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# The Effects of Turnover on Expert Effort Estimation

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**Abstract**

Turnover of the personnel represents a serious issue for management of software projects. The buildup of competences and phasing in of the people into the project requires both time and effort. This paper presents a case study of a large in-house agile software development project. The research goal was to determine the effects that turnover has on the expert effort estimation. In order to do this, paper examines relations across empirical data on a studied project. Study findings are the following: a) it is necessary to distinguish types of turnover, b) the general and planned turnover do not necessarily have a negative effect on estimation accuracy, and c) the unplanned turnover can have a significant negative impact on the reliability of the estimates and therefore should be treated with special attention. Results suggest that these facts should be taken into account both by the management and human resources.
**Keywords:** software engineering, effort estimation, employee turnover, HR analytics, statistical analysis, software project management

## 1. Introduction

In general, turnover of the personnel refers to the act of replacing one employee with another [1]. To be more specific, under the term turnover are considered both leaving, either voluntary or involuntary, and recruitment [2]. It is the normal feature of majority of projects and doesn't necessarily have only unwanted effects [3], but quite often it has an overall negative impact on business [4], [5]. This is particularly the case with unplanned turnover. According to [6] unplanned turnover is far more obstructive and costly for the organization then its planned variant. Thus, each type of turnover has to be observed separately. As it is discussed in the paper, attention will be directed to the unplanned type of turnover.

The turnover rates differ from one industry to other. It is typically highest in the hospitality, retail and customer service industries ranging between 15%-30% and lowest in public sector, financial services and insurance in range of 10-15% [7], [8]. In software, telco and technology industry it is around 15% and higher [9], [10], [11]. Today, software industry is particularly active and the increase of complexity and dynamics of software projects requires improvements in their management [12], [13]. As a reaction to this, different development methodologies emerge, one particularly popular is agile scrum [14].

The agile scrum methodology breaks the project into the cycles known as sprints. In scrum project members are grouped into scrum team facilitated by scrum master. As defined by the agile methodology every person on the project is a member of certain scrum team. During sprint planning each team member picks or is assigned typically a number of tasks and has to estimate the required effort. Using the tracking systems implemented on the project it is possible to monitor the progress of the work [15].

Effort estimation is a critical part of software project management [16]. Accurate estimates ensure planned project execution and compliance with the set time and budget constraints [17]. In order to improve the effort estimation process it is crucial to enhance understanding of the human estimator [18]. The studied project applied agile scrum development methodology and expert effort estimation. Expert estimation relies on estimators' judgment capability that is based on intuition [19], personal characteristics [20] and environment in which it is generated [21]. For these reasons it is interesting to observe its efficiency in relation to the turnover.

The case study presented in this paper gives the results of analyses conducted on a large [22] agile software development project executed in telco industry company. The studied project was developed in-house, while data source for the study was the tracking system. The fact that this was a large and long project, and thus relatively rare, made it interesting for the analysis. The intention of the study was to establish a relationship between the turnover recorded on a project and efficacy in expert effort estimation and to answer two questions: does turnover affect estimation performance and how. The answers then should help with more efficient project management.

The remaining part of the paper is the following. In Section 2 related research, as a basis for further considerations in the study, is presented. This is followed by a presentation of the approach to the study, sources of data and data itself, as well as metrics used to measure turnover and estimation error, all in Section 3. Section 4 brings up the results and their implications together with limitations of the study. Finally, the last section, Section 5 presents conclusions and directions for future work.

## 2. Related research

The topics of turnover and effort estimation have been studied extensively in the last years but in different contexts. The turnover presents a serious issue for every organization; it has impacts on the management, productivity, quality and reputation [23], [24] and in certain extent it is inevitable. Unfortunately, high turnover can severely impact the business, both financially and emotionally [25], [26]. The presence of significant turnover rate in an organization should indicate that there is some cause for it, as good employees that are satisfied with their jobs generally don't quit that easily [27]. Evidence-based research conducted in this direction dealt with the issues such as: how to quantify turnover, how it is distributed within an organization, what is the impact of turnover on an organization, how it relates to the wider context etc. [28].

Further interesting perspectives of the turnover are psychological and social. They try to identify the reasons why a person decides to leave an organization and what it means to the surroundings [29]. In this area, hundreds of published research articles both theoretical and empirical form a substantial body of knowledge [30]. A part of it dealt with identification of motives of those that leave, others focused on the complex group and organizational contexts such as culture, cohesion, gender composition, demography and so on [31]. In the recent period turnover research has been marked with several trends, such as search for the predictors of turnover in individual differences, dynamic modelling of turnover process with consideration of time and empirical research on the unfolding model [26].

The importance of the turnover to the field of software engineering is ever greater particularly as tech companies witness record high fluctuation of men power [32], [33]. In software development business job satisfaction, motivators and de-motivation are considered predictors of staff turnover [34], [35]. As studies report, turnover has become a culture in the Information Technology (IT) industry [36], [37]. However, the industry still has no adequate solution how to mitigate it [38]. Further research is needed to support the experts and reduce estimation performance drop caused by the staff turnover [39].

The study and practice of effort estimation evolved parallel to the software industry [40] as, in order to successfully run the business, one had to estimate, more or less accurately, the human and material effort i.e. the costs. The effort estimation is critical part of software project management [41] and it inherently carries a considerable amount of uncertainty [42]. Whatever model is implemented on the project, it should strive to reduce this so that the project converges to the successful end. Early models tried to relate the size of the product, either physical or logical, with the effort [43]. Formal [44] and analogy models appeared later [45]. Recent models use advanced techniques such as machine learning [46] and data mining methods for the purpose of estimating the effort [47]. Yet, expert effort estimation remains the most widely used technique [48]. Another area of the research is focused on the estimation error measurement [49] and the search for the reliable metrics, as well as on the comparison of different models [50], [51]. Besides simply relating the absolute values of estimated and actual effort, standardly used by the industry [52], researchers developed a number of more or less reliable measures of estimation error that indicate the accuracy of implemented models [53], [54]. De facto standard measures in this research area today are the magnitude of relative error with its derivatives, as well as indicator of the amount of correct predictions at set level, and they are described in more detail in Appendix C.

According to [55], staff turnover belongs to the class of project factors that needs to be addressed when estimating software development effort. With that in mind and in order to better understand the effort estimation, our research tries to determine the effects that turnover has on the efficacy of estimation process.

## 3. Study

This section provides the details related to the study itself. It is organized into three main parts. The first part gives an overview of the project used as a data source for the study. This is followed by the presentation of the background of expert effort estimation and estimation error measurement. Finally, in the last paragraph, the turnover phenomenon is discussed as well as used measurements and expressions.

Important part of the study refers to the statistical analysis. It was carried out in order to determine the relations that exist between different project parameters. This ultimately indicated the effects that various types of turnover have on the efficacy of the effort estimation on the project being analyzed. More details about the methodology used in the study are provided in the upcoming parts of the paper.

Furthermore, the conducted analysis uses multiple parameters. In order to make the text more readable definitions and formulas, together with the list of abbreviations are separated into the appendices sections that can be found at the end of the article. Therefore, if necessary at certain places, the reader is encouraged to refer to these parts of the paper.

### 3.1. Details of the analyzed project

The project under study was set up with the purpose to develop a complex solution for customers in telco industry. The requirements were set high regarding not only functionality but also performances and robustness of the system. The solution was sold to a number of customers, therefore it had to be scalable. The technologies used to build the solution were a mix of the open and Microsoft stack, depending on the component.

The primary source of data used in this study was the Application Lifecycle Management (ALM) system implemented on the project. The contemporary ALMs used on software projects serve as source code repositories, storages of associated documentation, and tracking systems in which activity on the project is recorded, but also as environments in which reporting and analytical activities can be carried out [56]. They provide a means to extract the data of interest [15], [57] in formats suitable for later manipulation and analysis [58]. Data preparation included structuring of the data into the format that allowed their transfer into tools used for the analysis.

Organization of the team on the project was done in the following way. Initially, a core team consisting of project managers and solution architects was set up, this team continued to exist almost intact, during the whole lifetime of the project. Shortly after, alongside them, an initial development team was formed and the work on the implementation of initial version (V1) started. Around the tenth sprint, due to the expected high incoming volume of the work and labor costs, this initial team was reinforced by the team formed on another location. Upon finishing the work on V1, the initial development team was disbanded while the team on, until then, the secondary location was reinforced by recruitment of new employees in order to continue with the development of the next version (V2) of the solution.

As it is evident from the facts stated above, the project went through several turbulent moments during the course of time. The most prominent ones were the following:

a) initially, when it was set up,
b) after the ramp-up of the team on the other location started and
c) when the initial team was dismounted and the team on the other location reinforced.

For the exact insight into the teams dynamics during the project lifetime please refer to the Figure 8. in Appendix A.

As already said, the project was executed following the agile scrum methodology. Right away we can assume that it was a choice for several reasons:

a) initially it was hard to perceive the whole set of functionalities that will be requested by the customer,
b) as the project expected long lifetime, so in this way it was possible to overcome the problem of changing requirements,
c) management obviously wanted smaller and more scalable teams, easier to manage and supervise, and finally,
d) it is possible that already at the start there was an intention to switch development to a lower cost location but it was important to go ahead with the project locally and then, once the core elements were in place, to look for a more favorable version of development viewed from the costs perspective.

The project lasted for the total of 33 sprints, where sprints S1-S15 occupied development of initial version (V1) while S16-S33 belong to the next version (V2). The total actual effort invested into the project, from the beginning until its end, was 34551.75 [h], at the same time the total estimated effort counted 35935.35 [h], like it is presented in Figure 1. So overall, the project was overestimated by 1383.60 [h] or if expressed relative to the actual effort by 4.00%. Right away we can notice that the direction of the error is not typically to software development projects as in practice most of them end up underestimated [59]. Regarding the magnitude of error, it is significantly below the average compared to the industry standard of 30-40% [60], [61] which is evidence of a good estimation practice. Nevertheless, taking into account the total project volume, and when converting these error hours into money it becomes clear why it is necessary to address this issue.

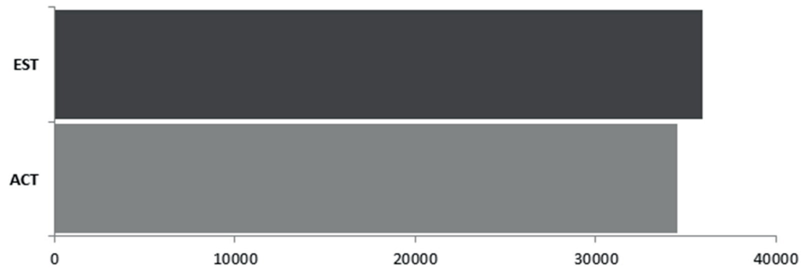


Figure 1. Total estimated and actual effort on the project in working hours

The whole project effort was recorded on the work items i.e. tickets stored within the ALM, these were the basic units of estimation. During the project lifetime the total of 3496 tickets were recorded within the tracking system. Out of that number 60.67% or 2,121 tickets were estimated correctly (EST=ACT), 15.68% or 548 were underestimated (EST<ACT), while 23.66% or 827 were overestimated (EST>ACT). The overestimation was not only more common but more than twice in size when it comes to the volume counted in hours of work. The relative underestimation per sprint amounted to -38.51 [h] and the relative overestimation to +84.22 [h]. To follow up, the maximal recorded underestimation was -61.00 [h] in S8, while the maximal overestimation was + 215.80 [h] in S24.

Out of the total of 33 sprints, 2 were estimated correctly (S1 and S5, HIT), 10 were underestimated (UNDER) and 21 were overestimated (OVER). The overestimation was not only more common but greater in volume (1,768.78 [h] vs. -385.18 [h]), with the average underestimation of -38.52 [h] while the average overestimation was +84.23 [h]. The maximal overestimate in particular sprint i.e. iteration was significantly greater in magnitude (+215.80 [h] in S24) than the maximal underestimate (-61.00 [h] in S8). All these numbers are extracted from the sprint numbers provided in the Table 8 in the Appendix B.

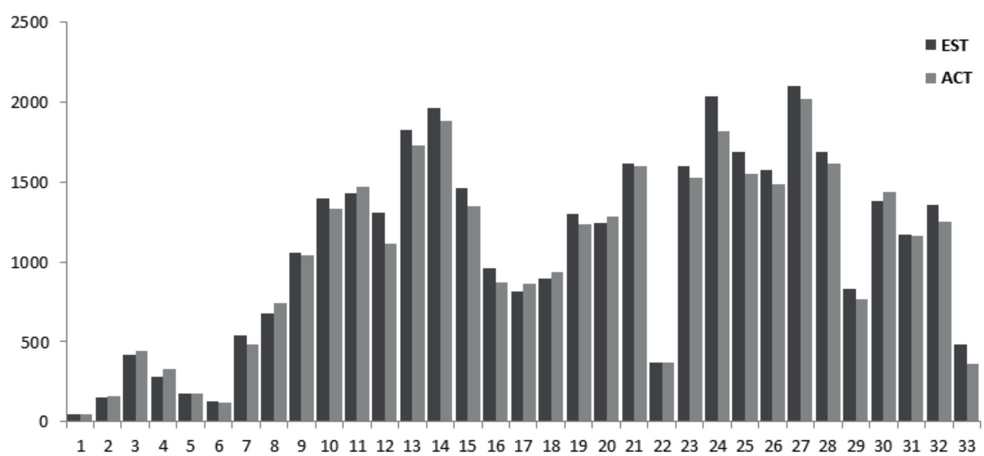


Figure 2. Estimated and actual effort per sprint

A visual representation of the estimated and actual effort per sprint is provided bellow, in Figure 2. From this it can be seen that during the projects lifetime the overall effort per sprint gradually increased in volume and then decreased by the end project, similar also occurred within V1 and V2, with occasional drops.

Regarding the absolute error (A-ERR) in estimation generated by the expert estimators, and expressed in hours, it fluctuated during the course of the projects. The relative estimation error (R-ERR), expressed as percentage relative to the actual value, followed a similar pattern. These oscillations are depicted in Figure 3. The exact numbers for both A-ERR and R-ERR can also be found in Appendix B.


Figure 3. Relative estimation error per sprint

### 3.2. Effort estimation and error measurement

As it was pointed, the expert effort estimation is today the most common technique used on software projects [62]. It relies on an expert judgment [61] and is therefore subjective i.e. highly depends on estimators' characteristics [63]. Each member of the team is an estimator, responsible to provide his own estimation of the effort required to execute a particular item assigned to him, as accurately as possible. Expert estimation can be classified, depending on the way it is being implemented, into an unstructured and structured form. Unstructured or ad-hoc estimation does not use strictly defined process but for the given list of estimation objects (items, work packages, etc.) each estimator provides his estimates in some agreed form [64]. This is usually done by simply assigning effort numbers next to each point in the list. In contrast, structured expert estimation typically follows predefined session procedure, led by the dedicated moderator. Usually predefined templates are used, estimation is preceded by the presentation and discussion about the topics that will be estimated and in case there are significant deviations the session repeats.

Estimation in the analyzed project was performed in a structured form. Considering that the project was executed according to the agile scrum methodology the work was broken down into sprints, cycles typically lasting for three weeks.

Project members were grouped into dedicated scrum teams of size 7±2 people. Within the tracking system, the specification of the required functionality that needed to be implemented was broken down into user stories, each assigned a level of priority awaiting their order at the backlog. During a sprint planning session, selected user stories were presented, assigned to teams and broken down into linked task recorded in a form of tickets. The tasks were elaborated in more detail, assigned to responsible team members that had to estimate the required effort. Once the estimation session was over, the figures and additional notes if necessary were recorded in the system, thus creating conditions for the start of the sprint.

The responsibility for handling the ticket was exclusively in the hands of its owner i.e. the team member it was assigned to. The effort for particular task was estimated in hours. General rule was that task should not exceed 16 [h], if that was the case it had to be broken down into sub-tasks. This was done in order to make the work more perceivable i.e. comprehensible. Once the task was taken into execution the efforts had to be regularly updated. In case the work could not be finished in a given sprint, the ticket was transferred into the following. Upon finishing the work on the task, the ticket had to be closed. The user story was realized and closed only after all the task linked to it reached that state. Depending on the relation between the estimated (EST) and final effort (ACT) each task could end up being: a) finished on time (EST=ACT i.e. HIT), b) underestimated (EST<ACT i.e. UNDER) or c) overestimated (EST>ACT i.e. OVER). As the user stories were in fact the collections of tasks, the similar case was with their final effort status. The same applies to sprints and consequently also to the overall project.

Calculation of the estimation error is performed based on the values of estimated (EST) and actual (ACT) effort. Besides the values of absolute and relative error typically used by the industry [65], there are a number of other scientifically accepted standard measures used to express the estimation error [53], [54].

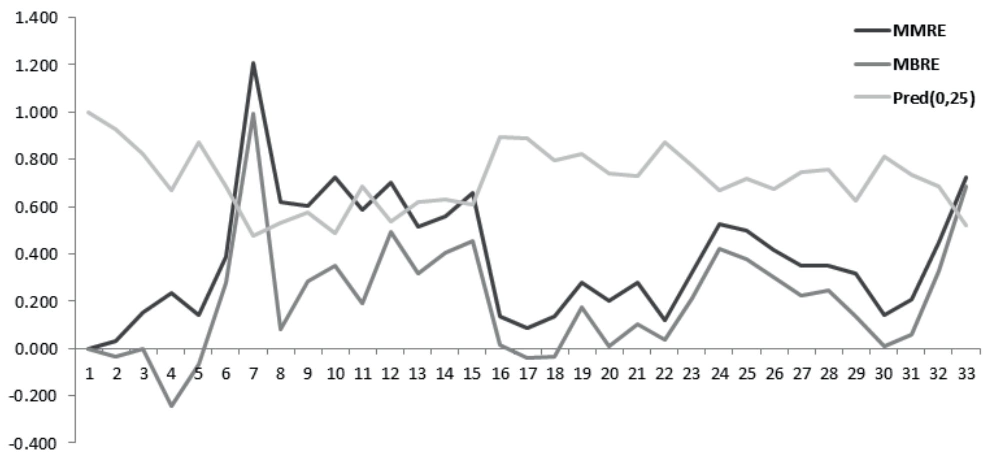


Figure 4. MMRE, MBRE and Pred(0.25) per sprint

In the study the most commonly used measures, the Mean Magnitude of Relative Error (MMRE), Mean Balance Relative Error (MBRE) and Prediction at level X (Pred(0.25)), are used. The reason for using multiple measures is to provide more accurate study results as they show different tendencies [66]. Values of these error indicators are provided in Table 8 in Appendix B and depicted here in Figure 4. For the insight on how-to perform these calculations, refer to Appendix C. It is worth keeping in mind that A-ERR and R-ERR are calculated for particular estimation instance (either a task, sprint or project) while MMRE, MBRE and Pred(0.25) are used to express the magnitudes of error in a collection of instances.

### 3.3. Markers of Turnover

For a general project, a ramp-up typically occurs at its beginning when resources i.e. project team members are accumulating. Here, the focus should be on the hiring of the right people for right positions as well as their optimal number depending on the planned volume of work. The mid-project period would desirably be the steady-state phase with a little or relatively low turnover, either in terms of in-coming or out-going of personnel, preventive actions should be taken to minimize it. Finally, the ramp-down typically comes at or near the end of the project, or a specific phase as it is the case after V1 of the studied project. It is a concept where work is either completed or wants to be shifted elsewhere, so there is no need for so many resources to complete the remaining activities, or they are required at some other place. Therefore, management starts to release resources, team members, consultants, etc. from the project. If we would draw the graph relating the engaged personnel and the time period of the project for a theoretical project, we would expect to see a step-up in an early phase of the project, then stabilization and finally step-down in the number of resources as the project comes to an end.

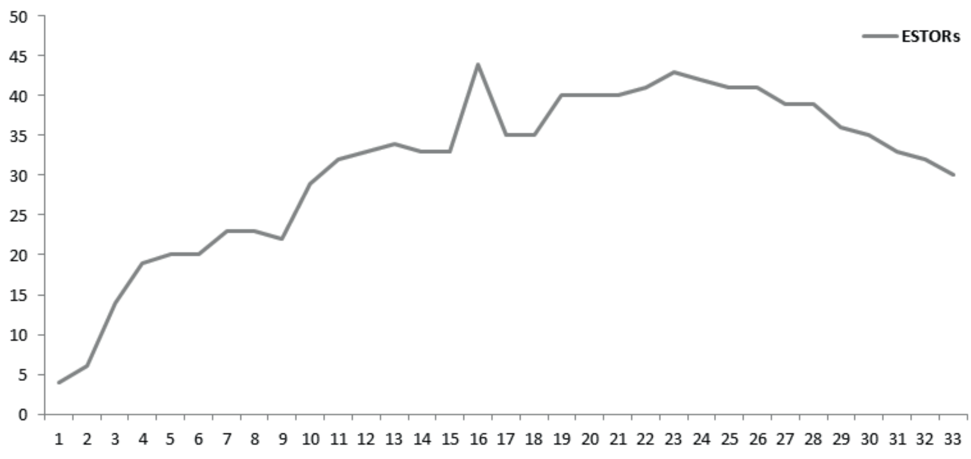


Figure 5. Number of estimators per sprint

Team dynamics of the studied project behave in a similar fashion. Graphical presentation of the overall number of estimators i.e. team size is depicted in Figure 5. This curve can be derived from the team setup provided in Appendix A. As already mentioned, the project started with a small team of managers and architects forming the core of the project, this marks the minimal number of participation on the project (4 in S1). Soon after that the build-up of a development teams started. On average the project consisted of 31 members, reaching at one point maximum of 44 members (S16).

The data regarding the project is presented in Appendix B, Table 8. Employee turnover is one of the most important project metrics. It is the percentage of the workforce that has left in a given period of time. Turnover is usually calculated on a monthly, quarterly or annual basis but it can also be calculated for an arbitrary period, here defined by the sprint duration. Furthermore, turnover can be calculated by taking into account all of those who left the team, project or company or it can focus on those who left voluntarily, involuntary, as it was planned by the project management, unexpectedly or otherwise.

By looking at the project numbers and team dynamics it is visible that the ramp-up of team (INs) occurred during the following sprints: S1-S5, S7-S8, S10-S13, S16, S19, S21 and S23. On the other hand, the drop-out of personnel form the project (OUTs) took place in: S7, S8, S11, S13, S15-S16, S23-S24, S26 and from S28 until the project ended. These departures from the project can further be divided into planned and unplanned ones. The planned reduction (P-OUTs) of the team members occurred in S16 and after S33, all the other turnovers were unexpected (U-OUTs). These numbers are the basis for turnover calculation.

To calculate certain form of the employee turnover rate, it is required to count the number of employees that left in a certain way and divide it with the average number of employees that were employed during that period. In order to calculate the average number of employees in a given period, one would have to count the number of people at the beginning and at the end of the period, sum it up and divide by 2. As the studied project consists of the sprint cycles instead of calculating the average, the number of team members available in that period will be used.

The formula to calculate the turnover is provided below [11]. As we differentiate planned from unplanned turnover, these can be calculated in the same way, by taking into account only certain type of input.

$$Turnover = \frac{Number\ of\ leavers\ (in\ some\ time\ period)}{Average\ number\ of\ team\ members\ (during\ that\ time\ period)}$$

Figures for thus calculated turnover in the studied project are provided in Table 8 of Appendix B, next in Figure 6 is the graphical presentation for general turnover. It is visible that the project experienced periods of no or relatively low turnover but that it also went through the moments of rather significant turnover. This mostly coincides with moments of disintegration of one and formation of a new team.

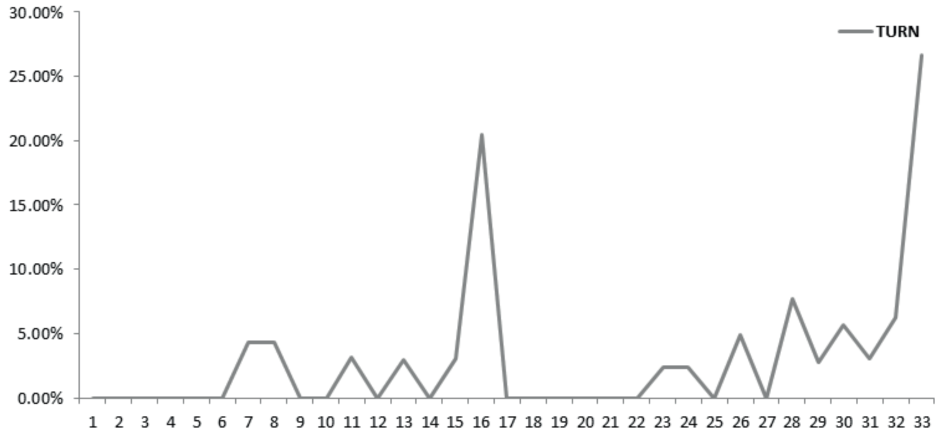


Figure 6. General turnover on the project

As noted, although this is a standard method to calculate turnover that organizations often use, it is a relatively crude measure. In this way it is not possible to distinguish cases of those who left because they wanted so, because they were forced to or otherwise [67]. Therefore, besides analyzing the effects of general turnover in the project, the study will also focus on determining the effect of planned and unplanned types of turnover on the reliability of the expert estimate. This will be investigated because the effects of the planned turnover can be more or less controlled, i.e. it is possible to timely undertake preventative measures to mitigate them, while for the unplanned turnover this is not possible. The effects of an unplanned turnover could be devastating for the project, a similar negative impact could be expected if the effort estimation proves to be not accurate enough. The cognition that these two phenomena are connected would contribute to their understanding.

The following section explains the analysis and presents the study results. In order to determine the relation between different markers of turnover and estimation error on the project, the results were obtained through a statistical analysis performed in SPSS Statistics v20. By determining the relationship between these dimensions, their type and strength, the study tries to confirm the assumption of negative effects that certain types of turnover have on the project.

## 4. Results

The following section presents the study results emphasizing the relations between the turnover and estimation error. This is followed by the discussion about the implications of the study to the software engineering field of effort estimation and project management in general. Finally, the section lists limitations of the study by pointing out potential threats to the validity.

### 4.1. Turnover and estimation error

For analytical purposes the descriptive statistics, Pearson Correlation applying a 2-tailed test and Linear Regression were used. First, the relations between the project parameters (total outs – OUTs, planned – P-OUTs, unplanned outs – U-OUTs and general turnover – TURN) which indicate different types of departures from the project and relative error in estimation (|R-ERR|) were determined. Secondly, an analysis was carried out to determine the relation between types of turnover (general, planned and unplanned) and different standard measures of relative estimation error (MMRE, MBRE and Pred). Parameters of these relations are summarized, for the first part in Table 1 and Table 2, and for the second in Table 3 and Table 4 which follow bellow.

**Descriptive Statistics**

| | N | Range | Minimum | Maximum | Mean | Std. Deviation | Variance |
|---|---|---|---|---|---|---|---|
| OUTs | 32 | 9 | 0 | 9 | 1.09 | 2.100 | 4.410 |
| P-OUTs | 32 | 9 | 0 | 9 | .44 | 1.722 | 2.964 |
| U-OUTs | 32 | 4 | 0 | 4 | .66 | .937 | .878 |
| TURN | 33 | 26.67% | 0.00% | 26.67% | 3.0294% | 5.79528% | 33.585 |
| \|R-ERR\| | 33 | 33.02% | 0.00% | 33.02% | 6.6892% | 6.23676% | 38.897 |

Table 1. Descriptive statistics for OUTs, P-OUTs, U-OUTs, TURN and |R-ERR|

**Correlations**

| | | OUTs | P-OUTs | U-OUTs | TURN | \|R-ERR\| |
|---|---|---|---|---|---|---|
| OUTs | Pearson Correlation | 1 | .898** | .591** | .978** | .571** |
| | Sig. (2-tailed) | | .000 | .000 | .000 | .001 |
| | N | 32 | 32 | 32 | 32 | 32 |
| P-OUTs | Pearson Correlation | .898** | 1 | .176 | .814** | .411* |
| | Sig. (2-tailed) | .000 | | .335 | .000 | .019 |
| | N | 32 | 32 | 32 | 32 | 32 |
| U-OUTs | Pearson Correlation | .591** | .176 | 1 | .696** | .523** |
| | Sig. (2-tailed) | .000 | .335 | | .000 | .002 |
| | N | 32 | 32 | 32 | 32 | 32 |
| TURN | Pearson Correlation | .978** | .814** | .696** | 1 | .664** |
| | Sig. (2-tailed) | .000 | .000 | .000 | | .000 |
| | N | 32 | 32 | 32 | 33 | 33 |
| \|R-ERR\| | Pearson Correlation | .571** | .411* | .523** | .664** | 1 |
| | Sig. (2-tailed) | .001 | .019 | .002 | .000 | |

| | | | | | |
|---|---|---|---|---|---|
| N | 32 | 32 | 32 | 33 | 33 |

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Table 2. Correlations between the OUTs, P-OUTs, U-OUTs and TURN with |R-ERR|

From this we see that relative estimation error |R-ERR| has significant positive correlation with all the project indicators (general. planned and unplanned) that mark different types of departures. The strongest relation being the one between the TURN and |R-ERR| ($r = 0.664$; $p = 0.00$) indicating strong negative effect that the general turnover has on the expert effort estimation efficacy.

Next, the analysis of the relations between the turnover and estimation errors expressed by de facto standard measures (MMRE, MBRE and Pred) follows. Descriptive statistics are presented in Table 3 and correlations in Table 4.

**Descriptive Statistics**

| | N | Range | Minimum | Maximum | Mean | Std. Deviation | Variance |
|---|---|---|---|---|---|---|---|
| TURN | 33 | 26.67% | 0.00% | 26.67% | 3.0294% | 5.79528% | 33.585 |
| P-TURN | 32 | 20.45% | 0.00% | 20.45% | 1.1356% | 4.25470% | 18.102 |
| U-TURN | 32 | 13.33% | 0.00% | 13.33% | 1.9881% | 2.93187% | 8.596 |
| MMRE | 33 | 1.209 | .000 | 1.209 | .38358 | .259931 | .068 |
| MBRE | 33 | 1.234 | -.242 | .992 | .20482 | .244908 | .060 |
| Pred(0.25) | 33 | .525 | .475 | 1.000 | .71494 | .132255 | .017 |

Table 3. Descriptive statistics for TURN, P-TURN, U-TURN, MMRE, MBRE and Pred(0.25)

**Correlations**

| | | TURN | P-TURN | U-TURN | MMRE | MBRE | Pred(0.25) |
|---|---|---|---|---|---|---|---|
| TURN | Pearson Correlation | 1 | .879** | .723** | .182 | .291 | -.150 |
| | Sig. (2-tailed) | | .000 | .000 | .311 | .101 | .406 |
| | N | 33 | 32 | 32 | 33 | 33 | 33 |
| P-TURN | Pearson Correlation | .879** | 1 | .307 | -.033 | .073 | .092 |
| | Sig. (2-tailed) | .000 | | .088 | .857 | .691 | .615 |
| | N | 32 | 32 | 32 | 32 | 32 | 32 |
| U-TURN | Pearson Correlation | .723** | .307 | 1 | .375* | .456** | -.381* |
| | Sig. (2-tailed) | .000 | .088 | | .034 | .009 | .032 |
| | N | 32 | 32 | 32 | 32 | 32 | 32 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| MMRE | Pearson Correlation | .182 | -.033 | .375* | 1 | .891** | -.895** |
| | Sig. (2-tailed) | .311 | .857 | .034 | | .000 | .000 |
| | N | 33 | 32 | 32 | 33 | 33 | 33 |
| MBRE | Pearson Correlation | .291 | .073 | .456** | .891** | 1 | -.700** |
| | Sig. (2-tailed) | .101 | .691 | .009 | .000 | | .000 |
| | N | 33 | 32 | 32 | 33 | 33 | 33 |
| Pred(0,25) | Pearson Correlation | -.150 | .092 | -.381* | -.895** | -.700** | 1 |
| | Sig. (2-tailed) | .406 | .615 | .032 | .000 | .000 | |
| | N | 33 | 32 | 32 | 33 | 33 | 33 |

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Table 4. Correlations between the TURN, P-TURN, U-TURN and MMRE, MBRE and Pred(0.25)

From the results it is evident that there does not exist statistically significant relation between the general turnover (TURN) or planned turnover (P-TURN) with none of the relative error measures, either MMRE, MBRE or Pred. This is somehow explainable as the first is general, and the other strictly controlled project parameter, driven by the management. Obviously, because of that, they do not reflect negatively on the success of the estimation.

In contrast, when it comes to the unplanned turnover, here the statistically significant correlation between U-TURN and all relative error measures (MMRE, MBRE or Pred) has been established. It is evident that the correlations between U-TURN and MMRE ($r = 0.375$; $p = 0.34$) and U-TURN and MBRE ($r = 0.456$; $p = 0.09$) are positive while the correlation between U-TURN and Pred(0.25) is negative ($r = -0.381$; $p = 0.32$). This is because greater values of both MMRE and MBRE indicate a bigger error in estimation, while for Pred(0.25) the negative prefix indicates the drop in estimation efficacy as these results suggest that with an increase of the unplanned turnover the proportion of accurate estimates within the set tolerance decreases.

The results of the linear regression analysis for these project parameters are summarized in Tables 5, 6 and 7. The graphical presentation of the distributions and correlations is provided in Figure 7.

**Model Summary**

| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate |
|---|---|---|---|---|
| 1 | .375[a] | .141 | .112 | .239942 |
| 2 | .456[a] | .208 | .181 | .222594 |

| | | | | |
|---|---|---|---|---|
| 3 | .381[a] | .145 | .117 | .116460 |

Predictor: a. (Constant), U-TURN

Table 5. Linear regression - Model summary

**ANOVA[1,2,3]**

| Model | | Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| 1 | Regression | .283 | 1 | .283 | 4.918 | .034[b] |
| | Residual | 1.727 | 30 | .058 | | |
| | Total | 2.010 | 31 | | | |
| 2 | Regression | .390 | 1 | .390 | 7.864 | .009[b] |
| | Residual | 1.486 | 30 | .050 | | |
| | Total | 1.876 | 31 | | | |
| 3 | Regression | .069 | 1 | .069 | 5.090 | .032[b] |
| | Residual | .407 | 30 | .014 | | |
| | Total | .476 | 31 | | | |

Dependent Variable: 1. MMRE, 2. MBRE, 3. Pred(0.25)

Predictor: b. (Constant), U-TURN

Table 6. Linear regression - ANOVA

**Coefficients[1,2,3]**

| Model | | Unstandardized Coefficients | | Standardized Coefficients | t | Sig. |
|---|---|---|---|---|---|---|
| | | B | Std. Error | Beta | | |
| 1 | (Constant) | .331 | .052 | | 6.421 | .000 |
| | U-TURN | .033 | .015 | .375 | 2.218 | .034 |
| 2 | (Constant) | .135 | .048 | | 2.829 | .008 |
| | U-TURN | .038 | .014 | .456 | 2.804 | .009 |
| 3 | (Constant) | .738 | .025 | | 29.521 | .000 |
| | U-TURN | -.016 | .007 | -.381 | -2.256 | .032 |

Dependent Variable: 1. MMRE, 2. MBRE, 3. Pred(0.25)

Table 7. Linear regression analysis parameters
Predictor: U-TURN; Dependent Variable: 1. MMRE, 2. MBRE, 3. Pred(0.25))

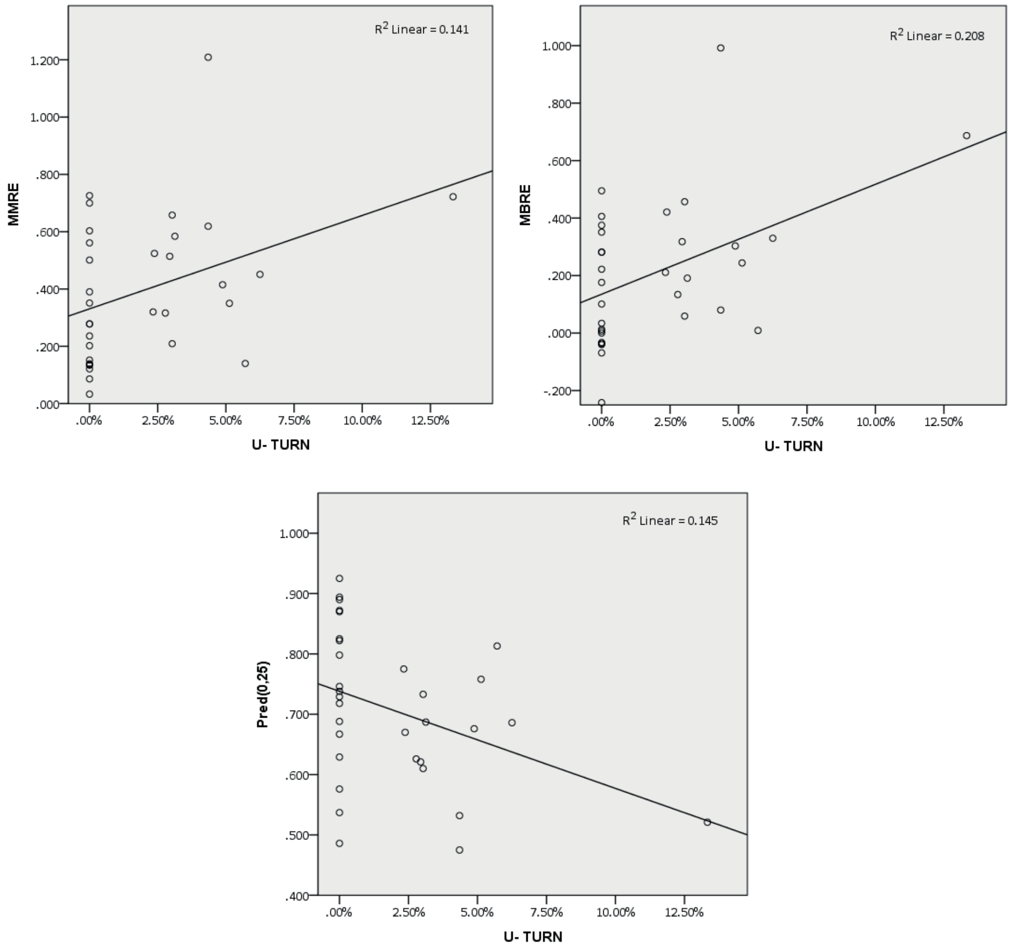


Figure 7. Distributions and correlations between U-TURN and MMRE, MBRE and Pred(0.25)

Based on the results of the analysis we can conclude that not all types of turnover are equally hazardous for the viability of the project. While the general (TURN) and planned types (P-TURN) of turnover seem not to compromise the estimation process, on the other hand, this was not the case with unpredicted turnover (U-TURN) that has especially negative effect on the expert estimation. This has been confirmed by the results obtained for all three standard measures of relative estimation error (MMRE, MBRE and Pred).

Through this analysis, that initially confirmed the existence of the relations between different project parameters which indicate the departure of team members from the project and relative estimation error and then, the effects that various types of turnover have on the standard measures used to express the relative estimation error on the project, its negative effect on the project viability has been proved.

### 4.2. Implications of the study

This study analyzed how different project parameters and turnover types influence the error in expert effort estimation. It showed that not all observed indicators used in analysis are related to estimation error. Among them only the general turnover showed significant correlation with relative estimation error. Then, when considering the relationship between turnover subtypes and standard error measures, the unplanned turnover was highlighted as a key indicator associated with the estimation error. This points its importance and that it have to be adequately handled if the project management process does not want to be jeopardized. This particularly applies to the large complex software development projects.

The implications of the study therefore relate to the ways to overcome this issue and, hence, minimize the negative impacts of turnover. They are primarily related to more efficient human resource and team management as well as the selection of appropriate development methodologies that provide a stable project environment in which it is possible to tackle a problem. Selection and implementation of an efficient development methodology create conditions in which it is possible to obtain reliable estimates. Experienced estimators, familiar with the project, are the ones able to generate reliable estimates. Only by merging all this together, conditions are created that ensure successful project management.

Therefore, implications of the study on one side go in the direction of human resource management responsible for taking care of the staff in general, and on the other to the management which handles people in the context of the particular project. Preventing turnover is sometimes beyond our reach, but it is important to be aware of the effects it may cause and to have effective mechanisms to overcome them. The conducted study was carried out with this purpose and it identified the key problems in relation between the turnovers and the effort of estimation.

### 4.3. Limitation of the work

The fact that the analysis was performed on a single large agile project is a potential limitation of this case study. For this reason it is possible that the statistical significance can be influenced by the sample. Still, the audience to whom this paper is intended to, belonging to both scientific and industry practitioner groups, is well aware that kinds of data sets required for such an analysis, are rare and difficult to acquire. However, this does not affect the quality of results obtained by the study and the methodology of the research carried out.

Drawing the conclusions from the empirical studies and generalizing it, particularly in the field of software engineering, can be difficult. This is especially the case when the quantity of research in the topic is scarce. Although both, the general turnover phenomenon and the effort estimation on software projects, have been studied extensively, the number of studies investigating their mutual influence is extremely small. As the results confirmed the negative effects that turnover can cause, this should be a guideline for further exploration of the topic.

## 5. Conclusions and Future work

The case study reported in this paper uses a statistical analysis in order to determine relation between the turnover and other related parameters on the error in expert effort estimation on the software project. It was conducted using the data set from a large project managed according the agile scrum guidelines. The purpose of the analysis was to improve the general understanding of the effects the turnover has on the project and in particular to the accuracy of the effort estimation.

The study applies methods from the statistical analysis, in particular the 2-tailed Pearson correlation and linear regression analysis, in order to identify the type, strength and significance of assumed relations. By taking into account different project parameters (OUTs, P-OUTs, U-OUTs), separating the general turnover (TURN) from its subtypes (P-TURN, U-TURN) and relating it to the industry (ERR and R-ERR) and scientifically accepted measures used to express estimation error (MMRE, MBRE and Pred), the study confirmed negative effects the turnover has on the reliability of the expert effort estimation process. However, not all types of turnover represent the same problem to the course of the project.

The planned turnover is acceptable and sometimes even desirable from the standpoint of the management as it can serve the purpose of rebuilding the team and/or reducing the cost. Contrary to that, the case study confirmed existence of a particularly negative effect that the unplanned type of the turnover has on the estimation process and thus indirectly on the project management. These evidence-based research findings have finally been confirmed as being valid and grounded on firm evidence. The conducted analysis proved effective and pointed that the greater attention should be focused on the turnover phenomenon in software business and its relation on the project management.

The study encourages a further research in this direction, as replication of the analysis on similar datasets collected in different environments could contribute to the general knowledge in the field of software engineering. A future research could also focus on application of different methods of analysis in order to obtain new insights. Next, from the management and human resource perspective, future work can be directed towards the ways that negative effects of turnover can be mitigated or avoided. To conclude, by studying the turnovers from different perspectives, software business can profit in many ways, as these findings can be useful for both scientific and industry auditorium.

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## Appendix A: Project team setup

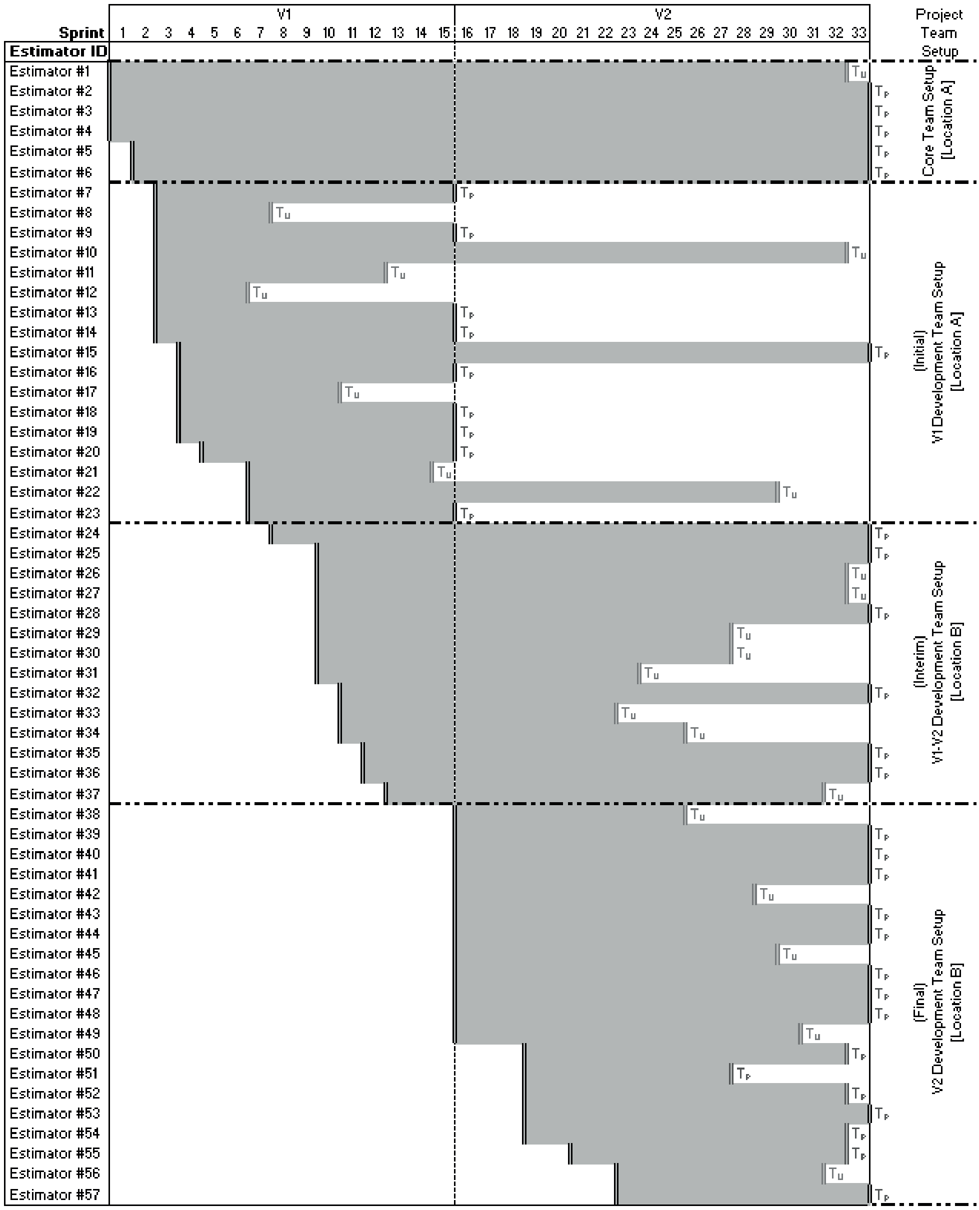


Figure 8. Team setup on a project
(Tp = Planned Turnover; Tu = Unplanned Turnover)

## Appendix B: Details of analyzed project

| SPRINT | ITEMs | HITs | UNDERSs | OVERs | EST | ACT | ERR |
|---|---|---|---|---|---|---|---|
| 1 | 4 | 4 | 0 | 0 | 48.00 | 48.00 | 0.00 |
| 2 | 10 | 7 | 2 | 1 | 150.00 | 160.00 | -10.00 |
| 3 | 31 | 26 | 5 | 0 | 414.32 | 443.32 | -29.00 |
| 4 | 39 | 24 | 10 | 5 | 280.80 | 326.98 | -46.18 |
| 5 | 23 | 18 | 1 | 4 | 176.48 | 176.48 | 0.00 |
| 6 | 16 | 10 | 3 | 3 | 124.00 | 120.50 | 3.50 |
| 7 | 40 | 15 | 8 | 17 | 536.00 | 483.50 | 52.50 |
| 8 | 47 | 23 | 12 | 12 | 679.00 | 740.00 | -61.00 |
| 9 | 85 | 35 | 20 | 30 | 1059.50 | 1039.50 | 20.00 |
| 10 | 107 | 38 | 30 | 39 | 1393.50 | 1335.00 | 58.50 |
| 11 | 99 | 52 | 27 | 20 | 1425.00 | 1467.00 | -42.00 |
| 12 | 95 | 33 | 23 | 39 | 1305.00 | 1109.50 | 195.50 |
| 13 | 124 | 60 | 25 | 39 | 1822.00 | 1729.00 | 93.00 |
| 14 | 124 | 57 | 26 | 41 | 1964.00 | 1878.50 | 85.50 |
| 15 | 118 | 56 | 24 | 38 | 1461.00 | 1346.00 | 115.00 |
| 16 | 151 | 119 | 14 | 18 | 962.00 | 869.00 | 93.00 |
| 17 | 91 | 79 | 10 | 2 | 814.00 | 866.00 | -52.00 |
| 18 | 109 | 79 | 19 | 11 | 895.00 | 936.00 | -41.00 |
| 19 | 126 | 89 | 16 | 21 | 1300.00 | 1233.00 | 67.00 |
| 20 | 141 | 92 | 19 | 30 | 1239.00 | 1287.00 | -48.00 |
| 21 | 166 | 105 | 28 | 33 | 1614.00 | 1601.80 | 12.20 |
| 22 | 39 | 32 | 3 | 4 | 369.50 | 372.00 | -2.50 |
| 23 | 160 | 104 | 23 | 33 | 1598.50 | 1523.00 | 75.50 |
| 24 | 200 | 120 | 21 | 59 | 2036.00 | 1820.20 | 215.80 |
| 25 | 177 | 113 | 17 | 47 | 1688.00 | 1549.00 | 139.00 |
| 26 | 182 | 106 | 25 | 51 | 1574.00 | 1482.69 | 91.31 |
| 27 | 248 | 152 | 39 | 57 | 2098.75 | 2017.02 | 81.73 |
| 28 | 178 | 118 | 20 | 40 | 1688.00 | 1613.75 | 74.25 |
| 29 | 91 | 52 | 12 | 27 | 832.00 | 765.50 | 66.50 |
| 30 | 155 | 113 | 21 | 21 | 1383.50 | 1437.00 | -53.50 |
| 31 | 116 | 78 | 18 | 20 | 1171.00 | 1162.50 | 8.50 |
| 32 | 156 | 89 | 25 | 42 | 1355.00 | 1253.29 | 101.71 |
| 33 | 48 | 23 | 2 | 23 | 478.50 | 359.72 | 118.78 |

Table 8. Project data (part 1/3)

| SPRINT | A-ERR | R-ERR | \|R-ERR\| | TYPE | MMRE | MBRE | Pred(0,25) |
|---|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00% | 0.00% | HIT | 0.000 | 0.000 | 1.000 |
| 2 | 10.00 | -6.25% | 6.25% | UNDER | 0.033 | -0.036 | 0.925 |
| 3 | 29.00 | -6.54% | 6.54% | UNDER | 0.152 | 0.000 | 0.822 |
| 4 | 46.18 | -14.12% | 14.12% | UNDER | 0.236 | -0.242 | 0.667 |
| 5 | 0.00 | 0.00% | 0.00% | HIT | 0.139 | -0.069 | 0.870 |
| 6 | 3.50 | 2.90% | 2.90% | OVER | 0.390 | 0.281 | 0.688 |
| 7 | 52.50 | 10.86% | 10.86% | OVER | 1.209 | 0.992 | 0.475 |
| 8 | 61.00 | -8.24% | 8.24% | UNDER | 0.619 | 0.080 | 0.532 |
| 9 | 20.00 | 1.92% | 1.92% | OVER | 0.603 | 0.282 | 0.576 |
| 10 | 58.50 | 4.38% | 4.38% | OVER | 0.726 | 0.351 | 0.486 |
| 11 | 42.00 | -2.86% | 2.86% | UNDER | 0.584 | 0.191 | 0.687 |
| 12 | 195.50 | 17.62% | 17.62% | OVER | 0.700 | 0.495 | 0.537 |
| 13 | 93.00 | 5.38% | 5.38% | OVER | 0.514 | 0.318 | 0.621 |
| 14 | 85.50 | 4.55% | 4.55% | OVER | 0.561 | 0.406 | 0.629 |
| 15 | 115.00 | 8.54% | 8.54% | OVER | 0.658 | 0.457 | 0.610 |
| 16 | 93.00 | 10.70% | 10.70% | OVER | 0.134 | 0.013 | 0.894 |
| 17 | 52.00 | -6.00% | 6.00% | UNDER | 0.086 | -0.040 | 0.890 |
| 18 | 41.00 | -4.38% | 4.38% | UNDER | 0.136 | -0.033 | 0.798 |
| 19 | 67.00 | 5.43% | 5.43% | OVER | 0.278 | 0.176 | 0.825 |
| 20 | 48.00 | -3.73% | 3.73% | UNDER | 0.202 | 0.007 | 0.738 |
| 21 | 12.20 | 0.76% | 0.76% | OVER | 0.278 | 0.101 | 0.729 |
| 22 | 2.50 | -0.67% | 0.67% | UNDER | 0.121 | 0.034 | 0.872 |
| 23 | 75.50 | 4.96% | 4.96% | OVER | 0.320 | 0.211 | 0.775 |
| 24 | 215.80 | 11.86% | 11.86% | OVER | 0.524 | 0.421 | 0.670 |
| 25 | 139.00 | 8.97% | 8.97% | OVER | 0.501 | 0.375 | 0.718 |
| 26 | 91.31 | 6.16% | 6.16% | OVER | 0.415 | 0.303 | 0.676 |
| 27 | 81.73 | 4.05% | 4.05% | OVER | 0.351 | 0.222 | 0.746 |
| 28 | 74.25 | 4.60% | 4.60% | OVER | 0.350 | 0.244 | 0.758 |
| 29 | 66.50 | 8.69% | 8.69% | OVER | 0.316 | 0.134 | 0.626 |
| 30 | 53.50 | -3.72% | 3.72% | UNDER | 0.140 | 0.009 | 0.813 |
| 31 | 8.50 | 0.73% | 0.73% | OVER | 0.209 | 0.059 | 0.733 |
| 32 | 101.71 | 8.12% | 8.12% | OVER | 0.451 | 0.330 | 0.686 |
| 33 | 118.78 | 33.02% | 33.02% | OVER | 0.722 | 0.687 | 0.521 |

Table 8. Project data (part 2/3)

| SPRINT | ESTORs | INs | OUTs | P-OUTs | U-OUTs | TURN | P-TURN | U- TURN |
|---|---|---|---|---|---|---|---|---|
| 1 | 4 | 4 | | | | 0.00% | | |
| 2 | 6 | 2 | 0 | 0 | 0 | 0.00% | 0.00% | 0.00% |
| 3 | 14 | 8 | 0 | 0 | 0 | 0.00% | 0.00% | 0.00% |
| 4 | 19 | 5 | 0 | 0 | 0 | 0.00% | 0.00% | 0.00% |
| 5 | 20 | 1 | 0 | 0 | 0 | 0.00% | 0.00% | 0.00% |
| 6 | 20 | 0 | 0 | 0 | 0 | 0.00% | 0.00% | 0.00% |
| 7 | 23 | 3 | 1 | 0 | 1 | 4.35% | 0.00% | 4.35% |
| 8 | 23 | 1 | 1 | 0 | 1 | 4.35% | 0.00% | 4.35% |
| 9 | 22 | 0 | 0 | 0 | 0 | 0.00% | 0.00% | 0.00% |
| 10 | 29 | 7 | 0 | 0 | 0 | 0.00% | 0.00% | 0.00% |
| 11 | 32 | 3 | 1 | 0 | 1 | 3.13% | 0.00% | 3.13% |
| 12 | 33 | 2 | 0 | 0 | 0 | 0.00% | 0.00% | 0.00% |
| 13 | 34 | 1 | 1 | 0 | 1 | 2.94% | 0.00% | 2.94% |
| 14 | 33 | 0 | 0 | 0 | 0 | 0.00% | 0.00% | 0.00% |
| 15 | 33 | 0 | 1 | 0 | 1 | 3.03% | 0.00% | 3.03% |
| 16 | 44 | 12 | 9 | 9 | 0 | 20.45% | 20.45% | 0.00% |
| 17 | 35 | 0 | 0 | 0 | 0 | 0.00% | 0.00% | 0.00% |
| 18 | 35 | 0 | 0 | 0 | 0 | 0.00% | 0.00% | 0.00% |
| 19 | 40 | 5 | 0 | 0 | 0 | 0.00% | 0.00% | 0.00% |
| 20 | 40 | 0 | 0 | 0 | 0 | 0.00% | 0.00% | 0.00% |
| 21 | 40 | 1 | 0 | 0 | 0 | 0.00% | 0.00% | 0.00% |
| 22 | 41 | 0 | 0 | 0 | 0 | 0.00% | 0.00% | 0.00% |
| 23 | 43 | 2 | 1 | 0 | 1 | 2.33% | 0.00% | 2.33% |
| 24 | 42 | 0 | 1 | 0 | 1 | 2.38% | 0.00% | 2.38% |
| 25 | 41 | 0 | 0 | 0 | 0 | 0.00% | 0.00% | 0.00% |
| 26 | 41 | 0 | 2 | 0 | 2 | 4.88% | 0.00% | 4.88% |
| 27 | 39 | 0 | 0 | 0 | 0 | 0.00% | 0.00% | 0.00% |
| 28 | 39 | 0 | 3 | 1 | 2 | 7.69% | 2.56% | 5.13% |
| 29 | 36 | 0 | 1 | 0 | 1 | 2.78% | 0.00% | 2.78% |
| 30 | 35 | 0 | 2 | 0 | 2 | 5.71% | 0.00% | 5.71% |
| 31 | 33 | 0 | 1 | 0 | 1 | 3.03% | 0.00% | 3.03% |
| 32 | 32 | 0 | 2 | 0 | 2 | 6.25% | 0.00% | 6.25% |
| 33 | 30 | 0 | 8 | 4 | 4 | 26.67% | 13.33% | 13.33% |

Table 8. Project data (part 3/3)

Legend:

| | |
|---|---|
| SPRINT | Sprint number |
| ITEMs | Number of items |
| HITs | Number of items in sprint where estimated effort is equal to actual effort (EST=ACT) |
| UNDERs | Number of items in sprint where estimated effort is smaller than actual effort (EST<ACT i.e. underestimation) |
| OVERs | Number of items in sprint where estimated effort is greater than actual effort (EST>ACT i.e. overestimation) |
| EST | Estimated effort in hours [h] |
| ACT | Actual effort in hours [h] |
| ERR | Estimation error in hours [h] |
| A-ERR | Absolute value of the estimation error [h] |
| R-ERR | Relative estimation error [%] |
| \|R-ERR\| | Absolute value of the relative estimation error [%] |
| TYPE | Type of estimation (HIT, OVERestimation or UNDERestimation) |
| MMRE | Mean Magnitude of Relative Error |
| MBRE | Mean Balance Relative Error |
| Pred(0.25) | Prediction at level X i.e. the portion of estimates that are within a tolerance of ACT e.g. 25% |
| ESTORs | Number of estimators in sprint [n] |
| INs | Number of estimators that entered the project [n] |
| OUTs | Number of estimators that left the project [n] |
| P-OUTs | Number of estimators that left the project as planned [n] |
| U-OUTs | Number of estimators that left the project unplanned i.e. unexpectedly [n] |
| TURN | General turnover [%] |
| P-TURN | Planned turnover [%] |
| U-TURN | Unplanned turnover [%] |

## Appendix C: Effort estimation and error calculation

Let EST be the value of the estimated effort, and ACT be the value of the actual effort. The estimation error (EE), also referred to as the residual [62], is the difference between these two values:

$$EE = EST - ACT \tag{1}$$

The absolute value is therefore:

$$EE = |EST - ACT| \tag{2}$$

Magnitude of Relative Error (MRE) is this value relative to the actual (ACT):

$$MRE = \frac{|EST - ACT|}{ACT} \tag{3}$$

MRE is the basic metric used to calculate Mean Magnitude of Relative Error (MMRE):

$$MMRE = mean\ (MRE) = \frac{1}{n}\sum_{i=1}^{n}\left|\frac{(EST_i - ACT_i)}{ACT_i}\right| \tag{4}$$

as emphasized in [68], for years the most widely used indicator of estimation accuracy [69]. The alternative measure proposed by Miyazaki [70], the Mean Balanced Relative Error (MBRE) is defined the following way [71]:

$$MBRE = mean\ BRE = \begin{cases} \dfrac{(EST - ACT)}{ACT} & ; EST - ACT \geq 0 \\ \dfrac{(EST - ACT)}{EST} & ; EST - ACT < 0 \end{cases} \tag{5}$$

The Pred(X) is a criterion that defines the predictions having a relative error of less than or equal to level X, the set threshold [72], [73], defined as:

$$Pred(X) = \frac{100}{N}\sum_{i}^{N}\begin{cases} 1 & if \quad MRE_i \leq X/100 \\ 0 & otherwise \end{cases} \tag{6}$$

Typically X is set to 25 [69] and it reveals the portion of estimates that are within a tolerance of 25% from the actuals.