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Visualising data for project portfolio decision making.

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Visualisations of project portfolio data are making an increasing impact on the management of portfolios of projects. Project portfolio management (PPM) approaches provide decision makers with a high-level strategic view of the projects in a portfolio to promote decisions that provide the best overall benefit. In industries where strategy is primarily delivered through projects, PPM is an essential capability; PPM decisions bridge strategy with its delivery through projects. Such decisions require analysis of information about a wide range of factors including strategic objectives, project performance, risks, resource requirements, and relationships between projects.

Visualisations of data are regularly used in PPM to assist decision makers to understand the data and 'see' the project landscape. The increased use of such visuals can be partially attributed to the increasing ease in creating graphical displays. Creating visuals was once a time-consuming manual process; now visuals can be almost instantly generated by software programs. Dashboards of multiple visuals have become a common feature of PPM and other management systems. However, the ease of creation does not ensure the visuals will be useful. Visuals can confuse, mislead and waste time when not created well, tailored to context and understood by the users. Research is important to understand whether and how visuals can enhance decision making – and to provide guidance for the effective use of visualisations in PPM.

Established PPM capabilities provide organisations with competitive advantages that enable them to compete and adapt to changes in the environment (Killen & Hunt, 2010). The decision environment and the processes that support decision making are central to PPM. A primary goal of a PPM process should be to support the decision makers and enhance their ability to make good decisions; such decisions affect the implementation of strategy, the development of competitive advantages, and survival and success of the organisation.

Portfolio-level decisions are often made a by a group of experienced managers and executives in portfolio review meetings – this group is often called the portfolio review board (PRB) (Killen, Hunt, & Kleinschmidt, 2008a; Mosavi, 2014). Decision boards that are made up of experienced and accountable representatives of different perspectives (finance, marketing, technical, operations etc) are most often recommended by research findings (Killen et al., 2008a). The goal is to gain input from multiple perspectives to best understand the project landscape and generate robust discussions that lead to well-informed and balanced decisions. Visuals have a growing influence in this process; visual representations of data are often provided to decision makers in advance, and referred to during the PRB meetings (Cooper, Edgett, & Kleinschmidt, 2001). Evidence is mounting on the ways that visuals can enhance the ability of decision makers to understand and discuss the relevant project portfolio data. For example, a case-based study of six organisations emphasised the importance of the dialogue during PRB meetings and how visuals can generate valuable discussions (Killen & Hunt, 2010).

This chapter outlines research on the use of visuals in PPM. It first introduces some of the theories and concepts that underpin the research, and then explains three programs of research that explore the role of visualisations of data for PPM decision making. Practical implications from these research studies are brought together in the concluding section to guide managers in improving the ways visuals are used to support PPM.

The role of cognitive limits in PPM decision making

PPM decisions are challenging – decision makers must absorb a wide range of information about the projects in the portfolio to support their decisions. When allocating resources to projects, or changing the priority or scope of projects, decision makers need to understand how each project fits with other projects in the portfolio on multiple dimensions. For example –

- How does this project fit with our strategy?
- Does this project complement or conflict with other projects?
- How strong and reliable is the need for this project (markets, customers, changing demographics)?
- What resources are required (funding, skills, equipment)?
- What benefits are expected (financial return on investment, strategic or reputational advantages)?
- Are other projects or external factors important for this project (does this project depend on another project? do regulations affect the project? will the project or its supply chain be affected by international events?).
- What are the risks involved (financial, safety, legal, reputational)?

These and other questions factor into the complex PPM decision-making task of choosing and supporting the best overall set of projects to meet short and long-term objectives. This volume of information about the projects and the portfolio presents a cognitive challenge for decision makers: How can they absorb and make sense of all the data in order to make good decisions? The research presented in this chapter explores the role of visuals in enhancing the ways decision makers understand, analyse and discuss information.

Concepts of cognition, cognitive fit and bounded rationality help to explain why making good decisions in such environments is challenging and how visuals can be of assistance. Cognition refers to the mental processes required for learning, solving problems, making decisions, absorbing information and forming memories (Newell, 1990). These mental processes represent a 'cognitive load' on the working memory of decisions makers. There are limits to the amount of information that can be handled by individual decision makers. These limits are often compared to limits in computer processing power; when the load is too high, information cannot be processed effectively. Similarly, in PPM decision making – once the cognitive load required to absorb and analyse portfolio information increases too much, cognitive capability becomes overloaded, and the quality of decisions is affected.

Although the analogy with computer processing can be useful, human cognition is much more complex than computer processing. In particular, humans possess nuanced perception capabilities and superior abilities to recognise patterns. When designed well, visual representations of data can complement human cognitive capabilities and improve decision makers' ability to understand the data (Tergan & Keller, 2005; Ware, 2012).

Recent research on the use of visuals for PPM has drawn on two main theories related to cognition: cognitive fit theory and the theory of bounded rationality.

Cognitive fit theory proposes that visuals are most effective when the elements used in the design of the visuals correspond to the problem at hand, in other words when there is a high level of 'cognitive fit' (Vessey, 1991). The second research theme discussed below provides further information on cognitive fit theory and its application in research on PPM visuals.

The theory of bounded rationality aims to provide a holistic way of understanding cognitive limits and decision making (Simon, 1955). According to the theory, human decision making is flawed due to the 'bounded rationality' resulting from three main impediments to making 'perfect' decisions. These are 1) limits in the reliability of the information (incomplete, inaccurate or outdated data), 2) limits in the amount of information that can be absorbed by the human decision maker (cognitive limits), and 3) limits in the time available to make a decision (Simon, 1955). According to the theory, decisions will be improved if the impact of one or more of these limits can be minimised.

Many of the efforts to improve PPM decision making aim to address these limits. Ensuring the reliability of the data is an essential part of PPM, as nothing can compensate for inaccurate data – and an effective PPM process requires that decision makers trust the information at hand. In response, PPM frameworks have a strong focus on processes designed to collect and maintain relevant, current and reliable data about projects, and to compile that data to support decision making. Much of the PPM guidance and literature documents methods for collecting, maintaining and collating data – including the use of visuals to display the data. In addition, PPM research repeatedly confirms that considerations on what types of data to collect, and how often to collect and update information, will depend on the context, the nature of the decisions in that environment and the time and effort involved. Tailoring and customising PPM often focuses on the mechanisms related to collecting and compiling data to reduce the effect on decisions from limits in the data. This tailoring includes the design and use of visuals to display data that is relevant for the decision context.

While many PPM processes aim to ensure accurate, up-to-date and reliable information to support better decision making, there is less attention given to the other aspects of the theory of bounded rationality (limits in cognitive capabilities and limits in available time). Two distinct streams of PPM research aim to reduce the impact from cognitive limits and to speed up the decision process, in very different ways. One of these streams involves the development of mathematical optimisation models to make or support project portfolio decisions, and the other stream explores the use of visuals in PPM decision processes (the focus of this chapter).

Mathematical models assign numerical values to measure and provide weighting factors for the many considerations in PPM decisions, and employ a range of algorithms to generate 'optimal' portfolios of projects. Despite the volumes of research in this area, and the increasingly sophisticated algorithms applied (see, for example, Abbassi, Ashrafi, & Sharifi Tashnizi, 2014; Mohagheghi, Meysam Mousavi, & Mojtahedi, 2020; Wu, Xu, Ke, Tao, & Li, 2019), such models are rarely used in practice. One drawback of such mathematical modelling is that the quantification of subjective information (such as the degree of strategic alignment) or information projecting the future (such as the expected NPV) can obscures the nuances of the situation. Executives and managers are often uncomfortable with using such models to support decision making; they expect to bring their experience and perspectives to discussions about strategic portfolio options at PRB decision meetings. Decision makers in one study expressed concerns that computer-based tools that reduce opportunities for face-to-face dialogue may jeopardise the process (Killen & Hunt, 2010).

In contrast, executives and managers embrace the use of visuals to enhance decision making. Research demonstrates the power of visuals in a range of strategic management and business activities (Bresciani, 2019; Bresciani & Eppler, 2015; Kernbach, Eppler, & Bresciani, 2015; Warglien & Jacobides, 2010). An increasingly influential stream of research on the use of visual representations of portfolio data reveals how visuals can address the limits in cognitive capability and the time available and improve project portfolio decisions. Three themes of PPM research on visuals are summarised below: 1) Research findings on the design of PPM visuals, 2) Cognitive fit and visualising project interdependencies as a network, and 3) the role of the decision maker, bias and heuristics in PPM decisions.

Theme 1) Designing visuals: research findings on the design of PPM visuals:

Visualisations have long been used in PPM decision making, however the prevalence and types of visuals employed are increasing. The most prominent type of PPM visual is the portfolio map (also called a bubble chart, see

Figure 1). Such 2 x 2 matrix-based visuals show the spread of project options (current and/or proposed projects) on two dimensions – with other information provided through graphical means and text labels – to provide a holistic view to support PPM decision making (Mikkola, 2001). Other PPM visualisations include score cards, dashboards, radar charts, pie charts, bar/stack graphs, bubble diagrams etc. (Cooper et al., 2001; Kodukula, 2014; Wideman, 2004). Research confirms advantages from the use of portfolio maps (Cooper, Edgett, & Kleinschmidt, 1999; Killen, Hunt, & Kleinschmidt, 2008b) and that the use of multiple types of visuals (rather than just one) can enhance the benefits (Killen, Geraldi, & Kock, 2020). Not all visuals are beneficial however – advantages are obtained when the visuals are well designed (Geraldi & Arlt, 2015) and decision makers are familiar with the visuals (Killen et al., 2020).

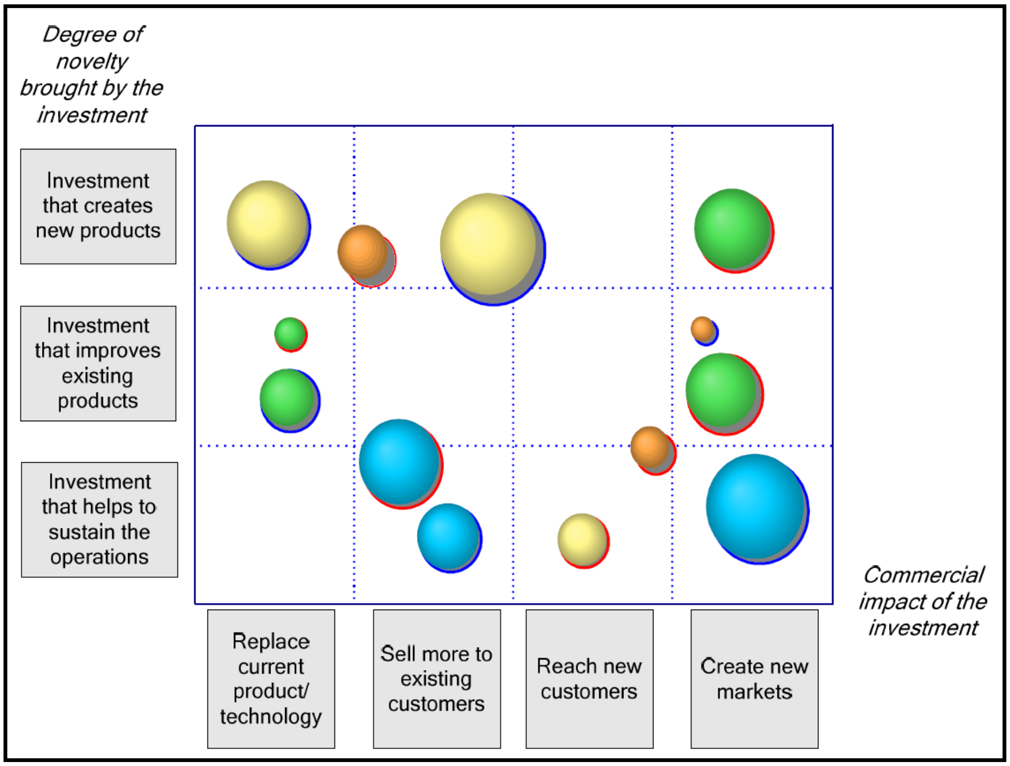

Figure 1: Example Portfolio Map (Arlt, 2010: 119)

Guidance on the design of visuals has been developed based on an extensive research study (Arlt, 2010; Geraldi & Arlt, 2015). Researchers tested a range of PPM visuals through experiments and interviews with 204 participants. The findings enhanced the understanding of which elements and options produced the most effective visuals to support decision making. Based on their in-depth research and the resulting insights on how the design of PPM visuals influence the decision process, Geraldi and Arlt (2015) offer five principles for the design of effective visuals to support strategic PPM decision making:

- Interactive: Organisations obtain greater benefits from visuals when the user is able to interact with the visuals by creating and customising the format or data. However too much interactivity reduces benefits – for example when users do not have a standard framework to guide their use of the visuals. The limits of interactivity are also explored in other studies; too much interactivity can be a negative if it overwhelms or distracts the decision maker or obscures relevant information (van der Land, Schouten, Feldberg, van den Hooff, & Huysman, 2013).

- Purposeful: Visuals should display a subset of the data in order to provide focus on information that is relevant to the PPM problem at hand. Whether a visual is purposeful will depend on the context – PPM visuals need to be tailored to suit the decision environment.

- Truthful: The underlying data should be accurate and trusted by users. User perceptions are important – the benefits from visuals will be decreased if users suspect deceit designed to manipulate perceptions. It is important to clearly portray the data using expected conventions such as standard formats for labelling axes and selecting the end points and range.

- Efficient: Visuals should be designed to take advantage of the natural human capacity to recognise patterns and interpret meaning. This principle aligns with the concept of cognitive fit, although the concept was not mentioned by Geraldi and Arlt (2015). Cognitive fit is discussed further in the next section.

- Aesthetic: Research confirms that visuals that are pleasing to look at produce better outcomes. This principle aligns with prominent guidance on visuals (Tufte & Robins, 1997)

Theme 2) Cognitive fit: visualising interdependencies between projects using network mapping

The theory of cognitive fit proposes that a visualisation will be more effective if the nature of the representation 'fits' with the nature of the problem. A high level of cognitive fit reduces the amount of cognitive energy required to interpret the visualisation by reducing the steps that must be done cognitively. For example, a line chart tracking sales volume over time has good cognitive fit for evaluating an increase or decrease in sales (the slope of the line directly shows the degree of increase or decrease), whereas a table of sales figures requires a number of cognitive steps to select and compare individual items of data in order to determine whether there is an increase or decrease in the sales.

The concept of cognitive fit is demonstrated through research on visualising interdependencies between projects. To make the best decisions, it is essential to understand how projects and project decisions affect other projects in the portfolio. However, standard PPM approaches often represent each project or project idea as an independent entity, with little recognition of the ways that projects affect each other (Bathallath, Smedberg, & Kjellin, 2016; Killen & Kjaer, 2012). The ability to incorporate information on dependencies between projects is a recognised weakness in common PPM approaches (Elonen & Artto, 2003). This section summarises research findings on the role of cognitive fit in supporting PPM decision making by using network mapping to represent project interdependencies (Killen, 2017; Killen & Kjaer, 2012).

Dependencies between projects can take many forms. Common types of dependencies are: Outcome dependencies, where a project depends on the outcomes from another project; Resource Dependencies, where a project depends on resources that are used by another project, or Learning Dependencies, where a project depends on the availability of knowledge that is developed through another project (Bathallath et al., 2016; Killen, 2017). When such interdependencies exist between projects, decisions made about one project will affect the success of other projects. The impact can cause delays or affect the quality or scope of project outcomes – and can even be critical, preventing successful completion of the project. Managing dependencies between projects requires first understanding where dependencies occur (between which projects, what type, and in what direction) and where dependencies and their effects cascade through a chain of dependent projects.

Visual project maps: A network mapping approach to visualise interdependencies

Traditionally, dependencies between projects have been recorded in spreadsheets or databases, and in some environments displayed visually using a grid-based visual display called a dependency map (Danilovic & Browning, 2007; Dickinson, Thornton, & Graves, 2001). Dependency maps list all projects on both the X and Y axis of the grid, and provide marks or dates to indicate dependencies on the relevant cells of the grid (see the top half of Figure 2). Although dependency maps can be useful, users must take several cognitive steps to analyse the information. For each dependency marked in the grid, users must check the row and column headers to determine which projects have interdependencies. In addition, the information is provided based on a pair of projects; additional steps are required to check for chains of flow-on dependencies.

Another way of viewing the interdependencies between projects is as a network. Similar to approaches used for social network analysis, a network mapping approach has been developed to improve understanding and managing project portfolio dependencies. Drawing upon the cognitive fit perspective, the network mapping approach was designed to have a strong 'fit' between the nature of the task and the visual representation. Using this approach, projects are the 'nodes' in the network (represented by circles), and the interdependencies between projects form the 'connections' between the projects (represented by arrows). Projects can be connected to multiple other projects in a 'network' of connections where the arrows indicate the direction of dependencies, and chains of dependencies can be followed by tracing connections (dependencies) across nodes (projects). The visual project map (VPM) approach was developed with a goal to better support more accurate and faster decision making by reducing the cognitive effort required to understand interdependencies. The bottom half of Figure 2 shows a portion of a VPM that displays the same data as the Dependency Matrix in the top half of the figure.

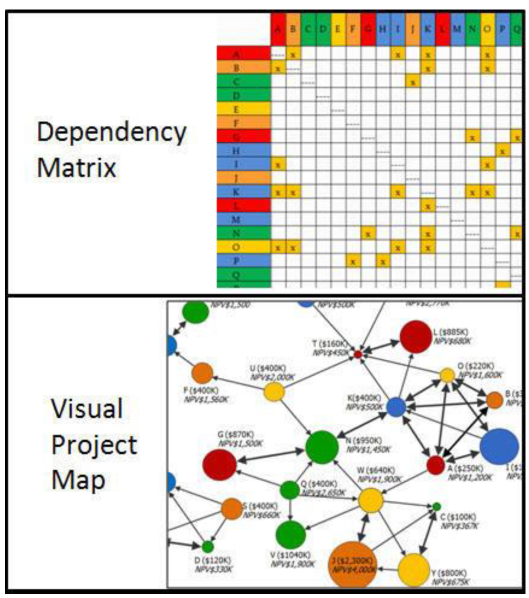

Figure 2 Example Dependency Matrix and Visual Project Map (VPM)

Extensive experimental research with 480 participants (Killen, 2017) complemented findings from implementing VPM in organisations (Killen & Kjaer, 2012) and provides strong support for using VPM to manage interdependencies. The experiments compared decisions made based on displays of the same data, represented using different formats. The results revealed that the choice of visual format affected the decisions. Decisions were more accurate, and were made more quickly when interdependency data were displayed in the VPM format instead of through a dependency matrix or a spreadsheet (Killen, 2017). Evidence that the format of the visuals can affect decisions also raises concerns about potential bias or undue influence from the format of the visuals. There is a danger that visuals will be formatted in a way to intentionally skew decisions in a particular direction, or that poorly designed visuals will inadvertently affect decisions. The power of visuals is clear, and the challenge is to design visuals that enhance decision making without creating additional bias.

Participants in organisations that trialled the VPM approach felt that the project mapping displays were an excellent device for communicating the relationships between projects to support strategic decisions, and to explain the decisions to others (Killen & Kjaer, 2012). Decision makers noted that the VPM displays enabled them to gain a holistic perspective and understand flow-on effects from portfolio decisions. One senior decision maker commented that the maps provided the ability to "see the connections and where the work needs to be done … it does add value to me and I can see [relationships] that I had not seen before" (Killen & Kjaer, 2012, p. 562).

These positive findings on the use of visual project maps can be explained by the high level of cognitive fit between the problem and the nature of the visual representation. The findings from research on using network mapping to evaluate portfolio interdependencies offers these implications for practitioners:

- Network-based visualisations of project interdependencies should be considered to support faster and better decision making.
- Cognitive fit between the task and the visuals should be a goal in the careful and purposeful design of visuals.
- Visuals are powerful. The findings serve to remind practitioners that the choice and design of visuals can influence or bias decisions.

Theme 3) Bias and Heuristics: the role of individual decision maker's experience and preferences

Research and practitioner publications regularly discuss the many different types and styles of PPM visuals and their application (Cooper et al., 2001; Geraldi & Arlt, 2015). Less attention is paid to the other side – to the qualities of the decision makers who view and use the visuals. While most research has focused on the actual visuals to determine what is most effective, recent research explores the impact from the individual decision makers' characteristics, and how they use visuals (Killen et al., 2020). The study involved 138 organisations, each with between 2 and 5 participants who completed a detailed survey. The multi-informant study collects different types of survey data from respondents in different roles to reduce bias and increase reliability and confidence in the findings. For example, a decision maker from each organisation reports on their experiences, their decision-making preferences, and the outcomes of the PPM process, while people closer to the PPM activities report on the details of the process.

The findings reveal that the decision makers' experiences and preferences affect the success of the decisions. Experience with visuals is associated with increased decision-making success, supporting propositions that familiarity with visuals reduces the cognitive load (Killen et al., 2020). When a decision maker is familiar with a visualization, the degree of mental energy required to understand the format of the visualization is reduced, and more time can be spent on analysing and discussing the data, thus increasing the benefits afforded by the visualisation (Paas, Renkl, & Sweller, 2003).

The study also evaluated the decision maker's tendency to use heuristics – the 'rules of thumb' or 'simple rules' often developed from experience that speed decision making. While such heuristics can provide benefits by capturing experience and embedding expert knowledge (Bingham & Eisenhardt, 2011; Kahneman & Klein, 2009), these simple rules often embed biases and detract from the quality of the decisions. Analysis of the survey results confirmed the negative influence on decision making when decision makers have higher levels of reliance on heuristics. However, the use of visualisations of data reduced this negative effect. By presenting the data from a new perspective, in an engaging and easy-to-interpret form, visuals may help 'break thorough' the bias associated with heuristic use. Visualizations can thus dampen the negative effects from decision makers' reliance on heuristics.

These findings are reinforced by another study involving two related experiments testing the use of decision support tools and the effect on heuristics for decision making (Schiffels, Fliedner, & Kolisch, 2018). Although the tools in this study were sorting tools rather than visual tools, the findings on heuristic use and cognitive load align. Schiffels et al.'s (2018) study found stronger evidence of heuristic use (and associated negative impacts on decisions) when cognitive limits are challenged. Decision support tools can help reduce the negative impact of cognitive limits and the reliance on heuristics. The study also confirms that familiarity with methods and tools is important for gaining the desired benefits. Findings from both studies suggest that a training program should accompany the introduction of new tools or visuals in decision processes (Killen, 2017; Schiffels et al., 2018).

Conclusion

This chapter brings together research on the use of visuals for project portfolio management and offers actionable insights for practice. The insights and recommendations are substantiated by the research findings, however it is important to recognise that no research study is perfect; every research study has strengths as well as limitations. Findings from qualitative case-based studies provide depth but may not be representative of other environments (Killen & Hunt, 2010; Killen & Kjaer, 2012). Experiment-based studies allow specific questions to be explored in a controlled situation, but can be subject to bias due to the experiment design and the selection of the participants, and may not reflect real-life situations (Arlt, 2010; Geraldi & Arlt, 2015; Killen, 2017; Schiffels et al., 2018). Large scale quantitative studies by Cooper et al. (1999) and Killen et al. (2008b) are able to identify a positive correlation between visualization use and portfolio success; however, these studies focus on the impact of only one type of visualization (portfolio maps), and are subject to single-informant bias as they involve a single respondent from each organisation. A recent large-scale quantitative study by Killen et al. (2020) provides improved confidence in the findings by extending the study to multiple types of visualisations and multiple informants – however as with most survey based studies, it only captures one point in time, and cannot determine the reasons behind the correlations.

By bringing together diverse studies, this chapter has provided a balanced view of the use of visuals for strategic PPM decision making. The combination of multiple studies that use a variety of methods with differing (and non-overlapping) strengths and weaknesses provides enhanced levels of understanding and confidence that could not be achieved through any one study alone (Tashakkori & Teddlie, 1998). Taken together, these studies support the use of visuals for PPM and provide guidance to enhance the benefits.

Implications for Practice

All indications suggest that visualisations will continue to play an increasing role and make a growing impact on society – and that visuals will continue to be a part of management environments and processes such as PPM.

Research combining academic and practice-based interests has increased our understanding of the impact of visuals in PPM. Findings from the research provides practical guidance for improving the ways that visuals are used to support strategic PPM decisions.

This chapter has summarised three themes of research that demonstrate the power of visuals and the benefits for strategic PPM decision making. Theories of cognitive fit and bounded rationality help to explain how visuals enhance the ability of PPM decision makers to absorb and understand information and to make good decisions. The research findings provide strong support for implementing visuals to enhance PPM results; the use of visuals is associated with better project portfolio performance and has been demonstrated to save time, support better decision making, and promote valuable dialogue during strategic portfolio review board meetings. Actionable guidance is offered to practitioners for improving the design and use of visuals to best support strategic PPM decision making.

In conclusion, derived from the collective findings reported in this chapter, the following five recommendations are offered to practitioners:

Consider where and how to use visualizations to improve project portfolio outcomes.

Remember that visuals can help or hinder PPM decision making. They can act as a cognitive aid, enhancing the ability of decision makers to understand the problem under consideration; or they can reduce decision quality by introducing bias, or by confusing or overwhelming decision makers if the visuals are not designed well and implemented appropriately.

Design visuals purposively and only use visuals that are designed to serve a need and help decision makers understand the information required to make effective decisions.

Most PPM processes will benefit from multiple (but not too many) visuals:

Research findings repeatedly demonstrate that visual displays of information can enhance PPM decisions. The use of multiple different types of visuals provides a range of perspectives to promote balanced considerations and can assist with reducing bias. Managers should be aware of the potential for bias from the use of heuristics in decision making and the potential for visualisations to reduce such bias. However, managers need pay careful attention to the design of each visual, and avoid introducing bias through poorly designed visuals or increasing decision makers' cognitive load by implementing too many different types of visualisations.

Design the visuals carefully:

Design visualizations to ensure they are fit for the task and tailored for context – considering visual aspects (layout, colours, and shapes) as well as information aspects (what subset of information is most relevant) and whether the nature of the visual fits with the decision problem (cognitive fit) (Geraldi & Arlt, 2015; Killen, 2017). Each visualisation should have a purpose and a place in the place in the PPM process. When designing visuals consider these questions: What is the visualisation meant to convey? What types of decisions will it support? What is the context of the decision? and What are the experiences, preferences and tendencies of the decision makers?

Testing, implementation and familiarisation:

Test potential visualizations with decision makers to iterate and improve the format and check whether and how the visual supports decision making. When introducing new visualizations, include guidance and training and allow time for decision makers to develop familiarity with visuals. Limit the number of visuals used, and do not change the format of visuals often. Only introduce new visuals that provide significant advantages, considering the 'costs' of the training and the time required for users to become familiar with the visuals.

Use visuals to enhance and support decision makers' dialogue about PPM decisions:

Finally, remember the important role visuals can play in decision meetings. Design the visuals and the process so that visuals can be referred to in the meetings to support a robust discussion about the portfolio decisions; such dialogue will bring out the wealth of knowledge and wisdom embodied in the decision makers to enhance strategic decision making.

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