Enabling procurement data value chains for economic development, demand management, competitive markets and vendor intelligence

Deliverable 4.2
Infographic and Storytelling Technology

<table>
<thead>
<tr>
<th>Delivery Date:</th>
<th>June 28, 2018</th>
</tr>
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<tbody>
<tr>
<td>Author(s):</td>
<td>Tom Blount (SOTON), Elena Simperl (SOTON), Laura Koesten (SOTON)</td>
</tr>
<tr>
<td>Dissemination Level:</td>
<td>Public</td>
</tr>
<tr>
<td>Work package:</td>
<td>WP4: Interaction design and storytelling</td>
</tr>
<tr>
<td>Version:</td>
<td>1.0</td>
</tr>
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</table>

Project co-funded under Horizon 2020 Research and Innovation EU programme under Grant agreement no. 780247
Document Metadata

Quality assurers and contributors

<table>
<thead>
<tr>
<th>Quality assurer(s):</th>
<th>Ahmet Soylu (SINTEF)</th>
</tr>
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<td>Contributor(s):</td>
<td></td>
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# Version History

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<tr>
<th>Date</th>
<th>Version</th>
<th>Description</th>
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<tbody>
<tr>
<td>04/06/18</td>
<td>0.1</td>
<td>Initial draft</td>
</tr>
<tr>
<td>06/06/18</td>
<td>0.2</td>
<td>Addressed minor comments and typos, etc.</td>
</tr>
<tr>
<td>12/06/18</td>
<td>0.3</td>
<td>Expanded definitions section</td>
</tr>
<tr>
<td>13/06/18</td>
<td>0.4</td>
<td>Included additional background context on HDI, data types and knowledge graphs</td>
</tr>
<tr>
<td>15/06/18</td>
<td>0.5</td>
<td>Expanded the conceptual framework to include an evaluation component</td>
</tr>
<tr>
<td>15/06/18</td>
<td>0.6</td>
<td>Restructured literature review (and framework) into three major sections: Narrative &amp; Structure, Data Properties, and Evaluation</td>
</tr>
<tr>
<td>16/06/18</td>
<td>0.7</td>
<td>Expanded “Other Visualisations” section to include Data Comics and Natural Language interfaces</td>
</tr>
<tr>
<td>19/06/18</td>
<td>0.8</td>
<td>Removed superfluous section on example technologies</td>
</tr>
<tr>
<td>25/06/18</td>
<td>0.9</td>
<td>Categorised the TBFY scenarios in terms of the conceptual framework</td>
</tr>
<tr>
<td>28/06/18</td>
<td>1.0</td>
<td>Submission-ready version</td>
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Executive Summary

This document introduces a conceptual framework for describing dimensions of data visualisation, based on a review of background literature and media, for the purpose of informing the initial process of ideation (described in D4.1) prior to the creation of visualisation and narrative components to support consortium members and the project (D4.4 and D4.6). It will also inform not only the design of these visualisation and interaction components (by aligning the relationships between key aspects of data properties and their appropriate visualisations), but the design of studies used to evaluate their effectiveness.

The first part of this deliverable discusses the fundamental concepts and definitions within human-data interaction and visualisation design, and investigates the existing literature in the field of data visualisation and data narratives. The second part of this deliverable presents a conceptual framework to represent three core facets of visualisation and interaction components: the way in which they convey information to their audience, the way they represent fundamental properties of the data that drive them, and ways of evaluating the overall effectiveness.

This document is of interest to the TBFY consortium, to ensure consortium members are informed about the ongoing process of developing suitable visualisation and interaction components to meet the specific user needs arising from TBFY, and the future visualisation and interaction prototypes and components (D4.4 and D4.6). Outside of the TBFY project, this deliverable is useful for future projects and initiatives within the procurement sector and, more generally, those intending to make use of human-data interaction and data visualisation.
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Definitions

Key Terms

Data: facts and statistics collected together for reference or analysis (cf. information)

Data Story: the process of translating data analyses into layman’s terms in order to inform, engage, and influence decision making

Fabula: the set of atomic, factual elements that make up the chronological sequence of events (and thus the chain of causality) within a narrative (cf. syuzhet)

Human-Computer Interaction: the study (and application) of the way in which people use technology, and the way in which it influences their behaviour and decision-making

Human-Data Interaction: the study (and application) of the way in which people manage data (both as subjects and analysts), and the way in which it influences their behaviour and decision-making

Information: data that has been given meaning through refinement, processing, and/or the addition of context (cf. knowledge)

Knowledge: appropriately collected information, such that it has become useful for a particular purpose

Narrative: an account (spoken, written, or otherwise conveyed) of a series of connected events

Reader: one who consumes a narrative

Story: see narrative

Syuzhet: refers to the parts of the fabula that are selected by an author to be exposed to the audience, and the order and manner in which they are presented

User: see reader

Visualisation, Data: a means of representing data visually using colour, spatial positioning, annotations, etc. to confer meaning (cf. information)

Visualisation, Narrative: a data visualisation that tells a particular story, often with a particular conclusion/message
Abbreviations

HCI: Human-Computer Interaction
HDI: Human-Data Interaction
NLG: Natural Language Generation
OPM: Open Provenance Model
SME: Small and Medium-sized Enterprises
W3C: World Wide Web Consortium
1 Introduction

This document introduces a conceptual framework for describing dimensions of data visualisation, based on a review of background literature and media, for the purpose of informing the initial process of ideation (described in D4.1) prior to the creation of visualisation and narrative components to support consortium members and the project (D4.4 and D4.6). It will also inform not only the design of these visualisation and interaction components (by aligning the relationships between key aspects of data properties and their appropriate visualisations), but the design of studies used to evaluate their effectiveness.

The first part of this deliverable discusses the fundamental concepts and definitions within human-data interaction and visualisation design, and investigates the existing literature in the field of data visualisation and data narratives. The second part of this deliverable presents a conceptual framework to represent three core facets of visualisation and interaction components: the way in which they convey information to their audience, the way they represent fundamental properties of the data that drive them, and ways of evaluating the overall effectiveness.

The conceptual framework has been used to inform the initial ideation process (described in D4.1), and will also be used to inform the design of the visualisation and interaction components to be developed throughout the project (D4.4 and D4.6) as well well as their evaluation, through the design of proposed user studies (also described in D4.1). It also has potential to be used beyond the TBFY project, by researchers aiming to leverage key relationships between visualisation technologies and their data.
2 Background and Literature Review

2.1 Background

2.1.1 Data

The Oxford Dictionary defines data as “facts and statistics collected together for reference or analysis” (Oxf, 2015). Data is the lowest tier of the Data-Information-Knowledge-Wisdom Hierarchy (Ackoff, 1989); that is, data made up of raw observations must be processed and structured to become information before it is useful. Knowledge describes the application of surrounding context to the information, and wisdom, how it is – or should be – acted upon.

2.1.1.1 Data Types

Data comes in many forms: textual, numeric, locative, and so on. Shneiderman (2003) presents a taxonomy for defining data types with respect to data visualisation:

- **1D**: linear data, sequentially arranged data such as alphabetical lists of names, program source code, or other text documents. Considerations when visualising include font size and colour, and what scrolling/selection method to use.

- **2D**: planar or geospatial data, including maps, spatial layouts, and relations between 1D data. Considerations when visualising include item colour, size, and opacity.

- **3D**: items with volume and/or complex relationships with other objects, such as molecules, the human body, or relations between 1- and/or 2D data. As with 2D data, considerations when visualising include item colour, size, and opacity.

- **Temporal**: 1D data that has a temporal aspect, such as the change in a particular variable over time. Distinct from 1D data as each item has a start and finish time.

- **nD/Multidimensional**: Higher dimensional data includes those with complex relationships between many individual variables. Visualising multidimensional data often follows the same principals as visualising 2D or 3D, with some form of selection (e.g. buttons or a slider) for browsing higher dimensions.

- **Tree/Hierarchical**: collections of items that form a structure of each item (except for the root item) linking to a parent item, with items and their links each supporting multiple attributes. Additional visualisation considerations include representing “interesting” properties of the structure (such as number of children).
• **Network**: an extension of tree/hierarchical data in which the items can have relationships with an arbitrary number of other items, and in which these links can form cycles. Considerations when visualising include highlighting particular routes through the network, e.g. the shortest path from one node to another.

### 2.1.1.2 Metadata and Provenance

Metadata refers to data that describes data; for example, the author of a particular document, or that last date it was modified. Metadata also includes provenance, which the World Wide Web Consortium (W3C) defines as “a record that describes the people, institutions, entities, and activities involved in producing, influencing, or delivering a piece of data or a thing.” Provenance can be used to inform decisions based on the quality or trustworthiness of data, as well as an aid to reproducing a dataset. The W3C define a number of standards for representing provenance on the web\(^1\) that evolved from the Open Provenance Model (OPM) (Moreau et al., 2008, 2011).

### 2.1.2 Knowledge Graphs

While there is no single widely-accepted definition for a knowledge graph, they are increasingly used in both research and industry, in fields such as large-scale data analytics, and cloud computing (Ehrlinger and Wöß, 2016). Paulheim (2017) describe a knowledge graph as having a schema of classes and relationships, representing real-world entities and their relationships as a graph, with the capability to model relationships between arbitrary entities covering various topics and domains.

### 2.1.3 Human-Data Interaction

The topic of Human-Data Interaction (HDI) seeks to analyse the decisions and actions users take when in the role of data-analysts, and as data-subjects (Haddadi et al., 2013; Mortier et al., 2013).

Shneiderman (2003) presents a taxonomy for describing different ways in which users may want to interact with data:

- **Overview**: gain an overview of the entirety of the data, through using a “zoomed-out” view, to gain a sense of the content and structure of the dataset
- **Zoom**: expand a portion of interest of the collection, to focus on a particular area of the dataset
- **Filter**: remove uninteresting or irrelevant items from the collection
- **Details-on-demand**: select a datapoint (or a group) to learn additional details, such as in-depth attributes
- **Relate**: view relationships between different items in the dataset, whether direct links (e.g. an owner-of relationship), or to compare properties
- **History**: keep a history of actions performed on the data (e.g. zooming and filtering), to undo changes and revert to an earlier state
- **Extract**: extract relevant data from the collection (or the query used to generate it) and export it in some other format

\(^1\)https://www.w3.org/standards/techs/provenance
2.1.3.1 Data Visualisation

Simply being presented with raw data is overwhelming to most users; to aid them in making sense of it, it is often necessary to visualise it in some form (such as a chart), using spatial positioning, colour, etc., to convey information. Tufte’s principles (1983) state that, to effectively communicate information, visualisations should not only show the raw data, but encourage the reader to compare different pieces of data, revealing different levels of detail as required. Showing a large amount of data in a constrained space relies on minimising “chartjunk” (extraneous or unnecessary visual information) and maximising the “data to ink ratio”. The Gestalt principles of grouping describe how readers group the visual elements of a chart or visualisation, whether by proximity, similarity, continuity, symmetry, etc. (Wagemans et al., 2012). Similarly, colour can play an important role in how readers interpret visualisations, both in terms of highlighting key information (Healey, 1996) and in aiding memory (Sanocki and Sulman, 2011).

2.1.3.2 Data Stories

To further elevate this within Ackoff’s (1989) hierarchy, it is often important to use the data to tell a story (Knaflic, 2015). This allows the author to impart additional context, to keep the audience interested and engaged (Ma et al., 2012), and to highlight the meaning and conclusions that can be drawn from the original data. Kosara and Mackinlay (2013) define a story as an ordered sequence of steps, with a clearly defined path through it. Each step may be formed of a combination of media, such as text, images, visualizations, audio or video.

A key point of narrative theory (that derives from Russian formalism) is the difference between the fabula and the syuzhet. The fabula is the set of atomic, factual elements that make up the chronological sequence of events (and thus the chain of causality) within the narrative; the syuzhet refers to the parts of the fabula that are selected by an author to be exposed to the audience, and the order and manner in which they are presented (Cuddon, 2012), mirroring the separation between data and information. Kosara and Mackinlay (2013) state that “going from exploration to analysis to presentation is a natural progression” that is mirrored by the progression of research in this field.

Increasingly, data storytellers (such as online journalists) are integrating visualisations into their narratives, or even telling the story solely through visualisation (Segel and Heer, 2010).

2.2 Literature Review

2.2.1 Methodology

The purpose of this literature review was to inform the creation of a conceptual framework to describe narrative and visualisation technologies, with regard to both the way in which they convey information to their audience, the way they represent fundamental properties of the data that drive them, and ways of evaluating the overall effectiveness.

As part of the systematic review of literature, the following approach was taken. Both the IEEE and ACM Digital libraries, as well as the Google Scholar search-engine, were searched for the terms “data visualisation”, “data storytelling”, “data narrative”, “interactive data visualisation”, as well as combinations of these phrases, synonyms, and alternative regional spellings (e.g. visualisation/visualization). The recent review paper by Tong et al. (2018) also provided a valuable catalogue of relevant literature as an initial starting-point. The bibliography of each relevant paper included was also examined for relevant related literature on data visualisation and storytelling.
2.2.2 Narrative and Interaction

2.2.2.1 Media and Structure

Narrative visualisations are present in a variety of formats and mediums, from simple print-media to new and evolving technologies such as virtual reality (see §2.2.5.2). Segel and Heer (2010) identify seven genres of narrative visualization, that can be used individually or as “building blocks” when constructing a visualisation. These genres are:

- **Magazine-style**: a page (or pages) of static text, possibly with embedded images
- **Annotated chart**: a data visualisation such as a bar chart or time-series graph, annotated to give further context and/or to highlight key areas of interest such as trends, peaks and troughs
- **Partitioned poster**: a page with multiple images/charts and minimal text, often with minimal suggestion of the order in which it should be consumed
- **Flow chart**: a sequence of text, images or charts with a non-linear (though deterministic) structure; ordering is often defined by choices made by the reader
- **Comic strip**: a sequence of panels or frames with a pre-defined (often linear) structure, usually containing images (sometimes overlaid with text as captions or “speech bubbles”)
- **Slide show**: similar to comic strips, but each “slide” is shown individually (and in some cases progression can be controlled by the author)
- **Film/video/animation**: live-action or animated video footage

2.2.2.2 Persuasion

The use of visualisations to tell a story often has implications with regard to exactly what story the author is trying to tell, through emphasis (or omission) of data and the way in which it is presented. Hullman and Diakopoulos (2011) define five different categories of “visualisation rhetoric” that can be used to highlighting a specific meaning or interpretation, or simply to reduce complexity and cognitive load:

- **Information access**: the inclusion or omission of relevant data and the use of metonymies (e.g. “the throne” instead of “absolute power”, or “suits” in place of “business executives”) and aggregation
- **Provenance**: the inclusion or omission of citations for data sources and methodologies, measures of uncertainty, and the identity and affiliation of the author(s)
- **Mapping**: how the information is visually presented, with regard to clarity or obfuscation, “noise” (repetition of values or labels, or the inclusion of otherwise unrelated information), and the use of implicit meanings in spatial layout, colour (e.g. “up” = more/better, “down” = less/worse), and groupings (cf. Gestalt principles). An example of adversarial usage of this type of rhetoric is shown in Figure 2.1
- **Linguistic-based**: how the information is presented textually, with regard to typography (such as bolding or italics), rhetorical or emotive language (such as the use of sarcasm, irony or rhetorical questions), use of analogies to draw similarities between information, and the way in which the reader is addressed

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Figure 2.1: A (deliberately) confusing visualisation, representing the organisation of the Democrats’ Health Plan, published by a Republican representative (reproduced from https://cbpowell.wordpress.com/2009/10/30/republican-take-on-democratic-health-plan-is-a-work-of-art/)

- **Procedural**: the manner in which the interactive elements of the visualisation affect its interpretation, including the use of default views, animations, suggestions or goals, as well as search and filtering tools.

### 2.2.2.3 Engagement and Interaction

Narratives and visualisations can be author-driven, or reader-driven (Segel and Heer, 2010). In a purely author-driven approach, there is an ordered structure and a linear sequence in which the narrative should be consumed, with limited other interaction from the user, and often a pervading message or ultimate conclusion. In a purely reader-driven structure, the user is free to browse the data, visualisations and/or narrative in whatever order they chose, to perform their own analysis, and to draw their own conclusions. Segel and Heer (2010) present a number of ways these different approaches can be combined:

- **“Martini-Glass” structure**: a format in which the opening of the narrative is linear, constrained and author-driven (the “stem” of the glass), but as the narrative progresses the approach opens up, allowing further interaction and letting the user explore more freely once they understand the topic and space.
• **Interactive slideshow:** similar to a typical slideshow presentation, but with a degree of interactivity present within the confines of each slide, allowing greater author control towards the end of the narrative, while also allowing interaction at the beginning and middle

• **“Drill-Down” narrative:** this structure presents an overview of the topic to the reader, then allows them to explore elements of interest in greater detail (often in a fractal manner). The author has limited control over the order in which the users consumes the narrative, and must consider this when selecting which elements can be expanded, and the details to include

Mahyar et al. (2015) propose a taxonomy for describing user-engagement with information visualisations, based on previous frameworks for information visualisation and existing literature from other domains; from low reader-engagement to high reader-engagement, their taxonomy is as follows:

• **Expose (Viewing):** the user is shown the information and is able to consume it in a directed manner

• **Involve (Interacting):** the user interacts with the visualization and manipulates the data

• **Analyse (Finding Trend):** the user can analyse the data to find trends and outliers

• **Synthesize (Testing Hypotheses):** the user is able to form and evaluate hypotheses

• **Decide (Deriving Decisions):** the user is able to make decisions and draw conclusions based on evaluations of different hypotheses

### 2.2.2.4 Motivation and Incentives

When examining the motivations for using a visualisation to complete a particular task, there are two key categories to consider: intrinsic and extrinsic (Leimeister et al., 2009; Hossain, 2012). Intrinsic motivation concerns the inherent benefits a task provide to the participants, such as a sense of fulfilment or enjoyment from navigating the visualisation and/or performing the task. Extrinsic motivation concerns motivation in the form of external rewards or some form of tangible benefit provided as a result of using the visualisation and/or completing the task, such as financial reward.

In their work on the application of crowdsourcing tasks, Smart et al. (2014) identify six types of incentives to improve engagement with tasks (Ryan and Deci, 2000; Smart et al., 2014; Smart and Shadbolt, 2015):

• **Economic (extrinsic):** financial reward such as direct monetary payment or indirect economic benefit

• **Altruistic (intrinsic):** selfless “good deeds” contributed for the good of a community (e.g. open-source-software projects)

• **Hedonic (intrinsic):** a task that inherently grants pleasure, often through leveraging ludic content (see §2.2.2.5)

• **Reputational (extrinsic):** contribution is rewarded through enhancing the reputation of contributors (e.g. through leaderboards)

• **Instrumental (extrinsic):** an inherent reward gained from using the system, such as the educational benefits of learning something new

• **Other:** any other type of motivation
2.2.2.5 Gamification and Data Games

Gamification describes the inclusion of elements commonly used in games to non-game systems to improve engagement and enjoyment (Deterding et al., 2011) and, as described in §2.2.2.4, has frequently been used to improve engagement with crowdsourcing tasks (Feyisetan et al., 2015). Examples of game elements that can be integrated into visualisations include (Figueiras, 2015):

- **Narrative context**: a framing device to invest the user in the task
- **Goals**: tasks that the user must complete, often for reward such as score or “experience points” (“XP”) (cf. ranks and reputations)
- **Levels**: progressively increasing challenge
- **Ranks and reputations**: a visible identifier of status and progress, usually acquired after accruing enough XP, and sometimes tied to other unlockable rewards
- **Time constraints**: a limit on the amount of time available to achieve goals for additional challenge

In contrast to “Games With A Purpose” (a technique used within the domain of human-computation used to solve problems that are trivial for humans to complete, but complex for artificial intelligence (Von Ahn, 2006)), Data Games are a primarily educational means of encouraging users to interact with data. Macklin et al. (2009) and Diakopoulos et al. (2011) examine the concept of “playable data”. Macklin et al. (2009) present three playable Data Games (*Kimono Colors*, *Mannahatta: The Game*, and *Trees of Trade: Biodiversity and Extinction*) which aim to explore what the playful navigation of datasets can reveal about them. Diakopoulos et al. (2011) work to characterise the use of game elements in infographics, and introduce a “game-y infographic” called *Salubrious Nation* (shown in Figure 2.2) in which users explore an interactive map of the United States and try to guess the statistics for various health-metrics for a highlighted location, based on the surrounding data. Similarly, Togelius and Gustafsson Friberger (2013) present a data game called “Bar Chart Ball”, in which the player must navigate a physics-enabled ball across the top of a bar chart showing real-world demographic data, from left to right, by manipulating the aspect of the data displayed.

2.2.3 Data Properties

2.2.3.1 Knowledge graphs

Purchase (2000) examines the way in which the aesthetics of visually representing relationships within knowledge graphs affects understanding. Participants were presented with a relational graph and asked to determine the shortest distance between two given nodes, the minimum number of nodes needed to be removed to break all paths between two given nodes, and the minimum number of edges needed to be removed to break all paths between two given nodes. Five aesthetic variables were altered: minimising bends, minimising edge crossings, maximise minimum angles, orthogonality and symmetry. Tested individually, crossings were found to have a significant effect on the response time and number of errors, whereas bends were only found to have a significant effect on number of errors and symmetry was only found to have a significant effect on response time. The remaining aesthetic considerations revealed no significant effects.
Figure 2.2: “Salubrious Nation: a game-y look at U.S. health” is an interactive visualisation in which users explore an interactive map of health data across the United States (screenshot from http://www.salubriousnation.com)
2.2.3.2 Uncertainty

There are a limited number of visual channels (such as location, size, colour, etc.) to draw on when visualising data. As the dimensionality of the data grows, required more channels to be accurately represented, the channels available to represent uncertainty falls. Pang et al. (1997) describe the ways in which uncertainty can be introduced: through acquisition of the data, through transformation of the data, and through visualisation of the data. Potter et al. (2012) present a taxonomy of quantifying types of data uncertainty at different dimensions, and of approaches to representing these uncertainties in data visualisations. They describe uncertainty as coming in two broad types. Epistemic uncertainties are those that could – in theory, if not practice – be wholly eliminated. They arise from experimental error, from inaccurate measurements, poor models, and/or missing data, and are sometimes referred to as “known unknowns”. Aleatoric uncertainties are those inherent to the problem at hand, and arise from, for example, reproducing an experiment and getting slight variations in the result due to immeasurably small variations in the initial conditions, and are sometimes referred to as “unknown unknowns”.

Potter et al. then additionally describe uncertainty in terms of as scalar, vector, or tensor uncertainties. The use of scalar uncertainties in visualisations, being the most commonly studied, are explored in further detail below, in relation to the different dimensions of data they are applied to. 1D data refers to a single variable at a single point, the uncertainty of which is typically represented as error bars or box plots. While this is often sufficient to represent the magnitude of the uncertainty, these techniques can inherently imply that the uncertainty distribution is normal or Gaussian, even when this is not the case. One way of representing non-normal distributions is to visualise the data as “fuzzy”; that is, to blur the datapoint to show the range of possible values. Similar techniques can be applied to 2D data (which can be interpreted in a number of ways, whether as a 2D probability density function, as two distinct 1D variables, or as a collection of 1D variables across 2D space). Other common techniques for visualising uncertainty in 2D data include colour mapping, opacity, texture and glyphs. 3D data is similar to 2D, though the distribution of data occurs throughout a volume rather than across a plane. However, due to the complexity of data being represented, a high proportion of the available visual channels are typically required. This commonly leads to the uncertainty being aggregated in some way, and focusing the visualisation of the uncertainty on location and relative size, rather than an exact quantification of the probability density function. ND, or non-spatial, data, occurs most often when time is added as a dimension to 1-, 2-, or 3D data, but can also refer to high-dimensional data. As a result, this is often visualised by extending the above methods with some form of animation to tween between different points in time.

2.2.3.3 Liveness

Another key feature of data visualisations is the “liveness” of the data; that is, the frequency with which the visualisation updates, if at all. Live data allows users to view, and potentially reason over, new trends in the data as they occur. Dynamic systems, especially those in which historical data is less useful (such as weather, road traffic, etc.), are well suited to live visualisations. Figure 2.3 shows a visualisation of live weather data, and Figure 2.4 shows a visualisation of on-going cyber-attacks.

Static data allows the author greater control over the story they wish to tell and allows for a more coherent narrative. However, if the trends in the data change over time such that the original visualisation becomes inaccurate, more work is required to reflect this in the visualisation.

2.2.4 Visualisation Evaluation

Kosara and Mackinlay (2013) make the case that traditional means for evaluating the effectiveness of vi-
Figure 2.3: “Windy” is a live visualisation of worldwide wind currents (https://www.windy.com)

Figure 2.4: “Norse Attack Map”; a live visualisation of cyber-attack data (http://map.norsecorp.com)
visualisations (e.g. time taken to complete a task) are insufficient for evaluating narrative visualisations and instead suggest a number of other metrics that could be used, including: engagement and interest, ability to remember key points, and being able to make more informed decisions. User studies (Cawthon and Moore, 2007) and expert reviews (Tory and Moller, 2005) can be used to evaluate visualisations, but Kosara and Mackinlay (2013) also argue for the use of crowdsourcing as a way to move away from traditional lab-evaluations, to reach a wider and more diverse audience, as well as accounting for more real-world usage. Ellis and Dix (2006) also provide guidance on ensuring rigour when conducting (and reporting) experiments on methods of data visualisation, including selection and design of user tasks, and the metrics by which their performance is evaluated.

2.2.4.1 Usability

A key way of evaluating the suitability of a visualisation is to require experimental participants to perform a particular task, supported by the visualisation. Wehrend and Lewis (1990) provide a classification of examples of common tasks used to evaluate visualisation systems (Wehrend and Lewis, 1990; Koua et al., 2006):

- **Locate**: locate a particular data point (e.g. an item with a value within a given range)
- **Identify**: identify if a relationship exists between given attributes (e.g. height and weight)
- **Distinguish**: distinguish how a particular attribute varies across a given domain (e.g. location)
- **Categorise**: categorise the displayed data into groups/regions, indicating spatial positioning and proximity
- **Cluster**: cluster the displayed data into groups/regions, indicating gaps in the data
- **Distribution**: describe the overall distribution of the data on display
- **Rank**: indicate the highest/lowest (or best/worst) values of each attribute displayed
- **Compare**: compare values at different spatial locations within the visualisation and identify an order of importance of data items
- **Associate**: determine/identify relationships between data items, both within groups and between them
- **Correlate**: discern which data items share similar attributes

2.2.4.2 Memorability

In contrast to Tufte’s principles (1983), Bateman et al. (2010) advocate that the use of “chart junk” does not harm accuracy of interpretation, or short-term recall, and can in fact aid long-term recall and the detection and interpretation of the author’s message. Additionally, participants in their experiment expressed a preference for embellished charts (such as the one shown in Figure 2.5) over those that contain “plain” data.

A study by Borkin et al. (2016) showed that the most memorable visualisations are those that require less eye-movement to recognise the visualisation, and that while pictograms or other graphical embellishments can serve as “visual hooks” to aid memorisation, it is the titles and embedded text that are key to recognition and recall. Including redundancy in the values shown (data redundancy) and in visualisation of trends (message redundancy) can also aid the understanding of the author’s message.
2.2.4.3 Understanding

Various studies described in this section use traditional metrics for determining the degree to which participants understand the visualisations when completing a given task, primarily response time, response accuracy, and task abort rate (Morse et al., 2000; Purchase, 2000; Cawthon and Moere, 2007).

2.2.4.4 Aesthetics

Another important consideration when evaluating visualisations is aesthetics, and the visualisation (or elements of the visualisation) that users simply prefer, even if they are not able to fully articulate why. Cawthon and Moere (2007) conducting a study in which they correlated aesthetics with effectiveness and make the case that “beautiful is usable”. They also describing how features of the data (e.g. structure and topic) should be taken into account when designing aspects of the visualisation (e.g. chart-type and colour).

2.2.5 Other Visualisation and Interaction Technologies

2.2.5.1 Data Comics

Zhao et al. (2015) use a comic-like approach to annotating more “traditional” visualisations with cartoon-style characters and speech bubbles, to enhance the meaning of individual visualisations, and to improve linkages between different visualisations. In their study, Zhao et al. explicitly chose not to record response time or accuracy, instead focusing on participants’ perception of speed and ease of use of the visualisations, and their overall experience. They found that making use of these features increased participants’ enjoyment and engagement when compared to visualisation slideshows without these features.

Bach et al. (2016) present work on using comics to visualise graphs, focusing in particular on the way changes in a network graph can be represented through the medium of comics, highlighting a number of
techniques to represent graph features and temporal changes in sequential images while avoiding reliance on text. For example, they compare approaches to temporal changes such as using “before/after” panels (showing a simple representation of before and after the change), “transition” panels (in which each step if the changes are shown), and “fast-forward” panels (similar to the transition approach, but with smaller/shorter transitionary panels, to highlight an overview of change rather than the individual steps). They found that while annotations aided understanding, they were in general not a requirement; the exception to this was the introduction of symbolic representation (for, for example, creation or removal of edges).

2.2.5.2 Virtual, Augmented and Mixed Reality

Virtual, augmented, and mixed reality (XR) have long been considered as a means of data visualisation (Schroeder, 1993; Leston, 1996), but recent advances in technology (and reductions in cost) have made it an increasingly attractive prospect for many applications. XR has the advantage of being a wholly immersive means of visualising data to users, allowing them to appreciate the size, scope and structure of the data; however, this immersion also presents challenges in developing intuitive interaction techniques (Marks et al., 2014).

2.2.5.3 Natural Language Interfaces

Natural Language Generation (NLG) is the process of transforming data (usually in the form of a knowledge-base) into human-readable prose. For example, Vougiouklis et al. (2017) use a neural-network to produce a textual summary of structured data (in the form of Semantic Web triples), and have previously presented work on training neural-networks to respond to conversations using multiple data sources, to tailor responses to input with additional relevant context derived from background knowledge (Vougiouklis et al., 2016). This is particularly relevant for informing the automatic-storytelling approaches in D4.3 and D4.5.

The use of NLG also has applications for use with voice interfaces and chat-bots, allowing users to “talk-through” their data in place of a traditional visualisation (Poola, 2017). The recently released Amazon Echo (aka Alexa)\(^2\) and Google’s Home (aka Google Assistant)\(^3\) both present novel interfaces for data presentation, and are available to a growing audience.

\(^2\)https://alexa.amazon.com/
\(^3\)https://assistant.google.com
3 Conceptual Framework

3.1 Description of Framework

Based on the work described in §2 a conceptual framework for describing features of narrative and visualisation technologies was developed, using the existing literature in this field as a guide. For each dimension, the influencing sources are listed, along with sample values (or, in the case of evaluation, sample metrics).

The framework is presented in three parts, reflecting the areas investigated in §2.2.2, §2.2.3, and §2.2.4. Table 3.1 describes the structure of narrative and interactive components of visualisations, Table 3.2 describes the visualisation of particular properties of data, and Table 3.3 describes the different means of evaluating visualisation approaches.

The conceptual framework has been used to inform the initial ideation process (described in D4.1), and will also be used to inform the design of the visualisation and interaction components to be developed throughout the project (D4.4 and D4.6) as well as their evaluation, through the design of proposed user-studies (also described in D4.1).

3.2 Relation to Innovation Scenarios

The following sections examine how the conceptual framework relates to each of the TBFY scenarios: economic development, demand management, competitive markets, and procurement intelligence. The key elements of each scenario relating to visualisation and interaction technologies are discussed, as is the way in which key elements of the conceptual framework could be applied. The relations between scenarios and frameworks helped shape the ideation process described in D4.1.

3.2.1 Economic Development

The first innovation scenario focuses on delivering better economic outcomes from public spending. In particular, supporting small and medium-sized enterprises (SMEs) by providing better access to public tenders, allowing them to compete with larger, more established organisations (making economic incentive an inherent key motivation). There are three key outcomes to this scenario that relate to visualisation technology and the presentation of data.

Firstly, the direct-engagement tool, which will allow smaller suppliers to identify opportunities that may be suitable for SME suppliers before a tender is awarded. Using data on whom contracts are awarded to, we can determine the likelihood of business going to smaller suppliers and then give a ranking to each opportunity on its suitability for smaller suppliers. To engender trust in the rankings applied, it will likely be important to display the provenance of the information used to provide each ranking, and to allow users...
Table 3.1: Descriptive framework of narrative and visualisation technologies

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Based On</th>
<th>Sample Values</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Medium</strong></td>
<td>N/A</td>
<td>Print, Desktop, Mobile, XR, Natural Language</td>
</tr>
<tr>
<td><strong>Data Type</strong></td>
<td>Shneiderman (2003)</td>
<td>1D/Linear, 2D/Planar/Geospatial, 3D/Volumetric, Temporal, nD/Multidimensional, Tree/Hierarchical, Network</td>
</tr>
<tr>
<td><strong>Genre</strong></td>
<td>Segel and Heer (2010)</td>
<td>Magazine-Style, Annotated Chart, Partitioned Poster, Flow Chart, Comic Strip, Slideshow, Film/Video/Animation</td>
</tr>
<tr>
<td><strong>Navigation</strong></td>
<td>Segel and Heer (2010); Tong et al. (2018)</td>
<td>Linear, User-directed path, Parallel, Random Access, Other</td>
</tr>
<tr>
<td><strong>Interaction</strong></td>
<td>Segel and Heer (2010)</td>
<td>Martini-Glass, Interactive Slideshow, Drill-down narrative</td>
</tr>
<tr>
<td><strong>Motivation/Incentives</strong></td>
<td>Ryan and Deci (2000); Smart et al. (2014); Smart and Shadbolt (2015)</td>
<td>Economic, Altruistic, Hedonic, Reputational, Instrumental, Other</td>
</tr>
<tr>
<td><strong>Game Elements</strong></td>
<td>Von Ahn (2006); Thaler et al. (2012); Togelius and Gustafsson Friberger (2013); Figueiras (2015)</td>
<td>Narrative context, Goals, Levels, Ranks and reputations, Time constraints</td>
</tr>
</tbody>
</table>
Table 3.2: Conceptual framework for data-property representation within narrative and visualisation technologies

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Based On</th>
<th>Sample Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knowledge Graphs</td>
<td>Purchase (2000)</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tabular</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Minimising bends</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Minimising edge crossings</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Maximise minimum angles</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Orthogonality</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Symmetry</td>
</tr>
<tr>
<td>Provenance</td>
<td>Moreau et al. (2011)</td>
<td>Embedded</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cited</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Not included</td>
</tr>
<tr>
<td>Uncertainty</td>
<td>Pang et al. (1997); Potter et al. (2012)</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Glyphs (error bars, etc.)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Colour mapping</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Opacity</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Texture</td>
</tr>
<tr>
<td></td>
<td></td>
<td>etc.</td>
</tr>
<tr>
<td>Liveness</td>
<td></td>
<td>Live</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Updated &lt;Daily/Weekly/etc.&gt;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Static</td>
</tr>
</tbody>
</table>

Table 3.3: Evaluation framework for narrative and visualisation technologies

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Based On</th>
<th>Sample Metrics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Usability</td>
<td>Wehrend and Lewis (1990); Ellis and Dix (2006); Koua et al. (2006)</td>
<td>Locate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Identify</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Distinguish</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Categorize</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cluster</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Distribution</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rank</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Compare</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Associate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Correlate</td>
</tr>
<tr>
<td>Memorability</td>
<td>Bateman et al. (2010); Borkin et al. (2016)</td>
<td>Recognition</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Short-term recall</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Long-term recall</td>
</tr>
<tr>
<td>Understanding</td>
<td>Purchase (2000); Ellis and Dix (2006); Cawthon and Moere (2007)</td>
<td>Task abandonment</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Response time</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Response accuracy</td>
</tr>
<tr>
<td>Aesthetic</td>
<td>Purchase (2000); Cawthon and Moere (2007); Bateman et al. (2010)</td>
<td>User preference</td>
</tr>
</tbody>
</table>
Table 3.4: Conceptual framework applied to the Economic Development scenario

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Potential Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medium</td>
<td>Desktop/Mobile/Natural Language</td>
</tr>
<tr>
<td>Data Type</td>
<td>2D/Temporal/Hierarchical/Network</td>
</tr>
<tr>
<td>Genre</td>
<td>Magazine-Style/Annotated Chart/Partitioned Poster/Slideshow</td>
</tr>
<tr>
<td>Navigation</td>
<td>Linear/User-directed path</td>
</tr>
<tr>
<td>Interaction</td>
<td>Martini-Glass/Drill-down narrative</td>
</tr>
<tr>
<td>Engagement</td>
<td>Viewing/Interacting/Finding</td>
</tr>
<tr>
<td></td>
<td>Trend/Testing Hypothesis/Deriving Decisions</td>
</tr>
<tr>
<td>Motivation/Incentives</td>
<td>Economic/Instrumental</td>
</tr>
<tr>
<td>Game Elements</td>
<td>Narrative context</td>
</tr>
</tbody>
</table>

to **interact** using a drill-down narrative, to explore and expand upon the reasoning given, helping guide future decisions.

Second, the value-for-money analysis tool, which will compare the performance of smaller suppliers when delivering value for money, by using the data on spending with smaller suppliers to build an evidence base to determine whether smaller suppliers are likely to deliver value for money. In this instance, **navigation** through the visualisation can be more directed, with the curated analysis of the data being used more directly to tell an authored story using, for example, an interactive slideshow as a primary means of **interaction**. However, the exact requirement for **liveness** of the data will inform the amount of authored curation that can feasible be applied.

Lastly, the overspend analysis tool, which will monitor overspending in contracts and link it to buyers and suppliers, to predict overspend in existing contracts and to show where buyers or suppliers have a significant history of overspending on contracts. The key feature here is, clearly, the discovery and understanding of (and ultimately, prediction of) trends; once again, users will most likely need to **navigate** freely, and it will be important to encourage and enable them to act at the higher levels of **engagement**, allowing them to discover and map out existing trends in the data, and use this information to aid predictions and drive decisions.

Table 3.4 shows the descriptive elements conceptual framework applied to this scenario, with potential values to consider during future design and development for each dimension.

### 3.2.2 Demand Management

The second innovation scenario, demand management, focuses on spotting trends in spending and supplier management, to achieve long-term goals such as cost savings and efficiency gains (meaning **economic** incentive is another key motivation).

The outcome relevant to visualisation and interaction is the demand visualisation widgets, that will show where demand for private sector supply is becoming unsustainable across Europe and monitor whether demand is outstripping the capacity for governments to pay for these services, by monitoring the growth in contracting in key markets.

As before, the key to this outcome is giving users of the system the ability to discover and recognise trends in the data and make decisions based on them. Therefore, freedom in **navigation** and the way in which users **engage** with the visualisation will be of high importance.

Table 3.5 shows the descriptive elements conceptual framework applied to this scenario, with potential
D4.2– Infographic and Storytelling Technology  
Dissemination Level: Public

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Potential Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medium</td>
<td>Desktop/Mobile/Natural Language</td>
</tr>
<tr>
<td>Data Type</td>
<td>2D/Temporal/Hierarchical/Network</td>
</tr>
<tr>
<td>Genre</td>
<td>Magazine-Style/Annotated Chart/Partitioned Poster</td>
</tr>
<tr>
<td>Navigation</td>
<td>User-directed path</td>
</tr>
<tr>
<td>Interaction</td>
<td>Drill-down narrative</td>
</tr>
<tr>
<td>Engagement</td>
<td>Finding Trend/Testing Hypothesis/Deriving Decisions</td>
</tr>
<tr>
<td>Motivation/Incentives</td>
<td>Economic/Instrumental</td>
</tr>
<tr>
<td>Game Elements</td>
<td>N/A</td>
</tr>
</tbody>
</table>

values to consider during future design and development for each dimension.

3.2.3 Competitive Markets

The third innovation scenario relates to competitive markets, in particular, identifying areas in which costs can be minimised by encouraging healthy competition between suppliers (again, meaning economic incentive is a key motivation).

The relevant contribution to this scenario will mainly be in communicating the results of the analysis of aggregated data about market conditions, specifically the market mapping widgets that will visualise the numbers of bids and the diversity of supply in markets across Europe, to monitor whether supply is sufficiently competitive.

Having identified areas where competition could be improved, visualisation components will need to display the relationship between tendering data and market competitiveness. This presents an interesting opportunity to provide an authored narrative visualisation (again, depending on the required liveness of the data), utilising a Martini-glass interaction structure.

While this data may also be used to identify supplier collusion, fraud, rigged markets, etc., exploitation of this will depend heavily on the intended audience and (particularly if aimed at audit-managers and government agencies) further scoping of user-needs and existing tools will likely be required. However, one interesting potential application is the game elements to the problem of fraud detection; by providing general users tools to detect these types of activities, and rewarding users for reporting them, it may be possible to marry this important service with public engagement, outreach and transparency.

Table 3.6 shows the descriptive elements conceptual framework applied to this scenario, with potential values to consider during future design and development for each dimension.

3.2.4 Procurement Intelligence

The final innovation scenario, procurement intelligence, revolves around producing advanced analytics to inform decision support, risk monitoring and supply market analysis for procurement and purchasing managers. As before, the relevant contribution to this scenario will be in communicating the analysis of results from the procurement intelligence widgets, and comes in three main parts: presenting procurement managers with rich supplier information and possible links with competitors; identifying potential irregularities in tender calls through connected clusters of conspiring participants; and comparing supplier profiles with tender and industry trends to identify bottlenecks, or other potential disruptions, early in the tendering process.
Table 3.6: Conceptual framework applied to the Competitive Markets scenario

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Potential Values</th>
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</thead>
<tbody>
<tr>
<td>Medium</td>
<td>Desktop/Mobile/Natural Language</td>
</tr>
<tr>
<td>Data Type</td>
<td>2D/Temporal/Hierarchical/Network</td>
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<tr>
<td>Genre</td>
<td>Magazine-Style/Annotated Chart/Partitioned Poster/Slideshow</td>
</tr>
<tr>
<td>Navigation</td>
<td>User-directed path</td>
</tr>
<tr>
<td>Interaction</td>
<td>Drill-down narrative</td>
</tr>
<tr>
<td>Engagement</td>
<td>Viewing/Interacting/Finding Trend/Testing Hypothesis/Deriving Decisions</td>
</tr>
<tr>
<td>Motivation/Incentives</td>
<td>Economic/Instrumental</td>
</tr>
<tr>
<td>Game Elements</td>
<td>Narrative context/Goals/Levels/Ranks and reputation/Time constraints</td>
</tr>
</tbody>
</table>

Table 3.7: Conceptual framework applied to the Procurement Intelligence scenario

<table>
<thead>
<tr>
<th>Dimension</th>
<th>Potential Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medium</td>
<td>Desktop/Mobile/Natural Language</td>
</tr>
<tr>
<td>Data Type</td>
<td>2D/Temporal/Hierarchical/Network</td>
</tr>
<tr>
<td>Genre</td>
<td>Annotated Chart</td>
</tr>
<tr>
<td>Navigation</td>
<td>User-directed path</td>
</tr>
<tr>
<td>Interaction</td>
<td>Drill-down narrative</td>
</tr>
<tr>
<td>Engagement</td>
<td>Finding Trend/Testing Hypothesis/Deriving Decisions</td>
</tr>
<tr>
<td>Motivation/Incentives</td>
<td>Economic/Instrumental</td>
</tr>
<tr>
<td>Game Elements</td>
<td>N/A</td>
</tr>
</tbody>
</table>

As with several scenario outputs above, the primary feature here is the explorative nature of the process, requiring users to **navigate** freely to discover trends, supported by the visualisation component. As such, any visualisation components deployed should again strive for supporting the higher tiers of **engagement**.

Table 3.7 shows the descriptive elements conceptual framework applied to this scenario, with potential values to consider during future design and development for each dimension.
4 Conclusion

In this document we review the existing literature on HDI and visualisation research, in particular examining narrative visualisations and the ways through which they can be made effective, memorable, persuasive and engaging. We then presented a conceptual visualisation and interaction framework, focusing on the role of the visualisation and interaction within the TBFY scenarios.

This work, combined with the initial ideation process described in D4.1, suggests that the next steps in the development of the visualisation and interaction components as part of WP4 should be to carry out a number of user studies, introducing elements of the visualisation described in this document (potentially combined with novel experimental interfaces) to the existing tools and platforms provided and maintained by consortium members, to best support their users and stakeholders in procurement-related tasks.
5 References


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