AN EMPIRICAL ANALYSIS OF SOFTWARE PRODUCTION PROBLEMS IN EUROPEAN SOFTWARE UNITS

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An Empirical Analysis Of Software Production Problems In European Software Units

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Abstract - In this paper, we analyze software production problem profiles and their link to the organizational contexts of European software production units. The data used in our study contains more than 3800 observations representing software production units in the Information Technology (IT), Production, and Service sectors. Software production problems examined in our study include those associated with management, technical, and quality related processes. Among the key findings in our analyses are: 1) across all sectors, software production units are concerned most with deficiencies in specifications related processes such as Requirement Specifications and Management of Customer Requirements, 2) the degree of software production problems vary according to company size and sector, 3) the use of ISO, Software Assessment Methods, and Software Process Improvement methods show only weak impact on problem levels in Quality related processes, and 4) employee attitudes, in particular technical management attitudes, can impact significantly problem levels in Quality and Specifications related software production processes.

1. Introduction

Despite the amount of software produced to date and our increasing dependence on software, current methods and techniques used in software development are immature relative to other engineering disciplines. Cost and schedule overruns are frequent. Hence, software project assessment, control, and management have emerged as key research areas whose results can impact greatly both development and consumer costs.

Although considerable progress in software engineering theory and practice has been made, there remains a paucity of empirical observations on software production and practices. Glass (Glass 1994) attributes this to a general lack of emphasis on empirical observations within the software engineering community. Bandinelli, et al. (Bandinelli, Fugetta et al. 1995) note that there are ‘very few published contributions...that describe real experiences and empirical studies’ (p. 441). While empirical surveys have their own limitations, Potts (Potts 1993), Fenton, et al. (Fenton, Pfleeger et al. 1994), Kitchenham, et al. (Kitchenham, Pickard et al. 1995) and others have argued for more empirical research in software engineering.

This research represents a step forward in enhancing our empirical understanding of the management of software production and deployment. The data used in our study contains more than 3800 observations representing European software production units in the IT, Production, and Service sectors. The broad objectives of this paper aim to serve both software engineering practice and theory by:

1. identifying patterns in problem profiles occurring across operating sectors and sizes; and
2. examining salient relationships between organizational contexts and software production problems.

The remainder of the paper is organized as follows. First we propose a set of research hypotheses concerning links between the organizational context and software production problems. Next, we present the ESPITI database used to test these hypotheses. This is followed by a two part database analysis section each of which follows the objective set forth above to provide empirical support for the proposed
hypotheses. A detailed discussion of the results, including managerial implications is presented and then final conclusions are given.

2. Research Hypotheses

![Figure 1: Conceptual model of relationships between company organizational contexts and software production problems](image)

In this section, we propose a basic model that embodies four principle hypotheses investigated in this study (see Figure 1). The four hypotheses relate software production problems to four categories of input variables: company profile, use of software process assessment methodologies, employee attitudes and management participation.

**H1 - Software production problems are influenced by company profile**

Size and turnover are common variables used to characterize companies. Prior research has shown that companies of different sizes behave differently and suffer from different sets of problems (Brooks 1975; Belady and Lehman 1979; Boehm 1981; Conte 1986; Card, McGarry et al. 1987; Maxwell, Van Wassenhove et al. 1996). For example, large companies often suffer from communication difficulties (Welsh and White 1981) while in many smaller companies, quality and test processes may have problems due to the lack of dedicated resources.

Prior research (Pathare, Dutta et al. 1997; Dutta, Kulandaiswamy et al. 1998) has demonstrated that country and sector have an influence on the adoption of software management best practices. It is to be expected that companies with a higher level of adoption of software best practices would have fewer software production problems. For example, the literature (Pathare, Dutta et al. 1997) shows that companies from certain sectors, such as Aerospace and Telecommunications, consistently score higher in their adoption levels of software best practices. This is partially due to the stringent quality and reliability conditions imposed on software products in these sectors. That is, the impact and consequence of particular production problems will vary according to target environment.

**H2 - The adoption of software process (assessment & improvement) methodologies leads to reduced levels of software production problems**

Among the recent approaches (Humphrey 1989; Dorling 1993; Paulk 1995) directed toward cultivating mature software engineering practices are Software Process Improvement (SPI), Software Assessment Methods (SAM), and ISO 9000 (ISO). All are approaches aimed at monitoring and controlling the software production process to deliver high quality software efficiently. These approaches attempt to break away from the widely held belief that “software development is an art” by installing procedures and mechanisms for managing the software production process.

For example, ISO embodies concepts aimed at addressing problematic areas in software production such as those found in document control, corrective action, inspection and testing, and quality system processes. The SPICE framework has the twin objectives of facilitating both process improvement and capability determination (Rout 1995). Therefore, it is expected to observe decreasing levels of software
production problems with increasing usage of SPI, SAM, or ISO. Such findings would be supported by other research demonstrating positive benefits of assessment and improvement frameworks (Wohlwend and Rosenbaum 1994; Herbsleb, Zubrow et al. 1997; Hollenbach, Young et al. 1997).

**H3 - Positive employee attitudes toward training, quality, technical environment (use of software methods) and ISO leads to reduced levels of software production problems**

New technologies bring the promise of improved quality and productivity. However, their existence alone does not guarantee improved results. It is not until the tools are adopted into the working culture that the payoffs are realized (Locke, Shaw et al. 1981). For example, although quality initiatives may be in place - such as code walkthroughs, such initiatives can require more effort on the employees part and in many cases can be circumvented. In such cases, employees must believe that the extra effort leads to some good - or else the discipline gets lost and the benefits of the tool go unrealized. Based on these assumptions, we expect to observe fewer problems in software production as attitudes become more positive. This hypothesis is supported by studies in the literature have demonstrated positive relationships between tool use and improved productivity (Waltson and Felix 1977; Albrecht 1979; Baily and Basili 1981; Boehm 1981; Lawrence 1981; Vosburgh 1984; Card, McGarry et al. 1987; Banker, Datar et al. 1991; Jones 1991; Kitchenham 1992; Nevalainen and Mäki 1994; Maxwell, Van Wassenhove et al. 1996).

**H4 - Increased management participation leads to reduced levels of software production problems**

It is important that senior business executives become involved in the management of critical IT projects (Rockart and Crescenzi 1984). About two decades ago, Adams (Adams 1972) claimed that “the successful implementation of an MIS depends on the active and informed participation of executive management” (p. 54) and Swanson (Swanson 1974) wrote “that management should be ‘involved’ in MIS development is a popular wisdom” (p. 178). More recently, several other authors have also reiterated such a stance (Nath 1989; Jarvenpaa and Ives 1991). For example, Nath (Nath 1989) noted in his survey that for both senior general managers and MIS managers “upper management commitment is deemed critical” (p. 71) for aligning MIS with their organization’s goals. Jarvenpaa and Ives (Jarvenpaa and Ives 1991) found from a survey of fifty five CEOs that those CEOs who participated in the management of IT were more involved in IT, and that this in turn led to their firm being more progressive in the use of IT. Thus, we expect that increased management participation will lead to decreased problems in software production.

### 3 ESPITI Survey and Database

#### 3.1 Data Collection

The data used in this report originates from a survey sponsored under the EC project called ESPITI (European Software Process Improvement Training Initiative). The survey was designed and administered jointly by the European Software Institute (ESI) in Spain and the Forschungszentrum Karlsruhe in Germany. At the end of the collection period (end 1995), the database was assembled and passed to INSEAD for analysis.

In total, data was collected from 3805 software units. The units responding to the survey have diverse profiles in terms of size, turnover, and operating sector and represent 17 countries. Although other empirical studies regarding software production have appeared in the literature (Basili V.R. 1981; Lawrence 1981; Conte 1986; Banker, Datar et al. 1991; Jones 1991; Kitchenham 1992; Putnam and Myers 1992; Maxwell, Van Wassenhove et al. 1996), the size and coverage of the ESPITI database are unique.

Germany and the UK combined contributed 32% of the total data with Austria, Portugal, and Italy also providing a strong number of responses. Responses were obtained from all levels of employees ranging from high level managers to software engineers. Of the valid responses, the majority came from technical employees: technical managers, software production team managers, and software engineers. Overall, the average company had a turnover range of between 2.5-5.5 million ECU with the total number of
employees ranging between 29-150 and software staff size between 4-28. Responses obtained are shown below in Table 1.

### Table 1: Company size breakdown by sector

<table>
<thead>
<tr>
<th>Number of Employees</th>
<th>IT</th>
<th>Production</th>
<th>Service</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-5 (very small)</td>
<td>322</td>
<td>22</td>
<td>144</td>
<td>25</td>
</tr>
<tr>
<td>6-50 (small)</td>
<td>709</td>
<td>118</td>
<td>260</td>
<td>29</td>
</tr>
<tr>
<td>51-300 (medium)</td>
<td>305</td>
<td>198</td>
<td>188</td>
<td>45</td>
</tr>
<tr>
<td>301-1250 (large)</td>
<td>119</td>
<td>232</td>
<td>174</td>
<td>50</td>
</tr>
<tr>
<td>&gt; 1250 (very large)</td>
<td>89</td>
<td>242</td>
<td>191</td>
<td>44</td>
</tr>
</tbody>
</table>

#### 3.2 ESPITI Questionnaire and Database Variables

The questionnaire was divided into three main sections: company profile, state of software production, and information and training requirements of the company. There were 14 main questions with many of the questions requiring multiple responses. In all, a maximum of approximately 60 responses was possible from the questionnaire. The majority of the questions required multiple choice or yes/no responses. From the questionnaire, 40 variables were derived and placed in the database for this analysis. In the following subsections, we present the variable descriptions by category, abbreviations, and value ranges. Included are notes on the treatment of certain variables for database representation and example questions when necessary for clarification.

**Independent Variables - Software Production Context**

The independent variables used in our study contained variables in the following categories (number of questions in parenthesis): company profile (5), use of software process assessment/improvement methods (3), employee attitudes (13), and management participation (8). Employee attitudes were queried against positive, negative, or neutral opinions on various issues. Management participation was measured through participation in the software development process.

**Dependent Variable - Problems in Software Production Processes**

The variables in this category serve as the focal point of our analysis and are the dependent variables in our models. The values represent the level impact that problems particular problems have on the software production process. The questionnaire presented a table listing processes found in Table 2 and asked for responses relating to problem levels of Major, Minor, or Never a problem. For analysis purposes, Don’t Know responses were eliminated.

### Table 2: Dependent Variable Group - Software production problems

<table>
<thead>
<tr>
<th>Concept</th>
<th>Variable</th>
<th>Description</th>
<th>Value Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specifications</td>
<td>RS</td>
<td>Requirements Specification</td>
<td></td>
</tr>
<tr>
<td></td>
<td>MCR</td>
<td>Management of Customer Requirements</td>
<td></td>
</tr>
<tr>
<td></td>
<td>CM</td>
<td>Configuration Management</td>
<td></td>
</tr>
<tr>
<td>Technical Skills and Environment</td>
<td>SAD</td>
<td>Systems Analysis and Design</td>
<td>impact on software production problems: major, minor or never.</td>
</tr>
<tr>
<td></td>
<td>PC</td>
<td>Program Coding</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SIS</td>
<td>Software Installation and Support</td>
<td></td>
</tr>
<tr>
<td>Management</td>
<td>PM</td>
<td>Project Management</td>
<td></td>
</tr>
<tr>
<td></td>
<td>DOC</td>
<td>Documentation</td>
<td></td>
</tr>
<tr>
<td>Quality</td>
<td>QA</td>
<td>Quality Assurance System</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SM</td>
<td>Standards and Methods</td>
<td></td>
</tr>
<tr>
<td></td>
<td>SST</td>
<td>Software and System Testing</td>
<td></td>
</tr>
</tbody>
</table>
4. Analysis

The overall analysis approach taken in this research is divided into two parts. The first part provides a descriptive analysis of software production problem profiles and organizational profiles. Results from four different analyses are reported: European (treatment of the entire database), Company Size, Company Sector, and both Company Size and Sector.

The second part of the analysis seeks to identify relationships between company profiles and software production problems. These results allow us to identify the most effective parameters for addressing software production problems. These experiments also include segregation by sector and company size.

4.1 Software Production Problems: Descriptive Analysis

In this section, we look for emergent patterns in software production problems among companies of different sizes and sectors. We then highlight differences across organization size, sector, and a combination of sector and size. Spearman rank correlation coefficients appear in parenthesis throughout this section of the analysis (unless specified, p<0.001 for correlation measures).

The average European software problem level in each software production process included in the questionnaire is shown in Figure 2. Program Coding emerged as the process in which companies report the lowest level of problems. Companies also reported relatively few problems in the System Installation and Support process - another technically related process.

Figure 2: Problem levels in software production processes - European Level

Requirements Specifications consistently emerged as the weakest process across all company sizes and was followed closely by high reported degrees of problems in Management of Customer Requirements abilities.

4.2 Organizational Context Profiles

In this part of the analysis, we examine the interrelationships among variables in the ESPITI database characterizing company profiles, usage of software process assessment/improvement methods, employee attitudes, and management participation. The analysis includes significant results across company size, sector, and size/sector.

65% of European companies do not use Software Process Improvement, 86% of European companies do not use Software Assessment Methods, and 80% of European companies do not use ISO 9000.

The overall attitude of management and technical staff on the Use of Quality Methods and Tools, Software Development Methods and Tools, and ISO 9000 is positive. ISO 9000 had the lowest support with 22% of Commercial and Technical Management and 36% of Technical Staff holding a negative viewpoint. The overall viewpoint of Management and Technical staff on Staff Training is also positive. However, despite the strong support for quality and especially ISO methods, very few companies are actually using these methods. The average number of reported training days per year budgeted for each member of staff involved in software production in Europe is 8.
Of the managerial staff who are involved in the introduction of a new software process/development quality system, the highest overall Level of Director Participation is by the Manufacturing Director. The Production and Operations Directors follow close behind when two of the three activities are considered. The Sales, Marketing, and Managing Directors are, in general, the least involved in the production process.

Considering company size, with respect to usage of ISO, larger companies report a higher percentage of usage than smaller companies. For example, the very large companies report over 37% of them use ISO while only 3% of the very small companies use ISO. This could be due to the high cost of training and implementation associated with gaining ISO certification. With regard to the use of software improvement and software assessment methods, weaker trends with respect to company size are observed.

Across all company sizes, the Technical Management had the most consistently positive views on quality, system development methods, use of ISO, and staff training: support for all averaged above 90% except for staff training which was about 77%. The technical staff showed the strongest support for the use of ISO (around 95%), however, they were the most negative with respect to training (only an average of 63% had a positive viewpoint on staff training). Staff training was viewed the most negatively in medium sized companies with maximum support observed at only 80%. The number of training days budgeted for technical staff was fairly consistent across company size. However a small gap between very small companies and the others exists (about 0.3 days). Surprisingly, as company size increased, a less positive perspective on quality methods by the commercial management was seen.

Very small companies consistently reported higher levels of management involvement in the introduction of a new quality or system development method. Except for the very small companies, manufacturing, product, sales, and managing directors were most involved in the very large companies. Medium sized companies also reported strong involvement from the marketing and finance directors.

The viewpoints of the IT sector were generally more positive than the other sectors on the issues of quality, system development methods, staff training, and ISO. The largest differences in these perspectives occurred between the commercial management viewpoints in the IT and Production sectors. In the Service sector, perspectives on ISO were consistently higher across company sizes than those found in the IT and Production sectors. In addition, unlike the other two sectors the highest relative levels of management participation are not found in the very small companies. The large and very large companies report the highest levels of management participation. The highest level reported in this sector comes from the manufacturing, production, and operations directors of large companies. The research director management of very large service sector companies is highest over all sizes and sectors.

4.3 Linking the Context to Software Production Problem Degree

In this section, we use the ESPITI database to examine the presence or absence of empirical support for the hypotheses linking software production problems to organizational contexts. Results produced by this analysis are obtained using ANOVA. In preliminary experiments, we found that the country parameter accounted for significant amounts of variance in the levels of software production problems and hence the following results include country as an input variable. Furthermore, only data points with complete information, with respect to the model being built, are used in the analyses. All models discussed in these results have R-square values greater than 0.25, absolute coefficient values greater than 0.3, and are significant to at least p=0.001.

Across all sectors and software production processes, the very large IT sectors had the most relationships meeting our reporting criteria (13) with the large and very small service sector companies following at seven reported relations each. According to software production processes that are most influenced, Standards and Methods top the list with eight reported relationships with Requirements Specifications and Management of Customer Requirements each following with six.

In the following subsections, we will report on relationships found between each of the variable groups, A-D, and problem levels in software production processes.

H1 - Software production problems are influenced by company profile

Concerning the linkages between problem levels and sector, we find some of the following results (by segregating the database by sector only). Figure 3 shows sector reported problem levels relative to the European mean. In this figure, the dark circle indicates the European mean. Points interior to the circle indicate problems in a particular software process, while points exterior show strength. According to this figure, organizations in the IT sector report fewer problems with testing processes (SST) than those
organizations in other sectors. The production sector organizations appear more focused on Quality (QA and SM): the reported level of quality related problems in the production sector is lower than in the other two. However, the production sector lags in many of the technical areas (system design, program coding, and test).

Across company size, we observe that on average, very small and small companies report lesser degree of problems in most processes than larger companies. Figure 4 illustrates comparisons between larger and smaller companies in the IT and Service sectors. Each of the graphs shows average organization problem levels relative to the related sector’s Industry Standard or mean problem levels (as opposed to the European mean as in Figure 3). The exception is in the quality related processes - Standards and Methods, Quality Assurance, and Software and System Testing - where the larger companies report fewer problems.

With respect to company turnover and number of software employees, only a few relationships meet our reporting criteria (Table 3 shows results for Very Large IT orgs only due to space limitations). The absence of reported results related to Turnover shows that it has no or little effect on problem levels in software processes. The number of employees variable is involved in the most number of relationships and affects mostly the very large companies.

The strongest relationship linking company context and problem levels is one linking the number of software employees and problem levels in Standards and Methods for very small IT companies. Very large Service sector companies can expect decreased problem levels in Software and System Testing and Quality Assurance as the number of employees increases. The very large IT companies show greatest decreases in problem levels in Requirement Specification, System Analysis and Design, and Software and System Testing processes as the number of employees increases. Thus our results indicate moderate support for hypothesis H-1.

Table 3: Regression results: Company Profile and Software Production Problems

<table>
<thead>
<tr>
<th>Process</th>
<th>Var</th>
<th>Sector</th>
<th>Size</th>
<th>R-Square</th>
<th>Obs</th>
<th>Fval</th>
<th>Coef</th>
</tr>
</thead>
<tbody>
<tr>
<td>Requirements Specifications</td>
<td>Number of Employees</td>
<td>IT</td>
<td>V. Large</td>
<td>0.592</td>
<td>92</td>
<td>8.704</td>
<td>0.818</td>
</tr>
<tr>
<td>System Analysis and Design</td>
<td>Number of Employees</td>
<td>IT</td>
<td>V. Large</td>
<td>0.601</td>
<td>92</td>
<td>9.050</td>
<td>0.856</td>
</tr>
<tr>
<td>Test</td>
<td>Number of Employees</td>
<td>IT</td>
<td>V. Large</td>
<td>0.740</td>
<td>92</td>
<td>17.092</td>
<td>1.241</td>
</tr>
</tbody>
</table>
H2 - The adoption of software process (assessment & improvement) methodologies leads to reduced levels of software production problems

According to the ESPITI database, evidence supporting decreased problem levels with increased use of Software Assessment Methods, Software Process Improvement, and ISO 9000 is weak. One common trend is that very small service sector companies report negative coefficients with respect to decreased problems levels in Requirements Specifications and System Support and Test and the use of ISO and Software Assessment Methods respectively. One possibility is that the usage of software process assessment and improvement methods makes problems more apparent (as opposed to the state of ignorant bliss).

Larger IT companies exhibit decreased problem levels in Project Management and Documentation with the use of ISO and Software Process Improvement methods respectively. Thus our results provide weak support for hypothesis H-2.

H3 - Positive employee attitudes toward training, quality, technical environment (use of software methods) and ISO leads to reduced levels of software production problems

As the largest number of variables in the database dealt with employee attitudes toward quality, technical environment, training, and ISO, it is no surprise that the greatest number of significant relations involve these variables (see Tables 4 and 5 for selected results on Very Large IT orgs.). Overall, attitudes were seen to impact problem levels in each of the software processes in some manner with the exception of the Documentation and Configuration Management processes. Relations between Quality Assurance and Management of Customer Requirements processes and attitudes accounted for about half of the reported relationships. The majority of the Quality Assurance related relations involved large service sector companies.

Table 4: Regression results: Technical Management Attitudes and Software Production Problems

<table>
<thead>
<tr>
<th>Process</th>
<th>Var</th>
<th>Sector</th>
<th>Size</th>
<th>R-Square</th>
<th>Obs.</th>
<th>Fval</th>
<th>Coef.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Software Installation and support</td>
<td>Technical Mgt. ISO Support</td>
<td>IT</td>
<td>V. Large</td>
<td>0.395</td>
<td>74</td>
<td>3.325</td>
<td>0.483</td>
</tr>
<tr>
<td>Requirements specification</td>
<td>Technical Mgt. training Support</td>
<td>IT</td>
<td>V. Large</td>
<td>0.473</td>
<td>78</td>
<td>4.855</td>
<td>0.400</td>
</tr>
<tr>
<td>Program coding</td>
<td>Technical Mgt. training Support</td>
<td>IT</td>
<td>V. Large</td>
<td>0.407</td>
<td>78</td>
<td>3.711</td>
<td>0.326</td>
</tr>
</tbody>
</table>

Figure 4: IT (left) and Service (right) Sector software production process problems relative to Industry Standard (mean level for sector). Interior to the Sector circle indicates inferior performance (higher than sector average problem levels).
Table 5: Regression results: Technical Staff Attitudes and Software Production Problems

<table>
<thead>
<tr>
<th>Process</th>
<th>Var</th>
<th>Sector</th>
<th>Size</th>
<th>R-Square</th>
<th>Obs.</th>
<th>Fval</th>
<th>Coef.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Software Installation and support</td>
<td>Technical staff quality support</td>
<td>IT</td>
<td>V. Large</td>
<td>0.388</td>
<td>75</td>
<td>3.269</td>
<td>0.476</td>
</tr>
<tr>
<td>Program coding</td>
<td>Technical staff methods support</td>
<td>IT</td>
<td>V. Large</td>
<td>0.392</td>
<td>81</td>
<td>3.659</td>
<td>0.352</td>
</tr>
<tr>
<td>Program coding</td>
<td>Technical staff training support</td>
<td>IT</td>
<td>V. Large</td>
<td>0.387</td>
<td>85</td>
<td>3.796</td>
<td>0.632</td>
</tr>
</tbody>
</table>

Of the 30 relationships reported in this section, five of them had negative coefficients. For very small service sector companies, increasingly positive attitudes of the technical staff toward systems and methods and staff training actually showed increases in problem levels in the Requirement Specifications process. The other negative relationships reported occur between technical management attitudes toward staff training and Requirement Specifications and Systems Analysis and Design.

Across all sectors, the most impact due to positive attitudes in all areas occurs in the IT and Service sectors. In both sectors, the attitudes of the technical management and technical staff have the most influence on software process problem levels. Within the IT sector, the very large companies can expect decreased problem levels in Requirements Specifications, Program Coding, Software Installation and Support, and Quality Assurance processes. Of these relationships, the most influential (largest magnitude coefficient) is the effect of commercial management attitudes on staff training and Quality Assurance (0.68).

In the Service sector, problems with Requirement Specifications in very small companies is influenced by employee attitudes, while in large companies, attitudes show strong influence on problem levels in Quality Assurance and Standards and Methods processes. Staff training attitudes were seen to influence both the Quality Assurance and Standards and Methods processes in large service sector companies as well. Of the relationships reported for large service sector companies, the Technical Staff attitudes have the greatest impact with the technical staff attitude and Standards and Methods linkage representing the maximal impact relationship (0.64).

H4 - Increased management participation leads to reduced levels of software production problems

The relationship between management participation and problem levels in software processes is weak. One of the two relations that met our reporting criteria shows a positive effect of the Production Manager on problem levels in the Program Management processes while the other shows an increase in problem levels in Program Coding (with a sizeable coefficient) as the Managing Director becomes more involved.

5. Discussion

The ESPITI database is unique because of its size and coverage of a number of European countries. The following paragraphs discuss some of the implications of the above findings.

Our results show that certain software production problems are lower in large companies. This could be due to a number of reasons. For one, large companies have more skills in software management (note that large companies are usually also large users of software and information technology) and thus have more in-house competence to deal with software problems. Large companies also typically operate in multiple locations and have to deal with multiple vendors and suppliers. Thus, they tend to emphasize the use of standards and methods, an aspect which could lead to lower software problems.

While our results for small and medium sized companies are not significant, research (Dutta and Evrard 1998) has shown that small and medium sized companies are struggling with a multitude of software problems. The reasons for these problems are varied, but the lack of adequate competence in software technologies is a primary cause. As small and medium firms form the bulk of the European economy (more than 90% of the total number of European Union (EU) businesses are comprised of SE’s, accounting for 25% of EU turnover), these issues need to be addressed within European countries.

Across sectors, there are marked differences in the problem profiles reported by organizations. Many of these differences are driven by the demands placed on the end product by the target environment; reliability and computational resource drivers immediately come to mind. A strong example that emerges from the ESPITI data shows quality related problems in the Production sector representing less of a risk factor than in the other two sectors analyzed. However, the relative weakness of the Production sector in
requirements related processes raise questions as to how effective the overall development process performs.

According to the ESPITI database, the influence of the use of ISO and other software process assessment and improvement methods on software production problems is quite weak. This result is surprising because there is significant evidence in the literature about the benefits of applying software process methodologies such as CMM (Herbsleb, Zubrow et al. 1997), Humphrey, et al. (Humphrey 1991), and Henry, et al. (Henry, Henry et al. 1994).

There are probably several reasons for our findings. As mentioned earlier, the large majority of the surveyed companies were not using software process assessment and improvement methods. Among the companies using these methods, it is likely that they are more aware of problems in their software production processes (as a consequence of having used these methods), and thus are more likely to report higher levels of problems in their responses to the ESPITI questionnaire.

In addition, prior research (Dutta and Van Wassenhove 1996) has identified some shortcomings of commonly used software process assessment and improvement methodologies. For example, models such as CMM (Humphrey 1989; Paulk 1995) primarily emphasize software processes at the expense of the broader organizational context in which software is developed and applied within organizations. Thus our findings of the weak support for hypothesis H-2 could result from inherent limitations of currently software process assessment and improvement methodologies.

Software process improvement frameworks such as CMM and SPICE also have maturity levels associated with them - which are not reported in the ESPITI data. Significant differences in the process requirements exist between adjacent levels in these frameworks. In addition, these frameworks are expensive to implement: significant internal and external resources must be committed to put these processes in place. An open question is how to make these approaches more accessible to small and medium enterprises. (The ESPITI data can be used to highlight this issue through other analyses that have shown a correlation between company size and ISO and SAM adoption levels).

Our results show also that employee attitudes have a significant impact on the entire software production process. Positive employee attitudes are reflected in lower problem levels in software. This result is consistent across sectors and company sizes. Our findings suggest that management should take the initiative to foster positive attitudes among employees towards training, quality, software development methods and tools and ISO. In particular, quality systems and standards require the concerted efforts of departments, who are diverse in both function and culture. In such cases, management leadership is vital for the success of these initiatives.

Although our findings with respect to training suggest little effect on software problems, this result should be interpreted with caution. The average number of training days budgeted per employee per year for the ESPITI sample of companies is very small - 8. Given the rapid changes in software technologies and the complexities of adopting software process assessment and improvement methods, we feel that this number should be increased significantly. We should note that firms in other knowledge intensive sectors (such as consulting) frequently budget more than three weeks of training per employee annually (Dutta and De Meyer 1997). This should point the direction for software employees.

Overall, we found that management participation has the greatest influence on the Requirements Specification, System Installation and Support, and Program Coding processes. Unfortunately on a size/sector basis, there were not enough responses to support strong results. However, in small IT companies, significant influences emerged between the management participation levels of the Production, Operations, Manufacturing directors on Configuration Management and Systems Analysis and Design, and Documentation processes respectively.

For many of the improvement initiatives, standards and system wide processes are required to implement effectively. The direct implication of this fact is that direction and support must come from the upper levels of the organization. The issue of the degree and timing of management involvement must be investigated further as management meddling has also been identified as a source of organizational paralysis. For example, grass-roots initiatives have succeeded by first piloting and then gaining approval by upper level management.

Cultural issues, though not discussed in this paper, clearly can have a large impact on the results. It is well known that some cultures are more self-critical than others and linguistic expressions of problem degree are not universal. These differences must be considered in the use of the results presented in this paper. Unfortunately, such analyses are beyond the scope of this paper.
6. Conclusions

Through analysis of the ESPITI Database, the following significant findings have emerged from our study:

1. Developing good requirements specifications and customer requirements management processes are the number one and two concerns of all European Software companies respectively. High problem levels in these specifications related processes consistently appear across companies of all sizes and sectors. The negative impact of poor specifications related processes on productivity, quality, and costs has been well documented in the literature. Soft requirements often lead to problems in scheduling and even project completion. In addition, without solid mechanisms for integrating the inevitable changes to such specifications, disaster lurks ahead.

2. Software problem levels vary according to company size and sector. Across company sizes, smaller companies generally have lower problem levels in software production processes. However, larger companies generally report lower problem levels in quality related processes. Across sectors, the IT sector reports the lowest problem levels in technical, but the highest problem levels in quality related processes.

3. The use of ISO, Software Assessment Methods and Software Process Improvement methods shows little impact on problem levels in quality related dimensions of software.

4. Employee attitudes have a significant impact on software problems. Problem levels in quality related software production processes are most affected by attitudes of the commercial management, technical management, and technical staff towards ISO, quality, and staff training. This trend emerges for the entire European software companies responding. Quality process problem levels are especially influenced by these company perspectives in large and very large Production and Service sector software units.

Finding the most efficient and effective path toward effective software management requires an understanding and identification of the relationships between controllable variables and software product output. The results of our study identify key variables that influence problem levels in software processes across both company sector and size.

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References and Related Publications


