Improving Team Performance By Identifying Significant Attributes Required In A Knowledge Management Solution for Fast Paced Research Teams

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Dedication

I dedicate this praxis to every woman who may decide to pursue her passions and seek higher education. The journey is long, the path is difficult, and there will be many times you question the sanity of your decision to undertake this effort. Never doubt that you are powerful and deserve the opportunity to pursue your dreams. Persist.

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Abstract

Improving Team Performance By Identifying Significant Attributes Required In A Knowledge Management Solution for Fast Paced Research Teams

Knowledge management, a systemic effort to enable information and knowledge to grow, flow and create value, has been proven to provide many benefits to organizations and programs. While the pace of today's research is increasing at accelerating rates, organizations' traditional knowledge management strategies, often time consuming and cumbersome, lack the ability to support fast paced teams. While it is impossible to develop a one-size-fits all solution, this research is focused on developing a knowledge management solution that would rapidly and effectively capture information by supporting the user needs within current utilized integrated processes within a specific fast paced team.

The results of this research show that there is seven required attributes that should be included in a proposed technical solution for the fast paced research team. These attributes include the capability of collaboration, search, labels/tagging, online activity, software deployment, entry time for information and intelligence/inference. Leveraging expert judgment from a fast paced team developed this conclusion. The experts provided their judgment responses to assess attributes a potential knowledge management solution should possess, and then a pairwise comparison analysis and ordinal regression analysis was conducted on the responses. While the results are specific for a particular high-performing team, they could apply to other research teams that perform fast paced research, and would in turn support accelerating knowledge management as an integral part of their innovation future for their organization.

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1. Introduction

Knowledge management (KM), defined as "a systemic effort to enable information and knowledge to grow, flow and create value" (O'Dell & Hubert, 2011), has been identified as a mechanism that can provide many benefits to organizations and programs (Levett & Guenov, 2000). The potential benefits of KM are numerous and include an increase in responsiveness, cost savings, increase in collaboration facilitation, increased decision making support, increased competitive advantage, and decreasing knowledge loss due to attrition and increase in innovation (C. BenMoussa, 2009). Specifically, around innovation, KM can capture insights and experiences to make available for future use, increasing ease to find and reuse sources, foster collaboration, and supporting innovation through generating new ideas (Levett & Guenov, 2000). One unique method of creating and developing new and innovative solutions, separate from KM, is the use of the design thinking process of ideation to generate a large number of relevant and impactful ideas in a short timeframe.

1.1 Domain Background

IDEO, a Palo Alto based design and consulting firm with an international presence, developed the process of design thinking as a human-centered approach to innovation and solving problems, with a specific focus on understanding the users and the context of the system or area being designed. The IDEO design thinking process has three unique aspects or spaces: inspiration, ideation and implementation (IDEO, 2016). Inspiration includes both an investigation of the problem / opportunity area, as well as exploration of similar problem / opportunity areas but in domains outside of the original domain.

Ideation is the process in which ideas are generated, developed and tested. Implementation is where the ideas generated from the ideation stage are put into production and built.

Tactical Advancements for the Next Generation (TANG) is a Navy based innovation approach centered on the warfighter, leveraging the IDEO design thinking process (DTP) and method to revolutionize advanced development in the Fleet (Smith, 2013). TANG mimics the IDEO design thinking process by utilizing the IDEO double bubble approach seen in Figure 1-1.

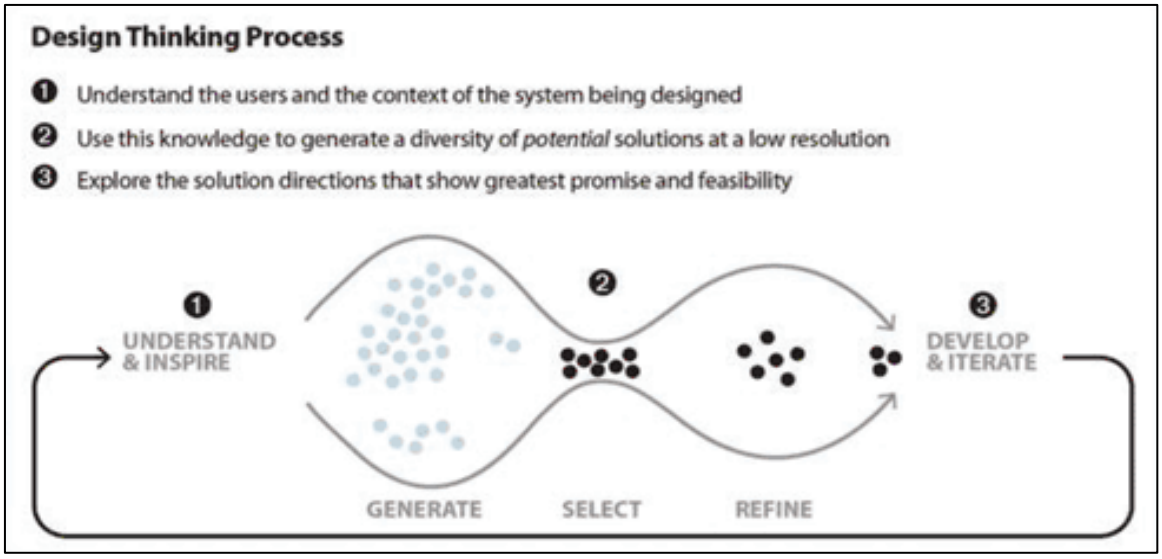


Figure 1-1: Design Thinking Double Bubble Developed by IDEO

The first step in the design thinking is the inspiration stage, where empathic research is conducted to gain insights and understand the users and the context of the system that is being designed. Empathic research is research done into both the function of a product, but also the users emotional responses to the product (Thomas & McDonagh, 2013). Within TANG, this first step to gaining insights includes three different types of research efforts: in domain research, analogous domain research, and technology research. In-domain research is where researchers conduct system research and user interviews in the

problem area domain, as the best way to understand the domain and gain empathy for the end users is to talk to them in their environment and observe them performing their tasks. A sample of potential and realistic travel locations for in-domain research can be seen in Figure 1-2. Travel can consist of not only continental U.S. travel, but could also include international travel as well. Quite often the travel done for the research is quite extensive and fast paced.

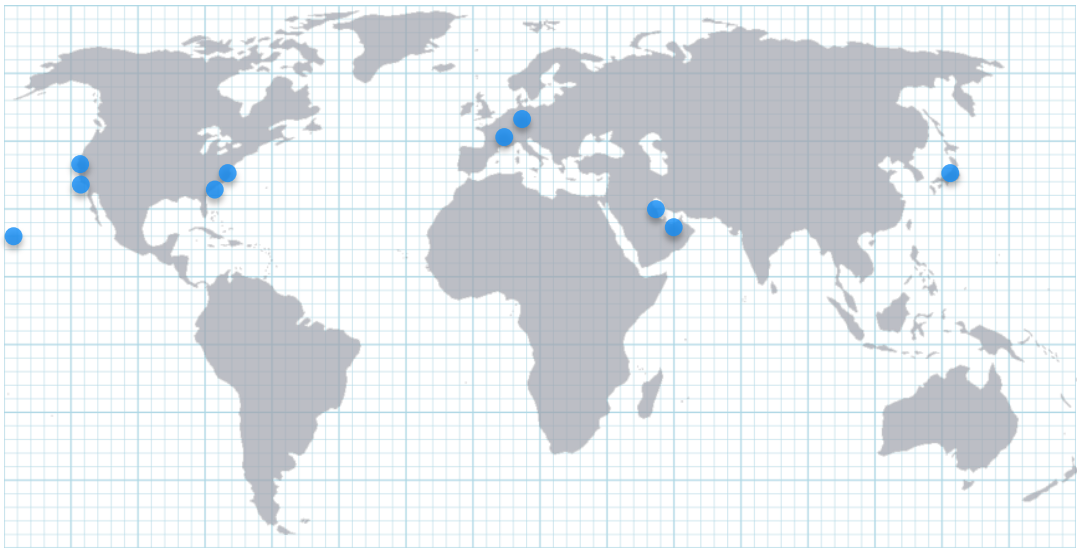


Figure 1-2: Sample Travel Locations for Research Phase

Analogous-domain research is where researchers explore other industries and technology companies with analogous challenges and solutions, to identify inspiration and insights that could be impactful to the problem being addressed. For example, the design thinking process was applied to redesign a hospital emergency room, where having highly competent individuals working as a team in a high pressure, time constrained environment with the right tools was crucial to mission success. Analogous domain research was done by studying NASCAR pit crews, as they have the same constraints (high pressure, time sensitive environment where team work is crucial to

success) but in a different domain. Observing and interviewing the pit crew led to direct changes and improvements in the hospital process and team dynamics.

Finally, technology research is completed to identify and understand the state of current technology that may be relevant for developing and implementing innovative solutions and to understand where industry is leveraging their investments for commercial impact. For the nature of this work, the research phase is quite often short fused, fast-paced, and with a small contingent of the broader team. As a result, the information is not captured in a long-term way for use in future projects.

The most difficult part of the research phase is synthesizing the content into a set of insights and high level themes that become the framework for the workshop. Synthesis is challenging due to the various perspectives that were explored in the research and the large amount of content. To create a powerful synthesis product, it's beneficial to have at least two researchers at involved in every part of the research. Being able to sync the rest of the team up on the findings enables a richer discussion with the broader team and opportunity for a more powerful synthesis.

The information and insights gained from the three types of research described above inform and inspire the main event, where they are shared out with in-domain users as they come together to ideate. The synthesis is reframed into "How Might We…" statements that are the opportunity areas to drive the brainstorming / ideation process. After the users generate a large number of ideas, a down selection of ideas occurs where individuals vote on the ideas or concepts they believe best holds merit. The ideas with the highest potential for impact are refined by the users using rapid prototyping tools and techniques to transform the concepts into the physical space to inspire feedback. After a

large number of ideas on potential solutions are generated, team members then vote on the idea they feel holds the greatest promise of success. All of the insights, ideas and solutions are delivered to the on-site stakeholders to determine which ideas are funded for follow on development.

1.2 Motivation and Purpose

An integral phase of the design thinking process is technology discovery and analogous domain research, where information and insights are leveraged to inspire brainstorming around a particular domain issue. However, as the information and insights are by definition domain agnostic to the selected challenge, the information and insights can be leveraged across multiple projects. It is common to have multiple TANG projects running concurrently, where different teams are making research trips that could benefit each other. Using the Design Thinking Corps (DTC) at APL as the target, fast paced is defined as week-long research trips where team members will conduct anywhere from three to six interviews per day, upwards of 5 consecutive days. These research trip weeks may occur consecutively, with little to no time to formally document information before moving on to the next phase of design thinking work. Due to the fast-paced nature of the TANG design thinking process, the analogous domain and technology discovery information is not captured in a long-term way for re-use in future projects.

While the analogous domain and technology discovery information could be used to inform future projects, capturing the information for use in future events is not practical with traditional cumbersome and time intensive KM strategies (Amine Chatti, 2012) and therefore not done effectively, negatively impacting the leveraging of knowledge gained and speed of the team. This is also problematic as diversity of knowledge is directly

related to improved innovation (du Plessis, 2007; Jiangfeng, Bin, & Patel, 2016). As TANG design thinking projects are often done concurrently, knowledge gained should be shared across team members to aid in collaboration and increased knowledge (Guan, Yang, Sun, Srivatsa, & Yan, 2015) with effective data representation to aid in seamless knowledge transfer (Quanz, Huan, & Mishra, 2012).

1.3 Three Processes Fundamental to Knowledge Management

There are three identified processes that are fundamental to KM: knowledge acquisition, knowledge sharing, and knowledge utilization (Tiwana, 2002). **Knowledge acquisition** is the process of developing skills and relationships, whereas **knowledge sharing** is the process of making available and disseminating what knowledge is known. Two instances or implementations of knowledge sharing are knowledge transfer and knowledge integration. **Knowledge utilization** is where knowledge is integrated or shared outside of the original source (Dalkir & Liebowitz, 2011).

Knowledge acquisition within the frame of the TANG program is defined and follows the design thinking process. The focus of this work is not to improve the knowledge acquisition, but rather focus on the knowledge sharing and knowledge utilization gaps that have been identified. The first step in any KM initiative should be the identification and understanding of what knowledge is critical, what is not critical, and what to keep (McCann & Buckner, 2004; Ndlela & Du Toit, 2001). Once the knowledge has been identified, codifying the knowledge from tacit (informal) to explicit knowledge (formal) (O'Dell & Hubert, 2011) must occur before the knowledge can be stored, shared and utilized.

One method of doing this codification is through the use of a data repository (Desouza & Evaristo, 2004). While data repositories can be useful in that they store large amounts of information, if they are not kept up to date then there are significant issues in sharing and transferring knowledge (Jasimuddin, Connell, & Klein, 2012) and user engagement (Chinying Lang, 2001). Traditional KM strategies can quickly become cumbersome and time intensive (Amine Chatti, 2012) and therefore not always used, negatively impacting the leveraging of knowledge gained in future efforts and the speed of the team. This is problematic as diversity of knowledge is directly related to improved innovation (du Plessis, 2007; Jiangfeng et al., 2016). Especially for teams where projects are often done concurrently, knowledge gained should be shared across team members to aid in collaboration and increased knowledge (Guan et al., 2015) with effective data representation to aid in seamless knowledge transfer (Quanz et al., 2012).

Technology can be extremely powerful, but when it's not design properly or applied to the right challenge is can become problematic and produce barriers to successful knowledge sharing and utilization (C. BenMoussa, 2009). While technology will not provide the ultimate solution to sharing knowledge, the integration of the right technology is important to achieving success (Riege, 2005). For example, for individuals or teams where time is of the essence and a scarce commodity which would decrease user engagement in traditional KM strategies (Chinying Lang, 2001; Riege, 2005), developing a solution that does not require large time requirements to engage in and utilize the KM technology is crucial.

A crucial consideration in knowledge creation and utilization within the organization or team is the human relationships (Chinying Lang, 2001) and dynamics. It's been shown

that without strong motivation (personal or group based) that knowledge sharing may be impaired (Y.-S. Wang, Lin, Li, & Lin, 2014). Extroversion and openness to experiences can help mitigate this. In addition to personality traits, the individuals commitment to the team has a positive relationship to willingness of sharing knowledge (Swart, Kinnie, Rossenberg, & Yalabik, 2014). From personal experience, design thinking practitioners exhibit the nature of openness, extroversion and strong commitment to the team.

For programs and design thinking processes that move rapidly, traditional KM strategies do not generally support such programs well as the goal of a KM solution should be to enhance action to make it effective, and not simply store knowledge (C. BenMoussa, 2009). A successful KM solution should make the collective knowledge available in a way that is adaptive and meets the needs of the users.

1.4 Problem Statement

Traditional knowledge management strategies, often time consuming and cumbersome, lack the ability to support fast paced teams, which result in increased costs[1] due to repetitive research across multiple projects, and low re-use of knowledge and thus decreased innovation.

[1] It is estimated from Mr. Smith (JHU/APL Design Thinking Corps Lead, Director of the Navy Tactical Advancements for the Next Generation Program) that one research trip per project is potentially due to repetitive research trips. It is estimated that by eliminating one research trip per project, each project could potentially save between 10-20% of the project travel budget and reduce the research phase by upwards of one week, thus providing more time to synthesize the information and data.

1.5 Thesis Statement

A rapid knowledge capture and management solution with a focus on addressing user needs would enable easy capture and increase sharing of knowledge across multiple projects.

1.6 Scope of Study and Research Goals

This research is focused on developing a KM solution that would rapidly and effectively capture information by supporting the user needs within current utilized integrated processes (Chai & Nebus, 2012), and could be used to build a knowledge repository for use in future design thinking efforts that satisfies the need for easily accessible insights and knowledge. Expected potential results/findings:

- Experts will prefer new KM solution with proposed new technology
- New KM solution would enable:
  - An easy to capture solution to enable fast and consistent documentation of information.
  - Easier to find and digest information that can be frequently accessed.
  - Stored information that could be able to be leveraged and used across multiple internal projects.

Due to internal organizational policies and constraints, it is not realistic to implement and test a solution within the allotted timeframe. Therefore, this research will focus on developing a solution based on expert judgment identifying the significant attributes required for a KM solution, and then assessing the solution against available technology.

2 Literature Review

For many years and across many domains, studies have looked into knowledge and experience sharing (Hwang, Singh, & Argote, 2015; Witherspoon, Bergner, Cockrell, & Stone, 2013) as a means to improve resource limited groups and organizations (Asrar-ul-Haq & Anwar, 2016). Experts develop knowledge channels through sharing knowledge and experiences over a long period of time, and is a way for knowledge resources to be used and exchanged (Oyemomi, Liu, Neaga, & Alkhuraiji, 2016; Z. Wang, Wang, & Liang, 2014). Knowledge networks are self-organizing systems where users can share practices, knowledge and information, and when done via computer systems are termed electronic knowledge networks (Faraj, Wasko, & Johnson, 2008). These systems enable the sharing and retrieval of knowledge within a group or organization (Amine Chatti, 2012). Knowledge networks both add value and provide support to innovation activities (Paruchuri & Awate, 2016), however the value added from the networks dependent strongly on the quality (helpfulness) and quantity (volume) of knowledge voluntarily shared by employees (Lou, Fang, Lim, & Peng, 2013; Wasko & Faraj, 2005). The willingness of employees to participate in a knowledge sharing system is driven by technological, social, and psychological factors (Dash Wu, Wu, & Zhu, 2012; Gillian Ragsdell & Clayton, 2016). These factors (enablers and barriers) can directly influence the quality, quantity and participation of knowledge networks (Sedighi et al., 2016).

2.1 Knowledge Management and Innovation

Knowledge management methodologies and practices can provide many benefits to organizations and programs, especially centered on innovation (Levett & Guenov, 2000).

Large numbers of organizations have leveraged knowledge management (Chihab BenMoussa, 2009), spending upwards of $73 billion on knowledge management software in 2007 with a rate of 16% increase per year (Murphy & Hackbush, 2007). However, there have not traditionally been high levels of success for implementing knowledge management strategies. Those implemented are not often found to have a high level of impact or to have higher than slightly positive satisfaction ratings (C. BenMoussa, 2009), especially if employee support and engagement of knowledge sharing has not been high.

2.2 Knowledge Sharing

Knowledge sharing is defined as transferring experience and organizational knowledge between various organizations, departments, team, and/or individuals (Crossan, Lane, & White, 1999; Ipe, 2003; McAdam, Moffett, & Peng, 2012; Oyemomi et al., 2016), and is vital for business and organizations (Asrar-ul-Haq & Anwar, 2016). Sharing knowledge across teams and between employees is a building block for successful organizations (Witherspoon et al., 2013), and permits experts to capitalize on knowledge-based resources (Z. Wang et al., 2014). Knowledge sharing increases both the application of knowledge, as well as the intellectual capital and organizational innovation (Z. Wang, Sharma, & Cao, 2016). Knowledge sharing has been shown to have reductions in time and cost, while showing improvements in innovation, development times and efficiency (Lin, 2007; Mesmer-Magnus & DeChurch, 2009; S. Wang & Noe, 2010).

The ability to share knowledge through the use of computers and information technology has been the focus of more traditional knowledge management studies (Huysman & De Wit, 2004). These studies tend to focus on codified knowledge and centralized knowledge repositories, where knowledge is treated as objects that are saved,

retrieve, and disseminated through information technology (Sedighi et al., 2016). Without focusing on the needed social interactions required to successfully exchange tacit knowledge, the desired results were not achieved in multiple practices and studies (Huysman & De Wit, 2004).

From this, more recently studies have focused on the need for social interactions to drive the engagement needed for exchanging both tacit and explicit knowledge (Van den Hooff & Huysman, 2009). This is especially true in networked environments (Ellison, Gibbs, & Weber, 2015), where contemporary knowledge sharing technologies rely heavily on improving and increasing engagement and participation from individuals (Chang & Chuang, 2011). Many factors have been shown to affect individual behavior around knowledge-sharing, such as personal and group characteristics (Asrar-ul-Haq & Anwar, 2016). Personal characteristics such as demographic variables of age and sex (Constant, Kiesler, & Sproull, 1994), qualities inherent to the individual (Cabrera, Collins, & Salgado, 2006), and perceptions and attitudes around knowledge sharing (G. W. Bock, & Kim, Y. G., 2002) have been shown to have impacts on knowledge sharing behaviors. While top management support (Connelly & Kevin Kelloway, 2003) and the culture of the organization and it's values and norms (G.-W. Bock, Zmud, Kim, & Lee, 2005; David & Fahey, 2000; McKinnon, Harrison, Chow, & Wu, 2003) can influence behavior towards knowledge sharing, the characteristics and cultural norms of teams within an organization tends to influence more localized knowledge sharing and participation (Bakker, Leenders, Gabbay, Kratzer, & Van Engelen, 2006; Sawng, Kim, & Han, 2006).

2.3 Participation in Knowledge Sharing and Networks

There is the expectation that to be a part of a knowledge network, individuals should responsibly engage and form reciprocal relationships (Brazier & Nevejan, 2014). More specifically within knowledge management, participation is defined as the ability to create, use and share knowledge within the context of the goals of the organization (Sedighi et al., 2016). Research has shown that the different levels of participation relate to different degrees of knowledge contribution (Chang & Chuang, 2011), where a higher degree of knowledge contribution is indicative of increased participation. There is research that assesses the amount of contributions from users (Chen & Hung, 2010) from the volume of knowledge shared (Sun, Fang, & Lim, 2012). Additionally, other knowledge management research focused on the social dimensions and motivations as related to quality of shared knowledge and quality (Wasko & Faraj, 2005) and value (Lou et al., 2013) of knowledge contributions.

The voluntary willingness of individuals is the most important organizational activity required for individuals to engage in knowledge sharing (Choi, Lev, & Kim, 2014; Llopis & Foss, 2016) and to help form and evolve knowledge networks (Bolisani & Scarso, 2014). These knowledge networks have multiple levels, with the nodes representing the knowledge sources and the relationship between individuals or groups as the paths. More recent studies include knowledge management technologies within organizations as part of the organizational knowledge network. Improved knowledge contribution can come from individual, group, and business interactions (Krätke, 2010). Electronically enabled knowledge networks have been reviewed and are largely shown to be self-organizing

technical systems that are socially oriented, specifically designed to create and share knowledge links (Faraj et al., 2008).

Knowledge networks utilize different types, functions and levels of conduits to exchange knowledge. For example, knowledge can be exchanged via instant messaging, discussion forums, or larger communities of practice to disperse information and knowledge. The multiple and varied channels of exchanging knowledge reduces some of the negative effects and weaknesses found in older centralized knowledge management solutions (Faraj et al., 2008). The multi-functional approach allows individuals to self-determine whom they communicate and share information with within a knowledge network, and are free to select the most appropriate method to share the information with the intended audience (Sedighi et al., 2016).

2.4 Perceived Benefits and Costs of Knowledge Sharing and Management

Individual perceived benefits and costs of knowledge sharing can be influenced by the different knowledge sharing channels available (Fulk & Yuan, 2013; Zhang, De Pablos, & Zhou, 2013). Many studies (Cyr & Wei Choo, 2010; Hung, Durcikova, Lai, & Lin, 2011; Sedighi, van Splunter, Zand, & Brazier, 2015) have investigated these influences, and they generally range from non-technical elements of individual benefits and costs to technical elements like information technology. Individual behavior around sharing knowledge and knowledge management is heavily influenced by weighing the perceived benefits against the perceived costs of sharing their knowledge (Yan, Wang, Chen, & Zhang, 2016). In general, perceived benefits are seen in the areas of knowledge reciprocation, positive emotions from helping others, and collective reputation, whereas

perceived costs include time and effort requirements for engagement in knowledge sharing (Hung et al., 2011; Lin, 2007).

2.4.1 Perceived Benefits

Research in psychological therapy has shown intrinsic and extrinsic benefits to be two distinctive and separate motivations (Ryan & Deci, 2000) for individuals to share, which has also been shown to exist within knowledge management research. (Kankanhalli, Tan, & Wei, 2005). Intrinsic motivation is behavior that is driven more by internal rewards (such as personal satisfaction, altruism and knowledge efficacy) than the appeal of tangible rewards (Sedighi et al., 2016). Knowledge efficacy is the individual's confidence in their ability and skill in preparing knowledge to be shared with others (Bandura, 1994). Altruism is expressed in sharing knowledge with other individuals to provide help, giving the individual who is helping a sense of gratification (Wasko & Faraj, 2005).

Extrinsic motivation is behavior driven by external rewards for knowledge sharing (Lou et al., 2013), and impacts the willingness of individuals in a knowledge network to voluntarily sharing knowledge (Hung et al., 2011; S. Wang, Noe, & Wang, 2014). Literature shows two main drivers for extrinsic motivation to be external regulation (non-monetary but material rewards and reputation (Deci, 2002; Hsu & Lin, 2008)) and internalized extrinsic motivation (expectation of reciprocity (Lou et al., 2013)) (Deci, 2002). Reciprocity can be seen in two different ways, either directly or generalized (Faraj & Johnson, 2011). In direct reciprocity individuals maintain an expectation of mutual sharing of knowledge, whereas general reciprocity the expectation is the return of sharing is from the community at large vice a particular individual.

2.4.2 Perceived Costs

Similar to how perceived benefits are a critical factor in to the willingness of an individual's to engage in knowledge sharing, perceived costs also play a critical factor in willingness to share knowledge (Fan, Zhang, & Yen, 2014). One perceived cost is the time and effort that may be required to engage in knowledge sharing, and can alter an individual's decision on when and if to share knowledge and participate in knowledge sharing activities (Connelly, Ford, Turel, Gallupe, & Zweig, 2014; Zhou & Chen, 2011).

For example, the cognitive cost of the mental effort required to engage in knowledge sharing as well as the time cost to execute the sharing has an impact on participant willingness (Yan et al., 2016), and this has been observed within the enterprise social media domain (Vuori & Okkonen, 2012). The voluntary willingness of an individual to share knowledge within a knowledge network is inversely related to the increased perceived cost to an individual to participate (Sedighi et al., 2016), and if the perceived cost outweighs the benefits then the individual likely will not participate (G.-W. Bock et al., 2005). Research has shown that both time and effort requirements to engage in knowledge sharing negatively affect the quantity and quality of individual knowledge sharing within knowledge networks (Sedighi et al., 2016).

3 Methodology

3.1 Overview and Approach

The literature review above identifies and addresses some common and well-known issues with traditional KM strategies. However, it is by no mean extensive, nor does it delve deeply into KM issues, needs and strategies that directly relate to fast-paced research teams. Further research into the literature did not discover any detailed research into these specific team dynamics. To identify and inform the next step of the research process, which is assessing the user needs, human factors knowledge elicitation efforts were utilized. Efforts include observation of interactions and performances within job tasks, and researching documentation to identify the needs inherent to the users within the TANG team.

Once the user needs were fully identified, this information was used to drive the requirements and inform the parameters that should be considered in developing the KM solution. A technology discovery phase occurred next, where an exploration of technology that is available commercially off of the shelf (COTS) occurred. During this technology discovery phase, the technology identified was documented in how well it addresses the user needs identified previously. The focus of COTS technology is that it allows for faster potential implementation of a solution to test and evaluate fit against user needs.

Due to company policies and constraints, it is not realistic to implement and test a solution within the allotted timeframe. Therefore, this research will focus on developing a solution based on expert judgment identifying the significant attributes required for a KM solution, and then assessing the solution against available COTS technology.

3.2 Research Hypotheses

To frame this effort, the following hypothesis is investigated in this research.

Null Hypothesis H_0: There is no difference in expert preference between current technology in use and proposed technology for meeting user needs within a KM solution.

Alternative Hypothesis H_a: There is a difference in expert preference between current technology in use and proposed technology for meeting user needs within a KM solution, with experts identifying the necessary requirements in preferred proposed new technology.

3.3 Data Collection Method

Through the literature review and human factors knowledge elicitation efforts such as observation of interactions, performances within job tasks and interviews, a set of user needs was identified. Leveraging previous work (Seibel, Mazzuchi, & Sarkani, 2006) these user needs were translated into "design attributes" (attributes that are needed by the user) as well as the break points (stratified layers that define or decide how well each attribute is met or required) for each attribute that should be considered to be included in a designed KM solution. Technology discovery also helped to inform the attributes and break points, where it influenced break points more than attributes. From the attributes and break points identification, a survey was developed that contain demographic questions, a discrete number of scenario based questions, and open-ended comment section.

3.4 Data Analysis Method

Experts and practitioners in the field of design thinking (with priority given to members of the TANG program) are first asked to perform a paired comparison task, to

determine the rank the order of attributes and help to identify what is determined to be most-important to least-important.

Second, experts were taken through the scenario set and asked to determine which attribute or set of attributes is most preferred in a theoretical KM solution, providing expert judgment on random combinations of break points for attributes. From this we determined and analyzed a model of expert judgment on attributes needed for a KM solution to be effective for fast paced research teams. Analysis of the regression results was performed, to understand the significant impact of each attribute on the model.

Finally, the results of the model were inspected and compared against the technology identified in the technology discovery phase. Feedback and expert assessment of the selected technology was captured, documented and analyzed. From there, a recommendation of COTS technology was provided to the TANG team.

3.5 Attributes and Breakpoints

To support an analysis via regression, a set of attributes with corresponding break points is required. The attributes and break points provide the needed characterization of the scenarios, allowing the experts to judge each scenario and determine if they would recommend the solution based on the set of pre-determined break point assigned for each attribute.

3.5.1 Attributes

The attributes were determined from analyzing and considering two different sources of information. First, a user needs analysis was conducted that focused on the nature and type of work performed on TANG. A user needs analysis is a process in which the goals and the needs of the end user is determined, and what related capability from technology

is needed to support the end user in achieving their goals (Lindgaard et al., 2006). This analysis included all phases of research mentioned previously. In addition to a needs analysis, a technology discovery was performed to understand the current state of available technology. This helps to inform the attributes and break points as the goal of this research effort is to develop and recommend a KM solution that could be implemented immediately. If an attribute or breakpoint was developed that did not exist currently, it was not considered for this research effort. The following attributes were identified from the needs analysis, with the reasoning documented in each description.

3.5.1.1 Online Accessibility

Given the amount of travel required for research, one need is to access information while not in the office. As part of the TANG process, each TANG project does extensive travel in the research phase. Often teams of two to six researchers will travel on a trip at a time, and will perform multiple interviews concurrently. As the team is largely mobile during these crucial phases of research, the ability to connect to a software system to either input information or access previous entered information becomes important. Therefore, an attribute that should be considered when selecting a KM solution should be whether or not the solution has the ability to be accessed online (or offline and then synced online later), while the team members are on travel location.

3.5.1.2 Software Deployment

Congruent with the Online Accessibility attribute, the method of software deployment should also be considered. Information is constantly updated and passed across the team members, with a large number of researchers relying heavily on tablet and smartphones for work connectivity. While it requires online accessibility, an attribute of software

deployment should be considered as it may have a large impact on the effectiveness of any potential KM solution. The knowledge needs should support the mobility of the researchers who need access on-the-go.

3.5.1.3 Encryption / Security Ability

While all the work is unclassified, the ability to restrict access to the information is a key to controlling the information assurance. With multiple researchers from multiple organizations working on concurrent projects, there is a need to give access to individuals as appropriate.

3.5.1.4 Information Capture and Storage Formats

The data and artifacts gathered during research and the events span a wide range of media types. During the research phase, mostly written notes and documentation is gathered from doing in-domain and analogous domain research. However, it is not uncommon to also have several Microsoft Office file types, photographs, video recordings, audio recordings, and PDF documents as part of the research capture. During the event, the media that is commonly generated is in video, audio, and photograph format. The KM solution must take these different file format needs into account.

3.5.1.5 Intelligence and Inference

A common complaint of KM systems is the difficulty in finding information. In a fast-paced environment, software assistance in finding information would be helpful and beneficial across all phases of research. While the type of intelligence and inference provided could vary, a KM solution should consider the impact of this feature and how it can assist the user in finding relevant and related information quickly.

3.5.1.6 Collaboration Capability

There are multiple researchers working on a given TANG project, and the ability to collaborate on the data captured would foster increased interactions on the team. While the domain of the multiple concurrent projects may vary, often times insights and anecdotes can be transferred across domains and provide value throughout the project. By considering social features, researchers can add value and interact with the content that is leveraged and created.

3.5.1.7 Labeling / Tagging Capability

The nature and variety of the research done often leads to unique and non-standard descriptors, acronyms, and names that are used to describe information and knowledge. Unique tags would allow for internally developed titles, descriptions and acronyms to be used, and the style of tagging content increases the find-ability of specific or relevant information.

3.5.1.8 Search Capability

The amount of information collected is large and unstructured, and the ability of a KM solution to support finding information through a search feature is crucial. Additionally, the type of search a system is able to perform should be considered, as optimized searches can lead to more efficient use of the tool and information.

3.5.1.9 Estimated Time for Information Entry

For a fast-paced team, the technology needs to be user friendly and intuitive, reducing the amount of time a researcher needs to upload information, find information, or extract information from the tool. The system should make it easy for the user to engage in these

tasks and should not require any superfluous tasks or actions that would increase the time requirement in utilizing the tool.

3.5.2 Attributes with Breakpoints

The attributes and breakpoints listed below in Table3-1 are the final set of attribute and break points used in the research. The attributes and breakpoints listed below were identified from a user needs observation assessment of the fast-paced research team, and cross-referenced with the information on the current state of the KM technology gathered during the technology discovery. A total of 9 attributes and corresponding 27 break points were identified for demonstration purposes. The use of the Likert scale data for the break points are important for comparative purposes of the scenario based regression analysis (Seibel et al., 2006).

Table 3-1: Attributes and Breakpoints

Attribute	Definition / Explanation	Break Points
Online Accessibility	The availability and accessibility of the information and features of the software online for uninterrupted and continuous availability.	1. Offline Only 2. Online Only 3. Online and Offline Accessibility
Software Deployment	The nature of the software as implemented for use. Installed software is located on-site, and installed on desktop or networks. Cloud and web based software is hosted on the platform servers and is available via the web or cloud. Mobile Application is the ability to access the software system on the go via a mobile device.	1. Installed on Desktop Only 2. Installed on Desktop and Cloud/Web Based 3. Installed on Desktop, Mobile and Cloud/Web Based
Encryption / Security Ability	The ability for the software to either secure or encrypt the stored information.	1. None 2. Permission Based (Role, IP Address, etc.) 3. Permissions Based and Server (System) Side
Information Capture and Storage Formats	The ability for the software solution to capture and store various forms of information.	1. Text Only 2. Text and Picture/Video 3. Text, Picture/Video, and/or Other (.xls, .pdf)
Intelligence and Inference	The ability for the software to provide artificial intelligence and/or inference of the knowledge entered. Predictive text suggests words or context based on user input, predictive analysis makes suggestions based on formal and informal learning use, and sense making to help the users connect the dots between information.	1. None 2. Predictive Text and/or Analysis 3. Sense-making
Collaboration Capability	The ability for the software solution to enable collaboration of information between multiple users at a given time.	1. Rank or “Like” feature only 2. In-context feedback (Comments or Message Boards) 3. Share, Comments, Rank feature
Labeling / Tagging Capability	The ability for the software solution to label or tag information with predetermined or user defined labels or tags.	1. None 2. Limited or Predefined Use 3. User defined and/or meta data tagging
Search Capability	The ability for the software solution to engage in a user initiated search functionality.	1. None 2. In document search 3. Optimized Search
Estimated Time for Information Entry	The estimated time required for a user to enter in text-based and image-based information.	1. > 30 min 2. 15 – 30 min 3. < 15 min

3.6 Paired Comparison

For the paired comparison part of the assessment, the expert was provided the following table to use for the assessment (Figure 3-1).

		A	B	C	D	E	F	G	H	I
		Online Accessibility	Software Deployment	Encryption / Security Ability	Information Capture and Storage Formats	Intelligence and Inference	Collaboration Capability	Labeling / Tagging Capability	Search Capability	Estimated Time for Information Entry
A	Online Accessibility									
B	Software Deployment									
C	Encryption / Security Ability									
D	Information Capture and Storage Formats									
E	Intelligence and Inference									
F	Collaboration Capability									
G	Labeling/ Tagging Capability									
H	Search Capability									
I	Estimated Time for Information Entry									

Figure 3-1: Paired Comparison Assessment Table

Within each of the blank cells, the expert was asked to compare the option in the row with the option in the column. No attribute was compared to itself, and every duplicate comparison was grayed out to ensure that each comparison is done only once. The expert decided which of the two options is most important, and in the cell, wrote down the letter that represents the attribute determined to be the most important attribute of the two.

The Bradley Terry model is a probability model that is widely used model for developing pairwise user preferences (Hu & Li, 2016) and can use that data to predict the outcome of a comparison. A paired comparison data set can be used to measure perceived magnitudes between objects. To analyze the paired comparison data leveraging the Bradley Terry model, the works of Wickelmaier and Schmid to develop a MATLAB function to estimate model parameters will be used (Wickelmaier & Schmid, 2004).

In addition to the Bradley Terry model, a weighted paired comparison was also analyzed. In this methodology, in addition the letter representing the attribute the expert also scored the difference in importance between the options, using the following scale:

- 0 – No difference/same importance between the two attributes
- 1 – Minimal difference between the two attributes
- 2 – Moderate difference between the two attributes
- 3 – Major difference/one attribute much more important than the other

This scoring was for the expert to weight the relative difference in importance between the two attributes. This allows for a relative ranking of attributes by importance.

3.7 Developing Scenarios

3.7.1 Scenario Development

This methodology was modeled after an approach that has been proven to help identify the decision criteria used by experts by using a scenario driven method (Seibel et al., 2006). The following describes the method used to create the scenarios by methodically alternating the breakpoint values for each attribute, to get appropriate variability between scenarios.

In an ideal data collection, every possible scenario would be presented to expert for them to judge. As there are a total of 9 system attributes, with 3 breakpoints within each attribute, which would be a total of 3^9 possible scenarios, for a total of 19,683 scenarios if every permutation was considered. Expecting each expert to provide a judgment on roughly twenty thousand scenarios is not realistic, and as a result a subset of the scenarios were used.

One option to reduce the number of scenarios would be to "combine" attributes. This "combination" would not result in a reduction in the number of attributes in total, rather it would combine them in a way that their breakpoints vary in conjunction with each other.

That is, when one attribute has a more functional break point value (number 3 in Table 3-1), the other attribute has a more functional break point value. Conversely when one attribute has a least functional break point value (number 1), the other attribute also has the least functional breakpoint value. This retains the individuality of the attribute, but does condense the trade space as with the combined variables there are a reduced number of variables that would need to be considered when alternating the breakpoint values for scenario generation. More details on this process are below in 3.7.2.

Another variable in determining the trade space is for the number of attributes combined, how many of those attributes should have a negative, or least functional breakpoint, and how many should have a positive, or most functional breakpoint, in order to make up a scenario. At least one attribute per scenario should assume a less functional breakpoint, but it was unclear how many attributes should be less functional in a scenario, compared to how many are most functional.

The aim is to retain the maximum number of non-combined attributes, while also creating a realistic trade space to ensure the expert is not overwhelmed with the number of scenarios. To achieve this, the following methodology was employed.

3.7.2 Creating "Combined" Variables

The first step in determine the number of "combined" attributes that would yield in sufficient number of scenarios is to understand the trade space between the number of total attributes and the number of attributes that assume a negative or less functional value and conversely a positive, or more functional, value. One option to explore this space methodically is to use a binary method of counting to identify scenario layout. In this method, each attribute is treated as a bit, where it can assume a value of either a 1 or

a 0. In this case, a positive value (breakpoint value of 3) is noted as a "1", and "0" is a negative value (breakpoint value of 1 or 2). To count in binary, all values start with a value of 0. Starting with the right most bit, each bit is turned "on" and "off" in succession. This produces a total of 2^9 or 512 scenarios. Next, for a given number of attributes (n), it was calculated how many scenarios would result if there were n-1, n-2 and n-3 positive attributes for each scenario. This can be seen in Table 3-2 below.

Table 3-2: Binary Counting with Nine Attributes

Attribute											
1	2	3	4	5	6	7	8	9	Exactly 8 Attributes are 1	Exactly 7 Attributes are 1	Exactly 6 Attributes are 1
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	1	0	0	0
0	0	0	0	0	0	0	1	0	0	0	0
0	0	0	0	0	0	0	1	1	0	0	0
0	0	0	0	0	0	1	0	0	0	0	0
0	0	0	0	0	0	1	0	1	0	0	0
.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.	.
0	1	1	1	1	1	1	0	0	0	0	1
0	1	1	1	1	1	1	0	1	0	1	0
0	1	1	1	1	1	1	1	0	0	1	0
0	1	1	1	1	1	1	1	1	1	0	0
1	0	0	0	0	0	0	0	0	0	0	0
1	0	0	0	0	0	0	0	1	0	0	0
.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.	.
1	1	1	1	1	1	0	1	0	0	1	0
1	1	1	1	1	1	0	1	1	1	0	0
1	1	1	1	1	1	1	0	0	0	1	0
1	1	1	1	1	1	1	0	1	1	0	0
1	1	1	1	1	1	1	1	0	1	0	0
1	1	1	1	1	1	1	1	1	0	0	0
					Total Scenarios				**9**	**36**	**84**

This methodology was repeated five more times, for attributes ranging in value from eight to four. By doing this, a trade space is generated between the number of total attributes and the number of attributes that assume a negative and positive, or more value. The results of the analysis can be seen in Table 3-3 below.

Table 3-3: Trade Space of Positive and Negative Attributes with Scenario Totals

# Attributes Total	# Negative Attributes	# Positive Attributes	# Scenarios Total
9	1	8	9
9	2	7	36
9	3	6	84
8	1	7	8
8	2	6	28
8	3	5	56
7	1	6	8
7	2	5	21
7	3	4	35
6	1	5	6
6	2	4	15
6	3	3	30
5	1	4	5
5	2	3	10
5	3	2	10
4	1	3	4
4	2	2	6
4	3	1	4

The next step in determining the number of "combined" attributes that should be considered is to use the results seen in Table 3-4, with a focus on the column "# Scenarios Total". As the binary method of counting had two breakpoint values be condensed down into the "0" value, it would be ideal if the number of scenarios chosen could be doubled so each break point value could be used, but without resulting in more than twenty to thirty scenarios. It is expected that if more than thirty scenarios were presented to the experts, it would put undue burden on the experts and there is a risk that

expert response would decrease. By doubling the number of scenarios, each negative or 0 space can be duplicated twice. This allows for each 0 space to be repeated, so both breakpoint 1 and 2 can be used in each unique scenario. So, the maximum number of scenarios in the "# Scenarios Total" column should be fifteen. Additionally, to increase the amount of variability into the scenarios, preference would be given to the conditions where there were two or three negative attributes and the maximum number of total attributes. Factoring these preferences in, Table 3-4 below shows the three rows that meet the conditions above.

Table 3-4: Trade Space of Combined Attributes

# Attributes Total	# Negative Attributes	# Positive Attributes	# Scenarios Total
9	1	8	9
9	2	7	36
9	3	6	84
8	1	7	8
8	2	6	28
8	3	5	56
7	1	6	8
7	2	5	21
7	3	4	35
6	1	5	6
6	2	4	15
6	3	3	30
5	1	4	5
5	2	3	10
5	3	2	10
4	1	3	4
4	2	2	6
4	3	1	4

The results from Table 3-4 indicate that there is one condition that has 6 attributes in total, and two conditions that have five attributes in total. This narrows the focus to determine if any of the original nine attributes can be combined in a way that results in

five or six attributes. Attributes will only be considered for combination if the combination is logical. That is, attributes will not be combined if there is no logical connection or similarity between the original attributes.

From reviewing the nine original independent attributes, the fewest number of logical connections and similarities combined attributes that could be achieved was six. Online accessibility and software deployment could be combined as the type of software deployment options depend directly on if the system can be access offline, online, or both. Intelligence and Inference and Collaboration Capability were combined due to the similarity of the functionality that each attribute can provide. This is also true for the Labeling / Tagging Capability and Search Capability Attributes. The level of functionality between these attributes is similar and therefore the attributes can be logically grouped together. The attributes of Information Capture and Storage Formats, Estimated Time for Information Entry, and Encryption / Security Ability were not similar enough to be combined together in any type of combination. Therefore, the resulting number of combined attributes is finalized to six, can be seen in Table 3-5.

Table 3-5: Combined Attribute Groupings

Combined	Attribute
1	Online Accessibility
	Software Deployment
2	Information Capture and Storage Formats
3	Estimated Time for Information Entry
4	Intelligence and Inference
	Collaboration Capability
5	Labeling / Tagging Capability
	Search Capability
6	Encryption / Security Ability

With the selection of six combined attributes, where four attributes have a value of 1 and two have a value of 0, there are a total of fifteen scenarios that meet these criteria and can be seen in Table 3-6 below. In the scenario, the binary 1 is a more functional breakpoint and is color-coded in green. The binary 0 is a less functional breakpoint value and is color-coded in red. This color-coding is for visual purposes only.

Table 3-6: Fifteen Color-Coded Scenarios in Binary Counting Format

Scenario	Attribute 1	Attribute 2	Attribute 3	Attribute 4	Attribute 5	Attribute 6
1	0	0	1	1	1	1
2	0	1	0	1	1	1
3	0	1	1	0	1	1
4	0	1	1	1	0	1
5	0	1	1	1	1	0
6	1	0	0	1	1	1
7	1	0	1	0	1	1
8	1	0	1	1	0	1
9	1	0	1	1	1	0
10	1	1	0	0	1	1
11	1	1	0	1	0	1
12	1	1	0	1	1	0
13	1	1	1	0	0	1
14	1	1	1	0	1	0
15	1	1	1	1	0	0

As mentioned previously, a positive value of "1" denotes a breakpoint value of 3, and a value of "0" can denote a breakpoint value of either a 1 or 2. The first step in determining the scenarios structure is for every value of "1" seen in Table 3-6**Error! Reference source not found.** above, fill in the scenario breakpoint value with a 3. For attributes that are combined, both attributes within the combined attribute pair will receive the same value. For example, in Table 3-7 below, any time Online Accessibility has a breakpoint value of 3, Software Deployment also has a breakpoint value of 3.

Table 3-7: Fifteen Color-Coded Scenarios with Breakpoint Value 3 Only

	Online Accessibility	Software Deployment	Information Capture and Storage Formats	Estimated Time for Information Entry	Intelligence and Inference	Collaboration Capability	Labeling / Tagging Capability	Search Capability	Encryption / Security Ability
	1		2	3	4		5		6
1				3	3	3	3	3	3
2			3		3	3	3	3	3
3			3	3			3	3	3
4			3	3	3	3			3
5			3	3	3	3	3	3	
6	3	3			3	3	3	3	3
7	3	3		3			3	3	3
8	3	3		3	3	3			3
9	3	3		3	3	3	3	3	
10	3	3	3				3	3	3
11	3	3	3		3	3			3
12	3	3	3		3	3	3	3	
13	3	3	3	3					3
14	3	3	3	3			3	3	
15	3	3	3	3	3	3			

The first step is to double the number of scenarios from fifteen to thirty, so both breakpoint 1 and 2 can be used in an alternating fashion to create unique scenarios. This creates the maximum number of scenarios that will be used (Table 3-8).

Table 3-8: Thirty Color-Coded Scenarios with Breakpoint Value 3 Only

	Online Accessibility	Software Deployment	Information Capture and Storage Formats	Estimated Time for Information Entry	Intelligence and Inference	Collaboration Capability	Labeling / Tagging Capability	Search Capability	Encryption / Security Ability
	1		2	3	4		5		6
1				3	3	3	3	3	3
2			3		3	3	3	3	3
3			3	3			3	3	3
4			3	3	3	3			3
5			3	3	3	3	3	3	
6	3	3			3	3	3	3	3
7	3	3		3			3	3	3
8	3	3		3	3	3			3
9	3	3		3	3	3	3	3	
10	3	3	3				3	3	3
11	3	3	3		3	3			3
12	3	3	3		3	3	3	3	
13	3	3	3	3					3
14	3	3	3	3			3	3	
15	3	3	3	3	3	3			
16				3	3	3	3	3	3
17			3		3	3	3	3	3
18			3	3			3	3	3
19			3	3	3	3			3
20			3	3	3	3	3	3	
21	3	3			3	3	3	3	3
22	3	3		3			3	3	3
23	3	3		3	3	3			3
24	3	3		3	3	3	3	3	
25	3	3	3				3	3	3
26	3	3	3		3	3			3
27	3	3	3		3	3	3	3	
28	3	3	3	3					3
29	3	3	3	3			3	3	
30	3	3	3	3	3	3			

For the first fifteen scenarios, the first unassigned attribute will be assigned the breakpoint value of 1 whereas the second unassigned attribute will be assigned the breakpoint value of 2. For example, in scenario 1 noted in row 1, the combined attributes of Online Accessibility and Software Deployment would be assigned a value of 1, and the Information Capture and Storage Formats would be assigned a 2. For the second fifteen scenarios, the first unassigned attribute will be assigned the breakpoint value of 2 whereas the second unassigned attribute will be assigned the breakpoint value of 1. This can be seen in Table 3-9 where scenario 16 noted in row 16, where the combined attributes of Online Accessibility and Software Deployment would be assigned a value of 2, and the Information Capture and Storage Formats would be assigned a 1.

Table 3-9: Thirty Color-Coded Scenarios with All Breakpoint Values Assigned

	Online Accessibility	Software Deployment	Information Capture and Storage Formats	Estimated Time for Information Entry	Intelligence and Inference	Collaboration Capability	Labeling / Tagging Capability	Search Capability	Encryption / Security Ability
	1		2	3	4		5		6
1	1	1	2	3	3	3	3	3	3
2	1	1	3	2	3	3	3	3	3
3	1	1	3	3	2	2	3	3	3
4	1	1	3	3	3	3	2	2	3
5	1	1	3	3	3	3	3	3	2
6	3	3	1	2	3	3	3	3	3
7	3	3	1	3	2	2	3	3	3
8	3	3	1	3	3	3	2	2	3
9	3	3	1	3	3	3	3	3	2
10	3	3	3	1	2	2	3	3	3
11	3	3	3	1	3	3	2	2	3
12	3	3	3	1	3	3	3	3	2
13	3	3	3	3	1	1	2	2	3
14	3	3	3	3	1	1	3	3	2
15	3	3	3	3	3	3	1	1	2
16	2	2	1	3	3	3	3	3	3
17	2	2	3	1	3	3	3	3	3
18	2	2	3	3	1	1	3	3	3
19	2	2	3	3	3	3	1	1	3
20	2	2	3	3	3	3	3	3	1
21	3	3	2	1	3	3	3	3	3
22	3	3	2	3	1	1	3	3	3
23	3	3	2	3	3	3	1	1	3
24	3	3	2	3	3	3	3	3	1
25	3	3	3	2	1	1	3	3	3
26	3	3	3	2	3	3	1	1	3
27	3	3	3	2	3	3	3	3	1
28	3	3	3	3	2	2	1	1	3
29	3	3	3	3	2	2	3	3	1
30	3	3	3	3	3	3	2	2	1

By utilizing this methodology, scenarios are methodically developed and do not follow a random creation pattern. The thirty scenarios that were used to collect data can be seen in Table 3-9. The scenario order was randomized when presented to the experts for their assessment, as seen in Table 3-10. This randomization was done to ensure there was no discernable pattern to the scenarios, thus engaging experts to focus on each scenario as it was presented and not hold in mind how the current scenario was a variation of the previous scenario.

Table 3-10: Randomized Thirty Scenarios

Original Scenario Number	Online Accessibility	Software Deployment	Information Capture and Storage Formats	Estimated Time for Information Entry	Intelligence and Inference	Collaboration Capability	Labeling / Tagging Capability	Search Capability	Encryption / Security Ability
	1		2	3	4		5		6
12	3	3	3	1	3	3	3	3	2
7	3	3	1	3	2	2	3	3	3
27	3	3	3	2	3	3	3	3	1
4	1	1	3	3	3	3	2	2	3
9	3	3	1	3	3	3	3	3	2
19	2	2	3	3	3	3	1	1	3
22	3	3	2	3	1	1	3	3	3
16	2	2	1	3	3	3	3	3	3
26	3	3	3	2	3	3	1	1	3
18	2	2	3	3	1	1	3	3	3
8	3	3	1	3	3	3	2	2	3
3	1	1	3	3	2	2	3	3	3
24	3	3	2	3	3	3	3	3	1
28	3	3	3	3	2	2	1	1	3
17	2	2	3	1	3	3	3	3	3
13	3	3	3	3	1	1	2	2	3
6	3	3	1	2	3	3	3	3	3
5	1	1	3	3	3	3	3	3	2
21	3	3	2	1	3	3	3	3	3
14	3	3	3	3	1	1	3	3	2
20	2	2	3	3	3	3	3	3	1
23	3	3	2	3	3	3	1	1	3
25	3	3	3	2	1	1	3	3	3
11	3	3	3	1	3	3	2	2	3
1	1	1	2	3	3	3	3	3	3
30	3	3	3	3	3	3	2	2	1
2	1	1	3	2	3	3	3	3	3
29	3	3	3	3	2	2	3	3	1
15	3	3	3	3	3	3	1	1	2
10	3	3	3	1	2	2	3	3	3

3.8 Technology Review and Assessment Process

A review of technology available in current practice was completed, with the intent of using the results of the paired comparison analysis and ordinal regression analysis to

identify which technology may best meet the needs of the team. The results of the technology review were provided to experts to assess and provide feedback, and will be compared with the final recommendation based on the research.

An initial review of current technology available within the realm of knowledge management was performed, leading to a down selection of fifteen technology solutions that had the potential to meet the needs of the research team. Each of the technologies were evaluated against the nine attributes and corresponding breakpoints, noting which breakpoints each technology was able to meet (Table 3-11) by noting a "1" if met.

Leveraging the results of expert preference via paired comparison analysis and the significant attributes identified in the ordinal regression analysis (both discussed in Analysis section below), a down selection to three technologies was performed. The down selection was determined by assessing which of the fifteen technologies best met the attributes and breakpoints by determine the score of teach technology. By summing the column of each technology, it was determined how well each technology supported the attributes and breakpoints. The three technologies with the top score based on analysis were chosen, and included the technologies Bloomfire, Evernote and Yammer. A summary page for each of the top three technologies were developed, and highlighted how each of the capabilities met the identified significant attributes of the Software Deployment, Online Accessibility, Search Capability, Labels and Tagging, Collaboration Capability, and Intelligence and Inference attributes. More detail is provided in the Result section below on how the significant attributes were identified. Additionally, a "Most Impressive Feature" was highlighted for each technology, where this was a feature that sets the technology apart from the other technologies.

Table 3-11: Potential Technology Solutions

		Potential KM Solutions														
Attribute	**Breakpoint**	Bloomfire	Logikcull	Inmagic Presto	Mango Apps	Trello	Knowledge Owl	Atlassian Confluence	Knowledge Plaza	Intuition Advantage	Plone	Kyield	Yammer	Google Communities	Evernote	Aha
Online Accessibility	Offline Only															
	Online Only			1			1	1	1			1	1	1		1
	Online and Offline Accessibility	1	1		1	1				1	1				1	
Software Deployment	Installed on Desktop Only															
	Installed on Desktop and Cloud/Web Based											1				1
	Installed on Desktop, Mobile and Cloud/Web Based	1	1	1	1	1	1	1	1	1	1		1	1	1	
Encryption / Security Ability	None															
	Permission Based (Role, IP Address, etc.)			1	1	1	1	1				1		1	1	1
	Permissions Based and Server (System) Side	1	1						1		1		1			
Information Capture and Storage	Text Only									1						
	Text and Picture/Video								1					1		
	Text, Picture/Video, and/or Other (.xls, .pdf)	1	1	1	1	1	1	1			1	1	1		1	1
Intelligence and Inference	None					1		1		1	1					1
	Predictive Text and/or Analysis	1	1	1	1		1		1				1	1	1	1
	Sense-making	1							1			1				
Collaboration Capability	Rank or "Like" feature only	1							1			1				
	In-context feedback (Comments or Message Boards)	1	1				1				1				1	
	Share, Comments, Rank feature	1		1	1	1		1		1			1	1		1
Labeling / Tagging Capability	None									1		1		1		
	Limited or Predefined Use								1							1
	User defined and/or meta data tagging	1	1	1	1	1	1	1			1		1		1	
Search Capability	None									1						
	In document search	1	1	1	1	1	1	1	1							1
	Optimized Search	1	1		1						1	1	1	1	1	
Estimated Time for Information	> 30 min		1	1	1	1	1	1	1	1	1	1				1
	15 – 30 min	1	1	1	1	1	1	1			1		1	1	1	1
	< 15 min	1											1	1	1	

4 Data Collection

As mentioned previously in the methodology section, the experts were asked to provide their expert judgment in three different ways. First, they were provided a data packet that requested demographic information, asked them to perform a Paired Comparison test, then immediately afterwards they were asked to give expert judgment on the scenarios. The data packet was provided in both Microsoft Word format, as well as Adobe PDF format. In the PDF format, they were able to enter in free text, as well as utilize radio buttons to provide responses in the scenario portion. Post analysis of the paired comparison data and scenario data, the experts were asked to provide their assessment and preference of the top three technologies from the technology review.

4.1 Data Package for Experts - Demographic Information

The first data collection page in the data packet was to capture demographic information on the experts. The purpose of this page was to capture the self-described background and expertise of the experts, as well as their current role as it relates to TANG and/or design thinking. The experts were then asked for length in years that they had been in the aforementioned role, and the number of years they have been involved with the TANG efforts. In addition to their current role, they were also asked if they had any other roles or experiences that related to TANG and/or design thinking. This information is captured to enable better understanding of the depth and breadth of experience of the pool of experts chosen. Finally, experts were asked to share their opinions on knowledge management, both in general and more specifically how it relates

to the TANG effort. The background information questionnaire can be seen below in Figure 4-1.

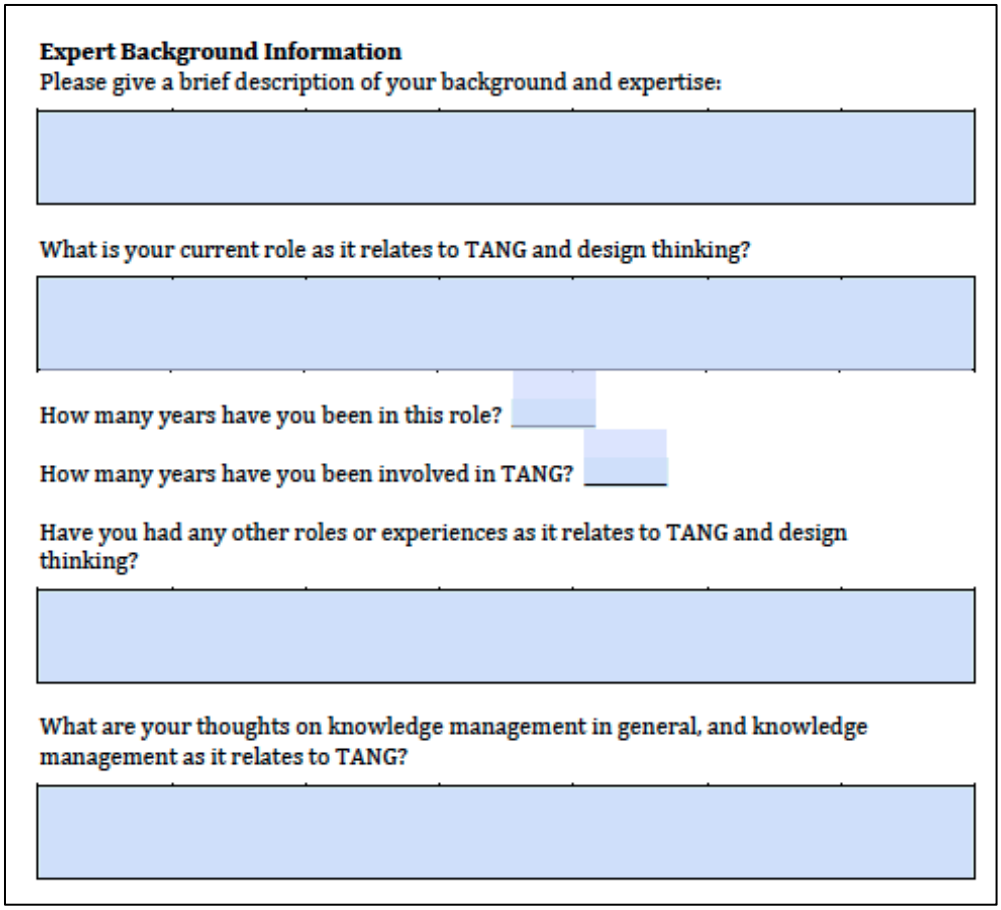
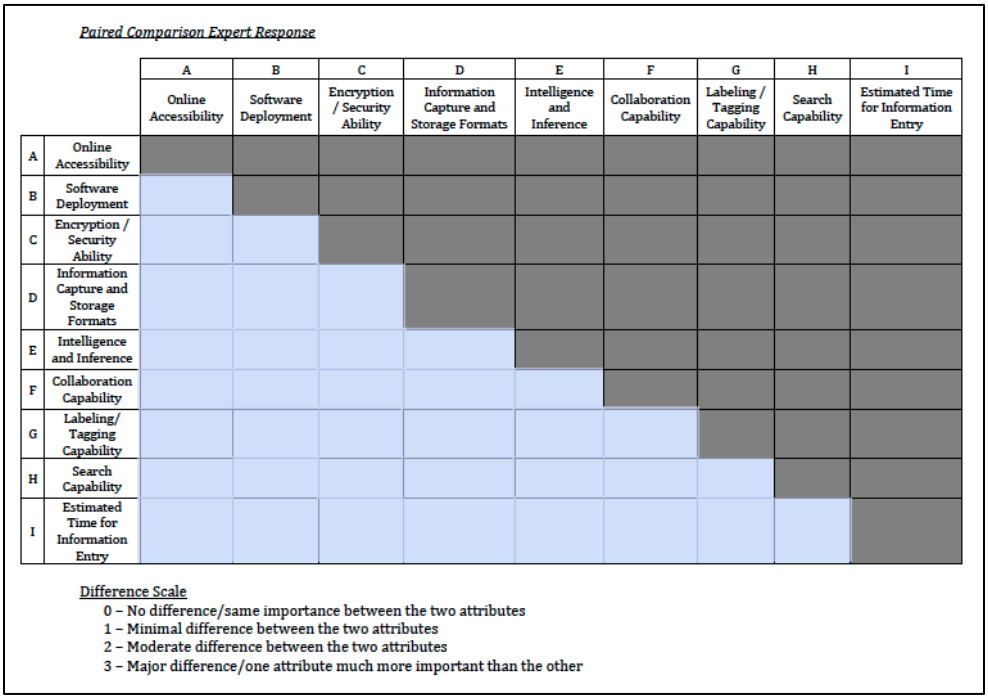


Figure 4-1: Expert Package - Background Information Page

4.2 Data Package for Experts - Paired Comparison Assessment

The second sheet in the data package was for experts to provide their preferences for each attribute via a paired comparison. For the paired comparison assessment, the experts were provided with the table and instructions shown in Figure 4-2 to use for the assessment. Within each of the blank cells, the experts were asked to compare the option in the row with the option in the column. No attribute was compared to itself, and every duplicate comparison was grayed out to ensure that each comparison is done only once.

The expert decided which of the two attributes is most important, and in the cell wrote down the letter that represents the attribute determined to be the most important attribute of the two. In addition, they also wrote down a number to indicate the difference in importance they feel exists between the two attributes. By providing both pieces of information, this allowed for both the Bradley Terry model and the weighted model analysis of expert response.



Paired Comparison Expert Response

		A	B	C	D	E	F	G	H	I
		Online Accessibility	Software Deployment	Encryption / Security Ability	Information Capture and Storage Formats	Intelligence and Inference	Collaboration Capability	Labeling / Tagging Capability	Search Capability	Estimated Time for Information Entry
A	Online Accessibility									
B	Software Deployment									
C	Encryption / Security Ability									
D	Information Capture and Storage Formats									
E	Intelligence and Inference									
F	Collaboration Capability									
G	Labeling/ Tagging Capability									
H	Search Capability									
I	Estimated Time for Information Entry									

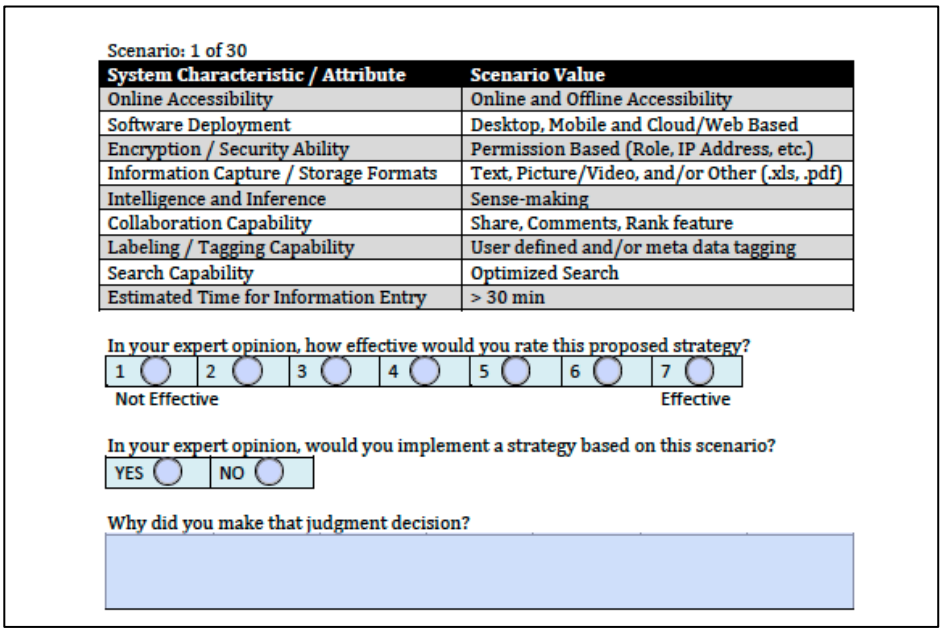
Difference Scale
0 – No difference/same importance between the two attributes
1 – Minimal difference between the two attributes
2 – Moderate difference between the two attributes
3 – Major difference/one attribute much more important than the other

Figure 4-2: Expert Package - Paired Comparison Assessment Page

4.3 Data Package for Experts – Scenario Assessment

The scenarios were generated and designed from a systematic distribution of the break point values across each survey attribute. Below in Figure 4-3 shows the first of thirty scenarios that were presented to the experts. For each scenario, the experts were asked to consider the values for each attribute presented and to provide judgment on the effectiveness of the given scenario and if they would recommend implementing a solution based on the values. There was also space for the expert to provide comments on

their reasoning for making that decision. Two scenarios fit onto a single page, therefore there were a total of fifteen pages of scenarios for the experts to assess.



Scenario: 1 of 30

System Characteristic / Attribute	Scenario Value
Online Accessibility	Online and Offline Accessibility
Software Deployment	Desktop, Mobile and Cloud/Web Based
Encryption / Security Ability	Permission Based (Role, IP Address, etc.)
Information Capture / Storage Formats	Text, Picture/Video, and/or Other (.xls, .pdf)
Intelligence and Inference	Sense-making
Collaboration Capability	Share, Comments, Rank feature
Labeling / Tagging Capability	User defined and/or meta data tagging
Search Capability	Optimized Search
Estimated Time for Information Entry	> 30 min

In your expert opinion, how effective would you rate this proposed strategy?

1 ◯ | 2 ◯ | 3 ◯ | 4 ◯ | 5 ◯ | 6 ◯ | 7 ◯

Not Effective — Effective

In your expert opinion, would you implement a strategy based on this scenario?

YES ◯ | NO ◯

Why did you make that judgment decision?

Figure 4-3: Expert Package - Scenario Assessment Page

4.4 Technology Review Packet

After the data packet that contained the demographic information page, paired comparison assessment page, and the scenario pages were returned from the experts, analysis was done on the responses. The details of the results of the analysis are in the next chapter. The results of the analysis were used to inform the technology review that resulted in the top three potential technologies, as mentioned in chapter 3. These summary pages (Figure 4-6, Figure 4-7 and Figure 4-8) were compiled with a cover page (Figure 4-4) and an instructions page (Figure 4-5) that was sent to experts. The experts were asked to first provide their rank preference for the technologies, as well as provide a free form comment on why they made that determination.

Figure 4-4: Expert Technology Review - Cover Page

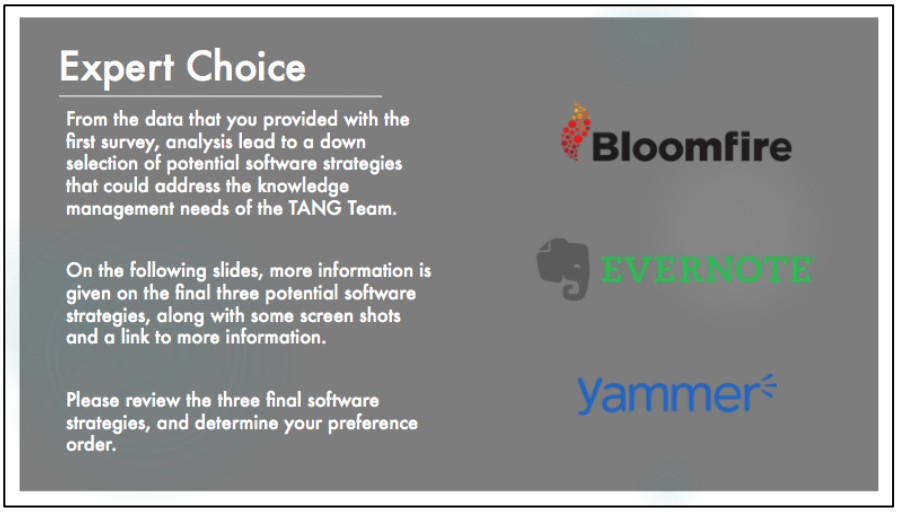


Figure 4-5: Expert Technology Review - Instructions Page

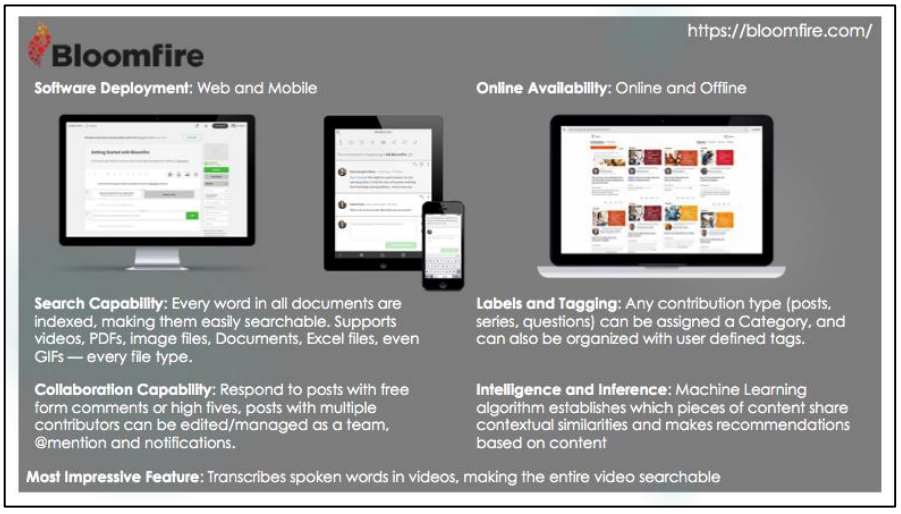


Figure 4-6: Expert Technology Review - Bloomfire

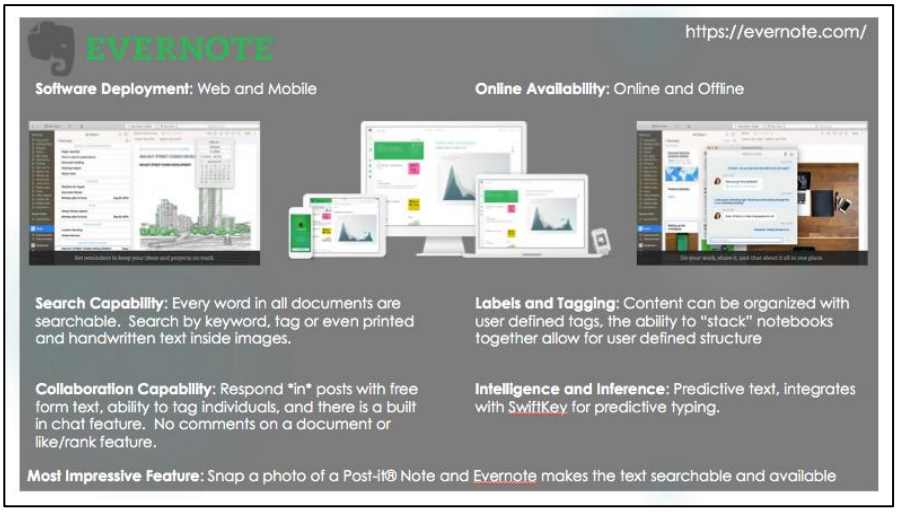


Figure 4-7: Expert Technology Review - Evernote

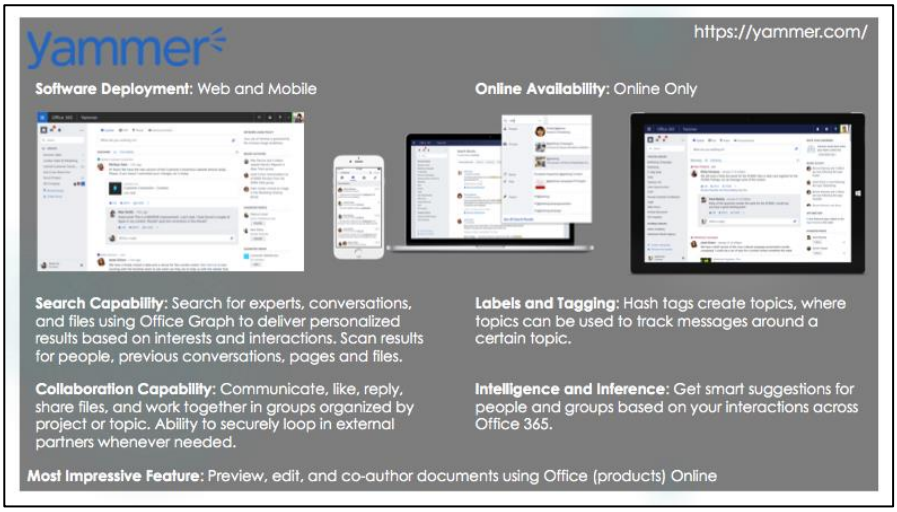


Figure 4-8: Expert Technology Review - Yammer

5 Analysis

5.1 Demographic Analysis

A total of sixteen experts were used as part of this research. Thirteen of the experts had direct interactions with TANG, either as a researcher or a facilitator, and the other three additional experts were familiar with or work at the TANG event but do not actively engage in the research.

To better understand the experience level of the experts, part of the background information page collected the amount of experience the experts had in TANG or related design thinking efforts. A histogram of the expert experience is shown in Figure 5-1. The average years of experience in TANG or design thinking work were 4.19 years, with a standard deviation of 1.76 years. The median amount of experience was 4.5 years. As the program is seven years in existence, we can see that the majority of the experts have been involved in TANG or design thinking efforts for over half of the lifetime of TANG.

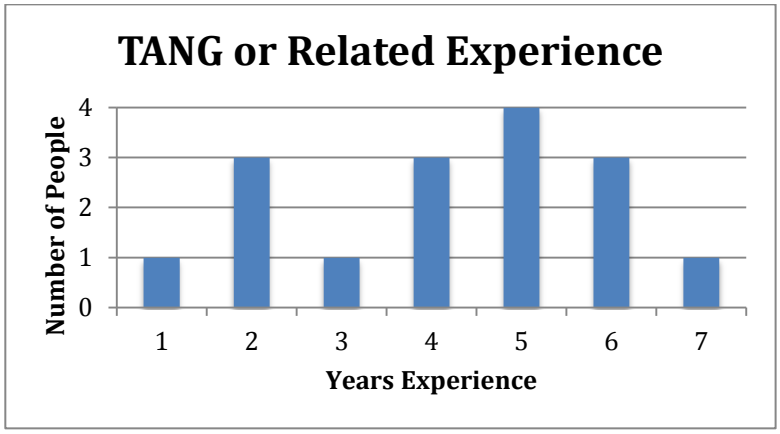


Figure 5-1: Expert Experience in TANG or Related Efforts

When the experts were asked to provide their thoughts on KM, both in general and as related to TANG, the experts overwhelmingly supported the need for a KM solution for the TANG and design thinking efforts. Below is a sample of the comments received:

"The TANG team has some amazing opportunities for research trips and subject matter expert conversations. The pace of the project and the structure of the team make it challenging to share the best practices. A better way to reference previous research trips would be great. "

"Knowledge management must show a return on investment. Traditional methods of writing documents may not be as effective/efficient as capturing video. The use of video in TANG helps capture processes and leads to a product for the customer."

"Tracking research, synthesizing and capturing insights, categorizing brainstorm ideas all benefit from some sort of knowledge management capability."

"I think a good knowledge management system can vastly improve the effectiveness and efficiency of the team."

"KM is incredibly important, and we don't have a good deliberate strategy for managing our research efforts."

5.2 Paired Comparison – Bradley Terry Model with MATLAB

The responses from the experts are shown in Table 5-1. While the majority of responses follow the instructions to provide both a letter and a number, for some responses when the expert felt there was no difference were marked as a 0, instead of a letter and a number. As a result, those responses could not be used in the Bradley Terry model analysis in the previous section. The results of the paired comparison assessment show the relative importance the experts place on the different attributes.

The analysis of the paired comparison data leveraged the works of Wickelmaier and Schmid, whom developed a MATLAB function to estimate the results of a the Bradley Terry model analysis, based on a matrix input of expert choice frequencies between the attributes (Wickelmaier & Schmid, 2004). The results of the expert assessments were tallied, and the expert choice frequencies can be seen in Table 5-2. In that table, the row

attributes were chosen over the column attributes. For example, when asked to compare the two, the Software Deployment attributes was chosen over the Online Accessibility attribute four times (row two, column one) whereas the Online Accessibility attribute was chosen over the Software Deployment attribute nine times (row one, column two). Ideally the sum of these two would equal the number of experts (sixteen), but due to missing data letters in the data this is not always the case.

Table 5-1: Weighted Paired Comparison Expert Responses

Expert 1	Expert 2	Expert 3	Expert 4	Expert 5	Expert 6	Expert 7	Expert 8	Expert 9	Expert 10	Expert 11	Expert 12	Expert 13	Expert 14	Expert 15	Expert 16
A2	B,3	A, 1	A,3	0	A,0	A,0	B,1	A, 2	0	B,3	A2	B,2	A-2	A, 2	0
c/2	A,1	A, 2	C,2	a,2	A,3	A,2	A,2	A, 3	A,1	C,3	C3	C,1	C-2	A, 2	C,4
c/2	B,1	B, 2	C,0	b,2	B,3	B,2	B,2	B, 2	B, 1	B,1	C3	B,1	C-1	B, 0	C,4
A/1	D,2	D, 2	D,3	a,2	A,0	A,1	A,2	0	A, 1	D,3	A1	D,0	A-1	A, 1	A,1
d/1	D,1	B, 3	D,1	b,1	B,0	B,2	B,3	0	D, 1	B,1	D1	B,1	D-1	D, 1	D,1
d/1	D,2	D, 2	D,1	c,1	D,2	D,2	D,3	D, 3	D, 2	D,2	C2	C,0	C-1	D, 2	C,4
E/2	A,2	E, 3	A,0	a,2	A,3	A,1	A,3	0	A, 2	E,3	A1	E,1	A-1	A, 1	A,1
e'1	B,2	B, 2	E,1	b,2	B,2	B,2	B,3	0	B, 2	B,2	E0	B,0	B-1	E, 0	B,3
e/2	C,2	E, 2	E,0	c,1	E,2	D,3	E,1	C, 3	C, 1	E,0	C1	E,1	C-2	E, 2	C,4
e/2	D,0	D, 1	D,2	d,1	D,2	D,2	D,2	D, 2	D, 2	D,2	D1	E,1	D-1	D, 1	D,2
F/2	F,0	F, 3	A,0	f,1	F,2	F,0	A,2	0	F, 1	A,2	F2	F,3	F-2	A, 0	A,1
f/2	F,0	F, 3	B,0	f,1	B,0	B,0	B,2	B, 1	F, 1	B,2	F2	F,1	F-3	F, 1	0
f/2	F,1	F, 2	F,0	f,1	F,2	F,2	F,2	F, 3	F, 2	F,1	F2	F,2	0	F, 2	C,4
f/2	F,0	F, 1	D,0	0	F,1	F,2	D,2	D, 2	D, 1	D,3	F2	F,2	F-1	F, 0	0
f/2	F,1	F, 2	E,0	f,2	F,2	F,2	F,2	0	F, 3	E,1	F2	F,2	F-1	F, 1	0
G'2	G,0	G, 2	A,2	a,1	A,1	A,2	A,2	0	G, 1	G,1	G1	G,1	G-2	A, 0	G,1
g/2	B,0	G, 2	B,2	b,1	B,0	B,2	B,2	0	G, 1	B,1	G1	B,1	G-2	G, 1	G,1
g.2	C,1	G, 1	C,3	0	G,2	G,1	G,2	C, 3	G, 2	G,2	C2	G,1	0	G, 2	C,4
g/2	G,0	G, 1	G,2	0	D,1	G,3	D,2	D, 1	0	G,0	D1	D,1	G-1	G, 0	G,3
g/2	G,1	G, 2	G,2	g,1	G,1	G,1	G,2	G, 1	G, 2	G,3	G1	E,1	G-2	G, 1	0
g/2	F,1	F, 1	F,1	f,1	F,2	F,2	F,1	G, 2	0	G,3	F2	F,2	0	F, 1	0
H/2	H,0	A, 1	A,0	0	A,0	A,0	A,2	0	H, 1	H,0	H3	H,1	0	A, 1	H,4
h/2	H,0	H, 2	A,0	h,1	B,0	B,0	B,2	0	H, 1	H,1	H2	B,0	H-1	H, 1	H,4
h/2	H,1	H, 2	H,2	h,2	H,2	H,2	H,2	H, 3	H, 2	H,3	C1	H,1	0	H, 2	C,4
h/1	H,0	D, 1	D,1	h,2	D,1	H,3	D,1	D, 1	H, 1	H,0	H1	D,1	0	H, 0	H,4
h/2	H,1	H, 2	E,1	h,1	H,2	H,1	H,2	H, 1	G, 3	H,3	H1	H,1	H-1	H, 1	H,4
h/2	F,1	H, 1	H,2	0	F,1	F,1	H,1	H, 3	0	H,3	F2	F,2	0	F, 1	H,4
g/2	H,0	G, 1	G,1	0	H,0	H,2	H,1	0	0	H,0	0	H,1	0	G, 2	0
I/0	I,0	A, 1	I,1	0	A,0	A,3	A,2	A, 3	A, 1	A,2	I2	I,2	I-1	I, 2	A,1
i/2	I,0	I, 2	I,1	0	B,0	B,3	B,3	B, 3	B, 1	B,3	I2	I,1	I-1	I, 2	0
c/2	I,1	C, 3	I,0	i,2	I,2	H,3	I,2	C, 3	I, 1	C,2	C1	I,2	C-1	I, 3	C,4
i/1	I,0	I, 1	I,0	i,1	I,0	I,3	D,1	D, 3	D, 2	D,3	I1	I,2	D-1	I, 1	I,1
e/1	I,1	E, 2	I,1	i,2	I,2	E,3	I,1	0	G, 3	E,2	I1	I,2	I-1	I, 2	I,2
f/2	I,0	I, 1	I,0	i,1	F,1	F,2	I,1	F, 3	F, 1	I,0	F2	F,0	0	I, 1	0
g/2	I,0	G, 1	G,1	0	I,1	G,2	I,1	G, 3	G, 1	G,3	I1	I,2	0	I, 1	0
h/2	I,0	H, 1	I,0	g,1	I,1	H,2	H,1	H, 3	H, 1	H,3	H1	I,2	0	I, 1	0

Table 5-2: Aggregate Choice Frequencies

	Online Accessibility	Software Deployment	Information Capture and Storage Formats	Estimated Time Info Entry	Intelligence and Inference	Collaboration Capability	Labeling / Tagging Capability	Search Capability	Encryption / Security Ability
Online Accessibility	0	9	9	10	11	5	6	6	8
Software Deployment	4	0	11	7	11	6	8	4	6
Information Capture and Storage Formats	7	5	0	5	7	1	5	2	7
Estimated Time for Information Entry	5	8	11	0	14	5	5	6	5
Intelligence and Inference	4	4	8	2	0	2	1	1	4
Collaboration Capability	10	9	14	9	12	0	10	6	7
Labeling / Tagging Capability	9	7	9	9	14	3	0	4	13
Search Capability	7	10	13	9	14	7	6	0	8
Encryption / Security Ability	7	8	8	11	10	7	6	5	0

The results of the assessment have a significant goodness of fit, with $\chi^2(28) = 22.9561$, $p < .001$, and can be seen in Table 5-3 below. In the table is the rank order of attributes in terms of expert preference.

Table 5-3: Paired Comparison Analysis Results - Bradley Terry Model

	Attribute	Weight
1	Collaboration Capability	19.22%
2	Search Capability	19.09%
3	Labeling / Tagging Capability	13.07%
4	Online Accessibility	11.19%
5	Encryption / Security Ability	10.16%
6	Software Deployment	8.92%
7	Estimated Time for Information Entry	8.87%
8	Information Capture and Storage Formats	4.61%
9	Intelligence and Inference	2.88%

The nine attributes can be divided into roughly three groups with Collaboration Capability and search Capability are the most important attributes from this paired comparison analysis. The attributes from Labeling/Tagging Capability through Estimated Time for Information Entry are the second group of roughly grouped attributes, with

Information Capture and Storage Formats attribute and Intelligence and Inference attribute being the last group in terms of expert ranking via this analysis method.

5.3 Paired Comparison – Bradley Terry Model with Circular Triad

The responses from the experts shown in the previous section was also run through a more traditional Bradley Terry Model, as it also took into account internal reliability of the expert. One common way to measure this is through calculating the experts circular triads (Brown, 2009). Circular triad occurs when an expert would decide that attribute A is greater than attribute B, attribute B is greater than attribute C, and would then note that attribute A is less than attribute C when logically it should be that attribute A is greater than attribute C (van Wijk, 2004). Notes and analysis help was obtained from Professor Thomas Mazzuchi, along with additional references (Brown, 2009) and were leveraged to calculate the number of circular triads for each expert. Once the circular triads are calculated for each expert, a statistical test is ran to determine if the expert answered randomly or not. The test hypothesis is:

Ho: The expert answered the pairwise comparison randomly

Ha: The expert did not answer the pairwise comparison randomly

This is performed as a standard one tailed hypothesis test, where if the null hypothesis cannot be rejected at a 5% level of significance, then the expert is dropped from the analysis (Kendall, 1962).

Leveraging the references of above, Table 5-4 shows the results of the analysis to determine the agreement within the group. The results of this analysis show that the agreement within the group is acceptable, with a significant level of less than .001.

Table 5-4: Expert Group Circular Triad Results

Coefficient of Agreement	15.37037037
Chi Square Stat	3536
df	216
Significance Level	0.000

The results of the individual expert analysis are shown below in Table 5-5. In the table, for each expert the number of circular triads was calculated and reported, as is both the test statistic and the significance level. It is important to note that the degrees of freedom for this test are 20.16. From the results below, it is noted that both expert 3 and expert 4 fail to reject the null hypothesis, and will be removed from future analysis. While expert 9 is just over the threshold, that expert will be kept in the analysis.

Table 5-5: Individual Expert Circular Triad Results

Expert	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Circular Triad	2	3	16	18	10.25	1	2	0
Test Stat	51.36	49.76	28.96	25.76	38.16	52.96	51.36	54.56
Significance Level	0.000	0.000	0.089	0.174	0.008	0.000	0.000	0.000
Expert	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Circular Triad	14.5	14	2	2.25	3	9.5	0	11.5
Test Stat	31.36	32.16	51.36	50.96	49.76	39.36	54.56	36.16
Significance Level	0.051	0.042	0.000	0.000	0.000	0.006	0.000	0.015

5.4 Paired Comparison - Weighted

The results of the assessments are determined by analyzing the weighted values for each attribute per expert judgment, and calculating the percentage equivalent to determine the relative importance of each attribute. For example, Table 5-6 below shows how the expert would fill out a scaled-down paired comparison, and how those values would be scored and weighed for each attribute. For each attribute, a count is performed

and documented using the weighting factor to tally the results. In the example below, attribute A (availability online) is marked twice in the matrix. The total weight for attribute A is 3, from the attribute A vs. B comparison (weight of 2) and the attribute A vs. D comparison (weight of 1). This is done for each attribute and documented. The overall weight for each attribute is calculated from the individual score of the attribute divided by the total score across all attributes. For attribute A, this would be the individual score of attribute A (3) divided by the total score from the paired comparison assessment (10), resulting in a final attribute weight of 3/10 = 30%.

Table 5-6: Example Weighted Paired Comparison Data and Analysis

		A	B	C	D
		Availability Online	Total Cost	Encryption / Security Ability	Estimated Time for Information Entry
A	Availability Online				
B	Total Cost	A, 2			
C	Encryption / Security Ability	C, 1	C, 1		
D	Estimated Time for Information Entry	A,1	D, 2	D, 3	

Attribute	Score	Weight
A	3 (2 + 1)	3/10 = 30%
B	0	0/10 = 0%
C	2 (1 + 1)	2/10 = 20%
D	5 (2 + 3)	5/10 = 50%
Total	10	

The results of the paired comparison assessment are shown in Table 5-7. The nine attributes can be divided into roughly three groups, with approximately 2% difference between each group. The first group consists of Search Capability and Collaboration Capability, the second group are the attributes from Labeling / Tagging Capability to Software Deployment, with Encryption and Security Ability and Intelligence and Inference being the last group.

Table 5-7: Paired Comparison Analysis Results - Weighted

	Attribute	Score	Weight
1	Search Capability	112	15.69%
2	Collaboration Capability	107	14.99%
3	Labeling / Tagging Capability	87	12.18%
4	Online Accessibility	80	11.20%
5	Estimated Time for Information Entry	80	11.20%
6	Information Capture and Storage Formats	79	11.06%
7	Software Deployment	78	10.92%
8	Encryption / Security Ability	65	9.10%
9	Intelligence and Inference	26	3.64%
	Total	714	

Search Capability, Collaboration Capability, Labeling / Tagging Capability, and Online Accessibility are the four most important attributes from the weighted paired comparison analysis and from the Bradley Terry model analysis. After the top four, Estimated Time for Information Entry and Information Capture and Storage Formats moved from seventh and eight place to fifth and sixth place, respectively. Software Deployment dropped from sixth to seventh place, and Encryption / Security Ability dropped from fifth place to eighth place. Intelligence and Inference remained in ninth place. The change in results indicates that when the relative importance that experts place on different attributes can have a strong impact on preference order. Given this effect, heavier emphasis will be placed on the results of the weighted paired comparison analysis when considered with the results of the scenario ordinal regression analysis.

5.5 Scenario Regression Analysis and Results

The data collected from the scenarios utilizing expert judgment were analyzed via ordinal regression analysis. All analysis, plots, tables and screenshots are from IBM SPSS Statistics Software Version 23. Before any statistical analysis was run on the data,

descriptive statistics of the data was evaluated. All independent variables had the same mean and standard deviation, which is to be expected from how the scenarios were created. As each variable assumed the same number of breakpoint values, it would be expected that the descriptive statistics would be identical. For the dependent variable, the mean value was 4.13 with a standard deviation of 1.713 (shown in Table 5-8). The units of this score would be "effectiveness", so the mean effectiveness score provided by the experts was slightly more positive than neutral, while the standard deviation had a reasonable but not large spread. This indicates that the judgment provided by the experts was not biased and initially neutral, but would also have values in "more" and "less" effectiveness as the scenarios were presented. Thus there is no indication of experts leaning more positive or more negative based on the mean reported score.

Table 5-8: Descriptive Statistics of Dependent and Independent Variables

Descriptive Statistics

	Mean	Std. Deviation	N
Effectiveness	4.13	1.713	480
Online_Accessibility	2.50	.765	480
Software_Deployment	2.50	.765	480
Info_Capture_Storage_Formats	2.50	.765	480
Time_Info_Entry	2.50	.765	480
Intelligence_and_Inference	2.50	.765	480
Collaboration_Capability	2.50	.765	480
Label_Tag_Capability	2.50	.765	480
Search_Capability	2.50	.765	480
Encryption_Security_Ability	2.50	.765	480

The results from the ordinal logistic regression can be used to determine which of the independent variables in the model have a statistically significant effect on the dependent variable. To complete an ordinal regression analysis, which can be considered

a generalization of a multiple linear regression, four assumptions should be inspected to determine if they are met before continuing on to the analysis. Below are the assumptions, and if they are met.

Assumption 1 – *The dependent variable should be at the ordinal level.* As the dependent variable of Effectiveness is data from a seven point Likert scale, the data is ordinal and this assumption is met.

Assumption 2 – *One or more independent variables are continuous, categorical or ordinal.* The independent variables are all ordinal in nature, so this assumption is met.

Assumption 3 – *There is no multicollinearity in the independent variables.* Multicollinearity is when two or more independent variables are highly correlated, which is problematic when explaining the impact of the independent variables on the dependent variables. To assess multicollinearity, a collinearity diagnostic should be run and either the Tolerance or the Variance Inflation Factor (VIF) could be consulted, as the VIF is simply the reciprocal of Tolerance. If the Tolerance value is less than 0.1 (or the VIF value is greater than 10) then a multicollinearity problem may be present. A collinearity diagnostic was run in SPSS, with the results below in Table 5-9.

Table 5-9: Collinearity Statistics

Coefficients[a]

Model		Collinearity Statistics	
		Tolerance	VIF
1	Online_Accessibility	.600	1.667
	Info_Capture_Storage_Formats	.600	1.667
	Collaboration_Capability	.600	1.667
	Search_Capability	.600	1.667
	Encryption_Security_Ability	.600	1.667

a. Dependent Variable: Effectiveness

The analysis shows the Tolerance values for the variables were greater than 0.1 (and the VIF values less than 10). The results of the analysis show there is not a problem with collinearity in this data set.

Assumption 4 – *There are proportional odds.* Proportional odds assumption is that each independent variable has an identical effect at each cumulative split of the ordinal dependent variable. This assumption is tested with a full likelihood ratio test, which compares the fit of the proportional odds model to a model with varying location parameters. The test compared the model fit between two different cumulative odds models, with one model being a proportional odds model (Null Hypothesis) and a cumulative odds model without proportional odds assume (General). If the assumption for proportional odds is not met, a significant difference would be found between the two models. In SPSS this test accomplished by running a Test of Parallel Lines analysis, with the results shown in Table 5-10 below.

Table 5-10: Test of Parallel Lines

Test of Parallel Lines

Model	-2 Log Likelihood	Chi-Square	df	Sig.
Null Hypothesis	495.887			
General	431.203	64.684	50	.079

The null hypothesis states that the location parameters (slope coefficients) are the same across response categories.
a. Link function: Logit.

The assumption of proportional odds was met, as assessed by a full likelihood ratio test comparing the fit of the proportional odds location model to a model with varying location parameters, $\chi^2(50) = 64.684$, $p = .079$.

All four assumptions were met to support an ordinal regression analysis, with the results of the analysis continued below.

5.5.1 Overall Fit of Ordinal Model

The goodness-of-fit test is an overall measure of how well the model fits the data. The first step to understanding the goodness-of-fit of the model is to first inspect the expected frequencies within each cell. If 80% or more of the cells have the expected frequencies, then the model is sufficient and the goodness of fit test can be run and measured. SPSS generated information that "There are 37 (17.6%) cells (i.e., dependent variable levels by observed combinations of predictor variable values) with zero frequencies.". This 80% level is met, as only 17.6% of the cells have zero frequencies.

In SPSS, there are two goodness-of-fit tests that are run, the Pearson and Deviance tests. The Pearson goodness-of-fit test calculates an overall summary measure of the Pearson residuals, whereas the Deviance test is a difference in fit between a current model and a model that perfectly fits the data. Each test is designed to provide a measure of how poorly the model fits the data, so a non-significant result indicates a good model fit. These results of the Pearson and Deviance goodness-of-fit tests are shown in Table 5-11

Table 5-11: Goodness-of-Fit Test

Goodness-of-Fit

	Chi-Square	df	Sig.
Pearson	137.170	164	.937
Deviance	153.766	164	.705

The Pearson goodness-of-fit test indicates that the model was a good fit to the observed data, $\chi^2(164) = 137.170$, $p = .937$. The Deviance goodness-of-fit test also indicates that the model was a good fit to the observed data, $\chi^2(164) = 153.766$, $p = .705$.

5.5.2 Overall Model Test

Another method to assess model fit is to inspect the change in model fit when comparing the full model to an intercept-only model. The overall model test is a test of the null hypothesis that the location coefficients for all variables in the model are 0. The likelihood-ratio test is presented in Table 5-12 shown below:

Table 5-12: Overall Model Test

Model Fitting Information

Model	-2 Log Likelihood	Chi-Square	df	Sig.
Intercept Only	617.680			
Final	495.887	121.792	10	.000

Link function: Logit.

The final model statistically significantly predicted the dependent variable over and above the intercept-only model, $\chi^2(10) = 121.792$, $p < .001$. Therefore we reject the null hypothesis that the model without predictors is as good as the model with predictors. At least one independent variable is statistically significant and adds to the prediction of the dependent variable.

5.5.3 Parameter Estimates

To determine which of the independent variables have a significant effect on the dependent variable, a factor analysis is done. A factor analysis in Ordinal Regression more specifically gives indications as to which of the breakpoint levels for each attribute have significant effects on the dependent variable of Effectiveness. The results of the factor analysis are shows in the parameters estimates in Table 5-13. The threshold coefficients for the Effectiveness dependent variable are not usually interpreted individually. For the attribute variables, each variable is broken into its associated

categories, which is a representation of a breakpoint. By default, the last category is the reference category for the other categories within that variable. The value in the B column is the parameter estimate, which represents the change in the log odds of being in this category rather than the reference category. In other words, it is a comparison between that category and the reference category. Positive coefficients mean a higher score on the dependent variable compared to the reference category. For example, there is a decrease in the log odds of 1.342 of scoring higher on the dependent variable (i.e. Effectiveness) for Online Accessibility = 1 (Offline Only) compared to Online Accessibility = 3 (Offline and Online Access). Log odds are not naturally intuitive for meaning, so an easier to understand reported change is to inspect the odds ratio. The odds ratio is the exponential of the log odds of the slope coefficient (the value in the Exp(B) column). In the example above, the exponential of -1.342 is $e^{-1.342} = .261$. This means that for Online Accessibility = 1 (Offline Only Only), the odds of scoring higher in Effectiveness is nearly four times *less* likely than that of Online Accessibility = 3 (Offline and Online Access). In easier to understand terms, an expert assessment on a knowledge management solution that only offers Offline Access is four times *less* likely to be rated Effective. The odds ratio of being in a higher category of the dependent variable Effectiveness for Offline Only Access versus Offline and Online Access is 0.261, 95% CI [0.148, 0.462], a statistically significant effect, Wald $\chi 2(1) = 21.251$, $p < .001$. This same analysis methodology can be applied to Online Accessibility = 2 (Online Only) compared to Online Accessibility = 3 (Offline and Online Access). From the table, we can see that the odds of Online Only Access having an impact on expert assessed Effectiveness was similar to that of Offline and Online Access (odds ratio of .761, 95% CI [0.435, 1.333]),

Wald $\chi 2(1) = 0.911$, $p = .340$. As each category is compared to the reference category for the attribute, it is not possible to use the results in Table 5-13 to determine the significance of the reference category.

Table 5-13: Ordinal Regression Parameter Estimates

Parameter Estimates

Parameter		B	Std. Error	95% Wald Confidence Interval		Hypothesis Test			Exp(B)	95% Wald Confidence Interval for Exp(B)	
				Lower	Upper	Wald Chi-Square	df	Sig.		Lower	Upper
Threshold	[Effectiveness=1]	-3.288	.3490	-3.972	-2.604	88.756	1	.000	.037	.019	.074
	[Effectiveness=2]	-1.949	.3147	-2.566	-1.332	38.348	1	.000	.142	.077	.264
	[Effectiveness=3]	-1.084	.3043	-1.680	-.487	12.683	1	.000	.338	.186	.614
	[Effectiveness=4]	-.088	.3003	-.676	.501	.086	1	.770	.916	.508	1.650
	[Effectiveness=5]	.929	.3052	.331	1.527	9.273	1	.002	2.533	1.393	4.606
	[Effectiveness=6]	2.344	.3316	1.694	2.993	49.941	1	.000	10.418	5.439	19.955
[Online_Accessibility=1]		-1.342	.2911	-1.912	-.771	21.251	1	.000	.261	.148	.462
[Online_Accessibility=2]		-.273	.2858	-.833	.287	.911	1	.340	.761	.435	1.333
[Online_Accessibility=3]		0[a]	.	.	.	.	.	.	1	.	.
[Info_Capture_Storage_Formats=1]		-.008	.2844	-.565	.550	.001	1	.979	.992	.568	1.733
[Info_Capture_Storage_Formats=2]		-.151	.2858	-.711	.409	.280	1	.597	.860	.491	1.505
[Info_Capture_Storage_Formats=3]		0[a]	.	.	.	.	.	.	1	.	.
[Time_Info_Entry=1]		.869	.2878	.305	1.433	9.110	1	.003	2.383	1.356	4.190
[Time_Info_Entry=2]		-.289	.2856	-.849	.271	1.023	1	.312	.749	.428	1.311
[Time_Info_Entry=3]		0[a]	.	.	.	.	.	.	1	.	.
[Collaboration_Capability=1]		1.202	.2907	.632	1.771	17.091	1	.000	3.325	1.881	5.878
[Collaboration_Capability=2]		-.195	.2854	-.755	.364	.469	1	.493	.822	.470	1.439
[Collaboration_Capability=3]		0[a]	.	.	.	.	.	.	1	.	.
[Search_Capability=1]		-1.088	.2884	-1.654	-.523	14.246	1	.000	.337	.191	.593
[Search_Capability=2]		-.927	.2879	-1.491	-.362	10.357	1	.001	.396	.225	.696
[Search_Capability=3]		0[a]	.	.	.	.	.	.	1	.	.
[Encryption_Security_Ability=1]		0[a]	.	.	.	.	.	.	1	.	.
[Encryption_Security_Ability=2]		0[a]	.	.	.	.	.	.	1	.	.
[Encryption_Security_Ability=3]		0[a]	.	.	.	.	.	.	1	.	.
(Scale)		1[b]									

Dependent Variable: Effectiveness
Model: (Threshold), Online_Accessibility, Info_Capture_Storage_Formats, Time_Info_Entry, Collaboration_Capability, Search_Capability, Encryption_Security_Ability

a. Set to zero because this parameter is redundant.

b. Fixed at the displayed value.

To do this, the variables were recoded in reserve order of the original breakpoints. Whereas Online Accessibility = 1 would originally indicate Offline Only Access, it would be recoded so Online Accessibility = 1 indicated Online and Offline Accessibility, which was previous assigned to Online Accessibility = 3. As such, Online Accessibility = 3 would then be recoded with the initial value of Online Accessibility = 1, or Offline Only Access. In other words, we are swapping the first and third breakpoint values in the coding to enable the original reference category (Breakpoint value = 3) to be tested for significance. Once the values were recoded, the factor analysis was rerun and the results are shown in Table 5-14. You will notice the names of the variables were altered to indicate these are the swapped breakpoints.

While understanding the proportional differences in preference between the breakpoints is interesting, the main goal of this analysis is to determine holistically which breakpoints in the attributes are significant to an expert when judging the effectiveness of a proposed solution. From doing the original factor analysis and the swapped factor analysis and inspecting the results, it was shown that for the following attributes, all breakpoint levels were significant for the following attributes:

- Online Accessibility (and Software Deployment due to combined attributes)
- Estimated Time of Information Entry
- Collaboration Capability (and Intelligence and Inference)
- Search Capability (and Labeling/Tagging Capability)

Both Information Capture and Storage Formats and Encryption / Security Ability attributes had no significant effect on the dependent variable of Effectiveness.

Table 5-14: Ordinal Regression Parameter Estimates - Swapped Breakpoints

Parameter Estimates

Parameter		B	Std. Error	95% Wald Confidence Interval		Hypothesis Test			Exp(B)	95% Wald Confidence Interval for Exp(B)	
				Lower	Upper	Wald Chi-Square	df	Sig.		Lower	Upper
Threshold	[Effectiveness=1]	-2.920	.9158	-4.715	-1.125	10.169	1	.001	.054	.009	.324
	[Effectiveness=2]	-1.581	.9089	-3.363	.200	3.027	1	.082	.206	.035	1.221
	[Effectiveness=3]	-.716	.9096	-2.499	1.066	.620	1	.431	.489	.082	2.905
	[Effectiveness=4]	.280	.9102	-1.504	2.064	.094	1	.759	1.323	.222	7.874
	[Effectiveness=5]	1.297	.9090	-.485	3.078	2.036	1	.154	3.658	.616	21.723
	[Effectiveness=6]	2.711	.9132	.921	4.501	8.813	1	.003	15.045	2.512	90.100
[Online_Swap=1.00]		1.342	.2911	.771	1.912	21.251	1	.000	3.826	2.163	6.768
[Online_Swap=2.00]		1.069	.3641	.355	1.783	8.621	1	.003	2.912	1.427	5.945
[Online_Swap=3.00]		0[a]	.	.	.	.	.	.	1	.	.
[Info_Swapped=1.00]		.008	.2844	-.550	.565	.001	1	.979	1.008	.577	1.760
[Info_Swapped=2.00]		-.144	.3605	-.850	.563	.159	1	.690	.866	.427	1.756
[Info_Swapped=3.00]		0[a]	.	.	.	.	.	.	1	.	.
[Time_Swapped=1.00]		-.869	.2878	-1.433	-.305	9.110	1	.003	.420	.239	.737
[Time_Swapped=2.00]		-1.157	.3644	-1.872	-.443	10.092	1	.001	.314	.154	.642
[Time_Swapped=3.00]		0[a]	.	.	.	.	.	.	1	.	.
[Collab_Swapped=1.00]		-1.202	.2907	-1.771	-.632	17.091	1	.000	.301	.170	.532
[Collab_Swapped=2.00]		-1.397	.3665	-2.115	-.679	14.529	1	.000	.247	.121	.507
[Collab_Swapped=3.00]		0[a]	.	.	.	.	.	.	1	.	.
[Search_Swapped=1.00]		1.088	.2884	.523	1.654	14.246	1	.000	2.969	1.687	5.226
[Search_Swapped=2.00]		.162	.3607	-.545	.869	.201	1	.654	1.176	.580	2.384
[Search_Swapped=3.00]		0[a]	.	.	.	.	.	.	1	.	.
[Encrypt_Swapped=1.00]		0[a]	.	.	.	.	.	.	1	.	.
[Encrypt_Swapped=2.00]		0[a]	.	.	.	.	.	.	1	.	.
[Encrypt_Swapped=3.00]		0[a]	.	.	.	.	.	.	1	.	.
(Scale)		1[b]									

Dependent Variable: Effectiveness
Model: (Threshold), Online_Swap, Info_Swapped, Time_Swapped, Collab_Swapped, Search_Swapped, Encrypt_Swapped

a. Set to zero because this parameter is redundant.

b. Fixed at the displayed value.

5.6 Technology Review and Assessment Analysis and Results

During the assessment phase of the technology as mentioned previously, each technology was graded and given a "1" for each breakpoint it supported. By considering both the results of the paired comparison and ordinal regression, the following 6 attributes were identified to be the most significant attributes when investigating potential KM technical solutions: Collaboration Capability, Search Capability, Labels and Tagging, Online Activity, Software Deployment and Intelligence and Inference. While Time of Information Entry variable was a significant variable to the regression model, it is very difficult to objectively evaluate that for the technologies. Therefore, the attribute was estimated based on the information and description provided by the product as well as user reviews. Focusing only on the significant attributes and associated breakpoints, a total was found for each potential KM deemed significant, with results in Table 5-15.

Table 5-15: Potential Knowledge Management Solution Tools - Evaluated

		Potential KM Solutions		
Attribute	**Breakpoint**	Bloomfire	Yammer	Evernote
Online	Online and Offline Accessibility	1		1
Software	Installed on Desktop, Mobile and Cloud/Web Based	1	1	1
Intelligence and	Predictive Text and/or Analysis	1	1	1
	Sense-making	1		
Collaboration Capability	In-context feedback (Comments or Message Boards)	1		1
	Share, Comments, Rank feature	1	1	
Labeling / Tagging Capability	None			
	Limited or Predefined Use			
	User defined and/or meta data tagging	1	1	1
Search	Optimized Search	1	1	1
Estimated Time for	15 – 30 min	1	1	1
	< 15 min	1	1	1
	Sum Total	10	7	8

The top 3 technologies of Bloomfire, Evernote, and Yammer were presented to the experts and eight out of the sixteen experts responded, giving a response rate of 50%. At the time the package and questionnaire was sent out, several experts were on travel for work or personal reasons and were unable to respond. A response rate of 50% is acceptable for this analysis. The results of expert response can be seen Table 5-16. The

experts selected Bloomfire for their first choice, Evernote for their second choice, and Yammer for their third choice. These results are consistent with the analysis of the technologies shown in Table 5-15.

Table 5-16: Expert Preference of Technology Solution

Technology	1st Choice	2nd Choice	3rd Choice
Bloomfire	6	2	1
Evernote	3	5	1
Yammer	0	2	7

Examining expert responses gives insight into their preference order. For Bloomfire, experts favored the machine learning algorithm and searchable video capability. For Evernote, experts liked the ability to recognize and search post it notes.

Expert comments on Bloomfire:

"The ability to search videos could dramatically alter the way in which we collect data for the better. Audio and video recordings allow us to capture research interviews holistically, so we remember what was actually said. However, the time it takes to re-watch and/or transcribe those videos prevents it from being a feasible option for thorough analysis – we have to rely on our notes."

"Bloomfire appears to be "a complete thought" in terms of what it offers. A machine learning algorithm that makes independent recommendations based on "contextual similarities". Supports all files types and has a speech recognition capability."

Expert comments on Evernote:

"Handwriting recognition of Evernote is pure gold. Post-it notes are the basic currency of design thinking, so any tool to capture and search handwritten notes is attractive"

"Evernote and Bloomfire are fairly neck-in-neck, but Evernote wins based on the extensive search feature – all words, everywhere"

Expert comments on Yammer:

"I ranked yammer second because of the integration with Microsoft office products and perceived interoperability with other tools that the team uses".

"Yammer seems ok, but lacking the level of capability we'd be looking for."

6 Findings

6.1 Hypothesis Results

The hypothesis for this research effort were:

Null Hypothesis H_0: There is no difference in expert preference between current technology in use and proposed technology for meeting user needs within a KM solution.

Alternative Hypothesis H_a: There is a difference in expert preference between current technology in use and proposed technology for meeting user needs within a KM solution, with experts identifying the necessary requirements in preferred proposed new technology.

The results show the experts do have a preference for proposed new technology, as evidenced by the significant results from this study. The subjective feedback also revealed strong expert preference and need for new technology to support their needs. Expert assessment was able to identify the necessary requirements a new technology solution should have.

6.2 Summary of Analysis

The results of the paired comparison test identified the expert identified rank preferences of the attributes. An ordinal regression analysis was performed with the nine attributes as the predictor variables and with expert determined effectiveness as the dependent variable. From the analysis, it was determined which attributes are statistically significant to the effectiveness of a KM solution. This research successfully identified the six attributes most important to a sample fast paced research team. By taking the results of the ordinal regression analysis to determine which attributes are significant, and

combining that with the preference order results from the paired comparison analysis, the following significant attributes can be ranked by preference:

1. Search Capability
2. Collaboration Capability
3. Labels and Tagging
4. Online Accessibility
5. Estimated Time for Information Entry
6. Software Deployment
7. Intelligence and Inference

Leveraging these results with an assessment of fifteen potential technologies that could meet the needs of the TANG team, the technologies were down selected to three technologies. The three technologies were provided to the experts for inspection, with the expert preferences aligning with the evaluation rank order preferences.

7 Conclusions

7.1 Recommendation of Technology

Bloomfire appears to offer the most features while supporting the identified requirements, and has been recommended to the TANG team for consideration as their KM technology solution. Bloomfire offers the most capabilities and features that match the significant attributes as identified from this effort. Additionally, Bloomfire was the highest rated technology in the KM solution assessment, as well as the technology favored by the experts during the technology review. It also offered the most advanced search of all the technologies, leveraging machine learning that will foster faster finding and accessing of information. The automatic video transcription offers an additional bonus feature, as all the video products produced from a TANG event are recorded and would then become easily searchable for little required work. This additional feature was very appealing to the experts, as evidenced in the comments they provided.

7.2 Impact to Organization

The focus of the TANG and design thinking efforts are specifically oriented towards the development of next generation innovation for the Navy. KM solutions have been shown that they have the potential to capture insights and experiences to make available for future use, increasing ease to find and reuse sources, foster collaboration, and supporting innovation through generating new ideas. If a KM solution was implemented and utilized systemically and methodically by the TANG team, all of these benefits would directly impact the nature of the TANG efforts and could have a tremendous impact to the work. For example, the ability for the entire team to leverage information

and knowledge captured on research trips that only a few individuals went on enables team collaboration and fosters cohesion, enabling the other team members to feel as if they were there and a part of the research trips. This will also aid in the TANG event, as more facilitators will have a deeper understanding of the domain research and problem areas by having all the information available at their fingertips, and not have to rely solely on high level information that is produced during the synthesis process. While this high level information is crucial and forms the backbone of the event, the ability for each facilitator to have a finer and more detailed understanding of the underlying problems areas allows for more detailed and specific prompts and interactions the facilitator can provide at the workshop. This allows for the final concepts that are produced from the TANG event to be richer in detail and more directly connect and address the problem areas identified in the research phase.

In addition to providing increased benefit to the discovery and research phase for the current TANG, a KM solution would also aid in the discovery phases of future TANGs. Having information from previous research easily accessible would provide a valuable on ramp as part of the discovery phase for a future event. The ability to find elements of information from previous research would help augment the thinking and mindset of the future event, and could help frame the How Might We questions used in the event. The ability to search on the people interviewed, the places visited, and any pictures taken of relevant information would serve as a way to utilize previous research for future events. This would lead to both a decrease in time, as well as an increase in collaboration around discussions and interactions. If the information and knowledge within the KM solution

was robust enough, researchers would be able cover more ground by reducing redundant research trips, thus decreasing the time and demand on people and cost resources.

Another impactful benefit the KM solution would have is to help connect information across multiple events in ways that are currently done, but are much more difficult to do with standard practices. This solution could help knit the fabric from project to project, uncovering larger strategic opportunities and insights that might have been missed without these connections. These cross cutting connections are ones that may not have otherwise made, but will lead increases richness of the discussion and provide a better product to the customer and sponsor.

By building a wealth of information for the current and future TANG teams and initiatives to leverage, several key additional benefits would be realized by the organization: increase in responsiveness, increase in cost savings, increase in collaboration facilitation, increased decision making support, increased competitive advantage, and decreasing knowledge loss due to attrition and increase in innovation. The TANG team members have already taken the results of this effort and begun crafting a solution for implementation.

7.3 Future Work

While this research is focused specifically on the TANG team and their needs, the results of this work could apply to other research teams that perform fast paced research. A careful investigation into the needs of a given team would need to be performed, and then compared against the results found in this study. It is recommended that the paired comparison page should be given to other potential teams as a first investigation into how those domain experts view the problem space. If the results are closely aligned with the

results in this document, these results could potentially be leveraged. If the results are disparate, a separate study should be conducted specifically for that team.

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