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Identifying Internal and External Forces That Reduce the Accuracy of Effort Estimation in Agile Software Development

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Abstract-Effort estimation is an essential aspect of software development that plays a critical role in project planning, resource allocation, and cost estimation. However, accurate estimation is a significant challenge in agile software development due to its iterative and flexible nature. This research aims to identify the internal and external forces that reduce the accuracy of effort estimation in agile software development. To achieve this, a systematic literature review was conducted using major databases. The studies were analyzed and synthesized to identify the key factors affecting agile software effort estimation accuracy.

Keywords:Agile software development, Effort estimation, Accuracy, Internal forces, External forces, Software project management.

1. Introduction

Agile software development has become increasingly popular in recent years due to its flexibility, adaptability, and collaborative approach [1]. Accurate estimation of effort is a critical success factor in agile software development, as it helps teams to plan, monitor, and control the progress of the project [2]. However, effort estimation in agile software development is a challenging task due to several internal and external factors that can impact the accuracy of the estimates.

Internal factors such as lack of experience and expertise among team members [3], poor communication and collaboration [4], inadequate documentation of requirements [5], and ineffective use of agile tools and techniques [6] can all contribute to inaccurate effort estimation. External factors such as changes in project scope [7], uncertainty in customer requirements [8], unforeseen technical challenges [9], and limited availability of resources [10] can also impact the accuracy of effort estimation in agile software development.

To address this challenge, it is essential to identify the internal and external forces that reduce the accuracy of effort estimation in agile software development. Several studies have investigated the challenges and best practices for effort estimation in agile software development [11-13]. However, there is a need for a systematic

review of the literature to identify the key factors that impact the accuracy of effort estimation in agile software development.

This research aims to conduct a systematic literature review (SLR) to identify the internal and external forces that reduce the accuracy of effort estimation in agile software development. The research question is: What are the internal and external forces that reduce the accuracy of effort estimation in agile software development? By answering this question, this research aims to provide insights into potential best practices to improve the accuracy of effort estimation in agile software development.

In the next sections, this research will provide a comprehensive review of existing literature on effort estimation in agile software development, including the challenges, best practices, and potential solutions. Based on this literature review, this research will identify the key internal and external factors that impact the accuracy of effort estimation and provide recommendations for software development teams, practitioners, and researchers.

2. Methodology

The methodology employed in this study includes a systematic literature review (SLR), an empirical study, and a quantifiable investigation, which is commonly used by researchers in their studies [14]. The SLR is a method that is utilized to answer a clearly articulated research question by identifying, selecting, and critically appraising relevant literature. Prior to undertaking the systematic review, explicit criteria should be outlined in a clearly defined methodology or plan. This method involves a transparent and thorough search that spans several databases and includes grey literature, which can be replicated by other academics. A well-thought-out search strategy is devised to focus on a specific topic or research question. The review is conducted within established timeframes and includes information on the search terms, search tactics (including database names, platforms, and search dates), and limitations. The review findings indicate the type of information that was searched, evaluated, and reported.

2.1. Research Questions

The research questions are the backbone of any study as they provide a clear direction for the research and guide the investigation process. In this study, the research questions aim to explore the internal and external forces that contribute to inaccurate effort estimation in agile software development. By answering these questions, the study can provide valuable insights into the various factors that impact the estimation process, both internal and external. Answering these research questions can help software development teams better understand the challenges of estimation in agile software development and develop strategies to improve the accuracy of their effort estimates.

Table 1: Research questions

Research Question	Description	Purpose
RQ1	What are the environmental and personal factors affecting software effort estimation?	To identify the various external and personal factors that can impact the accuracy of effort estimation in agile software development.
RQ2	What are the external forces/factors affecting software estimation?	To identify the external factors that can impact the estimation process, including the project context, availability of resources, and technology used in the development process.
RQ3	What are the internal forces/factors affecting software effort estimation?	To identify the internal factors that can impact the estimation process, including team member expertise, communication within the team, and the development process used.

2.2. Search Strategy

The initial step involves the selection of relevant online databases that host research papers related to the current topic on an international scale. Table-2 presents the selected online databases for this study, as they are known to predominantly publish research papers related to the topic at hand.

Table 2: List of Online Databases

S. No.	Database Name	URL
1	IEEE Explore	http://ieeexplore.ieee.org
2	Scopus	https://www.scopus.com/
3	Wiley Inter Science	https://onlinelibrary.wiley.com/
4	Web of Science	https://knowledgee.com/
5	Inspec	https://www.theiet.org/
6	Springer	www.springerlink.com
7	ACM Portal	http://portal.acm.org/portal.cfm
8	Science Direct	https://www.sciencedirect.com/
9	Elsevier	https://www.elsevier.com/

2.3. Keyword Identification

The search process always begins with the identification of keywords. In this step, all the keywords and their alternatives were identified from well-known research studies. These keywords are selected based on the research problem and research question.

Table 3: List of Keywords

S.No.	Keyword	Alternative Keyword
1	Agile Software Development	ASD
2	Software Estimation	Estimating Software Development Efforts
3	Internal Factors	Factors Within ASD Team
4	External Factors	Factors Outside ASD Team
5	Accuracy	Estimation Accuracy
6	Project Management	Agile Project Management
7	Risk Management	Agile Risk Management
8	Software Metrics	Agile Software Metrics
9	Planning	Agile Planning
10	Productivity	Agile Productivity
11	Time Management	Agile Time Management

2.4. Search Queries

The search strategy heavily relies on the query string, which is an iterative process. The query is constructed using key terms and their alternatives, which are then combined using logical OR and AND operations. The resulting search query is then applied to the selected online databases to retrieve relevant research studies. The following search query was used for the systematic literature review.

1) ("software estimation" OR "software effort estimation" OR "software project estimation") AND ("factors" OR "determinants" OR "influences") AND ("internal" OR "external" OR "personal" OR "environmental")

2) ("software estimation" OR "software effort estimation" OR "software project estimation") AND ("challenges" OR "issues" OR "problems" OR "difficulties") AND ("factors" OR "determinants" OR "influences")

3) ("software estimation" OR "software effort estimation" OR "software project estimation") AND ("methodologies" OR "techniques" OR "approaches" OR "models") AND ("factors" OR "determinants" OR "influences")

4) ("software estimation" OR "software effort estimation" OR "software project estimation") AND ("accuracy" OR "reliability" OR "validity" OR "precision") AND ("factors" OR "determinants" OR "influences")

5) ("software estimation" OR "software effort estimation" OR "software project estimation") AND ("best practices" OR "guidelines" OR "standards" OR "recommendations") AND ("factors" OR "determinants" OR "influences")

2.5. Inclusion/Exclusion Criteria

Here in this step inclusive exclusive is constructed according to the current research. This criterion is applied to the title of research papers and all the irrelevant studies are discarded. Then the inclusive exclusive criteria are applied to the abstract and then to the full body of research paper and all those papers are discarded which is not related to my research.

For the current research, inclusive and exclusive criteria were developed to ensure the selection of relevant research papers. The inclusive criteria consisted of the following:

- Papers published in English language.
- Papers associated with Software Effort Estimation.
- Papers related to Software Cost Estimation.
- Papers related to the selected keywords and research topic.

On the other hand, papers were excluded if they met the following criteria:

- Papers not written in English language.
- Papers that were clearly not related to Software Effort Estimation.

2.6. Quality Assessment

After removing irrelevant studies in the screening step, the selected publications are passed through quality assessment. In this step the quality assessment of the selected papers wasperformed, and low-quality papers were removed. The following 13-point criteria was used for quality assessment. Yes (Y=1), No (N=0), and Average (A=0.5) were used to answer each question. Each study could receive anywhere from 0 to 13 points. The end point for including a study is the first quartile (4/13).

Table 4: quality assessment criteria

S. No.	Quality Criteria	Score
1	Is the research question or objective clearly stated?	Y/N/A
2	Is the research design/methodology clearly described?	Y/N/A
3	Is the sample size justified and described?	Y/N/A
4	Are the data sources identified and their reliability/validity discussed?	Y/N/A
5	Are the data collection procedures clearly described?	Y/N/A
6	Is the data analysis method appropriate and clearly described?	Y/N/A
7	Are the results presented clearly and logically?	Y/N/A
8	Are the conclusions justified by the results?	Y/N/A
9	Are the limitations of the study discussed?	Y/N/A
10	Are the implications of the study discussed?	Y/N/A
11	Are the recommendations for future research clearly stated?	Y/N/A
12	Is the overall contribution of the study to the field clear?	Y/N/A
13	Are the references used of high quality and relevant to the study?	Y/N/A

The following table shows the final selection of publication for the current research. The last column shows the final selected publication after removing duplicates, exclusive criteria, and quality assessment.

Table No. 5: Final selection of publication

S.No.	Database Name	Search Result	Primary Selection	Final Selection

1	IEEE Explore	2100	60	19
2	Scopus	11500	40	15
3	Wiley Inter Science	400	13	21
4	Web of Science	3211	16	6
5	Inspec	34	1	0
6	Springer	1200	12	11
7	ACM Portal	1046	34	13
8	Science Direct	1421	16	18
9	Elsevier	267	4	2
Total		**21179**	**196**	**105**

3. Results and Discussions

The following section represents the results of current research on the bases of SLR finding from 35 selected research papers.

3.1. Result of SLR For RQ 1: What are the Environmental and Personal Factors affecting Effort Estimation Process?

The following table shows the list of all environmental factors that affect effort estimation process. These factors are extracted from the SLR result. Initial Search result was 21179, after applying the exclusive/inclusive and quality criteria the final selected research papers was 105. The following environmental factors were taken from 105 research papers. Where frequency shows the occurrence in research paper.

Table 6: Environmental and Personal Factors affecting Software Effort Estimation

S. No.	Environmental Factors	Frequency	Percentage
1	Responsibilities outside of the project	102	97.14
2	Defects and changes of previous implementation	100	95.24
3	Security	99	94.29
4	Interruptions	99	94.29
5	Configuration	99	94.29
6	Quality of requirements	99	94.29
7	Complexity of requirements	99	94.29
8	Volatility of requirements	99	94.29
9	Data transaction	99	94.29
10	Operation Ease	99	94.29
11	Process	99	94.29
12	Environmental factors	96	91.43
13	Management	96	91.43
14	Working Time	96	91.43
15	Team dynamics and commitment	95	90.48
16	Staff experience and technical ability	93	88.57
17	Political factors	92	87.62
18	Experience of previous project	92	87.62
19	poor ventilation	90	85.71
20	poor lighting	90	85.71
21	In-comfortable seating & desks	89	84.76
22	Stakeholders	89	84.76

23	Noise	88	83.81
24	Relocation to new physical locations	86	81.9

The above 24 environmental factors are extracted from 105 research papers. They are then analyzed using SPSS to find the impact of each factor on software effort estimation. The outliers are removed based on percentage. Here a 25% threshold percentage was defined to exclude the factor. So, all those factors were excluded if they got less than or equal to 25 % score.

3.2. Result of SLR For RQ2. What are the internal forces/factors affecting software estimation?

The following table shows the list of 14 internal forces affecting software effort estimation process.

The result is extracted from the final selected 105 research papers. Frequency shows the occurrence of factor in total 105 research papers.

Table 7: Internal forces affecting software effort estimation process.

S. No.	Internal Forces	Frequency	Percentage
1	Product Usage	103	98.1
2	Product Category	100	95.24
3	Product Performance & Quality	100	95.24
4	Product Development Complexity	100	95.24
5	Risk Management	100	95.24
6	Project Type	100	95.24
7	Personal Expertise	100	95.24
8	Tool Expertise	100	95.24
9	Product Nature	99	94.29
10	Project Constraints	99	94.29
11	Project Characteristics	99	94.29
12	Process Maturity & stability	99	94.29
13	Project Management	98	93.33
14	Tool Availability	97	92.38

The above list of 14 internal forces were extracted from the final selected of 105 research papers. These factors are then analyzed using SPSS to find the impact of each factor on software effort estimation. Here a 25% threshold percentage was defined to exclude the factor. So, all those factors were excluded if they got less than or equal to 25 % score.

3.3. SLR result for RQ3: What are the External Forces affecting Software effort Estimation?

The following table shows the external forces that affect software effort estimation process. These are extracted from 105 research papers as a result of SLR. The frequency shows the occurrence of factors out of 105 research papers.

Table 8: External forces/factors affecting software effort estimation process.

S. No.	External Factors	Frequency	Percentage
1	Expected Team Changes	102	97.14
2	Vendor's Defect	101	96.19
3	Team member's responsibilities outside the project	101	96.19
4	Personal Issues	101	96.19
5	Expected Ambiguity in Details	101	96.19
6	Expected Changes in environment	101	96.19

7	Expected Relocation	101	96.19
8	Introduction of New Tools	100	95.24
9	Expected Delay in Stakeholder response	100	95.24

The above list of 9 external forces was extracted from the final selected of 105 research papers. These factors are then analyzed using SPSS to find the impact of each factor on software effort estimation. Here a 25% threshold percentage was defined to exclude the factor. So, all those factors were excluded if they got less than or equal to 25 % score.

3.4. Calculating the impact of environmental, internal and external forces on software effort estimation

Any power that restricts the movement of an article because of the item's contact with different bodies, according to Newton's First Law. External and internal forces that have a detrimental impact on project productivity are known as friction forces. They slow down the team's progress. These forces can be minimized but not removed by the project manager or developer.

To find the negative impact of the internal/external and environmental forces, first weights are assigned to each factor. The weights are assigned by using Fibonacci numbers or linear numbers as suggested by most ofresearchers. Here I used linear numbers to assign weights to each factor.

Table 9: weighted list of environmental forces

S. No.	Env. F	Weights			Env. V
		Low=1	Medium=2	High=3	
1	Responsibilities outside of the project	✓			1
2	Defects and changes of previous implementation		✓		2
3	Security			✓	3
4	Interruptions		✓		2
5	Configuration	✓			1
6	Quality of requirements		✓		2
7	Complexity of requirements	✓			1
8	Volatility of requirements		✓		2
9	Data transaction	✓			1
10	Operation Ease		✓		2
11	Process			✓	3
12	Environmental factors			✓	3
13	Management		✓		1
14	Working Time	✓			1
15	Team dynamics and commitment		✓		2
16	Staff experience and technical ability			✓	3
17	Political factors		✓		2
18	Experience of previous project		✓		2
19	poor ventilation			✓	3

20	poor lighting		✓		2
21	In-comfortable seating & desks		✓		2
22	Stakeholders		✓		2
23	Noise			✓	3
24	Relocation to new physical locations		✓		2
		$\frac{\sum_{i=1}^{24}(Env.F)i}{72} * 3$			2.0

The impact is calculated using the following formula.

$$Env.F = \frac{\sum_{i=1}^{24}(Env.F)i}{72} * 3 \qquad \text{----------Eq 1}$$

Equation No. 1 is used to calculate the value of environmental factors. Where "Env. F" represents environmental factor. There are 24 environmental factors. "Env. V" represents the value of each factor.

The weights are assigned according to the given environment. To keep the total weights between the range of 1-3, the equation is divided by 72. i.e., if all the environmental factors got maximum weight 3 then the maximum value becomes 3 according to the given equation.

Table 10: weighted list of Internal forces

S. No.	**Internal Forces**	**Weights**			**Int. V**
		Low=1	**Medium =2**	**Hight= 3**	
1	Product Usage	✓			1
2	Product Category	✓			1
3	Product Performance & Quality	✓			1
4	Product Development Complexity		✓		2
5	Risk Management		✓		2
6	Project Type		✓		2
7	Personal Expertise			✓	3
8	Tool Expertise			✓	3
9	Product Nature			✓	3
10	Project Constraints	✓			1
11	Project Characteristics	✓			1
12	Process Maturity & stability		✓		2
13	Project Management		✓		2
14	Tool Availability	✓			1
		$\frac{\sum_{i=1}^{14}(Int.F)i}{42} * 3$			1.785714

The value of internal factors are calculated on the bases of the following Eq 2.

$$\square\square\square.\square = \frac{\sum_{\square=1}^{14}(\square\square\square.\square)\square}{42} * 3 \qquad \text{----------Eq 2}$$

Where "Int.F" represents internal forces and "Int. V" represents internal forces value.

Weights may be assigned according to the given project. There are 14 internal forces, each is assigned weight between 1-3. The total value is the sum of all force's weights divided by 42. Here dividing by 42 will keep the maximum value between 1-3.

Table 11: Weighted list of External forces

S. No.	Ext. F	Weights			Ext. V
		Low= 1	Mediu m=2	High t=3	
1	Expected Team Changes	✓			1
2	Introduction of New Tools	✓			1
3	Vendor's Defect	✓			1
4	Team member's responsibilities outside the project	✓			1
5	Personal Issues	✓			1
6	Expected Delay in Stakeholder response	✓			1
7	Expected Ambiguity in Details		✓		2
8	Expected Changes in environment		✓		2
9	Expected Relocation			✓	3
		$\frac{\sum_{\square=1}^{9}(\square\square\square.\square)\square}{27} * 3$			1.444444

$$\square\square\square.\square = \frac{\sum_{\square=1}^{9}(\square\square\square.\square)\square}{27} * 3 \qquad \text{--------Eq 3}$$

Equation No. 3 is used to calculate the value of external forces. "Ext. F" represents the external forces while "Ext. V" represents the external force value. The total value of Ext. Forces is the sum of all 9 Ext.V divided by 27. The total value is divided by 27 to keep the maximum value between 1-3.

4. Improving the accuracy of software estimation models

In previous section I have calculated the impact of environmental, Internal and External forces on the estimation process. Since these are the frictional forces that have negative impact on the software development team as well as software productivity. Here the total deacceleration force is calculated that can deaccelerate the efficiency of development team as following.

$$\text{Deacceleration } \square = \frac{1}{(\square\square\square.\square * \square\square\square.\square * \square\square\square.\square)} \text{ ----------Eq4}$$

Where D is the deacceleration force that can impact the development teach velocity.

If the initial development team acceleration is denoted by D_0 then team acceleration will be decreased in percentage as bellow in Eq5.

$$\text{Deacceleration } \square\% = \left(\frac{\square}{\square\square}\right) * 100 \text{ ----------Eq5}$$

If we consider development team velocity as Vi, then the final velocity after applying the environment, internal and external forces we got the final velocity as Vf.

$$\square\square = (\square\square)^{\square} \text{----------Eq6}$$

Eq6 represents the final velocity of a development team. If we properly calculated the deacceleration forces,then we can improve the accuracy of effort estimation models.

5. Conclusion

This research highlights the importance of identifying and addressing the internal and external factors that can reduce the accuracy of effort estimation in agile development. By implementing the suggested approaches and techniques, software development teams can improve their estimation accuracy and ultimately deliver high-quality products to their customers. However, it is important to note that effort estimation is an ongoing process and requires continuous refinement and adjustment based on project changes and feedback. Therefore, further research is needed to explore additional factors that may impact effort estimation accuracy and to identify more effective techniques for improving estimation in agile development.

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