Evaluating the Intention to Use the Use Case Precedence Diagram in Software Development Projects

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Abstract. The Use Case Precedence Diagram (UCPD) is a technique that addresses the problem of determining a software's scope and construction sequence from the developer's perspective. This paper presents a qualitative evaluation of the UCPD based on the Method Adoption Model (MAM), where the intention to use a method is determined by the users' perceptions. The results show that the intentions to use UCPD exist in undergraduate students and practitioners with at least 2 years of experience in the industry, but the relationships defined by the MAM are only confirmed with the results obtained with practitioners.

Keywords: UCPD, requirements precedence, software engineering experimentation, Method Adoption Model.

1 Introduction

Use cases technique was first proposed by Ivar Jacobson [11], and, since its inclusion in the Unified Modeling Language (UML) [16], its utilization has been greatly extended, making it a mandatory requirement for any software development project. The Use Case Precedence Diagram (UCPD) [18] is a technique based on use cases and its objective is to determine software construction sequences taking into consideration the developer's perspective in terms of ease of construction to define software requirements priorities.

According to UML, the relations that can exist between use cases are: include, extend, and generalization. In addition to the standard, UCPD proposes the inclusion of a new relation: precedence. The concept of this diagram was taken from Doug Rosenberg [20], who proposed the use of a similar diagram, specifying the relations "precedes" and "invoke" to determine user requirements. Fig. 1 shows an example of a UCPD. There are two rules to define the precedence relationship between use cases, one considers the precondition, and the other whether a use case needs the information that is registered by another use case (further details of these rules can be found in [18]).

The use cases that are on the left side of the diagram will be implemented before the ones that are on the right side. For instance, in Fig. 1, "Use case A" will be implemented before "Use case C".

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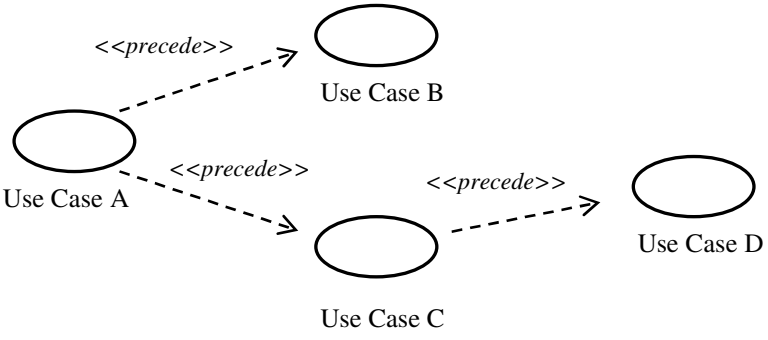

Fig. 1. Use Case Precedence Diagram

In [19], it was included the results of a controlled experiment in which UCPD is applied in case studies by practitioners and the obtained results show that UCPD has more significant advantages over the utilization of ad-hoc techniques.

Although the results obtained in the controlled experiment were satisfactory, there is a need also to assess users' response to the new procedure and their intention to use it in the future, for which reason we applied at the end of the experiment a questionnaire based on the Method Adoption Model (MAM) [14].

MAM was proposed by Moody and this model is an adaptation of the Technology Acceptance Model [9] defined by Davis. MAM explains and predicts the adoption of methods. The constructs of the MAM are the following:

- *Perceived Ease of Use:* the extent to which a person believes that using a particular method would be effort-free.
- *Perceived Usefulness:* the extent to which a person believes that a particular method will be effective in achieving the intended objectives.
- *Intention to Use:* the extent to which a person intends to use a particular method.

MAM defines that perceived usefulness is influenced by the perceived ease of use, and intention to use is defined by perceived usefulness and perceived ease of use. Many empirical studies that evaluate software methods have been carried using MAM with students and practitioners [1,7,17]. Some of them do not confirm the relationships between the constructs defined by the MAM.

The rest of the paper is organized as follows: Section 2 describes this study, Section 3 details the results obtained for the empirical study. Finally, a summary and our plans for future research will conclude our paper.

2 Description of This Study

Using the Goal/Question/Metric (GQM) template for goal-oriented software measurement [3], we defined this study as follows:

Analyze: user's responses
For the purpose of: evaluate
With respect to: intention to use UCPD

From the point of view of: the researcher
In the context of: undergraduate students and practitioners with at least 2 years of experience in software development projects, considering that the developer is free to select the sequence to construct use cases (there are no user's constraints).

Based on the MAM model, it was formulated the working hypotheses of this research which make reference to the intrinsic constructs of the model. These hypotheses are stated in the following way:

- Hypothesis 1 (H1): UCPD is perceived easy to use.
- Hypothesis 2 (H2): UCPD is perceived useful.
- Hypothesis 3 (H3): There is an intention to use UCPD in future software projects.
- Hypothesis 4 (H4): The perceived ease of use has a positive effect on the perceived usefulness of UCPD.
- Hypothesis 5 (H5): The perceived ease of use and perceived usefulness has a direct and positive effect on intention to use.

2.1 Participants

The undergraduate students who participated in this study were fourth year students of the Informatics Engineering program at the Pontificia Universidad Católica del Perú (PUCP) that were enrolled in the Spring '06 Software Engineering course. As part of the course, these undergraduate students had to develop a software using the Rational Unified Process methodology [10] and they utilized UCPD in order to define the sequence to construct software requirements.

The practitioners were 25 professionals with at least 2 years of experience who participated in a controlled experiment in 2007 and the quantitative results are detailed in [19]. This experiment was replicated in 2009 with 17 practitioners (with at least 2 years of experience too) who were graduate students of the Master in Informatics program at PUCP. 42 questionnaires filled by practitioners were processed: 25 obtained in the first experiment, and 17 in the second experiment.

2.2 Materials

It was designed a questionnaire which included one question for each constructor of the MAM. Each answer had to be quantified on a five point Likert-type scale [12]. It could be considered as a disadvantage to use only one question for each constructor, but there are some studies that have applied this same approach in other fields such as the medicine with appropriate results [6,8,21]. We wanted to create a user-friendly questionnaire.

The undergraduate students filled the questionnaire at the end of the semester, when they had finished their software projects. The practitioners filled the questionnaire at the end of the controlled experiment in which they were involved into. We commented to the participants that the purpose of the questionnaire is to know their honest opinion about UCPD.

Further details of the questionnaire used and the instruments utilized in the controlled experiment with practitioners can be found at:

http://macareo.pucp.edu.pe/japowsang/precedence/usecase.html

3 Results

The statistical hypotheses to test the working hypothesis H1, H2, and H3 are the following:

H_o: $\mu \leq 3, \alpha = 0.05$

H_a: $\mu > 3$

"μ" is the mean response obtained in the questions related to user's perception about UCPD. We can consider a positive perception of the participants, if the mean response is greater than 3, because a five point Likert-type scale was used in the questionnaries from 1 to 5.

To evaluate the MAM relationships, correlation coeficients and regression analysis were used to formally test hypotheses H4 and H5.

3.1 Perceived Ease of Use

Table 1 presents the results obtained with the question relate to perceived ease of use. It was established a significance level of 0.05 to statistically test the obtained results with undergraduate students and practitioners.

Table 1. Descriptive statistics for perceived ease of use

Variable	Undergraduate students	Practitioners
Observations	31	42
Minimum	3	2
Maximum	5	5
Mean	3.968	3.5
Std. Deviation	0.752	0.891

In order to determine if the obtained results followed a normal distribution, the Shapiro-Wilk test was applied. Since the computed p-values were lower than the significance level α=0.05, the normal distribution hypothesis was rejected for both samples (undergraduate students and practitioners). Due to these results, a parametric test, such as Student's t-test, cannot be used. The Wilcoxon signed rank test was chosen to test the statistical hypothesis defined previously (Ho: $\mu \leq 3$, Ha: $\mu > 3$).

Table 2. Wilkoxon signed rank test results for perceived ease of use

Variable	Undergraduate students	Practitioners
W	253	334
p-value	<0.001	<0.001

Since the computed p-values were lower than the significance level α =0.05, the null hypothesis Ho had to be rejected. It means that we can empirically corroborate working hypothesis H1: the undergraduate students and the practitioners perceived UCPD as easy to use.

3.2 Perceived Usefulness

Table 3 presents the results obtained with the question related to to usefulness. It was established a significance level of 0.05 to statistically test the obtained results.

Table 3. Descriptive statistics for perceived usefulness

Variable	Undergraduate students	Practitioners
Observations	31	42
Minimum	3	2
Maximum	5	5
Mean	4.419	3.905
Std. Deviation	0.7199	0.878

In order to determine if the obtained results followed a normal distribution, we applied the Shapiro-Wilk test. Since the computed p-values were lower than the significance level α=0.05, the normal distribution hypothesis was rejected for both samples (undergraduate students and practitioners). Due to these results, a parametric test, such as Student's t-test, cannot be used. The Wilkoxon signed rank test was chosen to test the statistical hypothesis defined previously (Ho: $\mu \leq 3$, Ha: $\mu > 3$).

Table 4. Wilkoxon signed rank test results for perceived usefulness

Variable	Undergraduate students	Practitioners
W	378	526.5
p-value	<0.001	<0.001

Since the computed p-values were lower than the significance level α =0.05, the null hypothesis Ho had to be rejected. It means that we can empirically corroborate working hypothesis H2: the undergraduate students and the practitioners perceived UCPD as useful.

3.3 Intention to Use

Table 5 presents the results obtained with the question relate to intention to use. It was established a significance level of 0.05 to statistically test the obtained results.

Table 5. Descriptive statistics for perceived usefulness

Variable	Undergraduate students	Practitioners
Observations	31	42
Minimum	2	1
Maximum	5	5
Mean	4.226	3.738
Std. Deviation	0.805	1.014

In order to determine if the obtained results followed a normal distribution, we applied the Shapiro-Wilk test. Since the computed p-values were lower than the significance level α=0.05, the normal distribution hypothesis was rejected for both samples (undergraduate students and practitioners). Due to these results, the Wilkoxon signed rank test was chosen to test the statistical hypothesis defined previously (Ho: $\mu \leq 3$, Ha: $\mu > 3$).

Table 6. Wilkoxon signed rank test results for perceived usefulness

Variable	Undergraduate students	Practitioners
W	370.5	457
p-value	<0.001	<0.001

Since the computed p-values were lower than the significance level α =0.05, the null hypothesis Ho had to be rejected. It means that we can empirically corroborate working hypothesis H3: the undergraduate students and the practitioners have the intention to use UCPD.

3.4 MAM Evaluation

To assess the relationships between variables proposed in the MAM, we must use the correlation coefficient, similar to the studies conducted by Davis [9] and Adams et. al [2].

According Muijs [15] in order to determine if there is a degree of relationship between two ordinal variables, the Spearman's correlation coefficient must be used (not the Pearson's correlation one). The Likert-scale used in the questionnaires is ordinal, for this reason Spearman's correlation (Spearman's rho) had to be used to evaluate MAM. The rules of thumb to determine the strength of a relationship proposed by Muijs are the following:

<0. +/-1 weak
<0. +/-3 modest
<0. +/-5 moderate
<0. +/-8 strong
>= +/-0.8 very strong.

Fig.2 presents Spearman's rho (ρ) and the strength for each relationship. It can be observed that usefulness and ease of use were significantly correlated each other for practitioners(ρ=0.549, p-value=0.000) but they were not correlated each other for undergraduate students. Usefulness and intention to use were significantly correlated each other for both type of participants (students and practitioners). Ease of use and intention to use were only significantly correlated each other for practitioners. It means that we can empirically corroborate working hypotheses H4 and H5 using the practitioners sample. Unfortunately, working hypotheses H4 and H5 can not be corroborated for the undergraduate students sample.

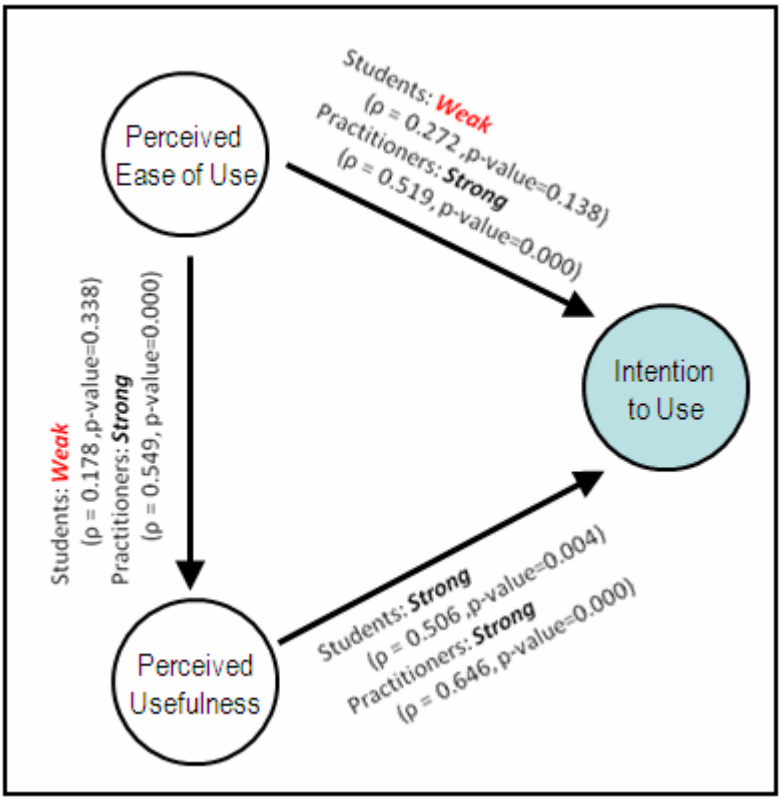

Fig. 2. Spearman's rho and strength for MAM's relationships

In order to confirm the causal relationships between variables defined in the MAM, a regression analysis had to be used , similar to the study included in Abrahao's Phd thesis [1], for those variables with a correlation coefficient equal or better than "moderate". Because the results obtained are ordinal, an ordinal regression model had to be used. This kind of regression model was proposed by McCullagh and Nelder [12].

Ordinal regression model for perceived usefulness and perceived ease of use. In order to determine the ordinal regression model for the practitioners sample, it was used the Perceived Ease of Use (PEU) as the independent variable and the Perceived Usefulness (PU) as the dependent variable. Table 7 shows obtained ordinal regression model for PEU and PU, calculated using SPSS software, using the *Probit* link function.

Using Table 7 and the definitions made by Borooah [4], if we want to obtain the perceived usefulness based on the perceived easy of use, we need to calculate the following: ***D = -0.796 x PEU.*** The PU was determined with the D calculated:

- PU = 2, if $D \leq -1.017$
- PU = 3, if $-1.017 \leq D \leq -2.072$
- PU = 4, if $-2.072 \leq D \leq -3.583$
- PU = 5, if $D \geq -3.583$

Table 7. Parameter estimates for Perceived Usefulness - Perceived Ease of Use

		Estimate	Std. Error	df	p-value
Threshold	[PU = 2.00]	1.017	.733	1	.165
	[PU = 3.00]	2.072	.755	1	.006
	[PU = 4.00]	3.583	.850	1	.000
Location	PEU	.796	.219	1	.000

The model chi-square is 14.101 with 2 degrees of freedom and p-value =0.000. This is highly significant, and the model confirms that perceived ease of use has a significant effect on the perceived usefulness for the practitioners.

Table 8. Test of parallel lines Perceived Usefulness - Perceived Ease of Use

Model	-2 Log likelihood	Chi-square	df	p-value
Null hypothesis	27.361			
General	27.143	0.218	2	0.897

For location-only models, the test of parallel lines assesses if the assumption that the parameters are the same for all categories is reasonable. Table 8 presents the test of parallel lines for the calculated model. As it can be observed in the above table, the chi-square value is insignificant and the p-value is greater than 0.05. It means the ordinal regression model calculated accomplish with the required assumption.

In the linear regression model, the coefficient of determination, R^2, summarizes the proportion of variance in the dependent variable associated with the predictor variables (independent variables). For ordinal regression models, it is not possible to compute a single R^2 statistic, so these approximations of a R^2 are computed instead.

Table 9. R^2 calculated for Perceived Usefulness - Perceived Ease of Use

Type of R^2	Value
Cox and Snell	0.285
Nagelkerke	0.312
McFadden	0.137

The results presented in Table 9 indicate that the calculated ordinal regression model explains between 31.2% and 13.7% of the variability of the perceived usefulness. It is important to note that these values must be interpreted with caution, since they are not direct equivalents to the R^2 statistics obtained in a linear regression model.

The regression model presented confirms the working hypothesis H4. This means the perceived usefulness is determined by the perceived ease of use for the practitioners sample.

Ordinal regression model for intention to use vs. perceived usefulness and perceived ease of use. In order to determine the ordinal regression model for the practitioners sample, the Perceived Ease of Use (PEU) and the Perceived Usefulness (PU) were used as dependent variables and the Intention to Use (IU) as the independent (predictor) variable. Table 7 shows obtained ordinal regression model for IU vs PEU and PU, calculated in SPSS software, using the *Probit* link function.

Table 10. Parameter estimates for Intention to Use vs. Perceived Usefulness and Ease of Use.

		Estimate	Std. Error	df	p-value
Threshold	[IU = 1.00]	1.868	.937	1	.046
	[IU = 2.00]	2.762	.925	1	.003
	[IU = 3.00]	3.898	.986	1	.000
	[IU = 4.00]	5.472	1.112	1	.000
Location	PEU	.415	.234	1	.076
	PU	.764	.248	1	.002

Using Table 10 and the definitions made by Borooah [4], if we want to obtained the perceived usefulness based on the perceived easy of use, we need to calculate the following: ***D = -0.415 x PEU + 0.764 x PU.*** The IU was determined with the D calculated:

- IU = 1, if $D \leq 1.868$
- IU = 2, if $1.868 \leq D \leq 2.762$
- PU = 3, if $2.762 \leq D \leq 3.898$
- PU = 4, if $3.898 \leq D \leq 5.472$
- PU = 5, if $D \geq 5.472$

The model chi-square is 21.906 with 2 degrees of freedom and p-value =0.000. This is highly significant, and the model confirms that perceived ease of use and perceived usefulness have a significant effect on the intention to use UCPD for the practitioners.

Table 11. Test of parallel lines: Intention to Use vs. Perceived Usefulness and Ease of Use

Model	-2 Log likelihood	Chi-square	df	p-value
Null hypothesis	53,521			
General	46,951	6,570	2	0.362

Table 11 presents the test of parallel lines for the calculated model. As it can be observed in the above table, the chi-square value is low and the p-value is greater than 0.05. It means the ordinal regression model calculated accomplish with the required assumption.

In the linear regression model, the coefficient of determination, R^2, summarizes the proportion of variance in the dependent variable associated with the predictor variables (independent variables). For ordinal regression models, it is not possible to compute a single R^2 statistic, so these approximations of a R^2 are computed instead.

Table 12. R^2 calculated for Intention to Use vs. Perceived Usefulness and Perceived Ease of Use

Type of R^2	Value
Cox and Snell	0,406
Nagelkerke	0,435
McFadden	0,191

The results presented in Table 12 indicate that the calculated ordinal regression model explains between 40.6% and 19.1% of the variability of the perceived usefulness. It is important to note that these values must be interpreted with caution, since they are not direct equivalents to the R^2 statistics obtained in a linear regression model.

The regression model presented confirms the working hypothesis H5. This means the intention to use is determined by the perceived ease of use and the perceived usefulness for the practitioners sample.

4 Conclusions and Future Work

This paper describes an empirical study that evaluates the intention to use the UCPD technique that is used to determine software construction sequences taking into account the developer's perspective. The study considers the perceptions of undergraduate students and practitioners with at least 2 years of experience in software development projects.

UCPD is perceived as easy to use and useful for all of the participants (undergraduate students and practitioners). Also, the participants of this study acknowledged having the intention to use UCPD in next software development projects. These results do not disagree with the quantitative results obtained in the controlled experiment with practitioners (previously published [19]) and the replicated experiment.

Although the perceptions of UCPD are positive for all of the participants, the relationships defined in the MAM are only confirmed with the statistical tests applied using the practitioners' sample.

Many researchers comment the benefits to use undergraduate students for research studies. However, it should be noted that in some situations, similar to this study, the results obtained with undergraduate students should be taken with caution and it is preferable to use practitioners with experience in the industry, in order to get confident results.

As a future work, we plan to replicate the controlled experiment with undergraduate students in order to contrast and confirm the results obtained in this study.

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