Guest editorial: Knowledge visualisation for strategic decision-making in the digital age

1. Introduction

In today's digital age, the proliferation of data and advanced technologies are transforming the way organisations manage, integrate and deploy their knowledge and competences, take strategic decisions, operate their business models and drive value creation mechanisms to meet diversified stakeholders wants and needs.

In this context, the approaches, models and tools for visual representation have become fundamental management means to process data and information, support knowledge management, enhance understanding and sense-making capabilities and facilitate decision-making process and actions planning (e.g. Bačić and Fadlalla, 2016; De Regt, 2014; Eppler and Platts, 2009; Foil and Huff, 1992; Lohse *et al.*, 1994; Lurie and Mason, 2007; Miah *et al.*, 2017; Munzner, 2014; Schiuma *et al.*, 2012; Tan and Platts, 2003; Tufte *et al.*, 1990).

A visual representation can concern data, information and knowledge, resulting in different domains of visualisation that focus respectively on data, i.e. symbols and facts, which are isolated and not interpreted yet (Ackoff, 1989; Keller and Tergan, 2005), information, i.e. data that has been interpreted or processed and therefore contains some meaning and can give answers to questions like "who?", "what?", "where?", "why?" or "when?", and knowledge, which is one step further information, which has been cognitively processed and incorporated into an existing human knowledge structure (Ackoff, 1989; Keller and Tergan, 2005). There are currently no defined boundaries between the different cited visualisation domains (Masud *et al.*, 2010). They appear overlapping since, commonly, in visualisation context, data, information and knowledge are used extensively interrelatedly (Chen *et al.*, 2008). Data, information and knowledge, can be, indeed, both the input and output of a visualisation process, raising questions about the exact role of data, information and knowledge in visualisation (Chen *et al.*, 2008).

Besides the issue of clarifying taxonomically the terminology used in the visualisation processes and the precise role played by data, information and knowledge (Cui *et al.*, 2006; Chen *et al.*, 2009), it is widely acknowledged that visualisation shapes the experience that people have with data, information and knowledge, and appropriate visual representations can make knowledge more accessible, meaningful and inspirational.

Several studies have analysed the use of visual representations to improve the management of knowledge on all levels, i.e. personal, interpersonal, team, organisational, inter-organisational and societal (see, e.g. Eppler, 2013; Eppler and Burkhard, 2007; Gavrilova *et al.*, 2019; Isokpehi *et al.*, 2020; Meyer, 2010; Tergan *et al.*, 2006).

These studies intersect different research fields such as knowledge management, computer science, psychology, and design and denote the broad research field of knowledge visualisation. Scholars have variously described and characterised the knowledge visualisation research area.

Meyer (2010) describes knowledge visualisation as a relatively new interdisciplinary field of research that focuses on creating and transferring knowledge by visualisations with and without the help of computers.

Similarly, Tergan *et al.* (2006) define knowledge visualisation as a field of study that investigates the power of visual formats to represent knowledge and supports cognitive processes in generating, representing, structuring, retrieving, sharing and using knowledge.

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According to Eppler and Burkhard (2007), "knowledge visualisation designates all graphic means that can be used to construct, assess, measure, convey or apply knowledge" (p. 112).

Burkhard (2004) argues that knowledge visualisation differs from information visualisation since it uses a visual representation to transfer knowledge between two persons and generate new knowledge. Moreover, according to the scholar, a trait distinguishing knowledge visualisation is the experiential and implementation dimension.

Isokpehi *et al.* (2020) identify the following functions of knowledge visualisation: "(1) coordination (coordinate the communication of knowledge workers); (2) attention (raise awareness and provide a focus for knowledge creation and transfer); (3) recall (improve memorability and thus foster the application of new knowledge); (4) motivation (energise viewers to engage in interpretation and explore the graphic); (5) elaboration (the process of visualising knowledge leads to further understanding and appreciation of concepts and ideas as one interacts with them); and (6) new insights (knowledge visualisations can reveal previously hidden connections and lead to sudden insights, a-ha experiences)" (p. 2).

Renaud and Van Biljon (2019) state that knowledge visualisation can help share, transfer communicate experiences, insights and potentially complex knowledge to support someone to decide and get action.

Some scholars have pointed out that visualisation is particularly crucial to catalyse and support cognitive decision-making processes (see, e.g. Chen, 2010; Platts and Tan, 2004; Sackett *et al.*, 2006).

Visualising knowledge helps reduce the cognitive load, misinterpretation, misuse, underutilisation or inability to use information, allows to externalise knowledge and to share it with others, generating new knowledge and supporting decision-making (Burkhard, 2004; Tergan *et al.*, 2006).

The usefulness of using visual representations, such as, e.g. diagrams, graphics, schemas, mind maps, social graphs captured in real-time, to address strategic, management, organisational and policy matters and make decisions, has been highlighted by many scholars (see, e.g. Berinato, 2016; Eppler and Bresciani, 2013; Eppler and Platts, 2009; Miah *et al.*, 2017).

Nowadays, creating and using a proper visualisation approach, models and tools to extract insights from a vast amount of data, identify hidden patterns and trends in huge datasets, understand phenomena and inform decisions have become more critical than ever.

The unpredictability of the socio-economic scenario, recently exacerbated by the pandemic, the rapid advance of digital technologies, the exponential growth pace of data and information require promptness in understanding and communicating phenomena and problems and taking the right decisions.

In such a context extremely volatile, managers and policymakers have to overcome the limitations of relying just on their own experience, intuition or feeling in decision-making (Eppler and Bresciani, 2013; Eppler and Burkhard, 2004, 2007; Tan and Platts, 2003) and need to improve their ability to interpret data and information and to enlarge the range of options before making their decisions (Tan and Platts, 2003).

Visual representations amplify decision-makers' working memory and cognition and improve their capability to process information and knowledge (Coury and Boulette, 1992).

The availability of information and knowledge properly visualised help decision-makers look at a problem in a new way and capture its key features, share thinking with colleagues, identify objectives, formulate alternatives and choose the best option, thus improving the decision-making process's outcomes decreasing uncertainty.

Numerous visualisation representations can be used to collect and transform data, information and knowledge in a visual form that enhances decision-makers' capabilities of evaluating, understanding and discerning. Sketch, diagrams, maps, images, objects,

interactive visualisation and visions/stories are traditional forms of knowledge visualisation (Burkhard, 2005; Meyer, 2010). Nowadays, a vast plethora of visual representations based on advanced computer graphics design is available, and it is going to be further developed by infographic and design specialists.

Proper knowledge visualisation representations for a comprehensive description of knowledge associated with a problem is not obvious and still represents a crucial managerial question. As underlined by Clevelend and McGill (1985) and Meyer *et al.* (1999), the visual representations for effective have to guarantee accurate visual decoding by the decision-maker and be consistent with the decision-makers' mental representation of the decision problem. Only those visual representations that are easy-to-use, to understand and appropriate against a decision problem can facilitate and support the perceptual and rational thinking of decision-makers (e.g. Duke *et al.*, 2005; Eppler, 2013; Eppler and Burkhard, 2007; Falschlunger *et al.*, 2016; Munzner, 2014). If not well-conceived and designed, visual representations can change the perception of a phenomenon or problem, highlight less important decision variables, introduce biases and induce inappropriate evaluations.

This special issue aimed to attract rigorous research studies from scholars all over the world, contributing to enrich theoretical and practical knowledge about the role of knowledge visualisation for strategic decision-making and providing fresh insights about approaches, models, processes and tools of knowledge visualisation for timely and effective decision-making in organisations.

The following section presents the synopsis of the papers included in this particular issue.

2. Synopsis of the special issue papers

The paper by Yigitcanlar *et al.*, "Pandemic Vulnerability Knowledge Visualisation for Strategic Decision-Making: A COVID-19 Index for Government Response in Australia", presents a "pandemic vulnerability knowledge visualisation index to support the strategic decision-making efforts of authorities". The research highlights "the need for a novel and balance vulnerability index to determine and visualise the high-vulnerability locations and communities, and help in informed strategic decision-making and responses of the authorities to the pandemic. The context of the investigation is Australia. The research identifies a total of ten indicators considered to meaningfully impact the vulnerability of local communities against the spread of the SARS-CoV2 virus and subsequent disease. These indicators allow to build a vulnerability index that, different from other vulnerability indices, also considers human emotions.

Ferreira *et al.*, in their paper "Strategic visualisation: the (real) usefulness of cognitive mapping in smart city conceptualisation", highlight "cognitive mapping's tangible usefulness as an expedient tool for strategic analysis, using smart cities as a complex object of study". The scholars build and compare various cognitive maps regarding factors and characteristics that sustain the best smart cities using the Strategic Options Development and Analysis (SODA) approach. According to the scholars, the study results "support the conclusion that visualisation is a powerful tool for managers to use when constructing strategic plans and making all the necessary decisions in different phases. The collaboration needed to render strategy content in a graphic form is what makes this approach a distinctive and vital sense-making activity".

The paper by Morea *et al.,* "Productivity Dispersion in the Italian Knowledge-Intensive Business Services (KIBS) Industry: a Multilevel Analysis", explores "the relationship between productivity changes, regional and sectorial characteristics in the KIBS industry using a sample of 18,549 firms operating in Italy for the period 2012–2018". The authors address strategic drivers connected to the regionals and sectorial factors to consider in strategic decision-making that can support KIBS services innovation in the digital era.

Medeiros and Maçada, in their work "Competitive advantage of data-driven analytical capabilities: the role of big data visualisation and organisational agility", analyse empirical evidence about "how data-driven culture and business analytics affect competitive advantage, considering the mediating effects of big data visualisation and organisational agility". The authors surveyed 173 managers who are big data visualisation and business analytics users in Brazilian organisations of various economic segments. They analysed data through structural equation modelling and mediation tests. The findings show that "data-driven culture and big data visualisation are antecedents of business analytics" and suggest "the importance of cultural and behavioural aspects related to the use of the analytical capabilities".

The paper titled "Visual Disclosure Through Integrated Reporting" by Raimo *et al.* shows an "innovative methodology to measure the use and degree of integration of visual tools within integrated reports and examines the factors affecting the visual disclosure". The authors developed a regression analysis on a sample of 134 international companies that published an integrated report in 2018. The analysis results showed that "the company's size and profitability and the degree of environmental sensitivity of the sector in which the company operates positively affect the level of visual disclosure of the integrated reports".

Iazzolino *et al.*, in their paper "Meta-choices in Ranking knowledge-based organisations", address knowledge visualisation and its connection with performance measurement from an epistemological point of view. They propose a theoretical contribution "or identifying the three main meta-choices problems that arise in the multidimensional benchmarking of knowledge-based organisations". The meta-choices problems concern the algorithm to use, the variables to consider and the data to analyse. The authors examine the case study of Italian universities.

The paper titled "Knowledge management visualisation in regional innovation system collaborative decision-making", by Ferreira *et al.*, analyses "the potential of knowledge visualisation in collaborative decision-making applied to the development of a multiple criteria framework supporting knowledge management through knowledge collaboration and knowledge sharing in the context of Regional Innovation Systems". The authors propose a multiple-criteria model that integrates knowledge visualisation and collaborative decision-making techniques (i.e. cognitive mapping and system dynamics) and supports knowledge collaboration and sharing among regional innovation systems actors. The model's potential is explored in a case study setting regarding the building of age-friendly smart living environments (SLEs).

Zhao *et al.*, in their paper "Knowledge visualisation for construction procurement decision-making: a process innovation", propose a knowledge visualised framework for supporting construction procurement system decision-making. The framework (process) is based on four influential decision supporting methods (mean utility values, analytic hierarchy process, fuzzy set theory and Delphi method) and computer programming (Matlab). It "implements four steps of knowledge visualisation advanced decision-making: (1) uniform rating for decision alternatives; (2) group decision for determining the decision attribute; (3) determining the final choice; (4) reporting the cognitive computing process". The proposed model helps decision-makers understand and improve their cognitive learning and facilitate a collaborative decision-making process.

The paper "The value of System Dynamics' diagrams for Business Model Innovation" by Linzalone *et al.* addresses the value of system dynamics visual tools, i.e. causal loop diagrams and stock and flow diagrams, to support decisions in business model innovation. The authors analyse a single-case study about business model diversification. An information and communications technology (ICT) service provider has added a new business model to its existing business model based on a digital multisided platform for passengers' transportation. The study highlights how the use of visual tools allowed entrepreneurs to

overcome the complexity of the business parameters concurring in the design of the business model.

Canonico *et al.*, in their paper "Visualising knowledge for decision-making in Lean Production Development settings. Insights from the automotive industry", discuss "how knowledge visualisation supports the development of a particular multiobjective decision-making problem, as a portfolio optimisation problem, in the context of inter-organisational collaboration between universities and a large automotive company". The authors analyse the empirical case regarding the setting up a multiobjective decision-making model, as a portfolio optimisation problem, for upgrading the lean production process quality at an FCA plant.

The study by Yan *et al.*, "Integrated Knowledge Visualisation and Enterprise Digital Twin System for Supporting Strategic Management Decision", proposes a strategic digital twin management decision system to provide a holistic view of a constant and frequent adjustment on every decision affecting the business performance over strategic time scales. The authors analyse a case study regarding how a UK-based firm makes strategic decisions for business development. The research results "reveal that data analytics and the visualised enterprise digital twin system offer better practices for strategic management decisions in dynamic and constantly changing business world by providing a constant and frequent adjustment on every decision that affects how the business performs over both operational and strategic time-scales".

Troise, in his study "Exploring knowledge visualisation in the digital age: an analysis of benefits and risks", analyses the main benefits and risks of knowledge visualisation by exploring a sample of 57 SMEs in Italy. "The main benefits highlighted in the study are related to stakeholder engagement, flexibility, knowledge transfer, signalling role, agility and, interactivity; on the other side, the risks identified are related to complexity, absorptive capacity, divergences, capabilities and, ineffectiveness".

The paper "A knowledge visualisation approach to identify and discovery inner areas: a pilot application in the province of Lecce", by Elia *et al.*, suggests a knowledge visualisation approach and algorithm to support public decision-makers to define the inner areas. It adopted the design science research approach, the research analyses the 97 municipalities of the Province of Lecce. The municipalities were analysed through a set of indicators and dynamic and interactive knowledge maps. According to the authors, "the approach and algorithm proposed to allow discovering similarities existing among distinct municipalities, based on the analysis of a set of multi-domain indicators". This can help policymakers be more aware of similarities existing among distinct towns and take more informed decisions on territorial development.

Secundo *et al.*, in their paper "Strategic Decision-Making in Project Management: A Knowledge Visualization Framework", propose a visual representation of knowledge involved in a system of project components and decisions. From a system view of project dimensions, the scholars identify eight types of strategic choices, i.e. growth, problem shifting, goals balancing, escalation, rewarding, resource allocation, problem fixing and cooperation. Then they propose "a visualisation map of project decision-making addressing six categories of knowledge (i.e. 'what knowledge', 'how knowledge', 'who knowledge', 'why knowledge', 'what for knowledge' and 'when knowledge')".

Kudryavtsev *et al.*, in their paper "Visualising knowledge for decision-making: outlining graphical templates", propose a framework to assist the understanding and selection of the proper visual templates for comprehensive description and representation of knowledge associated with a decision problem. The scholars offer a set of new classifications of visual knowledge templates. The classifications are based on four important criteria that encompass issues and questions that need to be considered when selecting knowledge visualisation templates to support problem-solving and decision-making. The requirements are (1) level of formality, (2) level of domain-dependence, (3) content types and (4) form of knowledge.

3. Conclusions

The big data "explosion", the daily navigation into an ocean of information coming from different sources, sites and stakeholders, the increase in the complexity of the systems being modelled, the current new scenario made even more unpredictable due to the pandemic crisis, make knowledge visualisation tremendously crucial for understanding and communicating phenomenon and problems, and to take right decisions.

This special issue investigates the emerging avenue that matches knowledge visualisation with strategic decision-making through theoretical and practical lenses. The selected papers, both conceptual and empirical, shed more light on several aspects of how knowledge visualisation helps in decision-making.

Indeed, research and practice on this relevant topic have been still progressing. Knowledge visualisation has great potential, and we are just beginning to exploit it.

Many issues also need to be further investigated in light of the wave of digital transformation that is overwhelming both public and private organisations and the new strategic decision challenges generated by the COVID pandemic. Therefore, more than ever, the relevance of knowledge visualisation in supporting strategic management decisions calls for a more in-depth investigation of the approaches, models, processes and tools supporting the creation, representation, structuring, retrieving, transfer, exchange and integration of knowledge at the core of decision-making and organisational value creation dynamics.

The structured collection of articles presented in the special issue provides novel theoretical approaches and clear empirical evidence of the value of knowledge visualisation for strategic decision-making. It represents one piece in our still incomplete mosaic of knowledge regarding visualisation and its high potential.

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