COMPARISON OF EXPERIENCED AND NOVICE COST ESTIMATORS' BEHAVIORS IN INFORMATION PULL AND PUSH METHODS

Semiha Kiziltas[1], Burcu Akinci[2] and Cleotilde Gonzalez[3]

[1] Dept. of Civil and Environmental Engineering, Carnegie Mellon University, 5000 Forbes Ave., Pittsburgh, 15213; PH (412) 268-3781, FAX (412) 268-7813; email: semiha@cmu.edu (corresponding author)

[2] Dept. of Civil and Environmental Engineering, Carnegie Mellon University, 5000 Forbes Ave., Pittsburgh, 15213; PH (412) 268-2959; FAX (412) 268-7813; email: bakinci@cmu.edu

[3]Dynamic Decision Making Laboratory, Dept. of Social & Decision Sciences, Carnegie Mellon University, 5000 Forbes Ave., Pittsburgh, 15213; PH (412) 268-6242; FAX (412) 268-6938; email: coty@cmu.edu

Word Count: 9300 words (including the abstract, main body, references and figure and table word equivalents)

COMPARISON OF EXPERIENCED AND NOVICE COST ESTIMATORS' BEHAVIORS IN INFORMATION PULL AND PUSH METHODS

Abstract

Construction cost estimators mainly use analogy-based decision making processes while estimating activity production rates in new bids. They need to search information items that will help them in understanding the differences/similarities between the current and previously completed projects to select appropriate production rates and make necessary adjustments. The objective was to understand the effect of information pull/push methods on the behaviors of cost estimators when they refer to information items from historical sources in structuring their decisions. Eleven experienced estimators and eleven novice civil engineering candidates participated in an experiment involving card-games, which simulated the information pull method, and in another experiment involving a prototype system, which simulated the information push method. Results showed that novices can behave like experienced estimators when information relevant to a decision is pushed to them; which has implications for the design of information systems. Results can help improve the estimates of novice estimators by providing them with decision support tools designed with the right information delivery method for their level of experience.

Keywords: construction cost estimating, project histories, historical data, expert-novice comparison, information push and pull, menu-driven information delivery

Introduction

Construction cost estimation, which means estimating the total cost of a project according to the productivity of individual construction activities that form a bid package, is a key task for the survival of construction companies in markets. A company's ability to get new projects depends on the accuracy of their cost estimates. Cost estimating requires analogy-based decision making; hence it requires using and comparing historical projects' data to a current project for estimating activity production rates. Since construction estimating departments are composed of both experienced and novice cost estimators, it is equally important to support the differing information needs of these two groups of estimators, to minimize any inaccuracies occurring due to estimators' biases and differences in experience. Research studies have provided evidence on the importance of understanding the differences between expert and novice decision makers in terms of how many information items they refer to and what types of information items (relevant/irrelevant) they look at in a decision task (Shanteau 1992a, Spence and Brucks 1997, Wilson and Schooler 1991). Such research studies help in defining what types of information items need to be represented in a decision support system. However, existing research studies are rather limited in the area of understanding the method in which information items should be provided to expert and novice decision-makers.

The objective of the present study is to understand the effect of how information is provided to experienced and novice estimators on their decision-making. Studying the behavior of expert and novice estimators when they use different information delivery methods in a decision making task will help design information systems that can be more beneficial to all decision-maker groups. In addition, understanding expert-novice differences in decision-making is essential for supporting their needs for better decisions.

Many research studies have been conducted to understand differences in expert-novice decision making behaviors. Some of the decision domains, within which expert-novice decision-making behaviors were compared, include naval officer's situation assessments (Federico 1995; Randel and Pugh 1996), marketing value assessments (Spence and Brucks 1997), conceptual engineering design (Ball et al.2004), air traffic control (Doane et al. 2004, Hyun et al. 2006), and aviation risk evaluation (Thompson et al. 2004). The study of expert-novice comparison within the architectural, engineering and construction (A/E/C) domain is rather a new area of study. Studying of problem-based learning of construction managers in situational simulation environment and understanding how expert and novice construction managers differ in their knowledge organization, information processing, and risk assessment in dynamic decision environments are examples of such studies within the A/E/C domain (Rojas and Mukherjee 2006, Watkins and Mukherjee 2008).

Within these decision domains, researchers looked at different aspects of expert-novice comparisons, such as problem categorization/ presentation required for defining how a problem can be solved (Chi et al. 1981, Newell and Simon 1972, Schoenfeld and Herrmann 1982), the effects of problem structure as structured, structurable, unstructured when defining a solution for a problem (Reitman 1965, Smith 1988, Spence and Brucks 1997), the effects of decision aids in the behaviors of experts and novices (Mackay and Elam 1992, Spence and Brucks 1997, Wilson and Schooler 1991), the amount of information that experts and novices use (Ettenson et al. 1987, Phelps and Shanteau

1978), and the types of information items that experts and novices use to understand how experts differentiate relevant information from irrelevant ones (Shanteau 1992a).

Understanding expert and novice decision makers' behaviors in information pull and push methods is also important. The effect of information pull vs. information push is well known in production control (Weitzman and Rabinowitz 2003), supply chains (Spearman et al. 1990) and web-based businesses (Cummings 2005). Information pull refers to cases in which decision makers initiate queries for receiving the desired information (Cybenko and Brewington 1998). On the contrary, information push occurs in cases in which information is delivered based on what information is assumed to be needed by decision makers without waiting to get decision makers' request for information (Fan et al. 2005). It is important to understand the implications of information pull vs. push methods within the construction estimating domain, as information systems utilized for supporting cost estimating decisions within the construction domain do not differentiate such delivery methods.

This paper provides findings of a research study conducted to learn the effect of the methods of information delivery to experienced and novice estimators. These effects are assumed in terms of the quantity and content of information items utilized by these groups during an estimating task. The research method includes experiments conducted with a card-game, which simulates the information pull method, and with a prototype system (to be referred in this paper as *tool*), representing a decision-aid tool, which simulates the information push method. Results of the experiments are provided to test two hypotheses that compare the differences between experienced and novice estimators when information is pushed to them or pulled by them.

Overview of the Decision/Task Domain: Construction Cost Estimating

Construction cost estimating is the process of determining how much it will cost to construct the elements specified within the scope of an upcoming project. Activity production rates are estimated while determining the construction costs for new bid submissions. There is evidence for analogy-based decision making in many naturalistic decision tasks (Klein 1998, Shepperd and Schofield 1997, Shepperd et al. 1996). This evidence is also specific to the construction projects. During the production rate estimation process, estimators generally use analogy-based decision-making (Hughes 1996, Rush and Roy 2001). We refer here to analogy-based estimating, the process of utilizing historical data in making new estimations, as also defined by Rush and Roy (2001). This process involves selecting a similar project from past projects that estimators were involved in, and adjusting the selected production rate based on a comparison of similarities and differences between the current project and the previous one. Each project in a construction domain is unique, since its location, its owner, and construction methods used can change from one project to another. Even though similar activities are executed in different construction projects, production rates achieved might be different, since different sets of factors existing in these projects might impact the production rates of activities differently. Hence for decisions regarding activity production rates, estimators need activity-specific contextual data to understand which conditions activity production rates were achieved in past projects (Kiziltas and Akinci, submitted). Using contextual information, they can understand the differences and similarities between the conditions in which upcoming activities are going to be performed and the conditions in which similar past activities got executed. The expertise of an estimator comes into picture in identifying the factors (i.e., information items) affecting the production rates of activities and hence in deciding which contextual information items to look into when estimating the production rate.

Cost estimating accuracy depends on experience (Akinci and Fischer 1998, Flanagan and Stevens 1990, Lowe and Skitmore 1994, Morrison and Stevens 1980a, b, Paek 1993, Park 1966, Skitmore 1989). Historical data are also important to identify similarities and differences of current and past projects in supporting cost estimating decisions (Paek 1993, Touran 1988). Lack of historical data can result in estimators' bias when estimators do not have experience in the particular activities being estimated. When estimators' bias occurs, cost estimates can either result in under budget or over budget, both of which are undesirable and costly in companies (Leung et al. 2007, Skitmore 1989).

In addition, estimating departments of companies are composed of both highly experienced and novice estimators. Both of these groups of estimators leverage historical data, and yet their contextual data needs are likely to be different due to their experiences and their roles during estimating. It is equally important to support those differing needs to minimize any inaccuracies occurring due to estimators' biases.

Construction cost estimating represents a good example of a structurable problem, where a solution to a problem can be obtained when relevant information is provided. Previous studies have shown that structurable problems are the ones where expertise can make a difference as compared to structured problems (Brucks 1985, Smith 1988, Spence and Brucks 1997). However, no particular research has been done for comparing experts and novices in the construction cost estimating domain in terms of the number and type of information items that they use. The goal of this study is to perform tests with both groups to understand how information delivery methods affect their information use.

Research Hypotheses

Literature studies provide different views on how many and what types of information items are needed by experts and novices during decision making. According to some researchers (Brucks 1985, Johnson 1980, Shanteau 1988), the amount of information used in a structurable decision making task, where general problem solving skills are enough to solve the problem, shows the level of expertise and hence experts are expected to use more information than novices. These studies state that experts can acquire information in a less structured environment as compared to novices (Brucks 1985), they are more flexible in searching for information (Johnson 1980), and more consistent in defining what information is important (Shanteau 1988). Especially in analogy-based decision making, experts show context dependent behavior (i.e., using information items to understand the situation before the actions to be taken for a specific goal) as compared to novices, who do not show such behavior (Federico 1993, 1995). Hence, in order to understand the context for a decision making task, experts are expected to ask for more information items.

In contrast, many research studies provided evidence that the amount of information used and expertise cannot be correlated (Shanteau 1992a). Novices use as many information cues as experts do among relevant information cues (Ettenson et al. 1987, Shanteau 1991), and the number of information cues used is relatively small (Hoffman et al. 1968, Reilly and Doherty 1989, Shanteau 1992a). Hence we can hypothesize that the quantity of information items/cues utilized are no different between novices and experts in the context of construction cost estimation.

There are also studies that differentiate expert-novice behaviors in terms of the types of information items/cues used when there are both relevant and irrelevant information cues (Shanteau 1992a). The theories are consistent in this category stating that the relevancy of the information was overlooked and not studied in detail, and that when both relevant and irrelevant information cues are provided to experts and novices, experts are better in selecting and using the relevant ones, due to their expertise (Shanteau 1992a). Hence, in addition to how much information they use, looking at the types of information cues utilized is also an important criterion to be studied; while research shows that novices would not be able to differentiate between relevant and irrelevant information (Shanteau 1992a).

In some studies, problem structure has been considered an important criterion affecting the behavior of both novices and experts (e.g., Brucks 1985, Shanteau and Stewart 1992, Smith 1988). There are three categories introduced by Smith (1988) as structured, unstructured and structurable problems. In a structured problem, where general problem solving skills are enough to solve the problem, experts and novices perform similarly (Brucks 1985, Johnson 1980, Shanteau 1992b). When the problem is inherently ill-structured or unstructured, there is no solution to the problem due to the limited/no reliable method. In ill-structured or unstructured problem solving cases, experts and novices cannot provide reliable performance, and both are subject to bias (Shanteau and Stewart 1992). The clear distinction of the effect of expertise can be observed in a decision problem that is structurable. Structurable problems cannot be solved with general decision making tasks at that time, but need relevant information to be solved. In such cases, experts consistently outperform novices in problem solving (Armstrong 1985, Johnson 1980, Spence and Brucks 1997).

We argue that in addition to the problem structure, it is also important to research the impacts of different information delivery methods, such as, how much information is utilized and the types of information items used in a decision-making process. Information push and pull methods, defined in the previous section, need to be studied for their effects on the type and the number of information items used by experts and novices. The method used for providing an information cue/item affects the behaviors of experts and novices (Spence and Brucks 1997). In this study, we claim that the number and the types of information items/cues used in a structurable decision task differ based on the approach that is used to deliver the information. There are debating views in terms of which information delivery method outperforms in the improvement of end task of the users in the other domains, such as in the domains of production control and planning (Weitzman and Rabinowitz 2003). Research on experts' and novices' behaviors with decision aids (e.g., a document listing important criteria to be considered for a decision task) showed that the performance of novices improves with utilization of decision aids (Spence and Brucks 1997). Novices behave with increased consistency like experts in terms of the number and types of information items used (Spence and Brucks 1997, Wilson and Schooler 1991). Thus, we form our null hypotheses as the followings:

Hypothesis 1 (H_1): *There is no difference between experts and novices in terms of the number and types of information items required in a structurable decision making task, when an information pull method is utilized.*

Hypothesis 2 (H_2): *Novices will behave differently than experts in terms of the number and types of information items/cues used, when an information push method is utilized during a structurable decision making task.*

Research Method

Experimental Design

The objective of the study reported here was to assess how experts and novices behave in cases of information pull and information push delivery methods. For this purpose, we had two experimental treatments for each participant. The effect of the information pull method was measured in the first experimental treatment with a card-game, and the effect of the information push method was measured in the second experimental treatment with a computer tool. There were two dependent variables; the number and types of information items used by experts and novices during the cost estimation process. One of the dependent variables, the number of information items, has been defined as a performance variable, and the other dependent variable, the types of information items, has been defined as a process variable.

Participants

To achieve the stated objective, two groups of estimators were selected for this study, as experienced estimators and novice estimators. We do not call experienced estimators as "experts" since one can be experienced on doing something without being an expert. Experts are expected to exhibit consistently superior performance on representative tasks from the domain. Since, there is no consistently held data in construction companies to define a performance measure for estimators (e.g., success rate on bids, profit history of awarded jobs for each estimator), we used the term "experienced" for the estimators who participated to the study from industry. An experienced person is expected to be well versed with the task domain and to have extended practice to gain more familiarity and knowledge in that domain (Lowe and Skitmore 1994). Participants of the study in the experienced group were professionals, who have been working at estimating departments of construction companies as cost estimators. There were eleven professionals in this group, who participated in the study from two construction companies, specialized in heavy civil and commercial construction projects. Experienced estimators were chosen such that they showed a wide variety of experience levels and had more than 12-years of work experience as cost estimators. Minimum work experience was 12 years and maximum was 35 years. Average work experience of experts was 22.9 years with a median of 24.5 years.

A novice is a beginner and does not have experience in a particular domain; however he/she is not a naïve decision maker, but a potential candidate who can work in the task domain that is considered in a study. Eleven novice estimators participated in this study and they were graduate and senior undergraduate students from Carnegie Mellon University in the Civil and Environmental Engineering program, who had basic knowledge of cost estimating. Minimum work experience for novices was zero years and maximum was 3 years. Average work experience for them was 0.27 years with a median of zero years.

Apparatus

The apparatus for the experiment included a collection of cards as a card-game, and a prototype computer tool. The collection of cards was used to measure the effect of an *information pull* method. Hence, the set of cards used in a card-game represented the aspects with which estimators would compare a current and a past project's activities. Detailed explanations of the card-game are provided in Kiziltas and Akinci (submitted).

The list of aspects to be included in the cards was initially developed from a previous study (Kiziltas and Akinci, submitted), detailing contextual information requirements of estimators for three construction activities. On average, there were 55 cards, corresponding to different information items, and they were grouped based on the category in which an information item would fit, as shown in Figure 1. Information items were grouped to make it easier to search and find the card that contained the information item requested by a participant. The categories of grouping were defined as (1) *Design (D),* which contained information items about the design features (e.g., height, number of openings of a wall) of components on which the activity, provided in the experiment acts on; (2) *Construction-process (CP)* category included information items related to process-characteristics, such as number of workers and equipment sizes utilized to perform an activity; (3) *Construction- site (CS)* category included information items specific to the zone at which an activity is executed and defines zone characteristics, such as site access conditions and soil conditions that play a role on the productivity of that activity; (4) *Project characteristics (P)* constituted project-specific information, such as its size, type, owner, etc. An additional set of cards included information on *production rates* that were achieved in a past project. In both experimental treatments, only relevant information was provided, hence information relevancy was not tested.

Within the design and process related categories of information items, there are information items required for basic production rate calculations, as shown in Figure 1. The information items that are required for basic production rate calculation are termed as “basic” knowledge items. These information items were defined based on standard production rate calculations, as known from any basic production estimation knowledge. Basic production rate calculations require knowing the *quantities* involved in an activity and the *resources* associated with it. Novices with basic knowledge of estimating are expected to pull at least these information items in the first place, and do not use information items that require deep knowledge and experience in estimating. Adjustments on the basic production rate require learning more about other conditions under which production rates were achieved, hence information items in this category are termed as “deep” knowledge items.

The cards were stacked in a box within four categories, where each category of cards was given a separate color. Color coded cards were numbered to enable recording the information items easier.

The second apparatus was a computer tool, which was developed by the authors. This tool provided a structured graphical user environment. This user interface represented a menu-driven interface, a recognition based menu, to reduce information overload as compared to command line interfaces (Paap and Roske 1988). Within this interface, categorized information items could be pushed to the participants when a participant selected a construction activity given in an experiment. This tool explicitly provided (pushed) contextual information items that can be used as dimensions to consider when making adjustments on production rates. Experiments with this system showed the effect of information push for expert-novice decision-making. The same information items that were listed in the card-games were presented to the participants in the tool. The only difference was the method of delivering the contextual information items. This interface represented a particular push technology which does not appear in naturalistic work space of estimators, as such project histories are reached in an ad-hoc manner during bid preparation sessions.

Graphical user interface (GUI) of the prototype incorporated three main parts, as shown in Figure 2. These parts divided the screen horizontally into three sections (a, b and c), and the top section was divided into equal halves with a vertical line (a and b).

The first part (Figure 2a), located on the top-left side of the screen, showed the activities that were within the scope of a past project, and listed these activities in a hierarchical tree structure.

The second part (Figure 2b), located at the top-right side of the screen, showed the 2D/3D view of the components within the scope of that project. This part helped the participants visualize the components that were associated with the selected activities.

The last part, located at the bottom (Figure 2c), showed production rates, one of which is the estimated production rate, associated with a selected activity, and the conditions under which these production rates were achieved. Figure 2c* shows the categories of contextual information items. Depending on the group selected from the drop down menus given in Figure 2c*, information items within the selected group is displayed to users. There are also two sections named as project level and component/zone level production history in Figure 2c*. These sections display the production rate of an activity at project level (i.e., in project level box), and in other levels of details (i.e., in zone/component level box). By looking at the information provided in this part, participants could identify the similarities and differences between the activity given in the task and the one displayed in the graphical user interface.

Procedure

Before the experiment, each participant reviewed a document containing the task description. This task description overviewed the individual tasks required from each participant. Each participant had a 15-20 min. training session, where the purpose of the experimental treatment was explained, the card-game or the tool was introduced.

The duration of both experimental treatments, corresponding to information push and pull methods, were approximately the same, around 1 hour 30 minutes. Participants performed first the information pull experimental treatment and, the information push experimental treatment. The reason for this order was that the second treatment represented a recognition based menu where information items were explicitly pushed to the participants, which would influence the results of information pull treatment if conducted in the first order.

Each participant received the experimental treatment individually. In the experiment, the task given to each participant was to estimate the production rate of an activity for an upcoming project, using the production rates achieved in a similar past project and adjusting the production rates achieved in the past project based on the identified similarities and differences between the current activities and the past ones. Information items used by them would define what aspects of an activity estimators look into when comparing the current activity with the same activities achieved in past projects. The same activity was provided for each treatment.

The first treatment incorporated a card-game, where each participant expected to initiate a request of information items. In the card-game, the contents of the cards were hidden from the participants and represented the information items that an estimator would need during estimating. The estimator's task was to ask for information items one at a time to compare the current and past activities. The person conducting the experiment pulled the cards based on the information item asked and provided the value of the information item to the estimator.

Each cycle of interactions between the participant and the experimenter included the following:

a) The participant requested an information item,
b) The experimenter located the card that contained that information item within the stacks and gave it to the participant. If there was no card associated with a required information item, then the information item was written on an empty card and was provided to the participant,
c) The participant read the information provided on the card, took necessary notes, and placed the card as open on the table to refer to it when necessary later in the game, when s/he is ready to make a decision on the production rate to use,

d) The experimenter recorded the color that represents the category of the card and the card number together on a record sheet, in the order that it was requested by the participant.

Each card-game continued until the participant of that card-game stated that s/he had enough information items to make an accurate adjustment to the past production rate of the activity, and hence estimate the production rate of the upcoming activity.

The experimental treatment with *information push* method included a prototype system (tool), which provided a structured graphical environment, where categorized information items could be pushed to the participants when a participant navigated to the activity given in an experiment. When each experiment started, the data about the experiment had already been loaded to the tool. A computer with 1.2 GHz and 512 MB RAM was used to run the prototype application, as the application did not require excessive memory and speed. Each participant used the tool individually and a cycle of interactions between the participant and the tool included the following:

a) The participant searched within the tree representing the activities executed in the project provided to them for the experiment (Figure 2a), and found the activity stated in the task description,
b) The participant clicked on the activity and highlighted it in the screen,
c) The tool graphically highlighted a set of components associated with that activity on the second part of the GUI,
d) The tool provided the production rates associated with that activity and its estimate at the bottom section of the screen (Figure 2c),

e) The tool displayed the information items, depicting the conditions under which those production rates were achieved, in a drop-down menu placed under four categories,

f) The participant started navigating within the screen and the drop-down menu to start using information items provided, recorded the information items that were selected among the ones that were pushed to them in the order of use,

g) The participant selected a category among the four within the drop-down menu to reach the information items (Figure 2c*),

h) The tool displayed the information items within that category to the user with the corresponding values from the project utilized in the experiments,

i) The participant went over the provided information items and recorded the ones that s/he used.

Each push treatment, utilizing the tool, continued until the participant stated that s/he had enough information items to make an accurate adjustment to the past production rate of the activity, and hence make an estimate of the production rate of the upcoming activity.

Results

Results of the two experimental treatments (i.e., pull and push) were obtained by assessing and analyzing the number and types of information items used by experienced and novice estimators. The results related to each dependent variable for testing of the hypotheses 1 and 2 are provided in the relevant sections below.

Analyses of the Performance Variable for Hypotheses 1 and 2 Testing

The performance variable of this experiment was defined as the number of information items used by the participants. Hypotheses 1 and 2 stated that there was no difference between experienced and novice estimators in terms of the number and types of information items required in a structurable decision making task, when an information pull method is utilized and vice versa when information is pushed to them. The descriptive statistics related to the number of information items used by experienced and novice estimators are provided in Table 1a.

It is evident from Table 1a that expertise is helpful for identifying and pulling the information items that are needed when making adjustments on the past production rates and hence estimating the production rate of an upcoming activity. Table 1a shows that, on average, experienced estimators pulled 23 information items with a standard deviation of three information items. In contrast, novices pulled around 13 information items with a standard deviation of three information items. Experienced estimators outperformed novices in terms of the quantity of information items asked when information is pulled by them. The results are quite contrary to the information use theories on expert and novice comparisons that are widely accepted in the literature. Such a difference in expert and novice behavior has arisen due to the fact that the information delivery method to the participants was not considered during those experiments. This point will be elaborated in the discussion section.

Table 1b shows that experienced estimators used 38 information items among 55 information items that were pushed to them, whereas novices used 36 of them. This result shows that, when information items are pushed to the participants, novices behaved like experts in using information items provided to them, since they asked for a similar number of information items as experienced ones did. The information items asked by novices were 36 items, and the standard deviation was around 14. Experts improved in the number of information items they use, showing a similar consistency in the number of information items used, as shown in standard deviation (~7).

We conducted statistical tests in three groups to support the above given summary findings. First, we looked at the effect of two independent variables (which are expertise and the information delivery method) on the dependent variable individually, and then we looked at the effect of the interaction between the two independent variables on the dependent variable. For the first case, we looked at the effect of expertise on the number of information items asked. We performed sample t-test and two-way analysis of variance (ANOVA) tests between subjects (i.e., comparison between experienced and novice estimators). We looked at the differences between the subjects. The purpose was to see if there is a relationship between the level of expertise and the number of information items used. The null hypothesis was:

$$H_0 : N_{experienced(E)} = N_{novice(N)}$$

According to test results, the null hypothesis, stating that $N_{experienced} = N_{novice}$, is rejected for information pull case. Number of information items asked by experienced and novice estimators are different when information is pulled by the participants, and the results of ANOVA and sample t-test are statistically significant (i.e., expertise has an effect on number of information items used) when an information pull method is used for 95% confidence interval. The p value, which is less than 0.1%, states that there is only 0.1% chance that we would get a difference in the means as large as 10.18 in absolute value, if the difference of means is zero. The difference in the means is unlikely, so the null hypothesis is rejected.

In contrast, for information push, the results demonstrate no significant effect of expertise ($0.05<p<0.575$). Hence, the number of information items used by experienced and novice estimators are close and the null hypothesis, stating that $N_{experienced} = N_{novice}$, is accepted in the case of information push. There is no significant difference in the behavior of experienced and novice estimators in terms of the number of information usage. Both of these results are important to support the effect of information push during decision making.

In our next set of analysis, we studied the relationship between the information delivery method and a participant's response. In order to analyze the statistical significance of the method of providing information items to users (i.e., a comparison within variables, such as behavior of novices in both experimental treatments), we performed repeated measures of ANOVA and paired t-tests. These tests are used when a dependent variable is measured on a group (e.g., novices, experienced) at least two times (i.e., repeated times). In this case, the null hypothesis was:

$$H_0 : N_{tool} = N_{card\text{-}game}$$

According to the test results, the null hypothesis, stating that $N_{tool} = N_{card\text{-}game}$, is rejected with $p < 0.001$. This result means that there is a difference between the number of information items used when information is pushed by a mechanism or pulled by the users. The chance of getting a sample mean difference, as large as 18.36 in absolute value is low ($p<0.1\%$). There is strong evidence that the number of information items in each case is different, hence the null hypothesis is rejected. Finally, we looked at the interaction between the independent variables. The statistical test used was repeated measures of ANOVA for the differences between and within variables. The null hypothesis tested was:

$$H_0 : N_{tool} = N_{card\text{-}game} \text{ regardless of expertise}$$

Given the test results, the p value is quite low, between 0.01 and 0.05. It is reasonable to conclude that the population means are not equal, and there is a statistically significant effect of the information delivery method in the behavior of experts and novices. The mean results that were given in Table 1 also show that experienced and novice estimators' behaviors are different in each information delivery method.

Analyses of the experiments conducted to test hypotheses 1 and 2 demonstrated that, novices behave like experts when a tool, which structures the information items and pushes to the novices, is used. It is because this tool shows the dimensions within which adjustments can be made to production rates, explicitly. As a summary, Hypotheses 1 and 2 stated that there were no differences between experienced and novice estimators in terms of the number of information items required in a structurable decision making task when information items are pulled by them, and they behaved differently when information items are pushed to them. The results obtained from the experiment showed some evidence that this is not the case and Hypothesis 1 and 2 should be rejected.

Analyses of the Process Variable for Hypotheses 1 and 2 Testing

We explored the first ten information items asked during the experimental treatments and summarized the results in Figure 3. The first ten information items show the importance of the items used for the decision makers and also represent a group of information items where more differences between experienced and novice estimators were observed. Figure 3 shows the frequency of referrals by all experienced and novice estimators to information items pulled within each category (i.e., design, construction-method, construction-site, project characteristics). Numbers in each column in the graphs show the number of participants that asked for an information item from a given category. In addition, there are labels represented on the columns in Figure 3. These represent whether the majority of the information items pulled by the users from a category are deep (D), basic (B) or both (B/D). These labels are set based on the definitions given in relation to Figure 1. Categories of information items displayed on each column in Figure 3 without a labeling also represented basic information items, but not shown as a label to keep the figure legible. A production rates category was also considered within the basic groups of information items in the analyses, since they are related to standard production rate calculations, and represent information items that will be requested within the basic group.

Figures 3a and 3c show the behavior of experienced estimators in card-games and in utilizing the tool, in terms of the types of information items asked within the first ten information queries. Similarly, Figures 3b and 3d show the same information for the novice group. Hence, by looking at Figure 3, one can compare the effect of an information delivery method for each group of participants and across groups. The following observations can be made in relation to Figure 3:

In terms of the types of information items pulled in card-games, experienced estimators showed a different trend as compared to novices, as observed from a comparison of Figures 3a and 3b. During the card-games, experienced estimators consistently asked for information items that required both basic (i.e., B) and deep (i.e., D) information items within the first 10 information queries. However, novices pulled information items that were always within the basic group, as shown in Figure 3b.

For the card-games, the number of people requesting information items from each category of information items (e.g., design, construction site) is also different for novice and experienced estimators, given the order of information items asked. For example, as can be seen from Figure 3a, within the first ten information items asked, two novices asked for an information item from the design category, and nine of them asked from the production rate category; whereas five experienced estimators asked for an information item from design category, two from the construction process, three from project characteristics and one from the production rate categories. Hence, the categories of information items, asked by novices and expert estimators, change with the order of information items used.

When an information push method is used (i.e., the tool), novice behavior is quite similar to experienced estimator behavior in terms of the types of information items used in the experiment, as shown in Figures 3c and 3d. This similarity is observed in the number of experienced/novice estimators using information items from a given category, and whether information items used from that category are from basic or deep categories, for any order of the information items used.

When the tool is utilized, experienced estimators still used information items requiring both basic and deep estimating knowledge, however, novices started to use information items that belong to the category of deep estimating knowledge.

When the number of novices asking for an information item from a given category of information items is observed over the order in which they were asked, novices' behavior also resembled experienced estimators'. Again given the Figures 3b and 3d, the number of novices asking information items from a given category increases for all the categories, other than the project characteristics and production rates categories. For example, the number of novices using an information item from the design category is very close to the number of information items used by experts. In addition, the novices' pattern looked similar to the experienced estimators' pattern for the information items asked from order first to order fifth.

The behavior of experienced estimators stayed the same in terms of the types of information items used within the first ten items, as can be observed by comparing Figure 3a and 3c. The number of experienced estimators asking for an information item from a category of information items in a given order in which such information item was used remained consistent. For example, experienced estimators used similar information items used as the eighth order.

Experienced estimators also remained consistent in their information usage when the basic/deep information item distinction is made. As can be observed by comparing Figures 3a and 3c, experienced estimators' behavior is quite similar when information delivery method is changed.

Results provide evidence that, when a tool, that structures contextual information items required for making adjustments on past production rates is used to explicitly present such information items to novices, novices will behave like experienced estimators in terms of the type and quantity of information items that they use. It is expected that this will likely improve the reliability of their estimates; as they will refer to the information items actually impacting production rates. The results shown in Table 1b, and Figures 3c and 3d provided some evidence towards rejecting both hypotheses formed in this research study.

Discussion and Conclusion

This study largely supports the existing theories in decision making of experts and novices, and extends them. Our study has shown that in structurable decision domains, the methods employed for information delivery (i.e., information push vs. pull) make a difference in the behaviors of experts and novices. Benefits of expertise are more obvious when information pull strategies are utilized in companies. Whereas when information push strategies are utilized to support decision making processes, novices behave like experts; hence the benefits of information push are increased considering all groups of estimators in companies.

When an information pull method is utilized to provide information items required during a decision-making process, novices are poor in pulling information items that require deep estimating knowledge, whereas experienced estimators outperform them in pulling those information items. Our study further demonstrated that there is a significant difference between experienced and novice estimators, when an information pull method is used, in terms of quantity and types of information items pulled.

In case of information push, novices behave like experienced estimators in terms of the number and types of information items they used. Differences, which were observed between novices and experts when an information pull method was used, decreased in the case of the information push method; both types of estimators showed quite similar patterns in terms of the number and types of information items asked, especially in design related contextual information. In both information pull and push methods, experienced estimators behaved similarly, and consistent among themselves in terms of the types of information items they use during decision-making.

Given these differences, our findings do not support the views of some previous research studies that concluded that experts and novices utilize the same number of information items (Brucks, 1985; Johnson, 1980; Shanteau, 1992b). Depending on how the information is provided to the decision makers, there is a difference in the number and type of information items utilized in decision making. In the information pull case, experts and novices used different number of information items.

A major implication of this study is relevant to the design of information systems. As provided in Figures 3 and 4, information systems can overcome the effect of experience when designed with an information push method. It is not claimed that novices will become experienced estimators but they will behave close to experienced estimators when they use such tools. Both experienced and novice estimators benefited from using the tool with a more improvement in novice behavior. Other implications of this study include possibility of accelerated learning of novices from historical data provided in a structured environment, and reduction in the number of novice questions towards experts to understand previous projects. This will save time to senior estimators while questioning novice estimators' decisions and while being questioned by novices and will thus has positive impacts in the performance of experienced estimators.

Acknowledgements

The project described in this paper was funded by a grant from the National Science Foundation (NSF), CMS # 0448170 and by the Pennsylvania Infrastructure Technology Alliance (PITA). Both supports are gratefully acknowledged. Any opinions, findings, conclusions or recommendations presented in this paper are those of authors and do not necessarily reflect the views of NSF and PITA. Authors also acknowledge the contribution of Varun Dutt for the GUI implementation of the developed tool.

References

Akinci, B., and Fischer, M. 1998. Factors affecting contractors' risk of cost overburden. Journal of Management in Engineering, **14**(1): 66-77.

Armstrong, J. C. 1985. Long range forecasting: from crystal ball to computer (2nd Ed.). John-Wiley and Sons, New York.

Ball, L.J., Ormerod, T.C., and Morley, N. J. 2004. Spontaneous analogizing in engineering design: a comparative analysis of experts and novices. Design Studies, **25**(5): 495-508.

Brucks, M. 1985. The effects of product class knowledge on information search behavior. Journal of Consumer Research, **12**(1): 1-16.

Chi, M., Feltovich, P., and Glaser, R. 1981. Categorization and representation of physics problems by experts and novices. Cognitive Sciences, **5**(2): 121-152.

Cummings, D. 2005. Push vs. pull: the battle for the best CMS [Electronic version]. Available from sitepoint.com/article/push-pull-best-cms. [cited 7 March 2008].

Cybenko, G., and Brewington, B. 1998. The foundations of information push and pull. *In* Mathematics of information coding, extraction and distribution. *Edited by* D. O'Leary. Verlag: Springer. pp. 9-30.

Doane, S.M., Sohn, Y.W., and Jodlowski, M.T. 2004. Pilot ability to anticipate the consequences of flight actions as a function of expertise. Human Factors, **46**(1): 92-103.

Ettenson, R., Shanteau, J., and Krogstad, J. 1987. Expert judgment: Is more information better? Psychological Reports, **60**(1): 227–238.

Fan, X., Yen, J. and Volz, R. A. 2005. A theoretical framework on proactive information exchange in agent teamwork. Artificial Intelligence, **169**(1): 23-97.

Federico, P. 1993. Expert and novice differences in recognizing similar situations. Human Factors and Ergonomics Society Annual Meeting Proceedings, 37: 915-919.

Federico, P. 1995. Expert and novice recognition of similar situations. Human Factors, **37**(1), 105-122.

Flanagan, R., and Stevens, S. 1990. Risk analysis. *In* Quantity surveying techniques: new directions. *Edited by* P. S. Brando. Oxford University Press, Oxford. pp. 121-138.

Hoffman, P.J., Slovic, P., and Rorer, L.G. 1968. An analysis-of-variance model for the assessment of configural cue utilization in clinical judgment. Psychological Bulletin, **69**(5): 338-349.

Hughes, R. T. 1996. Expert judgment as an estimating method. Information and Software Technology, **38**(2): 67-75.

Hyun, S. H., Kim, K. T., Song, S. M., Yoon, J. S., Lee, J.I., Cho, S. M., and Sohn, Y.W. 2006. Effects of expertise and situation complexity on visual attention and action planning for air traffic control. Human Factors and Ergonomics Society Annual Meeting Proceedings, **50**: 420-423.

Johnson, E.J. 1980. Expertise in admissions judgment. PhD thesis, Department of Psychology, Carnegie Mellon University, Pittsburgh, PA.

Kiziltas, S., and Akinci, B. (submitted). Information needs of cost estimators from past construction projects. Journal of Construction Engineering & Management.

Klein, G. 1998. Sources of power: How people make decisions. Massachusetts Institute of Technology Press, USA.

Leung, M., Skitmore, M., and Chan, Y.S. 2007. Subjective and objective stress in construction cost estimation. Construction Management and Economics, **25**(10): 1063-1075.

Lowe, D., and Skitmore, M. 1994. Experiential learning in cost estimating. Construction Management and Economics, **12**(5): 423-431.

Mackay, J.M., and Elam, J.J. 1992. A comparative study of how experts and novices use of a decision aid to solve problems in complex knowledge domain. Information Systems Research, **3**(2): 150-172.

Morrison, N., and Stevens, S. 1980a. Construction cost database. University of Reading Research Project Report 2, Reading, UK.

Morrison, N., and Stevens, S. 1980b. Cost planning in theory and practice: a construction cost database. Chartered Quantity Surveyor, **2**(June): 313-315.

Newel, A., and Simon, H.A. 1972. Human problem solving. Prentice-Hall Inc., New Jersey.

Paek, J. H. 1993. Common mistakes in construction cost estimation and their lessons. Cost Engineering, **35**(6): 29-33.

Park, W.R. 1966. The strategy of contracting for profit. Prentice-Hall Inc., New Jersey.

Phelps, R. H., and Shanteau, J. 1978. Livestock judges: how much information can an expert use? Organizational Behavior and Human Performance, **21**(2): 209-219.

Randel, J. M., and Pugh, H.L. 1996. Differences in expert and novice situation awareness in naturalistic decision making. International Journal of Human-Computer Studies, **45**(5): 579-597.

Reilly, B. A., and Doherty, M. E. 1989. A note on the assessment of self-insight in judgment research. Organizational Behavior and Human Decision Processes, **44**(1): 123-131.

Rojas, E., and Mukherjee, A. 2006. Multi-Agent framework for general purpose situational simulations in the construction management domain. Journal of Computing in Civil Engineering, **20**(3): 165-176.

Rush, C., and Roy, R. 2001. Expert judgment in cost estimating: modeling the reasoning process. Concurrent Engineering, **9**(4): 271-284.

Schoenfeld, A.H., and Herrmann, D.J. 1982. Problem perception and knowledge structure in expert and novice mathematical problem solvers. Journal of Experimental Psychology: Learning, Memory, & Cognition, **8**(5): 484-494.

Shanteau, J. 1988. Psychological characteristics and strategies of expert decision makers. Acta Psychologica, **68**(1-3): 203-215.

Shanteau, J. 1991. Psychological characteristics and strategies of experts. *In* Expertise and Decision Support. *Edited by* G. Wright and F. Bolger. Plenum Press, New York. pp. 227-249.

Shanteau, J. 1992a. How much information does an expert use? Is it relevant? Acta Psychologica, **81**(1): 75-86.

Shanteau, J. 1992b. Competence in experts: The role of task characteristics. Organizational Behavior & Human Decision Processes, **53**(2): 252-266.

Shanteau, J., and Stewart, T. R. 1992. Why study expert decision making? Some historical perspectives and comments. Organizational Behavior & Human Decision Processes, **53**(1): 95-106.

Shepperd, M., and Schofield, C. 1997. Estimating software project effort using analogies. IEEE Transactions on Software Engineering, **23**(12): 736–743.

Shepperd M., Schofield, C., and Kitchenham, B. 1996. Effort estimation using analogy. Proceedings of the 18th International Conference on Software Engineering, Berlin, Germany, 25-29March 1996. Berlin, pp.170-178.

Skitmore, R.M. 1989. Contract bidding in construction: strategic management and modeling. Longman Scientific and Technical, Harlow, Essex.

Smith, F.G. 1988. Towards a heuristics theory of problem structuring. Management Science, **32**(12): 1489-1506.

Spearman, M. L., Woodruff, D. L. and Hopp, W.J. 1990. CONWIP: A pull alternative to Kanban. International Journal of Production Research, **28**(5): 879-894.

Spence, M.T., and Brucks, M. 1997. The moderating effects of problem characteristics on experts' and novices' judgments. Journal of Marketing Research, **34**(2): 233-247.

Thompson, M.E., Onkal, D., Avcioglu, A., and Goodwin, P. 2004. Aviation risk perception: a comparison between experts and novices. Risk Analysis, **24**(6): 1585-1595.

Touran, A. 1988. Concrete formwork: constructability and difficulties. Civil Engineering Practice, **3**(2): 81-88.

Watkins, M. T. and Mukherjee, A. 2008. Using adaptive simulations to develop cognitive Situational models of human decision-making" Technology, Instruction, Cognition and Learning. **6**(3): forthcoming.

Weitzman, R., and Rabinowitz, G. 2003. Sensitivity of 'Push' and 'Pull' strategies to information updating rate. International Journal of Production Research, **41**(9), 2057–2074.

Wilson, T. D., and Schooler, J. W. 1991. Thinking too much: Introspection can reduce the quality of preferences and decisions. Journal of Personality and Social Psychology, **60**(2): 181-192.

Table 1. Descriptive statistics showing the number of information items asked/used by experts and novices in both experimental treatments

	Table 1a		**Table 1b**	
	Info Pull (Card-game)		**Info Push (Tool)**	
	Mean (Median)	*Std**	*Mean (Median)*	*Std**
Expert	23 (23)	2.7	38 (41)	7.4
Novice	13 (13)	3.4	36 (30)	14

*Std: standard deviation, values are rounded to the nearest number

Figures

Figure 1. A set of example information items within each category of information items

Figure 2. A screen dump from the prototype showing the basic GUI

Figure 3. Types of information items used by novices and experts in both information push and information pull methods

Figure 3a. Information pull(card-game) **–expert** behavior for types of information items pulled

Figure 3b. Information pull (card-game) **– novice** behaviors for types of information items pulled

Figure 3c. Information push (tool) **–expert** behavior for types of information items used

Figure 3d. Information push (tool) **– novice** behaviors for types of information items used