QUANTITATIVE ASSESSMENT OF WEB-BASED CONSTRUCTION MANAGEMENT SYSTEMS: APPLICATION IN REBAR DESIGN AND ESTIMATION

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SUMMARY: *Web-based systems for construction-related tasks do not always simultaneously reflect the expectations of their developers and users. There is no consistent methodology to measure the level of agreement between the user's expectation and the actual performance of a given web-based systems. To illustrate this, the differences in perception are assessed with respect to a system aimed at expediting the approval process of reinforcing steel bars. The expectations and the performance of the system are analyzed based on data obtained from structural designers, contractors and rebar suppliers. The paper shows how to specify the relationship between perception and actual performance of the system developed by the authors for the approval process of reinforcing steel design and estimation. Using quantitative methods, these relationships will be categorized with respect to the type of organization, prevailing type of construction and use of CAD components extracted from historical designs of similar structures. The difference in expectation and satisfaction from the performance of the system is analyzed and its potential impact on system's re-design is elaborated.*

KEYWORDS: *B2B, e-Work, reinforcing steel, CAD, user satisfaction*

1. INTRODUCTION

The construction industry worldwide is gradually adopting web-based project management tools. These tools are aimed at improving routine tasks in scheduling, estimating, project control and related activities. There is currently no consensus in regard to the motivation that has guided the architecture, engineering and construction (AEC) community to follow these trends. One explanation is that construction professionals are becoming more acutely aware of their own inefficiencies in the communication processes related to projects, and thus attempting to streamline their communication environment. The second explanation is that this is simply an effort to follow successful application cases already adopted by other branches of industry. Either way, the design and adoption of web-based management systems intended to improve construction-related tasks are not simultaneously reflective of needs and immediate expectations of systems developers and their construction industry users. Furthermore, there is no consistent methodology to reflect consensus between the expectations and actual performance for newly developed web-based systems. Even though software developers include solution tools for a variety of construction problems, users adopt them without prior assessment of their own real needs, and are often not even questioned about the performance of the system with relation to their initial expectations. It can become deceiving when a software system developer focuses on the needs of only one project participant, overlooking the others. The effect of IT and B2B tools for the improvement of the reinforcing steel (rebar) design and estimation workflow has not been considered in previous research, and is the focus of this paper.

To illustrate this problem, a web-based system called *B2B e-Work Intranet System* was developed for improving the approval process of rebar design and estimation for a reinforced concrete structure. The system was designed following basic material management protocols, including general requirements expressed by the main participants in the supply chain of rebar: contractor, supplier and designer [Castro-Lacouture, 2003]. This system was tested by sixty-five project stakeholders. Their expectations before testing the software were compared with their later perceptions of software performance.

The purpose of this paper is to describe the relationships between perceptions of expectation and performance of a web-based system for the approval process of rebar design and estimation, and to categorize these relationships in accordance with the type of organization, prevailing type of construction and use of CAD components extracted from previous design of structural drawings. The differences in expectation and satisfaction for the performance of the proposed web-based system are analyzed, as well as their impact on the system's re-design.

2. BACKGROUND

With the intention of facilitating information exchange on the Internet, several initiatives have been developed for the procurement of construction materials, thus aiming to bridge the design and procurement stages by connecting data on building components from design drawings with components from supplier's catalogues [eConstruct, 2003], [International Alliance for Interoperability, 2003]. This exchange of information is possible due to the existence of standards and specifications, and can help ensure the interoperability of applications developed for the web. Commercial software developers have taken advantage of these standards to develop their own standard tag definitions for building products. Ultimately, material vendors will understand data within the design documents, and two or more companies using different software systems will be able to exchange project data [Ross, 1999]. These and other similar technologies promise the creation of a harmonized solution to the communication gaps common in construction companies. However, the investment in information technology should be preceded by a prior assessment of potential stakeholders' satisfaction and expectations. Such an assessment can lead to assigning a specific value to the proposed system beyond the traditional cost/benefit impact [Klein & Jiang, 2001]. The success or failure of the technologies relies on performance indicators not readily available from construction practitioners; even the measures typically used to indicate potential success are inadequate. Different stakeholders involved in the deployment of an e-Business alternative for the exchange of construction data perceive technology performance criteria differently. Furthermore, projects determined as failures by an end user's organization are not necessarily viewed as failures by information systems professionals [Linberg, 1999], [Jiang et al, 2001]. It is necessary to focus on the expectations of construction stakeholders regarding the performance of the web-based solution to be adopted, as well as the satisfaction once the system is rendered and deployed in a typical business process. This way both groups of stakeholders and information system professionals will take full advantage of the technical capabilities of information exchange and protocols in the business process. The aim of these initiatives is clear, while the metrics used to gauge their success are still constrained to the network size of members willing to adopt the standards. Industry Foundation Classes (IFC) have been developed in order to support not only the individual requirements of software developers, architects, materials providers or contractors, but to also facilitate multi-discipline decision making across the different stages of a construction project. This approach allows the integrated representation of design and as-built models, thus minimizing the computational efforts associated with checking one model with the other to assess as-built conditions [Akinci & Boukamp, 2002].

There are still shortcomings in the way these standard developers and firms are considering the expectations of the upcoming web-based technologies. It is possible to design those communication technologies considering the needs of the stakeholders that are eventually going to use them, not just the needs of software developers and the elite group of construction firms willing to invest resources on research. The sole intention of exchanging standardized information can be achieved by a database management system (DBMS) based on relational models, considering attribute characteristics and design considerations as the providers of insights about the most important features that determine their value [Post & Kagan, 2001]. However this is not the main use that aecXML or bcXML aim for their next generation of construction industry Internet applications. Furthermore, the method used to measure the success of the web-based solution has to be linked to the expectations from the stakeholders. Each stakeholder may have their own perspectives as to which measures most reflect the success of a system [Jiang et al, 2002]. Each group of stakeholders has a different set of expectations and may judge the proposed system a success or failure on an entirely different set of criteria. If these expectations are studied before the prototype system is put in place and the satisfaction is measured based on the same set of indicators, it is likely that these metrics reflect the assessment of the stakeholders as a whole therefore less modifications have to be made to the system without affecting other stakeholders' interests.

The implementation of user satisfaction scales based on a previous understanding and agreement on the metrics used to evaluate an information system has been present in research for many years, although mainly for research purposes [Klein & Jiang, 2001], [Kettinger & Lee, 1999]. In relation to the service quality measurement of web-based information systems and electronic commerce, research has proven that differences in expectations and perceptions on service quality lead to modifications of web-based attributes and dimensions [Li et al, 2002], [Sullivan & Walstrom, 2001], [Tan et al, 2003]. The construction industry needs a methodology that supports the development of information systems in order to ensure that the product moves toward the collectively understood objectives. The approach adopted in this paper builds upon previous efforts related to the assessment of IT and its effects on construction management performance. In particular, significant previous research in this area is related to monitoring long term IT-induced value using balance scorecards and statistical tools [Stewart & Mohamed, 2003], [Stewart & Mohamed, 2004, Marsh & Flanagan, 2000]. Also, important initiatives are related to the evaluation of web-enabled project management tools for the improvement of quality, competitiveness and profitability by government, industry and clients, and the evaluation of process model applications in estimating and valuation [Alshawi & Ingirige, 2003], [Underwood & Alshawi, 1997].

With the outcomes of this paper, information system professionals will be aware of the construction industry needs, not as a general entity but as a composition of stakeholders' perceptions for expectation and satisfaction, as it pertains to the process of rebar design and estimating. Furthermore, the role of the proposed web-based system will have adequate means to verify its validity before deployment. Quantitative methods such as the User Information Satisfaction [Remenyi & Money, 2000], complemented with statistical tools, will help forecast the hypothetical performance of the proposed web-based solution based on expectation indicators.

3. B2B E-WORK SYSTEM

Presently, the traditional rebar approval process in a construction project follows a linear sequence. During design phase, engineers complete working drawings that comprise rebar information such as location, diameter, quantities, spacing and length, mainly with the assistance of computer-aided design (CAD) tools. This engineer's estimate is utilized by contractors to prepare their own bid estimates. However, contractors must rely on rebar suppliers to prepare the final take-off and pricing of rebar quantities. Rebar suppliers render these quantities in the form of shop or placing drawings that are prepared from photocopies or notes taken from the working drawings, and are commonly paper-based or created from scratch using a separate CAD file. These placing drawings govern the installation and assembly of rebar in the construction project. For that effect, the quantities have to be thoroughly checked by both designer and contractor for structural and constructability consistence. The linear character of traditional rebar approvals, in addition to the use of different formats for the preparation of working and placing drawings, make this overall process error-prone and subject to delays and conflicts among project participants.

A B2B e-Work system has been developed in order to bridge the existing communication gaps during the reinforcing steel (rebar) approval process among project participants [Castro-Lacouture, 2003]. The goal of the applied B2B e-Work system is to integrate the links in the supply interactions of rebar and help achieve a sustained information exchange in the construction process. This concept entitles the design and implementation of an information sharing mechanism between participants of a traditional construction project that incorporates rebar for its structural arrangement. The main focus is to achieve a collaborative environment in order to complete the estimation, revision, procurement and assembly of rebar in an effective and efficient manner. Fig. 1 shows the task structure for the B2B e-Work system.

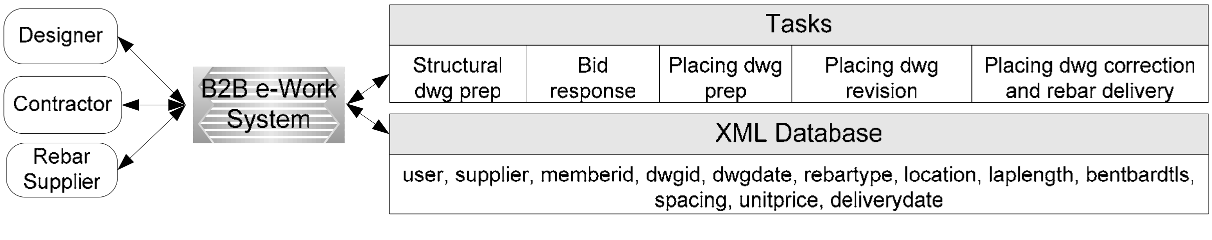

FIG. 1: Task Structure of the B2B e-Work System

The proposed system respects the sequencing of events that take place in the approval process of rebar, while expediting the revision and marking of possible errors in the placing drawings. These events are tied to tasks that represent the interactions among designer, contractor and rebar supplier. A complete description of tasks, events and database components is included elsewhere [Castro-Lacouture, 2003], [Castro-Lacouture & Skibniewsi, 2002]. For instance, in the last task the contractor and the designer download the placement drawing from the B2B e-Work system and proceed to make corrections. This downloading progression may take place simultaneously or asynchronously since the placement drawings are available in the system after having been uploaded by the rebar supplier. The rebar database can also be checked for discrepancies between the initial design and the proposed rebar layout with bent bars, detailing and overlaps. This information can be verified with the drawings, and project forums serve as communication tools to track comments or changes. The physical descriptions of the rebar, representations in the overall structural design, depictions of constructability issues, logistics details, purchasing and delivery facts and conditions are stored in an XML database file. The XML standard itself allows tag definitions to be transmitted with documents if necessary. The flexibility of XML and its authentic e-Commerce functionalities contributed to consider XML as the main source of data interchange.

4. ASSESSMENT OF THE B2B E-WORK SYSTEM

The assessment of the B2B e-Work system is based on responses to questionnaires sent to potential users of the system, such as design firms, contractors and rebar suppliers. Several statistical experiments are intended to study the behaviour of the responses in terms of several criteria. First, respondents are arranged based on the type of organization (e.g. designer, contractor or rebar supplier), prevailing type of construction (e.g. residential, commercial or industrial), and whether CAD electronic information is reused from the structural drawings during the preparation of the placing drawings. Secondly, respondents are asked to assess their expectations regarding the implementation of an Internet- based software that may help the communication, sharing and exchange of information among designers, contractors and rebar suppliers during the rebar design, bidding, award, estimation, and revision of shop/placing drawings. The respondents are provided with the IP (Internet Protocol) address of the B2B e-Work system, in order to complete the assessment of the performance. With the purpose of facilitating the data comparison between expectations and performance of the B2B e-Work system, the assessment is based on ten attributes that are intended to encompass both technical and functional characteristics of such system. A detailed description of attributes is included in Table 1. The questionnaire also comprises an overall system assessment, in which the respondents establish their impression of the B2B e-Work system once they answered the questions for the performance of the individual attributes.

TABLE 1. Description of Attributes Utilized in System Assessment

Attribute Number	Description
1	System’s response time
2	Flexibility of the system to produce desired rebar queries
3	Ability of the system to improve personal productivity
4	Help conflict resolution with contractor / designer / detailer
5	Standardization of rebar shapes / schedules
6	Ability to exchange / share rebar information
7	Expedite revision and correction of placing drawings
8	Ability to reduce total rebar workflow duration
9	Use e-Commerce platform for procurement of rebar
10	Overall cost-effectiveness of the information system

The questionnaire addresses the reduction in duration of different activities in the rebar workflow. These activities are related to the design and revision of structural drawings by designer and contractor, rebar bidding and awarding process, preparation of placing drawings by rebar supplier and revision and approval of placing drawings by contractor and designer. In order to compare the performance of the proposed B2B solution with the existing practices, a methodology based on the User Information Satisfaction (UIS) is utilized for the assessment of the proposed B2B solution. Statistical tools will be implemented to test and validate several hypothesis concerning the performance and value of the proposed solution vs. existing practices, and to assess the satisfaction of the expectations from respondents regarding the scope of the proposed B2B e-Work solution. These statistical tools consist of tests of hypothesis comparing means of the two processes with different variance values. Also, a matrix of correlation factors, Pearson moments, will be used to reflect the degree of lineal dependence between sets of data corresponding to the responses to expectations and performance, in order to trace tendencies and relationships among them. This statistical study, alongside the UIS analysis, will yield concrete results about the validation of the proposed system. As stated in the objectives set for this paper, the relationship between expectations and satisfaction for the B2B e-Work system will be established, categorizing this relationship in accordance with the type of firm (e.g. designer, contractor or rebar supplier), prevailing type of construction (e.g. residential, commercial or industrial) and use of CAD components extracted from previous design of structural drawings.

5. QUESTIONNAIRE DATA

The questionnaire was sent to designers, contractors and rebar suppliers in the United States. A total of 65 responses were received, in which 21 were designers, 24 contractors and 20 rebar suppliers. The distribution of responses based on the type of firm was very satisfactory, presenting a fair apportionment for analysis. The summary statistics for the 65 responses is shown in Table 2.

TABLE 2. Summary Statistics for UIS Questionnaire. n=65

Attr.	Expectation		Performance	
	Mean	Std. Dev.	Mean	Std. Dev.
1	3.32	0.64	2.74	0.64
2	3.12	0.63	3.43	0.61
3	3.43	0.59	3.32	0.62
4	3.25	0.69	3.65	0.51
5	3.18	0.90	3.25	0.59
6	2.91	0.84	3.55	0.50
7	3.40	0.68	3.48	0.53
8	2.97	0.68	3.34	0.57
9	2.23	0.68	3.31	0.50
10	3.29	0.52	3.58	0.53

The arrangement of responses based on type of organization, prevailing type of construction and reutilization of CAD information yielded the results shown in Table 3.

TABLE 3. Summary Statistics of Responses. n=65

Criteria	Frequency of Responses		
Organization	Designer	Contractor	Supplier
	21	24	20
Project Type	Residential	Commercial	Industrial /Heavy
	2	30	35
Reuse CAD	No	Yes	
	34	31	

Two responses had a combined prevailing type of construction, including both residential and industrial/heavy construction. Therefore the total number of responses is equal to 65. Mean and standard deviation values are calculated based on the equivalent numeric value of the category. For instance, commercial construction is equal to 1, while industrial/heavy is equal to 2. Similarly, the fact that the respondent is reusing or not CAD information is represented by 1 or 0 respectively.

6. USER INFORMATION SATISFACTION (UIS)

Traditional cost-benefit analysis may overlook intangible benefits provided by IT solutions [Remenyi & Money, 2000]. User satisfaction is the result of a comparison of user expectations of the information technology with the perceived performance or capability of the proposed solution. This is a holistic approach to systems effectiveness as it addresses the whole information technology rather than individual systems. Overall attitude to the information technology solution is influenced by the size and direction of the discrepancies or gaps between expectations and performance. A gap results when the perceived performance is different from the expectation. UIS is measured by the discrepancy between the user's perception score of the information system performance and the user's expectation score. The outcome in the measurement of differences between expectation and satisfaction will be complemented with tests of hypothesis in order to investigate the statistical validity of the comparisons.

The questionnaire is targeted to designers, contractors and rebar suppliers who have experience with rebar or have been exposed to the business of rebar design or estimation. Feedback from these parties involved in the most critical stages of rebar workflow is needed to assess the acceptance and applicability of the proposed solution from an external perspective. For the case of the rebar B2B solution, the expectation of practitioners is geared toward improvements to their existing practices. The ten attributes described in Table 1 address the features of the rebar B2B solution with respect to solving needs and limitations of existing practices of rebar design, estimation, revision and procurement prior fabrication and assembly. The questionnaire is divided into four parts. The first part collects information about the respondent, type of firm, specialty, experience and reuse of CAD components in placing drawings. The second part assesses the importance of ten attributes in ensuring the effectiveness of the information system. At this stage, the respondent has not seen the proposed solution yet. The third part uses the same attributes to evaluate the actual performance of the rebar B2B system. Finally, the fourth part collects the opinion of the user regarding the overall performance and value of the rebar B2B system, as well as perceived reductions in durations of critical stages of the workflow.

7. QUESTIONNNAIRE RESULTS

An analysis of the expectation and performance perceptions was initially carried out for the complete sample of 65 responses. TABLE 2 described the summary statistics for these data. The gap score is calculated by subtracting the expectation score from the performance score. It is intended to visualize the capability of the proposed B2B e-Work system to satisfy the expectations of the potential users regarding functionality and scope.

A negative gap means that the value of performance is lower than the value for expectation; therefore there is a perception of insufficiency in the performance of the proposed system with regards to the assessment of that particular attribute. On the other hand, a positive gap may indicate that the performance of the B2B e-Work system exceeds the expectations thus representing a positive benefit in the assessment of that particular attribute, but at the same time it may suggest a waste of resources when potential users do not expect such capabilities or changes in the scope of the system. The latter situation is considered when the gap exceeds a value of 1, or when the average value for expectation is surpassed by the average value satisfaction in more than one assessment unit.

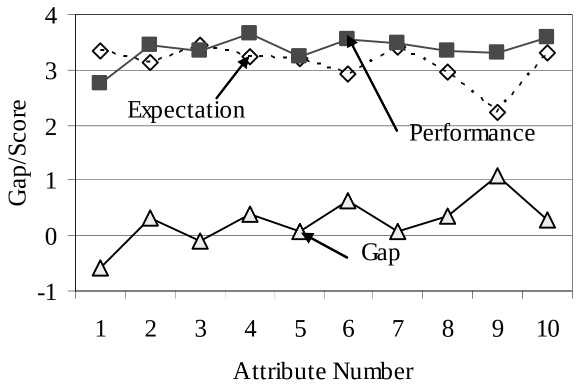

FIG. 2:UIS Diagram for All Responses. n=65.

Fig.. 2 presents a positive trend in the gap values for the sample of 65 respondents. With the exception of attributes 6 and 9, the gap absolute values are smaller than 0.50. This means a close development between the expectation and satisfaction trends. Attribute 6 (ability to exchange or share rebar information) and attribute 9 (use of e-Commerce platform for the procurement of rebar) have positive gap values of 0.65 and 1.08 respectively, meaning that respondents did not expect this feature in the proposed system, but it indeed satisfied their expectations. The fact that the gap is large may be due to the fact that potential users do not consider this feature as determinant to the improvement to the rebar workflow. These results will contribute to conclusions with regard to the factors that affect the design and performance of the proposed B2B e-Work solution for rebar design and estimation. In the latter case, this result is explained by the reluctance of some potential users to carry out procurement operations using the Internet as an enabler of e-Commerce. In the former case, the difference in values of expectation and satisfaction occurred because potential users did not expect the capability encountered in the B2B e-Work system. Respondents assessed their expectation values prior to accessing the B2B e-Work system, whose IP (Internet Protocol) address was provided upon completion of the expectation questionnaire.

There are cases of significant negative gaps, such as attribute 9 (gap value of –0.52). The way it should be interpreted is by acknowledging a deficiency in the B2B e–Work system's functionality or capabilities. This is closely tied to the Internet connection speed. Consequently it is an attribute that, although is very critical for the successful performance of a solution of these characteristics, can have a relatively simple way of enhancement using a faster connection speed.

Fig. 2 provides a description of the feedback from respondents regarding their perceptions on the expectations and satisfaction before and after assessing the B2B e-Work solution. Nevertheless, in order to comprehend the nature of the responses' trends as well as the relationships between the respondents' characteristics and their perceptions on the B2B e-Work solution, a more detailed analysis is carried out. These analyses consist of an investigation of the UIS method categorizing the responses based on type of firm, prevailing type of construction and reuse of CAD components for preparation of placing drawings.

7. 1 Type of Firm

Fig. 3, 4 and 5 illustrate the UIS diagrams for designers, contractors and rebar suppliers, respectively. As explained before, the number of responses for each category is almost a third of the total number of responses (n=65), thus ensuring a fair apportionment for analysis.

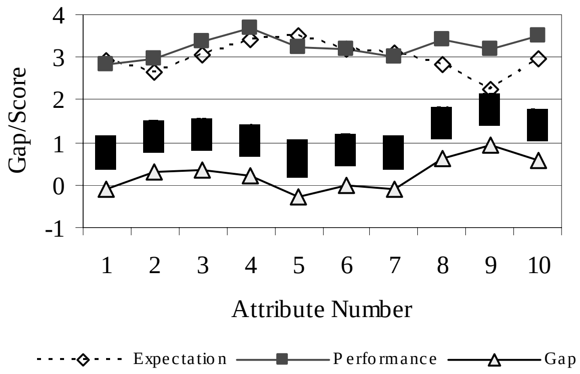

FIG. 3: UIS Diagram for Design Firms. n=21.

Fig. 3 features a close behaviour in expectation and satisfaction scores, with the exception of attributes 3, 8, 9 and 10. Attribute 3 (ability to improve personal productivity) reveals an interesting issue, in which designers give credit to the B2B e-Work system as an enabler of personal productivity, beyond expectations. For the case of attributes 8 (ability to reduce total rebar workflow duration), 9 (use e-Commerce platform for procurement of rebar) and 10 (overall cost-effectiveness of the information system), the performance of the proposed solution far exceeds the expectations.

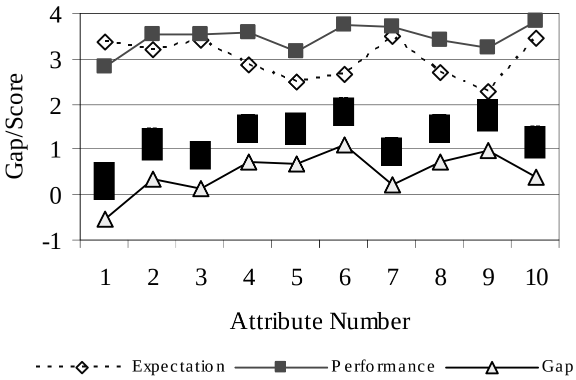

FIG. 4: UIS Diagram for Contractors. n=24.

In Fig. 4, the results for expectation and satisfaction show more divergence. It is explained by the low expectation scores given, in conjunction with the great level of satisfaction for almost every attribute. The small gap for attribute 10 (overall cost-effectiveness of the information system) plus its high expectation value, indicates that contractors expect and appreciate a cost-effective system.

The B2B e-Work solution was designed under those guidelines and that seems to be acknowledged by contractors. Other factors that are worth to look at are the recurrent big gaps in several attributes. This is explained by the considerable benefits offered by the B2B e-Work solution that were not expected by contractors prior to filling out the questionnaire. Also, the average value for expectations (3.00) is similar to the one obtained from designers (2.99). The difference lies in the higher average for satisfaction values by contractors (3.46) in opposition to the value by designers (3.24).

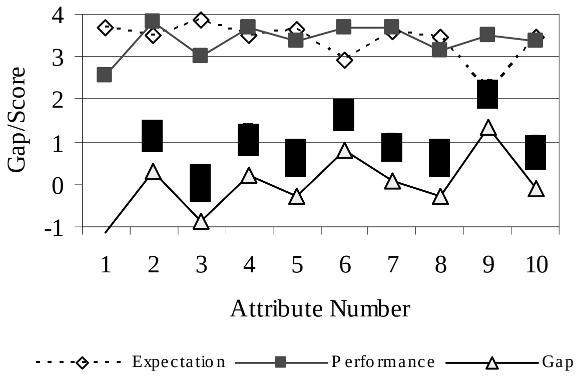

FIG. 5: UIS Diagram for Rebar Suppliers. n=20.

The assessment produced by rebar suppliers, shown in Fig. 5, draws some interesting results. There is a negative gap in attribute 1 (system's response time), 3 (ability to improve personal productivity), 5 (standardization of rebar shapes) and 8 (ability to reduce total rebar workflow duration). However, there are also significant positive gaps in attributes 6 (ability to exchange/share rebar information) and 9 (use e-Commerce platform for procurement of rebar). The fact that rebar suppliers acknowledge as an strength of the system the ability to access external databases and to distribute rebar information makes it possible for the system to attenuate the more general effects represented in the negative gaps described earlier.

7.2 Prevailing Type of Construction

The questionnaire contains three choices of prevailing construction type for the respondents to select from. These choices are residential, commercial and heavy construction. From the total number of respondents, only three of them stated their non-exclusive involvement with residential construction, while the vast majority of firms were solely involved with commercial or heavy construction.

There are a total of 30 responses from firms that have commercial as the prevailing type of construction, whereas 35 responses stated that heavy is the prevailing type. Since the percentage of responses that included residential construction is very small (4%), it was decided to carry out the study using values for commercial and heavy construction. It is expected to draw interesting conclusions from the two categories, aiming to find discrepancies or analogies in the way they perceive improvements in the rebar workflow.

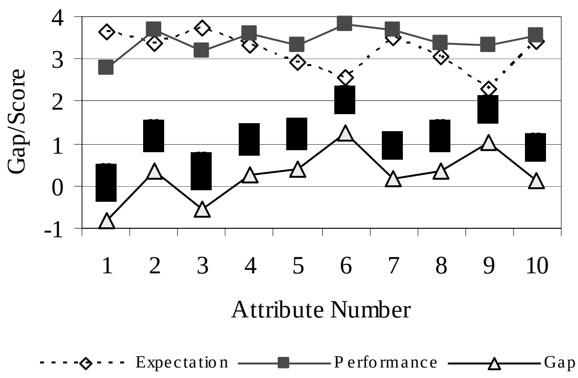

FIG. 6: UIS Diagram for Commercial Construction. n=30.

Fig. 6 shows the recurring trend of positive gaps at the ends and negative at the centre. For respondents that selected commercial construction, attributes 1 and 3 display considerable negative gaps that will be compared with their counterpart of industrial/heavy construction in order to determine differences or similarities in perception.

There is also a perceived lack of ability from the proposed system to help improve personal productivity. The assessment of attribute 9 (use e-Commerce platform for procurement of rebar) reveals very low expectation values (average below 2.50) whilst their satisfaction values exceed an average of 3.40.

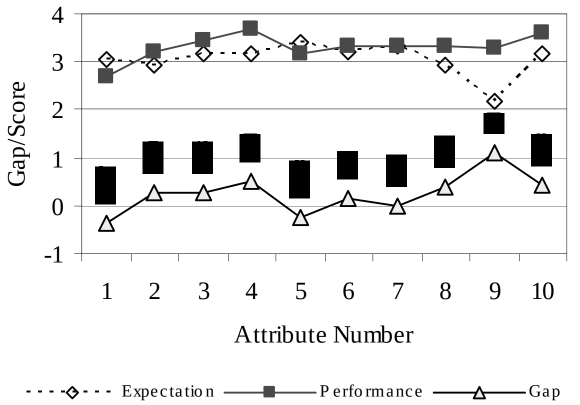

FIG. 7: UIS Diagram for Industrial/Heavy Construction. n=35.

The first seven attributes in the assessment of industrial/heavy construction, shown in Fig. 7, display narrower gaps that imply better satisfaction fitness, as opposed to commercial construction. In spite of having a lower mean for satisfaction values up to this point (3.30 vs. 3.44 for commercial construction), the expectation mean value is also lower (3.05 vs. 3.18).

Rather than having large negative gaps, industrial/heavy construction respondents set their satisfaction values very close to their expectation ones, albeit low. Attributes 2 (flexibility of the system to produce desired rebar queries), 3 (ability of the system to improve personal productivity) and 4 (help conflict resolution with contractor/designer/detailer) present a steady positive gap that demonstrates the suitability of the proposed system to the demands of the potential users in the industrial/heavy sector.

Once again, the evaluation of attributes 5 (standardization of rebar shapes/schedules), 6 (ability to exchange and share rebar information) and 7 (expedite revision and correction of placing drawings) based on the close encounter between expectation and satisfaction values, establish the suitability of the B2B e-work solution to the rebar workflow concerns. The three remaining attributes display a similar behaviour than for commercial construction, thus achieving high positive gaps, product of the perceived good performance of the proposed solution over the lower expectation from the respondents.

7.3 Reusing CAD Elements in Placing Drawings

The questionnaire also intended to determine the extent to which designers, contractors and rebar suppliers reuse CAD elements or components created during the design of structural drawings, in order to implement them in the assembly of placing drawings and rebar schedules. This will contribute to get an idea of the percentage of firms that reuse CAD components, thus targeting the purpose of the B2B e-Work system. Also, the classification of responses based on this premise will help understand the perceptions of expectation and satisfaction about the proposed solution.

According to the responses, there are 34 respondents who do not reuse CAD components as indicated before, and 31 who do use CAD components created during the design of structural drawings. Ultimately this assessment will yield interesting results from rebar practitioners regarding the question whether potential users who are keen on the reuse of CAD components will be more likely to recognize the value of the B2B e-Work solution to improve the rebar supply interactions.

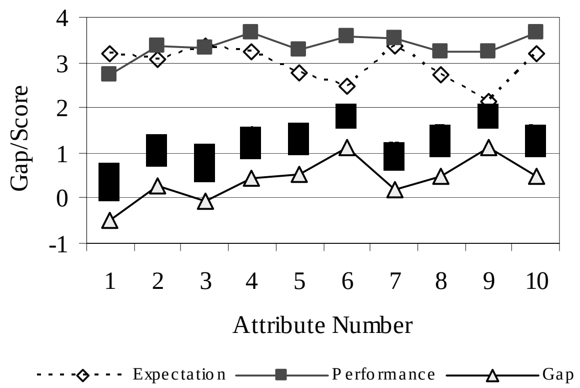

FIG. 8: UIS Diagram for CAD not Reused in Placing Drawings. n=34.

Two attributes boast the biggest gaps in Figure 8 for respondents that generally do not reuse CAD in placing drawings, while having relatively low expectation values: attribute 6 (ability to exchange/share rebar information) and attribute 9 (use e-Commerce platform for procurement of rebar) have a gap value of 1.12, displaying expectation values of 2.47 and 2.12 respectively.

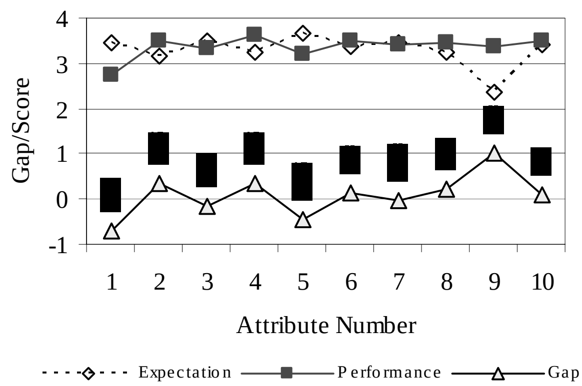

FIG. 9: UIS Diagram for CAD Reused in Placing Drawings. n=31.

Fig. 9 illustrates a better fit between expectation and satisfaction values. The main difference in the assessment of responses that do not reuse CAD components vs. those that do is comprised by the higher average expectation values for the latter (3.28 vs. 2.95), while the average satisfaction values are very similar (3.37 vs. 3.36). With regards to the attributes directly related to the handling of rebar information, the following conclusions are drawn: attributes 2 (flexibility of the system to produce desired rebar queries) and 4 (help conflict resolution with contractor/designer/detailer) present a slight positive gap for both categories of responses, attribute 5 (standardization of rebar shapes/schedules) has a positive gap for respondents who do not reuse CAD components but a negative one for respondents who do. The former category experiences a big gap in attribute 6 (ability to exchange/share rebar information) whilst there is practically no gap in the latter. Finally, the gaps for attribute 7 (expedite revision and correction of placing drawings) are also insignificant, thus suggesting that in spite of whether the firm is reusing or not CAD components from structural drawings and applying them in the design of placing drawings, the B2B e-Work system emerges as a promising option that satisfies the high expectations to deal with this concern. Attribute 9 (use e-Commerce platform for procurement of rebar) once again displays a considerable discrepancy between expectation and satisfaction values.

8. TESTS OF HYPOTHESES

Up to this point, the analysis using UIS has provided a detailed explanation of the trends in the differences between expectation and satisfaction scores. With the use of statistical tools it is intended to test whether the mean for satisfaction values is higher than for expectation values. The two-sample paired t test is going to be used for this endeavour since it tests the null hypothesis that the population mean of the paired differences of the two samples is zero [Devore, 2000]. In other words, it is going to compare the difference in values of pairs of satisfaction and expectation values. Some basic assumptions in this method are: first, the paired differences are independent, and second, the paired differences are all identically normally distributed (same mean and variance). However, it is not assumed that the two samples are independent of each other. In fact, they should be related to each other such that they create pairs of data points, such as the measurements on two matched people in a control study, or before and after treatment measurements on the same person. Since the same respondent created pairs of data points by assessing the respective expectation and satisfaction regarding the implementation of the B2B e-Work system for a given attribute, then this condition is fulfilled and the two-sample paired t test is valid.

The hypothesis for the paired t test is: does the average difference of the population μ_D differ from zero?

$$H_0 : \mu_D = \mu_1 - \mu_2 = 0 \quad \text{(Null hypothesis)}$$
$$H_1 : \mu_D = \mu_1 - \mu_2 < 0 \quad \text{(Alternate hypothesis)}$$

The test statistic ~~is:~~

$$T_0 = \frac{\overline{X}_d}{S_d / \sqrt{n}}$$

The t distribution will be used with 64 degrees of freedom since the data for this test consists of the 65 pair differences. The decision is aimed to reject the null hypothesis at a 5% level of significance. The test will be conducted for the samples of 18 attributes obtained from the questionnaire, not including those attributes with negative gaps (i.e. data security and system's speed), as sufficiently explained in the UIS analysis. Table 4 contains the information related to the two-sample paired t test. The paired t test is conducted for each of the 10 attributes, yielding a final decision to either reject or accept the null hypothesis at diverse levels of significance.

TABLE 4. Two-sample Paired t test Results
n=65, v=64, $-t_{\alpha\,(90\%)}=-1.282$, $-t_{\alpha\,(95\%)}=-1.645$, $-t_{\alpha\,(99\%)}=-2.326$

Attr.	$\overline{X}_D$	Sd	T_0	H_0 (90%)	H_0 (95%)	H_0 (99%)
1	0.585	1.367	3.447	ACCEPT	ACCEPT	ACCEPT
2	-0.308	1.460	-1.700	REJECT	REJECT	ACCEPT
3	0.108	1.594	0.545	ACCEPT	ACCEPT	ACCEPT
4	-0.400	1.732	-1.862	REJECT	REJECT	ACCEPT
5	-0.062	1.905	-0.261	ACCEPT	ACCEPT	ACCEPT
6	-0.646	2.083	-2.501	REJECT	REJECT	REJECT
7	-0.077	1.994	-0.311	ACCEPT	ACCEPT	ACCEPT
8	-0.369	2.208	-1.348	REJECT	ACCEPT	ACCEPT
9	-1.077	2.381	-3.647	REJECT	REJECT	REJECT
10	-0.292	2.370	-0.995	ACCEPT	ACCEPT	ACCEPT

According to Table 4, the null hypothesis is rejected in half of the attributes at a confidence level of 90%. For these attributes it can be stated that with a 90% confidence the mean of the satisfaction values is greater than the mean of the expectation values. Hence, by rejecting the null hypothesis the validation procedure acquires a favourable output for the performance of the B2B e-Work solution. Nevertheless, there are still several attributes for which there is not statistical evidence proving that the mean of the satisfaction values is greater than the mean of the expectation values. At a 90% confidence level, the null hypothesis is rejected for attributes 4 (help conflict resolution with contractor/designer/detailer), 6 (ability to exchange/share rebar information, 8 (ability to reduce total rebar workflow duration) and 9 (use e-Commerce platform for procurement of rebar).

However, what happened to the attributes for which the null hypothesis was not rejected at the 90% confidence level? In some cases such as attribute 8, it is rejected at a 90% confidence level but then it is accepted at a 95%. What constitutes a concern for the system validation is whether there is statistical evidence to state that the mean of the expectation values for any given attribute is greater than the mean of the satisfaction value. This needs to be tested for those attributes that disclose the most important characteristics of the B2B e-Work system from the rebar point of view. This means to conduct the test on those attributes in which the first null hypothesis was not rejected. The new alternate hypothesis test will be as follows, and the results of the two-sample paired t test are included in Table 5.

$$H_2 : \mu_D = \mu_1 - \mu_2 > 0 \quad \text{(New Alternate Hypothesis)}$$

TABLE 5. Two-sample Paired t Test. New Alternate Hypothesis.
$n=65$, $v=64$, $t_{\alpha\,(90\%)}=1.282$, $t_{\alpha\,(95\%)}=1.645$, $t_{\alpha\,(99\%)}=2.326$

Attr.	$\bar{X}_D$	Sd	T_0	H_0 (90%)	H_0 (95%)	H_0 (99%)
1	0.585	1.367	3.447	REJECT	REJECT	REJECT
3	0.108	1.594	0.545	ACCEPT	ACCEPT	ACCEPT
5	-0.062	1.905	-0.261	ACCEPT	ACCEPT	ACCEPT
7	-0.077	1.994	-0.311	ACCEPT	ACCEPT	ACCEPT
10	-0.292	2.370	-0.995	ACCEPT	ACCEPT	ACCEPT

The null hypothesis is accepted for most of the attributes at a 99% confidence level. The only case in which the null hypothesis is not accepted is in attribute 1 (system's response time). The analysis of gaps in the previous section provided a detailed explanation for this trend. By accepting the null hypothesis for these remaining attributes at a 99% confidence level, the validation method ensures that the B2B e-Work solution reflects satisfaction values in accordance to the expectation values. For those attributes in which the null hypothesis was rejected, it was stated at a 90% confidence level that the mean of the satisfaction values is greater than the mean of the expectation values.

9. CORRELATION MATRIX

The User Information Satisfaction (UIS) method provided a means of investigating the perceptions from respondents concerning the expectation and satisfaction scores in the form of gap values and trends. Then, with tests of hypothesis it was possible to study the statistical validity of the satisfaction values and their relative dominance over the expectation scores, or to test whether the mean values of satisfaction scores are close to the expectation values, under a certain confidence level. Although the data from the questionnaire have been carefully analyzed and studied in detail, the validation method still lacks a way of connecting the system's overall score with the satisfaction values conferred or the characteristics of the respondents. With the intention of finding any sort of relationship between the characteristics of respondents, the satisfaction values and the system's overall score, a correlation matrix will provide the numerical description of these potential relationships.

The correlation between two variables reflects the degree to which the variables are related. The most common measure of correlation is the Pearson Product Moment Correlation, called Pearson's correlation [Devore, 2000]. Pearson's correlation reflects the degree of linear relationship between two variables. It ranges from +1 to -1. A correlation (represented by r) of +1 means that there is a perfect positive linear relationship between variables, whereas a value of zero means that there is no linear relationship between the variables.

Table 6 contains the Pearson correlation matrix of the data built from responses to the questionnaire. This matrix includes the correlation coefficients among the characteristics of the respondents, the assessment of expectation and satisfaction values for the ten attributes and the overall system's score. The analysis of the correlation matrix indicates whether the observed relationships are strong or not.

TABLE 6. Correlation Matrix

	Type	CAD	Exp 1	2	3	4	5	6	7	8	9	10	Perf 1	2	3	4	5	6	7	8	9	10	Overall
Type	1.000	0.328	-0.452	-0.364	-0.482	-0.119	0.261	0.378	-0.137	-0.087	-0.095	-0.252	-0.089	-0.411	0.187	0.084	-0.139	-0.458	-0.332	-0.046	-0.048	0.032	-0.176
CAD	0.328	1.000	0.193	0.059	0.087	0.017	0.493	0.547	0.073	0.361	0.176	0.234	0.005	0.134	-0.001	-0.062	-0.086	-0.072	-0.104	0.192	0.154	-0.125	-0.147
Exp 1	-0.452	0.193	1.000	0.290	0.373	0.030	0.003	-0.031	-0.050	0.273	0.077	0.461	0.019	0.437	0.048	-0.265	0.076	0.310	0.274	-0.005	0.174	-0.105	0.153
2	-0.364	0.059	0.290	1.000	0.322	-0.108	0.042	-0.097	0.213	0.192	0.079	0.271	0.081	0.309	-0.268	-0.008	0.299	0.278	0.290	-0.119	0.278	0.015	0.051
3	-0.482	0.087	0.373	0.322	1.000	0.004	-0.005	-0.045	0.345	0.229	0.021	0.348	-0.028	0.303	-0.045	-0.109	0.005	0.239	0.232	-0.117	0.074	-0.221	0.137
4	-0.119	0.017	0.030	-0.108	0.004	1.000	0.305	0.094	-0.114	0.183	0.111	-0.292	-0.312	-0.108	-0.192	0.074	0.080	-0.085	-0.283	-0.017	0.049	0.071	-0.172
5	0.261	0.493	0.003	0.042	-0.005	0.305	1.000	0.579	-0.046	0.314	0.083	-0.050	-0.158	-0.090	-0.251	0.076	0.090	-0.196	-0.154	-0.002	0.081	-0.033	-0.216
6	0.378	0.547	-0.031	-0.097	-0.045	0.094	0.579	1.000	0.038	0.402	0.202	0.133	-0.304	-0.013	0.119	0.068	-0.269	-0.173	-0.213	0.066	0.069	0.123	-0.028
7	-0.137	0.073	-0.050	0.213	0.345	-0.114	-0.046	0.038	1.000	0.094	-0.068	0.194	0.029	0.293	-0.052	0.098	-0.055	0.165	0.284	-0.154	0.000	0.078	0.062
8	-0.087	0.361	0.273	0.192	0.229	0.183	0.314	0.402	0.094	1.000	0.049	0.244	-0.444	0.294	-0.013	0.058	-0.136	0.096	-0.045	-0.053	0.120	-0.166	-0.056
9	-0.095	0.176	0.077	0.079	0.021	0.111	0.083	0.202	-0.068	0.049	1.000	0.071	-0.038	-0.093	-0.032	-0.076	-0.145	0.124	-0.050	-0.165	-0.028	-0.121	-0.068
10	-0.252	0.234	0.461	0.271	0.348	-0.292	-0.050	0.133	0.194	0.244	0.071	1.000	0.091	0.382	0.188	-0.016	-0.035	0.208	0.333	0.083	0.190	-0.006	0.173
Perf 1	-0.089	0.005	0.019	0.081	-0.028	-0.312	-0.158	-0.304	0.029	-0.444	-0.038	0.091	1.000	0.052	-0.020	-0.190	0.173	0.069	0.050	0.246	-0.037	-0.187	-0.128
2	-0.411	0.134	0.437	0.309	0.303	-0.108	-0.090	-0.013	0.293	0.294	-0.093	0.382	0.052	1.000	0.123	0.095	0.005	0.331	0.318	-0.022	0.071	-0.018	0.131
3	0.187	-0.001	0.048	-0.268	-0.045	-0.192	-0.251	0.119	-0.052	-0.013	-0.032	0.188	-0.020	0.123	1.000	0.120	-0.094	0.120	-0.096	0.040	0.027	0.131	0.208
4	0.084	-0.062	-0.265	-0.008	-0.109	0.074	0.076	0.068	0.098	0.058	-0.076	-0.016	-0.190	0.095	0.120	1.000	0.397	0.166	0.112	-0.280	0.372	0.314	0.382
5	-0.139	-0.086	0.076	0.299	0.005	0.080	0.090	-0.269	-0.055	-0.136	-0.145	-0.035	0.173	0.005	-0.094	0.397	1.000	0.060	0.018	-0.160	0.218	0.134	0.108
6	-0.458	-0.072	0.310	0.278	0.239	-0.085	-0.196	-0.173	0.165	0.096	0.124	0.208	0.069	0.331	0.120	0.166	0.060	1.000	0.458	-0.010	0.246	0.056	0.344
7	-0.332	-0.104	0.274	0.290	0.232	-0.283	-0.154	-0.213	0.284	-0.045	-0.050	0.333	0.050	0.318	-0.096	0.112	0.018	0.458	1.000	-0.180	0.263	0.104	0.201
8	-0.046	0.192	-0.005	-0.119	-0.117	-0.017	-0.002	0.066	-0.154	-0.053	-0.165	0.083	0.246	-0.022	0.040	-0.280	-0.160	-0.010	-0.180	1.000	-0.098	0.112	-0.007
9	-0.048	0.154	0.174	0.278	0.074	0.049	0.081	0.069	0.000	0.120	-0.028	0.190	-0.037	0.071	0.027	0.372	0.218	0.246	0.263	-0.098	1.000	0.137	0.219
10	0.032	-0.125	-0.105	0.015	-0.221	0.071	-0.033	0.123	0.078	-0.166	-0.121	-0.006	-0.187	-0.018	0.131	0.314	0.134	0.056	0.104	0.112	0.137	1.000	0.456
Overall	-0.176	-0.147	0.153	0.051	0.137	-0.172	-0.216	-0.028	0.062	-0.056	-0.068	0.173	-0.128	0.131	0.208	0.382	0.108	0.344	0.201	-0.007	0.219	0.456	1.000

As observed in Table 6, the strongest relationship between the system's overall score and the performance scores was with attribute 10 (r=0.456), which indicates that if a respondent has scored highly on the overall cost-effectiveness of the information system, then this respondent was likely to confer a high system overall score. There were also strong positive relationships between the system's overall score and attributes 4 (r=0.382) and 6 (r=0.344). The greater the satisfaction regarding the conflict resolution among project participants and the ability to exchange or share rebar information, the higher the system's overall score. Another positive relationships, although weak, were found between the system's overall score and attributes 3 (r=0.208), 7 (r=0.201) and 9 (r=0.219). This set of slight correlation values indicates that the ability of the system to improve personal productivity, to expedite revision and correction of placing drawings and to perform e-Commerce transactions for procurement of rebar play a significant role for the respondent in the assessment of the overall score.

The prevailing type of construction is also negatively correlated with attributes 2 (r=-0.411), 6 (r=-0.458) and 7 (r=-0.332), which indicates that if a respondent conceded a high score on the flexibility of the system to produce desired rebar queries, the ability to exchange and share rebar information and to expedite revision and correction of placing drawings, then this respondent is more likely to have commercial as the prevailing type of construction. These conclusions are possible because of the sign of the correlation coefficient and the way the prevailing type of construction variable was coded: 1=commercial 2=industrial/heavy. When the correlation with type of construction is positive, industrial/heavy will have more of whatever is being measured on the attributes. The opposite is the case when the correlation is negative.

The reuse of CAD components was slightly correlated with the flexibility of the system to produce desired rebar queries (r=0.134), meaning that those who reuse CAD components are likely to consider the system flexible enough to produce the desired rebar queries, also with the ability to reduce total rebar workflow duration (r=0.192). This correlation, although not very strong, denotes a tendency from respondents who reuse CAD components to be more satisfied with the B2B e-Work solution in response to the reduction of the rebar workflow duration.

Finally, there is another slight positive correlation with the use of an e-Commerce platform for procurement of rebar (r=0.154), indicating that respondents that reuse CAD are more likely to be satisfied with the features of the proposed solution regarding e-Commerce capabilities.

10. CONCLUSIONS

There are numerous differences in the perceptions of expectation and satisfaction of software that could be used by software developers and construction practitioners in order to design and adopt the best system that suits the collective needs. To illustrate this, a system to be adopted in the approval process of rebar design and estimation was used to evaluate these perceptions. The basis for these differences was discussed with the assistance of the UIS method and the comparison of gap percentages. With the application of questionnaires it was possible to obtain from designers, contractors and rebar suppliers a direct feedback about the expectations and benefits of the proposed system. According to this method, the scope of the proposed solution is close to the expectations by practitioners regarding this type of solution.

The analysis of the Pearson correlation matrix indicates the numerical descriptions of the relationships between the characteristics of respondents, the satisfaction values and the system's overall score. The greater the satisfaction regarding the conflict resolution among project participants and the ability to exchange or share rebar information, the higher the system's overall score. The reuse of CAD components was slightly correlated with the high degree of technical competence from systems support staff, indicating that individuals who reuse CAD components consider the B2B e-Work system to require a high technical support staff, as opposed to those who do not. There is also some correlation with the ability to reduce total rebar workflow duration. This correlation denotes a slight tendency from respondents who reuse CAD components, to be more satisfied with the B2B e-Work solution in response to the reduction of the rebar workflow duration.

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