# SEXTAMT:A map to navigate the lands of factors affecting expert judgment software estimates

## **Supplementary material**

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### **Definition of the known set of papers**

To choose the oracle, we performed the following procedures, leading to a set of 25 papers:

* We evaluated the 32 selected papers in the SLM by Basten and Sunyaev [1] using our inclusion and exclusion criteria, selecting 23 papers. The papers we excluded were related to estimation methods outside the scope of expert judgment (six), inaccessible to us (one), available in book or grey literature (one), or were a duplicate article (one).
* We added one paper that we knew was relevant to the research topic from previous analysis about the topic.
* We performed an automated broad search in three known venues in Software Engineering: The Journal of Systems and Software (JSS), Information and Software Technology (IST) and IEEE Transactions on Software Engineering (TSE). This search was restricted to the period between 2015 and 2019. The search string used “(estimate OR estimation) AND (effort OR cost OR duration OR schedule OR size)”. We added one additional paper to our resulting from this search.

The inclusion criterion to select the known set of papers was IC01 – The paper presents an empirical study that investigates factors that affect software project estimates related to expert judgment. The exclusion criteria were:

* EC01 – The paper presents a systematic mapping/review, lessons learned, or opinion paper, rather than an empirical study on factors that affect software project estimates related to expert judgment;
* EC02 – The paper focus on factors affecting estimates related to estimation methods other than expert judgment;
* EC03 – The paper presents non-peer-reviewed results;
* EC04 – The paper is not written in English;
* EC05 – The paper is not accessible in full-text online;
* EC06 – The study is published as a book or grey literature;
* EC07 – The paper is a duplicate or a previous version of another already selected paper;
* EC08 – The paper does not describe the factors to allow for categorization.

### **Known set of papers inclusion and exclusion**

In **Table I** we show all the articles we considered for inclusion in our known set of papers. It describes the origin of the article, the reference, and the exclusion criteria we applied in the case we excluded the article.

**Table I - Articles considered for the known set of papers**

| **Origin** | **Paper** | **Exclusion Criteria** |
| --- | --- | --- |
| Previous SLM | Aranda, J., and S. Easterbrook (2005) “Anchoring and Adjustment in Software Estimation”, ACM SIGSOFT Software Engineering Notes, (30)5, pp. 346–355. | **-** |
| Previous SLM | Connolly, T., and D. Dean (1997) “Decomposed versus Holistic Estimates of Effort Required for Software Writing Tasks”, Management Science, (43)7, pp. 1029–1045. | **EC 05** |
| Previous SLM | Furulund, K.M., and K. Moløkken-Østvold (2007) “Increasing Software Effort Estimation Accuracy―Using Experience Data, Estimation Models and Checklists” in IEEE Computer Society (ed.) Proceedings of the Seventh International Conference on Quality Software, New York: IEEE Computer Society Press, pp. 342– 347. | **-** |
| Previous SLM | Glass, R.L., J. Rost, and M.S. Matook (2008) “Lying on Software Projects”, IEEE Software, (25)6, pp. 90–95. | **-** |
| Previous SLM | Gray, A.R., S.G. MacDonell, and M. Shepperd (1999) “Factors Systematically Associated with Errors in Subjective Estimates of Software Development Effort: The Stability of Expert Judgment” in IEEE Computer Society (ed.) Proceedings of the Sixth International Software Metrics Symposium, New York: IEEE Computer Society Press, pp. 216–227. | **-** |
| Previous SLM | Grimstad, S., and M. Jørgensen (2007) “Inconsistency of Expert Judgment-based Estimates of Software Development Effort”, Journal of Systems and Software, (80)11, pp. 1770–1777. | **-** |
| Previous SLM | Grimstad, S., M. Jørgensen, and K. Moløkken-Østvold (2005) “The Clients’ Impact on Effort Estimation Accuracy in Software Development Projects” in IEEE Computer Society (ed.) Proceedings of the 11th IEEE International Software Metrics Symposium, New York: IEEE Computer Society Press, pp. 4–13. | **-** |
| Previous SLM | Jørgensen, M. (2004b) “Regression Models of Software Development Effort Estimation Accuracy and Bias”, Empirical Software Engineering, (9)4, pp. 297–314. | **EC 07** |
| Previous SLM | Jørgensen, M. (2004c) “Top-down and Bottom-up Expert Estimation of Software Development Effort”, Information and Software Technology, (46)1, pp. 3–16. | **EC 02** |
| Previous SLM | Jørgensen, M. (2010) “Identification of More Risks Can Lead to Increased Over-optimism of and Over-confidence in Software Development Effort Estimates”, Information and Software Technology, (52)5, pp. 506–516. | **-** |
| Previous SLM | Jørgensen, M., B. Faugli, and T.M. Gruschke (2007) “Characteristics of Software Engineers with Optimistic Predictions”, Journal of Systems and Software, (80)9, pp. 1472–1482. | **-** |
| Previous SLM | Jørgensen, M., and S. Grimstad (2008) “Avoiding Irrelevant and Misleading Information When Estimating Development Effort”, IEEE Software, (25)3, pp. 78–83. | **-** |
| Previous SLM | Jørgensen, M., and T.M. Gruschke (2009) “The Impact of Lessons-learned Sessions on Effort Estimation and Uncertainty Assessments", IEEE Transactions on Software Engineering, (35)3, pp. 368–383. | **-** |
| Previous SLM | Jørgensen, M., and T. Halkjelsvik (2010) “The Effects of Request Formats on Judgment-based Effort Estimation”, Journal of Systems and Software, (83)1, pp. 29–36. | **-** |
| Previous SLM | Jørgensen, M., and K. Moløkken (2003) “Situational and Task Characteristics Systematically Associated with Accuracy of Software Development Effort Estimates” in Information Resources Management Association (ed.) Proceedings of the Information Resources Management Association Conference, Hershey, PA: Information Resources Management Association, pp. 824–826. | **EC06** |
| Previous SLM | Jørgensen, M., and K. Moløkken-Østvold (2004) “Reasons for Software Effort Estimation Error: Impact of Respondent Role, Information Collection Approach, and Data Analysis Method”, IEEE Transactions on Software Engineering, (30)12, pp. 993–1007. | **-** |
| Previous SLM | Jørgensen, M., and D.I.K. Sjøberg (2001) “Impact of Effort Estimates on Software Project Work”, Information and Software Technology, (43)16, pp. 939–948. | **-** |
| Previous SLM | Jørgensen, M., and D.I.K. Sjøberg (2004) “The Impact of Customer Expectation on Software Development Effort Estimates”, International Journal of Project Management, (22)4, pp. 317–325. | **-** |
| Previous SLM | Lederer, A.L., R. Mirani, B.S. Neo, C. Pollard, J. Prasad, and K. Ramamurthy (1990) “Information System Cost Estimating: A Management Perspective”, MIS Quarterly, (14)2, pp. 159–176. | **-** |
| Previous SLM | Lederer, A.L., and J. Prasad (1995) “Causes of Inaccurate Software Development Cost Estimates”, Journal of Systems and Software, (31)2, pp. 125–134. | **-** |
| Previous SLM | Lederer, A.L., and J. Prasad (2000) “Software Management and Cost Estimating Error”, Journal of Systems and Software, (50)1, pp. 33–42. | **-** |
| Previous SLM | Magazinović, A., and J. Pernstål (2008) “Any Other Cost Estimation Inhibitors?” in ACM (ed.) Proceedings of the Second ACM-IEEE International Symposium on Empirical Software Engineering and Measurement, New York: ACM Press, pp. 233–242. | **-** |
| Previous SLM | McDonald, J. (2005) “The Impact of Project Planning Team Experience on Software Project Cost Estimates”, Empirical Software Engineering, (10)2, pp. 219–234. | **-** |
| Previous SLM | Moløkken-Østvold, K., and K.M. Furulund (2007) “The Relationship Between Customer Collaboration and Software Project Overruns”, Proceedings of AGILE 2007 Conference, pp. 72–83. | **-** |
| Previous SLM | Moløkken-Østvold, K., and M. Jørgensen (2005a) “A Comparison of Software Project Overruns―Flexible Versus Sequential Development Models”, IEEE Transactions on Software Engineering, (31)9, pp. 754–766. | **-** |
| Previous SLM | Moløkken-Østvold, K., and M. Jørgensen (2005b) “Expert Estimation of Web-development Projects: Are Software Professionals in Technical Roles More Optimistic Than Those in Non-technical Roles?”, Empirical Software Engineering, (10)1, pp. 7–29. | **-** |
| Previous SLM | Morgenshtern, O., T. Raz, and D. Dov (2007) “Factors Affecting Duration and Effort Estimation Errors in Software Development Projects”, Information and Software Technology, (49)8, pp. 827–837. | **-** |
| Previous SLM | Prechelt, L., and B. Unger (2000) “An Experiment Measuring the Effects of Personal Software Process (PSP) Training”, IEEE Transactions on Software Engineering, (27)5, pp. 465–472. | **EC 02** |
| Previous SLM | Rombach, D., J. Münch, A. Ocampo, W.S. Humphrey, and D. Burton (2008) “Teaching Disciplined Software Development”, Journal of Systems and Software, (81)5, pp. 747–763. | **EC 02** |
| Previous SLM | Subramanian, G.H., and S. Breslawski (1995) “An Empirical Analysis of Software Effort Estimate Alterations”, Journal of Systems and Software, (31)2, pp. 135–141. | **EC 02** |
| Previous SLM | van Genuchten, M. (1991) “Why Is Software Late? An Empirical Study of Reasons for Delay in Software Development”, IEEE Transactions on Software Engineering, (17)6, pp. 582–590. | **EC 02** |
| Previous SLM | Wesslén, A. (2000) “A Replicated Empirical Study of the Impact of the Methods in the PSP on Individual Engineers”, Empirical Software Engineering, (5)2, pp. 93–123. | **EC 02** |
| Selected by us | Magazinius, A., Börjesson, S., and Feldt, R. (2012) "Investigating intentional distortions in software cost estimation - An exploratory study", Journal of Systems and Software, (85), pp. 1770-1781. | **-** |
| Automatic broad search | Conoscenti, M., Besner, V., Vetrò, A., Fernández, D. M. (2019) "Combining data analytics and developers feedback for identifying reasons of inaccurate estimations in agile software development", Journal of Systems and Software,156, pp. 126-135. | **-** |

### **Extraction form and complete data extraction**

The extraction form and the complete data extraction is available on the file Data extraction forms.xlsx under the same DOI as the current document.

### **Codes, intermediary factors, and factors**

**Table II** exemplifies two factors, showing both the structure of the candidate factors’ code, the intermediary factor (when existent), and the final factor label.

**Table II - Examples of factors**

|  |  |  |
| --- | --- | --- |
| **Factor** | **Factor (intermediary)** | **Example of code for the candidate factor** |
| Pressure | Overall pressure | **The survival pressure and business pattern of the company** is a **reason for inaccurate estimates.** |
| Customer pressure | **Pressure from senior manager[[2]](#footnote-2) and the client to set or change the estimation results** is a **reason for inaccurate estimates.** |
| Management pressure | **There are intentional decreases in software estimates** due to **management pressures.** |
| Schedule pressure | **Schedule pressure leads to more effort.** |
| - | **The sequence of the tasks to estimate** **have a statistically significant effect on their estimated effort** . |
| Sequence effect |  |  |

The complete set of categories, factors, intermediary factors, and codes is on the file factors.xlsx under the same DOI as the current document.

### **Underexplored lands: factors reported in one article only**

In Table III we present all the factors reported in one article only, also showing their category and the research strategy employed. The respondent strategy is associated with 71 factors; the field strategy is associated with 62 factors; the laboratory strategy is associated with 17 factors; and the data strategy is associated with 16 factors.

Table III - Factors from unique articles.

| **Category** | **Factor** | **Research strategy** |
| --- | --- | --- |
| Client and user issues | Competence in decision making [2] | Respondent |
| Client's mapped procedures [3] | Respondent |
| Realism of expectations [4] | Field |
| Data processing understanding [5] | Respondent |
| Too much feedback [6] | Field |
| The client itself [7] | Data |
| Environment issues | Amount and duration of interruptions [8] | Field |
| Culture [9] | Respondent |
| Feedback and learning opportunities [4] | Field |
| Unexpected events | Errors [10] | Respondent |
| Occurrence of foreseeable problems [10] | Respondent |
| Synergy effects [4] | Field |
| Mismatch between expected and real productivity [11] | Respondent |
| Political issues | Forcing to stay within the estimate [5] | Respondent |
| Bureaucracy [5] | Respondent |
| Bidding situations [12] | Field |
| Negotiations [13] | Field |
| Estimates interpreted as commitments [14] | Field |
| Resource assurance [15] | Field |
| Hiding activities [15] | Field |
| Team issues | Cooperation [14] | Field |
| Coordination [16] | Field |
| Cohesion [17] | Respondent |
| Expertise of new team members [18] | Field |
| Team maturity [18] | Field |
| New team formations [19] | Field |
| Knowledge sharing [20] | Respondent |
| Team guidance [20] | Respondent |
| Velocity [20] | Respondent |
| Team process experience [21] | Respondent |
| Individual issues | Software developer role [4] | Field |
| Project manager role [4] | Field |
| Insufficient focus on project manager role [4] | Field |
| The technical background of the role [22] | Laboratory |
| Plant team role [23] | Field |
| Implementer team role [23] | Field |
| Analogical-like versus algorithmic-like [24] | Laboratory |
| Considering the best case scenario only [20] | Respondent |
| Recalling past effort usage [25] | Laboratory |
| Handedness [26] | Laboratory |
| Biases | Selection bias [27] | Laboratory |
| Interdependence [28] | Laboratory |
| Group polarization [29] | Laboratory |
| Format [30] | Laboratory |
| Skill issues | Knowledge about satisfying the requirements [4] | Field |
| Overall skill [20] | Respondent |
| Higher skill than expected [4] | Field |
| Technical knowledge [3] | Respondent |
| Managerial skill [21] | Respondent |
| Experience | Software development experience [20] | Respondent |
| Developer experience [17] | Respondent |
| Domain experience [31] | Respondent |
| Higher average team experience [32] | Data |
| Attitudes and maturity | Motivation [33] | Respondent |
| Commitment [3] | Respondent |
| Management | Risk management [34] | Respondent |
| Replanning [35] | Respondent |
| Participative management style [36] | Data |
| Lessons learned from past projects [3] | Respondent |
| Accountability for estimates [37] | Respondent |
| Accuracy considered during performance reviews [5] | Respondent |
| Project management [4] | Field |
| Project planning [4] | Field |
| Coordination of functions [5] | Respondent |
| Change management | Impact analysis [10] | Respondent |
| Change control [20] | Respondent |
| Process issues | Use of standard Scrum [9] | Respondent |
| Standardization of processes [4] | Field |
| Process maturity [14] | Field |
| Requirements | Quality of requirements [2] | Respondent |
| Abstract language in business cases [38] | Data |
| Requirements' change management process [4] | Field |
| Epics [39] | Field |
| Rejection of the implemented functionality [39] | Field |
| Overlooking non-functional requirements [20] | Respondent |
| Realism of requirements [4] | Field |
| Gold plating [39] | Field |
| Business domain instability [40] | Field |
| Lack of detail in requirements [18] | Field |
| Backlog items complexity [21] | Respondent |
| Knowledge of backlog items [21] | Respondent |
| Item priority [21] | Respondent |
| Testing and rework | Test planning [41] | Field |
| Unavailability of external parties for testing [41] | Field |
| Insufficient time for testing [5] | Respondent |
| Ignoring the testing effort [20] | Respondent |
| Indecisiveness in processing user feedback [41] | Field |
| Need for testing [21] | Respondent |
| Test data quantity [8] | Field |
| Existence of more bugs [41] | Field |
| Defect reproducibility [17] | Respondent |
| Perception of defect criticality [17] | Respondent |
| Code coverage [17] | Respondent |
| Required test coverage [8] | Field |
| Number of test cases [8] | Field |
| Perceived negative attitudes about testing [41] | Field |
| Product characteristics | Library and tools availability [21] | Respondent |
| Prototype design [21] | Respondent |
| Reuse [21] | Respondent |
| Presentation interface [7] | Data |
| Development mode [42] | Data |
| Project and task characteristics | High priority on time-to-delivery [4] | Field |
| High priority on quality [4] | Field |
| Priorities of features [18] | Field |
| The software development model [43] | Respondent |
| Core application projects [36] | Data |
| Realistic plans and budgets [2] | Respondent |
| Problems with allocation of resources [4] | Field |
| Shared pool of resources [13] | Field |
| Project definition changes [44] | Data |
| Use of uncertain estimates as baselines [40] | Field |
| Project/task duration [45] | Data |
| Shared project vision [14] | Field |
| Strict time to delivery [9] | Respondent |
| Project domain [20] | Respondent |
| Task clarity [21] | Respondent |
| Deadline [21] | Respondent |
| Budget [21] | Respondent |
| Project priority [7] | Data |
| Concurrency of tasks [17] | Respondent |
| Higher risk projects [7] | Data |
| More consultants in the project [7] | Data |
| Use of 3G environments [45] | Data |
| Use of report generation tools [45] | Data |
| Changes to the technology [33] | Respondent |
| Estimation process | Annotation of stories [46] | Laboratory |
| Estimation of ideal effort prior to estimation of most likely effort [47] | Laboratory |
| Estimation of most likey effort prior to estimation of ideal effort [47] | Laboratory |
| Knowledge of participants of the project [3] | Respondent |
| Involvement of mature teams [18] | Field |
| Involvement of estimators not participating in the project [4] | Field |
| Customer involvement [20] | Respondent |
| Combination strategy of estimates of individual tasks [48] | Data |
| Coordination of stakeholders in estimation [18] | Field |
| Estimations by one person only [14] | Field |
| Test estimates made by testing specialist [41] | Field |
| Combination of estimation methods [49] | Data |
| Estimation process complexity [40] | Field |
| Use of expert judgement alone [11] | Respondent |
| Justificatives for estimates [4] | Field |
| Examination of past estimation performance [5] | Respondent |
| Examination of estimates by management [5] | Respondent |
| Estimation tools [34] | Respondent |
| Overlooking HCI and graphics design during estimation [4] | Field |
| Use of Fibonacci scale [50] | Laboratory |
| Estimation goals [13] | Field |
| Variation on the meaning of an estimate [51] | Laboratory |
| Debiasing workshop [52] | Laboratory |
| Performance in previous estimates | Lessons learned from past estimates [10] | Laboratory |
| Estimation errors in previous tasks [25] | Laboratory |
| Less confidence of previous accuracy [4] | Field |
| Organizational issues | Organizational dependencies [53] | Field |
| Distributed development | Multiple development sites [18] | Field |
| Number of development sites [20] | Respondent |
| Time differences [43] | Respondent |
| Geographical locations [21] | Respondent |
| Negative attitudes towards estimation | Negative attitudes towards estimation [14] | Field |
| None | Interaction with competitors [54] | Laboratory |
| Luck [10] | Respondent |
| Intention to avoid overspending [15] | Field |
| Completing more projects [55] | Respondent |
| The uncertainty level [43] | Respondent |
| Quality issues | Technical quality [21] | Respondent |
| Availability of documentation [17] | Respondent |
| Maintainability [17] | Respondent |
| Code volatility [17] | Respondent |

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2. In this case, the code also contributes to the management pressure intermediary factor. [↑](#footnote-ref-2)