EVOLUTION AND ADOPTION OF UML-BASED DEVELOPMENT TOOLS

by

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Abstract

This research tests nine hypotheses to examine the evolution and adoption of development tools that use the Unified Modeling Language (UML). Data for 70 suppliers and 53 buyers of these tools were used to: (i) measure the associations between stages of the life-cycle, supplier size, and product category, (ii) identify the temporal patterns of product, supplier and buyer diversity, and new suppliers and new buyers, and (iii) identify the reasons for which suppliers and buyers commit to development tools that use the Unified Modeling Language. The results are relevant to: (i) researchers interested in the adoption and diffusion of new technologies, (ii) product managers and sales managers of development tools, and (iii) market analysts. This research: (i) develops a method to identify reasons for buyer and seller commitment to UML-based development tools, and (ii) validates the density-dependence model using buyer data on UML-based development tools.

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Glossary

Artifact. A physical piece of information that is used or produced by a software development process. Examples of Artifacts include models, source files, scripts, and binary executable files. An artifact may constitute the implementation of a deployable component (Rational Unified Process Glossary, Version 2003.06.0065).

Eclipse. A platform designed to build integrated development environments (IDEs) that can be used to create applications from C++ programs to websites and Enterprise JavaBeans (EJB) applications.

IDE. Integrated development environment.

MDA. See model-driven architecture.

MDD. See UML-based development.

Model. A semantically closed abstraction of a system (Rational Unified Process Glossary, Version 2003.06.0065).

Model-driven architecture (MDA). A way of writing specifications and developing applications, based on a platform-independent model (PIM).

UML-based development (MDD). A way of developing software applications by using methodologies that assist in the identification and documentation of application requirements, data definitions, and programming specifications.

Object management architecture (OMA). An architecture that provides guidance on how standardization of component interfaces penetrate up - although not into - applications in order to create a plug-and-play component software environment based on object technology.

Object-oriented programming. (OOP) A programming approach based on the concepts of data abstraction and inheritance. Unlike procedural programming techniques, object-oriented programming concentrates on those data objects that constitute the problem and how they are manipulated, not on how something is accomplished (Rational Unified Process Glossary, Version 2003.06.0065).

OMA. See object management architecture.

Open source. A certification standard issued by the Open Source Initiative (OSI) that indicates that the source code of a computer program is made available free of charge to the general public.

Platform. The underlying hardware or software for a system.

Unified modeling language (UML). A language for visualizing, specifying, constructing, and documenting the artifacts of a software-intensive system.

1 Introduction

For the purpose of this research, a UML-based development tool is a software product that uses the unified modeling language (UML) notation to visualize, construct, and document the artifacts of software systems with the objective to automate and accelerate software construction. The scope of this research is limited to software tools that use software models only. Mathematical models and any other sort of models are excluded from this research.

UML-based development tools support methodologies that assist in the identification and documentation of application requirements, data definitions, and programming specifications. They also provide automated support for at least one object-oriented methodology and for some or all of the software development life-cycle phases. UML-based development tools reduce software development cycle-time and increase product quality (Kirzner, 2003).

Some software development tools providers are moving application development to higher levels of abstraction, specifically through visual modeling and in most cases using UML as the modeling language of choice.

UML-based development tools allow designers to build models using concepts that are closer to the problem domain. This makes models easier to specify, understand, and maintain.

The model for a software application can be thought of as the equivalent to the blueprint of a skyscraper building. The concepts used to build the blueprint are close to the domain understood by those who are familiar with skyscrapers.

A key principle of UML-based development tools is that code can be automatically generated from models. This makes models platform-independent, reducing or eliminating the high cost of making changes to the underlying technology.

UML-based development tools became available in 1991 with the release of development tools that generate code from a system model (e.g., Objecttime ToolSet). The number of tools increased with the advent of the unified modeling language.

According to Kirzner (2003), IBM's acquisition of Rational Software and Borland's acquisition of Togethersoft dramatically changed the UML-based development tools industry. Both IBM and Borland have plans to integrate UML-based development tools into full life-cycle application development suites.

1.1 Research objectives

This research examines the worldwide adoption of UML-based development tools from January 1991 to December 2003. The specific research objectives are to:

- 1) Examine whether the stages of the life cycle affect supplier size and product type.

- 2) Identify the temporal patterns of product diversity, supplier diversity, and buyer diversity as well as new suppliers' and buyers' entry rates.
- 3) Identify the reasons for which suppliers and buyers commit to UML-based development tools.

1.2 Motivation

The increasing adoption of UML-based development tools during the last decade, particularly the last three years, was the main motivation for this study. Since their introduction in 1991, UML-based development tools have been seen as a means to automate software development tasks such as software coding and code-model synchronization. Traditional engineering disciplines use models to understand complex problems and to aid in their solution. In the past, models were rarely used in software engineering and when used they played a secondary role. Even after the unified modeling language was adopted by the Object Management Group (OMG) in 1995, the number of suppliers of UML-based development tools did not increase considerably.

1.3 Relevance

To the knowledge of the author, this is the first empirical study on the adoption of UML-based development tools.

Temporal patterns of buyers across stages of the adoption life cycle are of interest to product and sales managers and temporal patterns of suppliers are of interest to buyers. The study of

these temporal patterns is also of interest to academics (Debackere, Koenraad, Clarysse, 1998; Klepper, 1996).

The reasons for which suppliers commit to UML-based development tools are of special interest to buyers and suppliers. The reasons for which buyers commit to UML-based development tools are of special interest to product managers, sales managers, and market analysts.

This research builds on the theoretical perspective developed by Keppler (1996) and Debackere et al. (1998) and the thesis completed by Peng (2004). There are three main differences between this thesis and that developed by Peng (2004). First, Peng's research focused on the adoption of a technical infrastructure anchored around Linux, an open source operating system. This thesis focuses on the adoption of mostly proprietary applications.

The second difference is that Peng uses suppliers' data to identify adoption stage transitions. In this research, buyer data is used to identify the adoption stage transitions.

The third difference between Peng's work and this research is that the hypotheses are tested using data on both suppliers and buyers.

1.4 Contribution

This research makes three important contributions. First, it measures the strength of the association between stages of the adoption life cycle and the attributes of buyers and suppliers of UML-based development tools. Second, to the knowledge of the author, this is the first empirical study that identifies the reasons for buyer and seller commitment to UML-based development tools. Third, it uses buyer data to determine the stages of its adoption life cycle.

1.5 Organization

This research is organized into seven chapters. Chapter one is the introduction. Chapter two provides a review of the relevant literature. Chapter three defines the research hypotheses. Chapter four explains the research method. Chapter five provides the results. Chapter six discusses the results. Chapter seven draws conclusions, lists the limitations of the research, and identifies opportunities for future research.

2 Literature review

This chapter is organized into five sections. Section 2.1 reviews the literature on UML-based development tools. Section 2.2 reviews the literature on theories of technology adoption. Section 2.3 summarizes the segmentation of primary software markets, software segments, and vertical market analysis provided by International Data Corporation (Kirzner, 2003). Section 2.4 summarizes the software taxonomy provided by International Data Corporation (Heiman, 2003). Finally, section 2.5 provides lessons learned from this literature review.

2.1 Research on UML-based development tools

2.1.1 Role of the unified modeling language in UML-based development tools

Modeling is the designing of software applications before coding. Projects of all sizes, from large to small, can take advantage of modeling, a task that must be considered an essential part in all software development projects. Modeling helps to visualize a design and validate the requirements before coding starts. Since it is not bonded to the underlying technology with which it will be implemented, anyone familiar with the unified modeling language notation can understand the model (Selic, 2003). UML-based development tools exploit these features of the unified modeling language to provide modeling and forward-engineering capabilities (e.g., the generation of code out of the model).

The unified modeling language can also be used to analyze the existing source code by translating it into a set of unified modeling language diagrams. UML-based development tools exploit this feature to offer reverse engineering (e.g., the creation of models out of the source code).

Advanced features of UML-based development tools include round-trip engineering, so if the code or model is modified the tool will automatically update the model or code accordingly.

Full benefits of UML-based development tools can only be achieved when the application provides automatic generation of complete programs instead of just code skeletons, automatically verifying models, for example, by executing them, although this feature can have impact on performance (Selic, 2003).

Kristina Joukhadar makes a comparison of what the Java mantra is with what the Object Management Group's (OMG) mantra should be: "If Java's mantra is *Write once, run anywhere*, the mantra of the Object Management Group's new Model Driven Architecture specification should be *Design once, build it on any platform*." (Joukhadar, 2001)

2.1.2 Characteristics of models

In order for a model to be effective, it must possess the following five characteristics (Selic, 2003):

Abstraction. The removal of common features of objects and procedures to help understand the essence more easily.

Understandability. The outcome of the abstraction must be represented in a way that requires reduced effort to understand it.

Accuracy. The model must represent a true-to-life representation of the modeled system's feature of interest (Selic, 2003).

Predictiveness. The ability to use the model to correctly predict the modeled systems' interesting but non-obvious properties, through experimentation or through some type of formal analysis (Selic, 2003).

Inexpensive. It must be significantly cheaper to construct and analyze than the modeled system. (Selic, 2003)

In summary, the unified modeling language is a cornerstone for any UML-based development tool.

2.2 Research on theories of technology adoption

2.2.1 Rogers' innovation diffusion model

Rogers (1983) defined an innovation diffusion model in which organizations respond to an innovation offer. Two variables were used to develop an adoptee categorization: the mean and standard deviation. Five groups of adopters are identified by Rogers: 1) the innovators are those who adopt the new technology offer immediately after it becomes available on the market because the technology is interesting to the them; 2) early adopters are those who embrace the new technology offer to use it as an advantage against their competitors; 3) early majority are those that adopt the technology only after the early adopters demonstrate they had a benefit with it; 4), late majority are those that embrace the new technology only after the majority of the population on the system have adopted it; and 5) laggards, by the time laggards adopt the technology, there might already be available a newer technology (Rogers, 1983).

The innovation diffusion model follows a normal distribution that represents the adoption rate of a new technology over time and a S-curve that represents a cumulative number of adopters.

2.2.2 Moore's technology adoption life-cycle model

The technology adoption life-cycle (TALC) has a bell-shaped distribution representing the total population of people exposed to the new technology offer; it also shows how the technology-based markets evolve (Moore, 2002). Four main stages are identified:

Early market, offering an immature product targeted to technology enthusiasts and visionaries who want to try the new technology because the underlying technology is interesting. The link to the market is through professional services and the suppliers' objective is to gain flagship accounts.

Crossing the chasm into the bowling alley, offering an application-like product targeted to niches of pragmatic customers. The link to the market is a solution to a problem that cannot be resolved with the current well-known applications available in the market. The suppliers' objective is to win a niche, then to try to expand to other niches.

Inside the tornado, offering commodity-like products targeted to technical buyers. The supplier's objective is to sell large amounts of the same offer.

Main street, offering extended commodity-like products targeted to end-users. The supplier's objective is to mass customize.

Moore categorizes the population into five groups of buyers according to their adoption strategy. Table 1 shows the five groups and their adoption strategies. Figure 1 shows the technology-based market development from Moore's perspective.

Table 1 Adoption strategies

Buyer groups	Adoption strategy
Enthusiast	Adopt the new offer because it is interesting and wish to explore its properties
Visionary	Adopt the new offer to create dramatic advantages over the competitors who do not adopt it
Pragmatist	Adopt the new offer when others have successfully implemented it
Conservative	Put off adopting the new offer as long as possible to conserve cash
Skeptic	Refuse to adopt the new offer

Figure 1 Technology-based market development

2.2.3 Density-dependence model

The density-dependence model explains why the adoption of new technologies, over time, usually follows an S-curve (Geroski, 2000). The adoption of new technology takes a long period of time, even when the adopters seem to obtain a benefit from it. The model is based on the forces of legitimation and competition, which help to establish the new technology and ultimately limit their take-up (Geroski, 2000).

In order to make the decision of adopting a new technology, the potential adopters of the new technology need to gain knowledge about it (to build up legitimation). The knowledge acquisition is considered legitimate if it comes from other users who have accumulated experience with the new technology. This knowledge transfer is known as word of mouth.

Although this knowledge transfer generates the S-curve, it does not explain the diffusion of an innovation from its origin, but from the point where the early users start using it. The knowledge transfer starts taking place some time after this point by word of mouth. The larger the number of early adopters, the faster the diffusion will be.

The current literature does not provide a method to identify when a new technology changes from one stage to another.

2.3 Segmentation of primary software markets

IDC divides the software market in three primary markets: packaged application software, application development and deployment software, and system infrastructure software. Table 2 shows these primary markets and their corresponding software markets definition.

Table 2 IDC's primary markets and software markets definition

Primary markets	Software markets
Packaged application software	Cross-industry applications <ul style="list-style-type: none"> • Enterprise resource management • Customer relationships management • Office and collaborative applications Industry specific applications <ul style="list-style-type: none"> • Services supply chain vertical views • Product supply chain vertical views
Application development & deployment	Information access and delivery (IAD) Information and data management Application design and construction tools Application life-cycle management (ALM)
Systems infrastructure software	Systems and network management Middleware and serverware , Security System-level and networking applications

(Toncheva et al., 2000)

Table 3 shows IDC's 20 vertical markets organized into seven sectors of the economy (Toncheva et al., 2002).

Table 3 Vertical markets by sector

Sector	Vertical market
Finance	Banking, Financial services, Insurance
Manufacturing	Discrete, Process, Automotive
Infrastructure	Transportation Telecommunications Broadcast and other communications Utilities
Reatil	Wholesale and retail
Services	Healthcare, Business, Legal Other services
Resource	Mining Agriculture / construction
Public	Government Education
Software	Information access and delivery Information and data management Application design and construction tools Application life cycle-management

(Extended from IDC's list)

In summary, the IDC segmentation helps to position the UML-based development tools within a specific software market and segment.

The vertical markets will help to categorize buyers of UML-based development tools.

2.4 Review of software taxonomy

ICD's taxonomy for application design and construction tools, the area of interest for this research, includes five specific markets (Heiman, 2003):

- Unified development environments, also known as integrated development environments
- Third Generation Language (3GL) tools
- Software construction components
- Analysis, modeling, design, and construction tools
- Web site design/development tools

In summary, the taxonomy provided by IDC offers an initial point to identify if a product offering can be considered a UML-based development tool.

Table 4 shows, in a nutshell, all of IDC's taxonomy characteristics for application design and construction tools.

Table 4 IDC's taxonomy for application design and construction tools

Functional Market	Market Characteristics	Tools Characteristics	Representative Vendors
Unified development environments	Represents the integration of rapid application development (RAD) tools, 4GL, and component-based development, construction and assembly tools, and some degree of automation	<ul style="list-style-type: none"> - 4GL/RAD tools. None-procedural, high-level language-based tools. Afford dictionary-based application development and perform semantic consistency checking - Legacy 4GL tools. Early abstracted development environment marketed before visual programming became available - Component-based development, construction and assembly tools, primarily used for construction of software components into larger components or applications - Component frameworks, packaged components in the form of open architecture component technology 	Microsoft (Visual Studio .NET) IBM (VisualAge) Oracle (Oracle9i) Computer Associates (IngresII) Sybase (PowerBuilder) AlphaBlox (Application Studio)
3GL tools	Includes both emerging and traditional programming languages	<ul style="list-style-type: none"> - Include all third generation object-oriented and none object-oriented, procedural tools such as edit, compile and debug tools. Java, C++ and COBOL continue to be the primary 3GL languages to develop business technology solutions 	Borland (Builder) Sun Microsystems (SunOne Studio) Micro Focus (Micro Focus COBOL)
Software construction components	Specific software libraries sold apart from a development environment	Construction components include class libraries, frameworks, ActiveX controls, Java applets, JavaBeans, Enterprise JavaBeans, DLLs, and sort of API-specific libraries.	Sitara (Jclass) ComponentSource (ComponentOne Studio for ActiveX) Oracle (Business Components for Java)
Analysis, modeling, design and construction tools	Support methodologies that assist in generating application requirements, data definitions and programming specifications	Analysis, modeling, design and construction tools provide automated support or at least one object-oriented methodology and some or all software- development life-cycle phases	Rational Software (ROSE) TogetherSoft (Together ControlCenter) Computer Associates (Erwin)
Web site design / development tools	Provide web-site and Web-page layout, design, object integration and all tools required to develop web-based applications	Tools provide visual abstraction through WYSIWYG editors, JavaScript, VBScript, data integration and deployment	Macromedia (Dreamweaver) Adobe (GoLive)

(Heiman, 2003)

2.5 Lessons learned from reviewing the literature

The unified modeling language is used as the foundation

The unified modeling language is used as the foundation of UML-based development tools. UML-based development tools exploit the benefits of using models. Tools can be classified based on the features offered. UML-based development tools can be classified on the following major categories: modeling-only, forward-engineering, reverse-engineering, round-trip engineering, and product-suite.

There are four stages of technology adoption

Moore (2002) identifies four stages of the technology adoption life-cycle: early market, crossing the chasm into the bowling alley, inside the tornado, and main street.

Legitimateness and competitiveness drive the technology adoption

The adoption of new technology follows an S-curve. This is explained by the density-dependence model, which combines the forces of the new technology legitimizing (recognition or credibility of the benefits of the new technology by the early adopters) and competition (Geroski, 2000).

Classification of buyers' markets

International Data Corporation (IDC), a well-recognized advisory firm, has a classification of 20 vertical markets organized into seven sectors of the economy.

Lack of methods to identify stage transitions

There is no literature available that explains how to identify when a stage transition is occurring.

Lack of empirical research on reasons to commit to a technology

There is no literature related to the reasons for which suppliers and buyers commit to a new technology.

Lack of empirical research on adoption of UML-based development tools

There is no empirical research on either the adoption of UML-based development tools or on the temporal patterns of agents associated with UML-based development tools.

Identifying stage transitions and reasons to commit

Based on data gathered for the research, the researcher defines a way to:

- identify stage transitions using buyers' data
- identify suppliers' reasons to commit to UML-based development tools
- identify buyers' reasons to commit to UML-based development tools.

Stage transitions are defined using a method devised by Peng (2004) on Linux adoption by firms.

3 Hypotheses

This chapter is divided into five sections. Section 3.1 develops the hypotheses to compare supplier and product attributes across adoption stages. Section 3.2 develops hypotheses to test temporal patterns of supplier and product diversity. Section 3.3 develops hypotheses to test temporal patterns of new suppliers and new buyers. Section 3.4 develops hypothesis to test supplier and buyer reasons to commit to UML-based development tools. Section 3.5 provides a list of the hypotheses.

3.1 Comparing supplier and product attributes across adoption stages

The first objective of this research is to measure the association between stages, buyers' and suppliers' attributes. The attributes of interest for this research are supplier size, supplier type, and product type.

Supplier size is used as a substitute for competence and financial means in empirical studies of technology diffusion (Geroski, 2000). The researcher expects that supplier size is a function of the adoption stage, therefore:

Hypothesis 1: The size of a new supplier is a function of the adoption stage.

Buyers' needs are different at each adoption stage (Moore, 2000). Organizations with diverse capabilities, needs, and goals will be willing to adopt the new technology at different times (Geroski, 2000). As buyers' needs change, the number and type of products offered by the suppliers change accordingly. It is expected that different product categories will be introduced at each stage, therefore:

Hypothesis 2: The type of a new product is a function of the adoption stage.

3.2 Temporal patterns of supplier and product diversity

The expected number of different product categories in the market for UML-based development tools is small. It includes modeling-only tools, reverse and forward-engineering tools, round-trip engineering tools, and product-suites.

It is expected that product diversity increases rapidly during the early adoption stages and then increases slowly during the final stages, therefore:

Hypothesis 3a: Product diversity increases rapidly during the early adoption stages and then increases slowly over the later stages.

Different supplier's types offer different product categories. Thus, supplier diversity and product diversity should behave in a similar way. It is expected that supplier diversity

increases rapidly during the early adoption stages and then increases slowly during the later stages, therefore:

Hypothesis 3b: Supplier diversity increases rapidly during the early adoption stages and then increases slowly over the later stages.

Frequently, a new market is comprised of multiple customer niches. As the market matures, a mainstream market develops. Therefore, it is expected that customer diversity increases at the early adoption stages and then decreases during the later stages.

Hypothesis 3c. Buyer diversity increases rapidly during the early adoption stages and then increases slowly over the later stages.

3.3 Temporal patterns of new suppliers and new buyers

The density-dependence model holds that: (i) during the product legitimization period, the number of new suppliers grows rapidly, establishing a positive relationship with the number of new entrants per month and the number of cumulative firms committing to UML-based development tools; and (ii) during the competition period, this relationship switches to a negative one (Debackere and Clarysse, 1998).

Thus, the researcher expects that the number of new suppliers and buyers will follow a bell-shape distribution, therefore:

Hypothesis 4a: New buyers' entry rate follows a bell-shape distribution.

Hypothesis 4b: New suppliers' entry rate follows a bell-shape distribution.

3.4 Reasons for commitment

Moore (2002) argues that customer needs are different at each adoption stage. While there is no empirical literature on whether the stage of adoption affects the reasons why suppliers and buyers commit to a particular technology, the researcher believes that the stage of the adoption cycle does affect the buyers' reasons for committing to UML-based development tools, therefore:

Hypothesis 5a: The reasons for which suppliers commit to UML-based development tools are a function of the adoption stage.

Hypothesis 5b: The reasons for which buyers commit to UML-based development tools are a function of the adoption stage.

3.5 List of hypotheses

Hypothesis 1: The size of a new supplier is a function of the adoption stage.

Hypothesis 2: The type of a new product is a function of the adoption stage.

Hypothesis 3a: Product diversity increases rapidly during the early adoption stages then increases slowly over the later stages.

Hypothesis 3b: Supplier diversity increases rapidly during the early adoption stages and then increases slowly over the later stages.

Hypothesis 3c: Buyer diversity increases rapidly during the early adoption stages then increases slowly over the later stages.

Hypothesis 4a: New buyers' entry rate follows a bell-shape distribution.

Hypothesis 4b: New suppliers' entry rate follows a bell-shape distribution.

Hypothesis 5a: The reasons for which suppliers commit to UML-based development tools are a function of the adoption stage.

Hypothesis 5b: The reasons for which buyers commit to UML-based development tools are a function of the adoption stage.

4 Research method

4.1 Unit of analysis

The unit of analysis is an organization that made a commitment to offer or purchase a UML-based development tool during the study period.

4.2 Study period

The study period is from January 1991, the month in which the first development environment that generated code out of a system model became available, to December 2003, the month where data collection stopped. The study period includes 156 months.

4.3 Sample

The sample used in this research is comprised of all known suppliers and buyers that committed to UML-based development tools during the study period.

4.3.1 Suppliers

The following sources of information were used to identify suppliers of UML-based development tools:

- International Data Corporation (IDC) competitive analysis
- Business Source Premier database

- OMG qualified service providers list
- Eclipse UML related plug-ins provider lists
- Google search engine

To identify suppliers of UML-based development tools using the Business Source Premiere database and the Google Web search engine, the following two strings were entered into the search engines: “model driven development” and “UML tools”.

4.3.2 Buyers

The sample of buyers was obtained from examining news releases posted on suppliers’ web sites and from reading news releases found in the Business Source Premier database. These news releases were found by performing queries searching for the supplier and product name.

4.3.3 Products

The sample of products was obtained from the websites of the suppliers in the sample.

4.4 Data collection

4.4.1 Company information

Information on suppliers and buyers was obtained from companies' websites and the Business Source Premier database.

For each supplier, the following information was collected:

- Supplier name
- Revenue reported on the date closest to the first announcement
- Date on which revenue was reported
- Number of employees
- Number of product offerings
- Years of operation

For each buyer, the following information was collected:

- Buyer name
- Revenue reported on the date closest to the first announcement pertaining to the commitment to UML-based development tools
- Date on which revenue was reported
- Number of employees

4.4.2 Product categories

UML-based development tools were classified into the following five product categories:

- (i) **Modeling-only.** Tools that aid in the design and development of software models through visual modeling.
- (ii) **Reverse-engineering.** Tools that enable UML visualization of source code.
- (iii) **Forward-engineering.** Tools that generate source code out of a system model. This category could be subdivided based on the degrees of code generation (percentage of code generated). For the purpose of this research, the degree of code generation does not matter.
- (iv) **Round-trip engineering.** Tools that provide forward and reverse-engineering.
- (v) **Product-suite.** Tools that provide round-trip features and other features that might include requirements management, automated software verification, and defect tracking.

4.4.3 Reasons for commitment

The news releases published by suppliers and buyers were used to identify the reasons why suppliers and buyers committed to UML-based development tools.

Each news release pertaining to a tool sale or purchase contains one or more quotes from the supplier and/or the buyer. Each news release contains a quote from the supplier when the news release is related to the release of a new product.

For each news release, the buyers' and/or suppliers' quotes were analyzed and a set of short reasons for commitment descriptions was compiled.

4.4.4 Identifying adoption stages

Stage transitions need to be identified to test hypotheses 1, 2, 3a, 3b, 3c, 5a, and 5b. The researcher used the method devised by Peng (2004) to identify adoption stages. Adoption stages are based on changes on product diversity; the first stage starts when the first product type is introduced and ends when a new product type is introduced and so on.

This approach is based on insights from Rogers (1983), Moore (2002), and Geroski (2000). According to these researchers, buyers' needs are different at each stage of the technology adoption life-cycle, therefore the diversity of the products offered enabled by new technology changes over time. If product diversity is measured over time, then it can be used to mark the changes from one stage to the next. (Peng, 2004).

The criteria used to validate if a change in product diversity marked a change in stage comprise three factors; (i) change in product type, any change in product type marks a change in the diversity of the product, (ii) the length of time between stage transition, and (iii) the minimum percentage of buyers classified in a stage. The last two factors were required to avoid a large number of stages.

4.4.5 Measurement of variables

Number of new suppliers. Number of new suppliers for month i is the sum of the companies that issued news releases announcing that they are developing or have introduced UML-based development tools during month i .

Number of suppliers. Number of suppliers for month i is the sum of the companies that issued news releases announcing that they are developing or have introduced UML-based development tools since the beginning of the study period minus the number of companies that have ceased to operate.

Number of new buyers. Number of new buyers for month i is the sum of organizations that issued news releases announcing that customers have purchased UML-based development tools or services during month i .

Existing buyers that stop using UML-based development tools are not considered to reduce the sample.

Number of buyers. Number of buyers for month i is the sum of the organizations that issued news releases announcing that customers have purchased UML-based development tools since the beginning of the study period minus the number of companies that have ceased to operate.

Suppliers' type. According to Malerba (2002), the agents can be companies or non-companies (e.g., universities, financial institutions, governments), as well as organizations at lower levels (e.g., application developers), or higher levels of aggregation (e.g., consortia). Suppliers that announced their commitment to UML-based development tools are classified into the following categories:

- Independent software vendors (ISV)
- Open source software developers
- Universities

Number of new products. Number of new products for month i is the sum of the new products introduced during month i .

New versions of existing products are not considered new products unless the product name is different (e.g., Rational Rose and Rational Rose RealTime are considered different products).

Number of products. Number of products for month i is the sum of new products introduced since the beginning of the study period minus the products that are no longer sold.

New Supplier and Supplier diversity. Diversity = $1 - \sum (p_i)^2$

Where:

i = supplier category

p_i = percentage of suppliers in category i

New supplier diversity refers to the diversity of the suppliers that announced their commitment to UML-based development tools in month i .

Supplier diversity refers to the diversity of the suppliers that announced their commitment to UML-based development tools from the beginning of the study period to the end of month i .

The minimum and maximum numbers that supplier diversity can take are zero and one respectively. A low diversity means that the number of suppliers offering UML-based development tools is low (e.g., under fifty percent of the supplier sample). A high diversity means that the number of suppliers offering UML-based development tools is high (e.g., fifty percent or more of the supplier sample).

Buyers' types. Buyers that announced their commitment to UML-based development were categorized into types using the N markets included in IDC's vertical market list (Toncheva, et al. 2002) and four additional markets identified by the researcher: information access and delivery, information and data management, application design and construction tools, and application life cycle management. Buyers were classified into the following buyer types:

- Banking
- Financial services
- Insurance
- Discrete manufacturing
- Process manufacturing
- Automotive manufacturing
- Transportation
- Broadcast and other communications
- Utilities
- Wholesale
- Retail
- Healthcare
- Business and legal
- Engineering / management
- Other services
- Mining
- Agriculture / construction

- Government
- Education
- Telecommunications
- Information access and delivery
- Information and data management
- Application design and construction tools
- Application life cycle-management

New Buyer and Buyer diversity. $\text{Diversity} = 1 - \sum (p_j)^2$

Where:

j = buyer category

p_i = percentage of suppliers in category j

New buyer diversity refers to the diversity of the suppliers that announced their commitment to UML-based development tools in month j .

Buyer diversity refers to the diversity of the suppliers that announced their commitment to UML-based development tools from the beginning of the study period to the end of month j .

The minimum and maximum numbers that buyer diversity can take are zero and one respectively. A low diversity means that the number of buyers that acquired UML-based development tools is low (e.g., under fifty percent of the buyer sample). A high diversity means that the number of buyers that acquired UML-based development tools is high (e.g., fifty percent or more of the buyer sample).

Product category. This can be modeling-only, backward-engineering, forward-engineering, round-trip engineering, or product-suite as specified in section 4.4.2.1.

Product diversity. $\text{Diversity} = 1 - \sum (p_k)^2$

Where:

k = product category

p_k = percentage of products in category k

Product diversity refers to the diversity of the UML-based development tools products bought from the beginning of the study period.

The minimum and maximum numbers that product diversity can take are zero and one respectively. A low diversity means that the number of products that entered the UML-based development tools market is low (e.g., under fifty percent of the product sample). A high diversity means that the number of products that entered the UML-based development tools market is high (e.g., fifty percent or more of the supplier sample).

Buyer size. The number of employees and the annual revenue measure size. The data used was that which was reported at the date closest to the date (time t) in which the supplier or buyer entered the UML-based development tools market. Privately held organizations do not publish their annual revenue or number of employees. For the purpose of this research, private organizations are considered small.

Number of products the company introduced. This refers to the total number of products introduced during the study period.

Size of the largest buyer. Size of the largest buyer at month i is the largest amount of revenue generated by a supplier operating in month i .

Density. The cumulative number of firms that enter the UML-based development tools market minus the number of firms that stop operations or abandon the related business.

Density squared (DENSQ). $= (\text{Density} * \text{Density}) / 1000$

5 Results

5.1 Sample

5.1.1 New suppliers

The supplier sample was comprised of seventy companies. Appendix I provides the names of the seventy companies in the supplier sample.

Table 5 provides the number of suppliers of UML-based development tools identified by source of information. Examining six sources of information identified a total of 101 suppliers.

Table 6 shows that of the 101 suppliers identified from six sources of information, 12 were companies that were out of business and 19 were no longer offering UML-based development tools as of December 2003. Thus, the sample used for this research included seventy firms (101 - 12 - 19).

Table 5 Number of suppliers identified by source of information

Source	Number of suppliers of UML-based development tools
IDC competitive analysis list	19
Business Source Premier database search	17
OMG list	22
Eclipse UML-related providers list	10
Objects by design web site list	82
Number of suppliers identified after eliminating redundancy	101

Table 6 Number of suppliers in the sample

Number of suppliers identified	101
Number of suppliers that were out of business as of December 2003	12
Number of suppliers that did not offer UML-based development tools as of December 2003	19
Number of suppliers in the sample	70

Throughout section five, a series of descriptive statistics are presented. These statistics include values for skewness, the p -value for skewness, kurtosis, and the p -value for kurtosis.

Skewness is a measure of the symmetry of a distribution around its mean. Kurtosis is a measure of the peakness of a distribution. Table 7 shows the skewness interpretation. A low p -value indicates the skewness is significantly non-normal. Table 8 shows the Kurtosis interpretation. A low p -value indicates the kurtosis is significantly non-normal. The p -value expresses the probability of observing a sample as extreme (or more so) when the null-hypothesis is true. The smaller the p -value the more untenable the null-hypothesis is.

Table 7 Skewness interpretation

Skewness	Interpretation
= 0	Distribution is symmetrical about the mean
> 0	Distribution has a right-tail skew - more observations in the left-tail than normal.
< 0	Distribution has a left-tail skew - more observations in the right-tail than normal.

Table 8 Kurtosis interpretation

Kurtosis	Interpretation
= 0	Distribution is normal
> 0	Distribution is more peaked than normal - more observations are clustered around the mean, with fewer in the tails than normal.
< 0	Distribution is squatter than normal - more observations are in the tails, with less clustered around the mean than normal.

5.1.2 Suppliers descriptive statistics

The research period has 156 months (from January 1991 to December 2003); thus, there are 156 observations of the variables entry rate, density, and supplier diversity. Table 9 shows the descriptive statistics of these variables.

Table 9 Descriptive statistics for suppliers' entry rate density and diversity

(N = 156)

	Mean	Variance	Standard deviation	Standard error	Coefficient -of- variation	Skewness		Kurtosis	
						Coefficient	p	Coefficient	p
Entry Rate	0.449	0.5974	0.7729	0.0619	172%	1.7449	< 0.0001	2.3645	0.0005
Density	17.949	448.449	21.1766	1.6955	118%	1.1780	< 0.0001	-0.1234	0.8500
Density Squared /1000	0.768	1.7389	1.3187	0.1056	172%	1.6906	< 0.0001	1.5428	0.0063
Supplier diversity	0.882	0.0621	0.2493	0.0200	28%	-3.1323	< 0.0001	8.5016	< 0.0001

The suppliers' entry rate, density, and density squared/1000 have positive skewness coefficient indicating that the distribution is skewed to the right. Suppliers' diversity has a negative skewness coefficient indicating that the distribution is skewed to the left.

Figures 2 and 3 illustrate the supplier entry rate and the supplier density over the 156 months. Supplier density refers to the cumulative number of UML-based development tools suppliers at the end of the month.

Figure 2 Monthly supplier entry rate **Figure 3 Supplier density**

5.1.3 Supplier types

Table 10 provides the breakdown of the number of suppliers in the sample by supplier category. Table 10 indicates that independent software vendors account for 88% of the companies in the sample.

Table 10 Supplier category

Supplier types	Number	Percentage
Independent software vendors	61	87.14%
Open Source	8	11.43%
University	1	1.43%
Totals	101	100.00%

Figure 4 illustrates supplier diversity over the study period.

Figure 4 Supplier diversity

5.1.4 Suppliers' annual revenue, age, and size

Table 11 provides the descriptive statistics for suppliers' annual revenue, size, and age. The data was collected for the month in which the first product was introduced into the market. Many of the companies in the sample were private companies. Thus, revenue data for only 28 out of 70 suppliers was available and employee data for only 30 suppliers was available. Age was available for all 70 suppliers in the sample.

Table 11 Descriptive statistics for supplier's annual revenue, size, and age

	n	Mean	Variance	Standard deviation	Standard error	Coefficient of variation	Skewness		Kurtosis	
							Coefficient	p	Coefficient	p
Revenue	28	21032.473	4267188079.562	65323.718	12345.022	311%	3.5379	< 0.0001	12.6804	< 0.0001
Size	30	13947.800	2232556504.441	47249.937	8626.619	339%	4.9197	< 0.0001	25.4980	< 0.0001
Age	70	12.400	137.490	11.726	1.401	95%	2.9612	< 0.0001	14.8826	< 0.0001

The supplier's revenue, size, and age have a positive skewness coefficient indicating that the distributions are skewed to the right.

Figure 5 shows the histograms for suppliers' annual revenue (millions), age (years), and number of employees. The majority of suppliers are small and young companies with revenue under US \$100 million.

Figure 5 Histogram for suppliers' annual revenue, age, and number of employees

5.2 New buyers

The buyer sample was comprised of 53 companies. Appendix II provides the names of the 53 companies in the buyer sample.

Examining suppliers' news releases identified the 53 buyers. The suppliers' news releases included the name of the buyer. Thus, the sample used for the research included 53 buyers. Error is introduced due to the fact that many buyers are not identified possibly because they did not want to be revealed.

Table 12 shows the descriptive statistics for the buyer sample.

Table 12 Descriptive statistics for buyers' entry rate, density and diversity

(N = 156)

	Mean	Variance	Standard deviation	Standard error	Coefficient-of-variation	Skewness		Kurtosis	
						Coefficient	<i>p</i>	Coefficient	<i>p</i>
Entry Rate	0.38000	1.16600	1.08000	0.08600	285%	3.6221	<0.0001	14.3396	<0.0001
Density	5.69000	171.67200	13.10200	1.04900	230%	2.6483	<0.0001	6.1987	<0.0001
Density Squared /1000	0.20300	0.38934	0.62397	0.04996	307%	3.6859	<0.0001	13.9086	<0.0001
Supplier diversity	0.28973	0.19661	0.44341	0.03550	153%	0.8852	<0.0001	-1.2188	<0.0001

Figure 6 shows the buyer entry rate. Buying activity starts in September 1999, stops for almost a year and starts again in June 2001. Beginning in January 2002, the number of buyers increases steadily.

Figure 7 shows the buyer density following the same pattern as the supplier and product diversity.

Figure 6 New buyers entry rate

Figure 7 New buyers density

5.3 Adoption stages

Buyer data is used to define when a change in adoption stage occurs. The changes in adoption stages were identified using the criteria described in section 4.4.4. A stage begins when all of the following criteria are met:

- a new product type is introduced by a supplier
- at least five percent of the buyer sample are classified as users of the stage and product type
- the last stage change occurred at least 12 months ago

The last two conditions are used to reduce the number of potential stage transitions during periods where many changes in product diversity occur within short periods of time.

5.3.1 Changes in product types identified from buyers' data

Based on the criteria to define adoption stages, the researcher used data from news releases to identify all the potential changes in adoption stages.

On September 1999 the initial state transition is defined by the first integration of two products, a forward-engineering tool from Visible Systems and a software repository to allow software development teams simultaneously to share and manage their designs.

The next potential state transition is in February 2000 when Matra Marconi Space purchased ObjectGeode product suite to provide a dynamic description of the software's behavior and

strengthened the developers' and customers' confidence in the design's robustness. Product type transitions from forward engineering to product-suite.

The next potential stage transition is in March 2000 when Lucent Technologies Inc. acquired RapidRMA modeling software to describe the data flow of its next generation systems prior to system completion. Product type change from product-suite to modeling-only.

The next potential stage transition is in August 2000 when the Northern Alberta Institute of Technology purchased over 150 licenses of Visual UML 2.5 to equip its computer systems technology program training labs. Product type transitions from modeling-only to round-trip engineering.

The next potential stage transition is in October 2001, when Broadband storage acquired System Architect from Popkin Software to manage the design of their software and systems in a real-time, high-performance embedded environment. With this transaction, six percent of the buyer sample is classified as user of the product-suit type, ten percent of the sample is classified within stage 1, and the last stage transition occurred twelve months or more before. All three conditions for a valid stage transitions are met; therefore this is a valid stage transition.

The next potential stage transition is in January 2002 when Dell Computer Corporation standardized on Visual UML and purchased an unlimited user site license for widespread

deployment and use throughout Dell EMEA (Europe, Middle East, Africa) division. With this transaction, six percent of the buyer sample is classified as user of the round-trip engineering product type. However it is less than twelve months after the previous stage transition.

The next potential stage transition is in June 2002 when Kennedy Carter consultants took the concept to a fully developed product achieving 100% automated Ada 95 code generation for BAE Systems. With this transaction six percent, of the buyer sample is classified as user of the forward-engineering product type. However it is less than twelve months after the previous stage transition.

The next potential stage transition is in October 2002 when Conti Temic Microelectronic GmbH acquired Statemate Rhapsody to allow them to 'feel' the systems behavior, make changes on the fly, validate their design, generate code, and conduct tests much more quickly. At this point, at least five percent of the buyers sample is classified on each of the product types, there is a period of at least twelve months from the previous stage transition, and at least five percent of the buyer sample is classified in the current stage; therefore this is a valid stage transition.

The final potential stage transition is in October 2003 when the Arizona Supreme Court in Phoenix acquired Visible Developer to allow their development teams to quickly produce well architected .NET solutions. At this point, at least five percent of the buyers sample is

classified on each of the product types, there is a period of at least twelve months from the previous stage transition, and at least five percent of the buyer sample is classified in the current stage; therefore this is a valid stage transition. Table 13 shows all potential adoption stage transitions identified from buyers' data.

Table 13 Potential stage transitions identified from buyers' data

Date	Buyer	Buyer vertical market	Product type	Stage transition
Sep/1999	Visible Systems	Application design and construction tools	Forward-engineering	First stage transition
Feb/2000	Matra Marconi Space	Transportation	Product suite	No
Mar/2000	Lucent Technologies Inc.	Telecommunications	Modeling-only	No
Aug/2000	Northern Alberta Institute of Technology	Education	Round-trip engineering	No
Oct/2001	Broadband storage	Other services	Product suite	Yes
Jan/2002	Dell Computer Corp.	Discrete manufacturing	Round-trip engineering	No
Jun/2002	BAE Systems	Other services	Forward-engineering	No
Oct/2002	Conti Temic Microelectronic GmbH	Discrete manufacturing	Product suite	Yes
Oct/2003	Arizona Supreme Court in Phoenix	Government	Modeling only	Yes

Table 14 shows the percentage of buyers classified in each of the product types and potential stages identified on Table 13.

Table 14 Percent of buyers by product type and potential stage

Stage transition	Year and month stage started	Percent of buyer sample in modeling-only	Percent of buyer sample in forward-engineering	Percent of buyer sample in reverse-engineering	Percent of buyer sample in product-suite	Percent of buyer sample in stage	Cumulative percent of buyer sample
1	Sep - 1999	0%	1.69%	0%	0%	1.69%	1.69%
2	Feb - 2000	0%	1.69%	0%	1.69%	1.69%	3.39%
3	Mar - 2000	1.69%	1.69%	0%	1.69%	1.69%	5.08%
4	Aug - 2000	1.69%	1.69%	1.69%	1.69%	6.76%	10.17%
5	Oct - 2001	1.69%	1.69%	3.39%	5.08%	11.86%	11.86%
6	Jan - 2002	1.69%	1.69%	5.08%	5.08%	13.54%	28.81%
7	Jun - 2002	3.39%	5.08%	8.47%	13.56%	30.5%	42.37%
8	Oct - 2002	8.47%	6.78%	11.86%	16.95%	44.06%	89.83%
9	Oct - 2003	18.64%	13.56%	15.25%	44.07%	10.77%	100.00%

Table 14 shows that some of the stages include less than five percent of the buyer sample and the number of months between stage transitions is less than twelve months. Stage 1 is considered to be before the first stage transition, from January 1991 to August 1998. For this reason, stages 1, 2, 3, and 4 are consolidated into stage 2. Stages 6 and 7 are consolidated into stage 3, and stage 9 becomes stage 4.

The four stages used to test hypotheses 1, 2a, 2b, 3a, 3b, 5a, and 5b are shown in Table 15.

Table 15 Adoption stages by product acquired

Stage transition	Year and month stage started	Percent of buyer sample in modeling-only	Percent of buyer sample in forward-engineering	Percent of buyer sample in reverse-engineering	Percent of buyer sample in product-suite	Percent of buyer sample in stage	Cumulative percent of buyer sample
1	Jan - 1991	0.0%	0.0%	0.0%	0.0%	10.1%	10.1%
2	Sep - 1999	9.1%	10.0%	12.5%	8.3%	32.2%	42.4%
3	Oct - 2001	36.4%	30.0%	62.5%	29.2%	47.5%	89.8%
4	Oct - 2002	55.5%	60.0%	25.0%	62.5%	10.2%	100.0%

5.4 Testing hypothesis 1

Hypothesis 1: The size of new supplier is a function of the adoption stage, was used to test the association between the supplier size (measured in revenue) and the adoption stage. Revenue data was obtained for only 28 of the 70 suppliers.

Table 16 shows the results of using the Mann-Whitney U test to compare the suppliers' revenue at stages 1 and 2. The results indicate that the mean rank of the supplier size at stage 1 is significantly larger than that at stage 2.

Table 16 Mann-Whitney U Test comparing suppliers' size between stages

Alternative hypothesis | Supplier size by stage: Stage 1 $\neq$ Stage 2
 n | 23 (cases excluded: 33 due to missing values)

Supplier revenue by stage	n	Rank sum	Mean rank	U
Stage 1	20	252.0	12.60	18.0
Stage 2	3	24.0	8.00	42.0

Difference between
 medians | -
 95.% CI | - to -

Mann-Whitney U statistic | 18
 2-tailed p | 0.1846 (normal approximation, corrected for ties)

Appendix III provides the Mann-Whitney U tests for the remaining pairs of stages. The results of all Mann-Whitney U tests show the following results:

- Suppliers entering the UML-based development tools market at stage 1 are significantly larger than those entering the market at stage 2.
- Suppliers entering the UML-based development tools market at stage 2 are significantly smaller than those entering the market at stage 3.
- Suppliers entering the UML-based development tools market at stage 3 are significantly smaller than those entering the market at stage 4.

The results support the acceptance of hypothesis 1, suggesting that there is an association between the suppliers' size (revenue) and the adoption stage. However, this association weakens as the adoption process advances.

5.5 Products sample

A total of 89 products were identified from the suppliers' web sites. Appendix IV shows the 89 products in the sample, the name of their suppliers, and the corresponding product category.

Table 17 shows the descriptive statistics for the product sample.

Table 17 Descriptive statistics for variables that describe the characteristics of products

(N = 156)

	Mean	Variance	Standard deviation	Standard error	Coefficient-of-variation	Skewness		Kurtosis	
						Coefficient	<i>p</i>	Coefficient	<i>p</i>
Entry Rate	0.5700	0.85300	0.92400	0.07400	162%	1.8060	<0.0001	3.0177	<0.0001
Density	22.2700	612.97200	24.75800	1.98200	111%	1.1704	<0.0001	0.0581	0.7525
Density Squared /1000	1.1050	3.53100	1.87915	0.15045	170%	1.8885	<0.0001	2.7082	0.0002
Product diversity	0.8903	0.06361	0.25222	0.02019	28%	-3.1185	<0.0001	8.4149	<0.0001

The product's entry rate, density, and density squared/1000 have positive skewness coefficients indicating that the distributions are skewed to the right. Product diversity has a negative skewness coefficient indicating that the distribution is skewed to the left. This means that product diversity has higher values at the end of the study period.

Figure 8 shows the monthly new product entry rate and stage transitions.

Figure 8 New product entry rate

Figure 9 shows product density. Product density follows the same pattern as the supplier diversity.

Figure 9 New product density and stage transitions

Product entry rate is scattered from January 1991 to January 1999; during 1999 the rate increases in a measured way, then from January 2000 to December 2003 it increases rapidly.

5.5.1 Product types

Table 18 provides the breakdown of the number of suppliers in the sample by product category.

Table 18 Number of products by product category

Product category	Number	Percentage
Modeling only	18	20.22%
Reverse-engineering	11	12.36%
Forward-engineering	27	30.34%
Round-trip engineering	23	25.84%
Product suite	10	11.24%
Totals	89	100.00%

Figure 10 illustrates product diversity over the study period. Diversity increases rapidly at the beginning of the study period and then levels off.

Table 19 shows the descriptive statistics for product categories. All product categories have a positive skewness coefficient indicating that their distributions are skewed to the right.

Figure 10 Product diversity and stage transition **Table 19 Descriptive statistics for product categories**

(N = 156)

	Mean	Variance	Standard deviation	Standard error	Coefficient-of-variation	Skewness		Kurtosis	
						Coefficient	<i>p</i>	Coefficient	<i>p</i>
Modeling only	0.115	0.1027	0.3205	0.0257	278%	2.4312	<0.0001	3.9611	<0.0001
Reverse-engineering	0.071	0.0660	0.2568	0.0206	364%	3.3879	<0.0001	9.6009	<0.0001
Forward-engineering	0.173	0.2215	0.4706	0.0377	272%	3.5347	<0.0001	15.7646	<0.0001
Round-trip engineering	0.147	0.1394	0.3734	0.0299	253%	2.3782	<0.0001	4.8553	<0.0001
Product suite	0.064	0.0733	0.2707	0.0217	422%	4.5377	<0.0001	22.1470	<0.0001

5.6 Testing hypothesis 2.

The Mann-Whitney U test was used to test hypothesis 2: The type of new product is a function of the adoption stage.

Table 20 shows the results of using the Mann-Whitney U test to compare the product types at stages 1 and 2. The results indicate that the mean rank of the product types at stage 1 is larger than at stage 2.

Table 20 Mann-Whitney U test comparing product types between stages

Alternative hypothesis		Product category by stage: Stage 1 $\neq$ Stage 2		
n		25		
Product category by stage	n	Rank sum	Mean rank	U
Stage 1	6	81.5	13.58	53.5
Stage 2	19	243.5	12.82	60.5
Difference between medians		-		
95% CI		-	to -	
Mann-Whitney U statistic		53.5		
2-tailed p		0.8165	(normal approximation, corrected for ties)	

Appendix V provides the Mann-Whitney U tests for the remaining pairs of stages.

The results of all Mann-Whitney U tests show the following results:

- The mean rank of the product types at stage 1 is larger than that at stage 2
- The mean rank of the product types at stage 2 is larger than at stage 3
- The mean rank of the product types at stage 3 is significantly larger than at stage 4

The results provide support for hypothesis 2. Results suggest that there is an association between the product category and the adoption stage.

5.7 Testing hypothesis 3a

The Mann-Whitney U test was used to test hypothesis 3a: Product diversity increases rapidly during the early stages, then increases slowly towards the later stages.

Table 21 provides the descriptive statistics for product diversity by adoption stage. For all stages, product diversity does not follow a normal distribution. For this reason the Mann-Whitney U test was used to compare product diversity in all 4 stages. Product diversity at stages 1, 2, and 3 has a negative skewness coefficient indicating that the distributions are skewed to the left. This means that product diversity increases during each stage.

Table 21 Descriptive statistics for product diversity by stage

Product diversity by stage	n	Mean	Variance	Standard deviation	Standard error	Coefficient-of-variation	Skewness		Kurtosis	
							Coefficient	<i>p</i>	Coefficient	<i>p</i>
Stage 1	129	0.867	0.0740	0.2720	0.0239	31%	-2.7759	<0.0001	6.2702	<0.0001
Stage 2	12	1.000	0.0000	0.0002	0.0001	0%	-1.4050	0.0313	0.7830	-
Stage 3	12	0.999	0.0000	0.0005	0.0001	0%	-1.9134	.0052	2.4445	-
Stage 4	3	0.999	0.0000	0.0002	0.0001	0%	-	-	-	-

Table 22 shows the results from the Mann-Whitney U test that compared product diversity between stages 1 and 2. Product diversity at stage 1 is significantly smaller than that at stage 2.

Appendix VI provides the Mann-Whitney U tests for the remaining pairs of stages. The results of all Mann-Whitney U tests provide the following results:

- Product diversity at stage 1 is significantly smaller than at stage 2.
- Product diversity at stage 2 is significantly smaller than at stage 3.
- Product diversity at stage 3 is significantly larger than at stage 4.

The results support the acceptance of hypothesis 3a suggesting that product diversity grows rapidly during the early stages then get saturated at the later stages.

Table 22 Mann-Whitney U test comparing product diversity between stages

Alternative hypothesis		Product diversity by stage: Stage 1 $\neq$ Stage 2		
n		141		
Product diversity by stage	n	Rank sum	Mean rank	U
Stage 1	129	8410.0	65.19	1523.0
Stage 2	12	1601.0	133.42	25.0
Difference between medians		-0.02707		
95.1% CI		-0.11080 to -0.00666 (normal approximation)		
Mann-Whitney U statistic		1523		
2-tailed p		<0.0001 (normal approximation, corrected for ties)		

5.8 Testing hypothesis 3b

The Man-Whitney U test was used to test hypothesis 3b: Supplier diversity increases rapidly during the early stages, then increases slowly towards the later stages.

Table 23 provides the descriptive statistics for supplier diversity by adoption stage. For stages 1, 2, and 3, supplier diversity does not follow a normal distribution. For this reason, the Mann-Whitney U test was used to compare supplier diversity. Supplier diversity at stage 1 has a negative skewness coefficient indicating that the distribution is skewed to the left. Supplier diversity at stages 2 and 3 have a positive skewness coefficient indicating that the distributions are skewed to the right. This means that during stage 1 supplier diversity increases at the beginning of the stage then decreases towards the end of the stage. This is

due to suppliers exiting the UML-based development tools market. During stages 2 and 3 supplier diversity increases, meaning that the number of suppliers entering the UML-based development tools market is growing. During stage 4 supplier diversity has a normal distribution, meaning that at the beginning of the stage the number of suppliers entering the UML-based development tools market is growing then some suppliers exit the market.

Table 23 Descriptive statistics for supplier diversity by stage

Supplier diversity by stage	n	Mean	Variance	Standard deviation	Standard error	Coefficient-of-variation	Skewness		Kurtosis	
							Coefficient	<i>p</i>	Coefficient	<i>p</i>
Stage 1	129	0.85696	0.071729	0.267823	0.023580	31%	-2.8045	<0.0001	6.3976	<0.0001
Stage 2	12	0.99901	0.000000	0.99901	0.000195	0%	-0.4141	0.4987	-1.4844	-
Stage 3	12	0.99904	0.000001	0.99904	0.000231	0%	-1.2426	0.0535	0.7196	-
Stage 4	3	0.99901	0.000000	0.99901	0.000088	0%	-	-	-	-

Table 24 shows the results from the Mann-Whitney U test comparing supplier diversity for stage 1 and stage 2. Supplier diversity at stage 1 is significantly smaller than at stage 2.

Table 24 Mann-Whitney U test comparing supplier diversity between stages

Alternative hypothesis	Supplier diversity by stage: Stage 1 $\neq$ Stage 2				
n	141				
Supplier diversity by stage	n	Rank sum	Mean rank	U	
Stage 1	129	8439.5	65.42	1493.5	
Stage 2	12	1571.5	130.96	54.5	
Difference between medians	-0.10903				
95.1% CI	-0.10974 to -0.01524 (normal approximation)				
Mann-Whitney U statistic	1493.5				
2-tailed p	<0.0001 (normal approximation, corrected for ties)				

Appendix VII provides the Mann-Whitney U tests for the remaining pairs of stages. The results of all Mann-Whitney U tests show the following results:

- Product diversity at stage 1 is significantly smaller than at stage 2
- Product diversity at stage 2 is significantly smaller than at stage 3
- Product diversity at stage 3 is larger than at stage 4

Table 25 shows the results of 1-way ANOVA for supplier diversity by stage. Product diversity at stage 1 is lower than at the other three stages; the mean difference between product diversity at stages 1 and 2 is significantly greater than the mean difference between product diversity at stages 2 and 3.

Table 25 1-way between subjects ANOVA Supplier diversity by stage

Supplier diversity by stage	n	Mean	Standard deviation	Standard error
Stage 1	129	0.85696	0.26782	0.023580
Stage 2	12	0.99901	0.00067	0.000195
Stage 3	12	0.99904	0.00080	0.000231
Stage 4	3	0.99901	0.00015	0.000088

Source of variation	Sum of squares	Degrees of freedom	Mean square	Ratio of Mean square / Mean square within	<i>p</i> (probability)
Stage	0.45061	3	0.15020	2.49	0.0627
Within cells	9.18134	152	0.06040	0.06040	
Total	9.63195	155			

The results support the acceptance of hypothesis 3b suggesting that supplier diversity grows rapidly during the early stages then it levels off at the later stages.

5.9 Testing hypothesis 3c

Hypothesis 3c: Buyer diversity increases rapidly during the early stages.

Figure 11 shows the buyer diversity by vertical market. Diversity changes over the study period, increasing rapidly at the beginning of 2000 then leveling off at the end of the study period. Diversity in Figure 11 is based on buyer type. Twenty four types of buyers were identified based on their vertical market.

Figure 11 Buyer diversity by vertical market

Table 26 provides the descriptive statistics for buyer diversity by adoption stage. For all stages, buyer diversity does not follow a normal distribution. For this reason, the Mann-Whitney U test was used to compare buyer diversity in all four stages. Buyer diversity at stage 1 has a positive skewness coefficient indicating that the distribution is skewed to the right. Buyer diversity at stages 2 and 3 has a negative skewness coefficient indicating that the distributions are skewed to the left. This means that buyer diversity grew at the beginning of stage 1 then decreased by the end of the stage. During stages 2 and 3 buyer diversity kept growing. During stage 4 buyer diversity grew at the beginning of the stage then started to decrease towards the end of the stage.

Table 26 Descriptive statistics for buyer diversity by stage

Buyer diversity by stage	N	Mean	Variance	Standard deviation	Standard error	Coefficient-of-variation	Skewness		Kurtosis	
							Coefficient	<i>p</i>	Coefficient	<i>p</i>
Stage 1	129	0.14263	0.112072	0.334772	0.029475	235%	1.9402	<0.0001	1.8104	0.0051
Stage 2	12	0.98606	0.000052	0.007184	0.002074	1%	-0.0245	0.9678	-1.7696	-
Stage 3	12	0.99746	0.000003	0.001623	0.000469	0%	-0.4632	0.4500	-0.6583	-
Stage 4	3	0.99901	0.000000	0.000282	0.000163	0%	-	-	-	-

Table 27 shows the results from the Mann-Whitney U test comparing buyer diversity between stage 1 and stage 2. Buyer diversity at stage 1 is significantly smaller than that at stage 2.

Appendix VIII provides the Mann-Whitney U tests for the remaining pairs of stages. The results of all Mann-Whitney U tests provide the following results:

- Buyer diversity at stage 1 is significantly smaller than at stage 2.
- Buyer diversity at stage 2 is significantly smaller than at stage 3.
- Buyer diversity at stage 3 is smaller than at stage 4.

The results support the acceptance of hypothesis 3c, suggesting that buyer diversity grows rapidly during the early stages then levels off at the later stages.

Table 27 Mann-Whitney U test comparing buyer diversity between stages

Alternative hypothesis	Buyer diversity by stage: Stage 1 $\neq$ Stage 2			
n	141			
Supplier diversity by stage	n	Rank sum	Mean rank	U
Stage 1	129	8385.0	65.00	1548.0
Stage 2	12	1626.0	135.50	0.0
Difference between medians	-0.98047			
95.1% CI	-0.99174 to -0.97959 (normal approximation)			
Mann-Whitney U statistic	1548			
2-tailed p	<0.0001 (normal approximation, corrected for ties)			

5.10 Testing hypothesis 4a

Hypothesis 4a: New buyers' entry rate follows a bell shape distribution.

Table 28 provides the descriptive statistics for buyer entry rate by adoption stage. For stages 1, 2, and 3 the buyer entry rate is not normally distributed. For this reason the Mann-Whitney U test was used to compare supplier diversity. Supplier diversity at stages 1, 2, and 3 has a positive skewness coefficient indicating that the distributions are skewed to the right. This means that the buyer entry keeps growing from stage 1 to stage 3. During stage 4 the buyer entry rate keeps growing at the beginning of the stage then starts decreasing.

Table 28 Descriptive statistics for buyers' entry rate by adoption stage

Buyer entry rate by stage	n	Mean	Variance	Standard deviation	Standard error	Coefficient-of-variation	Skewness		Kurtosis	
							Coefficient	p	Coefficient	p
Stage 1	129	0.0	0.04	0.21	0.02	455%	4.3577	<0.0001	17.2566	<0.0001
Stage 2	12	1.6	2.99	1.73	0.50	109%	1.4123	0.0306	1.1057	-
Stage 3	12	2.3	4.42	2.10	0.61	90%	0.8076	0.1954	0.6806	-
Stage 4	3	2.0	4.00	2.00	1.15	100%	-	-	-	-

Table 29 shows the results from the Mann-Whitney U test comparing the buyer entry rate for stage 1 and stage 2.

Appendix IX provides the Mann-Whitney U tests for the remaining pairs of stages.

Table 29 Descriptive statistics for buyers' entry rate by adoption stage

Alternative hypothesis		Supplier entry rate by stage: Stage 1 $\neq$ Stage 2		
n		141		
Supplier diversity by stage		n	Rank sum	Mean rank
Stage 1		129	8602.5	66.69
Stage 2		12	1408.5	117.38
U		1330.5		
Difference between medians		-1.0		
95.1% CI		-1.0 to -1.0 (normal approximation)		
Mann-Whitney U statistic		1330.5		
2-tailed p		<0.0001 (normal approximation, corrected for ties)		

The results of all tests throw the following results:

- Buyer entry rate at stage 1 is significantly smaller than at stage 2
- Buyer entry rate at stage 2 is smaller than at stage 3
- Buyer entry rate at stage 3 is larger than at stage 4

The results support the acceptance of hypothesis 4a, suggesting that new buyers' entry rate follows a bell shaped distribution.

5.11 Testing hypothesis 4b

Hypothesis 4b: New suppliers' entry rate follows a bell shaped distribution.

Table 30 provides the descriptive statistics for buyer entry rate by adoption stage. For all stages, supplier diversity does not follow a normal distribution. For this reason, the Mann-Whitney U test was used to compare supplier diversity in all 4 stages. Supplier entry rate at stages 1, 2, and 3 have a positive skewness coefficient indicating that the distributions are skewed to the right. This means that the supplier entry keeps growing from stage 1 to stage 3. During stage 4, the supplier's entry rate grew at the beginning of the stage then starts to decrease towards the end of the stage.

Table 30 Descriptive statistics for suppliers' entry rate by adoption stage

Supplier entry rate by stage	N	Mean	Variance	Standard deviation	Standard error	Coefficient-of-variation	Skewness		Kurtosis	
							Coefficient	p	Coefficient	p
Stage 1	129	0.3	0.45	0.67	0.06	192%	2.0017	<0.0001	3.6211	<0.0001
Stage 2	12	0.9	0.81	0.90	0.26	98%	1.0816	0.0888	1.4919	-
Stage 3	12	1.0	1.45	1.21	0.35	121%	0.7462	0.2299	-1.0542	-
Stage 4	3	0.7	1.33	1.15	0.67	173%	-	-	-	-

Table 31 shows the results from the Mann-Whitney U test comparing the buyer entry rate for stage 1 and stage 2.

Table 31 Mann-Whitney U test comparing suppliers' entry rate between stages

Alternative hypothesis		Supplier entry rate by stage: Stage 1 $\neq$ Stage 2		
n		141		
Supplier diversity by stage		n	Rank sum	Mean rank
Stage 1		129	8845.0	68.57
Stage 2		12	1166.0	97.17
U		1088.0		
Difference between medians		-1.0		
95.1% CI		-1.0 to 0		
		(normal approximation)		
Mann-Whitney U statistic		1088		
2-tailed p		0.0036		
		(normal approximation, corrected for ties)		

Appendix X provides the Mann-Whitney U tests for the remaining pairs of stages. The results of all tests throw the following results:

- Supplier entry rate at stage 1 is significantly smaller than at stage 2
- Supplier entry rate at stage 2 is slightly larger than at stage 3
- Supplier entry rate at stage 3 is larger than at stage 4

The results do not support the acceptance of hypothesis 4b, suggesting that new suppliers' entry rates do not follow a bell shaped distribution.

5.12 Buyers' vertical markets

Table 32 provides a breakdown of the number of buyers in the sample by vertical market.

The researcher used IDC's segmentation of software markets to classify buyers' type. Table 33 shows the descriptive statistics for buyers' vertical market.

Application design and construction tools and other services account for 20.34% each. Some developers of UML-based development tools are collaborating to supplement their applications with other products. Insurance, process manufacturing, wholesale, retail, business and legal, and mining had a zero percent rate.

Table 32 Number of buyers by category based on vertical market

Buyer category	Number	Percentage
Banking	1	1.69%
Financial services	2	3.39%
Insurance	0	0.00%
Discrete manufacturing	2	3.39%
Process manufacturing	0	0.00%
Automotive manufacturing	5	8.47%
Transportation	3	5.08%
Broadcast and other communications	1	1.69%
Utilities	1	1.69%
Wholesale	0	0.00%
Retail	0	0.00%
Healthcare	0	0.00%
Business and legal	0	0.00%
Engineering / management	4	6.78%
Other services	12	20.34%
Mining	0	0.00%
Agriculture / construction	1	1.69%
Government	4	6.78%
Education	2	3.39%
Telecommunications	4	6.78%
Information access and delivery	2	3.39%
Information and data management	2	3.39%
Application design and construction tools	12	20.34%
Application life cycle-management	1	1.69%
	59	100.00%

Table 33 Descriptive statistics for buyers' vertical market

	N	Mean	Variance	SD	SE	CV
Banking	156	0.006	0.0064	0.0801	0.0064	1249%
Financial services	156	0.013	0.0127	0.1129	0.0090	880%
Insurance	156	0.000		-	-	
Discrete manufacturing	156	0.013	0.0127	0.1129	0.0090	880%
Process manufacturing	156	0.000		-	-	
Automotive manufacturing	156	0.032	0.0312	0.1767	0.0141	551%
Transportation	156	0.019	0.0190	0.1378	0.0110	716%
Broadcast and other communications	156	0.006	0.0064	0.0801	0.0064	1249%
Utilities	156	0.006	0.0064	0.0801	0.0064	1249%
Wholesale	156	0.000		-	-	
Retail	156	0.000		-	-	
Healthcare	156	0.000		-	-	
Business and legal	156	0.000		-	-	
Engineering / management	156	0.026	0.0251	0.1586	0.0127	618%
Other services	156	0.077	0.0973	0.3119	0.0250	405%
Mining	156	0.000		-	-	
Agriculture / construction	156	0.006	0.0064	0.0801	0.0064	1249%
Government	156	0.026	0.0251	0.1586	0.0127	618%
Education	156	0.013	0.0127	0.1129	0.0090	880%
Telecommunications	156	0.026	0.0251	0.1586	0.0127	618%
Information access and delivery	156	0.013	0.0127	0.1129	0.0090	880%
Information and data management	156	0.013	0.0127	0.1129	0.0090	880%
Application design and construction tools	156	0.077	0.1231	0.3508	0.0281	456%
Application life cycle-management	156	0.006	0.0064	0.0801	0.0064	1249%

5.13 Suppliers' reasons for commitment

Suppliers' reasons for commitment were obtained from quotes found in suppliers' news releases and announcements. The quotes for all news releases and announcements were analyzed and a total of seven different reasons for suppliers to commit were identified. Table 34 shows the keywords used to identify suppliers' reasons to commit to UML-based development tools.

Table 34 Suppliers reasons to commit keywords

Suppliers' reasons to commit	Keywords
Add new features	Provide new, now include, offers
Capture niche market	Market niche, targeted to
Commit to open standards	Commit, open standard
Enter the market	First release
Offer reduced cycle time	Save time, reduce cycle, increase productivity
Participation in standards definition	Participate, define, standard
Supplement application	Integrate, supplement

Table 35 and figure 12 show the frequency distribution for suppliers' reasons to commit to UML-based development tools.

Table 35 Frequency distribution for suppliers' reasons to commit

Suppliers' reasons to commit	Number	Percentage
Add new features	32	29.36%
Capture niche market	10	9.17%
Commit to open standards	10	9.17%
Enter the market	22	20.18%
Offer reduced cycle time	10	9.17%
Participation in standards definitions	6	5.50%
Supplement application	19	17.43%
	109	100.00%

Table 36 shows the suppliers' reasons to commit to UML-based development tools categorical summary descriptive statistics.

Table 36 Suppliers' reasons for commitment categorical summary descriptive statistics

Variable	Suppliers' reason to commit
n	109
Groups	7
Mode	Add new features

Figure 12 Suppliers' reasons for commitment

5.14 Testing hypothesis 5a

Hypothesis 5a: Reasons for which suppliers commit to UML-based development tools are a function of the adoption stage. Test the association between the suppliers' reasons to commit to UML-based development tools and the adoption stage.

Table 37 shows the results of using the Mann-Whitney U test comparing the suppliers' reasons to commit at stages 1 and 2. The results indicate that the mean rank of the supplier size at stage 1 is significantly larger than at stage 2.

Appendix XI provides the Mann-Whitney U tests for the remaining pairs of stages. The results of all Mann-Whitney U tests throw the following results:

- The mean rank of suppliers' reasons to commit to UML-based development tools at stage 1 are significantly smaller than the mean rank at stage 2
- The mean rank of suppliers' reasons to commit to UML-based development tools at stage 2 is slightly smaller than the mean rank at stage 3
- The mean rank of suppliers' reasons to commit to UML-based development tools at stage 2 is significantly larger than the mean rank at stage 3

The results support the acceptance of hypothesis H5a, suggesting that there is an association between the suppliers' reasons to commit and the adoption stage. However, this association weakens as the adoption process advances.

Table 37 Mann-Whitney U test comparing suppliers' reasons to commit between stages

Alternative hypothesis		Supplier reason by Stage: Stage 1 $\neq$ Stage 2		
n		70		
Supplier diversity by stage	n	Rank sum	Mean rank	U
Stage 1	38	1304.5	34.33	652.5
Stage 2	32	1180.5	36.89	563.5
Difference between medians		-		
95.1% CI		- to - (normal approximation)		
Mann-Whitney U statistic		652.5		
2-tailed p		0.5895 (normal approximation, corrected for ties)		

5.15 Buyers' reasons for commitment

The buyers' reasons for commitment were obtained from sales-related supplier's news releases and announcements. Most news releases and announcements include quotes from the buyers indicating why they bought the product. All news releases and announcements were analyzed and a total of eight different reasons for buyers to commit were defined. Table 38 shows the keywords used to identify buyers' reasons to commit to UML-based development tools. Table 39 and figure 13 show the frequency distribution for buyers' reasons to commit to UML-based development tools. Table 40 shows buyers' reasons to commit to UML-based development tools categorical summary descriptive.

Table 38 Buyers' reasons to commit keywords

Buyers' reasons to commit	Keywords
Commit to open standards	Commit, open standard
Cost reduction	Reduce cost
Features provided	Features
Openness / flexibility provided	Openness, flexible
Reduce development cycle time	Reduce time
Sponsor education activities	Sponsor, education
Supplement application	Supplement, integrate
Use for education purposes	Training, lab

Table 39 Frequency distribution for buyers' reasons to commit

Buyers' reasons to commit	Number	Percentage
Commit to open standards	2	3.51%
Cost reduction	2	3.51%
Features provided	23	40.35%
Openness / flexibility provided	12	21.05%
Reduce development cycle time	8	14.04%
Sponsor education activities	1	1.75%
Supplement application	7	12.28%
Use for education purposes	2	3.51%
	57	100.00%

Table 40 Buyers' reasons to commitment categorical summary descriptive

Variable	Buyers' reason to commit
n	57
Groups	8
Mode	Features provided

Figure 13 Frequency distribution for buyer's reasons to commitment

5.16 Testing hypothesis 5b

Hypothesis 5b: Reasons for which buyers commit to UML-based development tools are a function of the adoption stage. Test the association between the buyers' reasons to commit to UML-based development tools and the adoption stage.

Table 41 shows the results of using the Mann-Whitney U test comparing the buyers' reasons to commit at stages 1 and 2. The results indicate that the mean rank of the supplier size at stage 1 is significantly larger than at stage 2.

Table 41 Mann-Whitney U test comparing buyers' reasons to commit between stages

Alternative hypothesis	Buyers' reasons to commit by stage: Stage 1 ≠ Stage 2				
n	24				
Buyers' reasons by stage	n	Rank sum	Mean rank	U	
Stage 1	7	105.0	15.00	42.0	
Stage 2	17	195.0	11.47	77.0	
Difference between medians	-				
95.1% CI	- to - (normal approximation)				
Mann-Whitney U statistic	42				
2-tailed p	0.2504 (normal approximation, corrected for ties)				

Appendix XII provides the Mann-Whitney U tests for the remaining pairs of stages. The results of all Mann-Whitney U tests throw the following results:

- The mean rank of buyers' reasons to commit to UML-based development tools at stage 1 is significantly larger than the mean rank at stage 2.
- The mean rank of buyers' reasons to commit to UML-based development tools at stage 2 is larger than the mean rank at stage 3.
- The mean rank of buyers' reasons to commit to UML-based development tools at stage 3 is larger than the mean rank at stage 4.

The results support the acceptance of hypothesis 5b, suggesting that there is an association between the buyers' reasons to commit and the adoption stage.

6 Discussion of results

This chapter is organized into seven sections. Section 6.1 states the research objectives and provides a summary of the results. Section 6.2 discusses results on the association between adoption stage and supplier size and product category. Section 6.3 discusses results on temporal patterns. Section 6.4 discusses results on the commitment to UML-based development tools. Section 6.5 discusses results on the suppliers' reasons to commit to UML-based development tools. Section 6.6 discusses results on buyers' reasons to commit to UML-based development tools. Section 6.7 presents the technology adoption life cycle for UML-based development tools.

6.1 Objectives and summary of results

The objectives of this research were to:

- Examine whether the stages of the life cycle affect supplier size and product category.
- Identify the temporal patterns of product diversity, supplier diversity, and buyer diversity as well as new suppliers' and buyers' entry rates.
- Identify the reasons for which suppliers and buyers commit to UML-based development tools.

Table 42 lists the results reported in Chapter 5.

Table 42 Summary of results

Hypothesis	Result	Rationale
H1: The size of a new supplier is a function of the adoption stage.	Supported	Results of the Mann-Whitney U test show that the mean rank varies across all adoption stages. The results indicate that the mean rank of the supplier size at stage 1 is significantly larger than at stage 2; the mean rank of the supplier size at stage 2 is significantly smaller than at stage 3, the mean rank of the supplier size at stage 3 is significantly smaller than at stage 4.
H2: The type of a new product is a function of the adoption stage.	Supported	Results of the Mann-Whitney U test show that the mean rank varies across all adoption stages. The results indicate that the mean rank of the product type at stage 1 is significantly smaller than at stage 2; the mean rank of the product type at stage 2 is significantly smaller than at stage 3; the mean rank of the product type at stage 3 is significantly larger than at stage 4.
H3a: Product diversity increases rapidly during the early stages then increases slowly towards the later stages.	Supported	Results of the Mann-Whitney U test show that the mean rank varies across all adoption stages. The results indicate that the mean rank of the product diversity at stage 1 is significantly smaller than at stage 2; the mean rank of the product diversity at stage 2 is significantly larger than at stage 3; the mean rank of the supplier size at stage 3 is significantly larger than at stage 4.
H3b: Supplier diversity increases rapidly during the early stages, then increases slowly towards the later stages.	Supported	Results of the Mann-Whitney U test show that the mean rank varies across all adoption stages.
H3c: Buyer diversity increases rapidly during the early stages then increases slowly towards the later stages.	Supported	Results of the Mann-Whitney U test show that the mean rank varies across all adoption stages.

Hypothesis	Result	Rationale
H4a. The number of new buyers will follow a bell shape distribution.	Supported	Results of the Mann-Whitney U test show that the mean rank varies across all adoption stages.
H4b. The number of new suppliers will follow a bell shape distribution.	Not supported	Results of the Mann-Whitney U test show that the mean rank does not vary across all adoption stages.
H5a. The reason for which suppliers commit to UML-based development tools is a function of the stage.	Supported	Results of the Mann-Whitney U test show that the mean rank varies across all adoption stages. However the association weakens as the adoption process advances.
H5b. The reason for which buyers commit to UML-based development tools is a function of the stage.	Supported	Results of the Mann-Whitney U test show that the mean rank varies across all adoption stages.

6.2 Association between adoption stage and supplier size and product category

It was found that the suppliers that entered the UML-based development tools market in the earlier stages were much larger than those that entered the market at later stages. In contrast, Peng (2004) found that suppliers that entered the Linux market at an early stage were smaller than those that entered at later stages.

The results confirmed that:

- there is an association between adoption stage and supplier size
- there is an association between adoption stage and product category

6.3 Temporal patterns

It was found that the entry rate of new buyers follows a bell shape distribution, whereas the entry rate of new suppliers does not.

The supplier entry rate is slow at the initial stage then starts to increase rapidly. There is a period where the entry rate slows down then increases very rapidly again.

The buyer entry rate increases slowly then begins to increase more rapidly in the intermediate stages and then starts to level off and finally the buyer entry rate starts to decrease.

Based on the results, product diversity follows an S-curve shape as indicated by Geroski (2000). Product diversity grows rapidly during the early stages and then levels off at the later stages.

In the same manner, supplier diversity and buyer diversity follow an S-curve. Both grow rapidly during the early stages then level off at the later stages.

6.4 Commitment to UML-based development tools

It was found that there is a relationship between the adoption stages and the reasons for which suppliers commit to UML-based development tools.

The results suggest that there is a relationship between the adoption stages and the reasons for which buyers commit to UML-based development tools.

6.5 Suppliers' reasons to commit to UML-based development tools

The three most representative reasons for which suppliers commit to UML-based development tools are:

- Add new features. 29% of the suppliers sample kept adding new features to their current products.
- Enter the market. 20.18% of the supplier sample was entering the market.
- Supplement applications. 17.43% of the supplier sample was supplementing their applications by integrating their products with other products. Suppliers of all sizes used two different means to supplement their applications and respond quickly to the market:
 - by partnering with other suppliers
 - by acquiring other suppliers

6.6 Buyers' reasons to commit to UML-based development tools

The two most representative reasons for which buyers commit to UML-based development tools are:

- Features provided. 40.35% of the buyers acquired UML-based development tools for the set of features offered.
- Openness / flexibility provided. 21.05% of the buyers acquired UML-based development tools for the openness / flexibility provided by the products.

6.7 UML-based development tools technology adoption life-cycle

Figure 14 shows the technology adoption life-cycle for UML-based development tools over the study period based on: i) product, supplier, and buyer density; ii) state transitions based on product categories introduced by suppliers, percentage of buyer sample classified as users of the product category at each stage, and a minimum stage length of twelve months.

Figure 14 UML-based development tools technology adoption life-cycle

Figure 15 shows the technology adoption life-cycle for UML-based development tools over the study period based on: i) product, supplier, and buyer density; ii) state transitions based on product categories introduced by suppliers, percentage of buyer sample classified as users of the product category at each stage, and a minimum stage length of twelve months.

Figure 15 Alternate UML-based development tools technology adoption life-cycle

7 Conclusions

This chapter is organized into three sections. Section 7.1 provides the conclusions of the study. Section 7.2 describes the limitations of the research. Section 7.3 describes suggestions for future research.

7.1 Conclusions

The results of this research lead to the following conclusions:

- There is an association between the adoption stages and supplier size and product category. For UML driven-development tools domain, suppliers in the earlier stages are much larger than those that entered the market in later stages.
- The suppliers entry rate is slow during stages 1 and 2, and faster during stages 3 and 4
- The buyers entry rate is slow during stages 1 and faster during stages 2, 3, and 4
- Supplier, product, and buyer diversity for the UML-based development tools domain follow an S-curve shape.

7.2 Limitations of the Research

The data used in the research is limited to information available in suppliers' and buyers' news releases and on the Business Source Premier database. Suppliers or buyers were not contacted to obtain data. As a result, data to measure supplier size was limited and the

number of firms for which the information was obtained may not be representative of the entire population.

Suppliers' and buyers' revenue and employee data was not necessarily available for private companies and these companies represent the majority of the sample.

There is no way to know when buyers stop using UML-based development tools.

The underlying platforms on which products can be used were not taken into account.

7.3 Suggestions for Future Research

The following opportunities for future research were identified:

- In order to gain additional insights, researchers might consider testing the differences in suppliers and buyers strategic concerns.
- Expand the product categories to include the underlying platforms on which product can be used (e.g., Windows, Linux, Unix, multi-platform). This can provide additional insights to product managers when planning future development, and to top management teams for planning acquisitions and partnerships passed on buyers' platform requirements.

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Appendix I. List of suppliers (listed in chronological order)

Supplier	Product	Supplier type	Revenue (millions \$ US)	Employees	Age (years)
MicroTOOL	ObjectiF	Independent software vendor	N/A	N/A	20
MID GmbH	Innovator	Independent software vendor	N/A	80	24
Object Time Limited	Object Tool	Independent software vendor	N/A	140	8
Microgold Software	WithClass Professional	Independent software vendor	10.2	80	19
Aonix	Software through Pictures UML	Independent software vendor	8.3	65	8
Object Plant	Object Plant	Independent software vendor	N/A	N/A	7
Telelogic	Tau UML Suite	Independent software vendor	128.0	908	21
Rational Software	Rational Rose	Independent software vendor	689.0	3561	24
Dia (Open Source)	Dia	Open Source	N/A	N/A	6
Flashline Inc.	Flashline	Independent software vendor	10.3	50	6
Visual Object Modelers	Visual UML Standard Edition	Independent software vendor	N/A	N/A	6
Artisan	Real-time Studio Professional	Independent software vendor	3.3	41	7
Memoire	Alma	Open Source	N/A	N/A	6
No Magic Inc.	MagicDraw UML Standard	Independent software vendor	N/A	N/A	9
MetaCase Consulting	MetaEdit+	Independent software vendor	N/A	N/A	13
Tri-Pacific Software	Rapid RMA	Independent software vendor	N/A	N/A	6
Softlab Limited	Visible Analyst 7.2	Independent software vendor	N/A	N/A	9
Allen Systems Group, Inc.	ASG-Rochade	Independent software vendor	147.6	900	18
Computer Associates	AllFusion Component Modeler	Independent software vendor	2934.0	16600	27
IntelliCorp, Inc.	NetProcess 5.2 Tool Suite	Independent software vendor	11.6	120	24
Interactive Objects	ArcStyler Personal Edition	Independent software vendor	N/A	N/A	14
Codagen	Codagen Architect	Independent software vendor	N/A	N/A	5
MetaMatrix	MetaBase Modeler	Independent software vendor	N/A	N/A	6

Supplier	Product	Supplier type	Revenue (millions \$ US)	Employees	Age (years)
Oracle	JDeveloper	Independent software vendor	9475.0	40650	27
Unimodeller	Unimodeller	Open Source	N/A	N/A	1
Ideogramic	Ideogramic UML, Desktop Edition	Independent software vendor	N/A	N/A	4
Visible Systems	Visible Analyst	Independent software vendor	5.3	40	23
Sparx Systems	Enterprise Architect Professional	Independent software vendor	N/A	N/A	4
Modelistic	Modelistic	Independent software vendor	N/A	N/A	6
Project Technology	BridgePoint	Independent software vendor	N/A	N/A	20
Mega International	Mega Designer	Independent software vendor	10.0	11	13
EctoSet	EctoSet Modeller	Independent software vendor	N/A	N/A	4
Microcross Inc.	Visual GNU X-Tools	Independent software vendor	N/A	N/A	4
Borland	Delphi Studio Architect	Independent software vendor	295236.0	1358	19
Novosoft LLC.	Novosoft LLC.	Open Source	N/A	N/A	12
Microsoft	Visual Studio .NET Enterprise Architect	Independent software vendor	0.64	5	8
Microsoft Visio	Visio 2002 Professional	Independent software vendor	25.3	50000	28
Sybase	PowerDesigner	Independent software vendor	926.1	4639	20
Quest Software, Inc.	Qdesigner	Independent software vendor	254.4	1642	17
Select Business Solutions	Component Architect	Independent software vendor	N/A	N/A	3
Excel Software	Quick UML	Independent software vendor	N/A	N/A	19
Eldean AB	ESS-Model	Independent software vendor	N/A	N/A	3
Popkin	System Architect	Independent software vendor	11.1	50	18
ProxySource	ProxyDesigner	Independent software vendor	0.512	4	4
Embarcadero	Describe	Independent software vendor	49.0	286	8
Eclipse	Eclipse platform	Open Source	N/A	N/A	6

Supplier	Product	Supplier type	Revenue (millions \$ US)	Employees	Age (years)
Eiffel Software Inc	Eiffel Studio	Independent software vendor	5.0	27	19
Fujaba	Fujaba	University	N/A	N/A	7
Objective Ideas AB	JSequence	Independent software vendor	N/A	N/A	15
MKS Inc.	MKS Integrity Solution	Independent software vendor	31.9	248	19
Logic Explorers	Code Logic	Independent software vendor	N/A	N/A	2
Kennedy-Carter	iUML	Independent software vendor	N/A	N/A	3
Proforma Corporation	ProVision	Independent software vendor	6.0	44	10
SlickEdit Inc.	SlickEdit v7.0	Independent software vendor	N/A	N/A	4
yWorks	yDoc	Independent software vendor	N/A	N/A	6
Artiso	Artiso Visual Case	Independent software vendor	N/A	N/A	4
Omondo	Omondo	Open Source	N/A	N/A	2
Compuware	OptimalJ	Independent software vendor	1264.0	9356	31
SAP AG	SAP NetWeaver	Independent software vendor	8831.0	30251	30
Visual Paradigm	Visual Paradigm for UML	Independent software vendor	N/A	N/A	2
Tigris.org	ArgoUML	Open Source	N/A	N/A	1
CanyonBlue	Koneso Modeler	Independent software vendor	N/A	N/A	1
Gentleware	Poseidon for UML - Community	Independent software vendor	N/A	N/A	4
Metanology	MDE for UML	Independent software vendor	N/A	N/A	4
Insoft	Prosa 2004 UML Modeler	Independent software vendor	N/A	N/A	17
I-Logix	Rhapsody Developer Edition	Independent software vendor	14.7	110	17
IDS Scheer AG	Aris UML Designer	Independent software vendor	179821.0	2011	20
Object Club	Jude Bamboo	Open Source	N/A	N/A	5
IBM-Rational	Rose XDE Developer for Visual Studio	Independent software vendor	89000.0	255157	80
Magna Solutions	Silverrun ModelSphere	Independent software vendor	N/A	N/A	1

Appendix II. List of buyers

Buyer name	Vertical market	Revenue (millions \$ US)	Employees	Age (years)
Accelerated Technology, Inc.,	Application design and construction tools	0.9	12	14
Arizona Supreme Court in Phoenix	Government			
Audi Group	Automotive manufacturing	29097.0	52689	
Austrian Aerospace	Telecommunications			7
BAE Systems	Other services	14911.0	68400	
Banco Nossa Caixa S.A.	Banking			
BMT Defence Services Limited	Transportation			16
Broadband Storage	Other services			4
Catalist Systems Corporation	Application design and construction tools			
Central Florida Investments Inc.	Other services			
Conti Temic Microelectronic GmbH	Discrete manufacturing			12
Dell Computer Corp	Discrete manufacturing	31168.0	34600	20
Department of Defense	Government			
DESE Research Inc	Other services			22
EADS Deutschland GMBH	Government			4
Embarcadero Technologies Inc.	Application design and construction tools	24.7	274	11
Fidelity National Financial	Financial services	5083.0	17600	157

Buyer name	Vertical market	Revenue (millions \$ US)	Employees	Age (years)
General Motors	Automotive manufacturing	186763.0	355000	96
Green Hills Software Inc.	Application design and construction tools	51.0	185	22
HART Communication Foundation	Other services			11
Hewlett Packard	Application design and construction tools	76061.0	142000	65
Intertech Consulting Inc.	Other services			
Investec Asset Management	Financial services			32
Junior Achievement Inc.	Other services			85
KEMA Consulting	Other services	150.0	1471	30
Leopold Kostal GmbH & Co. KG	Automotive manufacturing		9480	92
Lockheed Martin	Engineering / management	1289.0	125000	9
Lucent Technologies Inc.	Telecommunications	33577.0	30000	8
Matra Marconi Space	Transportation	8400.0	5000	14
Metanology Corporation	Application design and construction tools			
Microcross, Inc.	Application design and construction tools			4
MicroGold Software	Application design and construction tools	0.64	5	8

Buyer name	Vertical market	Revenue (millions \$ US)	Employees	Age (years)
MKS Inc.	Application life cycle-management	31.9	248	20
Nissan	Automotive manufacturing	61477.0	31128	71
Northern Alberta Institute of Technology	Education			42
Omicron NanoTechnology GmbH	Engineering / management			20
Optiz Consulting GmbH	Other services			
Power3, LLC	Other services			
Raytheon Company	Transportation	18109.0	78000	82
Saab Automobile AB	Automotive manufacturing	3143.0	8358	67
Scapa Technologies	Application design and construction tools			6
Softier Inc.	Application design and construction tools			2
SPAR Handels AG	Agriculture / construction	6822.0	35535	
Sun Microsystems, Inc.	Information access and delivery	12500.0	39400	22
TANDBERG Television	Broadcast and other communications	263.0	512	71
Tele Atlas	Information and data management	67.9	1850	20
TeleManagement Forum	Telecommunications			16
The National Trust	Other services			109

Buyer name	Vertical market	Revenue (millions \$ US)	Employees	Age (years)
The Peace Corps	Government			43
Visible Systems Corporation	Application design and construction tools	5.30	40.0	23
Vodafone Global Products and Services	Telecommunications	47962.0	66667	20
Yellow Roadway Corporation	Other services	2811.90	25000.0	80

Appendix III. Testing hypothesis 1

Testing hypothesis 1: The size of new supplier is a function of the adoption stage (Mann-Whitney U test).

Comparing stages 1 and 2:

n		(cases excluded: 33 due to missing values)		
n		23		
Revenue by Stage	n	Rank sum	Mean rank	U
Stage 1	20	252.0	12.60	18.0
Stage 2	3	24.0	8.00	42.0
Difference between medians		-		
95% CI		- to -		
Mann-Whitney U statistic		18		
2-tailed p		0.1846 (normal approximation, corrected for ties)		

Comparing stages 2 and 3:

n		(cases excluded: 16 due to 7 missing values)		
Revenue by Stage	n	Rank sum	Mean rank	U
Stage 2	3	7.5	2.50	10.5
Stage 3	4	20.5	5.13	1.5
Difference between medians		-		
95% CI		- to -		
Mann-Whitney U statistic		10.5		
2-tailed p		0.2286	(exact tables used, 100% ties)	

Comparing stages 3 and 4:

n | (cases excluded: 9 due to missing
5 values)

Revenue by Stage	n	Rank sum	Mean rank	U
Stage 3	4	11.5	2.88	2.5
Stage 4	1	3.5	3.50	1.5

Difference between
medians | -
95% CI | - to -

Mann-Whitney U
statistic | 2.5
2-tailed p | 0.8000 (exact tables used, 80% ties)

Appendix IV. List of products

Product	Supplier	Product type
AllFusion Component Modeler	Computer Associates	Product suite
AndroMDA	AndroMDA	Forward-engineering
AnyStates	XJ Technologies	Forward-engineering
ArcStyler Personal Edition	Interactive Objects	Forward-engineering
ArgoUML	Tigris	Reverse-engineering
Artiso Visual Case	Artiso	Round-trip engineering
BridgePoint	Project Technology	Forward-engineering
Codagen Architect	Codagen	Forward-engineering
Code Logic	Logic Explorers	Reverse-engineering
Component Architect	Select Business Solutions	Product suite
Delphi Studio Architect	Borland	Forward-engineering
Describe	Embarcadero	Product suite
Dia	Dia	Modeling only
EclipseUML	Omondo	Modeling only
EctoSet Modeller	EctoSet	Forward-engineering
Eiffel Studio	Eiffel Software Inc	Forward-engineering
Enterprise Architect Professional	Sparx Systems	Round-trip engineering
ESS-Model	Eldean AB	Reverse-engineering
FL	Novosoft	Forward-engineering
Fujaba	Fujaba	Round-trip engineering
Holocentric Modeler	Prism International	Product suite
Ideogramic UML, Desktop Edition	Ideogramic	Reverse-engineering
INNOVATOR	MID GmbH	Forward-engineering
iUML	Kennedy-Carter	Forward-engineering
J2U	Nasra Consulting	Reverse-engineering
JDeveloper	Oracle	Round-trip engineering
JSequence	Objective Ideas AB	Reverse-engineering
Jude Bamboo	Jude	Reverse-engineering
JVISION	Object Insight	Reverse-engineering
Konesa Modeler	CanyonBlue	Round-trip engineering
MagicDraw UML Enterprise	No Magic Inc.	Product suite
MagicDraw UML Professional	No Magic Inc.	Round-trip engineering
MagicDraw UML Standard	No Magic Inc.	Modeling only

Product	Supplier	Product type
MDE for EJB	Metanology	Forward-engineering
MDE for J2EE	Metanology	Forward-engineering
MDE for UML	Metanology	Modeling only
Mega Designer	Mega International	Round-trip engineering
MetaBase Modeler	MetaMatrix	Modeling only
MetaEdit+	MetaCase Consulting	Modeling only
Metamill	Metamill Software	Round-trip engineering
MIA-Generation Architect Edition	Model-in-Action	Forward-engineering
MIA-Generation Developer Edition	Model-in-Action	Forward-engineering
Modelistic	Modelistic	Round-trip engineering
ModelMaker	ModelMaker Tools	Round-trip engineering
Novosoft UML Library	Novosoft	Modeling only
Object Domain Standard	Object Domain Systems	Round-trip engineering
Object Plant	Object Plant	Forward-engineering
Object Tool	Object Time Limited	Forward-engineering
Object ToolSet	Object Time Limited	Forward-engineering
Objecteering Personal Edition	Softeam	Forward-engineering
ObjectiF	MicroTOOL	Forward-engineering
ObjecTime Developer	Object Time Limited	Round-trip engineering
OptimalJ	Compuware	Forward-engineering
Poseidon for UML - Community	Gentleware	Forward-engineering
Poseidon for UML - Professional	Gentleware	Round-trip engineering
Poseidon for UML – Standard	Gentleware	Forward-engineering
PowerDesigner	Sybase	Round-trip engineering
Prosa 2004 UML Modeler	Insoft	Forward-engineering
ProVision	Proforma Corporation	Modeling only
ProxyDesigner	ProxySource	Modeling only
Quick UML	Excel Software	Modeling only
Rapid RMA	Tri-Pacific Software	Modeling only
Rational Rose 98 (4.5)	Rational Software	Round-trip engineering
Rational Rose Real Time 2000e	Rational Software	Round-trip engineering
Rational Rose Real Time 2002.05.00	Rational Software	Round-trip engineering
Rational Rose Real Time 6.0	Rational Software	Round-trip engineering
Real-time Studio Professional	Artisan	Round-trip engineering
Rhapsody Developer Edition	I-Logix	Product suite
Rose Technical Developer	IBM-Rational	Modeling only

Product	Supplier	Product type
Rose XDE Developer for Java	IBM-Rational	Product suite
Rose XDE Developer for Visual Studio	IBM-Rational	Product suite
Silverrun ModelSphere	Magna Solutions	Round-trip engineering
Software through Pictures UML	Aonix	Forward-engineering
System Architect	Popkin	Product suite
Tau UML Suite	Telelogic	Product suite
Together Control Center	TogetherSoft	Round-trip engineering
Umbrello UML Modeller	Umbrello	Modeling only
UML Diagrammer	Pacestar	Modeling only
UML Studio	Pragsoft Corporation	Round-trip engineering
UMLGraph	UMLGraph	Reverse-engineering
UMT-QVT	UMT-QVT	Forward-engineering
Unimodeler	Unimodeler	Modeling only
Visible Analyst	Visible Systems	Modeling only
Visio 2002 Professional	Microsoft Visio	Reverse-engineering
Visual Paradigm for UML	Visual Paradigm	Modeling only
Visual Studio .NET Enterprise Architect	Microsoft	Modeling only
Visual UML Standard Edition	Visual Object Modelers	Round-trip engineering
WithClass Professional	Microgold Software	Forward-engineering
yDoc	yWorks	Reverse-engineering

Appendix V. Testing hypothesis 2

Testing hypothesis 2: The type of new product is a function of the adoption stage (Mann-Whitney U test).

Comparing stages 1 and 2:

n | 25

Product type by Stage	n	Rank sum	Mean rank	U
Stage 1	6	81.5	13.58	53.5
Stage 2	19	243.5	12.82	60.5

Difference between medians	-
95% CI	- to -

Mann-Whitney U statistic	53.5	(normal approximation, corrected for ties)
2-tailed p	0.8165	

Comparing stages 2 and 3:

n | 47

Product type by Stage	n	Rank sum	Mean rank	U
Stage 2	19	479.5	25.24	242.5
Stage 3	28	648.5	23.16	289.5

Difference between medians	-
95% CI	- to -

Mann-Whitney U statistic	242.5	(normal approximation, corrected for ties)
2-tailed p	0.5814	

Comparing stages 3 and 4:

n | 34

Product type by Stage	n	Rank sum	Mean rank	U
Stage 3	28	537.5	19.20	36.5
Stage 4	6	57.5	9.58	131.5

Difference between medians	-
95% CI	- to -

Mann-Whitney U statistic	36.5	(normal approximation, corrected for ties)
2-tailed p	0.0188	

Appendix VI. Testing hypothesis 3a

Testing hypothesis 3a: Product diversity increases rapidly during the early adoption stages and then increases slowly over the later stages (Mann-Whitney U test).

Comparing stages 1 and 2:

n | 141

Product diversity by Stage	n	Rank sum	Mean rank	U
Stage 1	129	8410.0	65.19	1523.0
Stage 2	12	1601.0	133.42	25.0

Difference between medians	-0.02707	to -	(normal approximation)
95.1% CI	-0.11080	0.00666	

Mann-Whitney U statistic	1523	(normal approximation, corrected for ties)
2-tailed p	<0.0001	

Comparing stages 2 and 3:

n | 24

Diversity by Stage	n	Rank sum	Mean rank	U
Stage 2	12	142.0	11.83	80.0
Stage 3	12	158.0	13.17	64.0

Difference between medians	-0.00004	to	
95.5% CI	-0.00012	0.00015	(exact)

Mann-Whitney U statistic	80	
2-tailed p	0.6707	(exact tables used, 42% ties)

Comparing stages 3 and 4:

n | 15

Diversity by Stage	n	Rank sum	Mean rank	U
Stage 3	12	105.0	8.75	9.0
Stage 4	3	15.0	5.00	27.0

Difference between medians	0.00019	to	
95.2% CI	-0.00093	0.00053	(exact)

Mann-Whitney U statistic	9	(exact tables used,
2-tailed p	0.2330	60% ties)

Appendix VII. Testing hypothesis 3b

Testing hypothesis 3b: Supplier diversity increases rapidly during the early stages, then increases slowly towards the later stages (Mann-Whitney U test).

Comparing stages 1 and 2:

n | 141

Supplier diversity by Stage	n	Rank sum	Mean rank	U
Stage 1	129	8439.5	65.42	1493.5
Stage 2	12	1571.5	130.96	54.5

Difference between medians	-0.10903		
95.1% CI	-0.10974	to - 0.01524	(normal approximation)

Mann-Whitney U statistic	1493.5		
2-tailed p	<0.0001	(normal approximation, corrected for ties)	

Comparing stages 2 and 3:

n | 24

Supplier diversity by Stage	n	Rank sum	Mean rank	U
Stage 2	12	132.0	11.00	90.0
Stage 3	12	168.0	14.00	54.0

Difference between medians	-0.00010	to	
95.5% CI	-0.00097	0.00062	(exact)

Mann-Whitney U statistic	90	(exact tables used,
2-tailed p	0.3186	58% ties)

Comparing stages 3 and 4:

n | 15

Supplier diversity by Stage	n	Rank sum	Mean rank	U
Stage 3	12	102.0	8.50	12.0
Stage 4	3	18.0	6.00	24.0

Difference between medians	0.00007	to	
95.2% CI	-0.00142	0.00081	(exact)

Mann-Whitney U statistic	12	(exact tables used,
2-tailed p	0.4484	87% ties)

Appendix VIII. Testing hypothesis 3c

Hypothesis 3c: Buyer diversity increases rapidly during the early stages.

Comparing stages 1 and 2:

n	141			
Buyer diversity by Stage	n	Rank sum	Mean rank	U
Stage 1	129	8385.0	65.00	1548.0
Stage 2	12	1626.0	135.50	0.0
Difference between medians	-0.98047			
95.1% CI	-0.99174	to - 0.97959	(normal approximation)	
Mann-Whitney U statistic	1548			
2-tailed p	<0.0001	(normal approximation, corrected for ties)		

Comparing stages 2 and 3:

n | 24

Buyer diversity by Stage	n	Rank sum	Mean rank	U
Stage 2	12	81.0	6.75	141.0
Stage 3	12	219.0	18.25	3.0

Difference between medians	-0.01079	to -	
95.5% CI	-0.01766	0.00552	(exact)

Mann-Whitney U statistic	141	(exact tables used,
2-tailed p	<0.0001	50% ties)

Comparing stages 3 and 4:

n | 15

Buyer diversity by Stage	n	Rank sum	Mean rank	U
Stage 3	12	85.0	7.08	29.0
Stage 4	3	35.0	11.67	7.0

Difference between medians	-0.00145	to	
95.2% CI	-0.00372	0.00046	(exact)

Mann-Whitney U statistic	29	(exact tables used,
2-tailed p	0.1363	53% ties)

Appendix IX. Testing hypothesis 4a

Hypothesis 4a: New buyers' entry rate follows a bell-shape distribution.

Comparing stages 1 and 2:

n | 141

Buyer entry rate by Stage	n	Rank sum	Mean rank	U
Stage 1	129	8602.5	66.69	1330.5
Stage 2	12	1408.5	117.38	217.5

Difference between medians	-1.0	
95.1% CI	-1.0 to -1.0	(normal approximation)

Mann-Whitney U statistic	1330.5	
2-tailed p	<0.0001	(normal approximation, corrected for ties)

Comparing stages 2 and 3:

n | 24

Buyer entry rate by Stage	n	Rank sum	Mean rank	U
Stage 2	12	135.5	11.29	86.5
Stage 3	12	164.5	13.71	57.5

Difference between medians	-1.0	
95.5% CI	-2.0 to 1.0	(exact)

Mann-Whitney U statistic	86.5	
2-tailed p	0.4428	(exact tables used, 96% ties)

Comparing stages 3 and 4:

n | 15

Buyer entry rate by Stage	n	Rank sum	Mean rank	U
Stage 3	12	97.0	8.08	17.0
Stage 4	3	23.0	7.67	19.0

Difference between medians	0.0	
95.2% CI	-3.0 to 3.0	(exact)

Mann-Whitney U statistic	17	
2-tailed p	0.9451	(exact tables used, 93% ties)

Appendix X. Testing hypothesis 4b

Hypothesis 4b: New suppliers' entry rate follows a bell-shaped distribution.

Comparing stages 1 and 2:

n	141			
Supplier entry rate by Stage	n	Rank sum	Mean rank	U
Stage 1	129	8845.0	68.57	1088.0
Stage 2	12	1166.0	97.17	460.0
Difference between medians	-1.0			
95.1% CI	-1.0 to 0		(normal approximation)	
Mann-Whitney U statistic	1088			
2-tailed p	0.0036	(normal approximation, corrected for ties)		

Comparing stages 2 and 3:

n		24		
Supplier entry rate by Stage	n	Rank sum	Mean rank	U
Stage 2	12	152.0	12.67	70.0
Stage 3	12	148.0	12.33	74.0
Difference between medians	0.0			
95.5% CI	-1.0 to 1.0 (exact)			
Mann-Whitney U statistic	70			
2-tailed p	0.9323 (exact tables used, 100% ties)			

Comparing stages 3 and 4:

n | 15

Supplier entry rate by Stage	n	Rank sum	Mean rank	U
Stage 3	12	99.0	8.25	15.0
Stage 4	3	21.0	7.00	21.0

Difference between medians	0.0	
95.2% CI	-2.0 to 2.0	(exact)

Mann-Whitney U statistic	15	
2-tailed p	0.7341	(exact tables used, 100% ties)

Appendix XI. Testing hypothesis 5a

Hypothesis 5a: Reasons for which suppliers commit to UML-based development tools are a function of the adoption stage.

Comparing stages 1 and 2:

n		70			
Supplier reason by Stage	n	Rank sum	Mean rank	U	
Stage 1	38	1304.5	34.33	652.5	
Stage 2	32	1180.5	36.89	563.5	
Difference between medians	-				
95% CI	- to -				
Mann-Whitney U statistic	652.5				
2-tailed p	0.5895 (normal approximation, corrected for ties)				

Comparing stages 2 and 3:

n | 67

Supplier reason by Stage	n	Rank sum	Mean rank	U
Stage 2	32	1072.0	33.50	576.0
Stage 3	35	1206.0	34.46	544.0

Difference between medians	-
95% CI	- to -

Mann-Whitney U statistic	576
2-tailed p	0.8382 (normal approximation, corrected for ties)

Comparing stages 3 and 4:

n	39			
Supplier reason by Stage	n	Rank sum	Mean rank	U
Stage 3	35	710.5	20.30	59.5
Stage 4	4	69.5	17.38	80.5
Difference between medians	-			
95% CI	- to -			
Mann-Whitney U statistic	59.5			
2-tailed p	0.6224	(normal approximation, corrected for ties)		

Appendix XII. Testing hypothesis 5b

Hypothesis 5b: Reasons for which buyers commit to UML-based development tools are a function of the adoption stage.

Comparing stages 1 and 2:

n		25			
Buyers' reasons by Stage	n	Rank sum	Mean rank	U	
Stage 1	7	101.0	14.43	53.0	
Stage 2	18	224.0	12.44	73.0	
Difference between medians	-				
95% CI	- to -				
Mann-Whitney U statistic	53				
2-tailed p	0.5292 (normal approximation, corrected for ties)				

Comparing stages 2 and 3:

n | 46

Buyers' reasons by Stage	n	Rank sum	Mean rank	U
Stage 2	18	430.0	23.89	245.0
Stage 3	28	651.0	23.25	259.0

Difference between medians	-
95% CI	- to -

Mann-Whitney U statistic	245	(normal approximation, corrected for ties)
2-tailed p	0.8703	

Comparing stages 3 and 4:

n		34			
Buyers' reasons by Stage	n	Rank sum	Mean rank	U	
Stage 3	28	508.5	18.16	65.5	
Stage 4	6	86.5	14.42	102.5	
Difference between medians	-				
95% CI	- to -				
Mann-Whitney U statistic	65.5				
2-tailed p	0.3831	(normal approximation, corrected for ties)			