

# European Digital Social Innovation Index (EDSII)

Construction  
Methodology

June 2019



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## Consortium partners



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## About DSI4EU

Building on five years of work led by Nesta in collaboration with DG CONNECT, the Horizon 2020-funded DSI4EU project is supporting digital social innovation in Europe to grow and scale through a combination of research, policy and practical support.

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# 1. Executive summary

This executive summary provides a brief overview of the steps we took to compile the European Digital Social Innovation Index (EDSII).

## 1.1 Introduction

The European Digital Social Innovation Index (EDSII) contains composite indicators measuring how well the ecosystems of 60 cities in Europe support digital social innovation (DSI) — *“a type of social and collaborative innovation in which innovators, users and communities collaborate using digital technologies to co-create knowledge and solutions for a wide range of social needs and at a scale and speed that was unimaginable before the rise of the Internet.”*<sup>23</sup>

The aims of the index are five-fold:

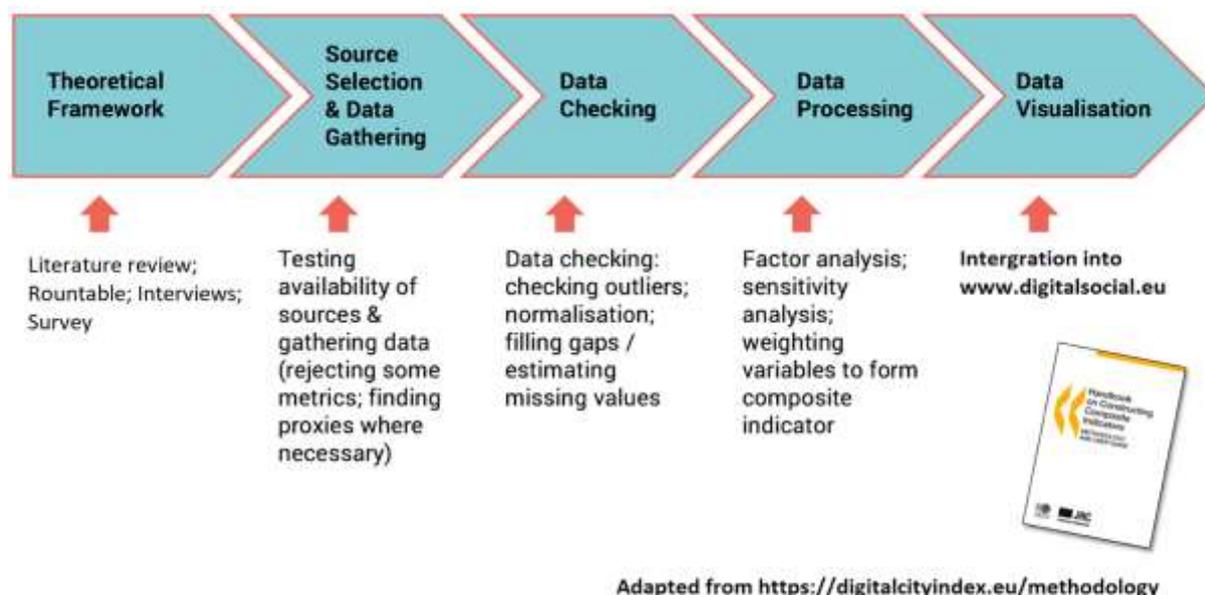
- 1)** Identify success factors for the creation, growth and sustainability of DSI.
- 2)** Help policymakers understand how they can better support DSI, drawing upon successful examples from other places.
- 3)** Incentivise the development and implementation of supportive policies.
- 4)** Inform practitioners about where in Europe has the best conditions for supporting DSI, which may influence where practitioners decide to set up or grow their initiatives.
- 5)** Raise awareness about, and interest in, DSI among people, communities and organisations not currently involved in the field.

The index includes 60 cities in total: 26 of the capital cities in the EU28 (Valletta and Luxembourg City were excluded due to unavailability of data) and an additional 34 non-capital cities chosen based on population size, known DSI activity, score on other indexes related to innovation, availability of data, and to ensure good representation across all of Europe.

## 1.2 Methodology

Below the steps used in the construction of the index. We have adhered to the ‘ideal sequence’ of steps detailed in the JRC/OECD Handbook on constructing composite indicators to guide our process, and these are illustrated (Figure 1) and described briefly below.

Figure 1. Flow diagram illustrating the ideal sequence steps for the construction of composite indicators as suggested by the JRC/OECD Handbook.



### 1.2.1 Theoretical Framework

The theoretical framework for the EDSII was built based on 11 semi-structured interviews and a roundtable event with experts from across Europe, combined with a review of existing academic literature, policy reports, and other related indexes. This research was distilled to give us a clear definition and understanding of the phenomenon we are measuring, ‘capacity to support DSI’, and used to identify 32 indicators for inclusion in the index and to structure these indicators into six dimensions or ‘themes’ (Figure 2).

From our research it was that clear that some indicators and themes are more important in measuring capacity to support DSI than others. To reflect this, indicators and themes were given different weights which were used in the later aggregation stage. Weightings were chosen based on a survey of 114 DSI experts, alongside internal workshops.

### 1.2.2 Source selection & data gathering

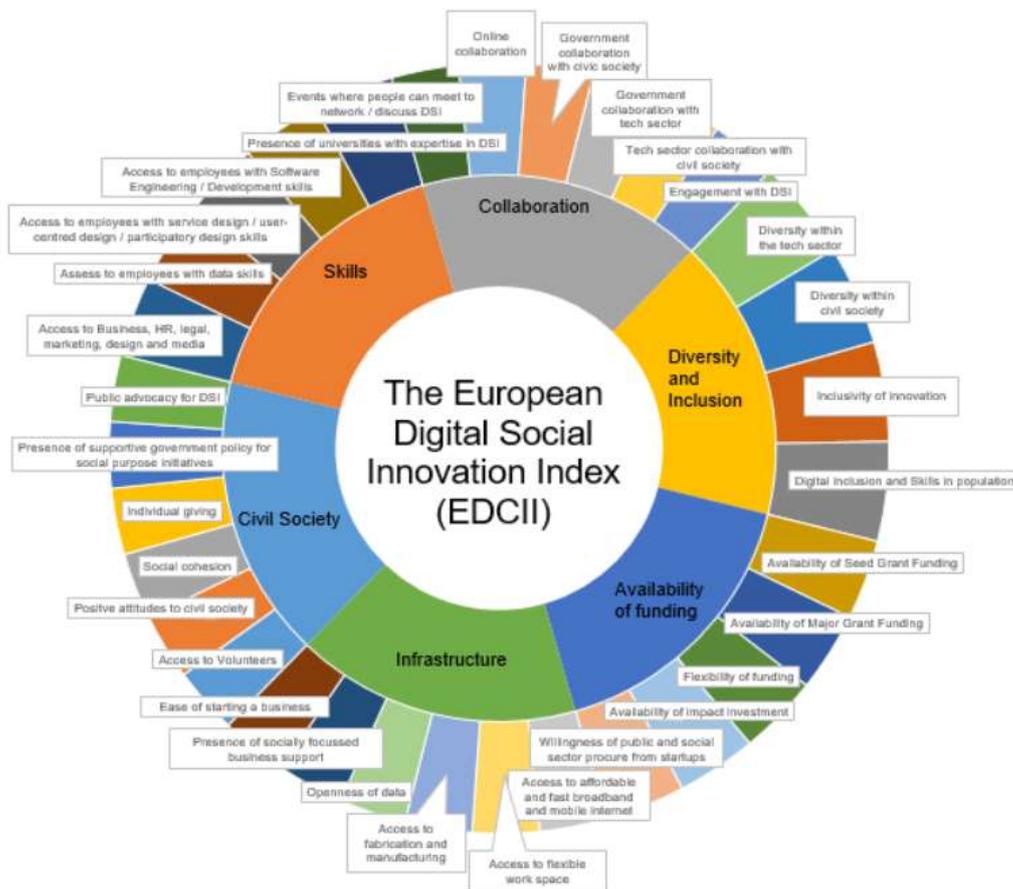
A wide variety of data sources were used in the index, including publicly available data (e.g. from the EU and other public organisations) and commercial data, as well as primary data collected through web scraping, API queries and a survey of

143 researchers, practitioners, policymakers and other people interested in DSI. Data was denominated accordingly (e.g. by city population, working age population or purchasing power) in order to make comparisons across different sized cities meaningful.

### 1.2.3 Data checking

- Treatment of outliers: Outliers were identified as values which are more than 1.5 times the interquartile range (IQR) above the upper quartile or below the lower quartile. Upper-end outliers were transformed to have the same value as the largest non-outlier in that variable and lower-end outliers were transformed to have the same value as the smallest non-outlier.
- Normalisation: A Min-Max normalisation was used to scale variables to be within an identical [0.1, 0.9] range.
- Imputation of missing values: After the initial data gathering exercise, 4% of the data that was needed was missing. These gaps were scattered across multiple indicators and cities. In order to work with a complete dataset, missing data were replaced with estimates calculated using multiple regression. In order to take into account uncertainty about the missing data, five predictions were made and a mean of these five values replaced the missing value.

Figure 2. The EDSII: themes and indicator



### 1.2.4 Data Processing

- **Multivariate Analysis:** Principal Components Analysis was used to explore the underlying structure of the data, particularly how different variables change in relation to each other and how they are associated. We also used a cluster analysis to give us some insight into which cities scores similarly across themes. In addition, we analysed the correlation between themes, and between themes and the overall index score by calculating Pearson correlation coefficients.
- **Weighting and Aggregation:** Indicators were aggregated using a weighted arithmetic mean to create theme scores. Theme scores were then aggregated using a weighted geometric mean to produce the overall index score. Using geometric aggregation meant that compensability is lower for theme scores with low value, so a city with a low score for one theme will need a much higher score on the others to improve its score. We believe that this reflects reality as our research suggested that all themes included in the Index are necessary to supporting DSI. Indicators

and themes were weighted using weightings chosen in the earlier theoretical framework stage.

- Robustness and Sensitivity Analysis: The robustness and sensitivity analysis checked the effect of several methodological decisions made throughout the index development process on the ranking of cities (e.g. indicator selection and weighting, treatment of outliers, imputation of missing data and aggregation method).
- Index validation: As a means of validating the index we compared cities' scores with the number of DSI organisations located in each city that have entered their information onto the [DSI4EU platform](#). We find a weak to moderate positive correlation.

### 1.2.5 Data visualisation

A visualisation was developed using [Tableau data visualisation software](#) and embedded into the [digitalsocial.eu](#) website. The data visualisation allows viewers to compare city scores and rankings for the overall index as well as for the individual themes. It also presents examples of strategies, policies and initiatives from across Europe which may help support DSI.

## 1.3 Challenges and limitations

We explore some of the reasons why EDSII scores do not correlate with DSI activity more strongly, including how favourable conditions for DSI do not necessarily lead to high levels of DSI if there is not a particular need for it (e.g. in places where there are social challenges are less major and/or urgent), potential issues around the choice of indicators, data quality and how indicators are weighed and aggregated. We also explore some of the challenges in producing an index measuring the capacity to support a project across a very broad range of technologies, organisation types, social challenges and stages of development.

# 1. Introduction

## 1.1 Background

DSI4EU is an EU-funded project which aims to support policy makers, funders and practitioners to grow and scale digital social innovation (DSI) in Europe and to harness the power of people and technology to tackle some of Europe's biggest social and environmental challenges.

A key part of DSI4EU is to better understand the systemic and macro-level conditions which support the creation, growth and sustainability of DSI initiatives, and to analyse geographically how different parts of the European Union are positioned to support DSI initiatives. Much of this builds upon research carried out by the preceding DSI4EU project, which explored the challenges to growth for DSI at both the macro (system) and micro (project) levels.<sup>1</sup> Building upon this, DSI4EU aims to use this analysis and understanding to influence and help policymakers (and other stakeholders) to proactively build ecosystems which are conducive to the growth of DSI.

The central activity within this area of work is the development of the experimental European Digital Social Innovation Index (EDSII), which aims to measure and compare the capacity of cities to support DSI. The aims of the index are explored below (Section 1.3).

Ultimately, our aim is to situate the Index within the wider framework of DSI4EU's activities, including direct policy engagement with cities, the European Commission and national governments, practical support and peer learning for DSI practitioners and other stakeholders, creation of accessible research on the current DSI landscape and the future of DSI, and building a stronger network of DSI in Europe.

## 1.2 Why an index for Digital Social Innovation?

Previous studies of DSI have tended to focus on measuring activity - the volume, geographical spread and characteristics of the DSI initiatives taking place around Europe. This has provided valuable insight and helped researchers, policymakers and other stakeholders to better understand and engage with the field.

Nevertheless, there has been less research looking at the enabling and hindering

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<sup>1</sup> Stokes, M., Baeck, P., Baker, T. (2017) 'What Next for Digital Social Innovation.' London: Nesta.  
<https://www.nesta.org.uk/report/what-next-for-digital-social-innovation-realising-the-potential-of-people-and-technology-to-tackle-social-challenges/>

factors behind this activity, exploring what helps or hinders DSI initiatives' creation and growth.

There are currently no comprehensive assessments, tools or methods for assessing the capacity of local, regional or national innovation ecosystems to support DSI initiatives.

#### A note on terminology

DSI is not the only term used to refer to the use of digital technology to address social challenges. 'Civic tech', 'tech for good' and 'social tech' are also used widely across Europe, and among many communities are much more widely recognised. For this reason, we have used these terms somewhat interchangeably in the development of the index and when speaking to people in the field. However, in the context of this report, we only use the term DSI.

### 1.3 Aims of the index

The purpose of the EDSII is to provide an open-source tool to measure and compare the capacity of cities to support DSI. This will support DSI projects and other stakeholders in the field in five ways:

1. Identify success factors for the creation, growth and sustainability of DSI. The Index has been produced by combining indicators for several key factors that are important to starting, sustaining and growing DSI projects. By identifying what these key factors are and disseminating our insights through the Index, we will enable a better understanding of the success factors for developing DSI ecosystems and raise awareness on how to spread and promote these conditions between funders, policymakers and other stakeholders.
2. Help policymakers understand how they can better support DSI, drawing upon successful examples from other places. The EDSII provides an overall score, allowing ecosystems in Europe to be ranked based on their capacity to support DSI at the city level. Alongside the overall score, a second output of the index is scores for how well ecosystems perform on different dimensions of the index. These dimensions, or themes, group several indicators, which together measure a particular aspect of an ecosystem's capacity to support DSI, for example, funding or skills. Using these themes, policy makers can use the index as a diagnostic tool to understand where their city is falling behind and thus what areas future policies should target for improvement. [The Index is](#)

[accompanied by the “Ideas Bank”, a collection of case studies of supportive strategies, policies and initiatives from across Europe](#) to enable sharing of best practice and replication/adaptation of successful experiences.

3. Incentivise the development and implementation of supportive policies. The scores allotted to ecosystems act as a competitive incentive for policymakers to implement supportive policies which aim to better support DSI within politicians and policy makers cities, regions or countries.
4. Inform practitioners about where in Europe has the best conditions for supporting DSI, which may influence where practitioners decide to set up or grow their initiatives. DSI initiatives are often set up in reaction to a particular local need. However, where there is some flexibility on where a DSI initiative could be located, or, more likely, where an existing initiative is looking to expand. The Index will provide practitioners with useful insight into where might be amenable for projects to locate or grow with maximum chances of success. Furthermore, the scores on individual themes will support practitioners to make informed decisions based on what is most relevant to their project’s characteristics and needs.
5. Raise awareness about, and interest in, DSI among people, communities and organisations not currently involved in the field. By providing an accessible benchmark for how cities rank in their ability to support DSI, we hope the Index will spark wider conversations and interest - for example within the startup sector, governments and funding institutions.

## 1.4 What are composite indexes and why are they useful?

Composite indexes attempt to measure complex social or economic phenomena by combining several individual indicators which, individually, would not adequately describe the phenomenon in question. The individual indicators that make up the composite index are selected, combined and weighted based on an underlying model of the structure of the phenomenon that is being measured.

The EDSII adds to a growing list of composite indexes which aim to explore how different geographic regions compare against a wide range of complex issues with more or less relevance to the field of DSI, including:

- Entrepreneurship and the digital economy - such as the European Digital City Index<sup>2</sup>, CITIE<sup>3</sup>, the Global Entrepreneurship Index<sup>4</sup>, the Digital Transformation Monitor<sup>5</sup> and the Global Innovation Index<sup>6</sup>;
- Digital skills and infrastructure - such as the Digital Economy and Society Index<sup>7</sup>;
- (Open) data - such as the Open Data Barometer<sup>8</sup>, the Global Open Data Index<sup>9</sup> and the European Data Portal<sup>10</sup>;
- Open licensing - such as Creative Commons' State of the Commons<sup>11</sup>;
- Sustainability - such as the Environmental Performance Index<sup>12</sup> and the Sustainable Cities Index<sup>13</sup>;
- Wellbeing - such as the OECD Better Life Index<sup>14</sup> and the Fab City Dashboard<sup>15</sup>;
- Social innovation and entrepreneurship - such as the Social Entrepreneurship Index<sup>16</sup> and the Social Innovation Index<sup>17</sup>.

None yet exists which is looking at DSI specifically, and our index aims to fill this gap.

### 1.4.1 The strengths of composite indexes

Composite indexes are useful in two particular cases: either when a single indicator could not conceivably measure the phenomenon due to its complexity and abstract nature; or when a single indicator is conceivable but would be too difficult or costly to measure.

While in theory we could scrutinise each indicator within a composite index individually (and indeed this is sometimes useful), combining them makes it much easier to interpret information without losing sight of, or access to, the underlying information.

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<sup>2</sup> <https://digitalcityindex.eu/>

<sup>3</sup> <https://www.nesta.org.uk/report/citie-a-resource-for-city-leadership/>

<sup>4</sup> <https://thegeedi.org/global-entrepreneurship-and-development-index/>

<sup>5</sup> <https://ec.europa.eu/growth/tools-databases/dem/monitor/>

<sup>6</sup> <https://www.globalinnovationindex.org/Home>

<sup>7</sup> <https://ec.europa.eu/digital-single-market/en/desi>

<sup>8</sup> <http://opendatabarometer.org>

<sup>9</sup> <https://index.okfn.org/>

<sup>10</sup> <https://www.europeandataportal.eu/>

<sup>11</sup> <https://www.arcadis.com/en/global/our-perspectives/sustainable-cities-index-2016/>

<sup>12</sup> <http://archive.epi.yale.edu/cgi-sys/suspendedpage.cgi>

<sup>13</sup> <https://www.arcadis.com/en/global/our-perspectives/sustainable-cities-index-2016/>

<sup>14</sup> <http://www.oecdbetterlifeindex.org/#/111111111111>

<sup>15</sup> <http://dashboard.fab.city/>

<sup>16</sup> <http://poll2016.trust.org/methodology/>

<sup>17</sup> <https://eiperspectives.com/technology-innovation/old-problems-new-solutions-measuring-capacity-social-innovation-across-world-0>

Indexes are particularly powerful tools for policymaking when they are captured over multiple years, allowing trends to be identified. These trends can help draw policymakers' attention to particular issues or help them evaluate the impact of specific interventions. Country or city rankings based on index scores are especially good at attracting media attention, facilitating public discussion, promoting accountability and harnessing competitive spirits to motivate policymakers into action.<sup>18,19</sup>

## 1.4.2 The weaknesses of composite indexes

Composite indexes, like all models, are by necessary simplified versions of reality. And while it is this simplification that makes them useful, it means that in some sense they will always have their errors and misrepresentations. Like all models, composite indexes are created through a combination of science and art, and their construction necessarily entails numerous decisions (such as the choice and weighting of indicators) which are more or less subjective. Such decisions are not always clear cut and are almost always subject to debate. Getting these decisions wrong, or having to ignore indicators that are too difficult to measure, can result in simplistic or inappropriate policy messages.

Even if constructed as accurately as possible, problems may arise if policy conclusions drawn from composite indexes are (consciously or unconsciously) erroneous. The complexity of composite indexes means misrepresentation is an ever-present risk. For this reason, it is important that those producing indexes are transparent about the processes, methodologies, decisions and experts used in constructing them, and about what their limitations are. Composite indexes should not become "black boxes" whose users are blind to the decisions and processes behind the final numbers. And policymakers should not make any policy-decisions based on a single index (or model more generally).

## 1.5 Geographical coverage

65 European cities were carefully selected through consultations with our partners and a process of internal deliberation. These cities were selected based on population size, known DSI activity, score on other indexes related to innovation,<sup>20</sup> availability of data and to ensure good representation across all of Europe and especially in traditionally underrepresented areas such as Eastern

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<sup>18</sup> Saisana, M., Saltelli, A., Tarantola, S. (2005) 'Uncertainty and sensitivity analysis techniques as tools for the quality assessment of composite indicators.' *Journal of the Royal Statistical Society A*. <https://rss.onlinelibrary.wiley.com/doi/abs/10.1111/j.1467-985X.2005.00350.x>

<sup>19</sup> Nardo, M., Saisana, M., Saltelli, A., Tarantola, S., Saltelli, A., Hoffman, A. (2008) 'Handbook on constructing composite indicators: Methodology and user guide.' Ispra: Joint Research Centre-European Commission. <http://www.oecd.org/sdd/42495745.pdf>

<sup>20</sup> e.g. [Resilient City index](#), [Smart city index](#), [Sustainable city index](#), [Innovation cities index](#)

and Central Europe. Five cities were later removed because of lack of good data: Valletta (Malta), Essen (Germany), Luxembourg City (Luxembourg), Naples (Italy) and Brno (Czech Republic). The remaining 60 cities included in the index are listed in table 1.

The EDSII focuses on ranking cities, rather than countries, for several reasons:

- This is in keeping with the principle of subsidiarity in policymaking, “the principle that social and political issues should be dealt with at the most immediate (or local) level that is consistent with their resolution”;<sup>21</sup>
- DSI is particularly active at city level, due both to the challenges faced by cities (ranging from transport and air pollution to provision of healthcare, housing and education), and the density of people, assets, infrastructure, knowledge and skills which allows for collaborative technologies to thrive;
- Cities are increasingly becoming a hotbed for innovative policymaking and strategies (both in digital and non-digital policy);
- In many countries, although not all, cities have significant power over the policy decisions which affect people’s day-to-day lives the most and effective ways of engaging with citizens.

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<sup>21</sup> <https://en.wikipedia.org/wiki/Subsidiarity>

*Table 1. Cities chosen to be featured in the EDSII*

Vienna	Marseille	Leipzig	Rotterdam	Barcelona
Austria	France	Germany	Netherlands	Spain
Brussels	Nice	Munich	The Hague	Bilbao
Belgium	France	Germany	Netherlands	Spain
Ghent	Paris	Stuttgart	Utrecht	Madrid
Belgium	France	Germany	Netherlands	Spain
Sofia	Toulouse	Athens	Krakow	Gothenburg
Bulgaria	France	Greece	Poland	Sweden
Zagreb	Berlin	Budapest	Warsaw	Malmo
Croatia	Germany	Hungary	Poland	Sweden
Nicosia	Cologne	Milan	Lisbon	Stockholm
Cyprus	Germany	Italy	Portugal	Sweden
Prague	Dortmund	Rome	Porto	Belfast
Czechia	Germany	Italy	Portugal	United Kingdom
Aarhus	Dresden	Turin	Dublin	Birmingham
Denmark	Germany	Italy	Ireland	United Kingdom
Copenhagen	Düsseldorf	Riga	Bucharest	Bristol
Denmark	Germany	Latvia	Romania	United Kingdom
Tallinn	Frankfurt	Vilnius	Cluj-Napoca	Edinburgh
Estonia	Germany	Lithuania	Romania	United Kingdom
Helsinki	Hamburg	Amsterdam	Bratislava	London
Finland	Germany	Netherlands	Slovakia	United Kingdom
Lyon	Karlsruhe	Eindhoven	Ljubljana	Manchester
France	Germany	Netherlands	Slovenia	United Kingdom

## 2. Methodology

The methodology followed when building the EDSII is based on that used for the European Digital City Index, which itself is adapted from the “ideal sequence” of steps detailed in the JRC/OECD Handbook on constructing composite indicators (Figure 1)<sup>22</sup>. In following this methodology and carefully documenting each stage of the process we have ensured the index is as robust and transparent as possible.

It is important to note that while Figure 1, and this document in general, presents this as a linear process in reality it was an iterative process where we were frequently required to revisit earlier steps.

### 2.1 Developing the theoretical framework

Throughout the development of the framework, we aimed to be as inclusive, transparent and open as possible, in keeping with the values of DSI and to create an Index which is not just useful but also accepted and welcomed as legitimate by different stakeholders in the DSI community.

#### 2.1.1 Defining the concept

As discussed above, the index compares the capacity of cities to support DSI initiatives. Although DSI continues to evolve as a field, for this index we continue to use the definition first outlined in our first study on digital social innovation, published in 2015:<sup>23</sup>

*“A type of social and collaborative innovation in which innovators, users and communities collaborate using digital technologies to co-create knowledge and solutions for a wide range of social needs and at a scale and speed that was unimaginable before the rise of the Internet.”*

When we refer to the ‘capacity to support’, we are looking beyond top-down government level policy levers,<sup>23</sup> considering ecosystem capacity in the broadest sense of the word. For this, we will analyse the DSI ecosystem as a whole including political, economic, social, cultural and technological factors affecting a city.

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<sup>22</sup> Nardo, M., Saisana, M., Saltelli, A., Tarantola, S., Saltelli, A., Hoffman, A. ‘Handbook on constructing composite indicators: Methodology and user guide.’

<sup>23</sup> As was the focus of the city initiatives for technology, innovation and entrepreneurship (CITE) index, <https://www.nesta.org.uk/report/citie-a-resource-for-city-leadership/>

## 2.1.2 Themes and indicators

Indicators were selected through a literature review (see Appendix 1 for a selected literature review) and consultation with experts and stakeholders in DSI through 11 semi-structured interviews<sup>24</sup> and a roundtable event.

An initial set of 69 possible indicators was narrowed down in an internal workshop at Nesta to 32 indicators to be included in the Index. Longlisted indicators were excluded from the shortlist because of either duplication (they were a subcategory of another indicator or were closely related to another indicator) or irrelevance (there was no strong link to DSI). These 32 indicators were then grouped by the research team into six themes (initially indicators were grouped into seven themes but one theme 'Support Systems' was later merged with the infrastructure and skills theme<sup>25</sup>), grouped alongside other related indicators. The six themes are:

- Skills
- Infrastructure
- Funding
- Diversity and Inclusion
- Collaboration
- Civil Society

Below we describe and discuss the justification for the inclusion of the 32 indicators we have chosen. We discuss the indicators under the subheadings of the seven themes.

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<sup>24</sup> Interviewees: Tom Walker (Engine Room), Paul Miller (Bethnal Green Ventures), Matt Jackson (Comic Relief; Anthropotech), Clémence Pène (C40 Cities), Rebecca Portail (Eurocities), Wietse Van Ransbeeck (Citizenlab), Krzysztof Izdebski (EPF), Regina Sipos (Social-Digital Innovation), Julia Kloiber (Open Knowledge Foundation Germany), Sandor Lederer (K-Monitor Association), Joe Gaylord (Social-Digital Innovation).

<sup>25</sup> The Support Systems theme was merged with Skills and Infrastructure because it was thought that the indicators it contained had more in common with indicators within other themes than with each other. The initial 'Support systems' theme contained the indicators: 'Ease of Starting a Business' (now part of Infrastructure theme), 'Presence of supportive government policy for social purpose initiatives' (now part of Civil Society theme) and 'Presence of socially focussed business support' (now part of Infrastructure theme).

### 2.1.2.1 Skills

Anecdotal evidence suggests a wide range of both technical and non-technical skills are needed for DSI initiatives to thrive. Drawing upon literature exploring related fields like entrepreneurship, social impact and social innovation, we can distinguish a number of soft skills (e.g. communications, administration) and hard skills (e.g. programming, data skills) which are commonly used as a measurement of human capital, powering ecosystems and helping them to grow.<sup>26</sup> Other literature highlights the importance of knowledge and skills as a requirement for grassroots innovation as well as a measurement of successful outcomes.<sup>27</sup>

Skills	
Access to business, HR, legal, marketing, design and media support	Growing DSI initiatives need access to people with a wide range of skill sets including HR, Legal, Marketing, Design, media and other business support professionals.
Access to employees with data skills	Data is often at the core of DSI initiatives products and services. Therefore, having access to people with skills in collecting, manipulating, analysing and interpreting data is crucial.
Access to employees with service design skills	DSI initiatives are able to meet their full potential when the product or service they offer is designed around the specific needs of their users and beneficiaries, which in turn requires people with service design skills.
Access to employees with software engineering/ development skills	DSI initiatives are typically based around a mobile or web app which require software development skills to create.
Presence of universities with expertise in DSI	Alongside doing research and teaching courses related to DSI, universities often hold events, provide equipment and workspace and collaborate with DSI initiatives.

<sup>26</sup> ITU. (2017) 'Bridging the digital innovation divide: A toolkit for strengthening ICT centric ecosystems.' Geneva: ITU.

<sup>27</sup> Smith, A., Stirling, A. (2018) 'Innovation, Sustainability and Democracy: An Analysis of Grassroots Contributions.' Journal of Self-Governance and Management Economics. <http://steps-centre.org/wp-content/uploads/2017/07/SmithStirling-2017-GI-ID-journal-article.pdf>

### 2.1.2.2 Civil society

Most DSI originates within civil society in its broadest sense, ranging from large charities to informal community groups. Through our review of literature and interviews, we found that an active, trusted and developed civil society is important in encouraging the creation of DSI and in encouraging citizen engagement in DSI. A culture of donating money and volunteering is important to supporting DSI initiatives and is indicative of public engagement in social causes more generally.

Civil Society	
Access to volunteers	DSI initiatives often rely on the support of volunteers. Alongside this, a culture of volunteering indicates an active civil society and public engagement in social causes.
Positive attitudes to civil society	As DSI tends to be bottom-up and citizen-driven, positive attitudes towards civil society would be expected to in turn generate trust in, enthusiasm for and active involvement in DSI initiatives from citizens.
Social cohesion	A cohesive society is essential for communities to come together to discuss and solve common problems, which in turn is important for DSI initiatives to grow and deliver impact.
Individual giving	Donations from individuals can help fund DSI initiatives but perhaps more importantly they indicate an active engagement in civil society by the public.
Public advocacy for DSI	Public advocacy from politicians and other public figures can raise awareness about DSI, encourage people to innovate and get involved in DSI, drive funding towards DSI, promote the adoption of supportive policies and attract other stakeholders such as funders and researchers.
Presence of supportive government policy for social purpose initiatives	Governments can help DSI initiatives to thrive through supportive policies such as defining legal forms which make it easier to set up and run social initiatives, providing tax relief for social initiatives and investors, and offering grants, loans and investment to social initiatives.

2.1.2.3 Collaboration

Given the open and multidisciplinary nature of DSI, collaboration (both online and offline) is a key success factor. DSI works best when a diverse group of people with different expertise (such as technology, social challenges and provision of public services) work together.

We know that explicitly outward-looking technologies which are powered by, and drive, collaboration are at the heart of DSI. As the DSI ecosystem remains relatively fragmented, it can be difficult for practitioners to identify, learn from and collaborate with similar projects. Collaboration and sharing of knowledge and best practice between policymakers, practitioners, investors and other stakeholders is key to enabling peer learning and supporting the sustainable growth of DSI (and something which we aim to facilitate through DSI4EU).

Collaboration	
Events where people can meet to network and discuss DSI	Events relevant to DSI are important for those interested and involved in the field (and related fields) to share knowledge, network and collaborate.
Online collaboration	As DSI is technology-based and open, online collaboration is common, including for software development on platforms such as GitHub.
Government collaboration with civil society	These three sectors are at the heart of DSI, and collaboration between all three – both bilaterally and as a group – is imperative for DSI to grow and scale its impact.
Government collaboration with tech sector	
Civil society collaboration with tech sector	
Engagement with DSI	An active community of people talking about DSI can help foster informal sharing of knowledge, collaboration, and uptake by potential users.

#### 2.1.2.4 Funding

Unsurprisingly, experts consistently said that the availability of funding is important for DSI initiatives at all stages of development. Grant funding in particular was highlighted as being crucial to starting and sustaining initiatives. Beyond grant funding, DSI initiatives which have potential to create financial as well as social returns may also look to raise larger amounts of money by selling equity in their business. With this in mind several interviewees suggested the importance of an active impact investment scene.

Further to this, entrepreneurship literature has highlighted the huge benefits associated with procurement from large organisations, helping startups scale up their operations and conveying validation to potential future customers<sup>28</sup>. A large number of DSI initiatives work in fields where the public and social sector holds a monopoly, such as in healthcare, education and employment support. It is for this reason why we have included an indicator measuring the ‘Willingness of public and social sector procure from startups’.

Funding	
Availability of seed grant funding	Access to relatively small amount of grant funding is needed get early stage initiatives off the ground. Here we are talking about grants of less than €200,000.
Availability of major grant funding	Access to larger grants is needed to fund established DSI initiatives to scale their project and impact. Here we are talking about grants of more than €200,000.
Flexibility / ability of grant funding to support DSI	Flexible funding allows agile product and service development and enables smaller organisations, citizen groups and collaborative projects to access funding.
Availability of impact investment	Impact investors can, in return for equity or debt, provide the investment needed to enable DSI initiatives to grow, but also often provide mentoring and guidance helping DSI initiatives to build a sustainable business model.
Willingness of public and social sector to procure from startups	Accessing procurement and commissioning is often the only way in which DSI initiatives are able to deliver at scale. In turn, DSI has the potential to enable public services to be delivered more efficiently and to involve citizens as co-creators rather than just users of services.

<sup>28</sup> European Commission (2017) ‘European Semester Thematic Factsheet Public Procurement.’ Brussels: European Commission. [https://ec.europa.eu/info/sites/info/files/file\\_import/european-semester\\_thematic-factsheet\\_public-procurement\\_en\\_0.pdf](https://ec.europa.eu/info/sites/info/files/file_import/european-semester_thematic-factsheet_public-procurement_en_0.pdf)

### 2.1.2.5 Infrastructure

DSI initiatives' creation, growth and sustainability is enabled by good infrastructure: digital (such as broadband and mobile internet and provision of open data), physical (such as workspaces, accelerators, makerspaces, fablabs) and process-related (such as those involved in setting up a business). While data is not often treated as infrastructure, as the Open Data Institute points out, 'Data is as important as our road, railway and energy networks and should be treated as such'. And in order to maximise data use and value, we need not only data assets but also the organisations that operate and maintain them, and guides describing how to use and manage the data.<sup>29</sup>

Infrastructure	
Access to affordable and fast broadband and mobile internet	DSI initiatives are typically based around a mobile or web app and therefore access to affordable and fast broadband and mobile internet is essential to potential developers and users.
Access to flexible workspace	DSI initiatives often rely on shared and flexible office space as a place to work, hold meetings and network, especially in early days. Alongside this, flexible workspaces facilitate the exchange of ideas and collaboration between people with different skills and from different sectors.
Access to fabrication and manufacturing facilities	DSI includes hardware as well as software-based initiatives (particularly open hardware). For this reason, it is important that spaces are available where users and producers can access fabrication equipment such as 3D printers, laser cutters and milling stations allowing them to prototype, manufacture and co-create innovations. Examples of such spaces include makerspaces, Fab Labs, hackerspaces and DIY Biolabs.
Presence of socially focussed business support	Support includes that offered by accelerators, incubators and other initiatives (mentoring, workshops, training programmes etc.)
Openness of data	The accessibility and quality of open data (i.e. data which anyone is free to access, use, modify, and share) is important to the DSI community: it can be used to help develop new products and services; and opening up government data increases transparency which is generally considered positive.
Ease of starting a business	While the most grassroots DSI initiatives may not have legal structures, it is almost always important if initiatives want to scale their impact and access funding. DSI will be more able to grow if it is easy, trusted and cheap to set up a business.

<sup>29</sup><https://theodi.org/topic/data-infrastructure/>

2.1.2.6 Diversity and inclusion

Diverse and inclusive communities, environments and sectors (of different genders, sexes, ethnicities, sexual orientations, abilities, ages etc.) lead to better, more sustainable DSI initiatives. A myriad of studies has shown that more diverse and inclusive companies and sectors are more innovative.<sup>39</sup> This is likely because more diverse groups encompass and bring with them a wider range of interests, experiences, backgrounds and ideas. Diversity is particularly important in the field of DSI where minority groups are more likely to have lived experience of the social challenges which DSI tries to tackle.

Furthermore, digital inclusion and digital skills among the population are important for DSI to grow because for DSI to deliver impact equitably it must be open and accessible to everyone, regardless of age, ethnicity, ability, gender, income or location. Indeed, emerging research from the civic technology community suggests that without digital inclusion, digital technologies can replicate or even exacerbate existing patterns of inequality and discrimination.<sup>40</sup>

Diversity and Inclusion	
Diversity within the tech sector	Greater diversity within these sectors suggests more progressive practices and a more inclusive culture. This has been shown to promote innovation but is also important because minority groups are more likely to have lived experience of the social challenges which DSI tries to tackle.
Diversity within civil society	
Inclusiveness of innovation	DSI is more likely to grow in an environment where all segments of society are able and encouraged to innovate. Places can promote inclusive innovation through policies and initiatives e.g. targeted grants, entrepreneurship education and extra-curricular outreach for young people.
Digital inclusion and skills in population	Societies must be skilled in and have access to digital technology if everyone is to benefit from DSI initiatives, particularly vulnerable groups who often have most to gain from DSI. A digitally-skilled population is also likely to be more innovative.

### 2.1.3 Weighting indicators and themes

The index takes a “nested” structure. Within this structure, each indicator has a score; these scores were combined to give a score for each theme; these theme scores were then combined to give a score for the index as a whole.

While some indexes weight individual indicators as equally important for the overall index score, it was clear from the literature review and interviews that some themes and indicators are more important than others. We therefore decided to assign indicators different weights when combined into the overall index score.

In order to determine how indicators and themes should be weighted, we conducted a survey in which 114 DSI practitioners<sup>30</sup>, public sector employees, researchers, intermediaries, funders and policymakers were asked to rank the themes and indicators in order of their importance to supporting DSI<sup>31</sup>. We used the median ranks given to themes and indicators to inform their relative weightings.

When ranking indicators, survey respondents were only told what the indicators would be measuring (e.g. “Public advocacy for DSI”), not how exactly they would be measured (e.g. “Number of articles which mentioned a DSI related keyword over the last 12 months at the country level”).<sup>32</sup> This means that the weights given by respondents did not take into account the quality of the data sources to be used in the index.

In response to this, weightings were revised after source selection and data collection. We weighted down indicators for which we had concerns about the data’s relevance to the indicator, analytical soundness, geographical coverage or age. Downweighting an indicator involved giving that indicator the same weight as that of the next highest weighted indicator in the same theme. Where the indicator already had the lowest weighting in that theme, we decreased its weight by the average difference between indicator’s weightings in the theme.

The final weightings used to aggregate indicators into themes and themes into the final ranking can be found in tables 2 to 7.

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<sup>30</sup> Survey conducted using SurveyGizmo (<https://www.surveygizmo.com/>). Respondents included practitioners, public sector employees, researchers, intermediaries, funders and policymakers.

<sup>31</sup> A detailed account of the weightings survey can be found in our previous report, “[A Theoretical Framework to the DSI Index](#),” p.12.

<sup>32</sup> This was a conscious choice, as we wanted responses to be informative of what people really thought was important to DSI outside the context of the particular data available at the time of collection for this index.

## 2.2 Source selection and data gathering

### 2.2.1 Data sources

Data sources for each indicator were chosen based on four criteria:

- their relevance to the indicator;
- analytical soundness;
- geographical coverage;
- their relationship to other indicators being considered.

A wide variety of data sources were considered during this stage including publicly available data (e.g. from the EU and other public organisations) and commercial data, as well as primary data collected through web scraping and API queries. In some cases, data sources were other indexes identified through the literature review. Also, for some of the 32 indicators, we combined multiple variables. This means that the index is made up of a total of 49 variables.

Occasionally we were unable to find either a direct measure or a proxy measure for an indicator that was identified as being important during the theoretical framework development. In order to collect data for these indicators we conducted a survey of 143 researchers, practitioners, policymakers, support organisations, funders or people otherwise interested in DSI from around Europe. In Tables 2-7 below, indicators using data from this survey are marked 'primary research' in the data source column.

It is important to note that the relevance of data sources to indicators is, to some extent, subjective and so the pros and cons of different data sources was discussed among the research team before final choices were made. Where indicators are dependent on, or affected by, size-related factors or the cost of goods or services in a particular country, they were scaled by a factor (e.g. working population or purchasing power parity) to compensate for this.<sup>33</sup>

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<sup>33</sup> Scaling factors include city population, active population [age 15 - 64], Twitter penetration and purchasing power parity. For some variables which are counting the number of specific facilities in a city (universities; incubators and accelerators; fablabs, biolabs and hackerspaces) it was decided that we would not expect absolute numbers of these facilities to increase proportionally to population size. For example, a small- or

Below we present information on the variables used for each indicator:

*Table 2. Civil society (weighing = 20%)*

Indicator name	Indicator description	Indicator weight	Measure used	Year	Data source	Geographic granularity	Geographic coverage	Comments
Access to Volunteers	DSI initiatives often rely on the support of volunteers. Alongside this, a culture of volunteering indicates an active civil society and public engagement in social causes.	18.18%	Percentage of population (16 years +) that participate in formal volunteering activities.	2015	<a href="#">European Community Household Panel (ECHP)</a>	Country	Countries of all cities included in the index are covered.	Data is also available at a more granular regional (NUTS 1) level with approval from Eurostat. However, we were unable to get approval to use this data in time for publication of the index.
Positive attitudes to civil society	As DSI tends to be bottom-up and citizen-driven, positive attitudes towards civil society would be expected to in turn generate trust in, enthusiasm for and active involvement in DSI initiatives from citizens.	18.18%	Percentage of survey respondents that reported to agree or strongly agree that they share the values or interests of NGOs in their region and trust them to act in the right way to influence political decision making	2014	<a href="#">Flash Eurobarometer 373</a>	Varies (NUTS1 / NUTS2 / NUTS3)	Missing data for Croatia (Zagreb).	Civil Society is broader than just NGOs and includes other types of organisations not referred to in the question, ranging from large charities to informal community groups. Also, sharing the values or interests of NGOs and trusting them to act in the right way to influence political decision making is not exactly the same as having a more general positive attitude towards them and their work. However, on balance this is a good proxy measure.
Social cohesion	Social cohesion is defined as the willingness of members of a society to cooperate with each other in order to survive and prosper. A cohesive society is essential for communities to come together to discuss and solve common problems, which in turn is important for DSI initiatives to grow and deliver	18.18%	Quality of support network measured by percentage answering 'yes' to survey question asking, "if you were in trouble, do you have relatives or friends you can count on to help you whenever you need them, or not?"	2014	<a href="#">OECD Regional Wellbeing Index</a>	NUTS1	Data missing for: Romania (Bucharest, Cluj-Napoca), Cyprus (Nicosia), Latvia (Riga), Bulgaria (Sofia), Lithuania (Vilnius), Croatia (Zagreb).	Several factors are involved in creating a cohesive society. To take into account these various factors, we combined variables of 4 factors commonly associated with social cohesion: quality of support network, identity, civic engagement and trust in people.

medium-sized city might have one or two fablabs, but we would not necessarily expect a city with five times the population to have five times as many fablabs. For this reason, we did not standardise these variables by city population, as we did for some other variables. It is hard to distinguish for which variables this would be the case but decided that it was more likely to be true for those for which absolute numbers are small. We therefore decided not to standardise count variables for which the maximum count number is less than 25 - still somewhat arbitrary, but in our opinion the most sensible option.

	impact.		Identity measured by percentage of respondents that answered 'Fairly attached', 'Very attached' to question asking how attached they feel to their city.	2017	<a href="#">Eurobarometer 83.3</a>	NUTS1	Regions of all cities included in the index are covered.
			Civic engagement measured by voter turnout at last national election.	2014	<a href="#">OECD Regional Wellbeing Index</a>	NUTS1	Data missing for: Romania, Cyprus, Bulgaria, and Croatia.

			Trust in people measured by average score given by respondents who were asked to score on a scale of 1-10 how much people can be trusted or not (where '1' means that "most people cannot be trusted" and '10' means that "most people can be trusted).	2014	<a href="#">Eurobarometer 81.5</a>	NUTS1	Regions of all cities included in the index are covered.	
The four variables were combined to create one indicator by first normalizing all variables to be within the same 0.1 to 0.9 scale and then calculating the mean of the 4 variables .								
Individual giving	Donations from individuals can help fund DSI initiatives but perhaps more importantly they indicate an active engagement in civil society by the public.	9.09%	Score from indicator on donating money to charity. This indicator was based on responses to the survey question: "Did you donate money to charity last 12 months (yes / no)"	2016	<a href="#">CAF - World Giving Index</a>	Country	Countries of all cities included in the index are covered.	We considered combining this data with data on donation-based crowdfunding, however, we were unable to find robust data for crowdfunding with good geographical coverage.
Public advocacy for DSI (e.g from political / leading figures)	Public advocacy from politicians and other public figures can raise awareness about DSI, encourage people to innovate and get involved in DSI, drive funding towards DSI, promote the adoption of other supportive policies and attract other stakeholders such as funders and researchers.		Response to survey question asking the extent to which respondents agree or disagree that DSI and related fields (i.e. civic tech, gov tech etc.) are regularly spoken about by politicians, public figures and in the media.	2019	Primary research	Country	Missing data for Denmark (Aarhus, Copenhagen), Slovakia (Bratislava), Czech Republic (Prague), Finland (Helsinki), Slovenia (Ljubljana), Estonia (Tallinn), Latvia (Riga), Austria (Vienna) and Lithuania (Vilnius).	City-level data would have been preferable but due to the relatively small number of survey respondents, this was not possible. Only data from countries which had at least 3 survey responses were included. This means that unfortunately country coverage was not particularly good for this variable. Furthermore, the threshold of 3 responses for inclusion is quite low. This means that for some countries the averages calculated for this variable were generated from a relatively small number of data points.

Presence of supportive government policy for social purpose initiatives	Governments can help DSI initiatives to thrive through supportive policies such as defining legal forms which make it easier to setup and run social initiatives, providing tax relief for social initiatives and investors, and offering grants, loans and investment to social initiatives.	18.18%	Response to survey question asking the extent to which respondents agree or disagree that government policies are supportive of social purpose initiatives, social innovation and social enterprise through policies such as specific legal forms, tax relief and fiscal incentives or financing mechanisms.	2019	Primary research	Country	See above.	See above.
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Table 3. Collaboration (weighting = 17.5%)

Indicator name	Indicator description	Indicator weight	Measure used	Year	Data source	Geographic granularity	Geographic coverage	Comments
Events where people can meet to network / discuss DSI	Events relevant to DSI are important for those interested and involved in the field (and related fields) to share knowledge, network and collaborate.	5.26%	Number of events with focus on DSI on meetups.com and eventbrite.com (per capita).	2018	<a href="#">Meetup API</a> / <a href="#">Eventbrite API</a>	City	All cities in index covered in theory though for some cities we were unable to identify any DSI events.	<p>DSI events were identified based on whether they contained any of a list of DSI related keywords in their titles (see Appendix 2 for list of keywords).</p> <p>We combined data from more than one events platform to try and control for the fact that penetration of a single platform is unlikely to be uniform across Europe. However, even with two platforms included this may still create bias in the data. For example, Facebook is a popular platform for organising events, especially in Eastern Europe, however we were unable to get access to the Facebook API.</p> <p>As mentioned above the choice of keywords may also have created bias. Data from meetups.com includes all events over the last three months within the 'Tech' category. Data from Eventbrite includes only upcoming events but includes events from the following categories: 'Business &amp; Professional', 'Community &amp; Culture', 'Science &amp; Technology', 'Charity &amp; Causes' and 'Government &amp; Politics'.</p>
Online collaboration	As DSI is technology-based and open, online collaboration is common, including for software development on platforms such as GitHub. While online collaboration is not necessarily place-based, the use of collaborative platforms in a location may indicate a culture of collaboration.	10.52%	Number of GitHub users with projects containing DSI related keywords in their descriptions based in city (per capita).	2018	<a href="#">GitHub API</a>	City	All cities in index covered in theory though for some cities we were unable to identify any GitHub users.	<p>Although GitHub is by far the largest host of source code in the world, other platforms for collaborative coding are available. Usage of GitHub rather than these other platforms may vary across Europe creating bias in this data. Alongside this, one again, the choice of keywords may create further bias (see Appendix 2 for list of keywords).</p> <p>Users are not required to share their location, so this data only represents a sample of the total number of users in each city.</p>

Tech sector collaboration with civil society	DSI works best when those with in depth knowledge of social issues are able to collaborate with people with technical expertise.	21.05%	Response to survey question asking the extent to which respondents agree or disagree that civil society organisations (charities, NGOs and volunteer based organisations) and the tech sector work collaboratively on DSI, for example through funding, collaborative projects, subsidised service provision and events.	2019	Primary research	Country	Missing data for Denmark (Aarhus, Copenhagen), Slovakia (Bratislava), Czech Republic (Prague), Finland (Helsinki), Slovenia (Ljubljana), Estonia (Tallinn), Latvia (Riga), Austria (Vienna) and Lithuania (Vilnius).	As above, city-level data would have been preferable but due to the relatively small number of survey respondents, this was not possible.  Only data from countries which had at least 3 survey responses were included. This means that unfortunately country coverage was not particularly good for this variable.  Furthermore, the threshold of 3 responses for inclusion is quite low. This means that for some countries the averages calculated for this variable were generated from a relatively small number of data points.
Government collaboration with civil society	Local and National governments are a fundamental stakeholder in the DSI ecosystem, carrying out three main roles: enabler (through policy, funding and support), customer (through contracts and procurement) and partner (through strategic deployment of DSI tools, products and services).	21.05%	Aggregated score given by panel of experts to question: "Are major civil society organizations (CSOs) routinely consulted by policymakers on policies relevant to their members?" 0 = No, 1 = To some degree, 3 = Yes.	2018	<a href="#">V-Dem</a>	Country	Countries of all cities included in the index are covered.	While this does not encompass all forms of government-civil society collaboration, we believe it is a useful proxy. Data which focussed on local-government collaboration with civil society would have been preferable, but to our knowledge this data does not exist.
Government collaboration with tech sector	DSI works best when those with in depth knowledge of social issues are able to collaborate with people with technical expertise.	21.05%	Proportion of GDP spent on Government R&D for	2014	<a href="#">European Commission (PREDICT)</a>	Country	Countries of all cities included in the index are covered.	Data which focussed on ICT R&D expenditure at the local level and/or from local governments themselves, would have been preferable but to our knowledge this data does not exist.

			ICT <sup>34</sup>					
			Score for Online Service Component of e-government development index	2018	<a href="#">UN E-Government Survey</a>	Country	Countries of all cities included in the index are covered.	Combining this with data which focussed on city-level e-government would have been preferable, but to our knowledge this data does not exist.
			Response to survey question asking the extent to which respondents agree or disagree that local and national government support, work with and procure from the technology sector (particularly start-ups and SMEs) to collaboratively improve public services and address governmental priority areas.	2019	Primary research	Country	Missing data for Denmark (Aarhus, Copenhagen), Slovakia (Bratislava), Czech Republic (Prague), Finland (Helsinki), Slovenia (Ljubljana), Estonia (Tallinn), Latvia (Riga), Austria (Vienna) and Lithuania (Vilnius).	As above city-level data would have been preferable but due to the relatively small number of survey respondents, this was not possible.  Only data from countries which had at least 3 survey responses were included. This means that unfortunately country coverage was not particularly good for this variable.  Furthermore, the threshold of 3 responses for inclusion is quite low. This means that for some countries the averages calculated for this variable were generated from a relatively small number of data points.
			The 3 variables were combined to create one indicator by first normalizing all variables to be within the same 0.1 to 0.9 scale and then calculating the mean of the 3 variables .					

<sup>34</sup> Data on countries GDP from [Eurostat \(2014\)](#).

Engagement with DSI	An active community of people talking about DSI can help foster informal sharing of knowledge, collaboration, and uptake by potential users.	21.05%	Number of tweets which include DSI related hashtags / keywords from users located in each city (per estimated number of users in city)	2018	<a href="#">Twitter API</a>	City	All cities in index covered in theory though for some cities we were unable to identify any DSI related tweets.	<p>While Twitter is used throughout Europe, its penetration may vary between countries. For this reason, we initially intended on combining Twitter data with data from Facebook, but at the time of data collection the Facebook API was not accessible.</p> <p>The number of users in a city was estimated by multiplying the city population by the proportion of that country's population that use Twitter.</p>
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Table 4. Skills (weighting = 17.5%)

Indicator name	Indicator description	Indicator weight	Measure used	Year	Data source	Geographic granularity	Geographic coverage	Comments
Access to Business, HR, legal, marketing, design and media support	Growing DSI initiatives need access to staff with a wide range of skill sets including HR, Legal, Marketing, Design, media and other business support professionals.	20%	Number of employees working in advertising and market research activities (per active population [age 15 - 64]).	2016	<a href="#">Eurostat</a>	Country	Countries of all cities included in the index are covered.	Data is also available at a more granular regional (NUTS 1) level with approval from Eurostat. However, we were unable to get approval to use this data in time for publication of the index.
			Number of employees working in legal and accounting activities; activities of head offices; management consultancy activities (per active population [age 15 - 64]).	2016	<a href="#">Eurostat</a>	Country	Countries of all cities included in the index are covered.	Data is also available at a more granular regional (NUTS 1) level with approval from Eurostat. However, we were unable to get approval to use this data in time for publication of the index.
			Number of employees working in financial and insurance activities (per active population [age 15 - 64]).	2016	<a href="#">Eurostat</a>	Country	Countries of all cities included in the index are covered.	Data is also available at a more granular regional (NUTS 1) level with approval from Eurostat. However, we were unable to get approval to use this data in time for publication of the index.
			Number of employees working in administrative and support service activities (per active population [age 15 - 64]).	2016	<a href="#">Eurostat</a>	Country	Countries of all cities included in the index are covered.	Data is also available at a more granular regional (NUTS 1) level with approval from Eurostat. However, we were unable to get approval to use this data in time for publication of the index.

			Number of employees working in employment activities (per active population [age 15 - 64]).	2016	<a href="#">Eurostat</a>	Country	Countries of all cities included in the index are covered.	Data is also available at a more granular regional (NUTS 1) level with approval from Eurostat. However, we were unable to get approval to use this data in time for publication of the index.
Access to employees with data skills	Data is often at the core of DSI initiatives products and services. Therefore, having access to staff with skills in collecting, manipulating, analysing and interpreting data is crucial.	20%	Number of users on data science stack exchange forum from city (per active population [age 15 - 64])	2018	<a href="#">Stack exchange API</a>	City	All cities in index are covered.	This is a proxy for number of data science employees as not all forum users will be employed as data scientists. It does however give an indication of the number of people with data science skills because as far as we know the use of Stack Exchange by data scientists is widespread and fairly uniform across Europe.
Access to employees with service design skills	DSI initiatives are able to meet their full potential when the product or service they offer is designed around the specific needs of their users and beneficiaries. Employing staff with service design skills can help initiatives achieve this.	20%	Number of service design higher education programmes, practitioners and researchers located in city (per active population [age 16 - 64])	2018	<a href="#">servicedesignmap.com</a>	City	All cities in index covered in theory, though for some cities the map did not contain any service design entities.	We are not able to determine how comprehensive the map is or whether some parts of Europe are better covered than others.
Access to employees with Software Engineering / Development skills	DSI initiatives are typically based around a mobile or web app which require software development skills to create.	20%	Number of users on the Stackoverflow (for programmers) forum from city (per active population [age 16 - 64]).	2018	<a href="#">Stack exchange API</a>	City	All cities in index are covered.	This is a proxy for the number of employees with programming skills as not all forum users are necessarily employed. It does however give an indication of the number of people with programming skills because as far as we know the use of Stack Overflow by programmers is widespread and uniform across Europe.

<p>Presence of universities with expertise in DSI</p>	<p>Alongside doing research and teaching courses related to DSI, universities often hold events, provide equipment and workspace and collaborate with DSI initiatives.</p>	<p>20%</p>	<p>Number of universities with academics publishing papers with titles or abstracts including DSI related keywords</p>	<p>2018</p>	<p><a href="#">Microsoft academic graph API</a></p>	<p>City</p>	<p>All cities in index covered in theory though we were unable to find any universities with expertise in DSI for some cities.</p>	<p>Microsoft academic graph API was queried for papers including DSI related keywords in their title or abstract (see Appendix 2 for list of keywords). This returned information on these papers including authors and their authors institutional affiliations. We then used the <a href="#">Unirank webpage</a> to put together a list of research institutes in each city. We then used a fuzzy match algorithm to combine these data sets and calculate the number of DSI related papers coming from institutions in each city of interest.</p>
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Table 5. Infrastructure (weighting = 15%)

Indicator name	Indicator description	Indicator or weight	Measure used	Year	Data source	Geographic granularity	Geographic coverage	Comments
Access to fast broadband and mobile internet	DSI initiatives are typically based around a mobile or web app and therefore access to affordable and fast broadband and mobile internet is essential to potential developers and users.	22.22%	Average mobile download speed (over 9 month period)	2019	<a href="#">Speedtest by Ookla</a>	City	All cities in index covered.	To aggregate the different data points used for this indicator, firstly the average mobile upload speed, download speed and latency (over a 9 month period) were normalised to be on the same scale and then combined by calculating the mean of these three variables for each city. This step was then repeated for broadband data. Finally, the aggregate for mobile was combined with the aggregate for broadband by calculating the mean of these two variables for each city.
			Average mobile upload speed (over 9 month period)	2019	<a href="#">Speedtest by Ookla</a>	City	All cities in index covered.	
			Average mobile latency (over 9 month period)	2019	<a href="#">Speedtest by Ookla</a>	City	All cities in index covered.	
			Average broadband download speed (over 9 month period)	2019	<a href="#">Speedtest by Ookla</a>	City	All cities in index covered.	
			Average broadband upload speed (over 9 month period)	2019	<a href="#">Speedtest by Ookla</a>	City	All cities in index covered.	
			Average broadband latency (over 9 month period)	2019	<a href="#">Speedtest by Ookla</a>	City	All cities in index covered.	
Access to flexible workspace	DSI initiatives often rely on shared and flexible office space as a place to work, hold meetings and network. Alongside this, flexible workspaces facilitate the exchange of ideas and collaboration between people with different skills and from different sectors.	22.22%	Number of co-working spaces (per capita).	2018	<a href="#">coworker.com</a>	City	All cities in index covered.	It is possible that the coworker.com platform is more popular in some parts of Europe than others which may cause bias in the number of coworking spaces reported for each city.

Openness of data	The accessibility and quality of open data (i.e. data which anyone is free to access, use, modify, and share) is important to the DSI community both because it can be used to help develop new products and services but also because the opening up of government data increases transparency which is generally seen to be a positive step for DSI.	22.22%	Score from the Global Open Data index, an index measuring how governments are publishing and using open data for accountability, innovation and social impact. The index is made up of themes covering readiness, implementation and emerging impact.	2016	<a href="#">Global Open Data Index</a>	Country	Missing data for Estonia (Tallinn).	Depending on who you talk to they will emphasise different aspects of what is important when it comes to open data. For example, while some will emphasise the quantity of data sources that are open and how often these are updated, others will see usability as being the most important thing. With this in mind, we decided to combine two different open data indexes which measure openness of data in different ways.
			Score from Open Data Barometer, an index measuring the openness of government data in the following categories: Budget, Spending, Procurement, Election results, Company register, Land ownership, National maps, Administrative Boundaries, Locations, National statistics, Draft legislation, National law, Air quality and Water quality	2016/2017	<a href="#">Open Data barometer</a>	Country	Missing data for Slovenia (Ljubljana), Lithuania (Vilnius), Romania (Bucharest, Cluj-Napoca) and Cyprus (Nicosia).	

Access to fabrication and manufacturing facilities	DSI includes hardware as well as software-based initiatives (particularly open hardware). For this reason, it is important that spaces are available where users and producers can access fabrication equipment such as 3D printers, laser cutters and milling stations allowing them to prototype, manufacture and co-create innovations. Examples of such spaces include makerspaces, Fab Labs, hackerspaces and DIY Biolabs.	11.11%	Number of Fablabs, DIYBio labs and Hackerspaces.	2018	<a href="http://diybio.org">diybio.org</a> / <a href="http://fablabs.io">fablabs.io</a> / <a href="http://hackerspaces.org">hackerspaces.org</a>	City	All cities in the Index covered in theory though we were unable to find any Fablabs, DIYBio labs or Hackerspaces in some cities.	Data was obtained using the <a href="#">makerlabs</a> Python library.
Presence of socially focussed business support	Accelerators and Incubators offer support to new ventures. The exact support offered varies, but may include workspace, training, networking opportunities, mentoring, funding or access to technical equipment. A growing number of accelerators and incubators have a focus on supporting socially focussed ventures.	16.67%	Number of socially focussed accelerators and incubators.	2018	<a href="http://F6S.com">F6S</a> / <a href="http://Crunchbase.com">Crunchbase</a> / <a href="http://Impactspace.com">Impactspace</a>	City	All cities in index covered in theory though for some cities we were unable to identify any socially focussed incubators or accelerators.	Socially focussed incubators and accelerators were identified on f6s by filtering by the 'market' tags: social innovation, social entrepreneur and social enterprise, and on Crunchbase by filtering for the 'categories' tags: social impact, impact investing, and social enterprise.
Ease of starting a business	While the most grassroots DSI initiatives may not have legal structures, it is almost always important if initiatives want to scale their impact and access funding. DSI will be more able to grow if it is easy, trusted and cheap to set up a business.	11.11%	Score from Starting a business sub - dimension of the Ease of doing business index.	2019	<a href="http://TheWorldBank.com">The World Bank - Ease of doing business index</a>	Country	Countries of all cities included in the index are covered.	This variable measures the number of procedures, time, cost and paid-in minimum capital requirement for a small- to medium-size limited liability company to start up and formally operate in each economy's largest business city.

Table 6. Funding (weighting = 15%)

Indicator name	Indicator description	Indicator or weight	Measure used	Year	Data source	Geographic granularity	Geographic coverage	Comments
Availability of Seed Grant Funding	Access to relatively small amount of grant funding is needed get early stage initiatives off the ground. Here we are talking about grants of less than €200,000.	16.67%	Response to survey question asking the extent to which respondents agree or disagree that it is relatively easy for a promising DSI initiative to access grant funding in the first years of operation (anywhere up to around €200,000).	2019	Primary research	Country	Missing data for Denmark (Aarhus, Copenhagen), Slovakia, Czech Republic (Prague), Finland (Helsinki), Slovenia (Ljubljana), Estonia (Tallinn), Latvia (Riga), Austria (Vienna) and Lithuania (Vilnius).	<p>As above, city-level data would have been preferable but due to the relatively small number of survey respondents, this was not possible.</p> <p>Only data from countries which had at least 3 survey responses were included. This means that unfortunately country coverage was not particularly good for this variable.</p> <p>Furthermore, the threshold of 3 responses for inclusion is quite low. This means for some countries the averages calculated for this variable were generated from a relatively small number of data points.</p> <p>The €200,000 cut-off used is relatively arbitrary. A potential issue with this is that this amount of money will go significantly further in some cities than others.</p>

Availability of Major Grant Funding	Access to larger grants is needed to fund established DSI initiatives to scale their project and impact. Here we are talking about grants of more than €200,000.	8.33%	Percentage of total EU structural funds going to ICT projects	2018	<a href="#">European Commission Structural &amp; Investment Funds Data</a>	Country	Data is missing for Denmark (Aarhus, Copenhagen), Netherlands and Belgium (Brussels).	<p>Decisions about the allocation of structural funds to individual projects are taken within member states. The percentage of total EU structural funds going to ICT projects may thus give an indication of a region's dedication to supporting ICT projects through grants. While ICT as a theme is broader than DSI, the majority of the ICT project stories presented on the European Commission website as being funded by structural funds appear to fit under our definition of DSI</p> <p>The €200,000 cut-off used is relatively arbitrary. A potential issue with this is that this amount of money will go significantly further in some cities than others.</p>
Flexibility of funding	Flexible funding allows agile product and service development. Given the bottom-up and collaborative nature of DSI, it is also important for small organisations, citizen groups and collaborative projects to access funding, rather than just large organisations.	25%	Response to survey question asking the extent to which respondents agree or disagree that funding available through grants, loans, equity and other mechanisms tends to be open and accessible to small organisations and collaborative projects and allows for flexible product and service design.	2019	Primary research	Country	Missing data for Denmark (Aarhus, Copenhagen), Slovakia (Bratislava), Czech Republic (Prague), Finland (Helsinki), Slovenia (Ljubljana), Estonia (Tallinn), Latvia (Riga), Austria (Vienna) and Lithuania (Vilnius).	<p>As above, city-level data would have been preferable but due to the relatively small number of survey respondents, this was not possible.</p> <p>Only data from countries which had at least 3 survey responses were included. This means that unfortunately country coverage was not particularly good for this variable.</p> <p>Furthermore, the threshold of 3 responses for inclusion is quite low. This means for some countries the averages calculated for this variable were generated from a relatively small number of data points.</p>

Availability of impact investment	Impact investors can, in return for equity or debt, provide the investment needed to enable DSI initiatives to grow their project and impact. Alongside the funding offered, impact investors will often also provide mentoring and guidance helping DSI initiatives to build a sustainable business model. Impact investors include institutions (e.g. venture capitalists, foundations and corporations) as well as individuals (e.g. business angels).	25%	Number of organisations working in the impact investment sector (per capita; includes impact funds, angels networks, banks and corporates that make impact investments, investment fund managers and other capital channels & intermediaries)	2018	<a href="#">Impact Space</a> / <a href="#">Crunchbase</a> / <a href="#">E6S</a>	City	All cities in the Index covered in theory but we were unable to find any DSI related grants going to organisations in some cities.	Impact investors were identified on f6s by filtering by the 'market' tags: social innovation, social entrepreneur and social enterprise, and on Crunchbase by filtering for the 'categories' tags: social impact, impact investing, and social enterprise.
Willingness of public and social sector procure from SMEs	Accessing procurement and commissioning is often the only way in which DSI initiatives are able to deliver at scale (particularly in fields where the public sector holds a monopoly, such as in healthcare, education and employment support). In turn, DSI has the potential to enable public services to be delivered more efficiently and to involve citizens as co-creators rather than just users of services.	25%	Proportion of money spent by local or regional authority contractors that is going to SMEs	2017	<a href="#">European Commission Tenders Electronic Daily (TED)</a>	City	All cities in index covered in theory but we were unable to find any DSI related grants going to organisations in some cities.	This data source is likely to exclude a large number of contracts that are made as part of smaller projects which fall below the minimum value thresholds which necessitate publication throughout the EU. Furthermore, governments - and departments of governments - vary significantly in their adherence to best practice and laws on open procurement.

Table 7. Diversity and Inclusion (weighting = 15%)

Indicator name	Indicator description	Indicator weight	Measure used	Year	Data source	Geographic granularity	Geographic coverage	Comments
Diversity within the tech sector	Diversity and inclusion of different genders, sexes, ethnicities, sexual orientations, abilities are important for innovation, as they bring a wider range of interests, experiences, backgrounds and ideas. Greater diversity in the tech world suggests more progressive practices and a more inclusive culture. Diversity and inclusion is particularly important for DSI as minority groups are often more likely to have lived experience of social challenges which DSI tries to tackle.	22.22%	Percentage of founders of tech firms that are female.	2018	<a href="#">CrunchBase</a>	City	All cities in index are covered.	We acknowledge that gender diversity and education level (used as proxy for socioeconomic status) are not the only important forms of diversity to consider. However, to our knowledge data on other forms of diversity (such as age, religion, race and ethnicity, sexual orientation and disability) in the tech sector are not available at the level needed for this index.
			Percentage of founders of tech firms that do not hold a degree minus percentage of regions population that do not hold a degree (tertiary education).	2018	<a href="#">CrunchBase</a>	City	All cities in index are covered.	Here we use education level as a proxy for socioeconomic status. A potential challenge with this measure is that it relies on founders reporting their educational attainment. This means that percentages not holding degree reported here are likely to be considerably smaller than the true number.
These two measures were combined to create one indicator by first normalizing both variables to be within the same 0.1 to 0.9 scale and then calculating the mean of the two variables.								

Diversity within civil society	A lack of diversity hinders innovation. A more diverse workforce means a wider range of interests, experiences, and backgrounds to draw upon. This leads to a better understanding of potential users and beneficiaries.	22.22%	Aggregated score given by panel of experts to question: "Are women prevented from participating in civil society organizations (CSOs)? 0: Almost always. 1: Frequently. 2: About half the time. 3: Rarely. 4: Almost never"	2017	<a href="#">V-Dem</a>	Country	Countries of all cities included in the index are covered.	As mentioned previously gender diversity is not the only important form of diversity to consider. However, to our knowledge data on other forms of diversity (such as age, religion, race and ethnicity, sexual orientation and disability) in the civil society sector are not available at the level needed for this index.
			Response to survey question asking the extent to which respondents agree or disagree that its civil society sector is diverse and inclusive in terms of gender, age, ethnicity, sexual orientation and ability.	2019	Primary research	Country	Missing data for Denmark (Aarhus, Copenhagen), Slovakia, Czech Republic (Prague), Finland (Helsinki), Slovenia (Ljubljana), Estonia (Tallinn), Latvia (Riga), Austria (Vienna) and Lithuania (Vilnius).	As above city-level data would have been preferable but due to the relatively small number of survey respondents, this was not possible.  Only data from countries which had at least 3 survey responses were included. This means that unfortunately country coverage was not particularly good for this variable.  Furthermore, the threshold of 3 responses for inclusion is quite low. This means for some countries the averages calculated for this variable were generated from a relatively small number of data points.
			These two measures were combined to create one indicator by first normalizing both variables to be within the same 0.1 to 0.9 scale and then calculating the mean of the two variables.					

Inclusivity of innovation	Digital innovation has the potential to improve the welfare of disadvantaged groups and minorities but can also lead to winner-takes-all markets which might increase inequality. At the same time, as DSI works to address social challenges - which are often experienced most acutely by disadvantaged groups and minorities - and is bottom-up, it is more likely to grow in an environment where all segments of society are able and encouraged to innovate. Places with policies and initiatives that aim to bring underrepresented groups into innovation (such as targeted grants, entrepreneurship education and extra-curricular outreach for young people) may provide a larger, more representative pool of innovators to develop and grow DSI initiatives.	22.22%	Percentage of respondents having participated in any course or activity relating to entrepreneurship at school.	2012	<a href="#">Flash Eurobarometer 354</a>	Varies (NUTS1 / NUTS2 / NUTS3)	All but Zagreb's region covered.	Entrepreneurship education is just one way that governments and other funders can promote inclusive innovation, however, we believe that it is a good indicator that it is something that is being taken seriously in a region. We tried to find additional data on the presence of targeted grants however, to our knowledge this does not exist in aggregate. Unfortunately, the data used for this indicator is relatively old (2012) so it may not capture more recent changes to regions' entrepreneurial education strategies.
Digital inclusion	Digital inclusion and digital skills among the population are important for DSI to grow. Firstly, target groups of DSI are often disadvantaged groups, who are also most likely to be digitally excluded. Secondly, for DSI to deliver impact equitably it must be open and accessible to everyone, regardless of age, ethnicity, ability, gender, income or location. Thirdly, a more digitally-skilled population is likely to be more innovative.	33.34%	Score for basic skills and usage Sub dimension of human capital dimension of DESI index	2018	<a href="#">DESI</a>	Country	Countries of all cities included in the index are covered.	The basic skills and usage sub-dimension captures information about whether the population are able to use the internet and uses it on a regular basis and whether they possess at least a basic level of digital skills in at least one of four Digital Competence domains: information, communication, content-creation or problem-solving. This, we think, is a good measure of the amount of the population that have the potential to benefit from (or even develop) DSI projects.

## 2.3 Data checking

### 2.3.1 Treatment of outliers

Index building is based on a benchmarking principle where baseline values considerably influence a city or country's index score as well as its rank. The presence of outliers may result in an inappropriate benchmark and must therefore be dealt with before the index can be constructed.

Outliers were identified as values which are more than 1.5 times the interquartile range (IQR) above the upper quartile or below the lower quartile. Large outliers were transformed to have the same value as the highest existing value in that variable which falls within the thresholds outlined above. Small outliers were transformed to have the same value as the lowest existing value in that variable which falls within the thresholds outlined above. Twenty-nine out of the 49 variables used in the index contained at least one outlier.

### 2.3.2 Normalisation

Indicators will have different measurement units and scales of magnitude. Data must therefore be normalised so that different indicators are on the same scale before they can be aggregated into the composite index. We used a simple min-max normalisation method with which we transformed variables to within an identical [0.1, 0.9] range using the equation below.<sup>35</sup>

*Equation 1. Min-max Normalisation [0.1, 0.9]*

$$Z_{i,j} = \frac{(0.9-0.1)(x_{i,j}-\min(x_j))}{((\max(x_j)-\min(x_j))+0.1)}$$

where  $z_{i,j}$  is the normalised value for city  $i$  and variable  $j$ ?

$x_{i,j}$  is the original value for city  $i$  and variable  $j$

$\max(x_j)$  is the maximum value for variable  $j$

$\min(x_j)$  is the minimum value for variable  $j$

### 2.3.3 Imputation of Missing Data

In order for the Index to fairly compare cities on a like for like basis, we require a complete data set with the same data points for every region. However, the geographical coverage of economic and demographic datasets is often

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<sup>35</sup> Data was normalised to a [0.1, 0.9] scale rather than a [0, 1] scale to allow the possibility of using a geometric mean aggregation of indicators, though ultimately we decided to use an arithmetic aggregation of indicators.

incomplete. Although the number of overall missing values was generally low (4%), of the 32 indicators included, 9 indicators (28%) had missing data for at least one of the 60 cities.

Where possible, our first approach was to try and find another data source which is more complete. When this was not possible, we used multiple regression to assign (or ‘impute’) estimates to missing values. In order to perform imputation, predicted values were calculated using the iterative imputer function in the [fancyimpute](#) Python library. Where data was missing for a particular variable, predicted values were computed using the other indicators in the same dataset as explanatory terms. In order to take into account uncertainty about the missing data, five predictions were made and a mean of these five values replaced the missing value.

In the later sensitivity analysis stage, we tested the effect of regression imputation by recreating the index, replacing missing data with the mean of the other variables in that theme obtained for that city, as was used in the European Digital City Index<sup>36</sup> (i.e. ‘theme mean imputation’).

## 2.4 Data processing

### 2.4.1 Factor analysis

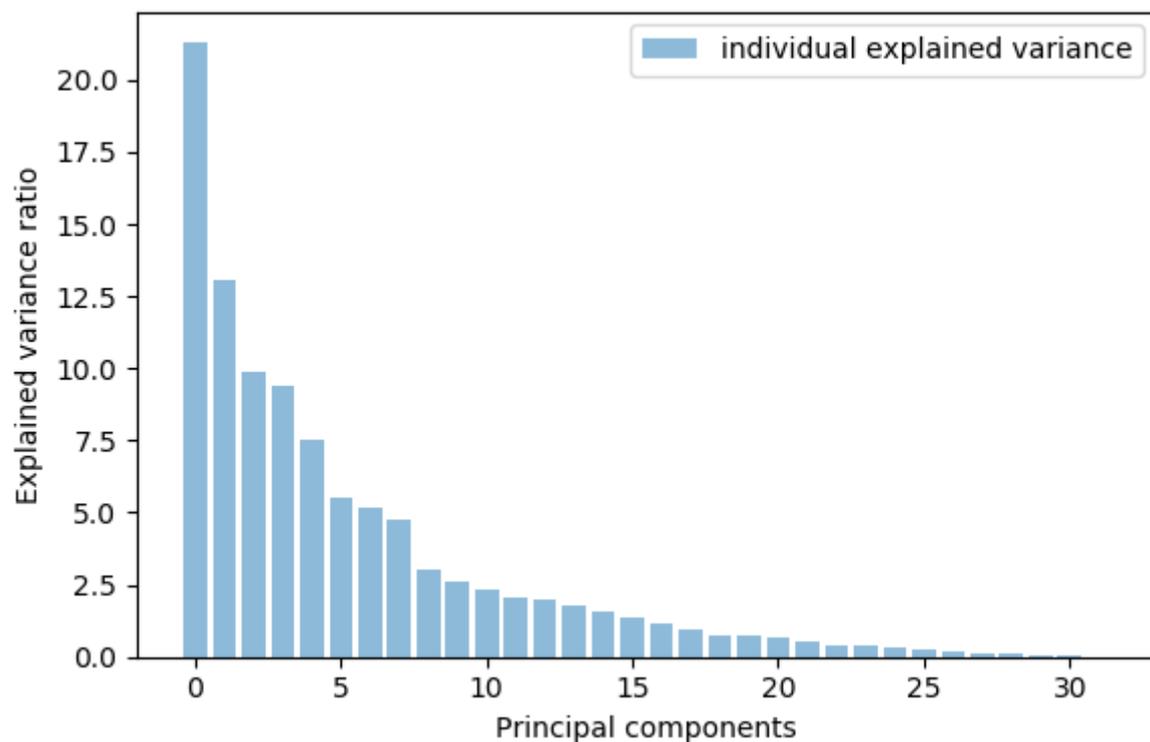
We assessed the overall structure of the data collected and processed using Principal Components Analysis (PCA)<sup>37</sup>. PCA helps reveal how different indicators change in relation to each other and how they are associated. This can help us decide whether the way we have grouped indicators into ‘Themes’ makes sense from a statistical point of view. We chose to describe the data using 7 principle components, because after 7 there is a large decrease in the amount of explained variance that each extra component adds (figure 3).

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<sup>36</sup> <https://digitalcityindex.eu/>

<sup>37</sup> PCA was conducted using the [scikit-learn](#) python library.

Figure 3. Variance explained by each principal component



These 7 components together explain 72% of the variance in the data. Only component loadings of more than 0.15 (or less than -0.15) were considered high enough to be taken into consideration when interpreting the results of this analysis. When indicators have high loadings within the same component, this indicates that those indicators are correlated.

We found some, but relatively low, similarity between the themes laid out in the theoretical framework stage and the statistical components calculated by the PCA (see Appendix 3 for PCA loadings). Component one of the PCA contains four out of six of the indicators in the 'Civil Society' theme suggesting that these indicators vary together and thus, make sense to be grouped under the same theme. However, the indicators 'Public advocacy for DSI (e.g from political / leading figures)' and 'Presence of supportive government policy for social purpose initiatives', which are also in the Civil Society theme carry a low loading weight in component one. Public advocacy for DSI appears to instead be correlated with indicators related to funding. This is perhaps unsurprising as more funding is likely to be available in cities in which there is public advocacy for DSI and civil society more generally (and vice versa). While it may have made sense statistically to move the Public advocacy for DSI indicator into the Funding theme, conceptually it was thought to fit better under the civil society theme.

Component two contains four out of five indicators in the 'Skills' theme. In an early version in the development of the index, the 'Presence of research institutions with expertise in DSI' indicator was grouped in the 'Infrastructure' theme but was later moved into the skills theme as a result of insights from this PCA and because this was thought to also make more sense conceptually.

'Availability of Seed Grant Funding', 'Availability of Major Grant Funding' and 'Flexibility of funding' all carry relatively high loadings in component 3. However, the other two indicators in the Funding theme, 'Availability of impact investment' and 'Willingness of public and social sector to procure from startups', do not— in fact they carry small but negative loadings. While from a statistical point of view these may, thus, fit better under a different theme, as they are both clearly related to funding, the decision was made not to move them.

The other components (4 - 7) extracted through the PCA fit less clearly with our conceptual themes than components 1-3.

## 2.4.2 Aggregation method

The next stage involved combining individual indicators into a composite index score. We decided to first combine indicators within the same theme to give theme scores and then to aggregate these theme scores to produce an overall index score by which cities could be ranked. The benefits of this are two-fold. Firstly, it means that themes that contain more variables were not automatically more influential to the final index score than those with fewer variables. Secondly, alongside the overall index scores we can present theme scores for each city. This makes it easier for users to understand a given city's score, in turn increasing its utility as a diagnostic tool.

During the framework development stage, we initially decided that themes and indicators should be aggregated in a non-compensatable fashion, meaning that a low score for one indicator or theme cannot be completely offset by a high score in another. In later discussions we decided that due to uncertainty around the reliability of individual indicators, it would be more sensible to allow compensability between individual indicators but not between themes.

In order to have compensability between indicators but not between themes, we aggregated indicators into themes using an arithmetic mean (commonly referred to as just a 'mean'; equation 2) and then aggregated themes into the final index score using a geometric mean (equation 3). Table 8 shows the overall city scores and rankings after weighting and aggregation.

Equation 2. Weighted arithmetic mean aggregation of indicators into theme scores

$$TS_{i,k} = \frac{\sum_{j=1}^J w_j z_{i,j}}{\sum_{j=1}^J w_j}$$

where  $TS_{i,k}$  is the aggregated theme score for city  $i$  and theme  $k$

$w_j$  is the weight given to variable  $j=1,\dots,J$

$z_{i,j}$  is the normalised value for city  $i$  and variable  $j=1,\dots,J$

Equation 3. Weighted geometric mean aggregation of theme scores into overall index score

$$IS_i = \left( \prod_{k=1}^K TS_{i,k}^{w_k} \right)^{1/\sum_{k=1}^K w_k}$$

where  $IS_i$  is the aggregated Index score for city or country  $i$

$w_k$  is the weight given to theme  $k=1,\dots,K$

$TS_{i,k}$  is the aggregated theme score for city or country  $i$  and theme  $k=1,\dots,K$

In the sensitivity analysis stage, we tested the effect of this aggregation method by recreating the index using all four combinations of arithmetic and geometric means to aggregate themes and indicators.

Table 8. Overall index scores and ranking of cities.

Rank	City	Score	Ranking	City	Score
1	London	0.777139	31	Ljubljana	0.428818
2	Amsterdam	0.69528	32	Lisbon	0.421566
3	Copenhagen	0.690727	33	Warsaw	0.41667
4	Stockholm	0.670986	34	Riga	0.413653
5	Paris	0.644413	35	Nice	0.409271
6	Madrid	0.626422	36	Cologne	0.405652
7	Brussels	0.612147	37	Prague	0.405016
8	Utrecht	0.603621	38	Karlsruhe	0.400701
9	Barcelona	0.590179	39	Bilbao	0.396394
10	Edinburgh	0.57726	40	Dresden	0.389127
11	Helsinki	0.565405	41	Stuttgart	0.386717
12	Rotterdam	0.557633	42	Hamburg	0.37892
13	Bristol	0.544807	43	Porto	0.369996
14	Eindhoven	0.542584	44	Leipzig	0.369008
15	The Hague	0.541183	45	Dusseldorf	0.367805
16	Malmo	0.540493	46	Vilnius	0.363161
17	Berlin	0.538464	47	Nicosia	0.362666
18	Dublin	0.524754	48	Bratislava	0.358211
19	Manchester	0.513389	49	Dortmund	0.3578
20	Vienna	0.511969	50	Tallinn	0.340155
21	Gothenburg	0.510701	51	Budapest	0.325167
22	Ghent	0.481605	52	Krakow	0.323216
23	Aarhus	0.476707	53	Rome	0.301632
24	Birmingham	0.476147	54	Milan	0.292907
25	Munich	0.466244	55	Bucharest	0.260599
26	Lyon	0.46523	56	Cluj-Napoca	0.224868
27	Belfast	0.457384	57	Turin	0.219127
28	Toulouse	0.441463	58	Sofia	0.218005
29	Marseille	0.436658	59	Athens	0.20998
30	Frankfurt	0.432685	60	Zagreb	0.185228

### 2.4.3 Cluster analysis

Cluster analysis is a descriptive tool which can be used to group data based on similarities/dissimilarities between cases. We used cluster analysis to give us some insight into which cities scores similarly across themes.

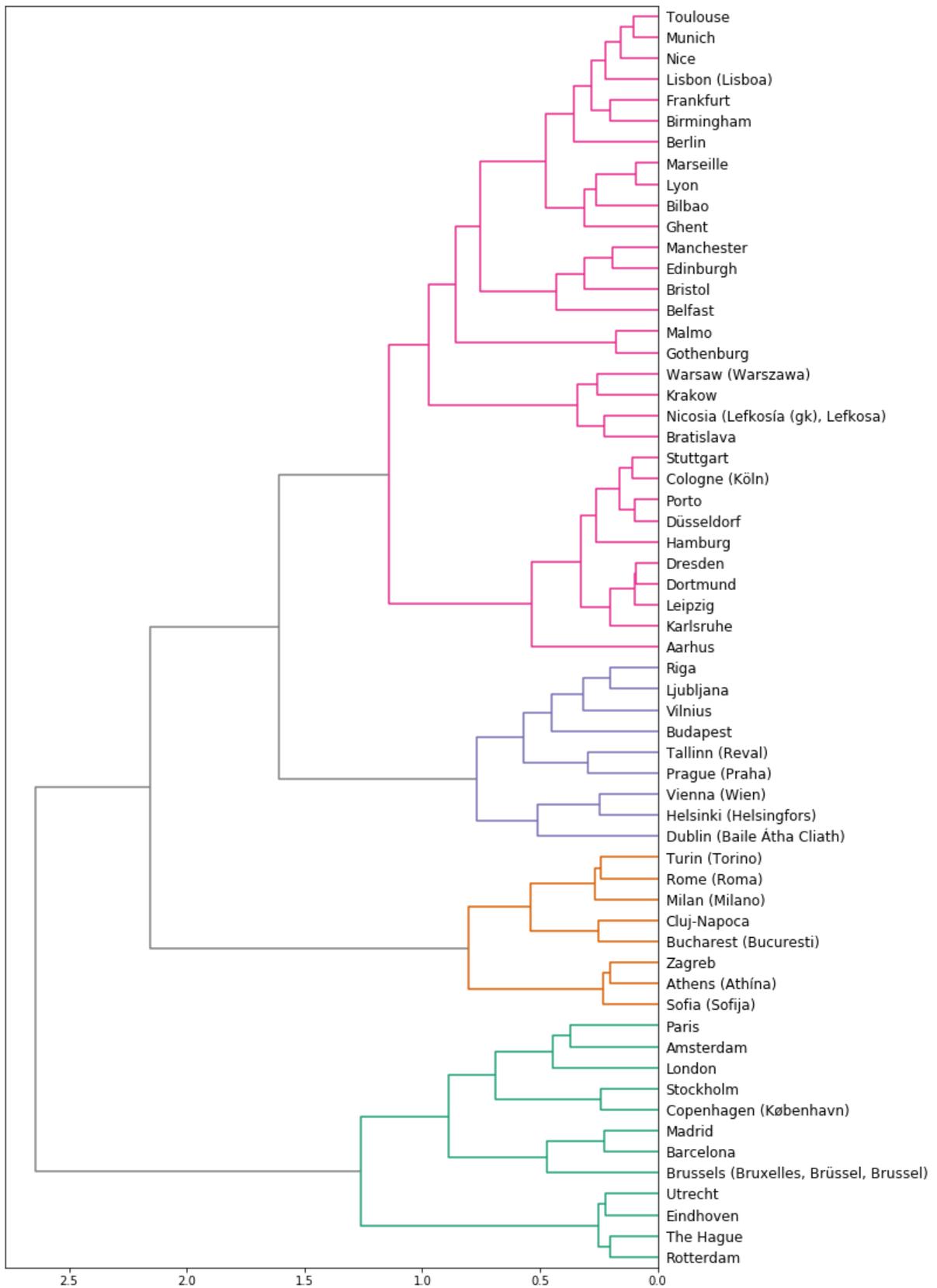
We used a hierarchical classification because we did not know the number of clusters there should be a priori. There are several clustering algorithms that can be used to categorise data based on the distance between data points. For all methods, a small distance is equivalent to a strong similarity. We use 'ward' as the method since it minimises the variants of distances between the clusters.

Deciding on the optimum number of clusters is largely subjective, although looking at the plot of linkage distance can be a useful guide. In this case, there is a sudden jump in the level of similarity among the 60 cities at a linkage distance of 1.5, indicating that the cities are best represented by four clusters (figure 4).

We noted the following four clusters:

- 1) Ljubljana, Vilnius, Budapest, Prague, Vienna, Riga, Dublin, Helsinki and Tallinn. Except for Dublin and Helsinki all these cities are situated in the Baltics or Central Europe. These cities take middle to bottom ranks in the index and generally excel in the skills theme but fall short in collaboration.
- 2) Cluj-Napoca, Bucharest, Zagreb, Athens, Sofia, Turin, Rome and Milan. These cities are all situated in South and Eastern Europe. They all rank towards the bottom of the index. They typically score particularly low for diversity and inclusion but do relatively well for skills.
- 3) Toulouse, Bilbao, Belfast, Karlsruhe, Leipzig, Dortmund, Dresden, Munich, Nice, Ghent, Düsseldorf, Frankfurt, Aarhus, Lisbon, Porto, Birmingham, Manchester, Berlin, Marseille, Lyon, Bristol, Edinburgh, Gothenburg, Warsaw, Krakow, Nicosia, Bratislava, Malmo, Hamburg, Cologne and Stuttgart. These cities are spread throughout the middle ranks of the index. They are spread throughout Europe geographically. They generally score relatively high on civil society, collaboration and diversity and inclusion, but fall behind on infrastructure and skills.
- 4) Amsterdam, London, Utrecht, Eindhoven, Rotterdam, The Hague, Barcelona, Madrid, Paris, Brussels, Copenhagen and Stockholm. These cities are situated in Western Europe. They all sit within top 15 ranks in the index and generally score highly across all six themes.

Figure 4. Dendrogram showing the relationship between cities determined through cluster analysis



#### 2.4.4 Theme correlations

In order to test the correlation between themes, we calculated theme by theme Pearson correlation coefficients. We find that there is a moderate positive correlation between several themes. The strongest positive correlations exist between the Collaboration and Civil Society themes and between the Civil Society and Funding themes (table 9). These correlations can be explained conceptually. For example, the collaboration theme contains indicators which relate to the collaboration between civil society and the tech sector and government; without a developed civil society such collaborations would not be possible. Further to this, civil society is more likely to become developed where there is funding available to support it and vice versa.

Although the themes all have a distinct focus, they all contain indicators that are clearly relevant to socially-focussed projects e.g. funding contains indicators related to grants and impact investing, and infrastructure contains indicators related to socially-focussed accelerators and incubators. It is perhaps unsurprising then that the Civil Society theme has a moderately strong positive correlation with four out of five of the other themes. Interestingly, the Skills theme has very little correlation with the other themes. This may be explained by the fact that this theme has little focus on skills normally associated with socially-focussed projects or civil society more generally. Diversity and Inclusion was also less heavily correlated with other themes.

Table 9. Theme by theme correlations

	Civil society	Collaboration	Diversity and Inclusion	Funding	Infrastructure	Skills
Civil society	1					
Collaboration	0.51	1				
Diversity and Inclusion	0.408	0.1	1			
Funding	0.447	0.368	0.326	1		
Infrastructure	0.405	0.571	0.132	0.628	1	
Skills	0.099	-0.089	0.232	0.295	0.404	1

We also investigated the correlation between themes scores and the overall index scores cities received. These correlations will of course largely be the result of the weighting themes were given in the index, so we were looking for correlations that stand out even when taking weightings into account (Table 10).

Unsurprisingly, all theme scores have a moderately strong correlation with overall index score. However, for Skills, and Diversity and Inclusion this correlation is weak relative to the other themes. This is a result of these themes being less strongly correlated with the other themes. Civil Society and Infrastructure on the other hand are highly correlated with the overall index score and with the other themes.

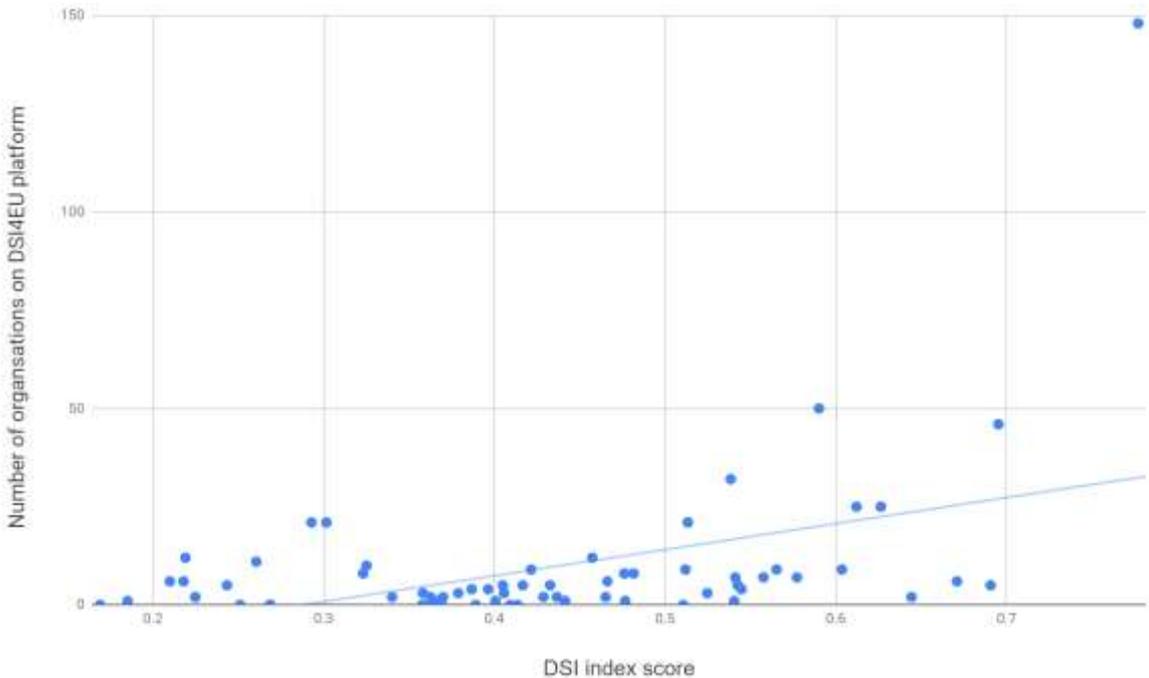
Table 10. Theme correlations with overall index score

Theme	Civil Society	Collaboration	Diversity and Inclusion	Funding	Infrastructure	Skills
Correlation with overall index	0.724	0.631	0.5	0.756	0.809	0.51
Weighting	20	17.5	15	15	15	17.5

### 2.4.5 Index validation

As a means of validating the index we compared cities' scores with the number of DSI organisations located in each city that have entered their information onto the [DSI4EU platform](#) (figure 5). Although we would expect some positive correlation between these two variables, we would not expect them to correlate exactly as they are not measuring the same thing. The EDSII is trying to measure the conditions which support DSI whereas the DSI4EU map is mapping DSI activity itself. Having the right conditions in place for DSI does not necessarily translate into high DSI activity. This is case for many possible reasons: for example, DSI (like social innovation more broadly) is often reactive to social challenges (such as inequality or corruption), so cities with supportive conditions for DSI but fewer or less serious social challenges may have less DSI activity than cities where the conditions are not as supportive but where there are many social challenges which demand solutions. Another reason is that the Index measures systemic conditions but does not take into account specific DSI-focused policies and initiatives taken by government.

Figure 5. Comparison of EDSII scores and number of organisations on the DSI4EU platform for each city.



We found there to be a weak to moderate positive correlation (Pearson correlation coefficient,  $r = 0.45$ ). This is perhaps less of a correlation than we would have expected, even bearing in mind the differences outlined above. We explore some of the possible reasons for this below.

Where it was thought that indicators would be affected by size-related factors, such as the population or purchasing power of the city or country, indicators were scaled to account for differences in these factors. As a final check whether the final score was affected by such factors, we tested whether there was a correlation between city population and the overall index score. We found that there was only a very small positive correlation (Pearson correlation coefficient,  $r = 0.19$ ), suggesting that our scaling of indicators was effective .

## 3. Sensitivity analysis

To understand the impact of the methodology decisions made, we tested the effect of the following:

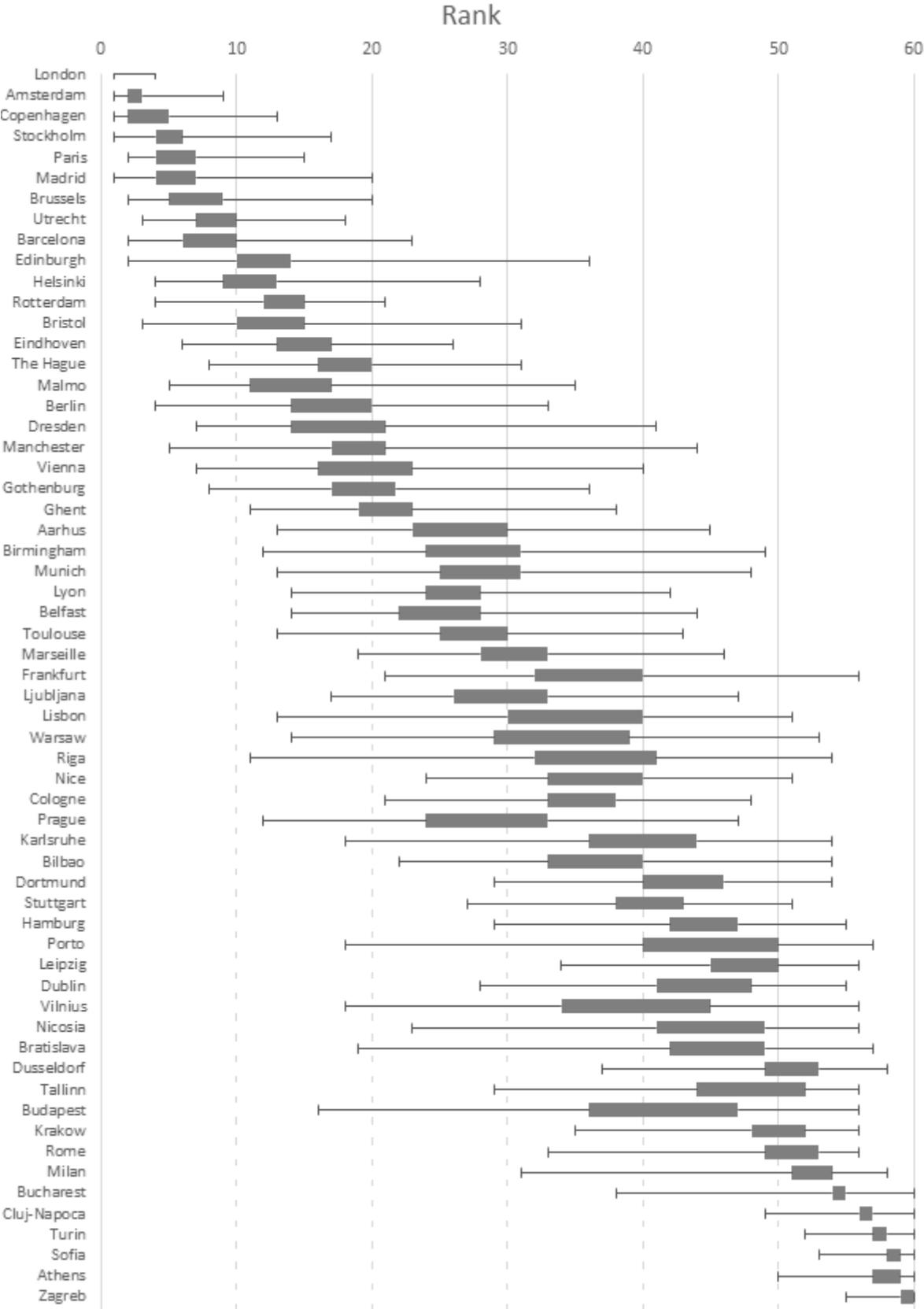
- Variable Selection - The effect of discarding a variable
- Outlier treatment - The effect of transforming outliers to the same value as the closest non-outlying value
- Imputation method - The effect of using multiple imputation rather than theme mean imputation to account for missing data
- Aggregation method - The effect of using geometric (variable) / geometric (theme) rather than arithmetic (variable) / geometric (theme) aggregation.
- Weight Selection - The effect of varying weightings of variables.

### 3.1 Indicator Selection

The aim of this analysis was to determine whether a single indicator had an excessively large impact on the overall ranking. To test this, we ran a Monte Carlo simulation that tested the effect of sequentially and randomly excluding indicators from the index. The results of this simulation are shown in figure 6. The wider the box and whisker, the more variable that city's rank is when indicators are removed.

In general, the top ranking and bottom ranking cities were the least sensitive to changes in the index composition with middle ranking cities being more sensitive (figure 6). London was particularly robust to changes in the indicator composition, ranking first in nearly all of the combinations tested. Helsinki, Tallinn and Dublin were particularly sensitive to which variables were included in the Index. Nevertheless, this analysis shows that the ranking is relatively stable, even to major changes in indicator composition.

Figure 6. Box and whisker diagram showing the impact of randomly removing indicators on the rank. Box = interquartile range; whiskers = range.



## 3.2 Treatment of outliers

It is often not possible to determine whether outliers are the result of a mistake during data collection or just an indication of variance in the data. It is, therefore, debatable whether outliers should be treated. We tested the effect of transforming outliers to the same value as the closest non-outlying value by recreating the index without treating outliers (see 'Rank with outliers' of table 11).

London and Paris remained in first and second position when outliers were untreated. Zagreb remained in last position and most of the bottom 10 positions remained relatively unchanged. A few cities, however, ranked considerably worse when outliers were not removed, such as Madrid, Barcelona, Brussels and Helsinki. This indicated that these cities had some low outliers which when treated improved their scores. Others did considerably better when outliers were not treated e.g. Birmingham, Berlin and Vienna, suggesting that these cities had high outliers that when treated decreased their scores. In general, however, while there are several small changes throughout the ranking, most cities did not move considerably.

*Table 11. City; rankings when index re-made without treating outliers, without imputing missing values, without weighting indicators, and with different methods for aggregating data. Green cells represent higher rankings compared to the final index, red cells represent lower rankings and yellow cells represent equal rankings.*

City	Index rank	Rank with outliers	Rank with theme mean imputation	Rank with equal weightings	Rank with geo-geo aggregation	Rank with arith-arith aggregation	Rank with geo-arith aggregation
London	1	1	1	1	1	1	1
Amsterdam	2	2	2	2	4	2	2
Copenhagen	3	4	15	19	2	13	13
Stockholm	4	6	4	4	11	5	5
Paris	5	3	3	3	6	3	3
Madrid	6	12	9	7	8	8	8
Brussels	7	15	13	11	18	18	18
Utrecht	8	5	5	5	7	4	4
Barcelona	9	18	14	9	16	16	16
Edinburgh	10	9	12	12	10	12	12
Helsinki	11	26	26	25	3	26	26
Rotterdam	12	8	7	10	14	7	7

Bristol	13	11	8	6	20	6	6
Eindhoven	14	14	11	15	21	11	11
The Hague	15	13	10	14	17	9	9
Malmo	16	19	17	16	29	14	14
Berlin	17	7	6	8	13	10	10
Dublin	18	24	21	18	27	21	21
Manchester	19	17	16	13	25	15	15
Vienna	20	10	30	28	5	38	38
Gothenburg	21	20	18	17	28	17	17
Ghent	22	33	33	30	40	41	41
Aarhus	23	25	41	43	9	42	42
Birmingham	24	16	20	22	30	23	23
Munich	25	28	23	26	26	25	25
Lyon	26	21	25	23	23	27	27
Belfast	27	23	22	20	31	19	19
Toulouse	28	22	19	21	32	20	20
Marseille	29	27	24	24	34	22	22
Frankfurt	30	30	28	31	36	28	28
Ljubljana	31	42	55	54	15	53	53
Lisbon	32	43	40	38	48	40	40
Warsaw	33	45	43	45	38	45	45
Riga	34	41	53	52	22	51	51
Nice	35	29	27	27	33	29	29
Cologne	36	34	32	33	37	31	31
Prague	37	52	50	48	12	50	50
Karlsruhe	38	31	29	29	39	24	24
Bilbao	39	40	38	32	46	37	37
Dresden	40	32	31	36	45	33	33
Stuttgart	41	37	34	35	41	34	34
Hamburg	42	38	35	37	44	35	35
Porto	43	46	42	41	51	39	39
Leipzig	44	35	37	39	43	32	32
Dusseldorf	45	36	36	34	42	30	30
Vilnius	46	44	57	55	24	55	55
Nicosia	47	48	44	42	53	43	43
Bratislava	48	47	58	57	35	58	58

Dortmund	49	39	39	40	47	36	36
Tallinn	50	49	51	51	19	46	46
Budapest	51	50	45	44	50	44	44
Krakow	52	51	48	49	52	47	47
Rome	53	53	47	47	55	49	49
Milan	54	54	46	46	54	48	48
Bucharest	55	55	49	50	59	52	52
Cluj-Napoca	56	56	54	56	60	57	57
Turin	57	57	56	58	56	54	54
Sofia	58	59	59	59	49	59	59
Athens	59	58	52	53	57	56	56
Zagreb	60	60	60	60	58	60	60

### 3.3 Imputation method

We tested the effect of using multiple imputation on missing values rather than using the simpler method of replacing missing data with the mean value of the other indicators in the same theme for that city ('theme mean imputation'). The imputation method used obviously has the largest effect on those cities with a lot of missing data.

London and Paris remained in first and second position when theme mean imputation was used and Zagreb remained in last position (see 'Rank with theme mean imputation' column of Table 11). Copenhagen, which was in third position, moves to 15th position when theme mean imputation is used. Aarhus and Helsinki also rank considerably worse when theme imputation is used (23rd to 40th position and 11th to 26th position, respectively). For most cities, however, rankings only change slightly.

### 3.4 Aggregation method

We used an arithmetic mean to aggregate indicators and geometric mean to aggregate themes. The use of geometric or arithmetic means to aggregate indicators and themes each have their own benefits, so we tested the effect that this decision had on rankings (Table 11). To do this we re-created the index using: arithmetic means to aggregate both indicators and themes (see 'Rank with arith-arith aggregation' column), geometric means to aggregate both indicators and themes ('Rank with geo-geo aggregation'), and a geometric mean to aggregate

indicators and an arithmetic mean to aggregate themes (‘Rank with geo-arithmetic aggregation’).

London remained in first position and most cities only experienced small changes in ranking with different aggregation methods. With geometric aggregation, compensability is lower for the composite indicator or themes with low values. This means that when using a geometric aggregation, a city with a low score for one indicator or theme will need a much higher score on the others to improve its score. Therefore, cities with one or a few very low scores experienced the largest effect of changing from arithmetic to geometric aggregation of indicators. Brussels, for example, moved from 8th to 18th position when geometric aggregation was used.

Similarly, using arithmetic rather than geometric aggregation of themes will improve the ranking of cities which fall behind on a particular theme. Generally, this appears to have less of an effect than changing the indicator aggregation method. However, some cities did experience considerably better rankings, Karlsruhe for example moved from 38th to 24th position when arithmetic aggregation of means was used.

### 3.5 Weight Selection

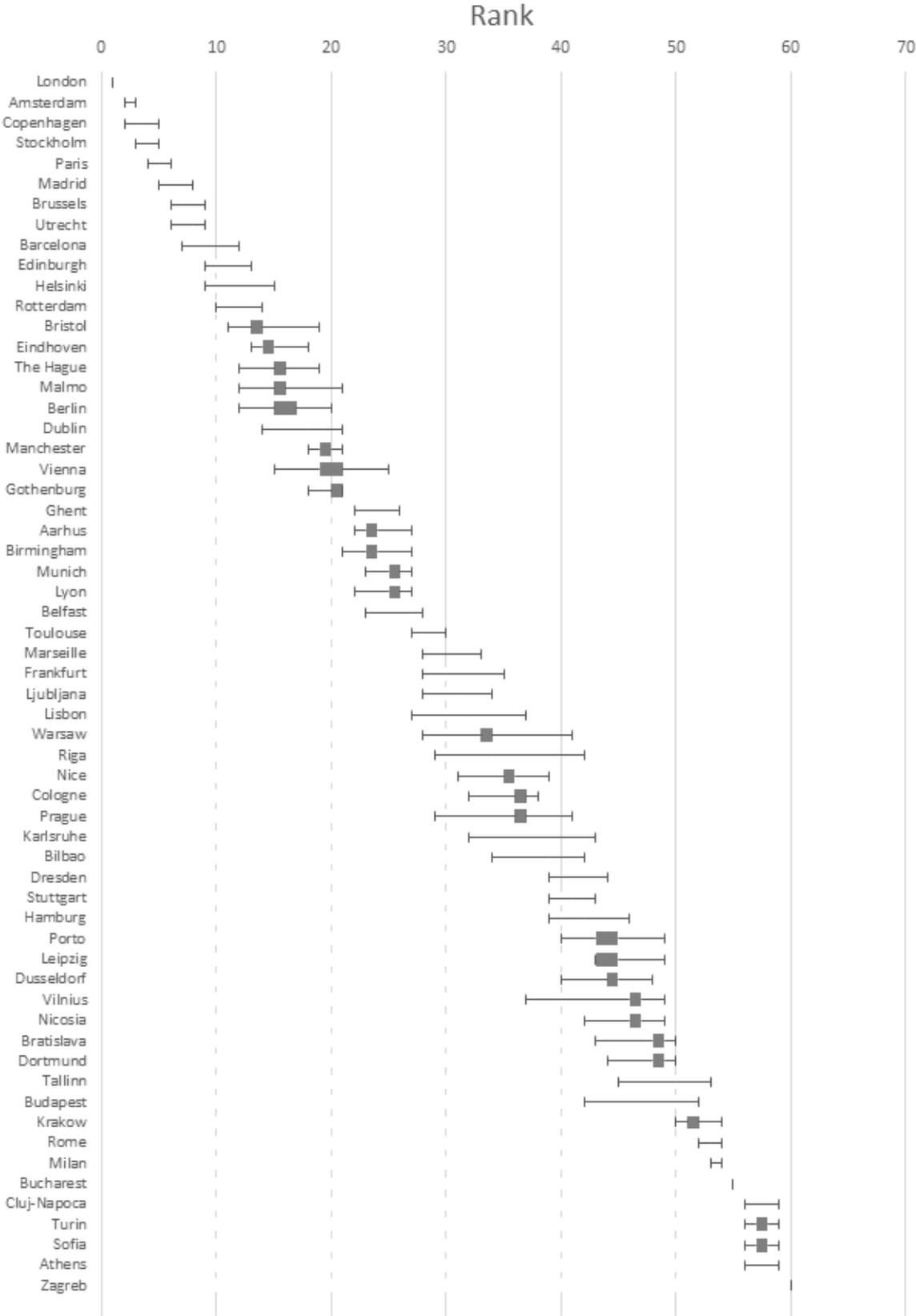
To measure how sensitive the rank is to the weighting selection we ran a Monte Carlo simulation. In this simulation, single indicator and theme weights were randomly selected from our possible values (specified in Table 2). The results of this simulation are shown in figure 7. The wider the box & whisker, the more variable that city’s rank is when the weighting is changed.

In general, weighting changes have very little effect on the ranking. This is because weightings in the index are generally not very extreme; all themes are weighted either 15%, 17.5% or 20%.

London maintains its first position in all versions of the index tested. As with the indicator selection, weight selection appears to have the largest impact on middle-ranking cities. However, even with these cities’ variation is relatively small.

We also tested the effect of equally weighing all indicators and themes (see ‘Rank with equal weightings’ column in table 11.) In general ranking changes were minor, reflecting the relative subtlety of the weightings applied. London and Amsterdam remained in first and second position when equal weighting was applied, and Zagreb remained in last position.

Figure 7. Box and whisker diagram showing the impact of removing each variable on the rank. Box = interquartile range; whiskers = range.



## 4. Data visualisation

A data visualisation was developed using [Public Tableau](#) software and [embedded into the digitalsocial.eu website](#). The interactive data visualisation allows viewers to compare city scores and rankings for the overall index as well as for the individual themes. It also presents examples of strategies, policies and initiatives from across Europe which may help support DSI.

## 5. Challenges and limitations

*"All models are wrong, but some are useful"*

*George Box, Statistician*

As is the case with all indexes, and models more generally, the EDSII does not perfectly describe cities' abilities to support DSI. We do, however, believe it will be useful tool to help policymakers understand how they can better support DSI and to incentivise the development and implementation of supportive policies. We also think it can inform practitioners about where has the best conditions to support DSI, helping them to decide where to set up or grow their initiatives.

Throughout the development of the index, several largely subjective decisions were made with regards to indicator choice, data processing and aggregation methods. While some indexes cloak such decisions in a veil of objectivity, we wanted to be transparent about where these decisions were made and how they might affect rankings. The sensitivity analysis we conducted shows that while these decisions can have major effects on rankings, most of the general structure of the ranking is relatively robust. The top ranking positions of London and Amsterdam were also very robust to changes in the methodology.

While several cities do rank better or worse than we would have expected, in general, the ranking of cities in the index is relatively unsurprising. However, we did expect to see a stronger correlation between the index and levels of DSI activity ([as mapped through the DSI4EU project](#)), as discussed above.

There are several possible reasons for why this might be the case. Indeed, it is most likely a combination of (some of) these reasons.

- **Favourable conditions for DSI don't necessarily lead to high levels of DSI.** As noted above, many DSI initiatives emerge as a response to unfavourable social, political and economic contexts, in an attempt to address social issues that have been overlooked by traditional institutions. For example, a large number of digital democracy initiatives have emerged in Eastern and Southern Europe addressing localised issues such as corruption and lack of government transparency. Some of the cities which are high-ranking in the index might simply be better places to live, meaning that bottom-up DSI is less necessary; and some of the cities which are low-ranking in the index might have conditions which lead people to develop DSI despite a less favourable ecosystem.

Taking this hypothesis to its logical end, places with more (or more serious) social challenges would be better “ecosystems” for DSI to grow. But, of course, we would not want to include this as an indicator in the composite index. Furthermore, country-specific contexts affect the nature of DSI in different places. For example, DSI initiatives tackling corruption and improving transparency and accountability are thriving in countries with weaker state institutions - but we would not argue that policymakers should weaken institutions to promote DSI. While this may at first seem facetious, these geographical and contextual differences have posed a real challenge in developing the framework, and one which we have not managed to completely solve thus far.

- Local and national policy initiatives focused on supporting DSI may play a greater role in supporting DSI initiatives than the wider ecosystemic factors measured by the index. While there are some indicators related to policy initiatives, such as the ease of doing business and socially-focused support, the index does not take into account governmental attempts to specifically support DSI and related fields. We are cataloguing some such attempts through the [Ideas Bank](#). The reason for the discrepancy between the index and known activity may be because those specific policy initiatives are far more important for the growth of DSI than ecosystemic factors.
- Data quality, availability and accuracy. As we had predicted from the beginning, we have faced several challenges regarding the quality, availability and accuracy of data and have had to make difficult - and ultimately subjective - decisions on data sources, including using proxy indicators, outdated data or geographically broad data, or even omitting

indicators altogether. This is an unavoidable consequence of developing an experimental index for a field which receives limited attention from government and academia. It is possible that some of the trade-offs we have made have influenced the scores.

- Decisions in the indicators and themes included in the theoretical framework. We based our decisions for the indicators and themes on a broad range of evidence: literature review, interviews and a survey. These involved experts and the wider DSI community and were developed in consultation with all the DSI4EU partners. It is nevertheless possible that some of these decisions regarding indicator choices and weighting are not as accurate or representative as we would like. While we are confident in our research methods, we think it is important to note that such decisions were far from being clear-cut.
- Incomplete mapping of DSI activity. We know that the DSI4EU database is neither comprehensive nor truly representative: it is largely crowdsourced; it is biased towards regions where DSI4EU partners have knowledge, networks and linguistic access and to the social areas they work in. Indeed, DSI is such a broad, active and fast-developing field that we could not possibly map all activity accurately. It is possible, therefore, that there is significant activity going on in some of the higher-ranking cities which we are not aware of, and we intend to explore those places in more depth over the coming months.
- The diversity of DSI as a field means a traditional index is simply not sufficient to measure ecosystemic factors which support it. The breadth of activity encompassed under the term DSI is vast: different actors (researchers, user-innovators, entrepreneurs, charities, start-ups, corporates); different social areas; reactive (e.g. an individual addressing a specific problem for them or their community) or proactive (e.g. a startup tackling an international development issue); localised or global; and much more. Most indexes focus on much more clearly-defined fields. It may be that the usual method of creating indexes cannot be applied to DSI as a whole.

A number of additional challenges arose when discussing the index and potential indicators with interviewees and roundtable participants. While we had anticipated some of these, as we continued to develop the framework we continued to come up against tricky questions. While this made it all the more important for our index methodology to be as inclusive as possible, we are aware that it is by no means definitive, and far from perfect. Largely, these challenges have resulted from the huge breadth of the field of DSI, and we outline a few specific challenges below.

- Stages of development. Several experts pointed out that the specific needs of DSI initiatives differ considerably depending on their stage of development.<sup>51</sup> For example, availability of advice and mentoring on running a social purpose initiative is likely to be much more important to early stage DSI initiatives than scaling DSI initiatives, while public procurement might be very important to an established initiative but of little interest to new initiatives.
- Breadth of organisational types. For-profit organisations will have different requirements to not-for-profit organisations, an example being that they will be more likely to be interested in selling equity and less reliant on grants.
- Breadth of social challenges. DSI is active in a vast range of social challenges - healthcare, education, transport, housing, justice, environment, democracy and migration to name only a few. Of course, each of these challenges is itself vast. The enabling and hindering factors for DSI initiatives varies enormously and it would be impossible to cater to all of these within a composite index.
- Breadth of technologies. DSI encompasses a huge range of technologies, so we have faced challenges with some infrastructural indicators. Open data and digital fabrication tools, for example, are central to the success of some DSI initiatives, but completely irrelevant for others. However, we have decided to include them as indicators and allow the survey findings to suggest how indicators like these should be weighted.

One possible way of addressing the four challenges above would be to effectively produce multiple indexes, one for each different type of DSI initiative (i.e. based on their stage of development, organisational type, social challenge they are addressing and technology they are using), by using the same indicators for each index but weighting them differently depending on characteristics of the DSI initiative. This would be presented using an online user interface allowing policymakers to pick and choose the different characteristics (e.g. sector, organisation type or development stage) they were interested in seeing an index and ranking for. While this approach was impossible within the scope of this project, it should be considered if another iteration of the index is created in the future. Furthermore, as the index is open-source and its methodology available to all, specific sectors or fields could tailor it to their needs if they desired.

We welcome questions or feedback on any aspect of the Index at [DSI@nesta.org.uk](mailto:DSI@nesta.org.uk). Also please visit the [DSI4EU website](#) for more research and data on digital social innovation in Europe.

## 6. Appendices

### Appendix 1. Selected literature review

Table 12. Literature review

No.	Title	Authors	Year	Key Factors Discussed
1	<a href="#">Fab City Whitepaper: Locally productive, globally connected self-sufficient cities</a>	Tomas Diez	2016	<ul style="list-style-type: none"> <li>• Government collaboration with civic society</li> </ul>
2	<a href="#">ARUP: City Resilience Index</a>	The Rockefeller Foundation ARUP	2015	<ul style="list-style-type: none"> <li>• Collective identity and community support</li> <li>• Effective mechanisms for community to engage with government</li> <li>• Cohesive communities</li> <li>• Actively engaged citizens</li> <li>• Inclusive and conducive collaboration between all actors involved in decision-making</li> </ul>
3	<a href="#">Innovation, Sustainability and Democracy: an analysis of grassroots contributions</a>	Adrian Smith Andrew Stirling	2017	<ul style="list-style-type: none"> <li>• Cultures of expertise;</li> <li>• Technical knowledge;</li> <li>• Access to material deliberation spaces;</li> </ul>
4	<a href="#">Assessing your innovation district: A how-to guide</a>	Jennifer S. Vey Jason Hachadorian Julie Wagner Scott Andes Nathan Storrington	2018	<ul style="list-style-type: none"> <li>• Infrastructure indicators;</li> <li>• Diversity and inclusion</li> </ul>
5	<a href="#">A Methodological Framework for Measuring Social Innovation</a>	Michael Hoelscher Georg Mildenerberger Eva Bund	2015	<ul style="list-style-type: none"> <li>• Knowledge;</li> <li>• Information/Communication technology (i.e. broadband prices)</li> <li>• Social climate;</li> <li>• Collaboration and networks;</li> <li>• Financial resources;</li> <li>• Political anchoring/support;</li> <li>• Social capital and networks;</li> </ul>

6	<a href="#">Measuring What Matters—Indicators of Social Innovativeness on the National Level</a>	Gorgi Krlev Eva Bund Georg Mildenberger	2014	<ul style="list-style-type: none"> <li>• Equal opportunities;</li> <li>• Subject specific competencies;</li> </ul>
7	<a href="#">Policy for social innovation: Five ways policy can support social innovation</a>	Madeleine Gabriel	2016	<ul style="list-style-type: none"> <li>• Access to social impact funds and grants;</li> <li>• Supportive regulation and legal framework;</li> </ul>
8	<a href="#">Blueprint of Social Innovation Metrics: Contributions to an Understanding of the Opportunities and Challenges of Social Innovation Measurement</a>	Eva Bund David-Karl Hubrich Björn Schmitz Georg Mildenberger Gorgi Krlev	2013	<ul style="list-style-type: none"> <li>• Equal opportunities;</li> <li>• Skill acquisition;</li> <li>• Social capital and networks (social cohesion);</li> </ul>
9	<a href="#">Bridging the Digital Innovation Divide: A toolkit for strengthening ICT centric ecosystems</a>	International Telecommunic ation Union Telecommunic ation Development Bureau Innovation Service of the Innovation and Partnership Department	2017	<ul style="list-style-type: none"> <li>• Infrastructure (i.e. tech hubs)</li> <li>• Capital and funding</li> <li>• Skills</li> <li>• Culture and communities</li> <li>• Policy and regulation</li> </ul>
10	<a href="#">The Logic of Innovation Locations: Understanding the drivers that enable cities to host innovation economies</a>	Tim Moonen Greg Clark	2017	<ul style="list-style-type: none"> <li>• Investors;</li> <li>• Pool of qualified workers;</li> <li>• Policy incentives to secure solutions to pressing problems;</li> <li>• Support of nation agencies and institutions for interdisciplinary research;</li> </ul>
11	<a href="#">The Global Creativity Index</a>	Richard Florida Charlotta Mellander Karen King	2015	<ul style="list-style-type: none"> <li>• Tolerance</li> </ul>
12	<a href="#">‘Everything is gentrification now’: but Richard Florida isn't sorry</a>	Oliver Wainwright	2017	<ul style="list-style-type: none"> <li>• Inclusion (in tech sector);</li> </ul>

13	<a href="#">Thomson Reuters Diversity and Inclusion Rating Methodology</a>	Thomson Reuters	2018	<ul style="list-style-type: none"> <li>• Diversity and Inclusion;</li> </ul>
14	<a href="#">The European Digital City Index</a>	Nesta	2016	<ul style="list-style-type: none"> <li>• Access to Capital</li> <li>• Business Environment</li> <li>• Digital Infrastructure</li> <li>• Entrepreneurial Culture</li> <li>• Knowledge Spillovers</li> <li>• Lifestyle</li> <li>• Market</li> <li>• Mentoring and Managerial Assistance</li> <li>• Non-Digital Infrastructure</li> </ul>
15	<a href="#">The FAB City: City Resilience Index</a>	FAB City		<ul style="list-style-type: none"> <li>• Education</li> <li>• Jobs</li> <li>• Income</li> <li>• Safety</li> <li>• Health</li> <li>• Environment</li> <li>• Civic engagement</li> <li>• Accessibility to services</li> <li>• Housing</li> <li>• Community</li> <li>• Life satisfaction</li> </ul>

## Appendix 2. Keywords used in analyses

'technology for good', 'tech for good', 'techforgood', 'tech4good', 'civic tech', 'civictech', 'civic technology', 'digital social innovation', 'non-profit tech', 'non-profit technology', 'nonprofit tech', 'nonprofit technology', 'Digital democracy', 'Démocratie Numérique', 'democrazia digitale', 'digitale Democratie', 'democracia digital', 'digitalt demokrati', 'ψηφιακή δημοκρατία', 'digitale democratie', 'digitálna demokracia', 'democrația digitală', 'Democracia virtual', 'digitalna demokracija', 'interneta demokrātija', 'skaitmenine demokratija', 'digitális demokrácia', 'digitální demokracie', 'цифрова демократия', 'digital demokrati', 'digitaalseks demokraatiaks', 'demokrazija digitali', 'cyfrowa demokracja', 'elektronička demokracija', 'daonlathas digiteach', 'e-democracy', 'e-démocratie', 'democrazia elettronica', 'e-Demokratie', 'democracia electrónica', 'Elektroninen demokratia', 'e-demokrati', 'Ηλεκτρονική δημοκρατία', 'e-democratie', 'e-demokracia', 'e-democrația', 'e-democrazia', 'e-demokracija', 'E-demokrātija', 'e-demokratija', 'e-demokrácia', 'e-demokracie', 'e-демократия', 'E-demokrati', 'e-demokraatia', 'e-demokrazija', 'e-demokracja', 'E-demokracija', 'e-daonlathas', 'open data', 'Données ouvertes', 'dati aperti', 'Offene Daten', 'Datos abiertos', 'Avoim data', 'Åbn data', 'ανοιχτά δεδομένα', 'otvorené dáta', 'date deschise', 'dados abertos', 'odprti podatki', 'atveriet datus', 'atviri duomenys', 'nyitott adatok', 'Otevřená data', 'отворени данни', 'Öppna data', 'Avaandmed', 'data miftuħa', 'otwarte dane', 'otvoreni podaci', 'sonraí oscailte', 'open hardware', 'Matériel ouvert', 'hardware libero', 'offene Hardware', 'hardware libre', 'Avoim laitteisto', 'åben hardware', 'ανοιχτό υλικό', 'otvorený hardvér', 'Open Hardware', 'sursa deschisa', 'hardware livre', 'odprta strojna oprema', 'atvērt aparatūru', 'atvira tehnine iranga', 'nyitott hardver', 'otevřený hardware', 'отворен хардуер', 'Öppen hårdvara', 'avatud riistvara', 'hardwer miftuħ', 'open hardware', 'otvoreni hardver', 'crua-earraí oscailte', 'code source ouvert', 'fonte aperta', 'offene Quelle', 'código abierto', 'Avoim lähdekoodi', 'åben kildekode', 'Ανοικτός Κώδικας', 'sursă deschisă', 'código aberto', 'Odprta koda', 'Atvērtais pirmkods', 'atviras resursas', 'nyílt forráskód', 'отворен код', 'Öppen källkod', 'Avatud lähtekood', 'sors miftuħ', 'otwarte źródło', 'Otvoreni kod', 'Foinse oscailte', 'open government', 'gouvernement ouvert', 'governoaperto', 'offene Regierung', 'gobierno abierto', 'avoin hallitus', 'åben regering', 'ανοικτή κυβέρνηση', 'open overheid', 'otvorená vláda', 'guvern deschis', 'governo aberto', 'odprta vlada', 'atvērta valdība', 'atvira vyriausybė', 'nyitott kormány', 'otvřená vláda', 'отворено', 'правителство', 'öppen regering', 'avatud valitsus', 'gvern miftuħ', 'otwarty rząd', 'otvorena vlada', 'rialtas oscailte'.

Additional words used in Twitter analysis: tech for good, technology for good, #techforgood, #tech4good, civic tech, #civictech, Civic technology, digital social innovation, #NGOtech, #ngotech, #nptech, #nonprofittech, Non-profit tech/ nonprofit tech, Non-profit technology/ nonprofit technology, #socialtech, #goodtech

Table 13. Keywords used in analyses with translations into English

English	Digital democracy	e-democracy	open data	open hardware	open source	open government	#Digitaldemocracy	#edemocracy	#opendata	#openhardware	#opensource	#opengovernment
French	Démocratie Numérique	e-démocratie	Données ouvertes	Matériel ouvert	code source ouvert	gouvernement ouvert	#DémocratieNumérique	#edémocratie	#Donnéesouvertes	#Matérielouvert	#codesourceouvert	#gouvernementouvert
Italian	democrazia digitale	democrazia elettronica	dati aperti	hardware libero	fonte aperta	Governo aperto	#democraziadigitale	#democraziaelettronica	#datiaperti	#hardwarelibero	#fonteaperta	#governoaperto
German	digitale Demokratie	e-Demokratie	Offene Daten	offene Hardware	offene Quelle	offene Regierung	#digitaleDemokratie	#eDemokratie	#OffeneDaten	#offeneHardware	#offeneQuelle	#offeneRegierung
Spanish	democracia digital	democracia electrónica	Datos abiertos	hardware libre	código abierto	gobierno abierto	#democraciadigital	#democraciaelectronica	#Datosabiertos	#hardwarelibre	#códigoabierto	#gobiernoabierto
Finnish	digitaalidemokratia	Elektroninen demokratia	Avoin data	Avoin laitteisto	Avoin lähdekoodi	avoin hallitus	#digitaalidemokratia	#Elektroninendemokratia	#Avoindata	#Avoinlaitteisto	#Avoinlähdekoodi	#avoinhallitus
Danish	digitalt demokrati	e-demokrati	Åbn data	åben hardware	åben kildekode	åben regering	#digitaltdemokrati	#edemokrati	#Åbndata	#åbenhardware	#åbenkildekode	#åbenregering
Greek	ψηφιακή δημοκρατία	Ηλεκτρονική δημοκρατία	ανοιχτά δεδομένα	ανοιχτό υλικό	Ανοικτός Κώδικας	ανοικτή κυβέρνηση	#ψηφιακήδημοκρατία	#Ηλεκτρονικήδημοκρατία	#ανοιχτάδεδομένα	#ανοιχτούλικό	#ΑνοικτόςΚώδικας	#ανοικτήκυβέρνηση
Dutch	digitale democratie	e-democratie				open overheid	#digitaledemocratie	#edemocratie				#openoverheid
Slovak	digitálna demokracia	e-demokracia	otvorené dáta	otvorený hardvér		otvorená vláda	#digitálnademokracia	#edemokracia	#otvorenédáta	#otvorenýhardvér		#otvorenávláda
Romanian	democrația digitală	e-democrația	date deschise	Open Hardware/sursa deschisa	sursă deschisă	guvern deschis	#democrațiadigitală	#edemocrația	#datedeschise	#OpenHardware/sursadeschisa	#sursădeschisă	#guverndeschis
Portuguese	Democracia virtual	e-democracia	dados abertos	hardware livre	código aberto	governo aberto	#Democraciavirtual	#edemocracia	#dadosabertos	#hardwarelivre	#códigoaberto	#governoaberto
Slovenian	digitalna demokracija	e-demokracija	odprti podatki	odprta strojna oprema	Odprta koda	odprta vlada	#digitalnademokracija	#edemokracija	#odprtipodatki	#odprtastrojnaoprema	#Odprtakoda	#odprtavlada
Latvian	interneta demokrātija	E-demokrātija	atveriet datus	atvērt aparātūru	Atvērtais pirkods	atvērta valdība	#internetademokrātija	#Edemokrātija	#atverietdatus	#atvērtaparātūru	#Atvērtaispirkods	#atvērtavaldība

Lithuanian	#skaitmeninedemokratija	e-demokratija	atviri duomenys	atvira technine iranga	atviras resursas	atvira vyriausybė	#skaitmeninedemokratija	#edemokratija	#atviriduomenys	#atviratechnineiranga	#atvirasresursas	#atviravyriausybė
Hungarian	digitális demokrácia	Az e-demokrácia	nyitott adatok	nyitott hardver	nyílt forráskód	nyitott kormány	#digitálsidemokrácia	#Azedemokrácia	#nyitottadatok	#nyitotthardver	#nyíltforráskód	#nyitottkormány
Czech	digitální demokracie	e-demokracie	Otevřená data	otevřený hardware		otevřená vláda	#digitálnidemokracie	#edemokracie	#Otevřenádata	#otevřenýhardware		#otevřenávláda
Bulgarian	цифрова демокрация	е-демокрация	отворени данни	отворен хардуер	отворен код	отворено правителство	#цифровадемокрация	#едемокрация	#отворениданни	#отворенхардуер	#отворенкод	#отвореноправителство
Swedish	digital demokrati	E-demokrati	Öppna data	Öppen hårdvara	Öppen källkod	öppen regering	#digitaldemokrati	#Edemokrati	#Öppnadata	#Öppenhårdvara	#Öppenkällkod	#öppenregering
Estonian	digitaalseks demokraatiaks	E-demokraatia	Avaandmed	avatud riistvara	Avatud lähtekood	avatud valitsus	#digitaalseksdemokraatiaks	#Edemokraatia	#Avaandmed	#avatudriistvara	#Avatudlähtekood	#avatudvalitsus
Maltese	demokrazija digitali	e-demokrazija	data miftuha	hardwer miftuh	sors miftuh	gvern miftuh	#demokrazijadigitali	#edemokrazija	#datamiftuha	#hardvermiftuh	#sorsmiftuh	#gvernmiftuh
Polish	demokracjacyfrowa	e-demokracja	otwarte dane	open hardware	otwarte źródło	otwarty rząd	#demokracjacyfrowa	#edemokracja	#otwartedane	#openhardware	#otwarteźródło	#otwartyrząd
Croatian	elektronička demokracija	E-demokracija	otvoreni podaci	otvoreni hardver	Otvoreni kod	otvorena vlada	#elektroničkademokracija	#Edemokracija	#otvorenipodaci	#otvorenihardver	#Otvorenikod	#otvorenavlada
Irish	daonlathas digiteach	e-daonlathas	sonraí oscailte	crua-earraí oscailte	Foinse oscailte	rialtas oscailte	#daonlathasdigiteach	#edaonlathas	#sonraioscailte	#cruaearraioscailte	#Foinseoscailte	#rialtasoscailte

## Appendix 3. PCA loadings

Table 14. Indicator loadings for each of the 7 principle components. Loadings of more than 0.15 are highlighted green and less than -0.15 are highlighted red.

	Principle component	Access to Volunteers	Positive attitudes to civil society	Social cohesion	Individual giving	Public advocacy for DSI (e.g from political / leading figures)	Presence of supportive government policy for social purpose initiatives	Events where people can meet to network / discuss DSI	Online collaboration	Civil society collaboration with tech sector	Government collaboration with civic society	Government collaboration with tech sector	Engagement with DSI	Diversity within the tech sector	Diversity within the civic sector	Activity to make innovation more inclusive	Digital inclusion	Availability of Seed Grant Funding	Availability of Major Grant Funding	Flexibility of funding	Availability of impact investment	Willingness of public and social sector procure from startups	Access to fast broadband and mobile internet	Access to flexible workspace	Access to fabrication and manufacturing facilities	Openness of data	Presence of socially focussed business support	Ease of starting a business	Presence of research institutions with expertise in DSI	Access to Business, HR, legal, marketing, design and media support	Access to employees with data skills	Access to employees with service design skills	Access to employees with Software Engineering / Development skills
0		0.32	0.21	0.19	0.33	0.10	0.09	0.18	0.15	0.04	0.25	0.27	0.14	-0.03	-0.03	-0.19	0.28	0.24	0.03	0.11	0.23	0.00	0.07	0.18	0.04	0.26	0.09	0.16	0.02	0.32	-0.04	0.03	-0.07
1		0.02	0.16	0.06	-0.04	-0.08	-0.18	0.09	-0.04	-0.31	-0.14	-0.19	0.12	0.26	-0.03	0.00	0.00	-0.02	0.12	0.17	0.17	-0.17	0.02	0.12	0.07	-0.09	0.20	0.20	0.17	-0.05	0.43	0.31	0.41
2		-0.07	0.03	-0.10	-0.14	0.31	-0.14	-0.05	-0.04	0.14	-0.23	0.06	-0.04	0.14	-0.30	0.06	-0.08	0.28	0.47	0.28	-0.01	-0.14	0.34	0.07	-0.07	-0.01	-0.12	0.15	-0.21	-0.03	-0.12	-0.08	-0.11
3		-0.20	-0.06	-0.29	-0.10	-0.01	0.16	0.11	0.22	0.37	-0.14	0.05	0.34	0.19	-0.05	-0.02	-0.23	0.10	-0.04	-0.18	0.19	0.01	0.00	0.05	0.30	0.09	0.30	0.00	0.31	0.02	0.01	-0.22	0.01
4		0.01	0.22	-0.15	0.05	-0.13	-0.19	0.34	0.27	0.07	0.02	-0.22	-0.21	-0.19	-0.28	-0.01	-0.24	-0.12	-0.08	-0.08	0.28	-0.10	-0.15	0.28	-0.21	-0.25	-0.04	-0.07	-0.21	0.15	-0.03	-0.11	-0.04
5		-0.02	0.06	0.08	0.08	-0.27	-0.48	-0.15	-0.05	-0.03	-0.01	-0.02	0.08	-0.24	-0.30	-0.33	-0.03	-0.16	0.16	0.15	-0.06	0.19	0.09	-0.23	0.31	0.01	0.19	-0.13	0.15	0.08	-0.11	-0.03	-0.12
6		0.02	-0.02	-0.18	0.00	-0.35	0.08	-0.10	-0.15	0.03	-0.15	-0.07	0.10	-0.06	0.00	-0.45	-0.06	0.19	-0.07	-0.21	-0.04	-0.28	0.03	-0.27	-0.19	0.13	-0.21	0.35	-0.17	0.19	0.10	-0.12	0.12
7		0.03	0.06	-0.24	0.11	0.32	0.20	-0.25	-0.12	0.04	0.06	-0.08	0.00	-0.11	-0.33	-0.17	0.09	0.23	-0.04	0.19	-0.10	0.23	-0.45	0.00	-0.01	-0.26	-0.05	-0.04	0.12	0.04	0.20	-0.11	0.19
8		-0.01	0.41	0.00	0.05	-0.07	0.03	-0.17	-0.44	0.02	0.05	-0.12	0.12	0.12	-0.06	0.28	-0.11	-0.15	-0.05	-0.14	0.06	0.34	0.00	0.10	-0.13	0.04	0.21	0.40	-0.07	0.04	-0.18	-0.12	-0.11