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Electronic Document Management Systems in the US Construction Industry

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Abstract: Research studies indicate an increase in the use of electronic document management systems (EDMS) for managing project documents by firms working in the construction industry over the past few decades. In addition to the basic function of providing the means to organize documents in a central repository, various EDMS's offer additional functionalities such as advanced document search capabilities and facilitating collaboration between project participants. A survey of the top design firms and contractors in the US was conducted in order to investigate the degree of adoption of electronic document management techniques. The objective of the survey was to identify characteristics of EDMS adopters in the industry in addition to the EDMS features/functionalities regarded as important by the users. A total of 141 respondents from 67 different top firms in the US participated in the survey. The results indicate the wide-spread use of EDM techniques by the leading firms in the industry. Concerns regarding document security and integrity play a major role in determining what document management practices are implemented.

1 Introduction

The term document management refers to the practices used to store, retrieve, transmit and share documents containing unstructured information such as letters, faxes, drawings, spreadsheets, etc. (Vidogah and Ndekugri 1998b). Traditionally, project documents in the construction industry were produced and shared in paper format (Anumba et al. 2003, Rezgui and Cooper 1998, Stewart and Mohamed 2004, Zhu and Issa 2003). Björk (2006) details the evolution of current electronic document management systems (EDMS) from the traditional document management practices. The increase in the use of personal computers, word processors and computer-aided design software resulted in a corresponding increase in the production of digital documents, both textual documents and schematic drawings. Gradually, as the method of document production became computerized so did the method of document distribution. The author points out that the implementation of EDMS's on internal networks even predates the widespread use of the world-wide web.

In its simplest form, an EDMS acts as a central storage of documents which can be accessed by users from different locations (Björk 2006). Various studies outlined the basic functions performed by an EDMS (e.g. Vidogah and Ndekugri 1998b, Zipf 2000). Turk et al. (1994) provide the following comprehensive list: (1) electronic archiving of documents; (2) creating, modifying and printing documents; (3) getting or referencing external documents; (4) providing document confidentiality and security; (5) management of the relationship between documents; and (6) extracting documents or data from documents. Craig and Sommerville (2006) add several interesting functionalities specifically for managing certain construction processes such as change orders, site instructions and contractor queries. Abdul Samad (2005) comments on the availability of many document management systems (DMS) for the construction

industry, some of which focus on providing optimum document search capabilities while others attempt to enhance collaboration between project participants. Al Qady and Kandil (2013) present a comprehensive review of electronic document management approaches used in the construction industry, ranging from the document-centric approaches (e.g. the use of hierarchical folder structures for organizing documents) to the information-centric approaches (e.g. model-based approaches).

There are many advantages gained by using EDMS's. Vidogah and Ndekugri (1998a) comment on the cost savings associated with the use of an EDMS as a result of a decrease in the time and effort required to research documents. Love et al. (1996) note the role of information technology systems in avoiding delays and additional costs in construction projects. Hjelt and Björk (2006) summarize the benefits of using an EDMS as follows: saving of time, simplification of work, protecting the investment made in creating the documents, enforcing quality standards, and enabling an audit trail to ensure accountability. The positive impact on construction projects resulting from the use of EDMS's was anticipated by researchers from the very early days of implementation of such systems. Both Kangari (1995) and Björk (2006) comment on the growing use of EDMS's especially among large contractors and predict further growth with the gradual decrease of hardware costs. Vidogah and Ndekugri (1998a) noted the extensive use of EDMS's by the insurance and banking industry and expressed disappointment that the majority of contractors have yet to discover the value of such systems. Specifically for claims management, Vidogah and Ndekugri (1998b) state that the major difficulty regarding access to the relevant information can be solved if the recent developments in EDMS are adopted by contractors.

Despite such benefits and despite the initial anticipated potential of advanced document management systems, document management practices in the construction industry have been described as inefficient and of limited reliability and cost-effectiveness (Chassiakos and Sakellaropoulos 2008, Lee et al. 2003), and inadequate and unable to provide the expected impact (Vidogah and Ndekugri 1998a). Document management practices have not effectively changed from the traditional paper-based method, in spite of the new medium offered by the latest technologies for electronic document production, storage and distribution (Zhu et al. 2007, Zhu and Issa 2003). In fact, the construction industry unlike other industries has been reluctant to embrace the new technology (Craig and Sommerville 2006, Lima et al. 2003, Stewart and Mohamed 2004). A study in the UK estimates that contractors spend only 0.5% of their turnover on IT, an amount significantly less than the average in other industries (Finch et al. 1996). This can be attributed to both cultural and practical reasons (Björk 2006). Vidogah and Ndekugri (1998a) state as part of the reasons for the problem a culture that is typically biased against paperwork with insufficient allocation of resources for the document management task. Mohamed and Stewart (2003) point out that a focus on the human aspect of IT including training on new IT applications is necessary to overcome the characteristic reluctance of industry practitioners to adopt new technologies which is an important step for the effective utilization of such technologies.

This study is part of a larger study on document management in the construction industry, focusing specifically on findings pertaining to EDMS's. It presents the results of a survey conducted to investigate the usage of EDMS's in major US firms working in the construction industry and the opinions of practitioners on the various features offered by EDMS's. The next section details the methodology used to design and administer the survey, followed by a detailed analysis of the responses. In the final section, the main findings of the study are summarized.

2 Survey Methodology

The target population used to sample respondents is Engineering News Record's (ENR) lists of top 400 contractors and top 500 design firms for 2011. Some firms appear on both lists, resulting in a total population of 863 firms. A questionnaire was developed as a web survey, soliciting information from employees of the top firms regarding implementation of EDMS's in their firms, what EDMS features are offered by their systems and their opinions on such practices. In addition, respondent information was requested in the questionnaire and, combined with general information on the firms collected from external sources, was used for the statistical analysis of the result, as detailed in the next section. Prior to survey administration, the questionnaire was refined based on reviews by two subject-matter experts and

a pretest designed to simulate actual survey deployment. The survey link was emailed to a sample of employees of the firms on ENR's top lists over two waves; an invitation email that describes the project and requests their response, followed by a reminder email after four weeks from the initial email.

3 Results and Analysis

3.1 Descriptive statistics

Figure 1 presents the distribution of the responses over the time period of survey deployment. The majority of the responses (65%) were completed on the first day of each round and the rate decreased drastically thereafter over the following weeks. Notwithstanding the drop in response rate, responses continued to arrive for several weeks after the start of each round (up to five weeks in the second round).

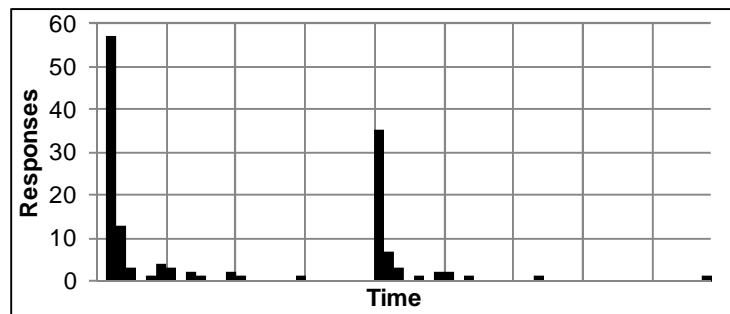


Figure 3 shows the distribution of the top ranking firms across the states for both the original population and the final sample. The relative variations between the number of firms with headquarters in each state are similar in both cases. States with high concentrations of firms are well represented in the sample, particularly California, Texas and New York. Some states with medium concentrations are not represented in the sample (notably Massachusetts and New Jersey), but in general the sample exhibits a trend very similar to that of the original population.

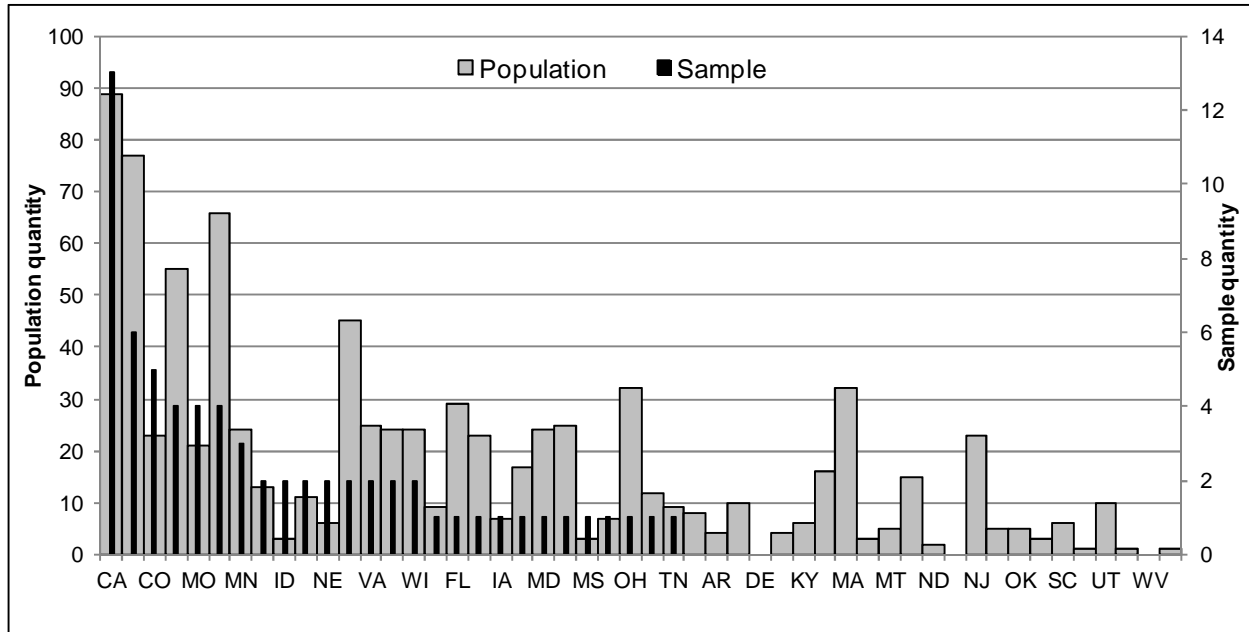


Figure 3 Variations of the quantity of firms in the population and the sample (by state)

Table 1 shows the distribution of the firms according to type in both the original population and the final sample. The proportions of each type are equivalent for both cases with the exception of the proportion of firms that are on both the top 400 contractors and top 500 design firm lists, which is relatively higher in the sample. This explains the higher average total revenues of the sample's firms (\$1,715 million) compared with the average total revenue of the original population (\$393 million), since such firms are generally large firms with relatively high revenues. Based on this discussion, the survey results are representative of the population in terms of organization type and region, but are considered skewed towards higher ranking firms (high revenue), assuming that such variables prove to be significant.

Table 1 Population and sample characteristics by firm type

Type	Quantity		Percentage	
	Population	Sample	Population	Sample
A/E	463	31	54%	46%
Contractor	363	26	42%	39%
Both	37	10	4%	15%

The majority of respondents either strongly agrees or agrees on recommending the use of EDMS's for managing construction project documents (81% ±7% at a 95% confidence level). About two-thirds of the respondents reported using an EDMS for managing project documents (63% ±9% at a 95% confidence level). Figure 4 presents the usage of different software systems for managing electronic documents reported by the survey respondents. In-house systems and cloud solutions are indicated separately in black.

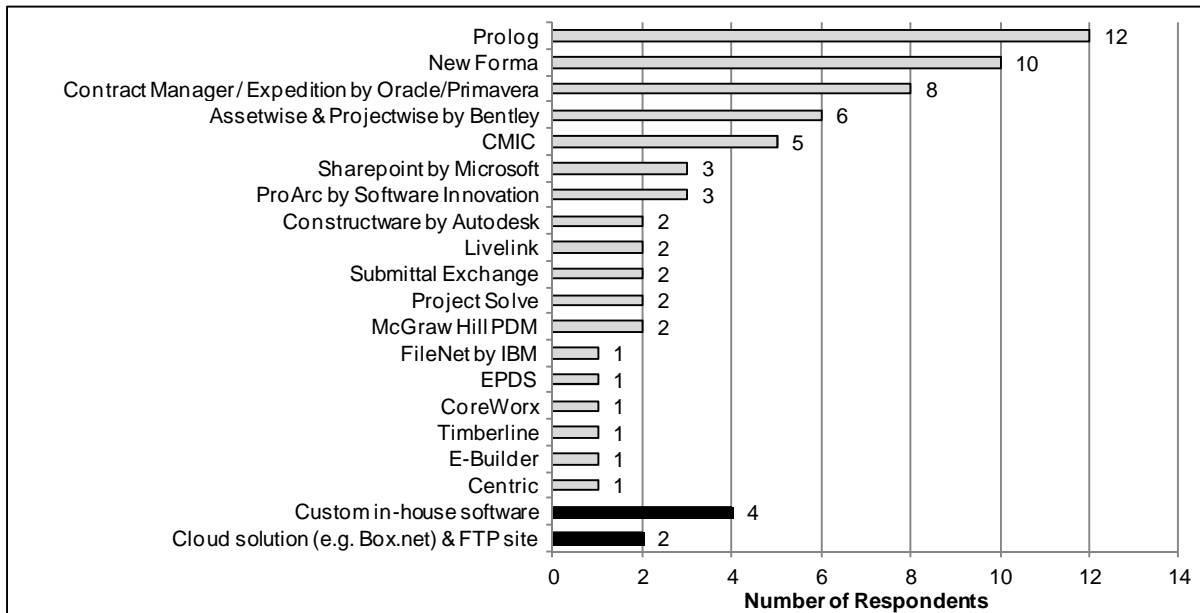


Figure 4 Software used by survey respondents

Figure 5 presents the degree of importance of a comprehensive list of EDMS features as indicated by the respondents, in which the solid lines represent the confidence interval of the results at a 95% level of confidence. Except for the automatic document classification and the user profiling features, the remaining features had the 'important' category (scale value 3) either well below or within the 95% confidence interval.

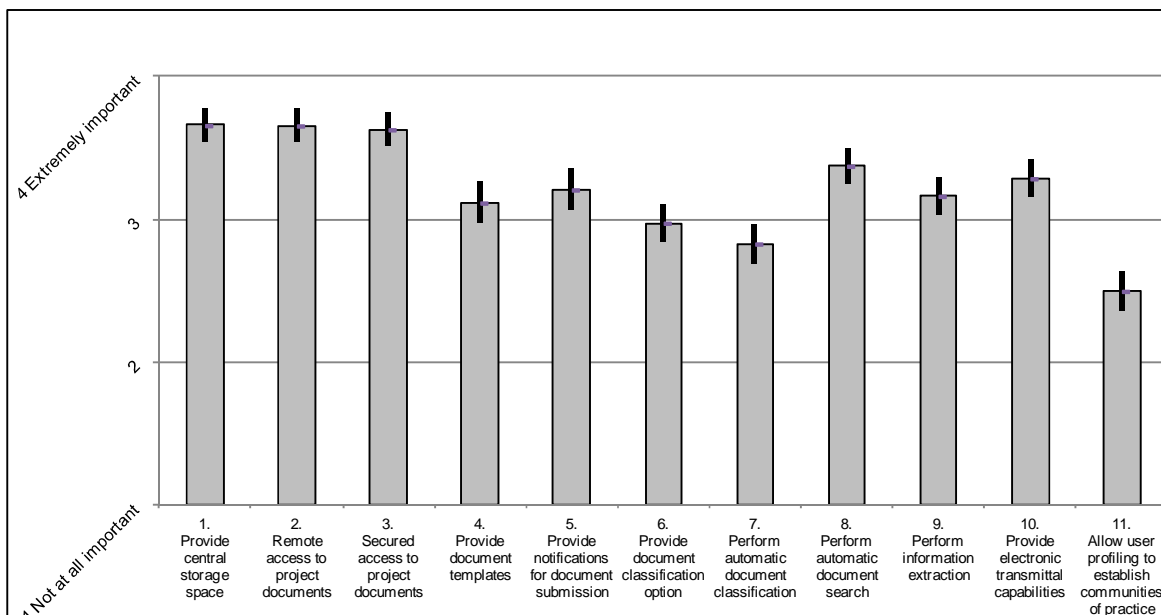


Figure 5 Importance of various EDMS features

3.2 Statistical Analysis

Statistical analysis was applied to investigate the factors affecting favorable/unfavorable opinions regarding each EDMS feature listed above. Several ordered probit models were developed to relate respondents' opinions on the features with variables representing characteristics of the respondents, their firms and document management practices implemented in the firms. Table 2 lists the variables applied in the analysis. The statistical significance of the effect of a specific independent variable on the respondents' opinion regarding the investigated issues is determined assuming a null hypothesis that the independent variable has no effect (i.e. the parameter estimate of the specific independent variable is assumed zero). Reported *p*-values of independent variables indicate the minimum significance level required in order to reject the null hypothesis, thus indicating the level at which the variable becomes statistically significant to the investigated issue. A level of significance of 90% was used for identifying the significant variables. The following results are noted.

Table 2 Variables used in statistical models

Variable mnemonic	Variable description
DOC_CLASSIFICATION	Are documents classified: 1 if yes, 0 if no
CLASS_KEYWORD	Classifying documents according to document keywords: 1 if category used, 0 if category not used
DOC_SEARCH	Method of document search: 1 if manual and automatic, 0 if manual only
SEARCH_CRITERIA	Criteria used for searching documents: 1 if both document content (text) and metadata, 0 if document metadata (properties) only
MANUAL_TRANSMIT	Frequency of use of manual document transmittal method: 3 if often, 2 if sometimes, 1 if rarely, 0 if never
EMAIL_TRANSMIT	Frequency of use of email attachment transmittal method: 1 if frequently, 0 if less frequently
SERVER_TRANSMIT	Frequency of use of server transmittal method: 3 if often, 2 if sometimes, 1 if rarely, 0 if never
EXPERIENCE	Years of experience of respondent: 0 if 5 or less, 1 if between 6 and 10, 2 if between 11 and 20, 3 if above 20
EXPERTISE_AREA	Respondents' area of expertise: 1 if core construction activity and supporting activity, 0 if supporting activity only
GENDER	Gender: 1 if male, 0 if female
PROFICIENCY	Respondent's proclaimed level of computer proficiency: 0 if novice, 1 if regular user, 2 if avid user, 3 if expert
REVENUE	Total revenue in 2011 (indicating rank)
TYPE	Organization type: 1 if design firm, 0 if contractor

Respondents that utilize content based search criteria have a higher probability of perceiving the central storage feature as very important relative to respondents that rely solely on metadata-based search criteria (*p*-value= 0.10). This indicates the impact a decentralized document storage approach has on frustrating the effectiveness of content search of documents' text.

Respondents from higher ranking firms are more likely to consider remote electronic access to documents as a very important EDMS feature (*p*-value= 0.08), probably as a result of the geographical dispersion of projects which makes remote access imperative. Highly experienced respondents (over 20 years of job experience in the industry) are less likely to assign a very high importance value to the functionality of remote access (*p*-value= 0.01), which may be attributed to concerns regarding the possible risk of compromising document integrity associated with remote access.

Secured access was perceived as very important to respondents that rarely used manual document transmittal techniques (p -value= 0.03) since security is an important concern when documents are shared electronically. Also, the probability of a very important assessment to the secured access feature is higher by 0.18 for avid computer users relative to the other user categories (p -value= 0.09), reflecting recognition of the security threat associated with electronic transmittal.

The majority of EDMS users in the survey confirmed the capability of their EDMS for assisting document production (70% \pm 10% at a 95% confidence level) either by providing document templates (87%) or by providing notification for submission requirements (81%). Respondents that utilize content based search criteria have a higher probability of perceiving the document template feature as very important relative to respondents that rely solely on metadata-based search criteria (p -value= 0.08) since electronic generation by the EDMS facilitates content analysis for both classification and retrieval. Similarly, respondents that frequently use email for transmitting documents are more likely by a probability of 0.18 to regard the document template feature as important compared with respondents that less frequently utilize such electronic transmittal method (p -value= 0.07). These results highlight how EDMS functionalities can promote specific practices among the users. As expected, expert computer users' probability of regarding the document template feature as very important is 0.52 higher than users with lesser computer proficiency (p -value= 0.05).

Respondents that implement document classification have a probability of viewing the classification feature as important that is 0.25 higher than those that do not implement document classification in their firms (p -value= 0.08), which testifies to the effectiveness of the document classification practice and emphasizes the importance of document classification. Experienced practitioners (between 15 and 20 years of experience) have a higher probability of regarding the classification feature as important than their respective counterparts (p -values of 0.07). Regarding the automatic document classification feature, respondents that implement document classification have a probability of viewing this feature as important that is 0.45 higher than those that do not implement document classification in their firms (p -value= 0.04), which is expected. However, respondents that implement content-based criteria for automatic document search (relative to respondents that only rely on metadata-based search criteria) are less likely by a probability of 0.13 to view automatic classification as an important feature (p -value= 0.10). Accordingly, automatic search based on content induces a negative opinion regarding the importance of automatic classification, indicating that the criteria used for automatic classification may not be appropriate for supporting effective content-based document search. Respondents from design firms are less likely to regard automatic classification as an important feature by a probability difference of 0.14 relative to respondents from contractors (p -value= 0.08), implying that contractors are more flexible regarding acceptance of new technologies. Respondents that work in core business activities such as in the technical and engineering areas have a probability for regarding automatic classification as important that is 0.25 higher relative to respondents working in supporting business activities such as the administrative, financial, human resources fields (p -value= 0.04).

Respondents that use automatic searches for document retrieval have a probability of regarding the automatic search feature as very important that is 0.30 higher than those that only rely on manual search (p -value= 0.07). Highly experienced respondents (with over 20 years of experience) have a 0.20 higher probability of having a very important opinion regarding this feature (p -value= 0.08). In addition, when classification according to document keyword (a content-based classification criteria) was used, a positive effect on the opinion regarding the importance of the automatic search feature was observed (p -value= 0.10), which indicates the contribution of keyword search towards an improved perception of automatic document search.

Respondents of higher ranking firms are more likely to recognize the significance of the information extraction feature in EDMS's (p -value= 0.02). Also, respondents that often transmit documents by uploading to servers have a probability for regarding the electronic document transmittal feature as very important that is 0.27 higher than respondents who less frequently use this document transmittal mode (p -value= 0.01).

The user profiling feature had the lowest average importance score among all 11 features investigated in this study (2.5 ± 0.12 at a 95% confidence level). However, respondents that work in core business activities such as in the technical and engineering areas were more responsive to the idea of profiling EDMS users to establish communities of practice. The probability of regarding such feature as important is 0.22 higher for this group of respondents relative to respondents working in supporting business activities (p -value= 0.08). This implies that EDMS's can be effective tools for establishing a community of practice within the construction industry for sharing and disseminating technical knowledge.

In general, the GENDER variable was not a significant variable in the majority of the models developed for this study. The effect of gender on the acceptance and adoption of new information technology is debatable; Davis and Songer (2009) offer an interesting summary of research on this topic. Regarding EDMS features, the probability of a very important opinion for the automatic search feature is 0.28 lower for male respondents compared to female respondents (p -value= 0.08), and the probability of an important opinion regarding the user profiling feature is 0.21 lower for male respondents compared to female respondents (p -value= 0.08). This suggests that female practitioners are more acceptable of advanced document management features than their male counterparts.

4 Summary and Conclusion

Figure 6 summarizes the impacts of the investigated variables on the opinions of the respondents regarding the EDMS features. A solid connecting arrow indicates an increase in the likelihood of an 'important' response for the specific EDMS feature (and consequently, a corresponding decrease in the likelihood of an 'unimportant' response) as a result of the corresponding variable; a dashed arrow indicates the opposite. Impact of an indicator variable on a specific EDMS feature is assessed by the marginal increase or decrease in the likelihood of a response resulting from a change in the value of the indicator variable while setting all other variables in the model at their mean values. In the figure, the impact is expressed by the thickness of the connecting arrows.

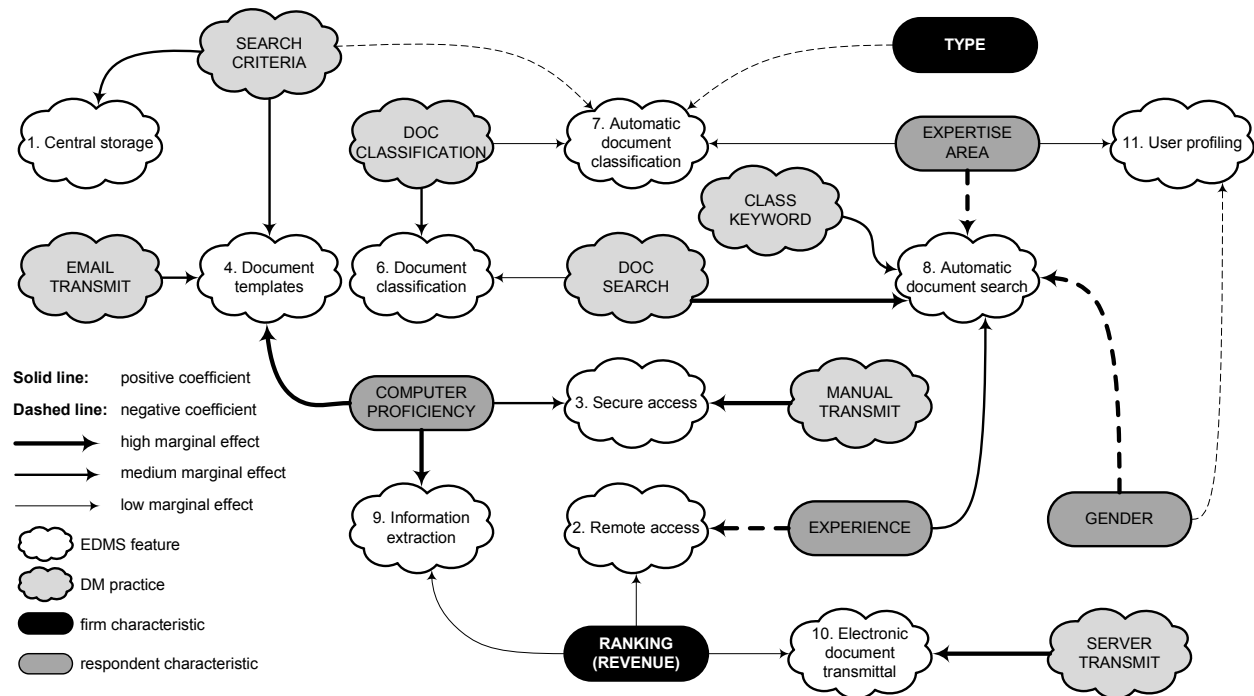


Figure 6 Factors affecting opinions on EDMS features

General comments by the respondents on the topic of the survey offered valuable insight on areas that are worth studying in the future. The use of Building Information Modeling is altering the meaning of project documents and is raising questions on interoperability between different systems, copyright ownership and legal liability; issues that require addressing in order to streamline information management on construction projects. Online project-based document management systems were recommended by a respondent for simplifying document management tasks, while another stated that outsourcing such tasks to a third party offers better quality control by experts and provides valuable document control expertise not necessarily available among project team members. Despite the huge advancements in software capabilities, the current economic situation does not encourage firms to invest in new systems, but to continue with their traditional practices.

A survey was conducted that covers the use of electronic document management systems in the US construction industry and investigates the opinions of industry practitioners from high ranking firms. The majority of respondents indicated the implementation of an EDMS in their firms and expressed opinions in favor of such use. The results of the survey were used to map practices, opinions induced by practices and characteristics of firms and respondents. Popular EDMS features require effective utilization of both document attributes (metadata) and document text content. By providing easier access to documents and faster document production/revision methods, EDMS's have also created security issues related to who is allowed access to project documents and what type of access is allowed in order to preserve integrity of the document body. As such EDMS features that address such issues were highly regarded by the respondents. The results of the survey identify to developers of EDMS's the expectations of industry practitioners, thereby enabling the development of systems that are better suited to industry needs. For professionals, the results indicate preferences of their industry peers and therefore offer the opportunity to compare and review their own practices.

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