Factors affecting the adoption of cloud for software development: A case from Turkey

ABSTRACT

Cloud-based solutions for software development activities have been emerging in the last decade. This study aims to develop a hybrid technology adoption model for cloud use in software development activities. It is based on Technology Acceptance Model (TAM), Technology-Organisation-Environment (TOE) framework, and the proposed extension Personal-Organisation-Project (POP) structure. Personally administered questionnaire sessions with developers and managers resulted in 268 responses regarding 84 software development projects from 30 organisations in Turkey. Structural Equation Modelling (SEM) is used for statistical evaluation and hypothesis testing. The final model was reached upon modifications and it was found to explain the intention to adopt and use the cloud for software development meaningfully. To the best of our knowledge, this is the first study to identify and understand factors that affect the intention of developing software on the cloud. The developed hybrid model was validated to be used in further technology adoption studies. Upon modifying conceptual model and discovering new relations, a novel model is proposed to draw the relationships between the identified factors and the actual use, intention to use and perceived suitability. Practical and social implications are drawn from the results to help organisations and individuals make decisions on cloud adoption for software development.

Keywords. Technology adoption; Cloud computing; Software development; Software engineering.

1. INTRODUCTION

Software projects - conducted to develop, test, and maintain software - usually consist of several phases. Software development is not only the activity of coding the software but it is a process which starts with gathering the requirements and conceptual design, and finishes with continuous maintenance of the product. The knowledge areas listed in "Guide to the Software Engineering Body of Knowledge" [1] can be considered as foundations to different activities in a software development project. Based on these knowledge areas we consider main activities in a software project as requirements management, design, development, test, deployment, and maintenance, whereas supporting activities as configuration management, documentation, quality assurance, and project management.

Different solutions usually emerge from a necessity of using a different approach to project management in software projects. Mostly, these solutions are traditional and local solutions such as buying and using proprietary software packages to handle different activities in a software project like scheduling, requirements gathering, testing, etc. In the last decade, with cloud computing becoming more popular and easier to access and use, cloud-based alternatives to these software packages have emerged. Cloud computing - as an idea - is not a new concept, however, it became practically viable only in the last decade with the advancements in hardware and computing capacities, the improvements in the Internet infrastructure, and the proliferation in the virtualisation technologies [2]. In its essence, "cloud computing" is similar to end users remotely benefitting from services hosted on a mainframe server. The technical NIST definition of cloud computing technologies is given as "*a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction*" [3]. Cloud services are developed and presented to users by cloud providers for both organisational and personal use cases with numerous different purposes from completing simple daily life tasks (e.g. keeping a calendar, storing e-mails) to meeting enterprise-level needs (e.g. ERP systems for manufacturing facilities, database management for companies).

In recent years, the cloud services began being direct solutions to specific needs and problems and the variation of cloud based systems increased significantly. Cloud solutions for the software development can be considered as one of these specific cloud services. There are cloud computing solutions that could be considered more traditional, such as using software solutions located on a cloud server as a Software-as-a-Service (SaaS), accessing a remote infrastructure to build the development environment on it instead of a local solution as an Infrastructure-as-a-Service (IaaS), or renting a platform on a virtual machine as a Platform-as-a-Service (PaaS) model for a programming or deployment environment [4] as well as solutions that rely on more recent technological developments like containerisation [5], or Function as a Service (FaaS, or serverless computing) and algorithm libraries that can be used during software projects [6]. Cloud technologies can replace or co-exist with local traditional solutions in every phase of software development projects. Some activities have more straightforward cloud-based solutions such as documentation or project management which might be easier to migrate to the cloud. On the other hand, migrating development (mainly coding) or testing activities to the cloud might take more effort to get used to and might initially cost more because it is essentially a new environment to complete the tasks that developers were used to handle traditionally. Even with the complexity and initial cost barriers, such migrations might be successful in the long term.

With all the factors in mind, it can be said that no alternative is be-all end-all solution in software development activities. Factors like complexity, cost, or data security and safety concerns push the developers and users to either adopting new cloud-based innovations or keeping the traditional methods. Technology adoption studies are useful in this regard to model and understand users' behavioural intention to use a new technology and what factors affect this intention in which circumstances.

The main driving motivation of this paper is that previous literature reviews show that a behavioural study focused on software development on the cloud has not been conducted. This study is a technology adoption study which aims to understand the factors that affect users' intention to adopt and use the cloud in software development activities. We hypothesised a conceptual model based on variables that might affect intention to use the cloud in software development activities. This model is tested with data collected from software developers and managers working in 30 different software development organisations (SDOs) in Turkey. Structural equation modelling (SEM) is used as the statistical analysis method to evaluate and modify the model. After a number of iterative steps, we reached the final model structure for cloud adoption in software development activities as well as conclusions about habits and preferences of software developers in Turkey, which is the population of this study.

The rest of this paper is structured as follows. In Section 2 related studies in cloud adoption and use of the cloud for software development are summarised. In Section 3 our methodology is described. Section 4 explains the theories and frameworks used in this study. The initial conceptual model is described in Section 5. Section 6 presents the results of exploratory and structural equation analyses. Section 7 presents a discussion on the findings of the study. Section 8 concludes the study and presents how validity threats were addressed.

2. RELATED STUDIES

Cloud technologies used in software development activities are of particularly interest to the software industry. However, there is a limited number of academic research conducted on the subject, and to the best of our knowledge previous research on cloud technologies in software development did not aim to explore the adoption and intention to use by individuals and communities. While earlier studies solely focused on the concept, challenges, and future of the cloud [7], [8], the recent studies focus on specific cloud-based solutions to different issues (security, testing, etc.) in software development [9], [10].

The early opinions and ideas of researchers on using the cloud in software development can be traced back to the time cloud studies were gaining traction in academia in general. Cloud technologies were suggested to possibly shift the software development paradigm. Weinhardt et al. [11] said that the future direction of cloud technologies suggest a way to employ ready-to-use application components on the cloud to develop software easily. In his editorial column, Erdogmus [7] made a point against the idea that cloud computing will remove the need to write a single line of code and to test. Dillon et al. [8] suggest that the interoperability of PaaS services was not entirely functional yet for end users to develop software on the cloud. Even though it is seen over time that cloud technologies did not revolutionarily change how software is developed, they have become valid (and in some cases, better) alternatives to traditional local solutions. Al-Rousan [12] in his paper examined the current challenges in global software development and suggests cloud-based solutions. Studies that focus on further challenges of cloud computing itself exist. Almorsy et al. [13] investigated one of the biggest concerns about the cloud: security. Regarding software development on the cloud, they mention secure software development lifecycle which is a security methodology for developers and how the methodology can be improved for cloud-based development. They suggest avoiding hardcoded security measures by supporting adaptive security.

Recent studies focus on specific cloud-based solutions instead of general ideas on using the cloud for software development. Malik and Singh [14] conducted a study on using several environments for software testing and the cloud was one of the possible considerations for testing. Cloud-based software testing is a concept that has been in use in industry for over a decade, which has attracted research interest for a longer time period with different studies [9], [15] which suggests Automated Software Testing as a Service; or cloud-based environments to be important for the future of software testing. Candea et al. [9] proposed three cloud-based testing service structures (Testing-as-a-Service, TaaS) for developers, end users, and certification services. Mittal et al. [15] suggested that providing TaaS might offer flexibility, scalability, and reduced costs while acknowledging the challenges such as issues about security, performance, customised configurations, and having full control of the testing environment.

Li and Gu [16] focused their research on cloud-based databases because of the increasing popularity of big data applications which require access to large databases. They suggest a hybrid database architecture which is cloud-based and allows simultaneous access to the database from different systems. Teixeira and Karsten [10] published their study on release management incorporating cloud services. Their solution exploits the OpenStack environment which is a cloud-based software ecosystem that eases the tasks in release management and aligns them with the organization's release procedure. Butt et al. [17] conducted a technology adoption study using SEM to understand factors that shape the usefulness of cloud technologies for agile software development. Oke et al. [18] proposes that cloud computing can be used for sustainability in software projects Al-Saqqa et al. [19] suggests that cloud computing is one of the technologies that can be beneficial specifically for agile software development. On the same point, Gochhait et al. [20] also directly focuses on the benefits of the cloud for agile software development.

There are also industry surveys and reviews on cloud adoption for software development. Even when they are not statistical technology adoption studies, they are highly useful to understand the interest in new technologies over time. Yau and An [21] gives a detailed, technical explanation of cloud technologies and how they can be relevant for software development when the concept of cloud for software development was a newer idea. Cusumano [22] summarises the development of the cloud for software development and gives a comparison of cloud providers from a business point of view. Non-academic articles such as Jones [23] and Burns [24] explain how cloud technologies can be used for software development and how developers can benefit from such technologies from an industry aspect.

In this current study we use certain variables from two existing technology adoption theories, namely Technology Acceptance Model (TAM) and Technology-Organisation-Environment (TOE) framework.

Previous studies on cloud adoption using TAM and TOE for the statistical model exist, although they do not focus on software development projects. Gangwar et al. [25] compared and evaluated different models (TAM only, TOE only, and two different hybrid models based on TAM and TOE) in the context of cloud adoption. In a previous study Gangwar et al. [26] used the TAM-TOE hybrid model to understand general cloud adoption by users. Both studies were interested in cloud adoption in a broad sense, hence they collected data from various sectors like IT, manufacturing, and finance. Safari et al. [27] conducted a Software-as-a-Service (SaaS) adoption study using TAM and TOE variables which also focused on general cloud service adoption. Priyadarshinee et al. [28] conducted a general cloud adoption study using technology adoption theories to build a model and using SEM as well as neural networks for statistical analysis. In their study they also compile variables used in previous cloud adoption studies and presented this summary of previous literature. The study by Shetty and Panda [29] uses TAM and TOE constructs to organise their review of the cloud use in small and medium-sized enterprises. Qasem et al. [30] developed a hybrid adoption model for organisational cloud acceptance at higher education institutions including TOE constructs. There is also research interest in governmental acceptance of cloud computing, with studies such as [31] focusing on factors affecting cloud adoption in e-government services.

Cloud computing is not the only domain within the software engineering sphere for which researchers conducted technology acceptance studies. Yasin et al. [32] designed a serious game for cyber security requirements education in software engineering and during the preliminary evaluation of the designed game, they used a TAM-based model to analyse developers' intention to play the game and effects of the game on learning. Thusi & Maduku [33] developed a model based on Unified Theory of Acceptance and Use of Technology (UTAUT) to evaluate the user behaviour of youth in South Africa towards mobile banking. Mezhuyev et al. [34] investigated the acceptance of search-based software engineering techniques, which are methods that employ search-based optimisation techniques in software engineering activities to find near-optimal solutions. They did not only develop a TAM model but also used SEM as the statistical method to analyse the model results. Kim et al. [35] conducted another technology acceptance study in IT domain that used SEM to evaluate the model on the factors that motivate IT professionals to adopt Semantic Web Technology. Qasem et al. [36] also based their statistical analysis of a cloud computing adoption model on SEM specifically for determinants of acceptance at higher education institutions.

Pisirir et al. [37] conducted a systematic literature review (SLR) to analyse and summarise the current state of cloud adoption literature that uses SEM as the statistical analysis method. In the SLR study, 92 relevant cloud computing - SEM studies were found in four main domains, namely business, personal use, healthcare, and education. However, researchers have not identified a cloud adoption study focusing on software development activities using SEM. In addition to this SLR focused on cloud adoption studies using SEM, other reviews and secondary studies on cloud adoption can be found [38]–[41]. SEM is continuously used as a statistical analysis method for cloud computing studies after publication date of the aforementioned SLR [37], as can be seen in recent studies such as [42], [43], [18].

3. METHODOLOGY

In this study a hybrid technology adoption model is developed to be tested with structural equation modelling (SEM) analysis. IBM SPSS Statistics AMOS 23 software package is used to run the SEM analysis. A SEM model typically consists of two parts, a measurement model and a structural model. The measurement model is the part of the SEM model that uses observed variables (indicators) to explain changes in unobserved (latent) variables. The structural model is the part of the SEM model researchers want the method to calculate, it is the relationships between latent variables that normally would not be possible to calculate with simple regression without the inclusion of measurement model. SEM aims to find significant relationships between latent variables using observed, measurable indicators. The latent variables in the structural model can be either exogenous (independent or causal variables, for example "complexity" or "perceived usefulness") or exogenous (dependent variable, for example "intention to use" or "perceived suitability") [44].

An extensive questionnaire consisting of these different groups of questions was prepared to execute with software developers, project managers, and senior executives in SDOs in Turkey. We designed the questionnaire together with expert scholars working in the domain of software engineering and cloud computing, and a pilot questionnaire was applied to academics and practitioners in the software industry. According to their feedbacks and recommendations, we revised and finalised the questionnaire. The full questionnaire used in this study, together with the item sources, is given in Supplementary Material. The results of the questionnaire study revised the initial model. Activities in this study and their outputs are summarized in Figure 1.

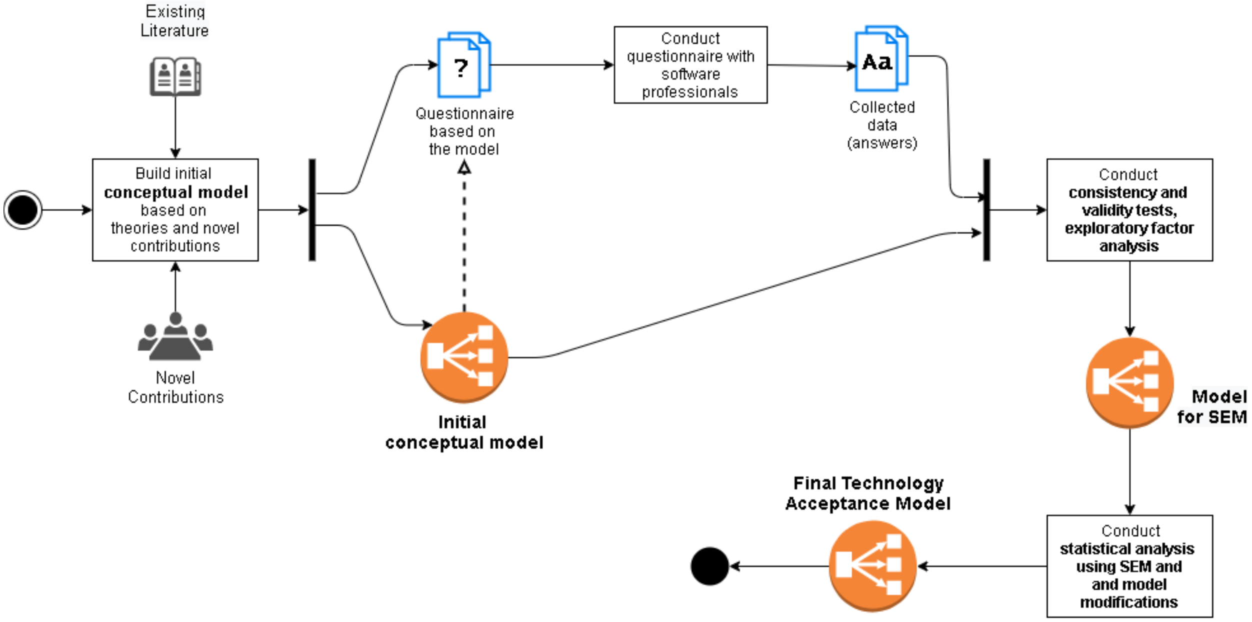

Figure 1: Methodology of the Study

4. TECHNOLOGY ADOPTION FRAMEWORKS

The hybrid adoption model used in this study contains constructs from Technology Acceptance Model (TAM) and Technology-Organisation-Environment (TOE) framework. TAM is selected because it particularly focuses on personal perceptions of individual users of the technology and measures how their perceptions of the technology might affect their behavioural intention. On the other hand, TOE suggests a framework for the technology adoption models at the organisational level, taking factors such as management support or competitive pressure into account. This section first gives a background for these two models, then explains our novel proposal structure Personal-Organisatio-Project (POP) framework.

4.1 Technology Acceptance Model and Technology-Organisation-Environment Framework

Davis [45] claimed that adoption of a new technology or an innovation is affected by users' perception of usefulness and ease of use of the innovation and developed the first TAM model based on Theory of Reasoned Action (TRA) [46]. TRA is not a theory specifically developed to deal with technological innovations but in general it aims to find the effect of individuals' attitude on their behaviours. After the initial TAM model, further improvements have been added over time, which resulted in TAM2 by Venkatesh and Davis [47] and TAM3 by Venkatesh and Bala [48]. Most recent TAM3 model consists of perceived usefulness and perceived ease of use with other factors that affect them as well as two variables with moderating effects on other pairwise relations in the model. Venkatesh and Bala [48] suggest that subjective norm, image, job relevance, output quality, and result demonstrability are the determinants of perceived usefulness whereas the effects on perceived ease of use is built on anchoring and adjustment framing of human decision making. It is hypothesised that computer self-efficacy, perceptions of external control, computer anxiety, computer playfulness, perceived enjoyment, and objective usability have effects on perception of the ease of use.

TOE is a framework for models that aim to explain the adoption and use of technological innovations in a business environment [49]. This framework is based on three main elements, namely technological context, organisational context, and environmental context [50]. The variables selected under each element vary between studies. Depending on the cultural background of the organisation, the user base (i.e. employers in the organisation who will experience the technological innovation), and characteristics of the technology in question; the appropriate model is designed by researchers. Technological, organisational, and environmental factors that are hypothesised to affect the intention to use the cloud in software development activities in this study are detailed in Section 3.

4.2 Personal-Organisation-Project Framework

The Personal-Organisation-Project (POP) structure in the model is the novel suggestion of this study. SDOs are mostly project based organizations and the characteristics of the software project may have an effect on the cloud use intention, so we suggest that integrating a set of factors that measure the current state of the people, their organisation, and the software project they are currently working on will consider several aspects of the technology use that are not measured by TAM or TOE and this will improve the results of the model. The factors in the POP structure are explained below.

- Personal cloud use aims to measure the familiarity and experience of individuals with cloud-based technologies in their non-professional daily lives. We hypothesise that if the users are already comfortable with using cloud services, they might perceive such services more suitable to their job and have higher intention to use cloud on software development.
- Project size is related to project complexity, and it is predicted that as project size increases, developers will find cloud alternatives less suitable and be less inclined to move their work to the cloud.
- Project budget is the budget allocated to the project by top management. It is mainly based on the size and scope of the project, and it can be affected by numerous factors such as project size, project duration, project team, importance and urgency of the project, or the project contractor. As cloud services are usually advertised as cheaper alternatives to local solutions with the freedom of pay-per-use cases, we hypothesise that cloud technologies will be more suitable to projects with stricter budget. Moreover, developers in these projects are expected to have higher intention to use the cloud in software development.
- Project team size is the number of team members for the particular project on which respondent developers are currently working. As moving software development efforts to cloud environments contributes to the communication within the team as well as documentation processes, it is predicted that developers working

on projects with larger team sizes will be more likely to want to adopt cloud technologies as these technologies will be more suitable to such projects.

- Organisation size is defined as the number of employers within the organisation. This does not necessarily affect the size and scope of the projects directly as a relatively small organisation might be undertaking one big project or a very large organisation might simultaneously be working on many projects with smaller teams. However, overall size of the company will still influence the decision of cloud usage on the management level at least. It is predicted that larger organisations will have higher intention to use cloud technologies as these technologies help with management, coordination, communication, and accessibility in the projects. Conversely, it is predicted that the size of the organisation will negatively affect the top management support that developers and employers individually perceive as well as the training and education opportunities.
- Number of licensed software in this study are accepted as requirements tools, design tools, test tools, maintenance tools, software engineering process tools, quality tools, configuration management tools, project management tools, operating systems, office applications, integrated development environments, and database management systems.

5. INITIAL MODEL DEVELOPMENT

In this study, we propose such a hybrid model, which is based on TAM, TOE and POP frameworks. As an outcome of the model, **"Actual Use – Perceived Suitability – Intention to Use"** structure is proposed in this study. If users are already using cloud technologies for some software development activities, they are more likely to have a more concrete idea about the suitability of the cloud for other software development activities, and if they find cloud computing suitable to their projects, they will have higher intention to use it. With these relationships in mind, a three-piece structure of "actual use – perceived suitability – intention to use" is suggested to replace the "intention to use" factor of technology adoption models.

We developed a hybrid technology adoption model by combining TAM, TOE and POP with the aim of explaining developers' intention to use the cloud in software development activities. The model structures shown in this study contain variables from these three frameworks. The model is built as a structural equation model (SEM).

The initial conceptual model is shown in Figure 2. For the sake of readability, the correlations between the exogenous variables and error terms are not shown. The initial hypotheses (*iH*) of the model are:

iH1: "Perceived usefulness will have a positive direct effect on intention to use the cloud in software development."

iH2a: "Perceived ease of use will have a positive direct effect on intention to use the cloud in software development."

iH2b: "Perceived ease of use will have a positive direct effect on perceived usefulness."

iH3: "Results demonstrability will have a positive direct effect on perceived usefulness."

iH4: "Image will have a positive direct effect on perceived usefulness."

iH5: "Subjective norm will have a positive direct effect on perceived usefulness."

iH6: "Job relevance will have a positive direct effect on perceived usefulness."

iH7: "Output quality will have a positive direct effect on perceived usefulness."

iH8: "Computer self-efficacy will have a positive direct effect on perceived ease of use."

iH9: "Computer anxiety will have a negative direct effect on perceived ease of use."

iH10: "Top management support will have a positive direct effect on intention to use the cloud in software development."

iH11: "Training and education will have a positive direct effect on intention to use the cloud in software development."

iH12: "Complexity will have a negative direct effect on intention to use the cloud in software development."

iH13: "Relative advantage will have a positive direct effect on intention to use cloud in software development."

iH14: "External support will have a positive direct effect on intention to use the cloud in software development."

iH15: "Personal cloud use will have a positive direct effect on intention to use the cloud in software development."

The novel hypotheses based on the POP structure are:

iH16: "Project size will have a negative direct effect on intention to use the cloud in software development."

iH17a: "Project budget will have a negative direct effect on intention to use the cloud in software development."

iH17b: "Project budget will have a negative direct effect on perceived suitability of the cloud in software development."

iH18a: "Project team size will have a positive direct effect on intention to use the cloud in software development."

iH18b: "Project team size will have a positive direct effect on perceived suitability of the cloud in software development."

iH19a: "Organisation size will have a positive direct effect on intention to use the cloud in software development."

iH19b: "Organisation size will have negative direct effect on top management support."

iH19c: "Organisation size will have negative direct effect on training & education."

iH20: "Number of licensed software will have a negative direct effect on intention to use the cloud in software development."

iH21: "Actual use of the cloud in software development will have a positive direct effect on perceived suitability of the cloud for software development."

iH22: "Perceived suitability of the cloud for software development will have a positive direct effect on intention to use the cloud in software development."

Figure 2: Initial conceptual model

One of the aims of this study is to build a final technology adoption model that can explain the intention to use the cloud for software development activities accurately, we revised and updated these initial hypotheses upon exploratory factor analysis of the collected data.

6. RESULTS

This section is divided in two sub-sections about exploratory and SEM analyses.

6.1 Exploratory Analysis Results

We reached out to 30 different SDOs in various sectors that develop software as either their primary or secondary business activity. The questionnaires were personally administered to software developers working in active software projects. Participants were selected with the help of management in the companies and they were included in the study only if they are familiar enough with the cloud concepts so they could accurately answer questions. The personal administration method is chosen over online surveys because of the control it provides over the respondents' care and attention to the questionnaire as well as the possibility of directly assisting the respondents in case they have a question regarding the questionnaire. 191 unique respondents from 30 SDOs have answered the questionnaire with respect to 84 different software development projects. This gave us a total of 288 different observations, as developers affiliated with multiple projects responded for all distinct projects separately.

After data cleansing, 268 of the responses were found valid for the analyses. 20 of the 288 answers had non-random response patterns and they are eliminated from the sample pool before statistical analysis. The low number of eliminated responses (20) from the initial pool may be explained by the use of personally administered questionnaires instead of online survey forms.

Demographics of the individual respondents as well as the projects they work on and SDOs participated in the research is given in Supplementary Material. The summary of demographics of the participants shows that the responses cover a wide selection of opinions of people from different domains, with varying experiences with the cloud, and working on different sized and budgeted projects. Supplementary Material also contains the descriptive statistics of responses regarding the three-piece intention structure in the model.

For the consistency of questionnaire items with each other, Cronbach's alpha values are checked. Cronbach's alpha is a measurement that is used to check internal consistency of questions related to the same variable in questionnaires, this measurement is desired to be above 0.7 [51]. Cronbach's alpha for TAM items is calculated as 0.803, and for TOE items is calculated as 0.722. Moreover, validity of item loadings is checked using Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO) parameter and the significance level of the Bartlett's Test of Sphericity. KMO indicates the degree of variance to which the factors in the model can cause in the model variables. Bartlett's Test of Sphericity is the result of a hypothesis test done to confirm whether the correlation matrix of the model variables is an identity matrix or not [44]. The absolute minimum for KMO values is 0.5 whereas the Bartlett's Test is desired to be significant ($p<0.001$), this means the factor analysis can be used with the current data. KMO values for TAM and TOE items are 0.789 and 0.667, respectively, whereas both p-values are very close to 0.00. Thus, we can say that item loadings have passed the validity test. Correlations between variable pairs are calculated and all the correlation coefficients are found to be between [-0.8, 0.8]. If there was a correlation coefficient between two variables closer to -1 or 1, one of these variables could have been removed from the model, this was not needed at this stage.

Exploratory factor analysis with Varimax rotation gives the groupings of items that are shown in Supplementary Material. Based on this result, item groupings are revised and latent factors in the model are updated. According to the exploratory factor analysis, items that measure "subjective norm" and "image", in fact, measure the same factor and there is no need to use two separate factors. Instead, these two items can load on a single factor, namely "image". Similarly, "output quality" and "job relevance" do not measure two different factors, furthermore they load on the "perceived usefulness" factor. Items that measure "output quality" and "job relevance" are combined with the ones measuring "perceived usefulness" and they all load on the factor "perceived usefulness". Items that measure "computer self-efficacy" and "computer anxiety" are found to measure the same variable, as they are in the opposite directions of each other, "computer anxiety" responses are reversed and then two variables are combined into one that is named "technology confidence" in this study. Last revision to the model is to combine items that measure "top management support" and "training and education" to load on a single "top management support" factor. All these combinations and revisions are in accordance with respect to existing definitions in literature.

Initial conceptual model and the hypotheses that this model aims to test and validate are revised after exploratory factor analysis. Hypotheses about the factors that are combined with others are removed and the ones about the new combinations of factors are updated. The revised hypotheses about pairwise relations of variables in the model are listed below. Other initial hypotheses are confirmed and validated to remain in the model.

H4: "Image will have a positive direct effect on perceived usefulness."

H5: "Technology confidence will have a positive direct effect on perceived ease of use."

H6: "Top management support will have a positive direct effect on intention to use the cloud in software development."

To reflect the final hypotheses on pairwise relations, the full hybrid model is revised with removed and combined factors. Revised conceptual model is given in Figure 4. Correlations between exogenous variables and error terms are again not shown to ease readability.

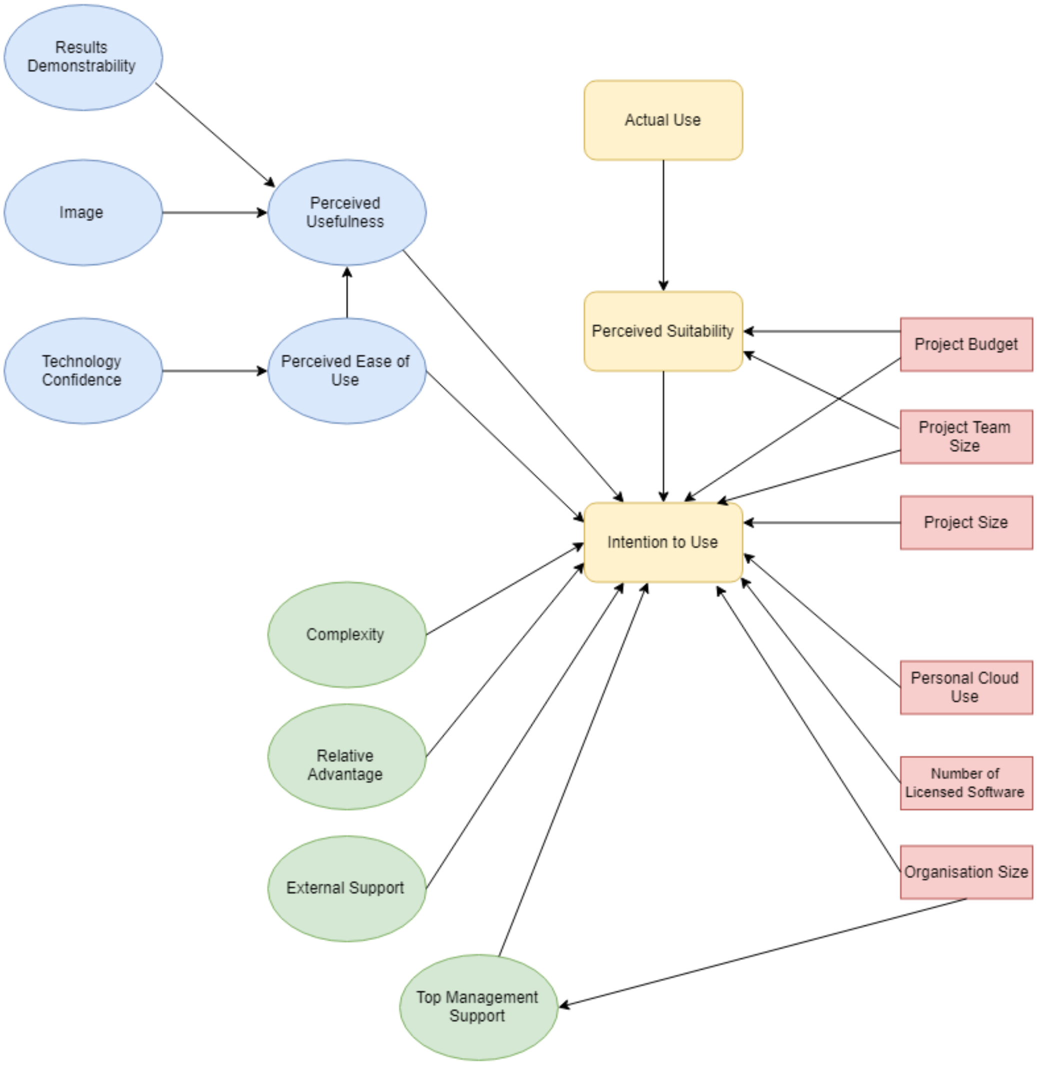

Figure 3: Revised conceptual model

6.2 Structural Equation Analysis Results

Estimates for the initial conceptual model are calculated with the collected data to test and validate the revised hypotheses. The AMOS output shows that there is a glaring issue beyond insignificant relations or poor goodness of fit indices. The covariance matrix between variables is found to be not positive definite, which means some of the eigenvalues of the matrix are not positive. This might be caused by high linear dependency between two variables in the model [52]. When the input covariance matrix is not positive definite, maximum likelihood method (which is used by AMOS for estimations) performs poorly, therefore the software simply gives an error message saying the solution is not admissible. To fix this error, highly correlated items can be discarded from the model to remove linear dependencies, or if it is a case of a model misspecification the model and relations between variables can be rebuilt.

AMOS offers modification indices to suggest correlations and regressions to add to the model. In the modification indices tab of the output, the possible additions are listed with how much they would improve the model (the chi-square value of the model) if they are applied. Furthermore, significance probabilities (p-values) of suggested relations can be checked in the estimates tab of the output to remove insignificant relationships from the model to achieve model parsimony. These additions and removals must be done one by one, and the model must be calculated again after each modification. These steps are beyond the scope of confirmatory SEM analyses, hence SEM analyses at this point become exploratory analyses of the cloud adoption model [44], [53].

Another issue to solve before the model modifications is that even though AMOS has an integrated method of dealing with incomplete data, which uses Full Information Maximum Likelihood (FIML) algorithm, it cannot suggest modification indices when it is used to calculate the model with incomplete data. At this point, we generated an alternative imputed data set by filling in the missing observations and responses with the median of values of each variable. SEM model is calculated with the complete (imputed) data and every modification (addition and removal of correlations and regressions) is applied to both models with original incomplete data (which still uses the FIML method to handle missing data) and the complete imputed data. Every modification suggested by AMOS based on the imputed data did indeed improve the model with the original incomplete data as well.

We reached the final model after these modification steps. We revised and updated the correlations and regressions between variables while following AMOS modification indices for additions and p-values for removals. All the modifications are applied not just based on statistical and numerical improvement of the model but actual variables and what they measure are also taken into consideration. We applied only the rational modifications and once it is determined that no further modification makes sense, we stopped the improvement of the model. The final model is given in Figure 5. Correlations between exogenous variables and error terms are not shown to keep the figure legible. Full AMOS graphic for the model calculations is given in Supplementary Material. Goodness of fit indices are improved, and the model has only statistically significant correlation and regression relations for the sake of parsimony.

The chi-square value of the model is 993.229 with 366 degrees of freedom. p-value for the chi-square is 0.001. The null hypothesis for the chi-square test is that the model fits the data (meaning, the population covariance matrix produced by SEM based on the model is not significantly different than the sample covariance matrix based on collected data). Scholars require the p-value for the test to be greater than 0.05 so that the null hypothesis that states that the model fits the data fails to be rejected. However, when sample size is large enough, it is possible to have a low p-value even though model does indeed fit the data [53]. This is why the model is not rejected just based on the chi-square test and further goodness of fit indices are examined. These indices are suggested by different researchers and the justification for using them is explained in relevant studies in the literature [44].

The ratio of Chi-square value to degrees of freedom of the model (CMIN/DF) is found as 2.714. For a good model fit, this value is desired to be between 2 and 3, which means that there is an acceptable fit in this study’s final model. RMSEA values closer to 0.06 (in the 0.04-0.07 interval for the best fit) mean better fit to data. The model in this study has an average of 0.080 for the RMSEA value with the lower ten percentile falling around the value of 0.074. CFI values are desired to be close to 1, which in this study is found as 0.803. The goodness of fit indices imply a good enough fit to data. As the modification indices did not suggest any further logical changes to the model in the exploratory steps, the study had to stop the improvements at this point to prevent obtaining an overfitting model to reach better goodness of fit indices. The final model is found to explain 69.6% of the changes in intention to use the cloud in software development with the variables and relationships in the model. This is a good amount of variance explained for a complex behavioural model and on the same level as previous cloud adoption studies analysed in the SLR [37].

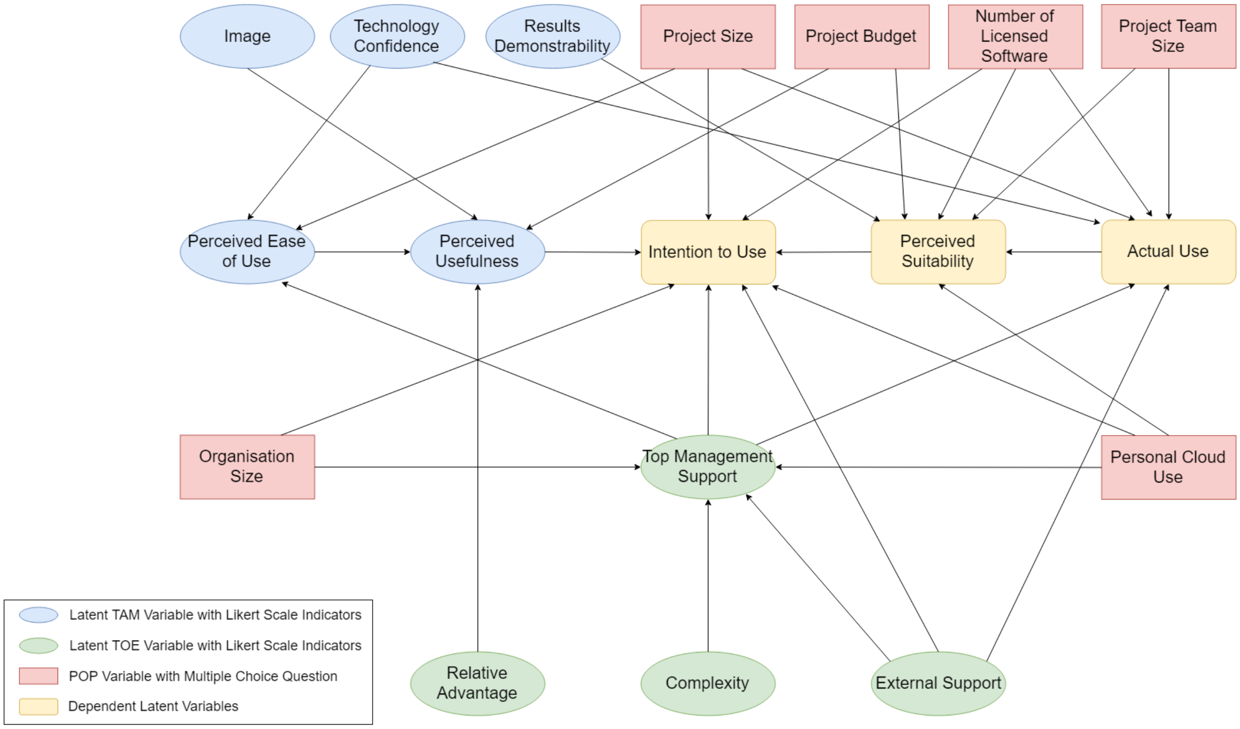

Figure 4: Final conceptual model

The analysis reveals three categories for the findings: the rejected hypotheses, the confirmed hypotheses, and new discoveries. We will discuss the relationships in the cloud adoption model under these categories with a focus on discovered effects. Table 10 lists the rejected hypotheses that are removed in the final model. The accepted hypotheses with their standardised regression weights and the significance levels (p-values) are given in Table 11. Additional significant relationships discovered with the exploratory SEM analyses on the model that were not initially hypothesised are discussed in Section 7.

Table 1: Rejected hypotheses

		Rejection reason
H2a	Perceived ease of use – Intention to use	No significant effect
H3	Results demonstrability – Perceived usefulness	No significant effect
H7	Complexity – Intention to use	No significant effect
H8	Relative advantage – Intention to use	No significant effect
H12a	Project budget – Intention to use	No significant effect
H13a	Project team size – Intention to use	No significant effect

Table 2: Accepted hypotheses

		Std. Reg. Wt.	**p-value**
H1	Perceived usefulness – Intention to use	0.208	<0.001
H2b	Perceived ease of use – Perceived usefulness	0.395	<0.001
H4	Image – Perceived usefulness	0.438	<0.001
H5	Technology confidence – Perceived ease of use	0.501	<0.001
H6	Top management support – Intention to use	0.154	<0.05
H9	External support – Intention to use	0.122	<0.05
H10	Personal cloud use – Intention to use	0.091	<0.05

H11	Project size – Intention to use	-0.083	<0.05
H12b	Project budget – Perceived suitability	-0.177	<0.001
H13b	Project team size – Perceived suitability	0.162	<0.001
H14a	Organisation size – Intention to use	0.122	<0.05
H14b	Organisation size – Top management support	-0.324	<0.001
H15	Number of licensed software – Intention to use	-0.077	<0.05
H16	Actual use – Perceived suitability	0.470	<0.001
H17	Perceived suitability – Intention to use	0.644	<0.001

7. DISCUSSION

In this study, the behavioural model for cloud adoption in software development is tested and validated. Two well-known and widely used theories from literature, namely TAM and TOE, are employed to design a hybrid conceptual model which also includes the novel suggestions of this study, POP and a three-piece intention structure. Upon receiving the results of the confirmatory study, the conceptual model is revised and improved with exploratory analysis steps. Thus, not only the revised theoretical model is validated to be used in similar studies in the future, but also it is made possible to draw specific conclusions about the population selected for this study.

From the collected data current actual use of the cloud in software development activities is not a common practice in Turkey. Organisations prefer to keep the software activities on their own dedicated servers (physical or private virtual servers on premise) and this is due to several different factors. Lack of interest by management, mandatory requirements by specific industries (e.g., elevated security measures in the defence industry), or users wanting to avoid the initial cost of migration (both financial cost and effort required to adapt to the new technology) may be listed as potential avoidance reasons. The organisations that are currently using the cloud technologies are mostly smaller scale start-up companies or larger firms with more innovative management teams who follow new developments closely.

Integrating variables about the characteristics of projects and organisations is found to improve the hybrid TAM-TOE model. Additionally, the hypothesised positive relations between the variables "actual use", "perceived suitability", and "intention to use" are confirmed. According to the conceptualised and validated model, personal perceptions of a new technology play a significant role in accepting that technology over current methods. In addition to personal factors, if developers feel that their top management supports the new technology, they are much more likely to want to use it. Project characteristics affect team members' intention to adopt and use the cloud more than organisational factors. It can be said that it is not fair to make one singular decision regarding cloud use per organisation, instead projects should be considered separately. Even in the same organisation, different projects may require different solutions.

The final model shows that 15 of the 21 initial hypotheses are validated and accepted while six of them are rejected due to finding no direct significant effect. No hypothesis is rejected for having an effect in the opposite direction of the hypothesis (i.e. negative effect is found where positive relationship was hypothesised, or vice versa). Five of these rejected relationships were assumed to have direct effects on intention to use and the other one on perceived usefulness. We discovered that these five factors have indirect effects on intention to use and they directly affect other endogenous variables in the model such as perceived suitability, actual use, perceived usefulness, perceived ease of use, and top management support which then affect intention to use. There are no new discovered direct effects on intention to use, instead the effects in the model are split onto the three-piece structure of "actual use – perceived suitability – intention to use". Relative advantage from TOE structures is found to have effects on the key factors of TAM (perceived usefulness) instead of directly affecting intention. Top management support is found to have direct effect on the key factors of TAM (perceived ease of use) in addition to directly affecting intention.

Discovered effects (DEs) must be examined one by one to make sure they are rational and consistent within the context of the study, which is using the cloud technologies for software development activities in SDOs, beyond being only numerically and statistically significant. If they do not make sense in the context of the study, the model might need a revision. If they are rational relationships, they may give insights about a specific part of the system that was gone unnoticed prior to the analyses. The discovered effects are listed in Table 12.

Table 3: Discovered effects (DEs)

		Std. Reg. Wt.	**p-value**
DE1	Project budget – Perceived usefulness	-0.144	<0.005
DE2	Relative advantage – Perceived usefulness	0.433	<0.001
DE3	Top management support – Perceived ease of use	0.431	<0.001
DE4	Project size – Perceived ease of use	0.393	<0.001
DE5	Personal cloud use – Top management support	0.279	<0.001
DE6	External support – Top management support	0.289	<0.001
DE7	Complexity – Top management support	-0.275	<0.001
DE8	Top management support – Actual use	0.636	<0.001
DE9	Project team size – Actual use	0.179	<0.001
DE10	Technology confidence – Actual use	0.159	<0.005
DE11	External support – Actual use	0.193	<0.05
DE12	Project size – Actual use	-0.118	<0.05
DE13	Number of licensed software – Actual use	-0.154	<0.005
DE14	Results demonstrability – Perceived suitability	0.228	<0.001
DE15	Personal cloud use – Perceived suitability	0.177	<0.001
DE16	Number of licensed software – Perceived suitability	0.143	<0.005

Discovered Effects (DEs) on Perceived Usefulness

Increases in project budget have a negative effect on perceived usefulness (DE1). This is consistent with the initially hypothesised effect of project budget on perceived suitability. Projects with more limited budgets are believed to benefit from the cloud technologies more than projects with higher allowances. The model and the collected data suggest that developers who work on projects with smaller budget find the cloud technologies more useful.

Another effect found on perceived usefulness is from relative advantage (DE2). Relative advantage is a factor that was adapted from the TOE framework, and it was initially hypothesised to directly affect intention to use. The model modifications show that relative advantage, in this case, affects perceived usefulness instead. Looking at the questionnaire item that measures relative advantage, that is "*using the cloud allows me to perform specific software development tasks faster"*, this effect is found to be reasonable.

Discovered Effects (DEs) on Perceived Ease of Use

Top management support (that is perceived by the individual developers in the form of both perceived management policies and actual education and training provided to them) positively affects their perception of ease of use of the cloud technologies for software development activities (DE3). This makes sense in both ways. An actual education and training provided to them in the company means that they will find new technologies easier to adopt and use, and the more support they perceive from their supervisors and managers, more confident they will be to accept new technology alternatives.

The other discovered relationship is more interesting. We found that project size has a positive effect on perceived ease of use (DE4). This is interesting because project size was hypothesised to have a negative effect on intention to use which is confirmed, additionally we discovered that it has a similar negative effect on actual cloud use. Developers perceive the cloud technologies as easier to use for larger projects, even though there is an overall decrease in actual current use and intention to adopt cloud technologies for such projects. Although larger projects are more intimidating to migrate over a new platform, which explains why project size expectedly has a negative effect on actual use and intention, when individual developers are asked the question about their perception on ease of use of the cloud technologies, they might not have answered only with their ongoing projects in mind and they might prefer to begin working on new large projects on the cloud platforms from the start. Therefore, this difference in effects of project size might be explained by the difference between developers' personal perceptions on the cloud technologies and their perception on the ongoing projects in the context of their organisation and management.

Discovered Effects (DEs) on Top Management Support

There are three additional effects discovered on top management support perceived by developers. Personal cloud use (DE5) and external support (DE6) are found to positively affect top management support while complexity (DE7) has a negative effect on it. While external support is related to top management support as a whole, other two effects are related to the training and education part of the top management support more than they are to the perceived support by management level. Both perceived complexity and personal cloud use of developers in their daily life measure their competence at using the cloud technologies in software development activities and this perception is also related to the level of training provided to them by the management.

Discovered Effects (DEs) on Actual Use

In the initial model we assumed actual use to be an exogenous variable that affects perceived suitability (which then affects intention to use). After modifications we found that actual use also is directly affected by other factors in the model while keeping the three-piece structure of actual use → perceived suitability → intention to use.

From factors that have direct effects on actual use, we found that top management support (DE8) has the highest effect with the greatest regression weight and highest significance level. Even in the cases where developers would be likely to use the cloud technologies, it is usually not preferred to adopt on the managerial level. In addition to top management support, project team size (DE9), technology confidence (DE10), and external support (DE11) are other factors that have direct positive effects on actual use. Projects with larger team sizes are more likely to already have adopted the cloud technologies because of the several benefits of the cloud technologies with regards to easier management, coordination, communication, and accessibility in the projects. Technology confidence is a personal factor that makes cloud technologies more tempting to use for developers. Their perceived external support means that they are more likely to have already adopted related technologies in their work.

Project size (DE12) and number of licensed software (DE13) are the factors that negatively affect the actual cloud use. These two factors were initially hypothesised to have negative effects on intention to use and in the final model these effects are confirmed. In addition to the potential adoption scenarios, they are discovered to have similar negative effects in the current cloud use cases as well. These, again, are reasonable in the context of this study.

Discovered Effects (DEs) on Perceived Suitability

Similar to the key factors of TAM (perceived ease of use and perceived usefulness), perceived suitability is a personal factor which is suggested to directly affect intention to use in this study. It was initially assumed to be affected by only the project characteristics (budget and team size) because even for the same developer this perception may differ between projects. These two effects are confirmed. Additionally, more factors in the model are discovered to directly affect developers' perception of suitability of the cloud technologies to their current project.

Results demonstrability which was initially assumed to increase the users' perceived usefulness is instead found to increase users' perceived suitability (DE14). Personal cloud use of developers in daily non-professional life similarly has a positive effect on their perceived suitability of cloud technologies to their professional work (DE15).

Finally, number of licensed software used in the project is discovered to have a positive effect on perceived suitability (DE16). This observation deserves a special examination because the same variable is also found to have negative effects on actual use and intention to use. How is it that when the amount of licensed official software purchased and used for the project increases, respondents are more likely to find the cloud technologies for these projects more suitable but the actual current use and intention to adopt the cloud decrease? The licensed official software packages purchased for the project are usually proprietary, commercial alternatives and these purchases are made by the management and not the developers themselves. In the case of having already purchased the expensive, proprietary programs; management might not be interested in immediately moving to the cloud technologies which support open-source alternatives and make the purchased software redundant in some version of a sunk cost fallacy. Managers' lack of interest in the migration to the cloud, in this case, might negatively affect the current cloud use and the intention of developers to adopt because top management support is found to have a greater effect on their perception of ease of use and intention. But at the same time, developers see that the project uses a large amount of officially licensed software programs, and they might be inclined to believe that the project, for that reason, would be more suitable for the cloud technologies. This is an interesting discovery that emphasises the differences in the viewpoints of managers and developers in the same system, viewpoints that also affect each other.

All the new suggested effects in the model are examined and found to be reasonable and consistent within the context of the study and the sample. Furthermore, as this was the intended outcome of exploratory analyses, they give more insight to what affects intention to use the cloud technologies in software development activities by developers in projects and companies with different characteristics than what was initially hypothesised. Both statistically significant and realistically meaningful conclusions are drawn from the results of the analysis.

8. CONCLUSION

Cloud computing in the last decade has become a technology in practical use in daily lives of individuals as well as in business activities of organisations. With the increase in cloud usage and its popularity, more specific cloud-based solutions are developed for particular areas. Software development is one of these areas because it is an extensive task that consists of many phases and activities and cloud-based solutions might help developers improve their performance. However, it is important to analyse which project activity could indeed be improved with cloud-based solutions and which ones would be hindered if the cloud is used over traditional methods that developers might feel more comfortable to use.

In this study we propose a hybrid technology adoption model for the use of cloud in software development projects. The hybrid model includes personal factors and perceptions of the users, organisational factors, and project-related factors to capture the cloud adoption from three perspectives. These factors are informed by validated frameworks and theories such as TAM and TOE, and also include our proposed POP structure. After iterations of the statistical analysis driven by user data, we propose the final conceptual model to be used to evaluate cloud adoption in software development activities.

To refine the hybrid adoption model and test its use in a real scenario, we conducted a technology adoption study with software development teams in Turkey. We found that there are several discovered relations in the cloud adoption process that were not initially hypothesised. A summary of findings includes:

- Actual use of the cloud was predicted to be an exogenous variable in the model that directly affects perceived suitability, and then intention to use indirectly. However, it is found that effects of causal factors on the current cloud use also should be taken into consideration for a more accurate model, which means actual use is also an endogenous variable whose change is explained by other variables in the model.
- It is discovered that as projects get larger (more line of code and more software tools required to complete the different steps of the project), developers will find the cloud technologies more suitable to the project while management will be less likely to make the decision to migrate to the cloud.
- Even in the cases where management does not support the adoption of the cloud technologies for the current software projects, they can be beneficial for future projects if they are to be used from the start.

8.1 Threats to Validity

Construct Validity: Errors while measuring the variables might occur due to miscommunication between researchers and respondents on the questionnaire items. To reduce this risk, the questionnaire sessions were conducted in personally administered sessions in the premises of the participant SDOs. Questionnaire sessions were arranged according to the respondents' schedule and in their own offices, at least one researcher has always been present during the questionnaire sessions to clarify anything when needed by respondents. Items in the questionnaire were worded as clear as possible with avoiding technical terms that could create confusion. Respondents were also allowed to skip any question they were not certain about.

Internal validity: Causal relationships between variables that were not considered to be included in the model might cause internal validity threats [54]. The variables that are in the conceptual model were analysed upon collecting data using exploratory factor analysis and variables were revised after the analyses to make sure all the relations in the final model are as intended and there are no casual relations or correlations that would affect the outcome.

External validity: Threats to external validity are potential limits to the ability to generalise the study results to a larger scope [54]. Selection of respondents, sample size, and changes to technology and people's perceptions of the technology over time might cause generalisation limitations. Respondents in this study were chosen as developers, project managers, and senior managers in SDOs in Turkey who are currently working on software development projects. Researchers contacted high level managers in SDOs for questionnaire arrangements and managers in organisations organised participants from relevant projects. Careful selection of participants, personally administered questionnaire sessions, and the sample size are argued to have no limitations to generalisation of the results. Regarding the change in technology and people's perception of the technology over time; we anticipate that at the current rate of developments in cloud technologies for software development and developers' perception of the cloud, the conceptual behavioural model and the methodology of the study will remain applicable over time.

Conclusion validity: Conclusion validity is whether the study is reproducible or not. All models and variables are defined carefully and the collected anonymous data is well-stored. Software (IBM SPSS Statistics AMOS 23) and algorithms (SEM) used for statistical analyses are proven to be appropriate and accurate by scholars and experts working in this field. We believe that with the same model and collected data, the primary study is entirely reproducible and other researchers would reach the same results and conclusions.

8.2 Limitations and Future Work

This study has reached meaningful results and it allows conclusions to be drawn from the findings. However, it is not without its limitations. The goodness-of-fit values of the adoption model with regards to the collected data can be improved. This can be done by the addition of different factors into the model that were not suggested in this study. For example, future studies directly focusing on variables such as cost or security concerns may be useful as these variables can make up a full model themselves with all sub-categories. Additionally, increase in the sample size might improve the indices. Even though the sample size of this study is enough to draw conclusions about the population, larger sample size with more observations and data can always improve the models. The data is collected from software developers, project leaders, and high-level managers in SDOs in Turkey. In future studies same questionnaire might be applied in different geographical locations to extend the model or compare the results between studies. However, this geographical location limitation is common in all information systems studies and it does not deter the claims and conclusions about generality of results [55].

REFERENCES

[1] P. Bourque, R. Dupuis, A. Abran, J. W. Moore, and L. Tripp, *Guide to the software engineering body of knowledge*, vol. 16, no. 6. IEEE Computer Society Press, 1999.

[2] Q. Zhang, L. Cheng, and R. Boutaba, “Cloud computing: state-of-the-art and research challenges,” *J. internet Serv. Appl.*, vol. 1, no. 1, pp. 7–18, 2010.

[3] P. Mell, T. Grance, and others, “The NIST definition of cloud computing,” 2011.

[4] C. Pahl and H. Xiong, “Migration to PaaS clouds - Migration process and architectural concerns,” in *c2013 IEEE 7th International Symposium on the Maintenance and Evolution of Service-Oriented and Cloud-Based Systems, MESOCA 2013*, 2013, pp. 86–91, doi: 10.1109/MESOCA.2013.6632740.

[5] C. Pahl, “Containerization and the PaaS Cloud,” *IEEE Cloud Comput.*, vol. 2, no. 3, pp. 24–31, 2015, doi: 10.1109/MCC.2015.51.

[6] G. C. Fox, V. Ishakian, V. Muthusamy, and A. Slominski, “Status of Serverless Computing and Function-as-a-Service(FaaS) in Industry and Research,” *arXiv Prepr. arXiv1708.08028*, 2017, doi: 10.13140/RG.2.2.15007.87206.

[7] H. Erdogmus, “Cloud computing: Does Nirvana hide behind the Nebula?,” *IEEE Softw.*, vol. 26, no. 2, pp. 4–6, 2009, doi: 10.1109/MS.2009.31.

[8] T. Dillon, C. Wu, and E. Chang, “Cloud computing: issues and challenges,” in *2010 24th IEEE international conference on advanced information networking and applications*, 2010, pp. 27–33.

[9] G. Candea, S. Bucur, and C. Zamfir, “Automated software testing as a service,” in *Proceedings of the 1st ACM Symposium on Cloud Computing, SoCC ’10*, 2010, pp. 155–160, doi: 10.1145/1807128.1807153.

[10] J. A. Teixeira and H. Karsten, “Managing to release early, often and on time in the OpenStack software ecosystem,” *J. Internet Serv. Appl.*, vol. 10, no. 1, p. 7, 2019, doi: 10.1186/s13174-019-0105-z.

[11] C. Weinhardt *et al.*, “Cloud computing--a classification, business models, and research directions,” *Bus. Inf. Syst. Eng.*, vol. 1, no. 5, pp. 391–399, 2009.

[12] T. Al-Rousan, “Cloud computing for global software development: Opportunities and challenges,” *Transp. Syst. Eng. Concepts, Methodol. Tools, Appl.*, vol. 2–3, no. 1, pp. 897–908, 2015, doi: 10.4018/978-1-4666-8473-7.ch045.

[13] M. Almorsy, J. Grundy, and I. Müller, “An Analysis of the Cloud Computing Security Problem,” 2016, [Online]. Available: http://arxiv.org/abs/1609.01107.

[14] V. Malik and S. Singh, “Exploring Computing Environment Possibilities for Risk Oriented Testing,” *Orient. J. Comput. Sci. Technol.*, vol. 10, no. 3, pp. 674–682, 2017, doi: 10.13005/ojcst/10.03.18.

[15] V. Mittal, L. Nautiyal, and M. Mittal, “Cloud testing-the future of contemporary software testing,” in *Proceedings - 2017 International Conference on Next Generation Computing and Information Systems, ICNGCIS 2017*, 2018, pp. 142–146, doi: 10.1109/ICNGCIS.2017.11.

[16] C. Li and J. Gu, “An integration approach of hybrid databases based on SQL in cloud computing environment,” *Softw. - Pract. Exp.*, vol. 49, no. 3, pp. 401–422, 2019, doi: 10.1002/spe.2666.

[17] S. A. Butt, M. I. Tariq, T. Jamal, A. Ali, J. L. D. Martinez, and E. De-La-Hoz-Franco, “Predictive variables for agile development merging cloud computing services,” *IEEE Access*, vol. 7, pp. 99273–99282, 2019, doi: 10.1109/ACCESS.2019.2929169.

[18] A. E. Oke, A. F. Kineber, B. Alsolami, and C. Kingsley, “Adoption of cloud computing tools for sustainable construction: A structural equation modelling approach,” *J. Facil. Manag.*, 2022.

[19] S. Al-Saqqa, S. Sawalha, and H. AbdelNabi, “Agile Software Development: Methodologies and Trends.,” *Int. J. Interact. Mob. Technol.*, vol. 14, no. 11, 2020.

[20] S. Gochhait, S. A. Butt, T. Jamal, and A. Ali, “Cloud enhances agile software development,” in *Research Anthology on Agile Software, Software Development, and Testing*, IGI Global, 2022, pp. 491–507.

[21] S. Yau and H. An, “Software engineering meets services and cloud computing,” *Computer (Long. Beach. Calif).*, vol. 44, no. 10, pp. 47–53, 2011, doi: 10.1109/MC.2011.267.

[22] M. A. Cusumano, “Technology strategy and management the cloud as an innovation platform for software development: How cloud computing became a platform,” *Commun. ACM*, vol. 62, no. 10, pp. 20–22, 2019, doi: 10.1145/3357222.

[23] B. L. Jones, “The Impact of the Cloud on Software Development. https://www.developer.com/cloud/the-impact-of-the-cloud-on-software-development.html. Accessed on 14 June 2020.,” 2017. .

[24] M. Burns, “Software Development in the Cloud: Benefits and Challenges,” *Tech Genix*, 2019. http://techgenix.com/software-development-in-the-cloud/.

[25] H. Gangwar and H. Date, “Understanding cloud computing adoption: A model comparison approach,” *Hum. Syst. Manag.*, vol. 35, no. 2, pp. 93–114, 2016, doi: 10.3233/HSM-150857.

[26] H. Gangwar, H. Date, and R. Ramaswamy, “Understanding determinants of cloud computing adoption using an integrated TAM-TOE model,” *J. Enterp. Inf. Manag.*, vol. 28, no. 1, pp. 107–130, 2015, doi: 10.1108/JEIM-08-2013-0065.

[27] F. Safari, N. Safari, and A. Hasanzadeh, “The adoption of software-as-a-service (SaaS): Ranking the determinants,” *J. Enterp. Inf. Manag.*, vol. 28, no. 3, pp. 400–422, 2015, doi: 10.1108/JEIM-02-2014-0017.

[28] P. Priyadarshinee, R. D. Raut, M. K. Jha, and S. S. Kamble, “A cloud computing adoption in Indian SMEs: Scale development and validation approach,” *J. High Technol. Manag. Res.*, vol. 28, no. 2, pp. 221–245, 2017, doi: 10.1016/j.hitech.2017.10.010.

[29] J. P. Shetty and R. Panda, “An overview of cloud computing in SMEs,” *J. Glob. Entrep. Res.*, pp. 1–14, 2021.

[30] Y. A. M. Qasem, R. Abdullah, Y. Yah, R. Atan, M. A. Al-Sharafi, and M. Al-Emran, “Towards the development of a comprehensive theoretical model for examining the cloud computing adoption at the organizational level,” *Recent Adv. Intell. Syst. Smart Appl.*, pp. 63–74, 2021.

[31] F. Mohammed and O. Bin Ibrahim, “Drivers of cloud computing adoption for E-government services implementation,” *Int. J. Distrib. Syst. Technol.*, vol. 6, no. 1, pp. 1–14, 2015.

[32] A. Yasin, L. Liu, T. Li, J. Wang, and D. Zowghi, “Design and preliminary evaluation of a cyber Security Requirements Education Game (SREG),” *Inf. Softw. Technol.*, vol. 95, no. December 2017, pp. 179–200, 2018, doi: 10.1016/j.infsof.2017.12.002.

[33] P. Thusi and D. K. Maduku, “South African millennials’ acceptance and use of retail mobile banking apps: An integrated perspective,” *Comput. Human Behav.*, vol. 111, no. July 2019, 2020, doi: 10.1016/j.chb.2020.106405.

[34] V. Mezhuyev, M. Al-Emran, M. A. Ismail, L. Benedicenti, and D. A. P. Chandran, “The Acceptance of Search-Based Software Engineering Techniques: An Empirical Evaluation Using the Technology Acceptance Model,” *IEEE Access*, vol. 7, pp. 101073–101085, 2019, doi: 10.1109/access.2019.2917913.

[35] D. J. Kim, J. Hebeler, V. Yoon, and F. Davis, “Exploring Determinants of Semantic Web Technology Adoption from IT Professionals’ Perspective: Industry Competition, Organization Innovativeness, and Data Management Capability,” *Comput. Human Behav.*, vol. 86, pp. 18–33, 2018, doi: 10.1016/j.chb.2018.04.014.

[36] Y. A. M. Qasem *et al.*, “A multi-analytical approach to predict the determinants of cloud computing

adoption in higher education institutions," *Appl. Sci.*, vol. 10, no. 14, p. 4905, 2020.

[37] E. Pisirir *et al.*, "Structural equation modeling in cloud computing studies: a systematic literature review," *Kybernetes*, vol. 49, no. 3, pp. 982–1019, 2019, doi: 10.1108/K-12-2018-0663.

[38] R. F. El-Gazzar, "A literature review on cloud computing adoption issues in enterprises," in *IFIP Advances in Information and Communication Technology*, 2014, vol. 429, pp. 214–242, doi: 10.1007/978-3-662-43459-8_14.

[39] A. C. M. de Paula and G. de F. de Carneiro, "A systematic literature review on cloud computing adoption and migration," in *Communications in Computer and Information Science*, 2016, vol. 703, pp. 222–243, doi: 10.1007/978-3-319-56390-9_11.

[40] M. Chiregi and N. Jafari Navimipour, "Cloud computing and trust evaluation: A systematic literature review of the state-of-the-art mechanisms," *J. Electr. Syst. Inf. Technol.*, vol. 5, no. 3, pp. 608–622, 2018, doi: 10.1016/j.jesit.2017.09.001.

[41] M. T. Amron, R. Ibrahim, and S. Chuprat, "A Review on Cloud Computing Acceptance Factors," *Procedia Comput. Sci.*, vol. 124, pp. 639–646, 2017, doi: 10.1016/j.procs.2017.12.200.

[42] F. Shahzad, G. Y. Xiu, I. Khan, M. Shahbaz, M. U. Riaz, and A. Abbas, "The moderating role of intrinsic motivation in cloud computing adoption in online education in a developing country: a structural equation model," *Asia Pacific Educ. Rev.*, vol. 21, no. 1, pp. 121–141, 2020, doi: 10.1007/s12564-019-09611-2.

[43] Z. Wang, N. Wang, X. Su, and S. Ge, "An empirical study on business analytics affordances enhancing the management of cloud computing data security," *Int. J. Inf. Manage.*, vol. 50, pp. 387–394, 2020, doi: 10.1016/j.ijinfomgt.2019.09.002.

[44] B. M. Byrne, *Structural equation modeling with AMOS: Basic concepts, applications, and programming*. Routledge, 2016.

[45] F. Davis, "Perceived Usefulness, Perceived East of Use, and User Acceptance of Information Technology," *MIS Q.*, vol. 13, no. 3, pp. 319–340, 1989, doi: 10.1016/S0305-0483(98)00028-0.

[46] I. Ajzen and M. Fishbein, "Understanding attitudes and predicting social behaviour," *Englewood Cliffs*, 1980, [Online]. Available: http://www.citeulike.org/group/38/article/235626.

[47] V. Venkatesh and F. D. Davis, "Theoretical extension of the Technology Acceptance Model: Four longitudinal field studies," *Manage. Sci.*, vol. 46, no. 2, pp. 186–204, 2000, doi: 10.1287/mnsc.46.2.186.11926.

[48] V. Venkatesh and H. Bala, "Technology acceptance model 3 and a research agenda on interventions," *Decis. Sci.*, vol. 39, no. 2, pp. 273–315, 2008, doi: 10.1111/j.1540-5915.2008.00192.x.

[49] L. G. Tornatzky, M. Fleischer, and J. D. Eveland, "Technological Innovation as a Process," no. January 1990, pp. 28–49, 1990.

[50] J. Baker, "The technology--organization--environment framework," in *Information systems theory*, Springer, 2012, pp. 231–245.

[51] J. Nunnally, "Psychometric methods." New York: McGraw-Hill, 1978.

[52] W. Wothke, "Nonpositive definite matrices in structural modeling," *Test. Struct. Equ. Model.*, vol. 154, pp. 256–293, 1993, [Online]. Available: http://www.amazon.co.uk/Testing-Structural-Equation-Models-Editions/dp/0803945078.

[53] N. J. Blunch, *Introduction to Structural Equation Modeling using IBM SPSS Statistics and AMOS*. Sage, 2017.

[54] P. Runeson and M. Höst, "Guidelines for conducting and reporting case study research in software engineering," *Empir. Softw. Eng.*, vol. 14, no. 2, pp. 131–164, 2009, doi: 10.1007/s10664-008-9102-8.

[55] H. Jafarkarimi, R. Saadatdoost, A. T. H. Sim, and J. M. Hee, “Behavioral intention in social networking sites ethical dilemmas: An extended model based on Theory of Planned Behavior,” *Comput. Human Behav.*, vol. 62, pp. 545–561, 2016, doi: 10.1016/j.chb.2016.04.024.

[56] T. Oliveira, M. Thomas, and M. Espadanal, “Assessing the determinants of cloud computing adoption: An analysis of the manufacturing and services sectors,” *Inf. Manag.*, vol. 51, no. 5, pp. 497–510, 2014.

[57] J. W. Lian, D. C. Yen, and Y. T. Wang, “An exploratory study to understand the critical factors affecting the decision to adopt cloud computing in Taiwan hospital,” *Int. J. Inf. Manage.*, vol. 34, no. 1, pp. 28–36, 2014, doi: 10.1016/j.ijinfomgt.2013.09.004.

[58] S. Çoban, E. Uçar, O. Chouseinoglou, C. Sevgi, and M. C. Testik, “Understanding the tendency of software development teams to develop software over the cloud,” in *CEUR Workshop Proceedings*, 2016, vol. 1721, pp. 14–25.

[59] V. Garousi, A. Coşkunçay, A. Betin-Can, and O. Demirörs, “A survey of software engineering practices in Turkey,” in *Journal of Systems and Software*, 2015, vol. 108, pp. 148–177, doi: 10.1016/j.jss.2015.06.036.

SUPPLEMENTARY MATERIAL

Questionnaire

ID	QUESTION	SOURCE
PU1	Using cloud for software development improves my performance.	[48]
PU2	Using cloud for software development increases my productivity.	[48]
OUT1	The results of my work is good when I use cloud for software development.	[48]
REL1	Usage of cloud is relevant in my job.	[48]
RES1	The results of using cloud for software development are apparent to me.	[48]
RES2	I believe I could communicate to others the consequences of using cloud for software development.	[48]
RES3	I would not have difficulty explaining why using cloud for software development may or may not be beneficial.	[48]
SN1	People who influence my behaviour think that I should use cloud for software development.	[48]
IMG1	Using cloud for software development is prestigious.	[48]
PEOU1	Interacting with cloud when developing software is clear and understandable.	[48]
PEOU2	Interacting with cloud when developing software does not require a lot of my mental effort.	[48]
CAX1	Developing software on cloud scares me.	[48]
CSE1	I can complete software development tasks on cloud even if there is no one to show me how to do it first.	[48]
TMS1	My company's management supports (e.g. providing resources, taking risks, etc.) the adoption of cloud for software development.	[56]
TMS2	My company's management understands the benefits of using cloud for software development.	[57]
TE1	My company provided me training for using cloud for software development.	[26]
CLX1	I find it difficult to integrate my existing work with the cloud-based services	[26]
CLX2	I find the use of cloud computing to be too complex for software development operations.	[56]
EXSP1	I think the existing laws and regulations are sufficient to protect the use of cloud for software development.	[56]
EXSP2	I think using cloud for software development is becoming one of the government major policies.	[57]
RAD1	Using cloud allows me to perform specific software development tasks faster.	[56]
INT…	I would want to use cloud computing in my project in the phase of …………	[58]
INT1	requirement management.	
INT2	design.	
INT3	coding and development.	
INT4	test.	
INT5	deployment.	
INT6	maintenance.	
INT7	configuration management.	
INT8	documentation.	
INT9	quality assurance.	
INT10	project management.	

SUI…	I find cloud computing suitable in my project in the phase of ………..	[58]
SUI1	requirement management.	
SUI2	design.	
SUI3	coding and development.	
SUI4	test.	
SUI5	deployment.	
SUI6	maintenance.	
SUI7	configuration management.	
SUI8	documentation.	
SUI9	quality assurance.	
SUI10	project management.	
ACT…	I am currently using cloud computing in my project in the phase of ………..	[58]
ACT1	requirement management.	
ACT2	design.	
ACT3	coding and development.	
ACT4	test.	
ACT5	deployment.	
ACT6	maintenance.	
ACT7	configuration management.	
ACT8	documentation.	
ACT9	quality assurance.	
ACT10	project management.	
PRSZ	What is the estimated size of your current software project in KLOC (kilo line of code)?	[59]
PRBG	What is the budget of your project?	[59]
PRTS	What is the team size of your current software project?	[59]
PCLU	How many of the following cloud services do you currently use in your personal life?	[59]
NOLS	How many of the following licensed tools and software do you use in your current software project with a license fee?	[59]
ORSZ	How many employers work in your organisation?	[59]

Participant Demographics, Project and Organization Characteristics

Supplementary Table 1 – Participant Demographics

Unique respondents (N = 191)					
Gender	***n***	***%***	***Education***	***n***	***%***
Female	32	16.8	High school or pre-graduate	4	2.7
Male	159	83.2	Graduate	121	63.3
			MSc	56	29.3
			PhD	9	4.7
Age	***n***	***%***	***Work Experience***	***n***	***%***
Less than 18	0	0	Less than a year	27	14.1
18-25	20	10.4	1 - 5 years	43	22.5
26-33	86	45.1	6 - 10 years	56	29.3
34-41	58	30.4	11 - 20 years	54	28.3
42 and older	27	14.1	More than 20 years	11	5.8

Supplementary Table 2 – Project Characteristics

Project (N = 84)					
Project Size	***n***	***%***	***Contractor***	***n***	***%***
<10 KLOC	4	4.8	Sole contractor	70	83.3
10-99 KLOC	13	15.5	Consortium	14	16.7
100-1000 KLOC	17	20.2			
>1000 KLOC	10	11.9	***Deployment Model***	***n***	***%***
No estimation	40	47.6	Own physical server	44	52.4
Project budget	***n***	***%***	Rented physical server	11	13.1
< $50,000	20	23.8	Rented virtual server	20	23.8
$50,000 - $100,000	7	8.3	Own virtual server	34	40.5
$100,000 - $500,000	17	20.2			
> $500,000	37	44.1	***Software Process Model***	***n***	***%***
Not disclosed	3	3.6	Agile	64	76.2
Project Team Size	***n***	***%***	Incremental	24	28.6
1 – 3	24	28.6	Waterfall	14	16.7
4 – 7	38	45.2			
8 – 15	12	14.3	***Programming Language***	***n***	***%***
16 - 35	10	11.9	Java	51	60.7
Financial Sources	***n***	***%***	JavaScript	49	58.3
100% domestic	70	83.3	PHP / ASP / JSP	29	34.5
Mostly domestic	5	6	C++	18	21.4
Mostly international	6	7.1	iOS / Swift	18	21.4
100% international	3	3.6	C#	16	19
Geographic Location	***n***	***%***	Python	16	19
Single office	63	75	Objective-C	11	13.1
Two offices in the same city	11	13.1	Other	14	16.7
More than two offices in the same city	1	1.2			
Multiple offices in two cities	6	7.1	***Mobility***	***n***	***%***
Multiple offices in more than two cities	3	3.6	No mobility	43	51.2
Developed Software Type	***n***	***%***	Less than half of the team partially mobile	22	26.1
Safety-critical and life-critical systems	25	29.8	Less than half of the team mostly mobile	1	1.2
Business applications	32	38.1	Half of the team partially mobile	13	15.5
Science/Engineering applications	8	9.5	More than half of the team partially mobile	1	1.2
System software	11	13.1	More than half of the team mostly mobile	3	3.6
Web applications	52	61.9	Almost entire team partially mobile	1	1.2
Mobile applications	30	35.7			

Supplementary Table 3 – SDO Characteristics

SDO (N = 30)					
Organisation Size	***n***	*%*	***Number of Projects***	***n***	*%*
1 - 9	8	26.7	1 - 10	18	60
10 - 49	9	30	11 - 25	8	26.7
50 - 99	0	0	26 - 75	2	6.7
100 - 499	7	23.3	76 - 200	0	0
500 +	6	20	200 +	1	3.3
Annual Business Volume	***n***	*%*	Not reported	1	3.3
< $100,000	2	6.7	***Organisation Sector***	***n***	*%*
$100,000 - $500,000	10	33.3	Banking / Finance	7	23.3
> $500,000	15	50	Public Sector	14	46.7
Not disclosed	3	10	Military and Defence	11	36.7
Organisation Age	***n***	*%*	Engineering / Manufacturing	9	30
1 - 10	14	46.7	IT / Telecommunication	13	43.3
11 - 25	9	30	Insurance	3	10
26 +	7	23.3	Healthcare	7	23.3
			Management	7	23.3

Questionnaire Responses regarding the three-piece model structure

"Intention to use" the cloud for software development activities is the main dependent variable in our model. It represents an individual user's desire to move to cloud-based solutions from previous alternatives currently in use. Questionnaire results for intention to adopt and use of the cloud in software development activities represents a noticeable level of interest for the cloud by developers. For all activities, majority of the responses fall above the average and developers claim that they would like to use cloud-based solutions in different software development activities. Supplementary Table 4 shows the descriptive statistics and frequencies of responses to the items regarding intention to use the cloud.

Supplementary Table 4 – Descriptive statistics and frequencies for intention to use the cloud

Activity	Mean	St. Dev.	Mode	Median	Never (1)	Rarely (2)	Sometimes (3)	Often (4)	Always (5)
Requirements	3.64	1.31	4	4	27	20	37	78	74
Design	3.42	1.27	4	4	28	23	53	78	49
Coding	3.72	1.27	4	4	23	25	37	85	84
Test	3.73	1.15	4	4	13	26	54	82	76
Deployment	4.04	1.17	5	4	15	12	33	68	111
Maintenance	3.63	1.23	5	4	22	12	63	63	69
Configuration	3.76	1.27	5	4	24	15	40	78	85
Documentation	4.08	1.13	5	4	14	13	21	86	108
Quality	3.53	1.36	5	4	28	16	41	56	62
Project Mgmt.	3.92	1.22	5	4	17	11	33	64	88

Perceived suitability is our addition to the dependent variables in the cloud adoption model. We propose that developers' perception of cloud-based solutions with regards to their current tasks will directly affect their intention to adopt and use the cloud. To assess their perception of the suitability of the cloud to their current projects, a set of questions were asked in the questionnaire. Descriptive statistics and frequencies of the responses are given in Supplementary Table 5.

Supplementary Table 5 – Descriptive statistics and frequencies for perceived suitability of the cloud

Activity	Mean	St. Dev.	Mode	Median	Never (1)	Rarely (2)	Sometimes (3)	Often (4)	Always (5)
Requirements	3.63	1.25	4	4	27	19	31	104	61
Design	3.36	1.09	4	3.5	20	24	76	89	31
Coding	3.63	1.15	4	4	21	16	54	101	57
Test	3.61	1.06	4	4	13	19	65	95	49
Deployment	3.82	1.20	4	4	19	10	39	80	76
Maintenance	3.46	1.15	4	4	20	19	56	84	37
Configuration	3.73	1.16	4	4	16	21	38	94	65
Documentation	4.06	1.07	4	4	13	10	24	101	97
Quality	3.43	1.32	4	4	27	22	50	58	54
Project Mgmt.	3.81	1.17	4	4	15	18	34	83	73

Actual use, unlike perceived suitability or intention to use, is not a personal perception, a behaviour, or a belief. It is the actual current state of the cloud usage in software development activities for the currently active projects of developers. It essentially measures the degree to which cloud technologies are utilised in the ten different activities of software life cycle on a Likert scale from 1 (never) to 5 (always). The detailed rundown of actual cloud use in software development activities in the SDOs that participated in the questionnaire is given in Supplementary Table 6. The respondents who always use the cloud technologies in any of the software development activities never exceed the 10% of the sample. Mean values of responses for all ten activities are below the average of the scale (2.5) with mode and median of the responses being 1 (except for two activities with the median value of 2). A big portion of the sample never use the cloud for software development currently.

Supplementary Table 6 – Descriptive statistics and frequencies for actual current cloud use

Activity	**Mean**	**St. Dev.**	**Mode**	**Median**	**Never (1)**	**Rarely (2)**	**Sometimes (3)**	**Often (4)**	**Always (5)**
Requirements	2.07	1.28	1	1	122	30	39	37	9
Design	1.94	1.17	1	1	130	42	52	15	11
Coding	2.30	1.44	1	2	119	29	40	38	26
Test	2.04	1.30	1	1	131	42	34	31	15
Deployment	2.32	1.50	1	1	126	20	28	51	25
Maintenance	1.93	1.32	1	1	144	32	28	22	18
Configuration	2.12	1.43	1	1	121	24	18	39	17
Documentation	2.45	1.41	1	2	99	27	49	48	21
Quality	1.95	1.37	1	1	133	21	27	18	20
Project Mgmt.	2.38	1.45	1	2	95	19	46	28	25

Exploratory Factor Analysis

Supplementary Table 7 – Rotated Component Matrix of TOE items

	Component			
	1	2	3	4
TMS2	.860			
TE1	.839			
TMS1	.798			
CLX2		.878		
CLX1		.839		
EXS2			.855	
EXS1			.750	
RAD1				.985

Supplementary Table 8 – Rotated Component Matrix of TAM items

	Component				
	1	2	3	4	5
PU1	.858				
PU2	.814				
OUT1	.737				
REL1	.549				
RES2		.888			
RES3		.827			
RES1		.710			
SN1			.914		
IMG1			.711		
PEOU2				.782	
PEOU1				.535	
CAX1_r					.823
CSE1					.823

SPSS AMOS Model