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Impulse: Using Knowledge Visualization in Business Process Oriented Knowledge Infrastructures

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Abstract: This article aims to stimulate research on business process oriented knowledge infrastructures by pointing to the power of visualizations. It claims that business process oriented knowledge infrastructure research is stuck and therefore needs to reinvent and revitalize itself with new impulses. One such stimulus is the use of visualization techniques in business process oriented knowledge infrastructures, with the aim to improve knowledge transfer, knowledge communication, and knowledge creation. First, this article presents an overview on related visualization research. Second, it proposes the Knowledge Visualization Framework as a theoretical backbone where business process oriented knowledge infrastructure research can anchor itself. The framework points to the key questions that need to be answered when visual methods are used in business process oriented knowledge infrastructures. Finally, the article compares the Tube Map Visualization with the Gantt Chart, and proves that the new format excels the traditional approach in regards to various tasks. The findings from the evaluation of 44 interviews indicates that the Project Tube Map is more effective for (1) drawing attention and keeping interest, (2) presenting overview and detail, (3) visualizing who is collaborating with whom, (4) motivating people to participate in the project, and (5) increasing recall. The results presented in this paper are important for researchers and practitioners in the fields of Knowledge Management, Knowledge Visualization, Project Management, and Visual Communication Sciences.

Keywords: Knowledge Visualization, Business Process Oriented Knowledge Infrastructures, Knowledge Visualization in Projects, Tube Map Visualization
Categories: H.5.2, H.5.3

1 Introduction

The fact that information is available does not automatically mean that it is also used, shared, or understood. Therefore the effective transfer of knowledge is becoming a key-challenge in today's organizations. And it is also a key in business process oriented knowledge infrastructures.

For a successful knowledge transfer different questions need to be answered: Who is the audience? What are the cultural, functional, or educational backgrounds of the recipients? Why is the information relevant to the individual recipients? Is the audience interested in an overview or in details? What are strategies to overcome the limited capacities of the listeners, such as limited time, attention, or mental capacity? Such and other questions are investigated in Knowledge Visualization.

Today, in business process oriented knowledge infrastructures the amount of information is growing rapidly. It results in various problems, such as information overload, increased complexity, and multiple involved stakeholders: While the amount of information is increasing, the general quality of the provided information is decreasing [Eppler 2003b]. At the same time, the contents are becoming more complex, abstract, and interrelated. And these more complex contents need to be transferred to different stakeholders with varying backgrounds and needs. In general, individuals can only understand something, if they can connect it to something they already know. Therefore knowing and addressing the individual contexts is a key success factor.

Today in business process oriented knowledge infrastructures mainly text and numbers are used. Rarely visual formats. And if, then only a very limited set of visualization techniques are being used, such as business diagrams, clip arts, or programs such as Microsoft Power Point, Excel or Visio.

On the other hand there exist endless visualization techniques, research fields, and creative individuals who constantly contribute new visual approaches. However, often the proposed techniques are not linked to an actual problem in organizations. That's why a lot of excellent ideas do no find their way into organizations.

Bridging this gap is one goal of the young field Knowledge Visualization. Knowledge Visualization concentrates on the fruitful use of visualization techniques in knowledge-intense processes, where knowledge has to be re-constructed by each individual. Knowledge Visualization is **mediating**, thus identifies, couples and integrates isolated research fields, and is **solution oriented**, thus aims to link the most promising visualization techniques to specific problems. The message of this publication is that linking business process oriented knowledge infrastructure research more strongly to knowledge visualization will stimulate research in business process oriented knowledge infrastructures and lead to new approaches. But getting an overview in the visualization research is time consuming and complex. That’s why this article aims to present a condensed overview with importance to business process oriented knowledge infrastructure research.

Next, benefits of visual representations are discussed.

2 Benefits of Visualizations

This section will briefly discuss benefits of visual representations.

Visual representations help for various functions: (1) to address emotions, (2) to illustrate relations, (3) to discover trends, patterns, or outliers, (4) to get and keep the attention of recipients, (5) to support remembrance and recall, (6) to present both overview and detail, (7) to facilitate learning, (8) to coordinate individuals, (9) to motivate people and to establish a mutual story, or (10) to energize people and initiate actions.

Several studies have proven the power of visualizations with regards to these functions. Examples: (1) [Miller 1956] reports that a human’s input channel capacity is greater when visual abilities are used. (2) Our brain has a strong ability to identify patterns, which is examined in Gestalt psychology [Koffka 1935; Ellis 1938]. (3) Visual imagery [Kosslyn 1980; Shepard and Cooper 1982] suggest that visual recall seems to be better than verbal recall. It is clear that humans have a natural ability to use images, but it is not yet clear how images are stored and recalled. (4) Several empirical studies show that visual representations are superior to verbal-sequential representations in different tasks [Larkin and Simon 1987; Glenberg and Langston

1992; Bauer and Johnson-Laird 1993; Novick 2001]. (5) Instructional psychology and media didactics investigate the learning outcome in knowledge acquisition from text and picture [Mandl and Levin 1989], or [Weidenmann 1989] explores aspects of illustrations in the learning process. A lot of further references can be found in [Burkhard 2005a]. But the question is: What is relevant to business oriented knowledge infrastructures? This will be discussed next?

3 An Overview on Visualization Domains with Importance to Business Process Oriented Knowledge Infrastructures

Visualization Sciences are highly interdisciplinary and fragmented. [Sachs-Hombach 2005] presents a valuable introduction to the different fields. This section extends this overview and introduces few fields with high relevance to business process oriented knowledge infrastructure research.

3.1 Information Design

Information design is the art and science of preparing information so that information is comprehensible, rapidly, and accurately retrievable, and easy to translate into actions. A major proponent is Tufte who examines how information can be presented in a way that is concise, compact, adequate, and easy to understand [Tufte 1983; 1990; 1997]. In France, Bertin published the '*Semiologie Graphique*' [Bertin 1967], wherein he organized the visual and perceptual elements of graphics according to the features and relations in data as discussed above. Horn investigates visual communication, visual argumentation mapping, and visual cognitive maps, for example to aid the policy making process [Horn 1998].

The difference between information design and information visualization, which will be introduced later, is that information visualization concentrates on computer-supported techniques whereas information design creates mainly static visual formats, such as maps, posters, and signs.

3.2 Information Architecture

Information architecture as discussed in [Wurman 1996] is related to information design. However, the same term is used by architects with computer skills [Schmitt 1999; Engeli 2001]. These proponents concentrate more on structural rather than presentational issues. In contrast to Wurman they see information as a virtual material that allows to create virtual spaces [Schmitt 1999; Engeli 2001]. The results are interactive and digital structures, which allow to visualize and explore information in new ways.

One example for such a virtual architecture or information architecture is the 3D trade floor visualization project by Asymptote Architecture [Moltenbrey 1999]. The project created an information space whereupon an abstract representation of the trading floors of the New York Stock Exchange was mapped with real time data streams, stock tickers, real-time CNN, three dimensional index charts, and a complex system to supervise technical and business alerts. For the presentation of the application a customized structure consisting of around fifty flat screens and an architecture was constructed. Asymptote Architecture realized what is discussed today: the extension of the rectangular computer screens to novel formats that are embedded in the architecture.

3.3 Information Art

Various experimental applications, mainly enabled through innovative experiments, are coming from media institutes or multimedia design studios. Regularly they present interesting approaches that break with the traditional user interface. The domain is sometimes refered to as information art, generative art, or info aesthetics [Manovich 2001; Manovich 2004]. Such artists use the computer as a tool to generate experimental artistic objects. They combine graphic design, interface design, and programming. Such information artists focus on structures, deal with aesthetic and emotional qualities, and demonstrate possibilities of digital visual communication design.

Visiting some currently interesting sites gives a better understanding of this field: examples for websites from artists are Yugo Nakamura (www.yugop.com), Lia (www.dextro.org), Caseya Reas (www.groupc.net), Lisa Jevbratt (www.jevbratt.com), Shonerwisson (www.sw.ofcd.com), Jared Tarbell (www.levitated.net). Examples for websites from exhibitions are *Documenta X* (http://www.documenta12.de/ archiv/dx/) or *Abstraction Now* (www.abstraction-now.at).

3.4 Information Visualization

Information visualization [Card et al. 1999; Chen 1999a; Spence 2000; Ware 2000] investigates the use of interactive computer-based methods for the analysis and exploration of large amounts of data using our innate abilities to effectively process visual representations. An established definition describes information visualization as *"... the use of computer-supported, interactive, visual representations of abstract data to amplify cognition*" [Card et al. 1999].

In the late 1980's when computers became affordable and powerful enough to support interactive graphics, researchers started to use computers for scientific simulations or the automation of workflows and business processes. Both resulted in large databases of abstract data. As a first reaction, the computing discipline Scientific Visualization arose in 1987. Scientific visualization was the basis and starting point for the new field *information visualization* which also has roots in statistical graphics and user interface design. In contrast to scientific visualization, the focus here are abstract data which lack natural representations (i.e., financial data, genomic data, transaction data).

Information visualization builds on theories in information design, computer graphics, human-computer interaction, and cognitive science. The results are new computer-applications which allow to interactively explore abstract data with visual methods, ideally in the sequence discussed by Shneiderman's Visual Information Seeking Mantra [Shneiderman 1996]): "*overview first, zoom-in and filter, then show details on demand*". Information visualization applications allow users to visually explore data in real-time and to discover patterns (e.g., trends, clusters, gaps, or outliers) concerning individual items or groups of items with the overall goal to derive new insights. Examples for information visualization applications are: Tree Maps [Johnson and Shneiderman 1991; Shneiderman 1992], Cone Trees [Robertson and Mackinlay 1991], Table Lenses [Rao and Card 1994], or Hyperbolic 3D [Munzner 1998]. Throughout the years various new innovative applications were developed, such as [Brodbeck et al. 1997; Brodbeck and Girardin 2003a; Brodbeck and Girardin 2003b] or [Vande Moere 2002; 2004].

3.5 Knowledge Visualization

Knowledge Visualization examines the use of visual representations to improve the transfer and creation of knowledge between at least two persons [Burkhard and Meier 2004]. Knowledge Visualization thus designates all graphic means that can be used to construct and convey insight [Eppler and Burkhard 2005].

Knowledge Visualization stresses one key process which is important in a knowledge oriented culture: The transfer of knowledge. In contrast to information, which is explicit, knowledge has to be re-constructed by each individual. This process happens through communication and interaction with explicit information - verbal or visual. In contrast to information visualization, Knowledge Visualization concentrates mainly on (1) the recipients (i.e., customizing the visual formats to the needs and backgrounds of the different stakeholders), (2) on other knowledge types than explicit information (i.e., distinguishing different types of knowledge, such as "know-why" or "know-how"), and (3) on the process of communicating this knowledge by use of one or more visualization method from information design, information architecture, information art, information visualization, or other fields.

While the previous fields concentrated mainly on developing new visualization techniques Knowledge Visualization primarily aims to structure and link existing visualization techniques to relevant and predominant problems. To do so, knowledge visualization researchers firstly collect and structure the existing visualization techniques, secondly identify and systemize keyproblems in knowledge-intense processes, and thirdly try to link the most promising visualization techniques to the individual problems. Only if no method seems promising, the knowledge visualization researchers invent a new and customized method to solve the problem. Knowledge Visualization is thus highly mediating and solution-oriented and bridges the gap between proposed ideas and real-world needs.

4 Knowledge Visualization Framework

Visual representations are powerful and have manifold functions, that can be exploited. However, if a non-expert is looking for a new visualization technique to overcome the limitation of a certain visualization type, it is difficult to know where to start the search. The Knowledge Visualization Framework therefore presented a theoretical framework that points to four key perspectives and key elements that need to be considered. The framework is based on the analysis of how architects use complementary visualizations to create and transfer knowledge [Burkhard 2004b; Burkhard 2004c; Burkhard 2005a]. Why learning from architects? Because architects have been for centuries experts in using complementary visualization techniques with the goal to visualize and effectively communicate knowledge to different stakeholders, or in other words *interfunctional knowledge transfer*, which is a predominant problem in todays' organizations.

For an effective transfer of knowledge through visualizations, four perspectives should be considered. They are based on four questions: (1) What's the goal of using a visualization method? (2) What type of knowledge needs to be visualized? (3) Who is being addressed? (4) What is the most promising combination of visualization methods? Answers to these questions lead to the Knowledge Visualization Framework, that is described in [Burkhard 2005b; Burkhard 2005a; Eppler and Burkhard 2005] and illustrated in Figure 1.

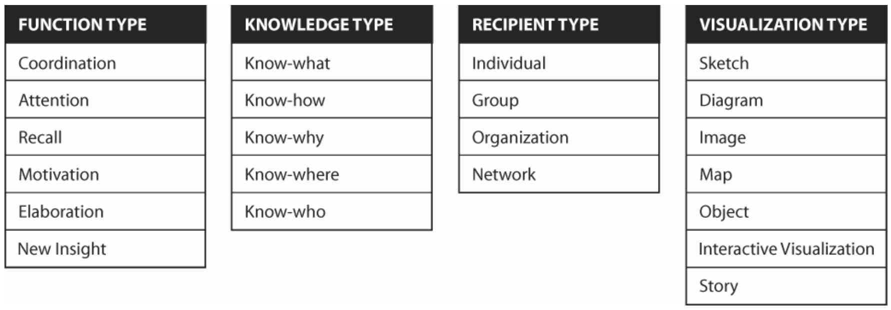

Figure 1: The Knowledge Visualization Framework consists of four perspectives that need to be considered when creating visualizations that aim to transfer knowledge

The **Function Type Perspective** distinguishes functions of visual representations based on research in visual perception and neuroscience [Koffka 1935; Farah 2000; Ware 2000]. Six functions with social, emotional, and cognitive functions are summarized in the CARMEN-Acronym [Eppler and Burkhard 2005]: (1) *Coordination*: Visual representations help to coordinate individuals in the communication process. (2) *Attention*: They allow to get the attention by addressing emotions, to keep the attention, and to identify patterns, outliers, and trends. (3) *Recall*: They improve memorability, remembrance, and recall. (4) *Motivation*: They inspire, motivate, energize, and activate viewers. (5) *Elaboration*: They foster the elaboration of knowledge in teams. (6) *New Insights*: They support the creation of new insights by embedding details in context, showing relationships between objects, or lead to a-ha effects.

The **Knowledge Type Perspective** aims to identify the type of knowledge that needs to be transferred. Five types of knowledge that are grounded in the knowledge management literature [Alavi and Leidner 2001] are differentiated: *Know-what* (Declarative knowledge, as facts), *Know-how* (procedural knowledge, as knowing how things are done), *Know-why* (experimental knowledge, as knowing why things occur which captures underlying cause-and-effect relationships and accommodates exceptions, adaptations, and unforeseen events), *Know-where* (orientational knowledge as knowing where information can be found), *Know-who* (individual knowledge as knowing an expert).

The **Recipient Type Perspective** aims to identify the target group and the context of the recipient. The recipient can be an individual, a team, an organization (one culture), or a network of subjects (different cultures). Knowing the context and the educational, emotional, and cultural background of the recipient/audience is essential for finding the right visualization method for the transfer of knowledge. From a business perspective, graphic design and information design do not focus enough on the recipient type perspective.

The **Visualization Type Perspective** structures the visualization methods into seven main groups that are derived from the practice of architects [Burkhard 2004b; Burkhard 2004a], namely *Sketches*, *Diagrams*, *Images*, *Maps*, *Objects*, *Interactive Visualizations*, *Stories*. The seven types are discussed in the next section.

5 The Visualization Type Perspective

The seven visualization types have been introduced and have been discussed in detail in previous contributions [Burkhard 2004b; Burkhard 2005a; Eppler and Burkhard 2005]. This section only presents a condensed introduction.

5.1 Sketches

Sketches represent the main idea, are atmospheric, and help to quickly visualize an idea. They present the key features, support reasoning and arguing, and allow room for own interpretations.

5.2 Diagrams

Diagrams are abstract, schematic representations used to explore structural relationships among parts by denoting functional relationship. Diagrams explain causal relationships, reduce the complexity to the key issues, structure and display relationships.

5.3 Images

Images are impressive, expressive, or represent reality. They catch the attention, inspire, address emotions, improve recall, and initiate discussions. Images are instant and rapid, instructive, and facilitate learning. Images can be used to depict metaphors. Visual metaphors support recall, lead to a-ha effects, support reasoning and communication, are instructive and facilitate learning. The use of visual metaphors is effective for the transfer of knowledge [Nonaka 1991]. Visual metaphors support remembrance, lead to a-ha effects, and support reasoning and communication. [Eppler 2003a; Eppler 2004] discusses the potential of visual metaphors, and shows that in social sciences and philosophy various authors have proven that metaphors are an ancient and powerful tool to transfer insights.

5.4 Maps

Maps use cartographic conventions to visually reference knowledge. A map generally consists of two elements: a ground layer that represents the context (e.g. a network, a project, a city) and individual elements that represent details (e.g. experts, project milestones, streets). Maps illustrate both an overview and detail, and interrelationships among these details. Various researchers investigate in Maps, e.g.

[Bertin 1967; Tufte 1990; Peterson 1995; Horn 1998; Eppler 2002; Burkhard et al. 2005a]. Maps can be used to map information as done in geographic or thematic maps. The benefits are discussed in the above references. But maps can additionally serve for further purposes, e.g. communication and learning purposes, such as: (1) To form or assess a person's cognitive map, (2) to brainstorm or summarizing contents, (3) for sense making by illustrating and overview and details, (4) for structuring information resources, (5) as visual interface to digital information repositories or multimedia databases, (6) for a mutual understanding of complex business information, (7) as cognitive aid for individual learning situations by enhancing memory, (8) for communicating complex ideas and other purposes. In the context of knowledge management maps are often called *Knowledge Maps* [Eppler 2002]. Various types can be distinguished [Burkhard et al. 2005b]: (1) *Heuristic Maps*, such as group sketches in workshops, (2) *Diagrammatic Maps*, such as Strategy Maps [Kaplan and Norton 2000], (3) *Metaphoric Maps*, such as the Project Tube Maps [Burkhard and Meier 2004], (4) *Geographic Maps* and geographic information systems (GIS), (5) *Three-dimensional Maps*, such as tin figures for the mapping of troops in the war in earlier days, (6) *Interactive Maps*, such as interactive cartography [Peterson 1995], or (7) *Mental Maps* such as the different mental maps of a city [Lynch 1960].

Two additional important mapping types are *Concept Maps* and *Knowledge Domain Structures. Concept Maps* [Novak 1980; Novak and Gowin 1984] illustrate items with geometric shapes and connecting lines that are tagged with descriptions of the relationship (e.g., "is-a", "part of", "related-to"-relationship). Another important subtype of maps are *Knowledge Domain Structures* [Chen 1998; Chen 1999b; Chen 2000; Chen 2003], that focus in representing the dynamics of scientific frontiers and new ways of accessing knowledge sources (such as authors, institutions, papers, journals, etc.) by visualizing linkages, relationships, and structures of scientific domains.

5.5 Objects

Objects exploit the third dimension and are haptic. They help to attract recipients, support learning through constant presence, and allow integrating digital interfaces. Objects in space are helpful for example for information points, knowledge fairs, or exhibitions. This type is very powerfully used in architecture or in exhibitions (think of the dinosaurs in a science museum), but rarely in business contexts. With new technologies, where one can print physical threedimensional objects[1], this might change in the near future, when companies use threedimensional visualizations, e.g., to visualize a prototype of a new product or even a physical model of threedimensional bar diagrams.

5.6 Interactive Visualization

Interactive Visualizations allow to access, explore, and make sense of different types of digital information. Interactive visualizations help to fascinate people, enable interactive collaborations across time and space and allow to represent and explore

[1] For example: http://www.3dprint.ch

complex data, or to create new insights. Another type of interactive visualizations are visually enhanced result sets or search result visualizations. Here search algorithms are combined with visual clues, such as highlighted keywords in texts or relevance ranking bars. Examples for such systems are Envision [Fox et al. 1993; Fox et al. 2002] or Gridvis [Weiss-Lijn et al. 2001]. An overview of such systems is presented by [Nowell et al. 1996; Börner and Chen 2002].

5.7 Stories and Mental Images

Stories and mental images are imaginary (non-physical) visualizations that are efficient in disseminating knowledge across time and space. The use of stories allows to transport an illustrative mental image by using spoken or written language. Stories help to establish a shared vision, which can motivate and activate individuals. A variety of books discuss the art of storytelling for the transfer of knowledge [Baker and Greene 1977]. [Snowden 2000] investigates the role of storytelling in business knowledge management at IBM. Similarly, a variety of books discuss storytelling in the context of business knowledge management [Kleiner and Roth 1998; Schnalzer and Thier 2002]. Finally, [Loebbert 2003] points to the management of stories in organizations.

This section presented an overview on seven groups of visualizations that can help also for business process oriented knowledge infrastructures.

6 Comparative Study: Project Tube Map versus Gantt Chart

This section presents a case study and evaluation of a visualization used in an education centre for health care professions, where a quality development process needed to be established. Traditional Gantt Charts did not manage to get the attention, to present an overview and to motivate the employees. That's why the management team was looking for a new visualization type. The Knowledge Visualization Framework allowed to quickly define the goals of the visualization: It should be a *Knowledge Map* and the concentrates on the functions *attention*, *motivation* and *coordination*. Based on these thoughts a customized solution, the Tube Map Visualization, was developed. The Tube Map Visualization[2] was introduced and discussed in [Burkhard and Meier 2004; Burkhard and Meier 2005]. Further a software algorithm for Tube Maps was developed [Stott et al. 2005].

In this section the Gantt Chart and the Tube Map Visualization Type are compared in a second evaluation.

6.1 Situation

In long-term projects where different individuals are involved effective communication becomes an important success factor. It can result in higher motivation, in better co-operation, and in higher productivity. Communication in

[2] The Tube Map Visualization has been invented and developed by vasp datatecture GmbH, www.vasp.ch

projects today mainly happens verbally or with text. One exception is the Gantt Chart Figure 2 a well known visualization method in today's project management.

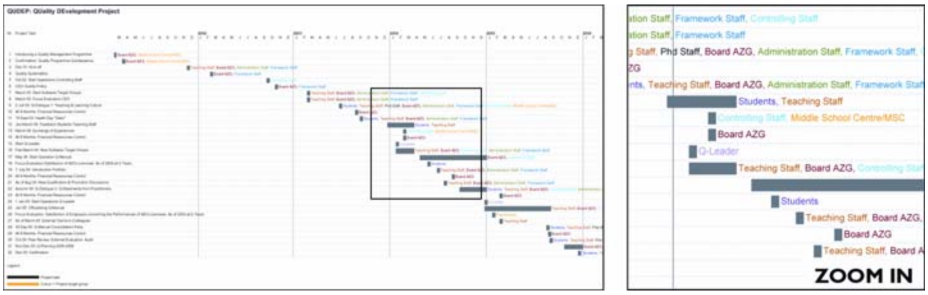

Figure 2: *A Gantt Chart (68x38cm) illustrates tasks and task duration with bars that are aligned to a timeline and followed by the involved groups per task. The tasks are listed on the left hand side.*

For the planning and controlling of projects Gantt Charts are effective. But, to address various individuals Gantt Charts are not the best means; especially if the individuals have different cultural, educational, or functional backgrounds. The hypothesis was that Gantt Charts (1) are not effective at attracting, fascinating, or motivating project members, and accordingly do not initiate discussions, (2) they are poor at illustrating inter-relationships among the involved project members and therefore do not present the 'big picture', and (3) they hardly support recall and are difficult to remember.

The Project Tube Map [Burkhard and Meier 2004] has been developed to overcome the limitations of the Gantt Chart. The Project Tube Map Figure 3 uses the metaphor of a tube system for knowledge communication, where the tube lines represent project groups and the tube stations project tasks. The task stations are further tagged with detailed descriptions, such as dates and instructions. The whole map is aligned to a timeline that runs from the left to the right and is illustrated through bars at the bottom of the visualization.

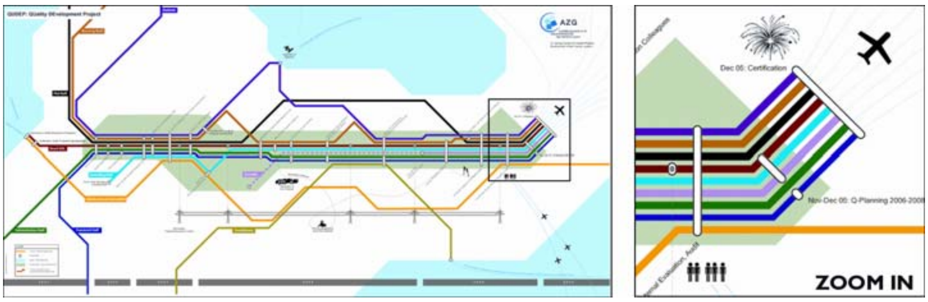

Figure 3: Full screenshot and zoom-in of the Project Tube Map (1.2x2.4m)

A previous evaluation [Burkhard and Meier 2004] indicates that the Project Tube Map has several advantages: It attracts and motivates individuals, illustrates overview and detail (because it integrates detailed descriptions of the milestones as stations), establishes a mutual story, and leads to discussions. These promising results were the motivation to investigate the differences between the Gantt Chart and the Project Tube Map in a second evaluation, which is presented next.

6.2 Hypotheses

In this comparative study five assumptions are tested:

- **Attraction**: People think the Project Tube Map is more attractive and catches more attention than the Gantt Chart.
- **Overview+Detail:** The Project Tube Map is more effective in illustrating the 'big picture' of the project.
- **Discussion**: The Project Tube Map initiates more discussions on the project than the Gantt Chart.
- **Motivation**: The Project Tube Map motivates individuals more to participate in the project than the Gantt Chart.
- **Recall**: The Project Tube Map sticks better in the recipient's memory than the Gantt Chart.

6.3 Target Group

The target group of this study consisted of a mixed group of 44 individuals with three different backgrounds: Project managers, students, and employees from large organizations that worked in long-term projects. The target group represented a mixed group as they typically appear in large projects in larger organizations. 34 percent of the population were female, 66 percent male. The average age was 31 years. 68 percent of the test persons have a university degree.

6.4 Procedure

With Adobe Illustrator CS two posters were designed [Fig. 2 and 3], which contain the same amount of information with one exception: The Project Tube Map has additional graphic symbols. Both posters are printed in the size of 68cm by 38cm. The population has been divided in two equal groups. One group started the procedure with the Project Tube Map, and the other with the Gantt Chart. In this procedure each participant was first asked to explore the visualization as long as he or she is interested in it. During this process, it was asked to think aloud and to point with the finger to items that catch the attention. The time was measured for this first part. Then, the recipient was asked to complete the first part of a paper based questionnaire. Next, the other format (Project Tube Map or Gantt Chart) was presented to the participant. It was again asked to brainstorm aloud while exploring and comparing the two formats. Comments were noted and again the time was measured. Finally, the participants were asked to fill in the second part of the paper based questionnaire. Roughly half of the participants were contacted two weeks later either with a telephone or face-to-face interview for measuring recall.

It needs to be stressed that the inventors of the Tubemap Visualization [Burkhard and Meier 2004] have not interviewed the participants, because they might have influenced the participants. The participants have been interviewed by one person, which has not been involved in previous work or in the development of the approach.

6.5 Evaluation

The results from the collected data are presented in Figure 4.[3] Next, the Tube Map Visualization and Gantt Chart are evaluated by comparing groups for *rather do agree* and *do agree* according to the five assumptions listed in the hypotheses.

Attraction: According to statement 1 ("To me, this display catches the eye") in Figure 4 the Tube Map (TM) catches more attention (TM 82% versus GC 48%, both for *rather do agree* and *do agree*) than the Gantt Chart (GC). According to statement 2 ("I am interested in this display") it interests the recipients more (TM 95% versus GC 52%). Statement 3 ("This display appeals to me") states that the Tube Map is more appealing (TM 83% versus GC 35%). Comparing the measured times for studying the formats indicates that the Project Tube Map has been viewed 1.41 times (mean) or 1.53 times (median) longer than the Gantt Chart. Observations of the participants and comments underlined that the participants from all groups were clearly more attracted and fascinated by the Tube Map. However, this might change, as soon as Tube Maps are used more regularly.

Concluding, it showed clearly that the Project Tube Map catched more attention than the Gantt Chart.

Overview+Detail: According to statement 4 ("This display shows an overview") the Project Tube Map presents a better overview (TM 87% versus GC 71%). If only the values for *very true* were compared, then the Gantt Chart scores better. However, statement 5 ("This display focuses too much on detail") indicates that the Gantt Chart rather focuses too much on detail (TM 13% versus GC 43%). The participant stressed that the Project Tube Map displays better how tasks and groups relate to each other, but does not illustrate task durations as the Gantt Chart does. Secondly the participants liked the task list in the Gantt Chart. One third stated that the Gantt Chart is well known and thus a better means than the Tube Map. Half of the population (equally in all three groups) consider the Gantt Chart as *boring and bureaucratic* and *predictable*. In the Project Tube Map, some persons considered the graphic symbols as not being well associated with the content and thus confusing. This point is true.

Concluding, this data indicates that the Project Tube Map is more effective in illustrate the 'big picture'.

Discussion: According to statement 6 ("Such a display in the transit area of our company would intensify debate about the project"), the Project Tube Map initiates more discussions on the project than the Gantt Chart (TM 61% versus GC 24%). The visual metaphor helps to build a mental model, which helps to discuss on the project. According to statement 7 ("Such as display should be available for every complex project"), participants that started with the Tube Map but also participants that started

[3] The data is not discussed for each group, because this was not the goal of the study and because there was no significant and clear pattern visible. The goal was to get insights from one mixed group, as it would occur in an organization.

with the Gantt Chart think that such a display should be used in every complex project (TM 65%, GC 48%).

Concluding, it shows that the Project Tube Map seems to initiate more discussions on the project than the Gantt Chart.

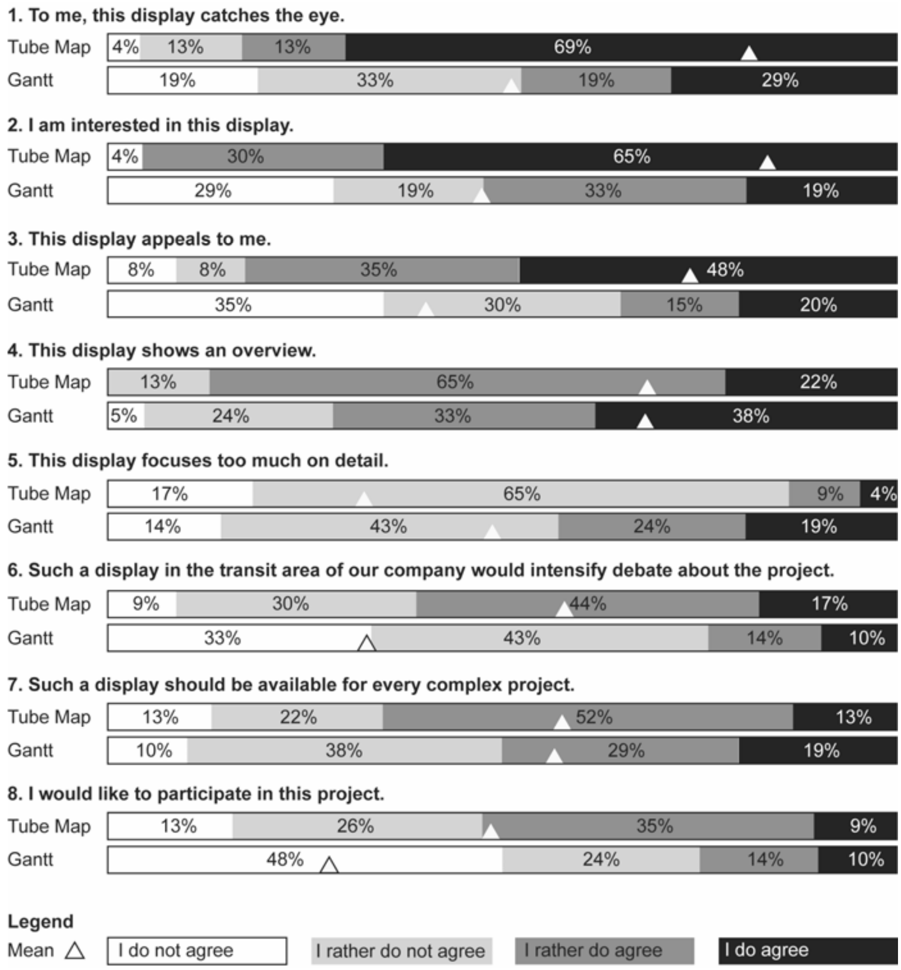

Figure 4: The results of the 44 questionnaires. The triangle represent the mean.

Motivation: According to statement 8 ("I would like to participate in this project") the Project Tube Map is motivating more to participate in the project (TM 44% versus GC 24%). This result is similar to our finding in the previous study [Burkhard and Meier 2004], where the Project Tube Map motivated the participants measurably to engage in the project.

Concluding, this data indicates that the Project Tube Map motivates individuals to greater participation in the project than the Gantt Chart.

Recall: The two formats were not specifically compared in regards to recall tasks. But several meetings with some of the participants two weeks after they participated in the study made clear that they remembered well the general structure and the main groups and tasks of the Project Tube Map, whereas they could not remember details about the Gantt Chart. The participants could reconstruct the Project Tube Map much more easily and recall different groups. Whereas initially some persons have been confused by the symbols, the interviews showed that the persons remembered the symbols precisely.

Concluding, several comments indicate that the Project Tube Map sticks better in the recipient's memory than the Gantt Chart and the various visual elements of the Project Tube Map help to re-construct the Project Tube Map content.

6.6 Conclusion and Guidelines for Project Tube Maps

This study indicates that the Project Tube Map is more effective than the Gantt Chart for the communication of long-term projects where individuals from different backgrounds are involved. A first finding is that the participants explored the Project Tube Map around 50 percent longer than the Gantt Chart. A second finding is that the Project Tube Map motivates people more to participate in the project than the Gantt Chart. Generally, it helps in catching the attention and illustrating the 'big picture', in initiating discussion, and motivating employees to participate in the project. In contrast, the Gantt Chart is more effective in a clear-structured approach and for the display of the task duration. Thus the formats complement each other.

Feedback allowed to derive general guidelines for creating Project Tube Maps: (1) Carefully use symbols as cognitive aides for recall, (2) use a clear title, legend and verbal project summary for the overall understanding, (3) use a clearly visible scaled time axis, (4) print the Project Tube Map on large posters and place them at lively places (e.g., next to the elevator), (5) add a small Gantt Chart to the Project Tube Map to illustrate task durations.

7 Summary

This article aimed to stimulate research on business process oriented knowledge infrastructures by pointing to the power of visualizations. The use of visualization techniques aims to improve the transfer, communication, and creation of knowledge. First, this article presents a condensed overview on related visualization research. Second, it proposed the Knowledge Visualization Framework as a theoretical backbone where business process oriented knowledge infrastructure research can anchor itself. The framework points to the key questions that need to be answered when visual methods are used in business process oriented knowledge infrastructures.

The framework serves also as a guideline for practitioners and allows to get orientation in the field of visualization research and to overcome the current intolerable situation, where individuals learn for years how to write and calculate, but rarely how to use visual formats.

Finally, the article compared the Tube Map Visualization with the Gantt Chart, and proved that novel knowledge visualization formats can excel established approaches, such as the Gantt Chart, in regards to various tasks. The findings from the evaluation of 44 interviews indicates that the Project Tube Map is more effective for (1) drawing attention and keeping interest, (2) presenting overview and detail, (3) visualizing who is collaborating with whom, (4) motivating people to participate in the project, and (5) increasing recall.

The results presented in this article are important for researchers and practitioners in the fields of Knowledge Management, Knowledge Visualization, Project Management, and Visual Communication Sciences.

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