Antarctic Cities

Volume 3
Antarctic Connectivity Index

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with

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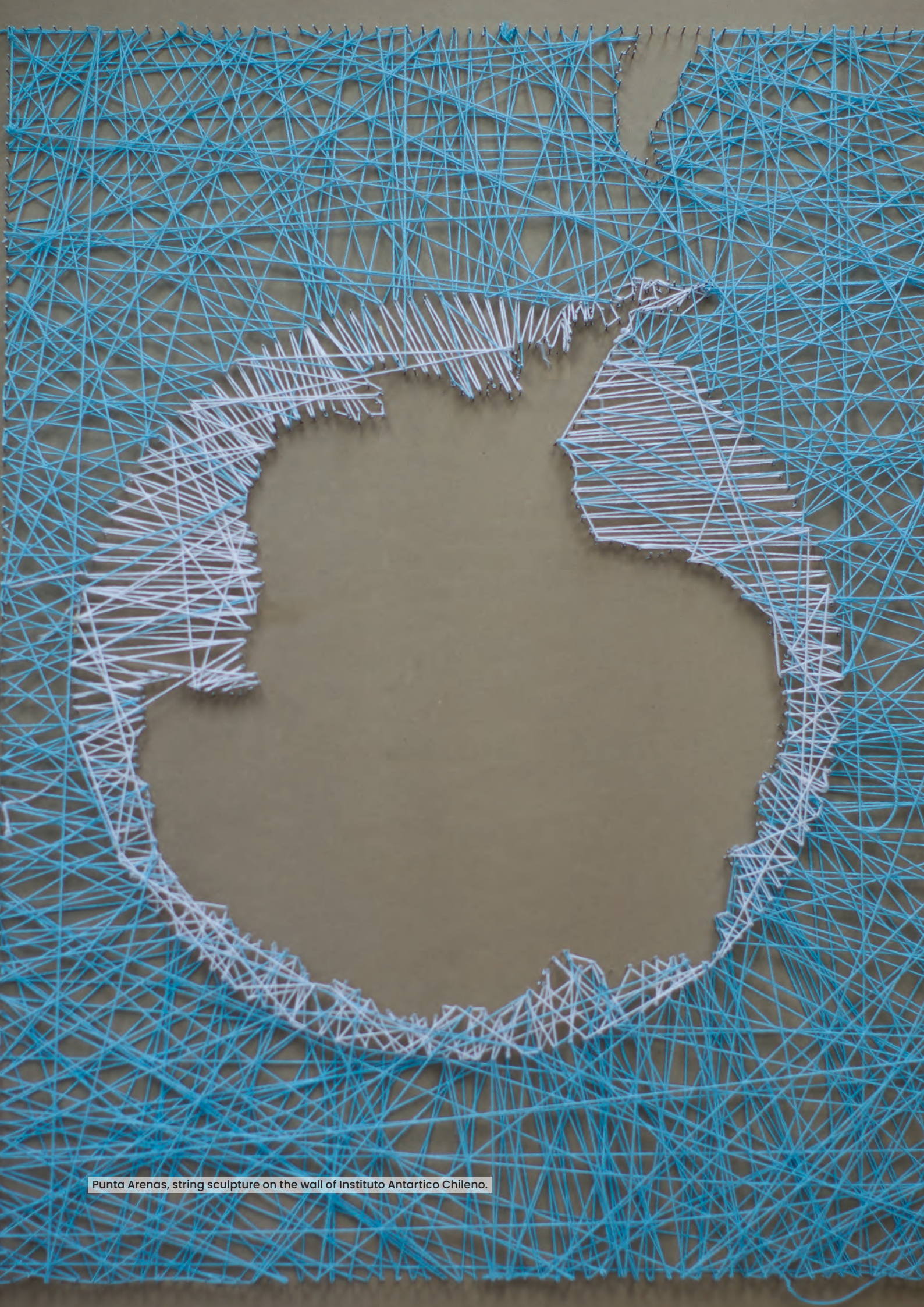The report, Antarctic Cities, comprises the following volumes

Antarctic Cities, Volume 1: From Gateway Cities to Custodial Cities
Antarctic Cities, Volume 2: Urban Sustainability Profiles
Antarctic Cities, Volume 3: Antarctic Connectivity Index
Antarctic Cities, Volume 4: Principles for Antarctic Connection

Punta Arenas, string sculpture on the wall of Instituto Antartico Chileno.

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Background to the Index

The *Antarctic Connectivity Index* is an innovative and comprehensive instrument developed through a collaborative project involving a number of universities, agencies and cities. It provides an evidence-based means of showing the various levels of connectivity of cities as they engage with Antarctica.

This *Antarctic Connectivity Index* seeks to understand the level and nature of the connections of cities across the world to the Antarctic region. For the purposes of this index, the concept of 'the Antarctic region' includes Antarctica, the Southern Ocean and the sub-Antarctic region. The notion of 'connectivity' is used in the deeper historical meaning of the condition of being 'joined together' from the Latin *conectere*, to bind or establish a relationship—rather than the contemporary thinning out of the concept as the establishment of a mediated communications channel. This mean that the connectivity is understood across a range of domains—ecological, economic, political, and cultural—rather than limited to communications technologies and other infrastructural means of connection.

The Index has been refined through comparative international case studies, surveys and research into current publicly available indicators. As a result of this process, we are at the beta-stage of developing a comprehensive instrument to gauge a city's current status as an 'Antarctic city'. The index is intended as a guide to thinking and practice as citizens of these cities contribute to Antarctica's future.

We are keenly interested in the activities of the Antarctic gateway cities and their transition to become Antarctic custodial cities. At the same time, this index is intended to have a global reach and allow for any city to evaluate its connections to the Antarctic. In setting up the index and its variables we have included consideration of cities other than the five gateway cities to bring in different kinds of relations to the Antarctic that are generally applicable.

Why a Connectivity Index?

Cities, in particular the group of cities called the gateway cities have struggled to clarify the level of their connectivity to Antarctica. There has been no previous way of assessing the level of this connectivity in more than a return-on-investment form. Moreover, most of the prior work on connectivity has been directed towards a particular aspect of connectivity, in particular, economic connections. Ecological, connectivity has largely limited to the direct impact of bases on the continent. Politically, claims to alternative forms of connectivity other than in relation to nation-state claims of sovereignty have had little purchase. And, culturally, the emotional, meaning-based and heritage-linked connection of cities to the Antarctic region has largely been limited to discussions of tourism.

In response to the various difficulties in developing a mapping process, the research team have used a consultative method framed by the Circles approach to give systematic guidance to choosing the basic indicators. Simultaneous work using the same approach is happening with other cities through the Sustainable Cities Collaboratory.

The Process for Developing the Index

Development of the *Antarctic Connectivity Index* was initiated through an Australian Research Council project led by the Institute for Culture and Society at Western Sydney University (see Volume 1 of this report). A series of dialogues was begun with a range of urban and Antarctic experts from three Antarctic 'gateway cities' central to the overall project—Hobart, Christchurch, Punta Arenas. Other cities considered for comparative measurement in the development of the tool include Cape Town, Ushuaia, Shanghai, and Goa, among others.

Workshops were held with experts in each of the three cities of Hobart (July 2017), Christchurch (October 2017), and Punta Arenas (November 2017), with follow-up in these cities across the period 2018–2019 as the index was formed. The consultation brought together urban and Antarctic experts in each city (116 in total) to develop the key questions and critical issues from which possible indicators were developed. These indicators form the basis for a scaled index. In other words, the index is formed both through a top-down framework, through the *Circles of Social Life* method, and a bottom-up process through unconstrained brainstorming sessions and then directed discussions (using the 'Critical Issues Definition' process of the Circles method).[1] It was considered important within this method to consider the broad range of possibilities for connectivity across the ecological, economic, political and cultural domains.

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1   Liam Magee, Andy Scerri, Paul James, Lin Padgham, James Thom, Hepu Deng, Sarah Hickmott, and Felicity Cahill, 'Reframing Sustainability Reporting: Towards an Engaged Approach', *Environment, Development and Sustainability*, vol. 15, no. 1, 2013, pp. 225–43; Paul James, with Liam Magee, Andy Scerri and Manfred B. Steger, *Urban Sustainability in Theory and Practice: Circles of Sustainability*, Routledge, London, 2015.

Core Partner Organizations

City of Hobart, Australia

Tasmanian Government, Department of State Growth, Australia

Instituto Antartico Chileno, Chile

Universidad de Magallanes, Chile

University of Canterbury, New Zealand

Christchurch City Council, New Zealand

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Edgardo Vega, Director del INACH

The Questions Guiding the Index

The process of setting up the index began with determining the *general question* that frames the project. This general question provides the core consideration for judging the quality and level of connectivity. Because this is a positive index, in effect treating higher levels of connectivity as normatively better (within limits), the question guides all aspects of the index development.[2]

How is the city positively connected to the Antarctic region in a way that enhances the sustainable future of that region, while it also enhances its own urban future?[3]

The concept of *'positive connectivity'* is important here, and accords with many other indices such as the Human Development Index. Most liveability, sustainability, and resilience indices are positive indices, even if they do not make explicit their normative orientation. Developing a notion of 'positive' connectivity entails specifying the normative orientation to the question of how connections are made to Antarctica.

From here our work went in two interconnected directions, both framed by the Circles of Social Life matrix of domains and subdomains:

1. The development of a top-level quantitative version in which agreed indicators, metrics, and data-parameters are used to compare levels of connectivity (see Table 1 below); and

2. The development of a more qualitative self-assessment process that moves from the top-level of the four domains down to the subdomains of the Circles' matrix (see Table 2 below).

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2 The question thus provides the basis for deriving the underlying algorithms that is used for calculating the level of the indicators. It should be noted at this this level of detail more is not always better, or different indicators can bear against each other.

3 Here the concept of 'sustainable' includes ecological, economic, political and cultural sustainability. And to repeat an earlier point, for the purposes of this Index 'the Antarctic' or 'Antarctic Region' means Antarctica, the Southern Ocean and the sub-Antarctic.

Christchurch, Antarctic Centre.

Developing a Quantitative Index

From the general question, working with experts in the three cities, we then developed the domain-level questions and the associated themes for naming the top-level indicators:

Ecology: To what extent do the city's connections with the Antarctic region enhance the ecological flourishing of the region?
            Indicator 1. The extent to which the city supports the biosecurity and environmental monitoring of the Antarctic.

Economics: How sustainable is the Antarctic to the ongoing economic prosperity of the city?
            Indicator 2. The level of sustainable economic return to the city from its connection to the Antarctic.

Politics: How important is the Antarctic in the political engagement of the city?
            Indicator 3. The level of political engagement with the Antarctic region managed through the city.

Culture: To what extent is the Antarctic region positively embedded in the cultural life of the city?
            Indicator 4. The level of cultural engagement with the Antarctic, manifest in the life of the city.

The process for developing the variables and their measurement associated with each of those indicators is much more complicated, but Table 1 below is set up to show a possible way of doing this.

Elaborating the Domain-Level Questions, Indicators and Variables

The themes for judging connectivity, like all the tools described in this report, are organized around the four-domain structure of the Circles of Social Life method. Based on the general question, simple domain-level questions were derived, and these become the basis for choosing the indicators and their variables. Both the indicators and their variables were then chosen as proxies for responding to the domain-level questions on the following basis:

- That they were as simple as possible while recognizing the complexity of different forms of connectivity.
- That they could act as fair representative indicators for the field covered by the domain-level question;
- That data was potentially available across the four cities to calculate the levels of the numerical variables;
- That they were positive indicators of connectivity that would potentially contribute to a positive or flourishing social engagement with Antarctica (see Appendix 2 below); and
- That they were relevant to cities beyond the current five gateway cities.

Table 1. Domain-Level Questions and Indicators in Relation to Variables

Domains	Questions	Indicators[4]	Variables

Ecology

The ecological domain is defined as the practices, discourses, and material expressions that occur across the intersection between the social and the natural realms, focusing on the important dimension of human engagement with and within nature, ranging from the built-environment to the wilderness.	To what extent do the city's connections with the Antarctic enhance the ecological flourishing of the whole Antarctic region?[5]	1. The level to which the city supports the biosecurity and ecological monitoring of the Antarctic region.	**1.1 The level of material support for the biosecurity of the Antarctic.** *Material Support* = percentage calculated as a proportion of the overall annual budget of national/federal and local government authorities spent on programs in managing material flows in and out of Antarctica. *Unit of measure* = percentage (of estimated annual urban budget) *Minimum value:* 0 % *Maximum value:* 5 % (NB. This value needs to be tested *Scale:* Linear *Managing material flows* = 1. border control on goods; 2. waste-management and pollution-control programs in Antarctica; and 3. surveillance and interception programs of illegal fishing in the Southern Ocean. *Constraint* = Programs run through the city. Unit of measure: No. of programs (across the three categories) This would need a clear definition of what constitutes a program. Minimum value: 0 Maximum value: 206 Scale: Linear
			1.2. The level of monitoring and modelling of bio-geographic and climatic patterns in the Antarctic. *Ecological monitoring* = Weather patterns including atmospheric and oceanographic; wildlife. *Level* = Calculated by adding together the following two variables and dividing by two (each needs to be normalised differently): 1. the number of variables monitored and modelled by scientists travelling to the Southern Ocean and the Antarctic. Unit of measure = number of variables Minimum value: 0 Maximum value: to be determined Scale: Log-linear 2. the number of monitoring initiatives launched/ monitored from the city (weather stations; remote sensing projects; monitoring of human impact; invasive species monitoring) Unit of measure: number of monitoring initiatives Minimum value: 0 Maximum value: to be determined Scale: Linear

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4 For each of the domains there are indicators chosen, made up of two variables. Each of the variables is worth 50 per cent of the whole calculation. This allocation is only nominal at this stage of development of the index but reflects our view that they are equally important, and too much emphasis on one or the other would skew a city's ecological relation to the region.

5 Note that the definition of 'ecology' includes humans in the environment. This qualifies the concerns of some critics who suggest that humans should leave Antarctica as 'pure' wilderness. Also, note that 'the Antarctic' in this and all subsequent uses refers to Antarctica and the Southern Ocean.

6 Here the maximum value of 20 needs to be tested against the question 'What is the maximum number of programs that would make for a flourishing connection?'

Economics

The economic domain is defined as the practices, discourses, and material expressions associated with the production, use, and management of resources.	How sustainable is engagement with the Antarctic to the ongoing economic prosperity of the city?	2. The level of sustainable economic return to the city from its Antarctic-related activities.	**2.1. The percentage of people in the city employed in jobs related to the Antarctic.** *Jobs related to the Antarctic* = Those positions that are substantially involved with Antarctic-related activities, including maintenance of vessels, provision of training, servicing of bases, and scientific research. *Substantially* = A significant proportion (i.e. more than a quarter) of the time of that position is devoted to Antarctic activities. *Percentage* = Calculated as a proportion of all jobs in the city. Unit of measure: Percentage Minimum value: 0 Maximum value: 5% Scale: Linear *Constraint* = This does not include those persons working in the tourist industry. This is because 2.2 below is effectively a measure of tourism and we do not want to double-count.

			2.2. The level of income for the city from Antarctic-related activities (adjusted for sustainability by measuring over time).
			
			Level = Percentage calculated as a proportion of the overall annual income of the city—i.e., gross metropolitan product (the value of all final goods and services produced within a metropolitan statistical area during a year, measured in relation to an average over the last five years).
			
			Constraint = This figure includes the following economic activities:
			
			    1. Visitors coming to the city primarily for Antarctic-related activities such as festivals or heritage visits, or for travelling to the Antarctic.
			
			Unit of measure: No. of visitors
			Minimum value: 0
			Maximum value: 2.0 x city's population
			Scale: Linear
			
			    2. Goods and services provided by businesses in the city for Antarctic-related engagement.
			
			Unit of measure: GMPpc in USD PPP
			Minimum value: 0
			Maximum value: 10,000
			Scale: Log-linear

Politics

Politics is defined as the practices, discourses, and material expressions associated with basic issues of social power, such as organization, authorization, and legitimation.	How important is the Antarctic to the political life of the city?	3. The level of political engagement with the Antarctic region managed through the city.	**3.1. The number and size of national Antarctic programs that operate through the city.** *Weighting* = One unit for each of the nation-states that operate national programs in Antarctica, including the country in which the city is located, divided by the relative size of the program measured by numbers of scientists, logistical personal and administrators:[7]

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7 Details of weighting of each national program will be provided on a scale of 1 to 9. This includes all 30 national Antarctic programs.

			Operate through the city = That is, either used as a gateway for travelling to Antarctica or used as the home-base for administering the national Antarctic program. Unit of measure 1 = number and size of Antarctic programs Unit of measure 2 = total employees employed by the city or its national government in the city/city-population Minimum value: 0 Maximum value: 0.2 Scale: Linear
			3.2. The proportion of national government budget allocated to employing staff supporting Antarctic-related programs in the city. *Government* = national or federal-level government. *Proportion* = percentage of total government budget devoted to the Antarctic that is allocated to employment in the city to run programs in that city or through that city into Antarctica. Unit of measure = percentage of government budget allocated to Antarctic programs Minimum value: 0 Maximum value: 1 per cent[8] Scale: Linear

Culture

Culture is defined as the practices, discourses, and material expressions, which, over time, express continuities and discontinuities of social meaning	To what extent is the Antarctic embedded in the cultural life of the city?	4. The level of cultural engagement with the Antarctic, manifest in the life of the city.	**4.1. The number of public memorials and heritage sites in the city that relate to the Antarctic.** *Site* = a building or place marked by a plaque or other public signifier of connection to the Antarctic. *Constraint* = This number only includes sites that are named as related to Antarctica and are listed in an official or unofficial city register. A site cannot be counted twice: for example, a statue of an Antarctic explorer immediately outside an Antarctic-related building cannot be counted as well as the building; a monument cannot be counted as well as the park that it is in. Unit of measure: Number of sites per capita (000's) Minimum value: 0 Maximum value: 19 Scale: Linear
			4.2 The intensity of Antarctic-related cultural events, exhibitions and archives held in the city. Events = discrete activities such as exhibitions, plays, readings, receptions, etc. Hence, a festival can include a series of events, but a designated series of performances of the same play is one event. Intensity = Measured as a proportion of the total of cultural events in the city *per capita.* Unit of measure: Number of events per capita (000's) Minimum value: 0 Maximum value: 110 Scale: Linear

8 This figure of 1 per cent is only nominal at this stage, but reflects the view that while funding connections to Antarctica is very important, it should only be a small proportion of the overall funding for ecological, economic, political and cultural flourishing in the city and beyond.

9 It is certainly possible to have more than 1,000 sites associated with the Antarctic in a 100,000-person town, particularly one with a long history of association with the region, but this was considered to be of a sufficient order to recognize the depth of association without the city becoming turned over to memorializing one place of connection.

10 As expressed in the previous footnote, Footnote 6, an ever-expanding number is not always better.

Calculating the Antarctic Connectivity Index

The Antarctic Connectivity Index is compiled from the variables described above. First, four domain-level indices are calculated. Individual variable data are tempered against lower and upper bounds, referred to as 'Minimum value' and 'Maximum value' in Table 1 above.[11] In most cases, variable values are assumed to be uniformly or normally distributed between the bounds, and consequently linear scales are assumed as the simplified default. Variables such as income are known to be positively skewed (Mincer 1958), and logarithmic reduction can produce more meaningful bases for comparing these variables.

Once individual data values are adjusted and optionally rescaled, they are averaged to produce a domain-level score. This score is further scaled to a nine-point scale, to be plotted against the Circles diagram. Four indices are produced, one for each of the domains.

Following the Human Development Index, the overall connectivity index is then derived from the geometric mean of the individual domain-level connectivity scores.[12] The justification for the geometric over the simpler arithmetic means is that extreme low values ought to be interpreted as more consequential than extreme highs; the geometric mean of the numbers [1, 5, 9] is, for example, lower than the mean of numbers [5, 5, 5]. For the purpose of the Connectivity Index, where high scores ought to be interpreted uniformly as preferable to lower scores, this has the effect of weighting the combined connectivity scores downward where low outliers exist. Use of the geometric mean ensures low connectivity on one domain cannot entirely be compensated for or substituted by high connectivity in another.

We use only the domain-level indicators in this calculation of the index. The more detailed subdomain indicators would be compiled and used to calculate domain and overall connectivity index values in the same way, with at least seven rather than two or three variables to represent each domain.

Showing How the General Equations Work

Equation 0.1 adjusts a raw data value against relevant lower and upper bounds.

Equation 0.1: $\text{Adjusted X} = \dfrac{X - LowerBound}{UpperBound - LowerBound}$

Equation 0.2 normalizes a value for a city's population, for cross-sectional comparison with other cities. 'X' is the value to be normalised; 'W' is a scaling factor to produce a meaningful value in the range [0, 1]; 'City Pop.' is the city's population; 'Base GMP' is the standard chosen for Gross Metropolitan Product (sometimes measured as 'Gross Regional Product'); 'City GMP' is this city's GMP, which may be above or below the Base GMP, and will adjust the per capita figures accordingly; 'Base CPI' and 'City CPI' are equivalent values for Consumer Price Index. While per capita figures will often be relevant to city-to-city comparison, GDP and CPI may be less so. In particular, compound CPI will be more relevant to longitudinal measures for a given city over time.[13] For cases where these additional normalization factors are not relevant, values of 1 can be passed to both 'Base' and 'City' values.

Equation 0.2: $\text{Normalized X} = \dfrac{W * X}{City\ Pop.} * \dfrac{Base\ GMP}{City\ GMP} * \dfrac{Base\ CPI}{City\ CPI}$

Equation 0.3 scales a value between 0 and 1 to another value between 1 and 9. The scaled value can be interpreted qualitatively, from "Vibrant" to "Critical", and displayed on the Circles diagram accordingly.

*Equation 0.3: Scaled X = X * 8 + 1*

Ecological Domain of the Connectivity Index

Equation 1.1: $Material\ Support = \dfrac{\left(\left(\frac{Material\ Support\ \% - 0}{10 - 0}\right) + \left(\frac{Material\ Flows - 0}{20 - 0}\right)\right)}{2}$

Equation 1.2: $Monitoring\ Levels = \dfrac{\left(\left(\frac{\ln(\#\ of\ Variables - 0)}{10 - 0}\right) + \left(\frac{\#\ of\ Monitoring\ Initiatives - 0}{20 - 0}\right)\right)}{2}$

Equation 1.3: $Ecological\ Connectivity\ Index\ (ELCI) = Scaled\left(\dfrac{Material\ Support + Monitoring\ Levels}{2}\right)$

Economic Domain of the Connectivity Index

Equation 2.1: $People\ in\ Antarctic\ Jobs = \dfrac{Percentage\ of\ Antarctic\ Jobs - 0}{10 - 0}$

Equation 2.2: $Income\ Levels = \dfrac{\left(\left(\frac{\#\ of\ Tourists - 0}{0.1\ x\ City\ Pop. - 0}\right) + \left(\frac{\ln(GDPpc - 0)}{\ln(10000 - 0)}\right)\right)}{2}$

Equation 2.3: $Economic\ Connectivity\ Index\ (ENCI) = Scaled\left(\dfrac{People\ in\ Antarctic\ Jobs + Income\ Levels}{2}\right)$

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11 These bounds are very rough estimates currently, and will need to be determined empirical for the final set of variables.

12 http://hdr.undp.org/en/content/why-geometric-mean-used-hdi-rather-arithmetic-mean

13 The approach to normalization, based on population, GDP and CPI, is well developed in the literature, and discussed by Pielke *et al.* (2008), Barthel & Neumayer (2012), and in an Australian context, Ladds *et al.* (2017).

Political Domain of the Connectivity Index

Equation 3.1: $Antarctic\ Program\ Size = \dfrac{\left(\frac{\#\ of\ Program\ Staff}{0.005\ *\ City\ Pop.}\right)}{0.2}$

Equation 3.2: $National\ Govt.Budget = \dfrac{\%\ of\ budget\ on\ Antarctic}{20}$

Equation 3.3: $Political\ Connectivity\ Index\ (PCI) = Scaled\left(\dfrac{Antarctic\ Program\ Size\ +\ National\ Govt.Budget}{2}\right)$

Cultural Domain of the Connectivity Index

Equation 4.1: $Number\ of\ Sites = \dfrac{\left(\frac{\#\ of\ Sites}{0.2\ *\ City\ Pop.(000's)}\right)}{1.0}$

Equation 4.2: $Number\ of\ Events = \dfrac{\left(\frac{\#\ of\ Events}{0.2\ *\ City\ Pop.(000's)}\right)}{1.0}$

Equation 4.3: $Cultural\ Connectivity\ Index\ (CCI) = Scaled\left(\dfrac{Number\ of\ Sites\ +\ Number\ of\ Events}{2}\right)$

Accordingly, the calculation of the Antarctic Connectivity Index is:

Equation 5.1: $Antarctic\ Connectivity\ Index\ (ACI) = \sqrt[4]{ELCI \times ENCI \times PCI \times CCI}$

Example Using the City of Hobart

We use the City of Hobart as an example here to show how the index might be populated. Most of the data values are made up to show the derivation of the index rather than being taken from actual statistics.

Population:	225,000[14]
GDP:	6,193[15]
Material Support %:	0.9
Material Flows:	12
# of Variables:	132
# of Monitoring Initiatives:	5
Percentage of Antarctic Jobs:	8.1[16]
# of Tourists:	6,434
GDP per capita, Antarctic-related:	$2,300
% of budget on Antarctic:	3.1
% of Events:	47

Using the equations above and these fictitious values produces the following index values:

Ecological Connectivity Index (ELCI) = 4.16 ("Unsatisfactory")

Economic Connectivity Index (ENCI) = 5.25 ("Basic")

Political Connectivity Index (PCI) = 2.2 ("Bad")

Cultural Connectivity Index (CCI) = 8.38 ("Good")

Antarctic Connectivity Index (ACI) = 4.47 = ~5 ("Unsatisfactory")

In this partly made-up example, the overall Antarctic Connectivity Index scores 'Unsatisfactory' despite the presence of a very high score on the Cultural Connectivity Index. This is the effect of the geometric mean calculation, which is weighed down more by the poor Political Connectivity Index score.

14 https://en.wikipedia.org/wiki/Hobart

15 https://economic-indicators.id.com.au/?StateId=6

16 https://www.hobartcity.com.au/Business/Doing-business-in-Hobart/Key-industry-sectors
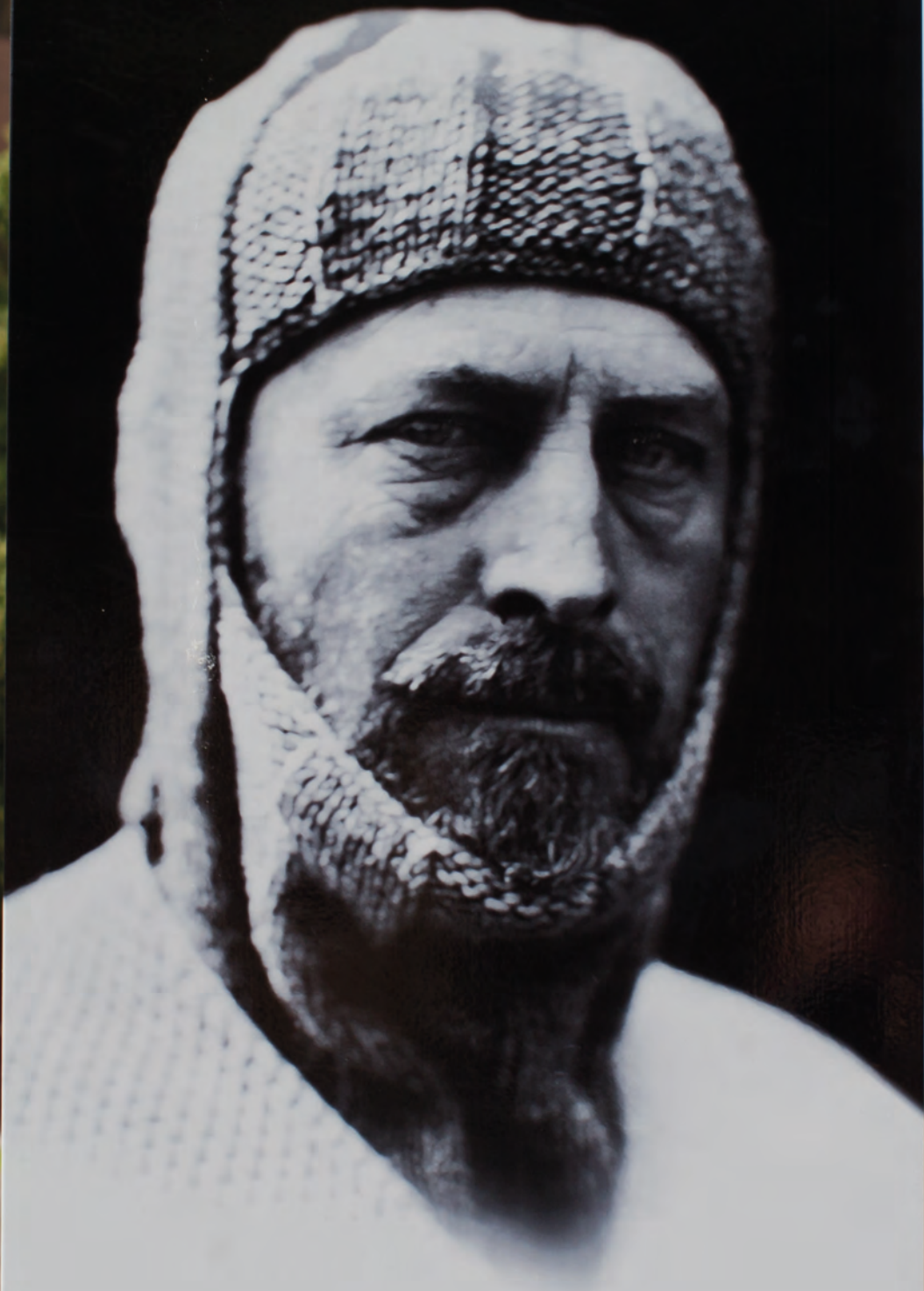
SIR DOUGLAS MAWSON

Hobart, Douglas Mawson board near the replica Mawson hut.

Developing a More Comprehensive Qualitative Index

Developing a qualitative-based index is a very different task. Although the qualitative index can be tested in terms of, and should be annotated through, the use of metrics, the qualitative index as developed below (see Table 2) is intended to be based on dialogue and debate between experts who then use a parallel 9-point scale as used for the Urban Sustainability Profiles (see Volume 2 of the present report). This time, the scale is one of intensity (all on the positive axis) rather than a positive-negative range from 'vibrant' to 'critical'.

Figure 1. Scale of Intensity of Connectivity

1	2	3	4	5	6	7	8	9
Not all all	Faint	Very Low	Low	Moderate	High	Very High	Momentous	Exceptional

Based on this scale and in response to the indicators and variables as laid out in Table 2, we have done a rapid assessment of the level of connectivity of the City of Hobart. This thought-experiment produced the graphic Figure 2. In making this illustrative assessment we were concerned to set the levels comparatively using the five current gateway cities as benchmarks in relation to other major cities across the globe as points of reference.

Hobart's highest score of '9: Exceptional' is based on the city's contribution to enquiry and learning about Antarctica. It has the most complete knowledge infrastructure of any gateway city, hosting the largest critical mass of Antarctic scientists and scholars anywhere in the world with world-class research and education institutions. This is the result of a decision made in 1981 to move the Australian Antarctic Program to Hobart from Canberra, which in hindsight marked an economic and cultural turning point for both the city and the state of Tasmania.

Politically, for example, Hobart is the stage for international discussions about the management of the Southern Ocean thanks to the annual meeting of the Commission for the Conservation of Antarctic Marine Living Resources (CCAMLR) which is held in the city each October. CCAMLR meetings have also become a focal point for political attention from environmental activist groups.

In relation to economics, the scores are based on the way in which the Antarctic sector provides significant employment and economic benefits to the city (as of 2017, over 750 people employed directly, and around 430 indirectly (State of Tasmania, 2017: 3). The Tasmanian Polar Network, a co-ordinated group of business, scientific, educational and government representatives, was established in 1999 to foster commercial and scientific activity in relation to the Antarctic sector. Hobart's southern connections are also political (the city hosts two secretariats who support and administer legal instruments within the Antarctic Treaty System); cultural (Hobart holds a biennial Antarctic festival, as well as permanent museum exhibits and archival holdings); and research-based (with numerous Antarctic researchers located in the Institute of Marine and Antarctic Studies and other parts of the University of Tasmania, as well as the Commonwealth Scientific and Industrial Research Organization [CSIRO] and the AAD).

Figure 2. A Connectivity Profile of the City of Hobart, 2021.

ECONOMICS
Production & Resourcing
Exchange & Transfer
Accounting & Regulation
Consumption & Use
Labour & Welfare
Technology & Infrastructure
Wealth & Distribution

ECOLOGY
Materials & Energy
Water & Air
Flora & Fauna
Habitat & Settlements
Built-form & Mobility
Embodiment & Sustenance
Emission & Waste
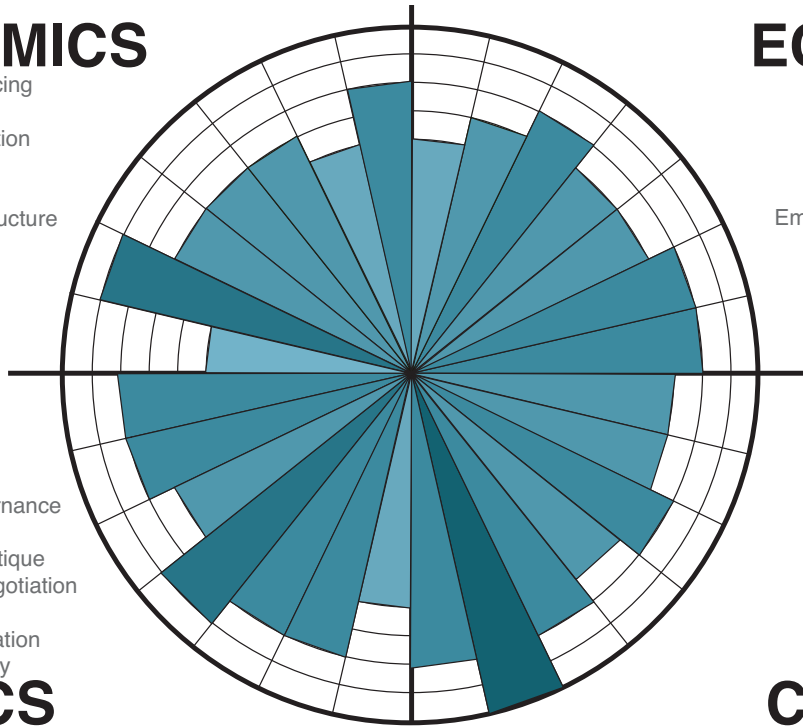
POLITICS
Organization & Governance
Law & Justice
Communication & Critique
Representation & Negotiation
Security & Accord
Dialogue & Reconciliation
Ethics & Accountability

CULTURE
Identity & Engagement
Creativity & Recreation
Memory & Projection
Belief & Meaning
Gender & Generations
Enquiry & Learning
Wellbeing & Health

Exceptional
Momentous
Very High
High
Moderate
Low
Very Low
Faint
Not at All
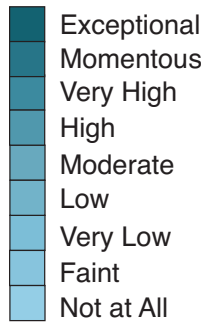
CIRCLES OF SOCIAL LIFE

All in all, this makes Hobart one the most Antarctic-connected cities in the world.

Table 2. Subdomain-level Questions and Indicators

Ecology

To what extent do the city's connections with the Antarctic enhance the ecological flourishing of the whole Antarctic region?

The ecological domain is defined as the practices, discourses, and material expressions that occur across the intersection between the social and the natural realms, focusing on the important dimension of human engagement with and within nature, ranging from the built-environment to the wilderness.

Subdomains	Questions	Indicators	Rationale for the Selection of the Indicators	Variables for using in the annotations explaining the connectivity score
1. Materials & Energy	To what extent does the city contribute to providing materials and energy necessary for sustainable engagement in the Antarctic and Sub-Antarctic?	The amount of renewably generated energy provided for Antarctica by infrastructure provided and/ or serviced by technicians travelling from or through the city.	National Antarctic Programs seek to harness natural energies to fuel their Antarctic research stations and bases therefore reducing dependency on fossil fuels. Implementation of alternative energy systems provides a positive connection by reducing (i) emission of greenhouse gases; (ii) risks of oil spills; (iii) costs of power generation; and increase efficiency of research station operations.	(Calculated in *mega joules*)
2. Water & Air	How much does the city contribute to monitoring and modelling the sustainability of the Antarctic and the Southern Ocean?	The level of monitoring and modelling of climate change and weather patterns in the Antarctic and the Southern Ocean. (NB. See Variable 1.2 for the quantitative index in domain of ecology.)	Monitoring the weather patterns of the Antarctic is of immense strategic importance to inform policy on global climate change. It represents a major aspect of the ecological connectivity between cities and the Antarctic. The Southern Ocean stores more anthropogenic heat and carbon dioxide than any other latitude band on Earth; therefore, it plays a key role in slowing the rate of climate change. The Southern Ocean is also home to a unique network of ocean currents—including the Antarctic Circumpolar Current—which transfer heat and carbon dioxide from the planet's surface to the ocean depths (Australian Strategic Policy Institute, 2015). Recent studies have shown that the Southern Ocean is warming to a greater depth and at a faster rate than the global ocean average. The chemical composition of this body of water is also rapidly changing (higher acidity levels; lower oxygen and salinity levels). In the face of	*Level* = Calculated by the number of variables monitored and modelled by scientists travelling to the Southern Ocean and the Antarctic. *Constraint* = This only includes monitoring and modelling programs run through the city.

			these changes, the capacity of the Southern Ocean to continue to slow down the rate of climate change is unknown (Antarctic Climate & Ecosystems Cooperative Research Centre, n.d.). Monitoring the Antarctic and the Southern Ocean's weather patterns is therefore crucial to predict and mitigate climate change effects.	
3. Flora & Fauna	To what extent do migratory birds, fish, seals, and whales that spend time in Antarctica or the Southern Ocean move regularly through the region associated with the city?	The extent to which migratory birds, fish, seals and whales, move between Antarctica and the region in question.	Engagement with the flora and fauna that traverse the Antarctic and Sub-Antarctic is an important aspect of ecological connectivity. One of the key issues concerned choosing the indicative species for measuring the connection. The choice involved balancing global and regional movement. We also considered the geographical spread of species of flora and fauna that have their main home in the Southern Ocean around Antarctica, including paleo-flora (in relation the shifting plates of Gondwana) such as the Southern Fulmar (South America, South Africa, Australia, New Zealand), the soft tree fern (Dicksonia *antarctica*) (Australia), the Antarctic hair grass (Deschampsia *antarctica*) (South America). However, it was difficult to find a list that was relevant globally and regionally. Secondly, this variable was considered a legacy of past connectivity rather than contemporary and active engagement. Flora and Fauna dispersal is also critical in the sub-Antarctic where thousands of kilometres of open ocean separate small landmasses. Several key dispersal mechanisms operate in the region including wind, ocean currents, transport with mobile animals (zoochory) and humans (anthropogenic transport) (Moon et al 2017). These mechanisms are being altered by changing environmental conditions and human activity.	This could, for example, be annotated using the following species: 1. Antarctic Tern (global— to the Arctic) 2. Wandering Albatross (southern global) 3. Antipodean Albatross *Diomedea antipodensis* (southern hemisphere) 4. Short–Tailed Shearwater or Mutton Bird, *Puffinus tenuirostris* (Australia, Pacific to the Bering Strait 5. Sooty Shearwater *Ardenna grisea* (Southern Ocean as well as Atlantic and Pacific Oceans) 6. Blue Petrel Halobaena caerulea (southern hemisphere) 7. Southern Right whale (southern global) 8. South Polar Skua *Catharacta maccormicki* (from Australia to Greenland and the Aleutian Islands) 9. Kelp Gull, Larus *dominicanus* (sub-Antarctic to subtropical southern hemisphere) With one point (out of nine points) allocated for each of the nine species.

4. Habitat & Settlements	To what extent does the city contribute positively to supporting the ecological sustainability of settlements in Antarctica?	The level of material support for the biosecurity of the Antarctic. (NB. Variable 1.1 for the domain.)	Control of invasive species into the Antarctic is an important part of maintaining the ecological sustainability of the continent. Part of this indicator includes the level of investment through the city in programs to manage invasive species in the Antarctic. See for example, ANTNZ Biosecurity and non-native species policy: https://www.antarcticanz.govt.nz/assets/Uploads/2013-Corporate-Policy-ENVIR-02-Biosecurity.pdf	*Material support* = Percentage calculated as a proportion of the overall annual budget of national/federal and local government authorities spent on biosecurity programs in managing material flows in and out of Antarctica. *Managing material flows* = 1. border control on goods; 2. waste-management and pollution-control programs in Antarctica; and 3. surveillance and interception programs of illegal fishing in the Southern Ocean. *Constraint* = Programs run through the city.
5. Built-Form & Mobility	To what extent does the city support transport connectivity to the Antarctic?	The number of ships and flights a year travelling to Antarctica from the city or passing through the city (not including those carrying tourists as their predominant passengers).	Cities and National Antarctic programs based in these cities provide transport and logistics in support of scientific research, Antarctic field operations, and search and rescue operations.	*Measurement* = A simple counting of numbers of 1. ships; and 2. flights that land in Antarctica *Constraint* = not including those carrying tourists as their predominant passengers. The issue here is, firstly, that tourists do not contribute significantly or directly to the ecological flourishing of the Antarctic. In fact, there might be an optimal upper level of tourist visitations after which the sustainability measure and therefore positive connectedness goes dramatically down. Secondly, tourism has been counted for its economic benefits (see below).
6. Embodiment & Sustenance	To what extent does the city support the sustainable movement of people to and from Antarctica?	The number of visitors to Antarctica and the average time that visitors spend on the continent, having departing from the city.	Because of the fragility of the continent, the embodied presence of visitors needs to be carefully monitored. Some visitors, such as scientific researchers and the support staff that make their time there viable contribute positively to the long-term ecological sustainability of the continent. However, at a certain point increasing the number of such individuals has a diminishing benefit.	*Measurement* = Number of persons (and person-days) spent in Antarctica *Constraint* = Not including tourists (because tourists do not add to the ecological sustainability of the continent and region). *Data source* = Customs. Scientific programs. The Australian Antarctic Data Centre, for example, contains info on the number of person-days in each station (no info about departure point)

7. Emission & Waste	To what extent does the city contribute to processing waste from Antarctic settlements?	The amount of waste from Antarctica treated in a sustainable way by the city.	Effective waste-management practices are vital to national efforts to protect the Antarctic environment. Waste handling of non-recyclable wastes are returned to countries for appropriate disposal via gateway cities.	*'Treated in a sustainable way'* = having a recycling and re-use program in a waste-management program. *Measurement* = tonnage in relation to the waste produced by the national program. This means that a city can score higher if they process the waste of other national programs.

Economics

How sustainable is engagement with the Antarctic to the economic prosperity of the city?

The economic domain is defined as the practices, discourses, and material expressions associated with the production, use, and management of resources.

Subdomains	Questions	Indicators	Rationale for the Selection of the Indicators	Variables
1. Production & Resources	How sustainable is engagement with the Antarctic for productive economic activity in the city?	The level of income for the city from Antarctic-related activities (not including tourism). (NB. Variable 2.2. See above.)	For some cities, the Antarctic sector is crucial in fostering an innovative economy that draws on a city's comparative advantages as a gateway to Antarctica and as a world leader in Antarctic and Southern Ocean scientific research. For others, Antarctica is irrelevant to their economy.	*Level* = Percentage calculated as a proportion of the overall annual income of the city—i.e., gross metropolitan product (the value of all final goods and services produced within a metropolitan statistical area during a year). *Constraint* = This figure includes the economic activities such as the goods and services provided by businesses in the city for Antarctic-related engagement, including scientific research activities and logistics. It does not include tourism, which is covered immediately below.
2. Exchange & Transfer	How economically vital to the city is the Antarctic tourist industry?	The level of income for the city from Antarctic tourism, both within the city, and travelling through the city to the Antarctic region.	Financial income to the city from tourists coming to the city for Antarctic-related activities is an important source of revenue for some cities. It is a form of connectivity which can be important for a city, and has the further consequence of facilitating global awareness of the continent.	*Tourist* = person travelling to Antarctica who uses the city as a point of departure, or comes to the city for an Antarctic event or experience.

3. Accounting & Regulation	How involved is the city in regulating activities directly concerned with Antarctic engagement?	The number of public officials in the city whose position descriptions include a role in regulating economic activities either occurring in the Antarctic or related to engagement with the Antarctic.	Antarctica-related tasks and positions are a crucial part of the regional public and policy-making work-scape.	The overall percentage of time by public officials in the city spent on Antarctic-related tasks (e.g., preparing the season opening logistically). Constraints = not including events that are primarily tourist-oriented.
4. Consumption & Use	To what extent do Antarctic-related events contribute to the economic sustainability of the city?	The financial value of Antarctic-related events in the city returned to the economy from visitors to the city *and* locals who attend these events.	Antarctic events can for some cities create financial revenue and benefits for the economy as well as enhance the capacity of human capital in the region through experiential education.	As above for the subdomain of 'exchange and transfer', this includes both tourists coming to the city on the way to Antarctica and those coming to the city as tourists for Antarctic related reasons, but it additionally includes the economic engagement of locals.
5. Labour & Welfare	How many people in the city are employed in jobs related to the Antarctic?	The percentage of people in the city employed in jobs related to the Antarctic. (NB. Variable 2.1. See above.)	Providing logistical support and conducting science forms a crucial part of the regional workscape.	*Jobs related to the Antarctic* = Those positions that are substantially involved with Antarctic-related activities, including maintenance of vessels, provision of training, servicing of bases, and scientific research, as well as public engagement and administration. *Substantially* = A significant proportion (i.e. more than a quarter) of the time of that position is devoted to Antarctic activities. *Percentage* = Calculated as a proportion of all jobs in the city. *Constraint* = This does not include those persons working in the tourist industry.

6. Technology & Infrastructure	How important is the city for providing technology and infrastructure to the Antarctic region?	The financial value of technology and infrastructure used in the Antarctic (expressed as USD–equivalent) that has been, invented, developed or manufactured in the city.	Technological and infrastructure investments related to Antarctic logistics are significant. Often, very specific containment facilities have to be provided for Antarctic samples; docking spaces have to be made available in ports to support Antarctic ship–based operations, and air–infrastructure and runways need to be maintain, all requiring significant investment by the city.	Percentage of the city's annual budget invested into Antarctic support infrastructure and technology.
7. Wealth & Distribution	To what extent is wealth generated by Antarctic–related activities used for the social good of all people in the city?	—The percentage of financial value accruing from Antarctic–related activities used for the social good of all people in the city as opposed to personal enrichment.	Wealth generated from Antarctica–related activities enriches public life in gateway city, creates work, contributes to a diverse and prosperous city.	The amount of money invested in the public infrastructure of the city as a proportion of the estimated financial value accruing from Antarctic–related activities.

Politics

How important is the Antarctic to the political engagement of the city?

Politics is defined as the practices, discourses, and material expressions associated with basic issues of social power, such as organization, authorization, and legitimation.

Subdomains	Questions	Indicators	Rationale for the Selection of the Indicators	Variables
1. Organization & Governance	How politically engaged is the city in governance issues relating to Antarctica?	The proportion of government budget allocated to employing staff supporting Antarctic–related programs in the city. (NB. Variable 3.2. See above.)	Different cities take a more or less active and engaged stance in shaping and influencing Antarctica's future. Time and money are being set aside for the participation in the governance of Antarctica and the Southern Ocean, e.g., through representatives from the city or organisations based in the city, at Antarctic Treaty Consultative Meetings or CCAMLR meetings.	*Government* = national or federal–level government. Proportion = percentage of total government budget devoted to employing Antarctic–related administrative staff in that city or through that city into Antarctica. This does not include scientists and technicians.)

2. Law & Justice	To what extent is the city engaged in issues of law and justice related to the Antarctic region?	The number of jurists, including lawyers, judges and legal scholars, working in the city, whose brief includes Antarctic–related issues.	Different cities have variable levels of interest and stake in Antarctic and Southern Ocean jurisprudence. Some cities offer forensic services where required, provide legal advice and support on Antarctic matters and educate young lawyers on Antarctic matters.	Number of times legal assistance is provided on Antarctic matters or the city is called upon to assist with forensic or legal investigations.
3. Communication & Critique	How prominent are Antarctic–related issues in the media of the city?	The number of political reports and opinion pieces in local newspapers per annum that refer to Antarctica and the Antarctic region.	Antarctica features variably in discussion via local media, but this is an important element of connectivity, informing different constituencies about developments occurring in the region.	(Calculated as a raw number.)
4. Representation & Negotiation	To what extent does your city act as a place for the negotiation or representation with other organizations and polities working in Antarctica?	The number of national Antarctic programs that are run through the city. (NB. Variable 3.1. See above)	Antarctica fosters important diplomatic, economic, and political connections on an international scale. Different cities are variably part of this process.	*Weighting* = One unit for each of the nation–states that run national programs in Antarctica, including the country in which the city is located, divided by the relative size of the program measured by numbers of scientists, logistical personal and administrators: details of weighting of each national program will be provided on a scale of 1 to 9. *Run through the city* = That is, the program either uses the city as a gateway for travelling to Antarctica or is located in the city as its home–base for administering the national Antarctic program. *Government* = national or federal–level government. *Proportion* = percentage of total government budget devoted to the Antarctic that is allocated to the city to run programs in that city.

5. Security & Accord	To what extent does the city contribute to questions of security that relate to the Antarctic?	The active involvement of the city in dealing with accidents, ships in distress, and alike, in the Southern Ocean.	The city plays an important role in making operations in Antarctica safe. It offers assists in search-and-rescue coordination and provides platforms and infrastructure towards SAR.	*Calculation* = 1. The number of SAR ('Search and Rescue') responses using the city's infrastructure (port, airport, ships, etc.); 2. The total budget spent annually in/by the city on SAR activities. 3. The number of fisheries enforcement responses using the city's port.
6. Dialogue & Reconciliation	To what extent does the city support or host dialogical forums that concern the Antarctic?	The number of forums held in the city or supported directly by the city concerning the Antarctic— including conferences, high-level meetings and workshops— which include the active participation of people from outside the city.	The city provides a crucial platform that supports critical discussion and engagement with issues concerning Antarctica.	(Calculated as a raw number, with the requirement that at least 10 per cent of those involved come from outside the city.)
7. Ethics & Accountability	How ethical are the city's transactions concerning the Antarctic?	The extent to which ethics approvals and accountability mechanisms are processed by agencies based in the city.	The city facilitates the transparency and clarity of the city's and its inhabitants' transactions with regard to the Antarctic. Mechanisms for accountability and ethical conduct (e.g. for research) are in place.	Calculated = 1. The number of ethics approvals processed by agencies based in the city 2. The number of Environmental Impact Assessments issued by agencies operating in the city.

Culture

To what extent is the Antarctic region positively embedded in the cultural life of the city?

Subdomain	Questions	Indicators	Rationale for the Selection of the Indicators	Variables
1. Identity & Engagement	To what extent does the city identify itself as connected to Antarctica?	The level of engagement Antarctic-related events held in the city. (NB. Variable 4.2. See above)	Events, when well-managed, engaged and participatory are considered positive for cultural flourishing. This indicator is intended to point to something different from similar indicators such as the number of organizations regularly involved in arts and cultural events related to the Antarctic. We also considered other indicators — the proportion of the city's population who are regularly involved in public cultural events related to the Antarctic either as a creator or consumer, but this was deemed too hard to measure in a consistent comparative way. — the number of organizations regularly involved in arts and cultural events related to the Antarctic.	*Events* = Defined as discrete activities such as exhibitions, plays, readings, receptions, etc. Hence, a festival can include a series of events, but a designated series of performances of the same play is one event. *Intensity* = Measured as a proportion of the total of cultural events in the city.
2. Creativity & Recreation	How much does the Antarctic figure in the creative expression of the city?	The number of creative works (including novels, plays, paintings, songs, music scores, etc.) written over the past 30 years by persons living the city that have the Antarctic as a setting for the content of the work.	Antarctica is an important element of the city's cultural and creative scene. Other possible indicators included the number of cultural and arts organizations in city that occasionally feature Antarctic themes in their work.	Number = a simple accounting exercise using six categories: 1. novels, 2. plays, 3. paintings, 4. plays, 5. songs, 6. music scores.[17] *Constraint 1* = a song and a music score with the same tune cannot be counted twice. *Constraint 2* = Paintings only include those hung in a public gallery or building and institutionally registered.
3. Memory & Projection	To what extent does the city remember and preserve the history of its relation to the Antarctic?	The number of public memorials and heritage sites in the city that relate to the Antarctic. (NB. Variable 4.1. See above.)	Antarctica-related (infrastructure?) plays an important part in the city's public representation, expression, and display. We also considered 'the extent of archives about the Antarctic held in the city' as an indicator in this subdomain. This is	*Site* = a building or place marked by a plaque or other public signifier of connection to the Antarctic. *Constraint* = This number only includes sites that are named as related to Antarctica and are listed on an official or unofficial city register. A site cannot be

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17 This, like all the variables, is a proposition only. It treats these arts forms as proxies for all art forms, but the art forms chosen could be changed.

			of the number of artefacts, the number of logical data records and the linear metres of written or printed records.	counted twice: for example, a statue of an Antarctic explorer immediately outside an Antarctic-related building cannot be counted as well as the building; a monument cannot be counted as well as the park that it is in.
4. Beliefs & Ideas	How important is the Antarctic in the everyday imagination of people in the city?	—The number of times that the words 'Antarctic', 'Antarctica', 'Antartica', or 'Antartida' appear in tweets sent from persons living in the city.	Antarctica features prominently in thought expressions and opinion exchanges of citizens.	Blogs, individual websites, social media, traditional media
5. Gender & Generations	To what extent are the youth of the city involved in cultural activities associated with Antarctica.	The number of children and youth participating in Antarctic related-activities such as science fairs, school events, and art competitions.	Having an Antarctic connection is crucial to youth and children getting involved in, and caring about, worldwide ecological and political issues, also related to Antarctica?	*Data source* = local education departments or authorities.
6. Enquiry & Learning	How active is the research being done in the city on Antarctica or directly related themes?	The number of applications for research funding on Antarctic related projects.	The Antarctic connection fosters an active and engaged scientific community based in the city.	Research funding given to institutions in the city for Antarctic research; Bibliometric data on Antarctic papers published by individuals based in the city.
7. Wellbeing & Health	To what extent does the city's connection to the Antarctic contribute to its citizen's sense of wellbeing?	The percentage of people in the city who agree with the statement, 'People in my city can influence the cultural meanings that shape our relationship to Antarctica.'	Engagement with Antarctica provides citizens with a sense of pride and influence. From the *Social Life* questionnaire, calculated as a percentage of total urban population responding to this question asked in a random survey.	

Liam Magee at an Antarctic Cities meeting,
Institute for Marine and Antarctic Studies.

Appendix 1. Notes for Researchers

Orientations

The Antarctic Connectivity Index (ACI) is a pioneering self-assessment tool designed to help gateway cities understand how they can enhance and improve connectivity with the Antarctic region. The aim of the ACI is to assist cities to accomplish their connectivity goals with Antarctica via four interrelated orientations:

- First, the Index is a tool that allows cities to produce baseline measurements of their current connectivity patterns with Antarctica, which should then be subsequently monitored and assessed over time.
- Second, the Index serves as a public platform upon which awareness raising exercises in relation to Antarctic sustainability can be launched.
- Third, the Index acts as portal among various government agencies, NGOS and the public, encouraging better communication, stronger networks and public engagement.
- Fourth, the Index serves as a means of awareness raising, allowing the gateway cities to promote public engagement and stewardship, and mobilize their citizenry in efforts to foster multiple ways of Antarctic connectivity and custodianship.

The index was built around a number of considerations that were crucial to its final form.

1. *The index is global in its scope, and measures the degree of connectivity that cities have to the Antarctic.*

   —*Antarctic*: The concept of *the Antarctic* refers to Antarctica and the Southern Ocean.

   —*Connectivity*: The concept of *connectivity* is intended to cover both objective and subjective connections, material and intangible connections.

   —*Global*: Here the term *global* denotes the spatial scope of the index. The index will be used in the first instance to showcase the degree and depth of connection of five 'gateway cities' (and what might become *custodial cities*) to Antarctica and the Antarctic region, but it has been developed so that any city across the globe can use the index to compare themselves in terms of that connectivity.

2. *The index measures the positive connectivity of cities to Antarctica.*

   In this case, we are taking positive connection to mean all connectivity *that expresses* or *enhances* the *flourishing* of the Antarctic as a zone of human engagement with other-species life and environmental phenomena (while at the same time shaping the sustainability of the cities). In turn, the concept of 'flourishing' refers to the *vitality, relationality, productivity, and sustainability*[18] of the human and non-human world, including the ecological systems of the Antarctic (see Appendix 1). The activities of cities across the world and the future of Antarctica are already entangled. We are trying to work out how this is positive. (See below on Page 6 for the *General Question* that we have chosen to represent this orientation.)

3. *The index is holistic and integrated.*

   Here 'holistic' means that we are treating connectivity very broadly across four domains of social life: ecological, economic, political and cultural. It also means that the relation between these different domains is made apparent in figuratively representing the degree of connectivity.

4. *The index is theoretically grounded.*

   The index is based upon the domain-structure of the *Circles of Sustainability* approach (see Appendix 2).[19] This approach provides a means of deciding upon issues that are systematically related, are comprehensive in their coverage, and can be readily understood. The approach works across four domains of social life—ecological, economic, political and cultural—each with seven subdomains. In each of these subdomains, a key question or questions will be asked that expresses a particular issue in relation to the many aspects of connectivity. These questions will in turn be linked to a set of possible indicators of how a city relates to the Antarctic.

5. *The index does not abstract the assessment into a single composite number representing the overall degree of connectivity.*

   The index is not being set up to derive a single hierarchical league table (though it will allow hierarchical lists by domain—ecological, economic, political and cultural. There are many reasons for this.

   - Firstly, league tables tend to distort relative relations.
   - Secondly, cities that are not at the top of league tables tend to have little interest in the comparisons, and those at the bottom resent the index without it making much difference to their policy.
   - Thirdly, because practices of connectivity are replete with countermanding and contradictory outcomes—for example, 'higher tourist numbers' is positive for economic engagement, but negative for ecological connectivity—we need to separate out domains that have systematic tendencies for such tension.

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18 These terms are themselves conceptually charged. See P. James, 'Creating Capacities for Human Flourishing: An Alternative Approach to Human Development', in Paola Spinozzi and Mazzanti Massimiliano, eds, *Cultures of Sustainability and Wellbeing*, Routledge, London, 2018.

19 The approach is based on P. James, with L. Magee, A. Scerri, and M.B. Steger, *Urban Sustainability in Theory and Practice: Circles of Sustainability*, Routledge, London, 2015; and L. Magee, *Interwoven Cities*, Palgrave McMillan, Basingstoke, 2016. See Appendix 2.)

6. *The index is constructed across two levels: the domain level and the subdomain level.*

The most general level of the index is based on choosing an (aggregate) indicator for each of the domains, one that acts as a proxy for the whole domain. The subdomain level of the index depends upon choosing an indicator or group of indicators for each subdomain.

7. The ACI uses an approach that comprises 4 Top-Level Indicators and 28 Sub-Level Indicators and is constructed with a nine-point scale describing different levels of connectivity:

    1. Not at all
    2. Faint
    3. Very low
    4. Low
    5. Moderate
    6. High
    7. Very high
   8. Momentous
    9. Exceptional

Practical Considerations

- It is important to choose indicators that are *already* readily availability, and are publicly accessible across at least the three core cities of the project, plus the gateway cities of Cape Town and Ushuaia. (*The core cities need to be willing to collect at least the domain-level data for this index on an annual basis into the future). The team behind the Antarctic Connectivity Index do not have the capacity to collect new connectivity data in a systematic and ongoing way without a partnership with the core cities.

- At the domain-level, each of the domains needs to have a minimum number of indicators that can act as a proxy for the domain. If the number of indicators is more than one, the indicators will be aggregated into a single figure. The basis of such as aggregation will be calculated on precise weightings between different indicators according to importance to give a single composite figure.

- At the subdomain level, each of the subdomains needs to have at least one question and one indicator, but it might need more questions and indicators to give a full coverage of the complexity of that subdomain. Ideally, if it is more than one it would exactly seven questions and seven potential indicators (organized at the sub-subdomain level) to cover different facets of connectivity.

- The questions and indicators in each domain and subdomain need to operate adequately as 'global' proxies for the issues covered by that domain or subdomain. That is, any chosen indicator needs to be applicable across different cities. For example, we would not choose a plant species such as Antarctic hair grass (Deschampsia *antarctica*) that only occurs in one continent as the basis for ascertaining connection by paleo-flora.

Appendix 2. Capacities for Human Flourishing

What capacities make for conditions of human flourishing? Posing this question suggests that if we can develop a working answer then we have the foundation for answering all those other more narrowly framed or precisely oriented questions such as what makes for good connectivity to Antarctica. Put the other way around, if we want to know the answers to practical and policy issues such as what makes for good connectivity or what makes for a liveable city, we need to go back to the basics concerning human flourishing in general. This move will not give us one-to-one or complete answers concerning what should be done—which in any case would partly depend upon differences in time and across place. But at least it will slow down the current tendency towards falsely connected fashion-statements about what constitutes good ways of doing things: 'more connectivity is good', 'good connectivity is smart', 'smart cities are better cities', 'better cities require fast connectivity', 'connectivity brings growth', and 'economic growth is the only way to increase the quality of life'. Figure 3 below shows how this works graphically based on a though experiment judging the global capacity for contributing to a flourishing world.

Figure 3. The Capacities for Human Flourishing
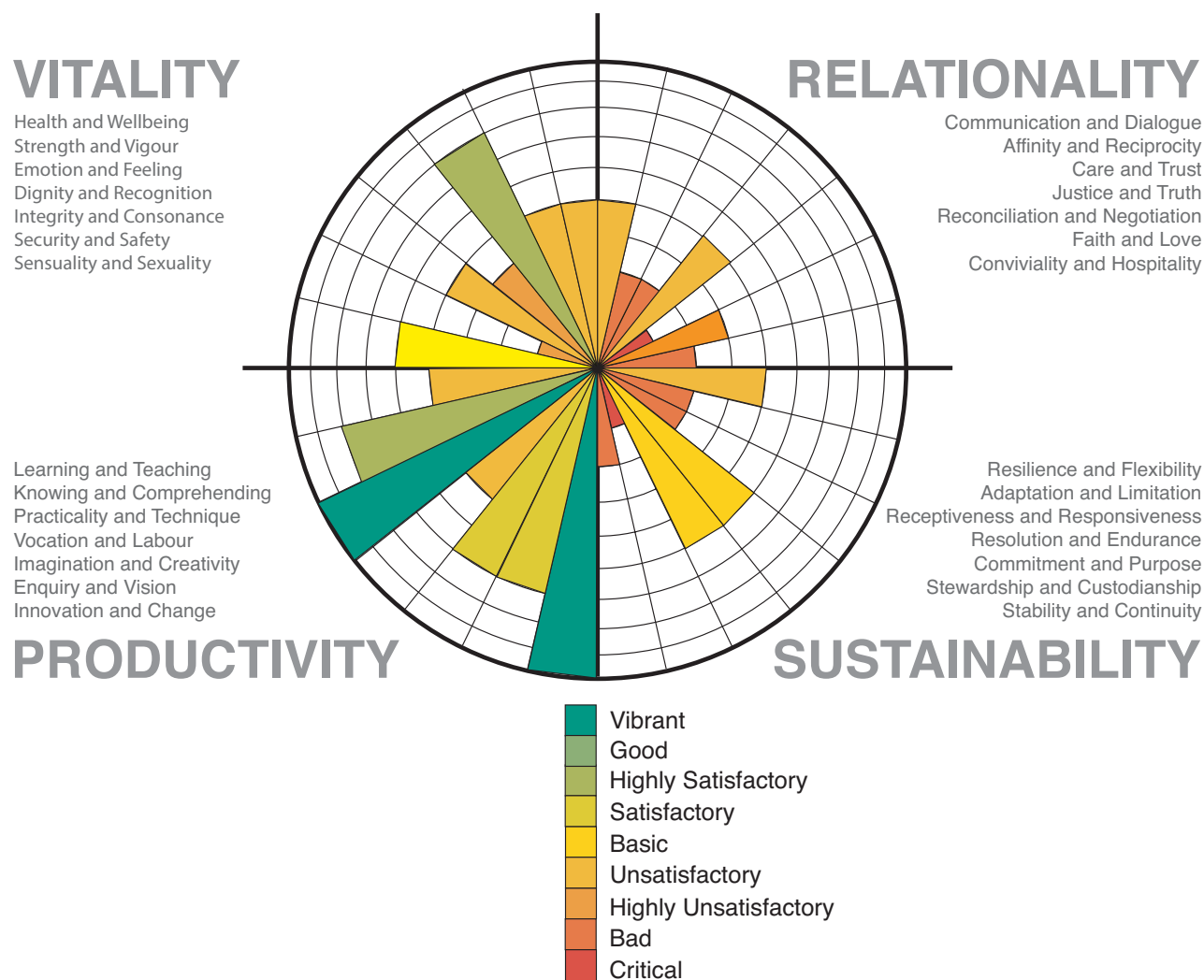
CIRCLES OF SOCIAL CAPACITIES

Appendix 3. Circles of Social Life Domain Structure

Figure 4. The Circles of Social Life

CIRCLES of SOCIAL LIFE
and beyond

ECONOMICS ECOLOGY NATURAL CULTURE POLITICS SOCIAL
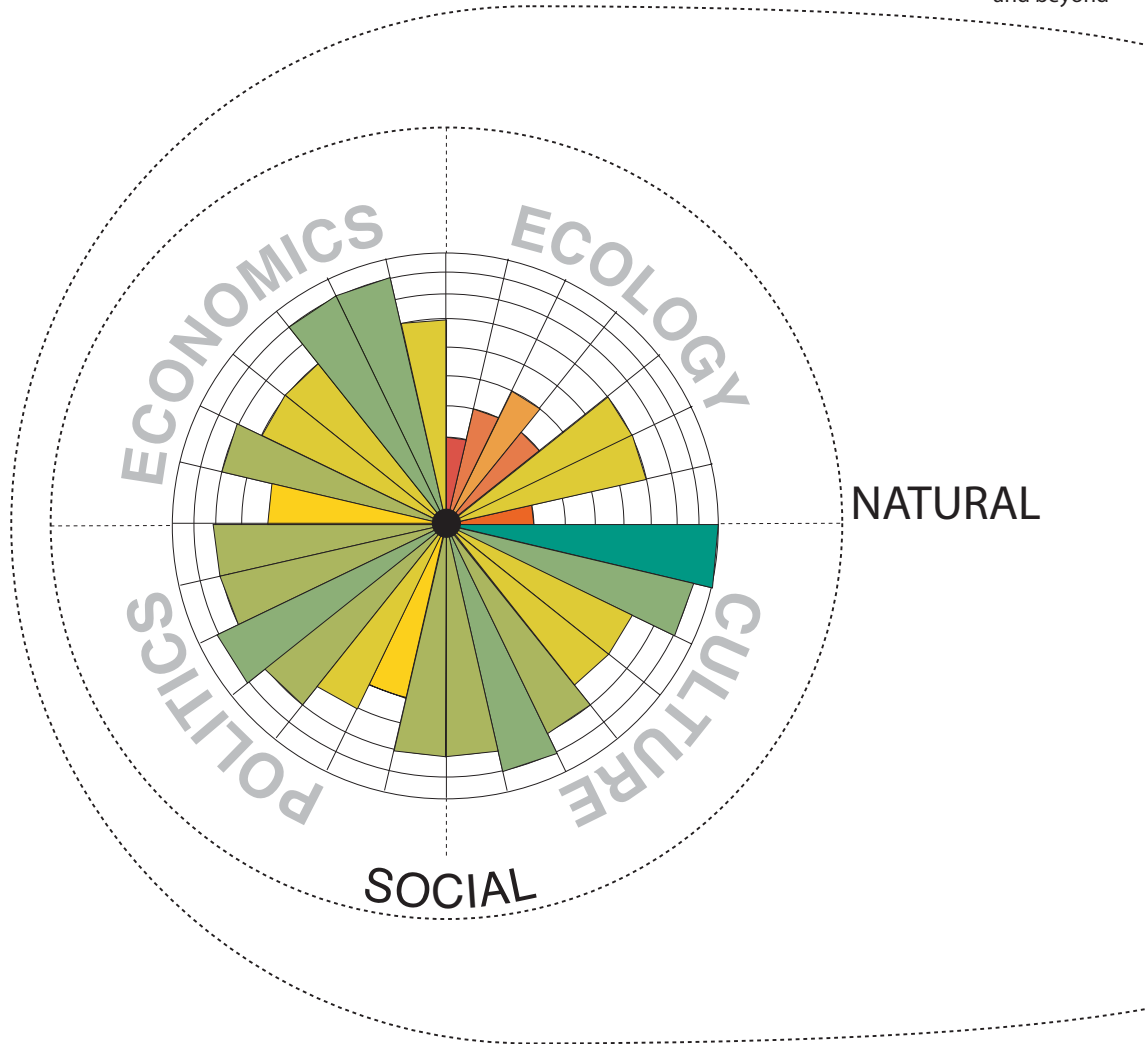
DOMAINS OF THE SOCIAL

ECONOMICS
Production & Resourcing
Exchange & Transfer
Accounting & Regulation
Consumption & Use
Labour & Welfare
Technology & Infrastructure
Wealth & Distribution

POLITICS
Organization & Governance
Law & Justice
Communication & Critique
Representation & Negotiation
Security & Accord
Dialogue & Reconciliation
Ethics & Accountability
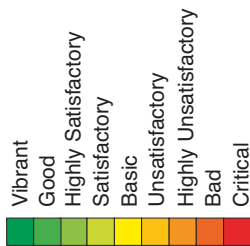
ECOLOGY
Materials & Energy
Water & Air
Flora & Fauna
Habitat & Settlements
Built-form & Transport
Embodiment & Sustenance
Emission & Waste

CULTURE
Identity & Engagement
Creativity & Recreation
Memory & Projection
Belief & Meaning
Gender & Generations
Enquiry & Learning
Wellbeing & Health

Legend (vertical): Vibrant · Good · Highly Satisfactory · Satisfactory · Basic · Unsatisfactory · Highly Unsatisfactory · Bad · Critical

Table 3 below elaborates on the domain structure of variables that sit behind the Antarctic Connectivity Index, as represented graphically in Figure 4. All of the these domains, perspectives (or subdomains) and aspects (or sub-subdomains) have careful definitions, though these have been left out in the interest of saving space.

Table 3. Summary of the Structure of the Urban Profile Process

Domains	Perspectives	Aspects
Ecology The ecological domain is defined as the practices, discourses, and material expressions that occur across the intersection between the social and the natural realms, focussing on the important dimension of human engagement with and within nature, ranging from the built-environment to the 'wilderness'.	1. Materials and Energy	1. Availability and Abundance
		2. Soil and Fertility
		3. Minerals and Metals
		4. Electricity and Gas
		5. Petroleum and Biofuels
		6. Renewables and Recyclables
		7. Monitoring and Reflection
	2. Water and Air	1. Vitality and Viability
		2. Water Quality and Potability
		3. Air Quality and Respiration
		4. Climate and Temperature
		5. Greenhouse Gases and Carbon
		6. Adaptation and Mitigation Processes
		7. Monitoring and Reflection
	3. Flora and Fauna	1. Complexity and Resilience
		2. Biodiversity and Ecosystem Diversity
		3. Plants and Insects
		4. Trees and Shrubs
		5. Wild Animals and Birds
		6. Domestic Animals and Species Relations
		7. Monitoring and Reflection
	4. Habitat and Settlements	1. Topography and Liveability
		2. Original Habitat and Native Vegetation
		3. Parklands and Reserves
		4. Land-use and Building
		5. Abode and Housing
		6. Maintenance and Retrofitting
		7. Monitoring and Reflection
	5. Built-Form and Mobility	1. Orientation and Spread
		2. Proximity and Access
		3. Mass Transit and Public Transport
		4. Motorized Transport and Roads
		5. Non-motorized Transport and Walking Paths
		6. Seaports and Airports
		7. Monitoring and Reflection
	6. Embodiment and Sustenance	1. Physical Health and Vitality
		2. Reproduction and Mortality
		3. Exercise and Fitness

		4. Hygiene and Diet
		5. Nutrition and Nourishment
		6. Agriculture and Husbandry
		7. Monitoring and Evaluation
	7. Emission and Waste	1. Pollution and Contamination
		2. Hard-waste and Rubbish
		3. Sewerage and Sanitation
		4. Drainage and Effluence
		5. Processing and Composting
		6. Recycling and Re-use
		7. Monitoring and Evaluation

Economics Defined as the practices, discourses, and material expressions associated with the production, use, and management of resources.	1. Production and Resourcing	1. Prosperity and Resilience
		2. Manufacture and Fabrication
		3. Extraction and Harvesting
		4. Art and Craft
		5. Design and Innovation
		6. Human and Physical Resources
		7. Monitoring and Reflection
	2. Exchange and Transfer	1. Reciprocity and Mutuality
		2. Goods and Services
		3. Finance and Taxes
		4. Trade and Tourism
		5. Aid and Remittances
		6. Debt and Liability
		7. Monitoring and Reflection
	3. Accounting and Regulation	1. Transparency and Fairness
		2. Finance and Money
		3. Goods and Services
		4. Land and Property
		5. Labour and Employment
		6. Taxes and Levies
		7. Monitoring and Reflection
	4. Consumption and Use	1. Appropriate Use and Re-use
		2. Food and Drink
		3. Goods and Services
		4. Water and Electricity
		5. Petroleum and Metals
		6. Promotion and Dissemination
		7. Monitoring and Reflection
	5. Labour and Welfare	1. Livelihoods and Work
		2. Connection and Vocation
		3. Participation and Equity
		4. Capacity and Productivity
		5. Health and Safety

		6. Care and Support
		7. Monitoring and Reflection
	6. Technology and Infrastructure	1. Appropriateness and Robustness
		2. Communications and Information
		3. Transport and Movement
		4. Construction and Building
		5. Education and Training
		6. Medicine and Health Treatment
		7. Monitoring and Reflection
	7. Wealth and Distribution	1. Accumulation and Mobilization
		2. Social Wealth and Heritage
		3. Wages and Income
		4. Housing and Subsistence
		5. Equity and Inclusion
		6. Re-distribution and Apportionment
		7. Monitoring and Reflection
Politics Defined as the practices, discourses, and material expressions associated with basic issues of social power, such as organization, authorization and, legitimation.	1. Organization and Governance	1. Legitimacy and Respect
		2. Leadership and Agency
		3. Planning and Vision
		4. Administration and Bureaucracy
		5. Authority and Sovereignty
		6. Transparency and Clarity
		7. Monitoring and Reflection
	2. Law and Justice	1. Rights and Rules
		2. Order and Civility
		3. Obligations and Responsibilities
		4. Impartiality and Equality
		5. Fairness and Prudence
		6. Judgement and Penalty
		7. Monitoring and Reflection
	3. Communication and Critique	1. Interchange and Expression
		2. News and Information
		3. Accessibility and Openness
		4. Opinion and Analysis
		5. Dissent and Protest
		6. Privacy and Respect
		7. Monitoring and Reflection
	4. Representation and Negotiation	1. Agency and Advocacy
		2. Participation and Inclusion
		3. Democracy and Liberty
		4. Access and Consultation
		5. Civility and Comity
		6. Contestation and Standing
		7. Monitoring and Reflection

	5. Security and Accord	1. Human Security and Defence
		2. Safety and Support
		3. Personal and Domestic Security
		4. Protection and Shelter
		5. Refuge and Sanctuary
		6. Insurance and Assurance
		7. Monitoring and Reflection
	6. Dialogue and Reconciliation	1. Process and Recognition
		2. Truth and Verity
		3. Mediation and Intercession
		4. Trust and Faith
		5. Remembrance and Redemption
		6. Reception and Hospitality
		7. Monitoring and Evaluation
	7. Ethics and Accountability	1. Principles and Protocols
		2. Obligation and Responsibility
		3. Integrity and Virtue
		4. Observance and Visibility
		5. Prescription and Contention
		6. Acquittal and Consequence
		7. Monitoring and Reflection

Culture Defined as the practices, discourses, and material expressions, which, over time, express continuities and discontinuities of social meaning.	1. Identity and Engagement	1. Diversity and Difference
		2. Belonging and Community
		3. Ethnicity and Language
		4. Religion and Faith
		5. Friendship and Affinity
		6. Home and Place
		7. Monitoring and Reflection
	2. Creativity and Recreation	1. Aesthetics and Design
		2. Performance and Representation
		3. Innovation and Adaptation
		4. Celebrations and Festivals
		5. Sport and Play
		6. Leisure and Relaxation
		7. Monitoring and Reflection
	3. Memory and Projection	1. Tradition and Authenticity
		2. Heritage and Inheritance
		3. History and Records
		4. Indigeneity and Custom
		5. Imagination and Hope
		6. Inspiration and Vision
		7. Monitoring and Reflection
	4. Beliefs and Ideas	1. Knowledge and Interpretation
		2. Ideologies and Imaginaries

		3. Reason and Rationalization
		4. Religiosity and Spirituality
		5. Rituals and Symbols
		6. Emotions and Passions
		7. Monitoring and Reflection
	5. Gender and Generations	1. Equality and Respect
		2. Sexuality and Desire
		3. Family and Kinship
		4. Birth and Babyhood
		5. Childhood and Youth
		6. Mortality and Care
		7. Monitoring and Reflection
	6. Enquiry and Learning	1. Curiosity and Discovery
		2. Deliberation and Debate
		3. Research and Application
		4. Teaching and Training
		5. Writing and Codification
		6. Meditation and Reflexivity
		7. Monitoring and Reflection
	7. Wellbeing and Health	1. Integrity and Autonomy
		2. Bodies and Corporeal Knowledge
		3. Mental Health and Pleasure
		4. Care and Comfort
		5. Inclusion and Participation
		6. Cuisine and Emotional Nourishment
		7. Monitoring and Reflection

Gabriella Rodan presenting in an
Antarctic Cities forum, Christchurch.

Appendix 4. Relationship to the Sustainable Development Goals

Table 4. Defining the Domains and Subdomains with Reference to the SDGs and their Targets

Ecology

The ecological domain is defined as the practices, discourses, and material expressions that occur across the intersection between the social and the natural realms, including the important dimension of human engagement with and within nature, ranging from the built-environment to the 'wilderness'.

Subdomains	Definition	Sustainable Development Goals —selected Targets
Materials & Energy	This subdomain comprises ecological issues pertaining to energy activation and materials extraction. In the first instance, materials and energy are the sources of life. That is why 'Materials and Energy' is the first subdomain.	7.2. By 2030, increase substantially the share of renewable energy in the global energy mix. 7.3. By 2030, double the global rate of improvement in energy efficiency.
Water & Air	This subdomain focuses on water and air, emphasizing the quality of the biosphere and the impact of human social life. It treats water and air as fundamental bases of the environment. This and the subdomain of 'Emission and Waste' are the areas most relevant to issues of climate change.	6.3. By 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials … 6.4. By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity …
Flora & Fauna	Here the subdomain considers the issue of particular biota in a given region with references to such questions as biodiversity, species equilibrium, species extinction, and so on. One of the crossovers to the next ecological subdomain of 'Habitat and Settlements' is of course that the quality of a habitat depends upon its complex biota.	15.2. By 2020, promote the implementation of sustainable management of all types of forests, halt deforestation, restore degraded forests and substantially increase afforestation … 15.8. By 2020, introduce measures to prevent the introduction and significantly reduce the impact of invasive alien species on land and water ecosystems and control or eradicate the priority species.
Habitat & Settlements	This subdomain considers the relationship between the ecological habitat and human settlement. The circle of life on this planet has become increasingly human-determined, hence the changing emphasis of this subdomain and those that follow on humans in the environment.	11.7. By 2030, provide universal access to safe, inclusive and accessible, green and public spaces … 15.5. Take urgent and significant action to reduce the degradation of natural habitats, halt the loss of biodiversity and, by 2020, protect and prevent the extinction of threatened species.
Built-Form & Mobility	This subdomain focuses on the impact of the built-environment and transport systems on natural ecosystems. Concerns here include spatial form, the nature of development and the basic ecology of housing people.	3.6. By 2020, halve the number of global deaths and injuries from road traffic accidents. 11.1. By 2030, ensure access for all to adequate, safe and affordable housing and basic services and upgrade slums.
Embodiment & Sustenance	This domain concerns the ecology of the human body—specifically physical health (emotional wellbeing is treated as having its primary orientation in the cultural domain). Sustenance refers to the physical sustenance, in particular the quality and accessibility of food and drink.	2.1. By 2030, end hunger and ensure access by all people … to safe, nutritious and sufficient food all year round. 3.2. By 2030, end preventable deaths of newborns and children under 5 years of age …

Emission & Waste	The critical issues here relate to the levels and impact of emissions—such as carbon, other gases, liquid waste, effluent, grey water—and 'solid' waste such as garbage and sewerage, etc.	12.4. By 2020, achieve the environmentally sound management of chemicals and all wastes throughout their life cycle, in accordance with agreed international frameworks … 12.5. By 2030, substantially reduce waste generation through prevention, reduction, recycling and reuse.

Economics

The economic domain is defined as the practices, discourses, and material expressions associated with the production, use, and management of resources.

Subdomains	Definitions	Sustainable Development Goals —selected Targets
Production & Resourcing	This subdomain covers economic issues such as resource-use and extraction, manufacturing, and fabrication, etc. Rather than assuming the dominance of any particular form of production, the focus potentially ranges from the practices of techno-scientific capitalism to those of hunting-and-gathering.	2.4. By 2030, ensure sustainable food production systems … 8.4. Improve progressively, through 2030, global resource efficiency in consumption and production and endeavour to decouple economic growth from environmental degradation …
Exchange & Transfer	This sub-domain potentially ranges from reciprocal exchange and barter to electronic finance capitalism. It considers the economic dimensions of such issues as transport, transfers of material goods, warehousing, and supply chains such as the 'food cycle', etc.	12.7. Promote public procurement practices that are sustainable, in accordance with national policies and priorities. 15.a. Mobilize and significantly increase financial resources from all sources to conserve and sustainably use biodiversity and ecosystems.
Accounting & Regulation	Accounting here includes the formal field of accounting but extends beyond it to take in all of questions of economic accountability. Similarly, regulation refers to more than modern rule-setting for conducting economic transactions. It also encompasses informal regimes that regulate economic practice.	10.5. Improve the regulation and monitoring of global financial markets and institutions and strengthen the implementation of such regulations. 12.6. Encourage companies, especially large and transnational companies, to adopt sustainable practices and to integrate sustainability information into their reporting cycle.
Consumption & Use	This category includes all issues of sustainability that relate to the end-use of material and immaterial goods. This ranges from the use of basic items for the sustenance of life including food consumption through to the consumption of services.	12.1 Implement the 10-Year Framework of Programmes on Sustainable Consumption and Production Patterns … 12.3 By 2030, halve per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains …
Labour & Welfare	The area of labour includes formal employment, but also informal employment in the reproduction of social life, contracting and unpaid work. It includes work in the home. Welfare is similarly defined in the broadest sense to include welfare situations that exist outside the modern welfare state. In other words, it is not presumed that all welfare comes from the state.	1.4 By 2030, ensure that all men and women, in particular the poor and the vulnerable, have equal rights to economic resources, as well as access to basic services, ownership and control over land and other forms of property … 8.5 By 2030, achieve full and productive employment and decent work for all women and men, including for young people and persons with disabilities, and equal pay for work of equal value.

Technology & Infrastructure	This subdomain refers to the wide range of basic economic issues of technological change from the effect of computerization to the techniques and technologies used to sustain the built environment, including economics questions of housing, commercial building, and state-directed infrastructure development such as roads and ports, etc.	9.1 Develop quality, reliable, sustainable and resilient infrastructure … to support economic development and human well-being, with a focus on affordable and equitable access for all. 9.a Facilitate sustainable and resilient infrastructure development in developing countries through enhanced financial, technological and technical support …
Wealth & Distribution	This subdomain relates to levels of wealth as distributed across a locale, as well as to questions relating to allocation and distribution of wealth, taking is issues as broad as taxation, education and healthcare budgets, etc.	1.2 By 2030, reduce at least by half the proportion of men, women and children of all ages living in poverty in all its dimensions according to national definitions. 10.1 By 2030, progressively achieve and sustain income growth of the bottom 40 per cent of the population at a rate higher than the national average.

Politics

Politics is defined as the practices, discourses, and material expressions associated with basic issues of social power, such as organization, authorization and, legitimation.

Subdomains	Definitions	Sustainable Development Goals —selected Targets
Organization & Governance	The domain of politics concerns the social relations of power. In this sense, this subdomain centres on how power is managed and governed. Relevant themes include the management of operational procedures, forms of administration and regulation, and the nature of public decision-making processes.	11.3 By 2030, enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management … 17.17 Encourage and promote effective public, public-private and civil society partnerships, building on the experience and resourcing strategies of partnerships.
Law & Justice	Here the emphasis is on the juridical-regulation of power rather than more procedural questions of 'Organization and Governance'. Key concepts include: human rights, civil legal processes, and obligation-based norms, etc.	5.1 End all forms of discrimination against all women and girls everywhere. 10.7 Facilitate orderly, safe, regular and responsible migration and mobility of people, including through the implementation of planned and well-managed migration policies.
Communication & Critique	The question of politics also pertains to the communication and dissemination of ideas, as well as to political movements that project these ideas. The kinds of issues that arise here include the availability of communications technology, mass-media concentration, and freedom of the press.	5.b Enhance the use of enabling technology, in particular information and communications technology, to promote the empowerment of women. 12.8 By 2030, ensure that people everywhere have the relevant information and awareness for sustainable development and lifestyles in harmony with nature.
Representation & Negotiation	This subdomain concerns the nature and extent of political representation for persons as either citizens of the state or members of public and private institutions. It thus includes the possibilities for negotiating outcomes and policies both in and through public and private institutions.	0.2 By 2030, empower and promote the social, economic and political inclusion of all, irrespective of age, sex, disability, race, ethnicity, origin, religion or economic or other status. 16.7 Ensure responsive, inclusive, participatory and representative decision-making at all levels.

Security & Accord	This subdomain ranges from the big negative things such as war, civil unrest, protest, and human insecurity to how secure individuals feel walking down the street or crossing the road. It ranges from local and personal senses of security to the ontological insecurities of our time—the sense of global risk incurred in living in a world of climate change, nuclear proliferation and global terrorism.	1.5 By 2030, build the resilience of the poor and those in vulnerable situations and reduce their exposure and vulnerability to climate-related extreme events and other economic, social and environmental shocks and disasters. 5.2 Eliminate all forms of violence against all women and girls in the public and private spheres, including trafficking and sexual and other types of exploitation.
Dialogue & Reconciliation	Linked closely to 'Law and Justice', and the other side of 'Conflict and Insecurity', this subdomain includes, firstly, the means of addressing issues of conflict resolution—for example, through deliberative and restorative justice—and, secondly, the possibilities of documenting, and registering the 'truth' of past conflicts.	NB. There are no SDG targets in this category
Ethics & Accountability	This subdomain includes major issues concerning the ethical basis of common dealings and the possibilities of corruption, both public and personal. It is concerned with the political practice of how codes of conduct are developed and enacted.	16.5 Substantially reduce corruption and bribery in all their forms. 16.6 Develop effective, accountable and transparent institutions at all levels.

Culture

Culture is defined as the practices, discourses, and material expressions, which, over time, express continuities and discontinuities of social meaning

Subdomains	Definitions	Sustainable Development Goals —selected Targets
Identity & Engagement	This subdomain concerns the quality and extent to which people engage with each other through public celebrations, rituals, and festivals, as well as across the boundaries of difference. It concerns social cohesion, cross-cultural engagement and the depth or complexity of meaning associated with that engagement.	NB. There are no SDG targets in this category.
Creativity & Recreation	'Creativity and Recreation' is concerned with issues that range from the level of creative participation in the arts, and the vibrancy of the 'cultural industries', to opportunities for leisure and recreation as positive responses to people, places, and things. This includes what is sometimes called the 'work/life balance'.	NB. There are no SDG targets in this category.
Memory & Projection	Meaning exists in the present both carried from the past into the present—as built-heritage, cosmologies, oral histories, creation stories and memories—and into the future as plans, projections, hopes and policies. This subdomain concerns all these issues of past and future.	NB. Whereas many SDGs have up to ten targets, there is only one SDG target in this category: 11.4 Strengthen efforts to protect and safeguard the world's cultural and natural heritage …

Beliefs & Ideas	All human societies generate different sites of meaning—from paintings and songs to places and institutions or practices of spirituality and religion, belief and faith. This subdomain deals with the depth and breadth of active cultural engagement with ideas.	NB. There are no targets in this category, although there is a substantial emphasis on knowledge and training. See below under 'Enquiry and Learning'.
Gender & Generations	Cultural issues of 'Gender and Generations' range across themes of cultural equality, reproductive relations, and inter-personal mutuality, including the strength of family and friendship relations, and intergenerational engagement.	NB. There are no targets that focus on the cultural considerations of gender or generations, however it should be noted that the categories of gender and childhood are singled out in many of the economic and political targets as important to the outcome of that target.
Enquiry & Learning	This subdomain concerns the vigour of institutions and processes of enquiry and learning. It not about how much money goes into supporting education, but rather focuses on broad questions of how much people want to learn across different stages of their lives and how vibrant is the culture of enquiry across all areas from science to the humanities.	4.1 By 2030, ensure that all girls and boys complete free, equitable and quality primary and secondary education leading to relevant and effective learning outcomes. 4.7 By 2030, ensure that all learners acquire the knowledge and skills needed to promote sustainable development, including, among others, through education for sustainable development and sustainable lifestyles, human rights, ...
Wellbeing & Health	The key theme covered by this subdomain is the facilitation and strength of cultural wellbeing. While the domain includes formal issues of mental health, it is not concerned with assessing the efficacy of the physical health and medical system.	NB. There are no targets in this cultural category of wellbeing. By comparison, even though there are no explicit targets that relate to wellbeing or mental health, there are many targets that are directed to physical or embodied health—see under 'Embodiment and Sustenance' above.

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