers's perspective, it was found that his projections are almost exclusively based on assumptions about future urbanisation and its likely effects on fertility rates in Africa – which were shown to be fundamentally flawed when compared against the available evidence in the urbanisation literature. As a result, his world population projections were dismissed as unrealistically low.

Lutz and his colleagues were found to mostly agree with the UN's population projections, with their main point of contention being Africa's future fertility declines. The difference between their projection of 9.2 billion people by 2050, and the UN's projection of 9.7 billion people, was found to be almost exclusively attributable to their 0.5 billion lower projection for Africa by 2050. The reason for their much lower projection for Africa is essentially the assumption that educational expansion in the region will be far greater than the UN expects, with the UN expecting more-or-less a continuation of current trends.

The perspective of Lutz and colleagues was found to be theoretically sound in the sense that it has been well-established that the improved education of women and girls will bring down fertility rates. But, in the end, their perspective was argued to be fundamentally flawed, because a significant and continuous improvement in education in the poor, high-fertility countries of Africa would only be possible if there was a significant and continuous improvement in the economic development and institutional capacity of these countries. And, as studies on Africa's economic future have shown (World Bank, 2010; Cilliers et al., 2011), most countries in Africa are bound to remain on the global economic periphery, largely due to infrastructure deficits and lack of institutional capacity. Also, as the UN pointed out (UNPD, 2015a: 4), the countries with the highest fertility rates in Africa are those where the least resources exist to improve education and family planning. And more important problems, such as hunger and disease, compete with education for finance. So, Lutz and his colleagues' perspective on world population was also argued to be too optimistic, and, as a result, the current medium-variant projection of the UN of 9.7 billion people by 2050 was deemed to be the most realistic and best supported by available evidence.

However, there was one more factor that none of the three perspectives on world population considered: the phenomenon of population cycles. In the analysis of the three perspectives it was found that all three assume that the fertility rates of every country in the world will continue to come down, until they all eventually have TFRs below the replacement-level, and that their TFRs will then stay there. The result would be that each country (and the world's) population will eventually stabilise and decline. The argument between the three perspectives is basically over when this stabilisation and decline will occur – with Randers expecting world population to peak by the early 2040s, Lutz and colleagues expecting it to peak by the 2060s, and the UN not expecting it to peak this century (Lutz, Butz, KC, et al., 2014; Randers, 2012; UNPD, 2015a). But, a recent study by Livi-Bacci (2015) on historic population cycles challenges this "decline and freeze" assumption, and argues against the notion that fertility rates and populations will stabilise around homogenous parameters.

Livi-Bacci argues that demography is largely determined by external factors – social, political, natural or economic – and that the current slowdown of world population growth should not be seen as the end of population cycles. Livi-Bacci's words turned out to be almost prophetic, because China changed their long-reigning one-child policy to a two-child policy a few days before the submission of this thesis, and the reasons behind this change are almost entirely economic. Other low-fertility countries, such as those from Europe, and also Japan and South Korea, have recently given clear indications that they too are pursuing higher fertility rates – also because they fear the negative economic consequences of ageing populations. So, it was argued that we might be witnessing the start of a new population cycle – where the fertility rates of low-fertility countries start to rise again.

At the end of this analysis, it is concluded that, in the coming decades, economic factors look set to both impede the decline of Africa's high fertility rates, and drive an increase in the fertility rates of low-fertility countries. If these developments materialise, the combined effect will be a much higher global population by 2050 than any of the three world population perspectives currently projects. If these two trends come to fruition in full force, a global population of closer to 11 billion people by 2050 – i.e. the UN's current high-variant – will not be unlikely.

The implications of a much higher world population by 2050 are many, and are serious. In terms of the Global Polycrisis, it would mean higher slum populations (due mainly to the higher population growth in Africa), and much higher demand for food, water and energy across the globe, which will only worsen poverty, food insecurity, water scarcity, climate change, ecological degradation and loss of biodiversity. Global efforts to overcome these threats would have to increase as the world population increases, as there will be less and less to share amongst more and more people. In terms of this study, the implications of a much higher global population in

2050 would mean that global urban populations are likely to be much higher than are currently projected – if current definitions of “urban” are used (UNPD, 2015c) – and that the overall demand for resources would also be much higher. With even higher levels of urban expansion and resource consumption up to 2050, the various threats of the Global Polycrisis will only intensify.

So, in closing, the analysis of the literature on world population growth also ended in a dead-end. Even though it was argued that the UN’s current medium variant of 9.7 billion people by 2050 looks to be the most realistic out of the three projections, it still seems like an optimistically low projection if recent developments in China and the unusually rapid fertility decline for Africa are taken into consideration. For this reason none of the three world population projections, or the studies that are based on them, can be taken at face value. For a study assessing the resource requirements of future urbanisation, using a range of population projections to 2050 would be a better option, and the UN’s current high-variant projection of 11 billion people by 2050 should certainly be one of the projections used.

CHAPTER 4

Analysing urban metabolism studies and approaches

4.1 Introduction

Up to this point we have mostly uncovered reasons for uncertainty over future urbanisation and population growth, effectively reaching a dead-end in the previous two chapters. We found that little can be said for certain about current or future levels of global urbanisation, partly because of incomplete and unreliable data in the key region of Africa, but also because there is no common definition for “urban”, and different definitions would likely to lead to vastly different results. The high degree of uncertainty over world population projections that were uncovered in the previous chapter only increases the uncertainty over future urbanisation, and also has significant implications for future resource demand. However, in order to quantify the likely resource requirements of future urbanisation, a suitable approach first needs to be found with which to measure global urban resource consumption. So, it is necessary at this point to pause the demographical mind-set we have been in for the last two chapters, leave the uncertainties about future urbanisation for later, and shift into a resource consumption mind-set.

In order to determine the resource requirements of future urbanisation, it is necessary to find the most appropriate way with which to measure current urban resource consumption, so this will be the focus of this chapter. The measurement of urban resource consumption falls within the field of “urban metabolism”, so this is the body of literature that will be analysed in this chapter.

The urban metabolism (UM) concept is loosely based on an analogy with the metabolism of living organisms, in the sense that urban settlements, like organisms, consume resources from their surrounds and then excrete wastes (Kennedy, Pincetl, & Bunje, 2011: 1965). Also, like organisms, the flows of energy and materials through urban settlements increases as they grow (Decker, Elliott, Smith, Blake, & Rowland, 2000). Understanding and quantifying these energy and material flows through urban settlements is a critical step towards sustainable development, and this is essentially the concern of the UM field (Kennedy & Hoornweg, 2012). UM can be defined as *“the sum total of the technical and socio-economic processes that occur in cities, resulting in growth, production of energy, and elimination of waste”* (Kennedy, Cuddihy, & Engel-yan, 2007). So, where sustainable development can be defined as development where resources are not consumed at a faster rate than the biosphere’s capacity to renew them, and wastes are not produced at a faster rate than the biosphere’s capacity to absorb them, the UM field can be seen to provide the tools with which to actually measure these resource flows and waste impacts.

In this chapter a chronological approach will be taken to analysing the UM field, starting with the origins and development of UM from 1965 to now (2015). The discussion will include a thorough overview of the majority of UM studies that have been published, as well as an introduction to the key concepts and methods that still form the foundation of UM studies today – such as material flows analysis (MFA), ecological footprints and linear and circular urban metabolisms. After this chronological overview, the problems with using conventional UM studies for a global assessment of current urban resource consumption will be discussed, after which alternative approaches will be considered. The chapter will then conclude with a discussion about the most appropriate resource consumption indicator, since the "domestic material consumption" (DMC) indicator is found to be problematic.

4.2 An overview of the UM field

4.2.1 The origins and early development of the UM concept (1960s to 1980s)

The UM concept has been around for exactly 50 years by now, but it took most of this time for it to rise to the prominence it is starting to enjoy today. The concept of UM was applied for the first time in 1965 by Abel Wolman, in his article entitled *The Metabolism of Cities* (Wolman, 1965). This was also the first time a city was presented as an ecosystem (Broto, Allen, & Rapoport, 2012; Mostafavi et al., 2014). Wolman produced his study in response to the worrying decline of water- and air-quality in American cities, which was brought on by the rapid expansion of urban areas in the decades following the Second World War (Wolman, 1965; Kennedy, Cuddihy, & Engel-yan, 2007). He used national data on food-, water- and energy-consumption, as well as estimates of air pollution, waste and sewage, to quantify the per capita inflows and outflows of a hypothetical US city with a population of 1 million people (Wolman, 1965; White, 2002; Kennedy, Pincetl & Bunje, 2011). A decade after Wolman's seminal work, the first UM studies were done on real cities, with Hanya & Ambe (1976) assessing the UM of Tokyo, Duvigneaud & Denayeyer-De Smet (1977) the UM of Brussels, and Newcombe, Kalma, & Aston (1978) that of Hong Kong.

During these early years another approach to UM developed alongside that of Wolman. Where Wolman's approach quantified UM according to the mass-equivalent of various resource flows, Eugene Odum's approach quantified UM according to energy-equivalents. Odum, who originally produced the ecosystem theory that underpinned Wolman's perspective on UM (Odum, 1953; Barles, 2010), also started looking at the metabolism of cities, and also from an ecological perspective – first describing the city as a heterotrophic system (Odum, 1975), and later as a parasitic ecosystem (Odum, 1989; Barles, 2010). However, Odum estimated UM in terms of solar energy equivalents – or "emergy" (with an "m") – not in mass flows, and this approach has found little mainstream traction since (Kennedy, Pincetl & Bunje, 2011; Broto et al., 2012). After these initial explorations of UM during the 1960s and 1970s, the UM concept practically disappeared from the mainstream literature during the 1980s, and only started to re-emerge during the 1990s (Barles, 2010; Kennedy, Pincetl & Bunje, 2011).

4.2.2 The re-emergence of UM and the development of key concepts and methods (1990s)

The re-emergence of UM in the 1990s came in the wake of the "sustainable development" concept rising to prominence in the global policy arena during the late 1980s (World Commission on Environment and Development, 1987). William Rees, Mathis Wackernagel and Herbert Girardet were some of the first scholars to make the connection between the sustainability challenges facing human civilisation and the metabolism of cities. They also introduced and developed key concepts and methods that are still used in UM studies today. Significant contributions to the study of UM were also made by Peter Baccini and Paul Brunner, who brought material flow analysis (MFA) to the fore as a method with which to measure UM.

In the early 1990s, Rees introduced the "ecological footprint" (EF) concept (Rees, 1992), which was then further developed alongside Wackernagel (Rees & Wackernagel, 1996). The EF approach can be applied to any population, and it essentially quantifies the amount of biologically productive land needed to support the resource consumption of the given population, with the concern being that the population should not exceed its ecological "carrying capacity" (Rees, 1992). Using the EF method, Rees & Wackernagel (1996) estimated, for example, that Vancouver's contemporary population of 472,000 people required two million hectares of land to support their consumption patterns – an area 180 times larger than Vancouver.

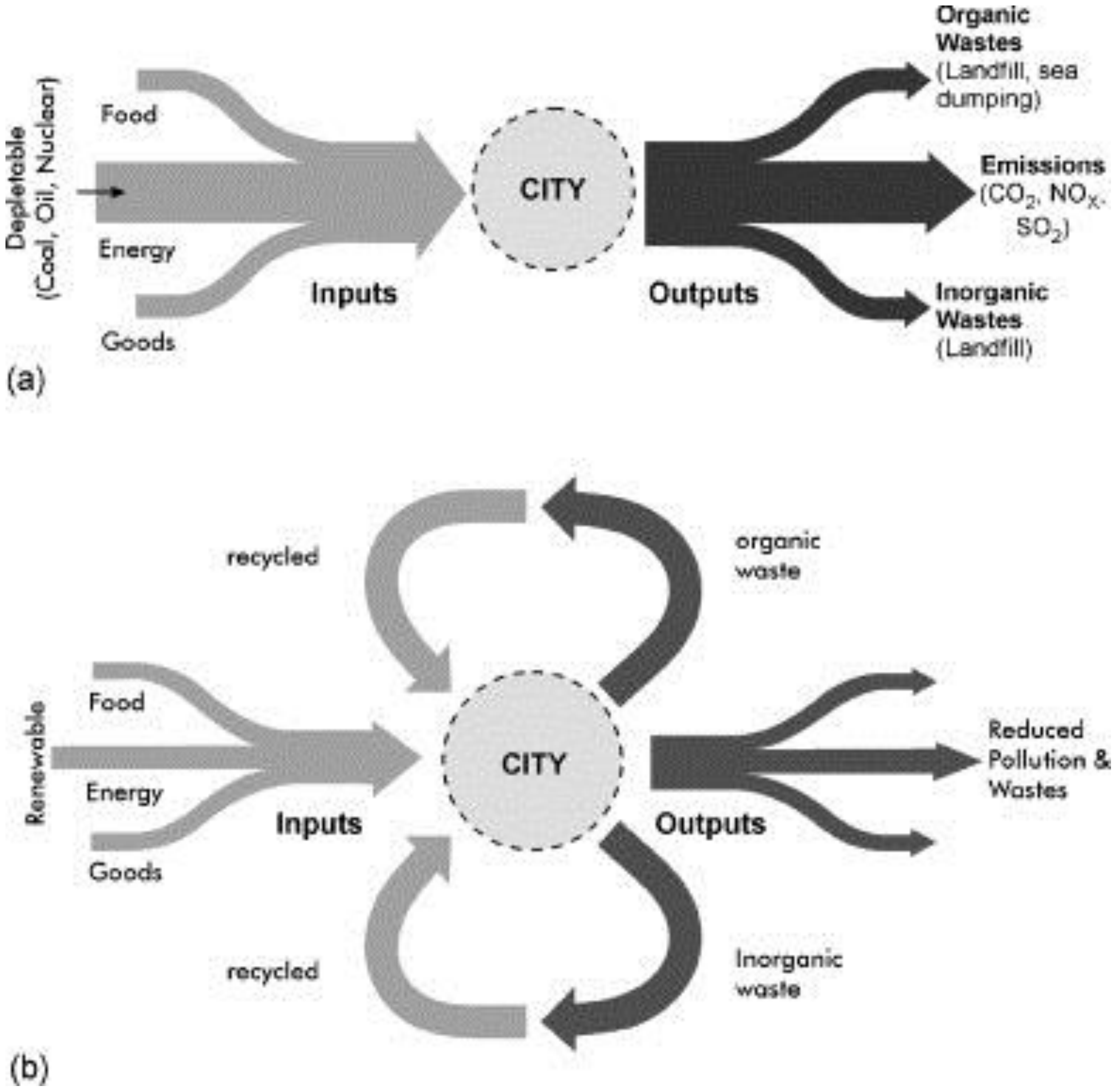
Girardet then adopted Rees & Wackernagel's methodology in 1995 to quantify London's ecological EF, which he at the time found to be around 125 times larger than its surface area (Girardet, 2004: 15). However, in light of a study conducted in 2000 (Best Foot Forward, 2002), Girardet later admitted that his original estimate for London was wrong, and that the city actually required more than double the land area than he originally estimated – which equated to twice the UK's surface area (Girardet, 2004). Girardet also translated the EF approach to the planetary scale, stating that if every person on the planet consumed resources like the average London resident, we would require three planets, and if every person on the planet lived like the average Los Angeles resident, we would require five planets (Girardet, 2004: 15). So, the footprint approach, as developed by Rees, Wackernagel and Girardet, for the first time offered a simple and easy-to-understand way of expressing urban resource consumption.

Besides his contribution to the footprint approach, Girardet made his own original contribution to the study of UM in the early 1990s, by introducing the concepts of linear and circular urban metabolisms (Girardet, 1992). These concepts were also premised on the notion of the city as an ecological system, but as ecological systems that are currently transgressing the laws of nature.

In nature, as explained by ecological theory (Odum, 1953), there are no wastes – the "waste" of one organism is a resource for the next organism – which results in circular resource flows (material, chemical, etc.), or "circular metabolisms". But Girardet argued that modern cities have linear metabolisms – as illustrated by Figure 4.1 (a) – where various resource "inputs" are extracted and imported from their hinterlands and consumed, with their "outputs" being disposed of in the form of waste (Girardet, 1992, 2004; Brunner, 2007; Barles, 2010).

Girardet's concept of linear urban metabolisms illustrated the inherent unsustainability of modern cities, and he argued that in order for cities to become sustainable, they would have to adopt the circular metabolisms of natural systems – where the "waste" of one component or process is always a resource for another (Girardet, 1992). Such circular urban metabolisms can be achieved by reducing consumption, shifting to more renewable resources, and recycling waste outputs to become new resource inputs (Girardet, 1992) – as is illustrated in Figure 4.1 (b).

Figure 4.1: A linear urban metabolism (a) vs. a more circular urban metabolism (b).



Source: (Girardet, 2004).

Girardet's concepts of linear and circular urban metabolisms became fundamental to UM studies, for a number of reasons. Firstly, it served as a useful way to illustrate the ultimate goal of sustainable development, which Goodland & Daly (1996: 1002) defined as *"development without growth in throughput of matter and energy beyond regenerative and absorptive capacities"*. Secondly, the linear and circular urban metabolism concepts helped to illustrate the reasons behind our major sustainability challenges – such as resource depletion, climate change, ecological degradation and solid and toxic waste proliferation – while also suggesting solutions to these problems – such as dematerialisation, decarbonisation and "dewatering" (Barles, 2010: 440). Thirdly, the concepts helped highlight the crucial role of urban infrastructures (transport-, energy-, water-, sewage-, communication-, building-, etc.) in our quest for sustainable development, since it is these infrastructures that conduct the flows of materials and energy to, through and out of the urban space – and it is they that will have to be reconfigured if a shift from linear to circular urban metabolisms is to materialise (Girardet, 2004; Monstadt, 2009; Weisz & Steinberger, 2010; Hodson, Marvin, Robinson, & Swilling, 2012; Ramaswami et al., 2012; Bulkeley, Broto, & Maassen, 2013; Muller et al., 2013; UNEP, 2013).

So, the linear and circular urban metabolism concepts of Girardet greatly advanced the conceptualisation of UM. However, it was the concurrent development of material flow analysis (MFA) during the 1990s that enabled the quantification of the actual material and energy flows through urban spaces.

In 1991 Baccini & Brunner published a book entitled *The Metabolism of the Anthroposphere*, which included an application of the MFA methodology to cities (Baccini & Brunner, 1991). The MFA methodology has been around for a long time, taking over a century to develop out of various disciplines (Fischer-Kowalski, 1998; Fischer-Kowalski & Huttler, 1999), but, until Baccini & Brunner applied MFA to the urban scale, it has only been used to quantify resource flows at the national scale (Fischer-Kowalski, 1998; Fischer-Kowalski & Huttler, 1999; Broto et al., 2012). Later in the 1990s, Baccini & Bader (1996) published a German textbook on regional MFA (Kennedy, Pincetl, et al., 2011), and Baccini also expanded on the application of MFA to the regional and urban scale from the perspective of sustainable development (Baccini, 1996, 1997).

MFA, and the more detailed substance flow analysis (SFA), is essentially the analysis of stocks and flows[29] of materials or substances[30] within a defined system (Baccini & Brunner, 2012). MFA

[29] *Stocks* are the materials/substances remaining within a process or system during the analysis period (for example, in a city, this would often be the materials/substances contained in urban infrastructures), while *flows* are the amount of materials/substances that flows per time unit through a conductor (for example, the waste, sewage, water or food being transported by urban infrastructures) (Baccini & Brunner, 2012).

is similar to Wolman's original UM approach (Wolman, 1965) in terms of quantifying resource flows according to their mass (Kennedy, Pincetl & Bunje, 2011), and therefore differs from the energy-equivalent "emergy"-approach introduced by Odum (1975, 1989). Nevertheless, these two UM/MFA approaches (based on mass and energy) are not that far apart, in that they measure the same items, but just use different units of measurement (Kennedy, Pincetl & Bunje, 2011). Some scholars have used both approaches in the same study, quantifying their material flows in mass units, and their energy flows in energy units (Haberl, Fischer-Kowalski, Krausmann, Martinez-Alier, & Winiwarter, 2009; Krausmann, Fischer-Kowalski, Schandl, & Eisenmenger, 2008); but, this can be confusing, and it makes comparisons difficult, so most MFA studies report both their material and energy stocks and flows in terms of raw material mass.

Even though UM studies were still sparse during the 1990s (Barles, 2010; Mostafavi et al., 2014), fundamental advances were made in the measurement and conceptualisation of UM during this decade, thanks largely to scholars such as Rees, Wackernagel, Girardet and Baccini. The late 1990s, however, saw a re-emergence of published UM studies on real urban areas – such as those done on the Swiss Lowlands (Baccini, 1997), Taipei (Huang, 1998) and Sydney (Newman, 1999) – and in the new millennium empirical UM studies only grew in number, scale and quality; as did the methodologies and methods that underpin them.

4.2.3 UM studies in the 21st century (2000 to 2015)

The first decade of the new millennium saw a sudden flurry of activity in the UM field. Published UM studies on specific cities and urban regions were becoming more common, and many scholars attempted to advance the UM field conceptually and methodologically.

In his study of Sydney, Newman (1999) argued that liveability measures should be added to UM analyses. Hendriks, Obernosterer, Muller, Kytzia, Baccini, and Brunner (2000) did a MFA study on Vienna and the Swiss Lowlands, illustrating MFA's usefulness as an environmental policy decision-making tool for urban areas. Warren-Rhodes & Koenig (2001), also using MFA, built on the original UM study of Hong Kong by Newcombe et al. (1978), showing how consumption of food, water and materials have escalated in the city between 1971 and 1997. EF studies were done on London (Best Foot Forward, 2002) and Cape Town (Gasson, 2002), and in the same year Barrett, Vallack, Jones, & Haq (2002) applied both the MFA and EF approaches to York in the UK in order to assess both the city's material flows and the ecological pressures these flows create. Huang & Hsu (2003) used the energy-equivalent approach of Odum (1989) when they looked at the connection between ecological systems and urban economics in the city of Taipei.

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[30] In the MFA and SFA field, *materials* is an umbrella term for goods and substances, with goods being defined as "economic entities of matter with a positive or negative economic value that comprise one or several substances", and substances defined as "the physical matter of which a good consists" – such as nitrogen, carbon or iron (Baccini & Brunner, 2012: 94-95). So SFA can be seen as a sub-category of MFA.

Hammer, Giljum, Bargigli, & Hinterberger (2003) developed a method for applying MFA to the regional level. Kane & Erickson (2007) analysed New York City's water supply from an urban metabolism perspective, while Browne, O'regan, & Moles (2009) assessed the change in material efficiency of Limerick, Ireland between 1996 and 2002. Codoban & Kennedy (2008) argued for UM to be used as a guide for how to design more sustainable cities, and used four Toronto neighbourhoods as their case studies. Barles (2009) and Niza, Rosado, & Ferrao (2009), in their analyses of Paris (and its wider region) and Lisbon respectively, developed new methodologies to overcome the difficulties encountered when applying MFA to the urban and regional scale.

Meanwhile, the footprint method was developed further to include, amongst others, water footprinting (Hoekstra & Chapagain, 2006), carbon footprinting (Wiedmann & Minx, 2008) and even nitrogen footprinting (Leach et al., 2012). As a result, carbon footprints were done for twelve metropolitan areas (Sovacool & Brown, 2009) and a water and energy footprint was done for Singapore (Novotny, 2010). A conventional EF study was also done for Cardiff (Collins, Flynn, Wiedmann, & Barrett, 2006). Towards the end of the first decade of the 21st century, a flurry of energy-equivalent UM studies also started to appear from scholars in East Asia, such as the Beijing study of Zhang, Yang, & Yu (2009) [for a detailed overview of these, see the thorough review of Zhang (2013)].

This proliferation of UM studies continued into the second decade of the 21st century, and the depth and complexity of the conceptual and methodological considerations continued to increase. This can be illustrated with an overview of some of the articles that appeared in the *Journal of Industrial Ecology*'s special edition, "Sustainable Urban Systems" (for the editorial, see: Kennedy, Baker, Dhakal, & Ramaswami, 2012). In this edition, Kennedy & Hoornweg (2012) argued that a standardised, comprehensive framework is needed for the mainstreaming of UM; Ramaswami, Chavez, & Chertow (2012) took an in-depth look at the carbon footprinting of cities; Hodson, Marvin, Robinson & Swilling (2012) considered what the separate approaches of MFA and transition analysis could learn from each other in terms of reshaping urban infrastructure; Broto, Allen & Rapoport (2012) also considered inter-disciplinary learning, and did a comparative analysis of different approaches to UM within industrial ecology, urban ecology, ecological economics, political economy and political ecology; and Ramaswami et al. (2012) cut across seven major disciplines with their "social-ecological-infrastructural systems framework for interdisciplinary study of sustainable city systems". More recently, Mostafavi, Farzinmoghadam, Hoque & Weil (2014) also presented an interdisciplinary conceptual framework for UM, called IUMAT (Integrated Urban Metabolism Analysis Tool). These studies, as well as the UM studies from the previous decade, highlight not only the increasing diversity and complexity of the UM field, but also its growing global reach and interdisciplinarity.

UM studies in the second decade of the 21st century also became more ambitious in scale. Besides further studies on individual urban areas – such as those on Los Angeles (Pincetl et al., 2014) and Curitiba (Conke & Ferreira, 2015) – Kalmykova, Rosado, & Patrício (2015) performed a MFA analysis to assess the dynamics of resource use over the last 20 years in Sweden, looking at both the national scale and the urban scale (Stockholm and Gothenburg), and also included social and economic indicators in their study. But the most ambitious UM studies came from Saldivar-Sali (2010), Kennedy, Ramaswami, Carney, & Dhakal (2011) and Kennedy et al. (2015), who, with the goal of making global UM comparisons, started assessing groups of cities – with their studies covering 155 cities, 44 cities and 27 megacities respectively.

4.3 Problems with using UM for assessing future urban resource requirements

The UM field has come a long way since its humble beginnings, and it clearly plays a vital role in our quest for sustainable development. The old adage "what is not measured is not managed" is perhaps applicable in this regard. Without knowledge about the resource "inputs" and waste "outputs" (and resource throughputs and recycling) of urban areas, we would not be able to adequately assess the resource requirements and environmental impacts of our consumption – and effective management of our sustainability problems (such as decoupling economic growth from resource consumption) would therefore not be possible. However, with all the advances that have been made over the last number of decades, there are still fundamental problems with UM that leaves it incapable of accurately assessing the resource requirements of future urbanisation.

Firstly, with every UM study there is the challenge of where to draw the boundaries – both in terms of the resources that are assessed, and in terms of the physical boundaries of the urban area. The most challenging tends to be the drawing of physical boundaries – especially in big urban agglomerations, where multi-jurisdictional governance structures often create confusion (Kennedy, Stewart, Ibrahim, Facchini, & Mele, 2014). Barles (2009) overcame this problem in her analysis of Paris by breaking the urban region down into three levels, namely: the city of Paris; Paris and its suburbs; and the entire urban region. Nevertheless, this challenge is a problem in all urban areas (as was established in Chapter 2), and it means decisions always have to be made about where to draw the line between "part of this urban area" and "not part of this urban area", or between "urban" and "rural". Furthermore, when assessing waste flows such as GHG emissions, even using clear political jurisdictions become problematic (Kennedy, Steinberger, et al., 2010), because what about GHG emissions that were emitted outside the urban boundaries, in the urban hinterland, for consumption within the urban boundaries (e.g., for electricity generation, or transport)? These demarcation challenges means that each UM study has to make key decisions; and, as with the urban demarcation inconsistencies uncovered in Chapter 2, meaningful comparisons on a global scale between UM studies become difficult or impossible if a plethora of boundary definitions are being used.

Secondly, there is still a major lack of UM data. More than 75 UM studies have been published since Wolman (1965), with around 20 of these focussing on specific cities (Kennedy & Hoornweg, 2012). But, with 1,692 urban settlements being accounted for in the latest *World Urbanisation Prospects* report by the UN (UNPD, 2015c), the current UM coverage is a mere drop in the ocean in the global context. To gain meaningful insights about current global urban consumption from these few UM studies would therefore not be possible – let alone to say something about future urban resource requirements.

Thirdly, the datasets that are available are mostly not comparable, because hardly any UM studies use exactly the same methodologies or methods. For example, even though the two recent studies by Conke & Ferreira (2015) and Kalmykova et al. (2015) both use MFA (in their assessments of Curitiba, and Stockholm/Gothenburg respectively), Conke & Ferreira use an application of MFA proposed by Kennedy & Hoornweg (2012), while Kalmykova et al. use an application proposed by Niza et al. (2009). The diversity of approaches to UM-assessment have led the leading scholars in the field to call for a standardised, uniform methodology or framework – including guidelines on how to set boundaries – so that meaningful comparisons can be made between studies of differing space and time (Barles, 2010; Kennedy & Hoornweg, 2012). However, this has still not occurred, and currently an assessment of global urban resource consumption based on existing UM studies would not be feasible, and therefore also not a study of resource requirements for future urban growth.

Furthermore, and fourthly, whether it would ever be possible (or practical) to do a thorough global UM study is another question. Any UM study, particularly one that involves MFA (which is the majority of studies reviewed here), can be incredibly data-intensive (Barles, 2009; Kennedy & Hoornweg, 2012; Conke & Ferreira, 2015). Issues of data-availability and -gathering was originally anticipated by Wolman (1965), and Kennedy, et al. (2014) identify the formidable challenge of UM data collection as a key reason why many cities do not conduct comprehensive material and energy flow analyses. Furthermore, as Brunner (2007) pointed out, cities are almost completely dependent on their hinterlands for supply of resources and disposal of wastes, which means it is practically impossible to assess the full UM of any city – because you have to draw the line somewhere. The dynamic nature of material and energy flows, and of the socio-economic factors that influence them, makes the task of getting a relatively accurate snapshot of global UM even more difficult, because things are constantly changing. So, as useful (and critical) as a UM studies are to managing resource and waste flows at the urban and regional scale, it does not seem as though a bottom-up UM approach would ever be a realistic way to do an accurate and comprehensive assessment of global urban resource consumption.

However, there are a few ways in which scholars have tried to get around some of these problems. The next section will look at these alternative approaches, which were considered in this study's quest to establish current urban resource consumption on the global scale, and the resource requirements of future urban growth.

4.4 Alternative approaches for assessing global urban resource consumption

When it became clear that data from available UM studies would not be a suitable basis for assessing global urban resource consumption, alternative approaches had to be considered instead. From an analysis of the literature, three alternative approaches were identified, namely: 1) using available country-level consumption data and scaling it down to the country's urban population; 2) using Bettencourt's scaling laws to predict urban consumption based on urban populations; or 3) using Saldivar-Sali's urban metabolic typologies to predict urban consumption. The considerations of these three alternative approaches will be covered in this section.

4.4.1 Alternative 1: Use country-level data and scale it down to the urban level

Due to data limitations on the urban level, UM studies often use country-level data in some degree. In his seminal UM study, Wolman (1965) used national data to compile the resource consumption profile of his hypothetical American city. More recently, Niza et al. (2009), Saldivar-Sali (2010), Kennedy, Ramaswami, et al. (2011), Muller et al. (2013) and Kalmykova et al. (2015) all used scaled down country-level data where urban-level data were not available. So, it was worth exploring the possibility of using country-level data and scaling it down to the urban level.

A key upside of taking this "top-down" approach to measuring urban resource consumption, is the increasing availability of standardised metabolic data on the global- and country-level. In 2007, Behrens, Giljum, Kovanda, & Niza (2007) published a pioneering study, where they used an MFA approach to calculate global resource consumption (of fossil fuels, biomass, construction minerals and metal ores) between 1980 and 2002. A year later, in their study of socio-metabolic-regimes and -transitions, Krausmann, Fischer-Kowalski, Schandl & Eisenmenger (2008) presented metabolic data on 175 countries for the year 2000. Shortly after, Krausmann, Gingrich, et al. (2009) used MFA to calculate the annual global extraction of fossil fuels, biomass, construction minerals and metal ores between 1900 and 2005. In 2012, Dittrich, Giljum, Lutter, & Polzin (2012) presented regional and global trends in resource extraction and consumption for the period 1980 to 2008, and two years later Schaffartzik, Mayer, et al. (2014) presented an even more thorough study on regional and global trends in resource consumption, covering the period of 1950 to 2010. Then, last year, Giljum, Dittrich, Lieber, & Lutter (2014) published an MFA study on all countries world-wide from 1980 to 2009. One can now also find country-level resource extraction and consumption data online at materialflows.net – an initiative of the Sustainable

Europe Research Institute. So, while urban-level metabolic data is still severely lacking for most cities of the world, global and country-level metabolic data is now widely available.

However, the analysis of the urbanisation literature in Chapter 2 challenges the logic of such a top-down approach. In order to scale down country-level data to the urban level, you need to know what the proportion urban is. But, as we know from Chapter 2, current definitions of "urban" and "rural" differ widely from country to country, which leaves official urbanisation data practically useless in terms of making meaningful global comparisons. Even if the problem of deciding how to attribute a certain amount of resource consumption to urban areas could be overcome, comparisons on a global level would be futile, since every country's definition of "urban" is different. For example, in Sweden any settlement with a population of more than 200 people would be included as "urban", but in Switzerland any settlements of less than 10,000 people would be excluded as "rural"; while in Uganda any settlement of more than 2,000 people would be counted as urban, while any settlements of less than 20,000 in Nigeria would be seen as "rural" (UNPD, 2015c). For political and administrative purposes on the national level these demarcations between urban and rural might make sense, but from the perspective of an academic study attempting to estimate global urban resource consumption they do not.

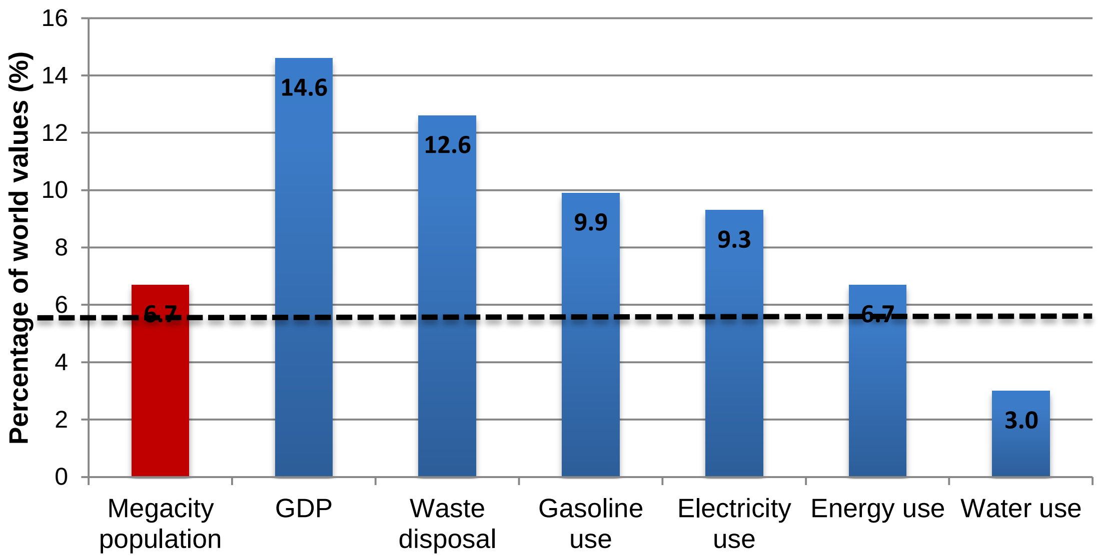
Using available country-level data and scaling it down to the country's urban population would therefore contradict the logic of the urbanisation argument that was made in Chapter 2. The fundamental issues that were uncovered in relation to urban and rural demarcation in Chapter 2 could not now be ignored, just to allow for an easy path to (apparently) answering the broader research question. So, on these grounds, this approach had to be rejected.

4.4.2 Alternative 2: Bettencourt's scaling laws

Another alternative that was considered was to scale resource consumption to urban populations, by following Bettencourt's scaling laws. Bettencourt and his colleagues found that various properties of a city – such as demographic, socio-economic and even behavioural properties – conform to a set of scaling laws that relate to their population size, and which can be used to predict the various properties of urban areas for whom other data are not available (Bettencourt, 2013; Bettencourt, Lobo, Helbing, Kühnert, & West, 2007). For example, from studying thousands of cities worldwide, it was found that, in general, socio-economic characteristics (such as wages and new inventions) increase per capita with population size (i.e. scaling super-linearly), while the amount of infrastructure (such as roads, cable length, etc.) decreases per capita with population size (i.e. scaling sub-linearly) (Bettencourt, 2013). A range of energy-related scaling relationships were also found: residential electricity was found to scale linearly; total electricity super-linearly; and gasoline-use sub-linearly (Kennedy et al., 2015; Bettencourt, 2013; Bettencourt et al., 2007). Each national urban system has some differences in their exact scaling functions, but overall the scaling laws were found to be consistent across nations and time. As a result, these scaling relations could theoretically be used to predict a variety of characteristics, including resource consumption characteristics, that an urban area will assume as it gains of loses population (Bettencourt et al., 2007).

In their recent UM study on the world's 27 megacities, Kennedy et al. (2015) found that the values of average resource use in these cities largely conformed to Bettencourt's scaling laws. In their study, correlations were established for electricity consumption, heating and industrial fuel use, ground transportation energy use, water consumption, waste generation and steel production, in terms of heating-degree-days, urban form, economic activity, and population growth (Kennedy et al., 2015). Figure 4.2 illustrates the consistency of Kennedy et al.'s findings with Bettencourt's scaling laws, related to population size. They found GDP and total electricity use to scale super-linearly with population size, which is consistent with Bettencourt's theory of socio-economic factors and total electricity-use scaling super-linearly. However, where Bettencourt expects gasoline use to scale sub-linearly, Kennedy et al. found it to scale super-linearly – which they suspected to be a result of regional variances in transportation fuel types and use (Kennedy et al., 2015). Kennedy et al. also added waste disposal and water use as factors that could be scaled with population, arguing that waste disposal scales super-linearly because it is closely related to GDP, and arguing that water use scales sub-linearly because most of the global water supply is used in agriculture, which they see as "a predominantly rural activity" (Kennedy et al., 2015: 5987).

Figure 4.2: Megacity resource and waste flows as a percentage of world values



Source: Kennedy et al. (2015).

In light of the empirical evidence which supports it, Bettencourt's scaling laws seem promising as a method with which to establish global urban resource consumption: all we need is country-level data and urban population figures. However, in light of the literature analysis done in Chapters 2 and 3 of this paper, this approach, unfortunately, seems fundamentally flawed too.

Firstly, even though "thousands" of cities were analysed in the development of this theory, Bettencourt and colleagues almost exclusively looked at cities in the USA, Europe, China and Japan (Bettencourt, 2013; Bettencourt et al., 2007). This leaves serious questions over the applicability of these scaling laws to the African context, where slum urbanism is still the predominant form of urbanism (UN, 2015).

Secondly, even if scaling laws were developed for Africa, these would be erroneous due to the erroneous nature of current urbanisation and population estimates for the continent. As was explained in Chapter 2, there is a significant lack of recent and reliable census data for a number of countries in SSA (such as Nigeria, Angola and the DRC), so their current population estimates are little more than guesswork. There is also evidence of over-estimation of urbanisation in SSA, and they too suffer from a plethora of definitions for "urban", which make comparisons between countries largely meaningless. And with such a high uncertainty in current national and urban population estimates, there would inevitably be a high level of uncertainty in the results of a study that employed Bettencourt's population scaling laws to Africa.

Thirdly, with the significant disagreement and uncertainty that reigns over world population projections to 2050, any approach that relies on accurate population figures is problematic. In Chapter 3 it was shown that current projections of world population in 2050 range between just under 8 billion (Randers, 2012) to nearly 11 billion in the UN's high-variant (UNPD, 2015b) – indicating the high degree of uncertainty over future fertility rates, particularly those of Africa. Furthermore, with recent changes in the fertility policy of China, and signs of further change, as well as signs from other low-fertility countries that they want to increase their fertility rates, the future population picture is becoming increasingly uncertain. So, in light of the analysis done in Chapter 3, it would be problematic to adopt a method that relies on future population projections.

So, there are a number of reasons why Bettencourt's approach of scaling resource consumption to urban population size has to be rejected, and why another approach should be considered. The last approach that will be considered as an option to estimate global urban resource consumption is the urban metabolic typology approach developed by Saldivar-Sali (2010).

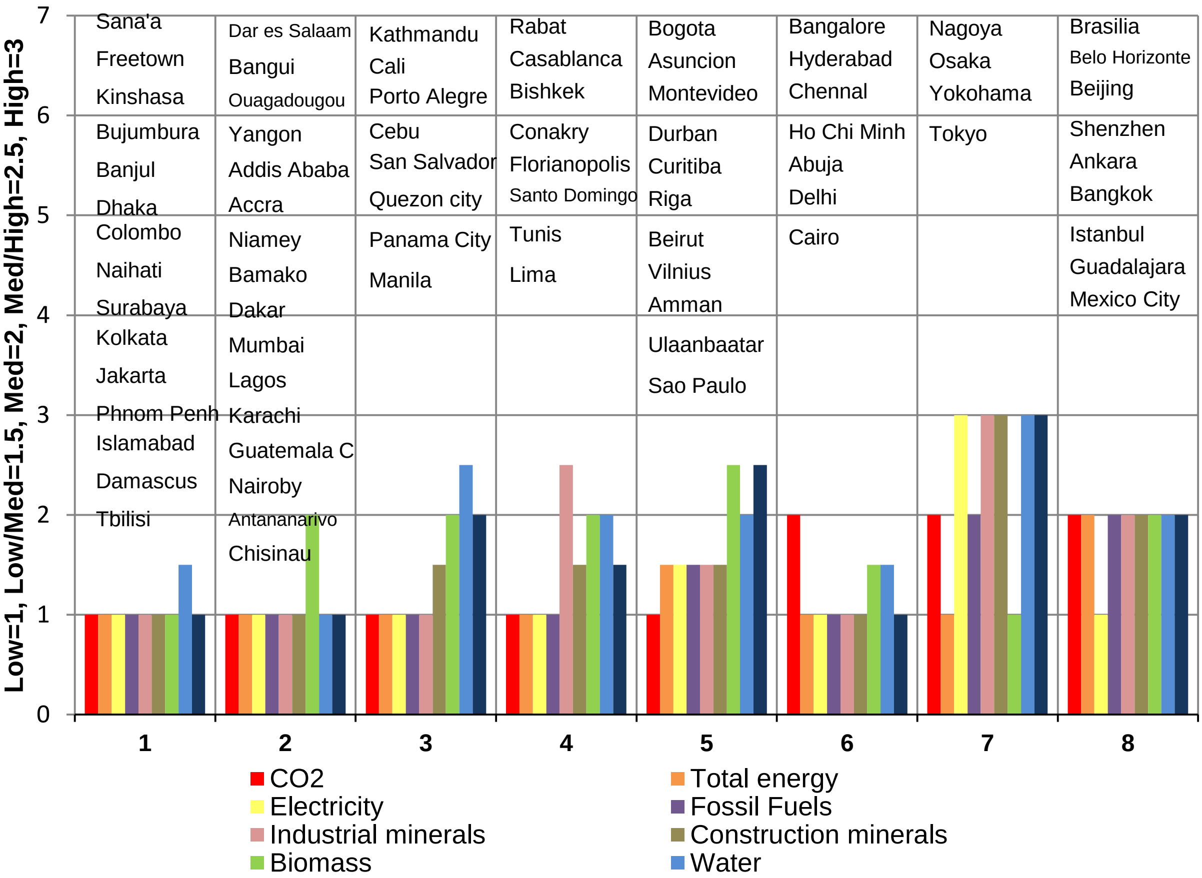
4.4.3 Alternative 3: Saldivar-Sali's urban metabolic typologies

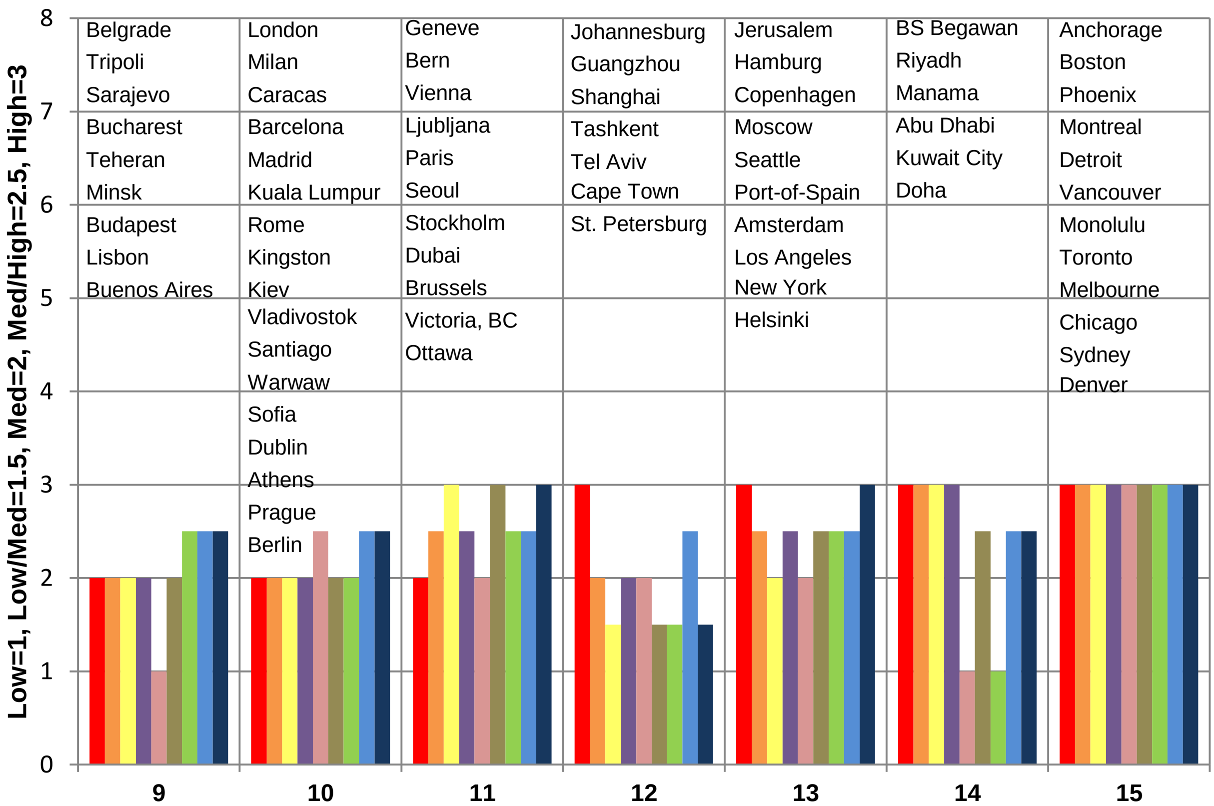
In 2010 Artessa Saldivar-Sali published a thesis through the Massachusetts Institute of Technology which grouped 155 cities according to 15 resource consumption profiles (Saldivar-Sali, 2010). The underlying hypothesis of her thesis was that cities from around the world are likely to exhibit similar resource consumption patterns to other cities with similar socio-economic and climatic characteristics, and that they can be classified accordingly. In other words, that cities from around the world could be grouped according to certain resource consumption typologies – or "metabolic profiles" (Saldivar-Sali, 2010: 10). The premise of this hypothesis is the belief that a limited number of independent variables – namely population, income (GDP), climate and density – largely determine the metabolic profile of a city. She supports this assumption with academic literature that have established a link between climate and energy consumption, as well as with the earlier work of Krausmann, Fischer-Kowalski, Schandl & Eisenmenger (2008), who found that the development status (income) and population density of countries had a strong correlation with resource consumption.

Saldivar-Sali's method of compiling the urban metabolic profiles was pretty simple. A classification tree analysis was used to help determine how the four "predictor" variables of population, GDP, climate and density affect resource consumption (Saldivar-Sali, 2010). Classification trees, containing decision rules, were produced for eight material and energy categories, namely: total energy; electricity; fossil fuels; industrial minerals & ores; construction minerals; biomass; water; and total domestic material consumption (DMC). Urban metabolic profiles were then developed for all the cities, after which the cities were grouped with other cities that displayed identical or almost identical consumption levels in these eight categories. This process resulted in 15 different urban metabolic profiles, which are illustrated in Figure 4.3.

Saldivar-Sali's approach to assessing global urban resource consumption overcomes some of the problems with UM mentioned earlier, and it potentially provides a way to determine the resource requirements of future urbanisation. Even though this approach is still data-intensive, and still leaves you with the problem of where to draw the boundaries (both in terms of the physical urban boundaries, and the system boundaries of the resource flows you are tracking), it provides a standardised UM dataset that allows you to make comparisons between global cities. It also, importantly, helps overcome the issue of data gaps. By simply applying the classification decision-trees to a city's independent variables (population, GDP, climate and density), the city will be grouped alongside other cities who possess the same variable characteristics, and their most likely metabolic profile will thus be determined (Saldivar-Sali, 2010). The model can also potentially be used to assess future developments by changing the relevant material and energy components and relating it to the relevant metabolic profile (and the cities contained therein).

Figure 4.3: Urban resource consumption profiles





Source: Saldivar-Sali (2010)

Even though Saldivar-Sali's approach still relies on accurate population figures, which we found to be a problem, it still seems promising. However, there is a fundamental problem in this approach that prevents us from establishing the resource consumption (and future resource requirements) of urban areas: the use of domestic material consumption (DMC) as a consumption indicator. And this is a problem that affects all the UM studies who use DMC as their consumption indicator – which are practically all the UM studies who use MFA.

4.5 The joker in the pack: Indirect resource consumption

There is one underlying factor which challenges the accurate measurement of urban resource consumption more than any other: the use of "domestic material consumption" (DMC) as an indicator. The DMC of a particular area (such as a city, country or region) is calculated by adding domestic extraction (DE) of raw materials to all physical imports, and subtracting all physical exports (UNEP, 2011). The DMC concept was originally developed for MFA on the country-level (EUROSTAT, 2001), but it becomes problematic when applying it to the urban level.

As Barles (2009) found in her MFA study of Paris and its region, the DMC of an urban area can easily become misleading, due to the dependence of urban areas on their immediate hinterland for key operational functions. In Barles's case it had to do with wastes (sewage, landfill wastes, etc.), which were treated and disposed of outside the city boundary, and which were not being accounted for in trade statistics (a key source for calculating "exports" in MFA). A similar problem was found by Kennedy et al. (2010) in attributing GHG emissions to a city, because power plants are usually situated outside the boundaries of the urban areas that consume their electricity. These two studies illustrate that there is a fundamental problem with DMC: by simply measuring the obvious, domestic or "direct" material consumption of an economy, the less obvious, upstream or "indirect" material consumption, which enables the domestic consumption, is not being accounted for – even though it is part of the overall resource requirement of the economy.

But the DMC problem is one that extends much further than an urban area's immediate hinterland. In the globalised, interconnected world of today, where cities are now nodes in a regional and global exchange network, rather than the economically isolated settlements of yesteryear, the urban hinterland extends much further than its immediate surrounds (Billen, Garnier, & Barles, 2012). And this, once again, raises serious demarcation question. For example, what about fossil fuels consumed and GHG emissions generated by factories in China, to produce goods for the consumption of urban residents in the USA? What about grand infrastructure built on farms in Africa, owned by supermarket groups who sell the produce in European cities? This kind of upstream resource consumption, from the distant hinterlands, are generally not accounted for in the UM studies – even though it clearly forms part of the overall resource requirements of an urban settlement.

In the UM field, only the studies that use a footprint methodology include the distant hinterlands of urban areas, but these measurements are not quantified in mass units (Wiedmann & Minx, 2008). Amongst none of the MFA-based UM studies reviewed earlier was evidence found of resource consumption in distant hinterlands being attributed to the consumption of the urban area/s in question. In the urban metabolic typology study of Saldivar-Sali (2010), mention was made of indirect resource consumption, but the indicator used in the construction of the typologies was DMC.

Furthermore, the theory of metabolic profiles developed by Krausmann et al. (2008), on which Saldivar-Sali's urban metabolic typology approach is based, is itself based on a DMC approach. Kennedy et al. (2015), in their UM assessment of the world's 27 megacities, also considered upstream resource consumption – in terms of transport fuels and emissions (such as air travel and shipping) – but only to exclude these (due to various difficulties) and to also focus on DMC. Kennedy et al.'s focus on DMC is well-illustrated by their comment about the majority of water-use being attributed to agriculture, since this is "a predominantly rural activity" – even though much of this water is probably embodied in the biomass consumption of the urban areas.

The entire population-scaling perspective of Bettencourt and his colleagues (Bettencourt et al., 2007; Bettencourt, 2013), in terms of energy or material consumption, is also built around DMC, and it is reasonable to believe that their scaling results would become erratic if all upstream energy and material requirements were also accounted for. So, amongst the scholars studying resource consumption on the urban level, the DMC perspective is still dominant – and this is a problem, because DMC does not account for hidden flows of resources that were necessary to enable final consumption.

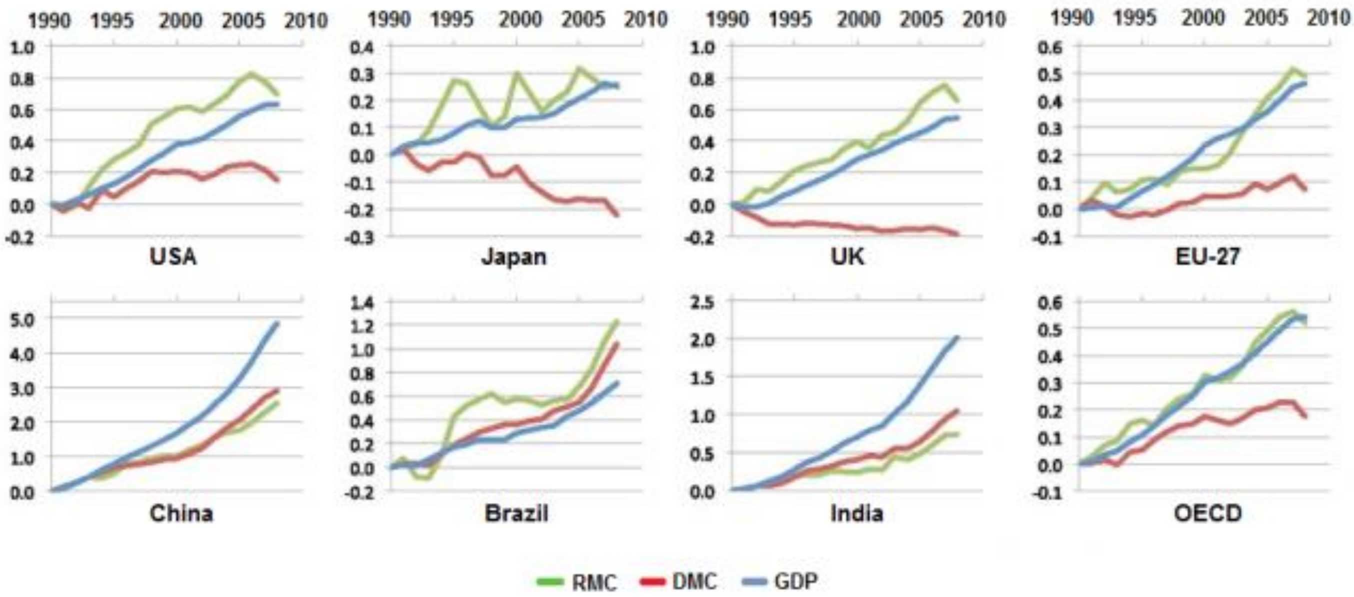
Scholars who study resource flows on the global- and national-level have, for a while now, been considering both direct and indirect flows of materials and energy (Krausmann et al., 2009, 2008; Schandl & West, 2010; Dittrich, Bringezu, & Schütz, 2012; Dittrich, Giljum, et al., 2012), but a consumption-based indicator that captures indirect resource flows have only been closely investigated more recently – under the label of either the "material footprint" (MF) indicator, or the "raw material consumption" (RMC) indicator (Wiedmann et al., 2015; Muñoz, Giljum, & Roca, 2009; Bruckner, Giljum, Lutz, & Wiebe, 2012; Schoer, Weinzettel, Kovanda, Giegrich, & Lauwigi, 2012; Kovanda & Weinzettel, 2013; Giljum et al., 2014; Schaffartzik, Wiedenhofer, & Eisenmenger, 2015). Seeing that "RMC" is the more widely-used term, and also because it more explicitly states what exactly it is indicating, it is the term that will be used here.

Unlike DMC, the RMC indicator includes all upstream resource flows in the calculation of an economy's consumption. It effectively takes a top-down approach by allocating the proportion of used raw material extraction (i.e. total used DE on the global level) to the economy where the final products are consumed (Wiedmann et al., 2015). Unlike with the calculation of DMC, the RMC approach does not track the physical movement of resources within or between countries, but instead enumerates the monetary link between the beginning of a production chain (where raw materials are extracted from the natural environment) and the end point where the final products are consumed (Wiedmann et al., 2015: 6271). The "raw material equivalents" (RME) of trade flows – which includes all upstream materials that were required for the production of the traded goods – are calculated by applying data of monetary transactions to global data on the DE of raw materials (such as those published by the British Geological Society: BGS, 2015). The RMC of an economy is then calculated by adding the RME of imports to the used DE of the economy, and subtracting the RME of exports (Schaffartzik, Wiedenhofer, & Eisenmenger, 2015; Wiedmann et al., 2015). The global RMC is therefore equal to global used-DE.

Unlike the "total material requirement" (TMC) or "total material consumption" (TMR) indicators that are also sometimes used as an alternative to DMC (Fischer-Kowalski et al., 2011; Kovanda, Van de Sand, Schütz, & Bringezu, 2012), the RMC indicator does not include unused raw material extraction. This is because unused-DE, which mainly consist of mining overburden, is often not properly accounted for, making it practically impossible to quantify relatively accurately at present (Wiedmann, 2015). For a more detailed explanation of why unused material extraction is excluded, as well as the reasons why the TMC or TMR indicators are problematic, see (Wiedmann, 2015). What is important to keep in mind, however, is that the RMC indicator still does not encapsulate all the raw materials extracted from the Earth's lithosphere – it only includes used material extraction. Adding unused extraction can easily increase the RMC amount by a third (Wiedmann et al., 2015). So, the total amount of ecological disturbance created by resource extraction is still not properly reflected by the RMC indicator.

Nevertheless, the RMC indicator is a step in the right direction, because, unlike the DMC indicator, it attributes responsibility for raw material extraction and consumption to the economies who consumes the final products. If the DMC indicator is used, the full raw material requirements of the given economy is not reflected, and this would mean that, for example, rich countries – or rich urban areas – who have offshored their resource-intensive and polluting processes (and mostly import finished or partially-finished goods instead of manufacturing it themselves), would appear to have far more resource efficient economies than they actually have (Schoer, Weinzettel, Kovanda, Giegrich, & Lauwigi, 2012). Wiedmann et al. (2015) exposed this flaw of DMC – showing that the apparent resource productivity increases (i.e. decoupling) that is said to have occurred in countries of the EU and OECD over the last 20 years (UNEP, 2011) – which were measured as GDP/DMC – were, in fact, misguided. By instead calculating GDP/RMC, and thereby including all upstream raw materials that were used to produce the products they consume, Wiedmann et al. (2015) showed that no resource decoupling has taken place in the world's wealthy countries – as illustrated by the graphs in Figure 4.4. The resource productivity of developing countries remained relatively similar, when measured as GDP/RMC, but the economies of developed countries were shown to still be as resource-intensive as ever. The limited DMC indicator was just hiding this inconvenient truth.

Figure 4.4: The difference in resource efficiency when measured by DMC and RMC



Source: Wiedmann et al. (2015).

The results illustrated in Figure 4.4 are highly relevant to the measuring of urban resource consumption, because it illustrates the likely difference in results of UM studies if the RME of goods imported into urban areas could be quantified. As of yet, the RMC indicator has not been applied in a UM study. But, considering the near-complete dependence of urban areas on their hinterland (Brunner, 2007), and the global extent of the modern-day urban hinterland (Billen et al., 2012), it can be expected that the RMC of many urban areas would be far higher than their DMC; particularly those situated in relatively wealthy countries with a high-reliance on distant imports.

This theory can be supported by comparing the DMC and the RMC of Singapore, which is an affluent city-state with a population of 5.6 million people (UNPD, 2015a). Singapore's DMC of raw materials in 2008 was estimated to be 32 t per capita (www.materialflows.net/data); but their RMC for the same year and the same materials were estimated to be 70 t per capita (Wiedmann, 2015) – i.e. just over double their DMC. So, one can expect the resource requirements of urban areas situated in relatively wealthy countries to be far higher than their DMC figures indicate, once the full extent of their raw material requirements are brought into the picture. On the other hand, the RMC of urban areas with a large manufacturing sector might be significantly lower than their DMC, because the raw materials expended locally for production purposes will be attributed to the final country or city where the products are consumed, instead of being seen as domestic consumption.

So, due to these fundamental issues with the DMC indicator, none of the UM studies or approaches reviewed in this chapter can be used to give an accurate representation of current global urban resource consumption, let alone give an accurate picture of the resource requirements of future urbanisation. A DMC-based assessment would not deliver a complete picture of the resource consumption of urban areas. Put differently, the raw materials required to "feed" the metabolism of urban areas would not all be accounted for – with a massive discrepancy seeming probable for wealthier cities. So, determining the resource requirements of current or future urbanisation would not be possible by using DMC as a consumption indicator; and, since no RMC data exists for cities, this analysis of the UM field has found another dead-end.

4.6 Summary and conclusion

This chapter set out to find the most appropriate method for measuring global urban resource consumption, and to this end an analysis of the UM field was undertaken. The analysis started with a thorough review of the development of the UM field, which gave an overview of the majority of UM studies that have been undertaken since 1965, as well as brief explanations of the key concepts and methodological advances, such the concepts of linear and circular urban metabolisms, and the EF and MFA methodologies. However, a number of problems were found that would make a bottom-up UM assessment of global urban resource consumption difficult.

Firstly, UM studies are faced with the same demarcation problems encountered in Chapter 2, where questions have to be asked about where to draw the urban boundary. Secondly, it was found that there is still a major lack of UM data, with only about 20 to 30 city-specific UM studies undertaken since 1965, out of the 1,692 urban settlement recognised in the UN's latest *WUP* report (UNPD, 2015c). Thirdly, most of the UM studies that have been done are not comparable, because few of them use the same methods or methodologies. This was found to be a common problem in the field, with some of the leaders of the field calling for a more standardised approach (Barles, 2010; Kennedy & Hoornweg, 2012). But, fourthly, the plausibility of using a bottom-up UM approach to assess global urban resource consumption was questioned, because with so many urban settlements around the world, this would be an incredibly data-intensive process – especially if MFA was used. So, alternative approaches with which to assess global urban resource consumption was considered.

Three alternative approaches were considered, namely: 1) using available country-level consumption data and scaling it down to the country's urban population; 2) using Bettencourt's scaling laws to predict urban consumption based on urban populations; or 3) using Saldivar-Sali's urban metabolic typologies to predict urban consumption.

The approach of using country-level consumption data and scaling it down to the country's urban population was found to be a common approach in the UM field, in cases where city-level data was not available. The benefit of this approach is that standardised country-level data consumption data is now available for most countries of the world. However, the old problem of urban demarcation rears its head with this approach, because questions again have to be asked about where to draw the line between "urban" and "rural" – and why one settlement is excluded and another one included.

So the scaling laws of Bettencourt was then considered – an approach that was recently used by Kennedy et al. (2015) in their UM assessment of the world's 27 megacities. But this approach was also found to be problematic in light of the literature analyses done in Chapters 2 and 3. In developing his scaling laws, Bettencourt mostly looked at the USA, Europe, China and Japan – so their applicability to the African context, where slum urbanism is prevalent, was questioned. Also, with such a high degree of uncertainty over Africa's current and future populations – due both to a lack of recent census data, signs of over-estimation and different definitions of "urban" – it was questioned whether it was even possible to develop accurate scaling laws for Africa. Furthermore, with the high degree of uncertainty over world population growth to 2050 that was uncovered in Chapter 3, it was felt that a population-based approach to assessing the resource requirements of future urbanisation would not be appropriate. So, the urban typology approach of Saldivar-Sali was then considered instead.

Saldivar-Sali's approach to assessing global urban resource consumption was found to overcome a number of the problems encountered with UM mentioned earlier. Even though the urban typology approach is still data-intensive, and still leaves you with the problem of where to draw the boundaries (both in terms of the physical urban boundaries, and the system boundaries of the resource flows you are tracking), its benefit is that it provides a standardised UM dataset that allows you to make comparisons between global cities. It also, importantly, helps overcome the issue of data gaps. Because, by simply applying the classification decision-trees to a city's independent variables (population, GDP, climate and density), the city will be grouped alongside other cities who possess the same variable characteristics, and their most likely metabolic profile will thus be determined. The model can also potentially be used to assess future urban resource consumption by changing the relevant material and energy components and relating it to the relevant metabolic profile.

However, as promising as Saldivar-Sali's approach seems, it relies on the DMC indicator to measure resource consumption – and the DMC indicator does not account for upstream resource flows (i.e. "indirect" resource consumption). This means the full extent of the urban area's hinterland is not included by the DMC indicator, and the full amount of resources required to enable final consumption by the urban settlement is therefore not accounted for. The RMC indicator was considered as an alternative to DMC, and it was argued that this would be a more suitable indicator with which to assess the full resource requirements of current or future urbanisation.

However, no MFA-based UM studies were found that used the RMC approach. Only the footprint methodologies consider upstream resource consumption, but they measure resource consumption in terms of land area, not in mass equivalents of raw materials. But the city-state of Singapore was used as an example of what the likely result would be if RMC was applied to city in a wealthy country, with their per capita RMC for 2008 found to be double that of their DMC. But, because all of the UM approaches that were considered are built around DMC, and no RMC data was found for cities, it has to be concluded that another dead-end has been reached, and no way has been found to measure global urban resource consumption.

CHAPTER 5

Reflections, and new perspectives

5.1 Introduction

As the previous three chapters show, my analysis of the literature on global urbanisation, population growth and urban resource consumption led me to a dead end each time, and I found myself in a position where I could no longer approach the research problem in what at first seemed to be the obvious route. My analysis of the literature essentially revealed that current estimates and projections of global urbanisation and population growth, as well as the available data and approaches of the urban metabolism field, are too inaccurate to be used in a study that is trying to ascertain the global resource requirements of future urbanisation.

However, these realisations did not occur until very late in my research process, since it took a while for me to come across the key documents that led me to these conclusions. And it also took a while for me to then realise and accept that the data I was working with (and have collected over months) might be fundamentally flawed. So, once I did realise the extent of these fundamental problems, and that I would have to shift my approach once again – and throw away all the Excel spreadsheets, calculations and conceptualisations I have worked on over months – the pressure mounted, and so did my urgency to make progress. This resulted in me working at an increasingly frantic pace, speeding from one dead-end to another, and finding myself back at the same point time and time again, with no clear path forward.

Through my frustration (and at this point despair) I for some reason recalled an article that I came across three years earlier in my Complexity Theory module at the Sustainability Institute. It was an article by the late complexity philosopher, Paul Cilliers, entitled *On the importance of a certain slowness* (Cilliers, 2006). In this article Cilliers explained that, when dealing with complexity, a slower approach is necessary, so that there is space and time for reflection to occur. Because, as Cilliers put it, an "unreflective fastness" will only return you to the same place (Cilliers, 2006: 107). So, remembering this importance of a certain slowness, and the need for reflection when dealing with complex problems, I withdrew from the literature, and my computer, and instead walked in the garden and lay on my bed, and gave my mind the space and time to reflect.

The insights of this period of reflection are contained in this chapter. The writing will be less formal than the previous chapters, because the process was more philosophical than academic. The results are new perspectives on defining "urban" and measuring global urban consumption.

5.2 Wrestling with the absurdity of the rural-urban dichotomy

In trying to find the most appropriate way with which to assess the resource requirements of future urbanisation, the main sticking point was the issue of urban demarcation. This was a problem both with the estimates and projections of global urbanisation, and with the measuring of urban resource consumption. It was clear that every country and scholar analysed also encountered the problem of where to draw the boundary between "urban" and "rural", since nearly every country and scholar drew the boundary in a different place. The question of which resources to include as urban consumption and which not, or which settlements to include as "urban" and which ones to exclude as "rural", had no clear standard or logical answer. But, in order to compile an accurate assessment of the resource requirements of future urbanisation, a standard and logical way of defining "urban" and determining global urban consumption would be necessary. So, I realised that a way had to be found to do so.

While reflecting on the problem of how to determine what is "urban" and what is not, I remembered something Potts said in one of her articles regarding the definition of an urban settlement. Potts argued that settlements should be defined as urban only if most of the members of the community are employed in "non-rural" activities (i.e. not in agriculture, fishing, forestry, etc.). Her reasoning for this was that such a definition puts the focus on the key structural economic element of urbanisation, and measures how the economically active portion of a population moves between rural- and urban-based livelihoods and settings (Potts, 2011: 1382-1383). In other words, Potts suggested that in defining "urban" and "rural" the focus should go on what is being measured with urbanisation, and in her opinion it is economic development – with the question being, what proportion of the population are still employed in rural activities, and what proportion of the population have moved on into other sectors of the economy?

This seemed like a logical approach to defining "urban" and "rural", but I also realised that this definition might not be suitable for everyone. For example, a large number of urban settlements are defined (often amongst other criteria) according to municipal or other administrative boundaries (UNPD, 2015c). The purpose of this definition is likely because city or town administrators care mainly about who is within their jurisdiction and who is not. For them the line between "urban" and "rural" is more about governance and administration, and using administrative boundaries as a definition of "urban" and "rural" therefore suits their purposes. They do not necessarily care how many people outside of their administrative boundary are employed in agriculture or not – they are "rural" residents because they live on that side of the municipal border.

But, following this line of thinking, it dawned on me that the definition of "urban" and "rural" is perhaps fluid, and changes – or should change – according to what is being measured or assessed; and perhaps I should ask the question, "what exactly is it that we are trying to measure?" Maybe the answer to this question would help me draw a more logical line between "urban" and "rural" – at least for the purposes of this study.

So, my line of reflection then changed to ask: in trying to quantify the resource requirements of future urbanisation, what exactly is it that we are trying to measure? Are we trying to establish all the material and energy requirements of urban areas, or just some? Should we perhaps only try to assess the resource requirements for the physical urban fabric (infrastructure / "stocks")?

In this sense I considered the study of Muller et al. (2013), who quantified the CO_2 emissions of urban infrastructure development to 2050. They did so by focussing on the CO_2 emissions of three key infrastructure materials: steel, aluminium and cement. So, I considered taking a similar approach, to only focus on key infrastructure materials – i.e. the materials that would be required to build the physical structures of the cities. But this brought up further questions:

Do we only quantify the per capita urban fabric required by the additional population to 2050? What about retrofitting of existing infrastructure for existing populations? And what about all the people living in slums? Do we assume there are still a large number of people living in slums by 2050, or do we assume all slums have been eradicated? Is eradication of slums by 2050 even possible? If the living-situation of slum dwellers started improving significantly, would this not prompt more people to move from rural areas to urban areas, which will only create more slums? But, even if we decided that we would include urban fabric for new-builds, retrofitting and for eradication of current slums, there are still more questions that need answering:

In trying to quantify the required urban fabric, behind which materials do you draw the line? Do you only focus on steel, cement and aluminium? What about all the other materials that go into roads, wiring, pipes and glass? And why are we not including flows? Surely urban areas require far more resources for their functioning than just the materials contained in their stocks. So, if we do not include flows, are we truly measuring the resource requirements of future urbanisation? With a stock-only approach we would be excluding perhaps the most important resource requirement of all: energy. So, I realised that perhaps I should try and find a way to determine the fossil fuel consumption of urban areas as well, alongside infrastructure materials.

But, at this point I came full circle, because the questions then came back to the rural-urban dichotomy: Even if we found a logical way to decide exactly which materials to focus on, why are we counting the materials and energy embodied in or consumed by a house on this side of the rural-urban divide, but not the materials and energy contained in or consumed by the exact same house on the other side of the divide? Why are we including a settlement with a population of

2,100 people, but not an almost identical settlement down the road with a population of 1,900 people? Why are we including a shack in an urban slum, but excluding a large house on a farm, built out of brick and mortar, connected to sewage, electricity and water, consisting of all the modern conveniences, which would have been seen as a mansion if it was in an urban suburb?

So, in trying to define exactly what it is that we are trying to measure in "the resource requirements of future urbanisation", and hopefully finding a logical way to determine what we should exclude as "rural", I only found myself back at square one – where do you draw the line? And why? The rural-urban dichotomy remained a problem, and remained illogical. And I found myself in yet another dead-end. So, I removed myself from the literature and my desk again (which I have returned to in the meantime to explore my ideas), and allowed myself more space and time to further reflect on the problem.

During this "second reflection", I remembered a concept that I encountered during my reading, called "socio-metabolic regimes". This concept was contained in the study of Krausmann, Fischer-Kowalski, Schandl, & Eisenmenger (2008), which underpinned the urban typologies approach of Saldivar-Sali (2010) that was analysed in Chapter 4. But Saldivar-Sali drew her inspiration from Krausmann et al.'s approach of grouping countries according to certain resource consumption typologies ("metabolic profiles"), based on factors such as density and income. My interest was drawn by the continuum-like transition between socio-metabolic regimes, and also the material and energy characteristics associated with these regimes. An overview of the socio-metabolic regime theory will be given in the next section.

5.3 An overview of the socio-metabolic regimes theory

The concept of "socio-metabolic regimes" was first developed by German scholar Sieferle (1982, 2001: in Krausmann et al., 2008). It is based on the theory that, over the time of human history, certain modes of production and subsistence have existed which shared certain fundamental characteristics in the way that they consumed natural resources and changed their environments (Krausmann et al, 2008: 639). From a global perspective, three socio-metabolic regimes have been identified, namely: the regime of hunters and gatherers; the agrarian regime; and the industrial regime (Krausmann et al., 2008; Haberl, et al., 2009).

The energy systems of the socio-metabolic regimes are seen as their most basic constraint and definitive characteristic (Krausmann et al., 2008). As opposed to hunter-gatherers who rely solely on foraging for their subsistence, agrarian societies started to "colonise nature" (Fischer-Kowalski & Haberl, 1997) by becoming actively involved in the reproduction of the resources on which they relied for subsistence (Haberl et al., 2009). By domesticating animals and manipulating their natural environments to produce more of the plant-resources that they required for food, fibre and fuel, societies of the agrarian regime effectively created a "controlled solar energy system" (Sieferle, 1997: in Haberl et al., 2009: 2). So, the energy expenditure of a typical agrarian society is largely determined by the amount of solar energy they can trap in the biomass that they cultivate. Krausmann et al. (2008) estimated that biomass forms about 95 percent of the agrarian society's primary energy supply, with wind and water power also forming a small part.

The inherent limitations of the biomass-based energy system of the agrarian regime – which can be summarised as low energy density, a lack of conversion technologies, reliance on animal power and high energy costs of transport (Krausmann et al., 2008: 642) – were broken free of during the Industrial Revolution as a result of technological change and the increasing use of a new type of energy-carrier: fossil fuels. At the start of the Industrial Revolution coal first started being used as a source of fuel in households and to power some industrial processes, but it was through the development of the steam engine and iron-ore-based railroad system that the energy transition to an industrial regime truly started taking off (Krausmann et al., 2008: 643). Oil and natural gas eventually started being extracted as well, as conversion technologies evolved, and today fossil fuels contribute over 80 percent of our primary energy supply (IEA, 2015a). The fossil fuel-based energy system is therefore at the core of the industrial socio-metabolic regime.

With the energetic constraints of the agrarian regime broken free of, a completely different kind of human society evolved. Thanks to the high energy density of fossil fuels, energy turned from being a scarce to an abundant resource – and, as a result, labour productivity in the industrial and agricultural sectors could be increased exponentially, which in turn increased the number of people who could be fed from one unit of land significantly (Krausmann et al., 2008). This major increase in agricultural output, as well as the major decline in the costs of long-distance transport, resulted in unprecedented population growth and growth of urban agglomerations (Krausmann et al., 2008). These increases in industrial output, population growth and urbanisation not only contributed to unprecedented economic growth, but also resulted in massive increases in the levels of per capita energy and material consumption (Krausmann et al., 2008; Haberl et al., 2009). People and goods were travelling further, buildings and infrastructures were becoming bigger and energy-intensive luxuries such as central heating and air condition became the norm (Krausmann et al., 2008).

So, each socio-metabolic regime has its own distinct "metabolic profile" of per capita material and energy consumption (and population density), and this profile is largely determined by its main source of energy and its conversion technologies. Table 5.1 (on the next page) shows the metabolic profiles that Haberl et al. (2009) estimated for the three socio-metabolic regimes:

Table 5.1: The metabolic profiles of the three global socio-metabolic regimes

	Unit	Hunter-gatherers	Agrarian society	Industrial society
Total energy use per capita	GJ/cap/yr	10 – 20	40 – 70	150 – 400
Use of materials per capita	t/cap/yr	0.5 – 1	3 – 6	15 – 25
Population density	cap/km²	0.025 – 0.115	< 40	< 400
Agricultural population	%	0%	> 80%	< 10%
Biomass share of energy use	%	> 99%	> 95%	10% – 30%

Source: Haberl et al. (2009: 2).

Krausmann et al. (2008: 638) goes on to argue that an economic and technical understanding of industrialisation should therefore be complemented by a socio-metabolic one, where the process of industrialisation is seen as a transition from an agrarian socio-metabolic regime to an industrial one, measured according to these socio-metabolic indicators. They also point out that the majority of the world's economies are still involved in this industrialisation process, and that there are still people who find themselves mainly within the agrarian regime (Krausmann, et al. 2008).

5.4 A re-definition of urbanisation from a socio-metabolic perspective

The theory of socio-metabolic regimes prompted me to start thinking about urbanisation from a different perspective. It set in motion a snowball-effect of realisations, which did not all evolve in logical succession, but rather alongside each other, in a complimentary way. So the next two sections will not chart the sequence of the development of these realisations, but will rather attempt to lay them out as logically as possible, leading to the new perspectives that I propose.

The key realisation that I had was that the agrarian and industrial socio-metabolic regimes do not exist as a dichotomy. There is no line between the two that causes you to be either 100 percent "agrarian" or 100 percent "industrial", as there is with "rural" and "urban". The transition from an agrarian regime to an industrial one occurs along a continuum, where certain metabolic characteristics, particularly pertaining to energy use, changes over time. In a mainly agrarian society, biomass energy (i.e. captured solar energy) dominates, with other renewable energy such as wind and water also playing a small role. In a mainly industrial society, fossil fuel energy dominates, with biomass energy and other renewable energy playing a small role. So, from the perspective of socio-metabolic regimes, and a continuum-like transition between the two, it can be said that the degree to which a society uses fossil fuel and biomass energy largely determines how far along the continuum of industrialisation they are. Per capita fossil fuel consumption can therefore be seen an indicator of the degree of industrialisation of a society.

However, from a broader resource consumption perspective (than just looking at energy), one can argue that the other main categories of abiotic materials – i.e. metal ores, industrial minerals and construction minerals – also belong to the industrial regime, and can also be used as indicators of industrialisation. All of the other abiotic material categories are made up of a subset of materials that are, like fossil fuels, industrially mined from the Earth's lithosphere (EUROSTAT, 2013; BGS, 2015). Even though agrarian societies have been removing easily-accessible metals from the earth since the Iron Age, it was done by labourers and perhaps animals – i.e. done within the boundaries of an agrarian energy system, not an industrial one. Also, the mainstream data for construction minerals, metal ores and fossil fuels generally do not include those materials that are harvested "naturally" by people who are still in the agrarian or hunter-gather regimes, because their consumption is not officially accounted for (EUROSTAT, 2013). The material flow datasets that are available in the mainstream usually rely on mining data, such as those produced by the British Geological Survey (BGS, 2015; Schandl et al., 2015). So, the mainstream data for the abiotic material categories of fossil fuels, industrial minerals, construction minerals and metal ores can safely be assumed to represent the extraction needs of those in the industrial regime.

When one then starts to think of the differences between the agrarian and industrial regimes in terms of shelter, or habitat, connections can be made between the industrial regime and urbanisation. The shelter and general habitat of an agrarian society is limited by its energy system and the materials within its vicinity, so it has to be constructed by human and perhaps animal labour, and from natural materials that went through some basic "hand-made" processing. On the other hand, the shelter and general habitat of an industrial society – to its extreme – is probably a megacity in an "industrialised" or "developed" country, such as London, Paris or New York. During the industrial revolution in England, urbanisation went hand-in-hand with industrialisation (Wheeler & Beatley, 2004; Wyatt, 2009) – as it has done elsewhere. China's industrialisation over the last two decades has gone hand-in-hand with massive urban expansion, with entirely new cities being created all over the country (Liu et al., 2003; Zhang, 2004). Industrialisation and urbanisation can therefore be seen as inextricably linked, and it can be argued that urbanisation is merely the habitat component of industrialisation.

So, following on from the current line of reasoning, the process of industrialisation – which, from a socio-metabolic perspective, indicates the movement from an agrarian regime to an industrial regime – can also be seen as a process of urbanisation. Urbanisation from this perspective, then, also takes place along a continuum, with a mainly agrarian human settlement at the one end (for example, a traditional Nepalese village in the Himalayas), and a mainly industrial human settlement on the other end (for example, the city-state of Singapore). If we accept that we can attribute all the abiotic material categories (i.e. fossil fuels, industrial minerals, construction minerals and metal ores) to the industrial regime, and to the process of industrialisation, and if we see industrialisation and urbanisation as two components of the same process (with the latter merely being the habitat component of the former), then the *degree* of industrialisation *and* urbanisation of a region, country, settlement or person can be measured according to the per capita consumption of abiotic resources. And the hypothesis can then be made that:

the higher the per capita consumption of abiotic resources,
the more urbanised the society.

5.5 Measuring urban resource consumption from the proposed perspective

Based on the analysis done in Chapter 4, it is further argued that the above hypothesis can only be accurately measured if RMC is used as a consumption indicator – not DMC. Because, as explained in Chapter 4, DMC does not reflect the full amount of raw materials consumed by the economy of a settlement, country or region, since it does not include the upstream resources that are required to enable final consumption. But the RMC indicator includes these upstream resource requirements. So, the RMC indicator will be the more accurate indicator with which to measure the per capita consumption of abiotic materials, and therefore the degree of urbanisation.

An interesting element of using the RMC indicator to measure urban resource consumption is that an urban settlement can be held responsible for "urbanisation" taking place somewhere else, at its expense. As a simplistic example: if a factory and labourer dwellings were built in China to produce products for consumption in New York, the RMC indicator would include the raw materials that went into this "urban development" as part of New York's consumption – i.e. it would be seen as an extension of New York. So, even though New York "offshored" these production responsibilities, the RMC indicator would treat this factory and labourer dwellings as if they were still in New York. Or, another example: the metal ores, construction minerals and fossil fuels that goes into setting up and running an industrial farm in the middle of Africa, which produces food for an European supermarket chain, would be attributed to the urban areas where the final products are consumed, if the RMC indicator was used. So, while globalisation extended the urban hinterland until it reached to all corners of the globe, the RMC indicator can now allow us to bring the hinterland back to the town or city where the final products are consumed.

To illustrate how this approach would be used to determine degrees of urbanisation, let us go back to the case of Singapore. As mentioned in Chapter 4, Singapore's consumption of raw materials in 2008, when measured as DMC, was estimated to be 32 t per capita (www.materialflows.net/data), but their RMC for the same year and the same materials were estimated to be 70 t per capita (Wiedmann, 2015) – just over double their DMC per capita. The difference between these two figures essentially indicates the extent to which Singapore is reliant on its hinterland for raw materials. But, also, following the perspective that is proposed here, the abiotic component of this difference (i.e. Singapore's abiotic RMC less their abiotic DMC) indicates the extent to which Singapore has caused urbanisation elsewhere, for its consumption.

So, if a previously agrarian-style farm in Bangladesh has been transformed into a more industrial-style farm with large-scale mechanisation, fossil fuel inputs, and so on, in order to produce food for a supermarket chain in Singapore, then the RMC indicator would attribute the raw materials used by this farm as part of Singapore's consumption – and in so doing re-connect Singapore to its hinterland. In other words, the raw materials used by this farm in Bangladesh to produce food for Singapore would be counted as urban consumption, not rural consumption.

However, if this newly industrialised farm in Bangladesh sold a quarter of their produce to the local rural community, the RMC indicator would attribute a quarter of the raw materials used by this farm as part of the local rural community's "urban consumption". This might sound crazy, and some might ask "how can a rural community's consumption be counted as urban?" But this is only a sticking point if you are still stuck in the rural-urban dichotomy paradigm – where one is either 100 percent "rural" or "urban", but never both. The problem can be overcome when you think in terms of a rural-urban continuum, where there are *degrees* of urban (or rural) – with per capita consumption of the abiotic materials being the degrees along the continuum. And think in terms of "the higher the per capita abiotic RMC, the more urbanised the country, region, settlement or person". So, in this rural community in Bangladesh, their increased consumption of fossil fuels, construction minerals and metal ores (as a result of their increased consumption of industrially-produced food), will indicate the *degree* to which they have moved along the rural-urban continuum – i.e. the degree to which they are now urbanised.

One final example, to hopefully clear up any remaining confusion. Let us take an unquestionably rural area, such as the Sahara desert. Following a conventional route (by using the UN's urbanisation data and national definitions of "urban" and "rural"): if some billionaire decides to build a mansion as big as the White House right in the middle of the Sahara desert, and connects it with piping and wiring over thousands of kilometres to municipal services in Cairo (water, sewage, electricity, internet, etc.), then the materials and energy contained in and used by this settlement, and the infrastructure that connects it, will be excluded as "rural" in a study that tries to assess global urban resource consumption. The energy and material consumption of this mansion and its infrastructure will not be considered "urban", because it is so clearly in a rural area (and it has a population of only 2 – the billionaire and his wife). But this exclusion only makes sense when thinking of "rural" and "urban" as a dichotomy, where you are either one or the other, and where this line is defined by something arbitrary, such as a population threshold or invisible administrative boundaries. And also when you are not focussing on what we are actually trying to measure here – which is the resource requirements of urbanisation. However, when thinking of "rural" and "urban" as two opposites of a long continuum, and you make resource consumption your focus, then it makes sense to include the industrially mined abiotic materials embodied in and consumed by this settlement and its infrastructure as "urban consumption" – with the per capita RMC of abiotic materials indicating the *degree* to which this human settlement is urbanised (which would be, more urbanised than a shack in a slum in Cairo). So, we are not saying the Sahara desert is now suddenly an urban area – we are not counting the sand – we are just looking at the urban component within it.

After all, every megacity in the world started with one house. And that house was a first step along the continuum of urbanisation of that megacity. It indicated the degree to which that area was urbanised at that stage – which was more than what it was before the house was there.

5.6 Conclusion: the simplicity of measuring global urban resource consumption

From this combined socio-metabolic and indirect resource consumption perspective, it makes sense to define urbanisation along a continuum, where there are *degrees* of urbanisation, and where the degree of urbanisation is measured according to the per capita RMC of abiotic materials by the region, country, settlement or person. From the global perspective, however, the proposed approach simplifies matters considerably, because global urban resource consumption would then simply be the global used-DE of abiotic materials. So, to calculate the likely resource requirements of future urbanisation, one would only have to calculate the likely future demand for fossil fuels, industrial minerals, construction minerals and metal ores.[31] And, following the findings of Chapter 3, this should be done by using a range of future world population projections.

There are a few implications that come along with this proposed approach, but these will be considered in the concluding chapter, next, alongside the broader implications of the previous chapters. But what will be clear at this point is that this proposed perspective of measuring global urban resource consumption requires a paradigm shift both from our current notions of "urban" and "rural", and from how we currently think about the process of urbanisation.

[31] From the proposed perspective biomass can be seen as a relic from our agrarian past, and indicates the degree to which we still belong to the agrarian regime – which we can never fully escape. However, if a distinction could be made between "naturally"-produced biomass and industrially-produced biomass, one could make a case for industrially-produced biomass also being attributed to "urban consumption".

CHAPTER 6
Conclusion

6.1 Summary

6.1.1 Purpose of the study

Faced by the Global Polycrisis – which consists of the interconnected threats of climate change, ecological degradation, biodiversity loss, food insecurity, water scarcity, income inequality, poverty and over-consumption of resources – human civilisation in the 21st century are essentially confronted by a choice of either finding a pathway of sustainable development, or entering a phase of collapse. It is increasingly being recognised that urban areas, where the majority of energy and materials are consumed, are not only key contributors to the Global Polycrisis, but also hold the key to a pathway of sustainable development. However, with the UN projecting that 2.4 billion people will be added to the global urban population by 2050, serious questions have to be asked over the sustainability of this future urbanisation. But nobody in the urbanisation literature seems to be asking these questions. Almost everyone in the mainstream urbanisation literature seems to assume that urbanisation can continue unabated, and that somehow the resources will be found to make this happen. So, this study originally set out to find an answer to the pertinent question: "what are the resource requirements of future urbanisation?"

However, in order to answer this question realistically, the validity of three key sets of data had to be investigated, namely: estimates and projections of urbanisation, population growth and urban resource consumption. And, during the analyses of the literature within these three themes, fundamental and far-reaching problems were uncovered. So, the objective of this study had to shift from trying to assess the resource requirements of future urbanisation, to critically analysing the key datasets on which such a study would be built – as a pre-requisite for answering the research question (by a later study). The new objectives of this study then became to:

- assess the validity of the available data on global urbanisation;
- assess the validity of the available data on global population growth;
- assess the validity of the available data on global urban resource consumption; and
- propose the best way to assess the resource requirements of future urbanisation.

Chapters 2, 3 and 4 of the thesis analysed the relevant literature surrounding the first three objectives, and Chapter 5 answered the fourth objective, providing a new way to define urbanisation and measure global urban resource consumption from a socio-metabolic perspective. The most salient findings from the three literature analyses and proposed new theory will be summarised here, before the implications of the findings are discussed.

6.1.2 Chapter 2: Analysing urbanisation data

Chapter 2 focussed on the validity of urbanisation figures, and in particular on the critique of the mainstream narrative on urbanisation, which has come mainly from scholars studying urbanisation in Africa. Amongst other issues (such as the misleading use of the terms “city” and “urbanisation”), it was found that the UN has been guilty of over-estimating urbanisation in the key region of Africa for decades (Beauchemin & Bocquier, 2004; Agence Française de Dévelopment, 2008; Satterthwaite, 2010; Potts, 2008, 2009, 2011, 2012a), and also that the notion of “rapid” urbanisation in Africa was not supported by the evidence. The work of Potts showed that, even though the urban populations of many African countries have been growing rapidly, Africa’s rural population has largely kept pace with urban population growth, and the net result has been only a small increase of the urban percentage – and in some cases even resulting in counter-urbanisation (Potts, 2012a, 2012b). The analysis of the UN’s latest *WUP* report (UNPD, 2015c) also found that there are 12 African countries and also two high-fertility Asian countries (Afghanistan and Pakistan) – with a combined total population estimate of 574 million people (and a combined total population projection of 1.2 billion people by 2050) – for whom censuses have not been held for about 20 to 40 years. So, their current urbanisation and population estimates are little more than guesswork, based on linear projections of very old census data. This leaves a significant question mark over the accuracy of these countries’ – and Africa’s, and the world’s – estimates and projections of population and urbanisation.

But, besides this already high degree of uncertainty over the available urbanisation figures – particularly those for the key region of Africa – an even bigger problem was uncovered, which affects all the countries of the world: the problem of urban demarcation. Even though it is often mentioned in the literature that there is no common definition for an urban settlement, the full extent and implications of this problem does not seem to be grasped by anyone in the urbanisation literature (except for Satterthwaite, 2010; and McGranahan & Satterthwaite, 2014). So, the profound nature of this problem only became clear when the actual urban definitions of each country were scrutinised. From this analysis it was found that there are a number of different criteria – ranging from administrative boundaries to the percentage of the population employed in agriculture – but that population thresholds were used by most countries to some degree. However, these population thresholds ranged from settlements of 200 people in Sweden and Denmark, to settlements of 50,000 people in Japan, and just about every number in between. In Uganda, for example, the threshold is 2,000 people, but in Nigeria it is 20,000; in Australia it is 1,000 people, but in Spain it is 10,000; in Albania it is 400 people, but in Viet Nam it is 4,000 people (UNPD, 2015c: 101-119). Also, it was found that countries often change their urban demarcation criteria from one census period to another. So, not only is it practically impossible to make meaningful comparisons of urbanisation levels between countries, but also *within* some countries over time.

Chapter 2 therefore concluded that little can be said with certainty about current levels of global urbanisation, which puts future projections of urbanisation in even more doubt. Besides a high degree of uncertainty over urbanisation levels in the key region of Africa, the global level of urbanisation can also vary widely, depending on which definition of "urban" you use. If we defined settlements as "urban" by using Japan's population threshold of 50,000 people, the world could still be mostly rural, but if we used Sweden's population threshold of 200 people, the world could perhaps have been over 90 percent urbanised quite some time ago. So, it was concluded that the inaccuracies, inconsistencies and uncertainties that are imbedded within the urbanisation estimates and projections of the UN are of such a nature that their data must be considered too inaccurate and unrealistic to form the basis of comparative study of global urbanisation – particularly one looking to the distant future.

6.1.3 Chapter 3: Analysing world population growth

Chapter 3 focussed on population projections, which not only underpins urbanisation projections, but also indicates the potential future demand for resources. Three sets of population projections were found and analysed, namely: those from the United Nations Population Division; those of Jørgen Randers (of *Limits to Growth* fame); and those of Wolfgang Lutz and his colleagues from the Vienna Institute of Demography. Their world population projections for 2050 were found to range between just under 8 billion people (Randers's projection) to nearly 11 billion people (the UN's high-variant projection), which is clearly a very significant variance. So, it was decided that the assumptions underpinning the three sets of population projections had to be scrutinised, in order to establish which projection was the most likely to materialise.

Randers's projection – which is that world population will peak at 8.1 billion people in the early 2040s, before stabilising and declining, ending up back at just under 8 billion by 2050 – was found to be based on shaky empirical foundations. His projection was essentially based on the assumption that the total fertility rate (TFR) in all countries, except those of Africa and South Asia, will come down to nearly 1.0 by 2050, and that the TFR in the countries of Africa and South Asia will be around 3.0 by then – which represents a significant fall for them from current fertility levels (UNPD, 2015a). Randers's assumption for such major fertility declines was found to be based on assumptions about future urbanisation, which were contradicted by the urbanisation literature analysed in Chapter 2. In scrutinising Randers's forecasts, it was found that he believes most people on the planet in 2050 will be living in megacities, and that this megacity environment will result in all women – including those in poor, high-fertility countries – having less children for economic and practical reasons. But, in Chapter 2 it was argued that, based on the available evidence (UN, 2015; UNPD, 2015c; Stanilov & Scheer, 2004), the majority of people on the planet today live in villages, towns, suburbs and slums – not in large cities, or megacities – and that current trends indicate that this situation is highly unlikely to change by 2050 (UNPD, 2015a). Furthermore, Randers's assumption that fertility rates would come down almost automatically along with urbanisation was contradicted by demographers, who highlighted the need for investments in education and healthcare (Population Reference Bureau, 2014b), and also the role played by cultural norms in the high fertility rates of Africa (Lutz, 2014). Fundamental flaws were also highlighted in Randers's assumptions about the effects of urbanisation on fertility rates in Africa, because, as Potts (2011) pointed out, due to high rural fertility rates, urbanisation in Africa would slow even further if fertility rates in their cities started coming down faster. So, Randers's driver of fertility declines – urbanisation – would only slow itself if it did lead to fertility declines in Africa. For these reasons Randers's world population perspective was dismissed as empirically weak and unrealistically low.

The world population projections of Lutz and his colleagues from the Vienna Institute of Demography were then analysed. Their projections were found to also be based on the expectation that fertility rates would decline at a faster pace than the UN projects, but they based their rapid fertility declines mainly on assumptions about education expansion – particularly in Africa.

It was found that practically the entire 0.5 billion difference between the medium-variant projections for 2050 of Lutz and colleagues (9.2 billion) and the UN (9.7 billion) was due to a lower projection by Lutz et al. for Africa. Where the UN estimated Africa's 2050 population to reach 2.5 billion by 2050, Lutz and his colleagues estimated it to reach 2 billion. The reason for this much lower projection by Lutz et al. was found to be an assumption that continuous improvements in education will be occurring in Africa over the coming decades, and that these will follow a similar trajectory to those countries of the world who are further on in the development process than them.

But, this assumption was found to be flawed. Based on thorough studies of Africa's infrastructure deficit and economic outlook to 2050 (World Bank, 2010; Cilliers et al., 2011), it was argued that the significant and continuous economic growth that would be necessary for the significant and continuous investment in educational expansion that Lutz et al. envisions, is highly unlikely to occur in the coming decades. This is mainly because the countries in Africa with the highest fertility rates are also the ones who are the poorest, with the least positive economic outlooks, and where matters of life and death often compete with education for limited resources. So, the population projections of Lutz and colleagues for Africa (and therefore the world) were also dismissed as too optimistic, and the UN's medium-variant was, as a result, considered to be the most realistic out of the three.

However, all three sets of population projections were found to make one further assumption that is highly questionable. All three population projections make the underlying assumption that the fertility rates of low-fertility countries will stay low (below the replacement level), and that fertility rates in all other countries will continue to come down over the coming decades, until all countries end up with fertility rates around or below the replacement level – and that they will then stay there. This assumption includes China, where all three perspectives assume their one-child policy will remain in place. The only thing the three perspectives disagree on, is the pace and timing of this "decline and freeze" of countries' fertility rates.

But, based on a recent study of historic patterns of population cycles (Livi-Bacci, 2015), and also on very recent developments in China and other low-fertility countries, this "decline and freeze" assumption was challenged. Since late-2013 there have been signs that China was considering abolishing their one-child-policy – which has been in place since the late-1970s – and that all citizens would then be allowed to have two children (and this then occurred in late-2015, two days before the submission of this thesis). The main reason for this ideological U-turn by China was found to be economic in nature, and that it is a situation that affects all countries who experience below-replacement level fertility rates for too long – namely, a negative dependency ratio due to an ageing population.

But it is not just China who has shown a clear intent to raise their low fertility rates: clear indications have also been made this year by a number of other low-fertility countries – such as Japan, South Korea and a handful of European countries – that they now too intend on raising their low fertility rates. So, it was argued that we are not likely to see the end of population cycles – as is suggested by the general "decline and freeze" assumption – and that we might be entering a new population cycle now, where low-fertility countries start raising their fertility rates again, due to economic concerns.

The conclusion of Chapter 3 was therefore that, in the coming decades, economic factors look set to both impede the decline of Africa's high fertility rates, and drive an increase in the fertility rates of low-fertility countries; and that, if this materialises, the combined effect could be a global population by 2050 closer to the UN's current high-variant projection of 11 billion people. Zeng (2007) calculated that a universal two-child policy in China could result in 200 to 300 million more people on the planet by 2050; so, combined with higher fertility rates in other low-fertility countries, as well as slower fertility declines in the high-fertility countries of Africa, the UN's current medium-variant of 9.7 billion people by 2050 starts looking like it could be a significant under-estimation. The implications for this study of a much higher world population by 2050 is that global urban populations by 2050 are likely to be much higher than is currently projected (even if current definitions were used), and also that the overall demand for resources – and their related environmental impacts – would be much higher in 2050 than current population projections indicates.

6.1.4 Chapter 4: Analysing urban metabolism studies and approaches

Pausing the demographic mind-set then for a moment, Chapter 4 set out to find the most appropriate approach for measuring global urban resource consumption. To this end an analysis of the UM field was first undertaken.

The analysis started with a thorough review of the development of the UM concept, which included an overview of the majority of UM studies that have been undertaken since 1965, as well as brief explanations of the key concepts and methodological advances – such the concepts of linear and circular urban metabolisms, and the EF and MFA methodologies. However, a number of problems were found that would make a bottom-up UM assessment of global urban resource consumption very difficult.

UM studies were found to be faced with similar urban demarcation problems as those encountered in Chapter 2, where questions have to be asked about where to draw the urban boundary. It was also found that there is still a major lack of UM data, with only about 20 or 30 city-specific UM studies undertaken since 1965, out of the 1,692 urban settlement recognised in the UN's latest set of urbanisation data. Also, most of the UM studies that have been done are not comparable, because few of them use the same methods or methodologies. So, alternative approaches with which to assess global urban resource consumption was considered.

Three alternative approaches were considered, namely: 1) using available country-level consumption data and scaling it down to the country's urban population; 2) using Bettencourt's scaling laws to predict urban consumption based on urban populations (Bettencourt, 2013); or 3) using the urban metabolic typologies of Saldivar-Sali (2010) to predict urban consumption. But problems were encountered with all three alternative approaches, with the familiar issues of urban demarcation and uncertainty over future populations excluding the first two alternatives. The approach of Saldivar-Sali seemed promising, since it overcame a number of the problems found with conventional UM studies – such as a lack of data – but ultimately this approach (and most others) were discounted due to one fundamental problem: the use of the domestic material consumption (DMC) indicator to measure urban resource consumption.

It was argued that the DMC indicator does not account for upstream resource flows (i.e. “indirect” resource consumption), and that this means the full amount of resources required to enable final consumption by an urban settlement are not accounted for. The “raw material consumption” (RMC) indicator (also known as the “material footprint” indicator) was considered as an alternative to DMC. However, RMC data is currently only available for the country level. But, to illustrate the likely difference if a city’s resource consumption was measured according to the RMC indicator, instead of the DMC indicator, the city-state of Singapore was used as an example (since country-level RMC data exists for Singapore, thanks to Wiedmann et al., 2015). In making the comparison, it was found that Singapore’s RMC for 2008 was double that of their DMC, which suggests that urban areas, particularly in the developed world, are likely to have far higher resource requirements than their DMC indicator suggests, due to a significant dependence on their hinterlands for their high material consumption.

As a result of these findings, it was concluded that none of the UM approaches offered a suitable way with which to measure the full extent of global urban resource requirements. And, after the previous two chapters also ended with a dismissal of the available data, it became clear that the conventional route of assessing the resource requirements of future urbanisation would not work. The available data on global urbanisation, population growth and urban resource consumption were all found to be significantly inaccurate.

So, finding myself in this dead-end, I decided to withdraw from my work to give myself the necessary time and space to reflect on the problems that I encountered in trying to determine the resource requirements of future urbanisation. Chapter 5 captured these reflections, and the resulting new perspectives on urbanisation that came from them.

6.1.5 Chapter 5: Reflections, and new perspectives

During my reflection, a key realisation was that the problems of urban demarcation could perhaps be overcome by being specific about exactly what it is that you want to measure – and demarcating the “urban” portion accordingly. So, I started thinking about a socio-metabolic definition for urbanisation, by focussing on *what* we need to quantify: i.e. the material requirements of urban areas. But then a number of critical questions came to light, such as: “why count the materials and energy embodied in or consumed by a house on this side of the urban-rural divide, but not the materials and energy contained in or consumed by the exact same house on the other side of the divide?” “Why include a settlement with a population of 2,100 people, but not an almost identical settlement down the road with a population of 1,900 people?” So, even from a socio-metabolic perspective, the rural-urban dichotomy was still found to be deeply problematic.

But my continued reflection eventually led me to a new perspective of urbanisation, and urban resource consumption. Based on the theory of socio-metabolic regimes (Krausmann et al., 2008; Haberl et al., 2009), I developed a socio-metabolic definition of "urban", which overcomes the dichotomy by creating a continuum between "rural" and "urban". From the perspective of socio-metabolic regimes, it was argued that urbanisation and industrialisation are intrinsically linked, and that urbanisation can be seen as merely the habitat component of industrialisation. The process of industrialisation – which, from a socio-metabolic regime perspective, is the movement from the agrarian regime to the industrial regime – can therefore also be seen as a process of urbanisation. But, instead of defining the degree of industrialisation (and urbanisation) according to per capita consumption of biomass and fossil fuels (i.e. according to the primary energy consumption of the agrarian and industrial regimes), it was argued that the other categories of industrially mined abiotic materials – namely, construction minerals, industrial minerals and metal ores – should also be attributed to the industrial-urban regime. And that if this was done, one could hypothesise that: "the higher the per capita consumption of abiotic resources, the more urbanised the society".

The benefit of this proposed perspective of determining urbanisation and measuring urban resource consumption is that the problematic rural-urban dichotomy is overcome. Instead a rural-urban continuum is created, where there are *degrees* of urbanisation, based on the per capita consumption of abiotic materials. This would mean that even if a family in a distinctly rural area were consuming industrially-mined abiotic raw materials – such as those that would be contained in and required by a modern house – then this per capita consumption of these "industrial" materials by this family would indicate the *degree* to which they are urbanised.

The RMC indicator was proposed as the best indicator with which to measure the per capita consumption of urban areas, since it includes all upstream resource expenditure that is needed to enable consumption in the final location. It therefore allows for the urban area's global hinterland to be connected to it. In terms of measuring the global resource requirements of global urbanisation, the benefit of this perspective is that it is incredibly simple: the global used-DE of abiotic materials would then represent the global resource consumption of urbanisation.

6.2 Discussion

In terms of answering the overarching research question, this study has failed. In the process of trying to establish what the resource requirements of future urbanisation would be, fundamental problems were uncovered in the key datasets on which the answer to this question would have been based. So the focus of the study had to shift, or zoom in, to assess the validity of the available figures on urbanisation, population and urban metabolism, and to propose the best way forward for measuring the resource requirements of future urbanisation. These new objectives were met through an extensive analysis of the relevant literature, and a certain amount of philosophical reflection. So, in terms of meeting the new objectives, the study succeeded.

There are a number of implications attached to the results of this study; not only for the fields that were the focus of the study, but also for the broader paradigms of the Global Polycrisis and sustainable development. The most important implications will be considered here.

Firstly, if the new theory that is proposed is accepted, then answering the question of what the resource requirements of future urbanisation will be is far simpler than previously thought. If all industrially-mined abiotic raw materials are attributed to the industrial socio-metabolic regime, and to the collective process of industrialisation and urbanisation, then this consumption of abiotic materials would indicate the current and historic resource requirements of urbanisation. To calculate the future resource requirements of global urbanisation, all that would have to be done is to calculate the potential future demand for these abiotic materials (using a range of population projections, as suggested by the analysis of Chapter 3). Furthermore, when measuring resource requirements at the global level, there would be no need to draw a distinction between the RMC and DMC indicators, since global RMC and DMC are both equal to global DE. It is only when breaking the picture down to the regional, national, urban or individual scale that the RMC indicator will have to be used to indicate full resource requirements. This would particularly be important when creating future "catch-up" scenarios – which are scenarios where those in the developing world are expected to catch up to the level of material consumption of those in the developed world (UNEP, 2011) – because the level to catch up to would be much higher when using the RMC indicator than when using the DMC indicator (as illustrated by Singapore's case).

On this point, and secondly, a key implication of this study is that those who have developed future "catch-up" scenarios – such as UNEP (2011) – have probably underestimated future resource demands significantly. Not only because they calculated the per capita consumption of those in the developed world by using the DMC indicator (which does not reflect the true resource requirements of their material standard of living), but also because their future scenarios are underestimating future populations too. In particular, since Africa and Asia are where the vast majority of future population growth is set to occur, these future scenarios are underestimating the number of people who will have to "catch up". So, both the level of material consumption to catch up to and the number of people who have to do the catching up are currently underestimated – and considerably so.

Thirdly, by using the RMC indicator to measure urban resource requirements – and resource efficiency – the role of density diminishes significantly. Krausmann et al. (2008), Saldivar-Sali (2010) and UNEP (2011) are amongst those who placed significant emphasis on density in determining per capita resource consumption, but this only holds true when using DMC as a consumption indicator. But the density of a city such as Singapore will have little effect on its upstream resource consumption. So, just like DMC tells only half the story, density solves only half the problem. The RMC indicator implies that urban areas cannot only look to density to increase their resource efficiency – they also have to look at other factors, such as the distance that their imports travel, the energy mix of the countries they import goods from, and their overall reliance on imports. In order to truly achieve resource efficiency – i.e. reduce their RMC – cities would not only have to gain efficiencies from manipulating their urban density, they would also have to, for example, increase their local production of food and goods (relying less on imports) and favour trading partners who have reduced the carbon intensity of their energy systems.

Fourthly, the results of this analysis seriously questions the certainty that emanates from the mainstream literature on urbanisation, and from the studies who use the UN's urbanisation estimates and projections as if they are fact. This certainty was exposed to be unfounded: we can say little for certain about current levels of global urbanisation, let alone future levels of urbanisation. What we can say with some certainty, however, is that the majority of the people on the planet do not live in the modern, high-rise urban centres that are often depicted in the pictures of mainstream reports on urbanisation (such as in McKinsey & Company, 2011, 2013; and World Economic Forum, 2014) – the majority of the people on the planet live in villages, towns, suburbs and slums. So, those who study and disseminate information about urbanisation, and those who design policies related to urbanisation, need to re-adjust their mind-set and narrative to accommodate this inherent uncertainty, and, importantly, to focus more attention and resources to there where the majority of the people on the planet live. Because the battle for sustainability will not only be fought in large cities – all types of human settlements will play a key role.

Fifthly, the results of this study implies that all future studies who rely on population projections will have to be revised. These include studies assessing future demand for energy (OECD/IEA, 2008), materials (UNEP, 2011), food and water (FAO, 2011), climate change and other environmental impacts (OECD, 2012b; IPCC, 2015), and, of course, urbanisation (UNPD, 2015c). The latest UN medium-variant for world population in 2050 is already higher by about 0.7 billion people than it was in 2005 (UNPD, 2005, 2015a) – in other words, by the equivalent of the current population of Europe – so, any of these forecasts based on older population projections will already require an upward-revision. But the suggestion of this study that Africa's fertility rates will not come down as rapidly as expected, and that low-fertility countries' fertility rates will not stay as low as expected, means that the global population in 2050 could be far higher than currently projected; to the extent that some of these vital forecasts might be under-valuing world population in 2050 by a billion people or more. It is therefore imperative that those who use population projections revise their studies, and employ a range of population projections, which must include a scenario closer to 11 billion people. Otherwise the strategies and policies that we put in place today might still not be enough to achieve sustainable development – even if we meet them.

A sixth implication that can be drawn from this research is that, from the proposed socio-metabolic perspective of urbanisation, the world is far more urbanised than previously thought. Because, if per capita consumption of abiotic materials (including fossil fuels) indicate the *degree* to which someone or a settlement is urbanised, then one could assume the majority of the world's current "rural" population to be urbanised to a degree – with many perhaps being more urbanised than not. So, if this definition of urban was used, we could have been mostly urban decades ago.

A seventh and very important implication of the research findings is that significant advances made towards decoupling and sustainable development could be out-paced by population growth. Because, no matter how significantly technological development and re-design can bring down global per capita consumption of raw materials (and its related environmental impacts), we will not get any closer to absolute decoupling and sustainable development if the global population keeps growing – as this research suggests it will. The full implication of this then is that decoupling (resource efficiency) would not be enough to bring about sustainable development – steps will also have to be taken to bring about world population stabilisation and decline. To assume that this will happen automatically – as everyone who produces world population projections assumes – is a very risky assumption to make. The signs are that this will not be the case: population stabilisation and decline ultimately is bad for our growth-based economic system, and it is therefore an outcome that many countries will try to avoid. Considering the critical role that population growth plays in the Global Polycrisis, and this problem of our economic system relying on population growth, "unabated world population growth" should perhaps be added as another component of the Global Polycrisis.

And, lastly, the proposed perspective does not only have implications for how we define "urban" from a socio-metabolic perspective, but also for the way we view sustainable development. Because, if moving from an agrarian regime towards an industrial regime is seen as industrialisation, or "development" (with urbanisation forming the habitat component of this industrialisation and development), then does sustainable development mean de-industrialisation and de-urbanisation, and moving back towards an agrarian regime? Because, as was discussed in Chapter 1, in order to reach our goal of sustainable development, we have to drastically reduce our consumption of fossil fuels and other raw materials, through decoupling. And this would mean renewable energy limits would eventually apply again, as it does in the agrarian regime. So, in this sense it *would* mean that sustainable development is movement back along the continuum towards an agrarian regime.

However, due to modern conversion technologies, our ways of capturing renewable energy has improved significantly, so we would perhaps not have to move all the way back to an agrarian way of life to become sustainable. And, through re-designing our urban infrastructures, buildings, products and systems with sustainability in mind – reducing our consumption and creating circular metabolisms wherever possible – we could conceivably bring our per capita material and energy consumption down closer to a typical agrarian per capita consumption level, but while still living in urban areas. So, it can be argued that the extent to which we can remain industrialised and urbanised while still achieving sustainable development will depend on the extent to which we can re-design our urban infrastructures, buildings, technologies, products and systems – and bring down our populations. If our progress in these areas are slow and minimal, then we would probably have to return to a traditional agrarian way of life if we have any hope of reaching a path of sustainable development; but, if our progress in these areas are fast and extensive, then we could possibly remain a mainly urban and industrialised species, while also being sustainable.

6.3 Limitations of the study

As should be evident by now, the research results are significant in a number of ways, and to a number of academic fields. However, there are some limitations that must be noted:

Firstly, in critiquing the mainstream narrative on urbanisation, there was a heavy reliance on the work of Potts alone, and mainly a focus on Africa. This was because, apart from the other studies mentioned, no other studies were found that questioned the mainstream narrative on urbanisation – everyone else just seem to take the data at face value. So, further studies in the region of Africa and other countries of the world would be necessary to give a more complete critique of the mainstream narrative on urbanisation, and to further support or reject the work of Potts.

Secondly, no calculations were made to assess what the future world population could be if the proposed population theory came to fruition. It was, unfortunately, out of the scope of this study to do so. Only the work of Zeng (2007) could be relied on to estimate what impact a two-child policy in China would have on world population growth to 2050, but this is a relatively old study. So, indications that the world population by 2050 could be closer to 11 billion people is – like some of the UN's population estimates! – no more than guesswork. If Africa's fertility rates come down much slower than expected, and China and other low-fertility countries manage to raise their fertility rates over the coming decades, there could be much less than or much more than 11 billion people on the planet by 2050. This would have to be determined by another study.

Thirdly, the RMC concept is still very new, so the peer-reviewing process has not yet come into full force, and it has not yet been applied at the urban scale. As the concept gains more traction in the broader social metabolism field, but also – hopefully – the urban metabolism field, valid critiques and issues might arise. So, we have to wait and see whether RMC delivers on the promise it is showing.

And, lastly, the proposed new theory is limited to re-defining urbanisation from a socio-metabolic perspective, and only useful to give the "big picture" of urban resource consumption. It does not solve the broader problem of urban demarcation, which scholars studying other aspects of urbanisation will still encounter. It also does not offer the level of detail that a traditional, "bottom-up" UM approach can, so in practical terms it is not nearly as useful as UM studies.

6.4 Recommendations for further research

A number of potential research topics can be extrapolated from this study. Some of the most obvious questions would be:

- What are the resource requirements of future urbanisation – if measured according to the proposed method (i.e. future demand for abiotic materials)?
- What results would a "freeze and catch-up" scenario deliver if the RMC indicator was used to determine per capita consumption of developed countries/cities, and higher population figures were used?
- What would global levels of urbanisation be if standard definitions of "urban" were used?
- In countries where the definition of "urban" has changed over time, what would their rates of urbanisation be if the definition was kept constant?
- How would slower fertility declines in Africa and higher fertility levels in low-fertility countries – particularly in China – affect world population growth this century?
- How would a much higher global population in 2050 affect future scenarios for energy / food / water demand, and/or environmental impacts / climate change?
- What is the "material footprint" (RMC) of cities? And how does it compare to their DMC?
- Can we lower populations and still achieve economic growth in the long-run?

Of all these suggestions for future research, the most critical is that of re-evaluating future demand for energy, food and water, and environmental impacts (such as GHG emissions), based on higher population figures. Because, if the policies and strategies that we put in place today are based on information that are significantly underestimating future resource demand and environmental impacts, then we will still not reach a path of sustainable development – even if we succeed in our planned efforts.

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