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BENCHMARKING

EUROPEAN SOFTWARE MANAGEMENT PRACTICES

The strategic importance of software has long been understood by practitioners and policy makers all over the world. Not only does software form the backbone of such industries as banking, airlines, and publishing, it is an increasingly important value-adding component of most consumer products, including televisions, cameras, cars, and mobile phones.

How and why hundreds of European companies adopt, reject, or ignore dozens of potentially valuable software management practices

In addition to software's ubiquity, the amount of code in most consumer products and systems is doubling every two to three years [6]. Consequently, software developers are scrambling to cope with the pressures of systems that are not only a couple of orders of magnitude larger and more complex than those developed a few years ago but also have to meet ever-increasing demands for quality and performance.

The management of software development leaves much to be desired. This view was summed up by W. Wayt Gibbs in [6], "Studies have shown that for every six new large-scale software systems that are put into operation, two others are cancelled. The average software development project overshoots its schedule by half; larger projects generally do worse."

In view of the recurrent problems in software development, a significant effort has been invested over the last decade in developing models and identifying practices that can lead to more effective software management. For example, the Software Engineering Institute (SEI) in Bilbao, Spain, has pioneered research in the assessment and improvement of software processes in collaboration with the U.S. Department of Defense and major U.S. business organizations [7]. The principle motivation for SEI's work is that "the quality of a software product is largely determined by the qual-

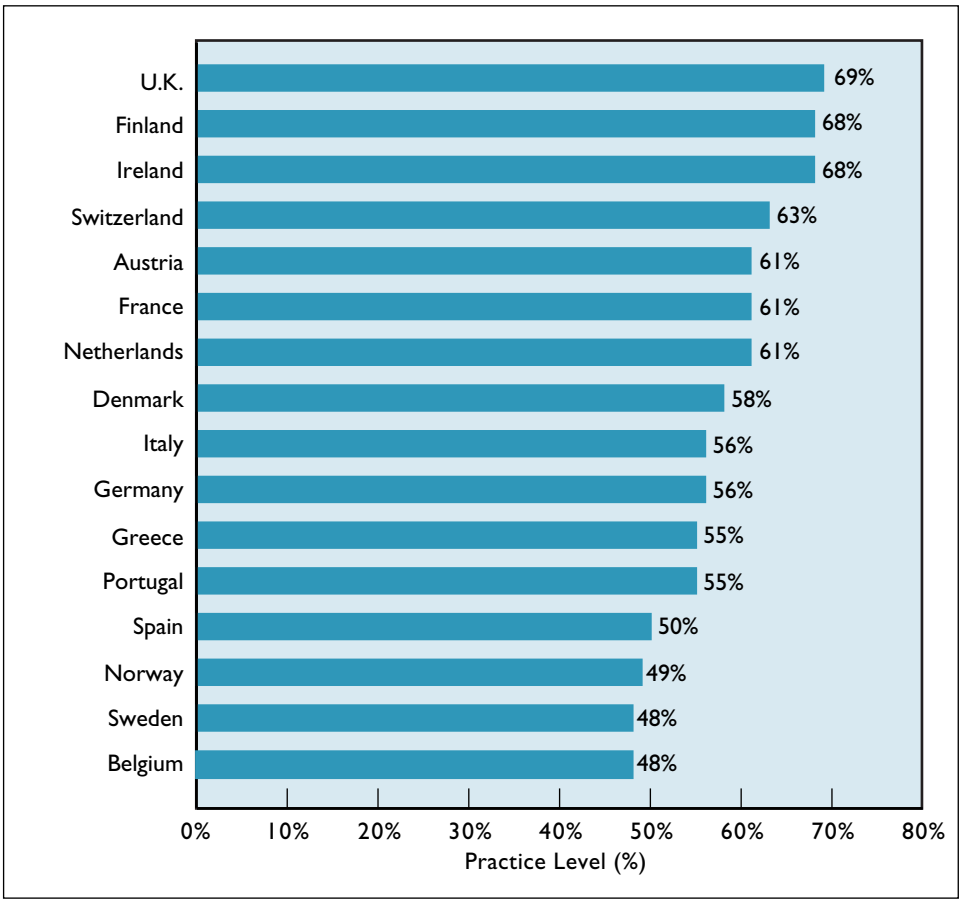


Figure 1. Organizational issues (practice levels by country)

ity of the software development and maintenance processes used to build it" [10].

On the other side of the Atlantic, the European Software Institute (ESI), established in 1993 by 14 leading European companies with support from the European Commission and the Basque government, focuses "mainly on the organizational and management challenges of producing software, as it is increasingly recognized that purely technological solutions yield benefits that are difficult to sustain and often eroded" [4].

In recognition of the importance of effective management practices for software development, ESI collaborated with INSEAD beginning in 1994, initiating multiple pan-European surveys on European software management practices (SMPs). Here we report and evaluate the results of a recent survey conducted by the European Commission to assess adoption of selected SMPs within European organizations (see the sidebar "How the Survey Was Done").

Published studies on the state of SMPs in Europe are

How the Survey Was Done

The first step was development of the SMP questionnaire by an independent organization for the European Commission. It contained 42 questions structured into five sections: organizational issues (8 questions); standards and procedures (13 questions); metrics (8 questions); control of the development process (6 questions); and tools and technology (7 questions). The number of questions was limited to avoid creating a too-lengthy questionnaire that would risk reducing the response rate.

The SMPQ was influenced by earlier research in software process improvement, exemplified by various models, including SEI's Capability Maturity Model (CMM) [7], Europe's Bootstrap model [3], and Software Process Improvement and Capability dEterminator (SPICE) [5]. Questions represented certain common practices within these models and were validated by experts in the European Commission. The focus was on determining the existence of SMPs, not to assign adequacy (or capability) ratings to the SMPs [5]. In accordance with the rating scheme of SPICE [5], SMP existence was scored using a binary scale of nonexistent (N) or existent (Y) scores.

The SMPQ was distributed as part of the call for proposals under the European Software and Systems Initiative (ESSI) research initiative sponsored by the European Commission. All organizations submitting an ESSI project proposal were asked to submit a completed SMPQ. It was stated that the questionnaire responses would be evaluated separately and would not affect assessment of the project proposal.

We received 463 valid responses from companies in 33 business sectors and 17 European countries. The country-based split of responses included: Italy (89), Spain (82), Germany (78), France (36), Greece (31), U.K. (29), Denmark (17), Switzerland (16), Norway (15), Holland (13), Belgium (11), Ireland (9), Austria (8), Sweden (8), Portugal (7), Luxembourg (3), and Hungary (1). However, Luxembourg and Hungary are not included in the analysis in this article because the sample size was too small.

Analysis. We define the practice level for a responding company as the percentage

Table 1. Organizational issues (high and low practice levels)

Software management practices (average levels)	Countries with high practice levels	Countries with low practice levels
Each software project has a software project manager (95%)	All countries with adoption levels close to the average best practice level	
The software project manager reports to a business manager responsible for the overall benefit of the project to the business (85%)	All countries with adoption levels close to the average best practice level	
A software quality assurance function is in a reporting line independent from software development project management (42%)	France (69%); U.K. (67%)	Belgium (18%); Greece (20%); Spain (23%)
A change contol function for each project (54%)	U.K. (81%); Austria (75%)	France (34%); Sweden (38%)
Training program required for all newly appointed software managers to familiarize them with in-house software project management procedures (41%)	Ireland (67%); Finland (62%)	Norway (13%); Austria (25%); Denmark (27%)
Procedures for maintaining awareness of state-of-the-art software engineering technology (38%)	Finland (62%); Greece (57%); Ireland (57%)	Sweden (13%); Portugal (14%); Belgium (18%)
Procedures for ensuring appropriate levels of user/customer input throughout the project (65%)	Ireland (100%); Switzerland (87%)	Spain (40%); Belgium (45%)
Procedures to ensure the availability of nonsoftware resources (such as hardware design specialists) critical to project success (44%)	Netherlands (69%); Denmark (60%)	Norway (20%); Belgium (27%); Portugal (25%)

rare; but for a few exceptions [1], most are private and ad hoc [8, 11, 12]. In fact, even on a global basis, there are "very few published contributions . . . that describe real experiences and empirical studies" of software processes [2]. Thus, there is a strong need for published research to provide an initial assessment of the state of SMPs in Europe and to establish benchmarks against which country-to-country and longitudinal (country-to-country over time) comparisons can be made.

Organizational practices. The distribution of adoption levels for organizational SMPs across countries is shown in Figure 1. For each project, most organizations (95%) appoint project managers who also (in 85% of organizations) report to business project managers responsible for the overall benefit of the project to the business. There is an emphasis on ensuring customer input throughout these projects (65%).

The emphasis on training staff is not as high, with only 41% of the organizations having procedures for

of SMPs adopted by, that is, existing within, that company. We define the practice level for a group of companies (a group was defined with respect to some criterion, such as country) as the average of the practice levels of all companies in that group. We use the terms *practice level* and *adoption level* interchangeably in this article.

For each section of the questionnaire, we pursued the following analyses:

- Overall extent of adoption of SMPs across all responding companies.
- Practice levels for individual countries.
- Countries with very high or very low adoption levels for specific SMPs.

We also performed two aggregate analyses for all questions in the questionnaire:

- By country, tracing key drivers of the differences between those with the highest and those with the lowest practice levels.
- By company, comparing those with high and those with low adoption levels.

For the sake of brevity, we might write that, say, Country X has a low adoption level; such statements are to be interpreted as meaning that the companies from Country X that responded to the SMPQ have a low adoption level. We cannot make categorical statements about all companies in a particular country based on the data we considered.

There were few published research studies against which we were able to compare our results. Also, no published study (to the best of our knowledge) provides a country-to-country (within Europe) comparison of SMPs; most group all European countries together as a set. However, we reference two unpublished reports, one by an independent consulting company for the ESI in 1994 [12] and another by Rubin Systems, Inc., a consulting firm, in 1995 [11]. The former is a study of 84 organizations from 11 European countries, the latter a study of 73 European and 124 North American (Canada and the U.S.) companies. Both studies, though relatively recent, do not differentiate among individual European countries.

Table 2. Standards and procedures (high and low practice levels)

Software management practices (average levels)	Countries with high practice levels	Countries with low practice levels
Management formally assesses each project's benefits, risk, and viability (74%)	Finland (92%)	Greece (57%)
Management formally conducts periodic reviews of the status of each project (81%)	U.K. (96%); Netherlands (92%); Spain (92%); Finland (92%)	Sweden (50%); Portugal (57%)
Procedures to ensure a disciplined software development process is followed by external software subcontractors (32%)	U.K. (63%); Switzerland (60%)	Belgium (9%); Austria (13%); Sweden (13%); Portugal (14%)
For each project, independent audits (such as walkthroughs and inspections) conducted for each major stage in the development process (45%)	U.K. (74%); Finland (69%); Switzerland (67%)	Portugal (29%); France (31%); Spain (32%)
Common coding standards applied to each project (66%)	U.K. (81%); Switzerland (41%)	Belgium (45%); Denmark (47%)
Documented procedure for estimating software size (20%)	U.K. (41%); Switzerland (40%)	Sweden (0%); Portugal (0%); Norway (7%)
Formal procedures for estimating software development effort, schedule, and cost (51%)	Finland (77%); Austria (75%); Switzerland (73%); U.K. (70%)	Sweden (13%); Belgium (36); Germany (37%)
Formal procedures for handing off software deliverable from one group to another (43%)	U.K. (78%); France (60%)	Belgium (27%); Denmark (27%)
Mechanism to ensure that software projects selected for development support the organization's business goals (36%)	Netherlands (62%); Norway (60%); U.K. (59%)	Belgium (0%); Sweden (13%); Portugal (14%); Italy (17%)
Procedures ensure that the functionality, strengths, and weaknesses of the business system the software is replacing are formally reviewed (24%)	Netherlands (54%); Denmark (40%)	Norway (0%); Sweden (13%); Greece (13%); Italy (13%)
Test planning prior to programming based on user requirements and high-level design documents (52%)	U.K. (78%); Switzerland (67%); Ireland (67%)	Portugal (29%); Belgium (36%); Greece (37%)
Independent testing conducted by users under guidance of software quality assurance before the system goes live (51%)	U.K. (78%); Ireland (67%); France (66%)	Spain (30%); Belgium (36%)
A procedure to check that the system configuration passing user acceptance testing is the same as the one implemented for live operation and that no changes are made directly to a live system (60%)	U.K. (85%); Austria (75%)	Belgium (36%); Sweden (38%); Denmark (40%)

training all newly appointed software managers. A lower proportion (38%) have established procedures for maintaining awareness of the state of the art in software engineering technology. Establishing these procedures contrasts with the importance (70%) of training staff, as found by an earlier survey [12].

The Mann-Whitney U test [9] was used to test whether there were statistically significant differences between the practice levels of the various countries.[1] Statistically significant differences were found between several pairs of high- and low-adoption countries, such as the U.K. and Belgium.

Analyses of the specific practice levels for each country revealed several differences across countries. Table 1 summarizes countries with high and low adoption levels for each SMP relative to the average practice levels (computed across all responding organizations). However, countries with adoption levels close to the average practice level for a specific SMP are not listed in Table 1.[2]

Standards and procedures practices. An analysis of all companies reveals that a majority (74%) have established procedures to formally assess the benefits, viability, and risk of software projects and conduct periodic reviews (81%) of the status of software projects. Common coding standards for each project are relatively popular (66%) for companies, and formal methods are often (51%)

[1]The Mann-Whitney U test is the most powerful nonparametric alternative to the t-test for independent samples and is well suited to the sample sizes considered in our data set.

[2]This convention is also used in Tables 2–5.

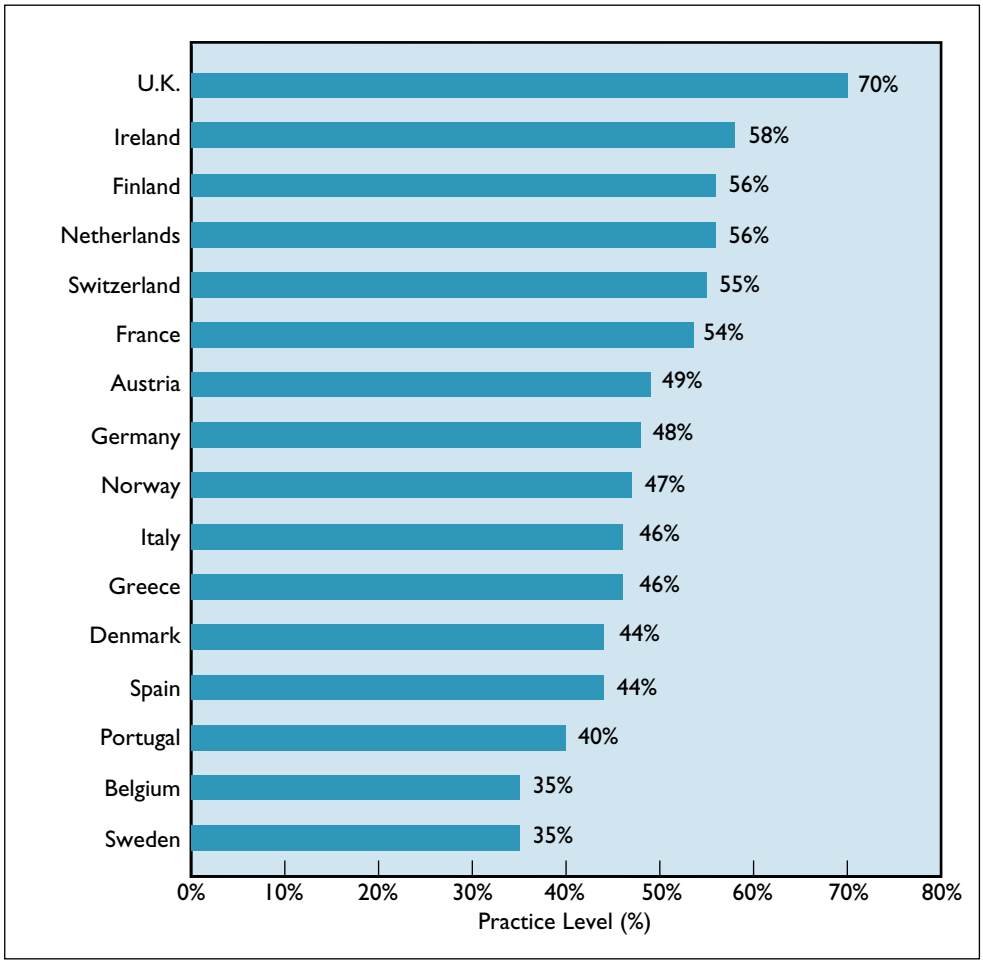


Figure 2. Standards and procedures (practice levels by country)

used to estimate schedules and costs. These figures are consistent with other findings (for example, Azuma and Mole [1] found that over 65% of their surveyed organizations had standards for all stages of the lifecycle). An ESI study [12] also found that a large proportion (>90%) of companies viewed standards as critical for quality and productivity improvement.

However, fewer companies (36%) ensure that software projects selected for development actually support their business objectives, and even fewer (24%) rethink the functionality, strengths, and weaknesses of their business systems (such as clerical procedures) before automating them with the software system. Thus, there seems to be a trend of automating existing procedures without adequately focusing on reengineering them to align with the organization's strategic objectives. This was partly confirmed by an earlier study [12] that found a low degree of user involvement in business reengineering projects.

The variation of overall practice levels for standards and procedures across countries is shown in Figure 2. A similar set of countries lead (the U.K., Finland, and Ireland) and lag (Belgium, Sweden, Portugal, and Spain) the practice levels in Figures 1 and 2. Mann-Whitney U tests [9] again showed statistically highly significant differences between pairs of high and low practice levels, such as between the U.K. and Sweden. A further breakdown of the adoption of specific standards and procedures practices across countries is summarized in Table 2.

Metrics practices. Tracking and performance metrics are generally used more widely by organizations than are testing and estimation metrics, a trend confirmed by Rubin in 1995 [11]. About half (56%) of the organizations responding to our survey's SMP questionnaire (SMPQ) track actual project costs and times against estimates. Only 10% of the responding organizations systematically gather and analyze data for testing all stages of the development process. While many organizations emphasize planning of the testing process (see Figure 2), they do not manage the process with explicit metrics. There is a focus on postimplementation problem tracking, with 75% of all companies reporting that they logged and analyzed postimplementation software problems and their resolution.

The use of metrics-related practices in various countries is shown in Figure 3. For example, French companies have the highest practice levels for metrics. Germany seems to have a lower overall practice level compared to its relative position in Figure 2. The overall adoption for metrics-related practices for all countries is lower than for the previously mentioned practices. Low use of these practices is in agreement with the observation by Azuma and Mole [1] of low use of metrics in European companies, with most companies reporting they use only a few metrics. Our

Table 3. Metrics (countries with high and low practice levels)

Software management practices (average levels)	Countries with high practice levels	Countries with low practice levels
Records of actual project resourcing and timescales vs. estimates maintained and fed back into the estimation process (56%)	Sweden (75%); Netherlands (69%)	Greece (43%); Portugal (43%); Ireland (44%)
Records of software size maintained for each software configuration item and fed back into the estimation process (16%)	France (43%); Switzerland (33%)	Sweden (0%); Belgium (0%); Finland (8%)
Statistics on the sources of errors in software code gathered and analyzed for their cause, detection, and avoidance measures (28%)	Finland (62%); U.K.(41%)	Belgium (9%); Denmark (13%); Sweden (13%)
Statistics on test efficiency gathered and analyzed for all testing stages in the development process (10%)	Ireland (44%); Finland (23%)	Belgium (0%); Norway (0%); Portugal (0%); Sweden (0%)
"Earned value"* project tracking throughout the software development process (34%)	Finland (69%); Sweden (60%); U.K. (52%)	Portugal (0%); Belgium (18%)
Estimates made and compared with actuals for target computer performance (48%)	France (66%); Austria (63%); Sweden (63%); Finland (62%)	Portugal (29%)
Post-implementation software problem reports logged and their resolution tracked and analyzed (75%)	U.K. (96%); Austria (88%)	Sweden (63%)
Records from which all current versions of software systems can be quickly and accurately reconstructed in the development environment (64%)	U.K. (93%); France (89%)	Portual (43%); Belgium (45%); Spain (45%)

* = Actual vs. planned deliverables analyzed, designed, unit tested, system tested, acceptance tested over time

survey found statistically significant differences in the practice levels of countries with high and low overall adoption levels, such as France and Portugal. We also performed an analysis (see Table 3) to identify countries with high and low adoption levels for specific metric management practices.

Development process control practices. We observed an average level of adoption of SMPs among all organizations for controlling the development process. About half (52%) of the responding companies require the business project manager to gain agreement and sign-off from all relevant parties before publishing or revising a consolidated project plan. A significant proportion of organizations have established procedures for controlling changes to software requirements (60%) and to the software code itself (60%).

Figure 4 shows the overall adoption levels across countries for practices in the control of the development process. There are no changes in the list of countries with high and low adoption levels, except for Greece in the third position and a significant drop by the Netherlands relative to its place in Figures 1–3. The Mann-Whitney U test was used to confirm that the differences between the practice levels of countries with high and low adoption rates were significant. For example, the difference between the practice levels of the U.K. and Portugal was found to be significant. Countries with particularly high and low adoption levels for each specific management practice are highlighted in Table 4.

Tools and technology practices. A majority of responding companies (68%) use software tools for project planning, estimating, scheduling, and critical path analysis. Our observation about the proportion of companies using automated tools for software process control are similar to those found by Rubin [11]. Prototyping methods for ensuring software requirements were used by 58% of reporting organizations, considerably higher than the percentage (40%) observed in an earlier ESI study [12].

The use of automated tools for testing is not widespread. A small proportion (25%) of the responding companies used software tools to ensure coverage of all logic paths, and even fewer organizations (19%) use such tools to assist in forward and backward tracing of software requirements to software designs through to code. Our observations on the proportion of organizations using automated tools for testing are similar to those found by Rubin.

Figure 5 shows the variation in the practice levels across countries. Comparing the relative positions of the surveyed countries, it is interesting to note that the Netherlands, France, and Denmark have considerably higher positions in this section than in the previous sections in the SMPQ. In contrast, Ireland and Switzerland are considerably lower than in the

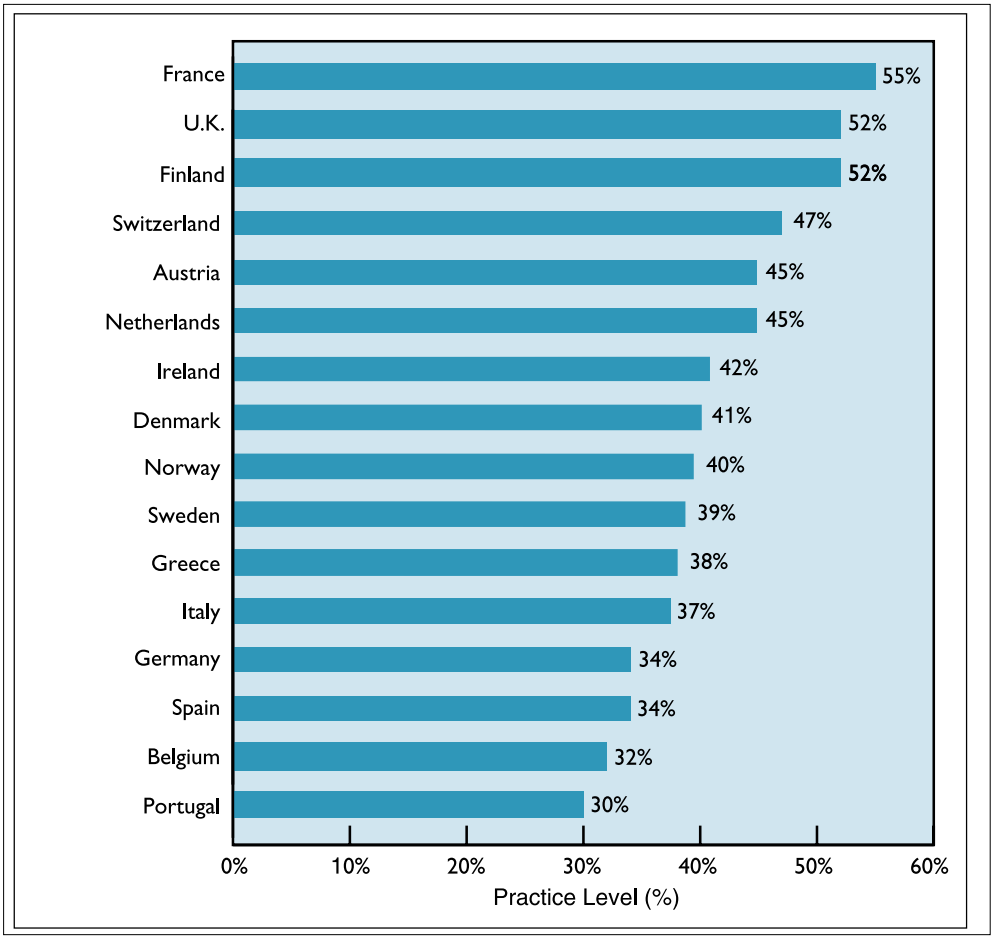


Figure 3. Metrics (practice levels by country)

Table 4. Control of the development process (countries with high and low practice levels)

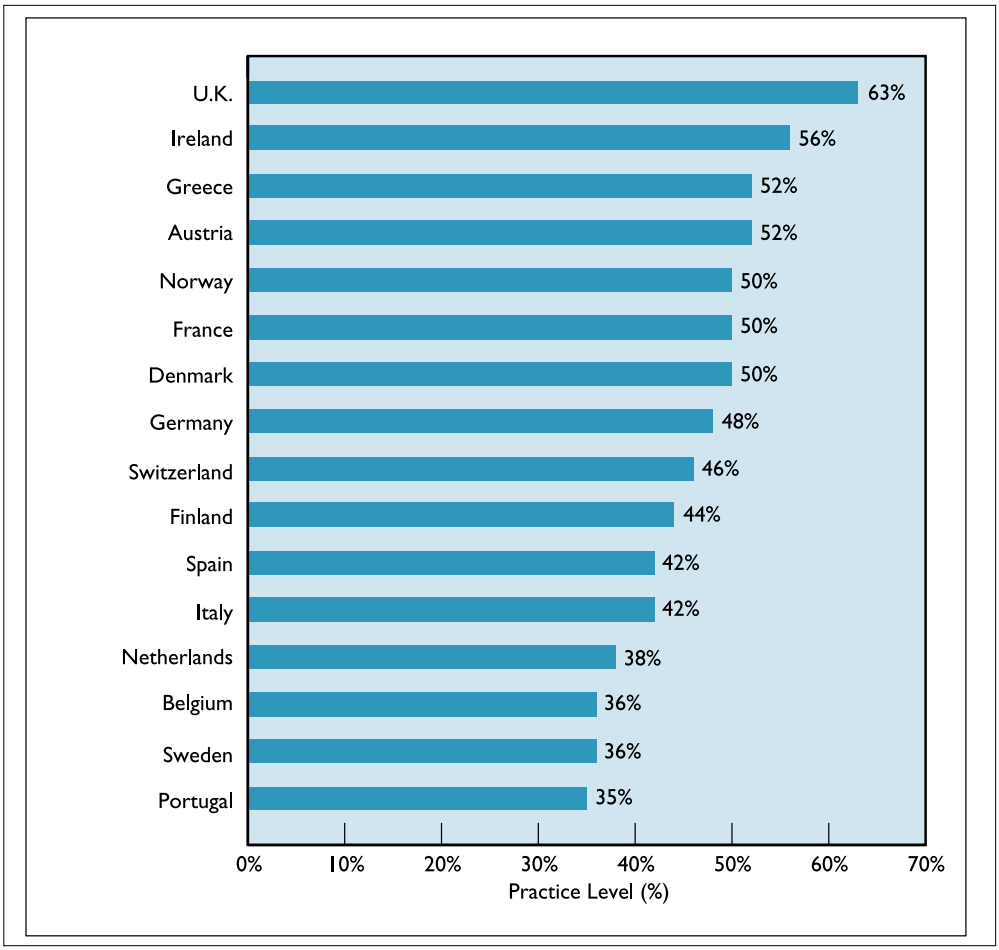
Software management practices (average levels)	Countries with high practice levels	Countries with low practice levels
Estimates, schedules, and subsequent changes made only by project managers with direct control of project resources (73%)	Austria (100%); U.K. (93%)	Denmark (45%); Portugal (57%)
Business project manager obtains agreement and sign-off from all parties before publishing or revising a consolidated project plan (52%)	Switzerland (73%); U.K. (70%)	Sweden (25%); Portugal (29%) Austria (38%); Holland (38%)
Procedures for controlling changes to software requirements, designs, and documentation (60%)	U.K. (85%); Demark (80%); Austria (75%)	Belgium (27%); Sweden (38%); Switzerland (40%)
Procedures for controlling changes to the code (62%)	Netherlands (92%); Austria (88%); U.K. (81%)	Portugal (29%); Sweden (38%)
Regression testing routinely performed during and after initial implementation (25%)	Greece (47%); U.K. (44%); Norwat (40%)	Netherlands (0%); Finland (8%); Belgium (9%)
Procedures to ensure that every required function is tested/verified (51%)	Ireland (78%); U.K. (70%)	Netherlands (15%); Finland (31%); Belgium (36%)

previous sections in the SMPQ. Mann-Whitney U tests were again used to confirm statistically significant differences between countries with high and low practice levels, such as the U.K. and Sweden.

Countries' aggregate practice levels. The variation in the aggregate (all five sections of the SMPQ) for the various countries is shown in Table 5. The U.K. leads in most practices in the SMPQ. France and Ireland have contrasting strengths and weaknesses. Finland is relatively weak in the control of the development process and the use of tools. The Netherlands is particularly weak in the control of the development process. Countries with high aggregate adoption levels tend to use more SMPs related to organizational issues, standards and procedures, and metrics. Portugal, Belgium, and Sweden lag in the overall adoption levels, with relative weaknesses in standards and procedures and in control of the development process. Germany's low ranking is surprising but consistent with earlier research [8].

Mann-Whitney U tests were used to confirm statistically significant differences

Figure 4. Control of the development process (practice levels by country)



between countries with high aggregate adoption levels (such as between the U.K. and France) and those with low aggregate adoption levels (such as Portugal, Belgium, and Sweden). There are no statistically significant differences between countries with high aggregate adoption levels, such as France and the U.K. or Ireland and the U.K.

Implications of the Survey's Results

Our results are interesting because it is the first published study of SMPs across countries within Europe. The SMPQ was readministered and we are now analyzing the aggregate data set. A trend analysis of SMP adoption levels over several years will give us a more in-depth understanding of the SMP adoption rates across countries.

By country. Competence in software development is commonly regarded as critical to the competitiveness of nations. Thus, a longitudinal trace of practice levels is important for policy makers in governmental bodies and decision makers in organizations. An understanding of the adoption levels of SMPs can be used by policy makers to decide where to direct government-sponsored research efforts.

An important conclusion from our study is that there are significant differences in the adoption levels of SMPs across European countries. These differences argue against the prevalent trend in the literature [1] and in unpublished studies [11, 12] to group all European countries for analyses. Such a view can have important managerial consequences. For example, North American firms considering setting up software-intensive operations in Europe have to differentiate among European locations. Choosing a particular European country for an offshore site requires special attention to the weaknesses of the software practices in the chosen country.

The results of our survey show that there are leading (such as the U.K., France, Ireland, and Finland) and lagging (such as Portugal, Belgium, and Sweden) countries with respect to the adoption levels of SMPs. Countries with high aggregate adoption levels tend to have adopted more practices related to organizational issues, standards and procedures, and metrics. This knowledge of the relative strengths and weaknesses in the adoption levels of European countries can motivate coordination of the transfer of best practices across European firms. For example, Portuguese organizations can learn from U.K. firms how to improve their SMPs.

Our investigation sought to identify the drivers for the differences in adoption levels of countries with the highest (U.K.) and lowest (Sweden) practice levels. For example, a major driver was found to be the higher adoption in the U.K. of practices related to standards and procedures. The U.K. emphasizes procedures for estimating and tracking different aspects of projects and for controlling

changes to the code and specifications. Effective project management is viewed as a key strength of many European countries, such as the U.K. and France, in earlier studies [8]. The relevance of software projects in the U.K. increases when they are linked to an organization's strategic goals and when all stakeholders are involved in the project planning process. The use of common standards, prototyping, and design notations also seems to be helpful.

By company. Our analyses of the survey data have shown relatively low to average aggregate practice levels for the surveyed organizations. As the questions in the SMPQ are relatively balanced across different categories, these low practice levels indicate room for improvement in software processes within European firms. Such a conclusion is not surprising and is consistent with concerns raised in the literature [6, 7]. Although our study did not present proof of causality between adoption of the surveyed practices and improved software performance, increased value through improved software process maturity is documented in the literature [5, 7, 10].

Managers can use the results of our study to develop a better understanding of the practice levels in their own organizations relative to those of other organizations. By checking their adoption of the SMPs listed in Tables 1–4, managers can benchmark their own adoption levels against the results of our study. While this benchmarking is incomplete (for example, there is no direct correlation between the adoption of SMPs and good business performance in companies responding to our survey) and subject to errors (such as those caused by biases in the survey sample), it can provide a useful start for assessment and improvement.

To further explore these implications and identify areas for future emphasis, we ranked companies in decreasing order of their aggregate practice levels and then divided them into three groups:

- The 100 companies with the highest levels of adoption in the high-adoption group
- The 100 companies with the lowest levels in the low-adoption group
- The rest in the medium-adoption group

The high-adoption group had a mean practice level of 75.9% (standard deviation 7.7%), and the low-adoption group had a mean practice level of 21.5% (standard deviation 7.1%). The difference between the mean practice levels of these two groups was found to be statistically highly significant. The mean adoption levels of the high- and low-adoption groups for each SMP were compared to identify areas where the groups diverged. We found that the largest differences occurred for the following SMPs:

- Risk and viability assessment of projects prior to making commitments
- Procedures for effort, schedule, and cost estimation
- Independent quality assurance functions
- Procedures for handoff from one group to another
- Inspections and walkthroughs for each major stage of the development process
- Testing prior to the start of coding
- Mechanisms for controlling changes to code, software requirements, designs, and documentation

The drivers of the differences between the high-and

Table 5. Aggregate practice levels by country

Country	Aggregate Practice Levels	Relative Ranking by Country for Each Section of the SMP Questionnaire				
		Organization	Standards and Proc.	Metric	Develop. Process	Tools and Tech
U.K.	65%	1	1	2	1	1
France	55%	5	6	1	5	3
Ireland	54%	2	2	7	2	12
Finland	54%	2	3	2	10	9
Netherlands	52%	5	3	5	13	2
Austria	52%	5	7	5	3	5
Switzerland	52%	4	5	4	9	12
Denmark	49%	8	12	8	5	4
Greece	47%	11	11	11	3	10
Norway	47%	14	9	9	5	7
Germany	47%	9	8	13	8	7
Italy	45%	9	10	12	11	12
Spain	43%	13	12	13	11	15
Portugal	41%	11	14	16	16	11
Belgium	40%	15	15	15	14	6
Sweden	38%	15	15	10	14	16

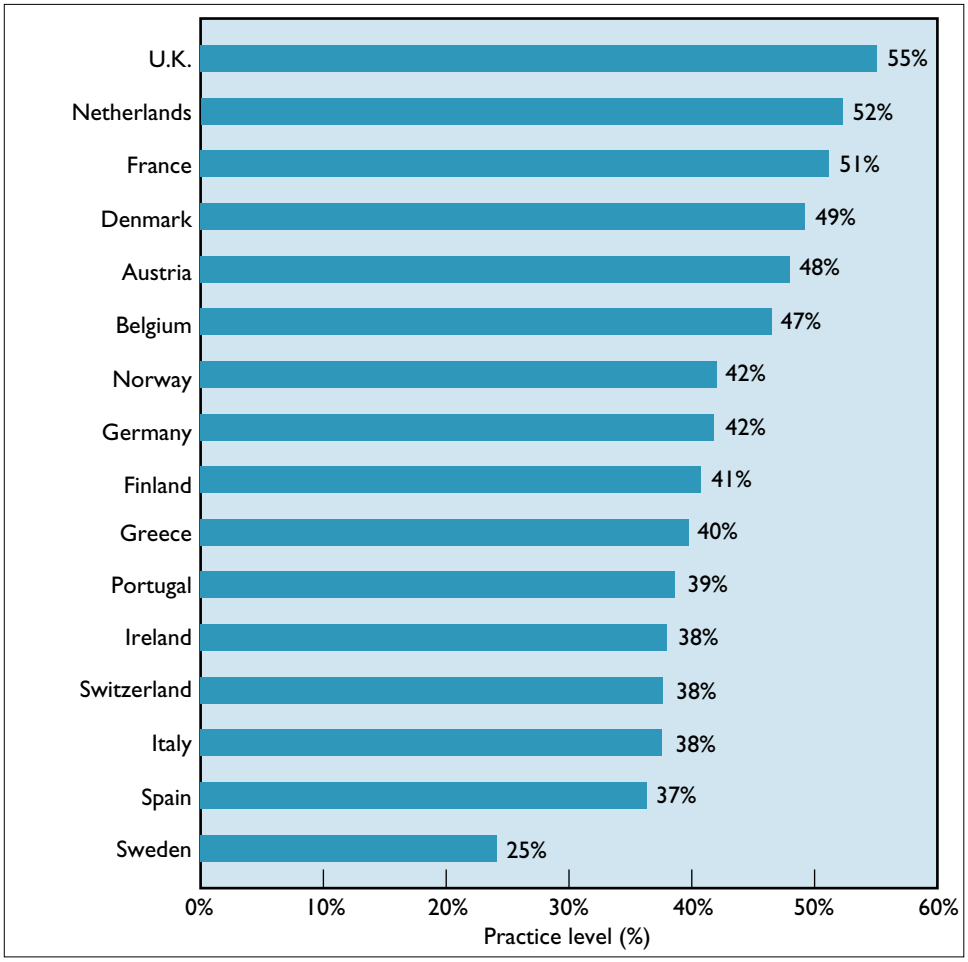


Figure 5. Tools and technology (practice levels by country)

low-adoption groups tend to cluster around appropriate standards for tracking, estimating, and inspecting different aspects of the project. Change control and quality assurance functions also seem to be critical. However, the use of metrics and automated tools for testing and development do not figure as primary reasons for the different adoption levels. This lack of metrics and tools is probably due to the low overall level of adoption of these practices within all organizations and cannot be interpreted as indicative of the degree of relevance of these practices.

Conclusions

The results of our survey should be treated with some caution. The SMPQ was designed to determine practice-existence scores, not adequacy ratings. Thus, an organization's answering yes to a particular question does not measure the capability [5] or adequacy of the organization's implementation of that specific practice. It is quite possible (and likely) that the actual capabilities of the responding organizations for the different software practices is lower than what would be suggested by the ratings we derived. Moreover, many organizations may have adopted certain practices on paper and then answered questions in the affirmative, even though they may not have actually implemented the practices. And because some countries were represented by small samples, our findings for the adoption levels of practices in these countries need further verification.

While more research needs to be done to further validate these results, our survey and evaluation and this article provide a useful start for future study. C

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