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**AN ANALYSIS OF THE DIFFERENCE IN SOFTWARE PROJECT MANAGEMENT
PRACTICES BETWEEN ORGANIZATIONS REGISTERED TO ISO 9001 AND
NON-REGISTERED ORGANIZATIONS**

by

Chris FitzGibbon, B.Comm. (Honours)

A thesis submitted to
the Faculty of Graduate Studies and Research
in partial fulfillment of
the requirements for the degree of

Master in Management Studies

School of Business
Carleton University
Ottawa, Ontario

January 1998

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Acceptance Sheet

The undersigned recommend to the Faculty of Graduate Studies
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Thesis Supervisor

Director, School of Business

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December 19, 1997

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Abstract

This research investigates the differences in project management practices between software organizations registered to the ISO 9001 quality standard and those not ISO 9001 registered. Three project outcomes are used to conduct this comparison: project duration, schedule overrun and project manager satisfaction that the software met customer requirements. The study examines the following project characteristics: time spent planning, time spent testing, time spent developing software code, time spent maintaining project records, time spent conducting design reviews and code inspections, customer involvement in the software development process, involvement of software engineers in project planning, and project manager power. Data were collected on 52 software projects from organizations operating in Canada.

The study found no significant differences between the two samples could be explained by any of the project characteristics examined. However, ISO 9001 and non-ISO 9001 software organizations did differ in their projects' schedule overruns. The study also found a difference in the importance attributed to the project characteristics by ISO 9001 and non-ISO 9001 samples.

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Chapter 1

Introduction

Many software organizations operate without formalized procedures, cost estimates and project plans resulting in conditions described as chaotic (Humphrey, 1986: 7). Typical results include projects with missed budgets, schedule overruns and expectations (Bennatan, 1992: 9; Royce, 1993: 90; van Genuchten, 1991: 582-83; Thamhain and Wilemon, 1986: 75) and software that is unusually error-prone and frequently displeasing to end users (Royce, 1993: 90).

Over 250 software development standards have been developed in the last 25 years (Bennatan, 1992: 115). Registration to the ISO 9001 standard is becoming increasingly important to software development organizations around the world (Thompson and McParland, 1993: 331). To many software organizations, the ISO 9001 quality standard has become the means of ensuring the production of quality software. Registration of a software company's quality system to ISO 9001 provides independent third-party assurance that an effective software development process is in use (Bailetti and FitzGibbon, 1995: 11). A quality system is a set of organizational structures, procedures, processes and resources needed to implement quality management (ISO 9000-1, 1994).

In Canada, less than 50 organizations that develop software have registered their quality system to ISO 9001. A recent survey of Canadian software companies found that 91 percent of respondents considered the quality of their software products to be very important, however, only four of the 104 respondents felt their quality system was

adequate for registration to ISO 9001 (Information Technologies Industry Branch, 1994: 8).

1.1 Objective of this Research

The objective of this research is to examine the differences in software project management practices between organizations registered to the ISO 9001 quality standard and organizations not ISO 9001 registered. The study focuses on the projects of software organizations that develop custom software applications. Three measures of software project outcome are used in this research: 1) project duration, 2) schedule overrun, and 3) project manager satisfaction with the project.

1.1.1 Project Duration

Project duration is the time required to complete a software development project. The project starts when personnel are assigned to analyze the requirements of the custom application and ends when the customer formally accepts the product. Customer acceptance occurs on the final sign-off date.

1.1.2 Schedule Overrun

Schedule overrun is the difference between the estimated and actual date of final sign-off.

1.1.3 Project Manager Satisfaction with the Project

Project Manager Satisfaction with the Project is the project manager's perception of how well the software project met the client's requirements.

1.2 Research Question

The research question is:

Are there differences in the software project management practices of software development organizations that are registered to the ISO 9001 standard and those that are not ISO 9001 registered?

1.3 ISO 9001, the Software Process and Project Management

This section provides an overview of ISO 9001 and defines the software process and project management.

1.3.1 ISO 9001: Overview

ISO 9001 is part of the ISO 9000 series of international standards developed by the International Organization for Standardization (ISO) and adopted by 71 countries. The ISO 9000 series contains a total of five documents, three of which contain quality standards:

- *ISO 9001: Quality Systems - Model for Quality Assurance in Design, Development, Production, Installation, and Servicing;*
- *ISO 9002: Quality Systems - Model for Quality Assurance in Production, Installation, and Servicing;*

- *ISO 9003: Quality Systems - Model for Quality Assurance in Final Inspection and Test.*

The other ISO 9000 documents, named ISO 9000 and ISO 9004, are guidelines for the selection of the appropriate standard and its use. The ISO 9001 standard is the most comprehensive quality standard in the ISO 9000 series and is the most applicable of the ISO 9000 standards to software design and development. Registration to ISO 9001 certifies that a company's quality system and the processes used to design, develop, produce, install, and service a product or provide a service meet the 20 requirements shown in *Appendix A*.

The ISO 9000 series of standards provide guidelines on quality management and assurance. The standards are based on the assumptions that all work is accomplished by a process and that all processes in the organization are managed (Stelzer, Mellis, and Herzwurm, 1996: 2). ISO 9000 provides a framework for a quality system, but it does not specify the particulars for implementation. The standards describe what elements quality systems should encompass but not how a specific organization should implement these elements (ISO 9000-1, 1994). ISO 9000 standards are not specific to any industry and they apply to organizations of all sizes. The focus is on a supplier's engineering and production process. This focus is based on the premise that a high quality process will result in the production of high quality products and services. The standards emphasize achieving customer satisfaction through prevention of non-conformance rather than through testing. Although the scope of the standards is most applicable to contractual arrangements, provisions are made to include development processes in which no formal

customer is identified such as production of off-the-shelf software. All customer-oriented development and production processes can be registered to an ISO 9000 standard.

Registration to an ISO 9000 standard provides assurance from an independent accredited registrar that an organization has a documented quality system that satisfies the standard's requirements and that an ISO 9000 program has been implemented at the company's facility. ISO 9000 standards do not certify the specifications or performance of products.

The principles underlying the requirements of the ISO 9000 series of standards are contained in Table 1.1.

Table 1.1: Principles Underlying ISO 9000 Standards

Say what you do	Document each step in your company's business process
Do what you say	Ensure that all processes adhere to written procedures
Show what you have done	Document evidence that the quality system complies with the ISO 9001 requirements and that the quality standard is being implemented effectively
Verify	Conduct periodic internal audits to ensure continued suitability, compliance, and effectiveness of the quality system

ISO 9001's generic nature does not consider the special requirements of software. The production process in software is a relatively insignificant part of the total development effort. Definition of requirements, as well as design, implementation, maintenance, verification, and validation, account for a larger share of development activities. Other factors differentiating software include the market demand for open systems and the global nature of the software industry. Such needs led to the introduction

of ISO 9000-3: *Guidelines for the Application of ISO 9001 to the Development, Supply and Maintenance of Software*. The objective of ISO 9000-3 is to facilitate the implementation of ISO 9001 requirements to the software engineering process. ISO 9000-3 provides guidelines; it does not add any requirements to ISO 9001.

1.3.2 Software Process

The software process can be defined as a set of activities, methods, practices and transformations that people use to develop and maintain software and the associated products (Paulk, 1995: 4). The objectives of software process management are to produce products according to plan while simultaneously improving the organization's capability to produce better products (Humphrey, 1989: 3).

1.3.3 Software Project Management

Software project management can be defined as the process of planning, organizing, staffing, monitoring, controlling, and leading a software project (IEEE, 1987, 2). The primary project management activities are (Bennatan, 1992: 2-3):

Supervision and control: includes the efficient management of the software development team members and requires constant awareness of the real status of their work on the project;

Planning: includes the preparation of good estimates, the maintenance of the software development schedule and the efficient assignment of personnel;

Customer relations: includes documenting the customer's requirements, controlling changes required by the customer, handling the customer's involvement in the software development process, providing reports and organizing reviews and product demonstrations;

Technical leadership: requires the ability to provide guidance in the solution of technical problems that arise during project development.

Software project management is more difficult than the management of other projects because software development is less deterministic than other areas of technology. This is because software projects are less measurable, more difficult to estimate, and more dependent on subjective human factors (Bennatan, 1992: 3). Software engineers are more difficult to manage than engineers in most other areas of technology (Bennatan, 1992: 61).

1.4 Contribution of this Research

1.4.1 Contribution to Project Management Practice

This research identifies the similarities and differences in software project management between ISO 9001 and non-ISO 9001 organizations. The conclusions identify how these differences impact project outcomes and how they may be used to assist organizations to better understand the value of ISO 9001 registration. Specifically, this study found no significant differences between the two samples that could be explained by any of the project characteristics examined. However, ISO 9001 and non-ISO 9001 software organizations did differ in their projects' schedule overruns and the attributed importance to project outcome of the project characteristics.

This study provides empirical results as the basis for conclusion instead of speculation or opinion. The results may contradict several popular assumptions regarding the differences between the two groups.

1.4.2 Contribution to Academic Literature

Very little empirical research has been conducted on the application of ISO 9001 to software organizations (Stelzer, Mellis, and Herzwurm, 1996: 1). This study is the first empirical research comparing the software project management practices of ISO 9001 organizations and non-ISO 9001 organizations. The results of this research can be used to support or invalidate the prescriptive and descriptive literature. A thorough review of the existing empirical research on ISO 9000 is included and topics for further research are identified.

1.5 Organization of the Thesis

The thesis consists of six chapters. Chapter 2 contains the literature review. Chapter 3 lists and defines the hypotheses for this research. The research design employed in this thesis is described in Chapter 4. In Chapter 5, the results of the research are discussed. Chapter 6 provides the conclusions and limitations of the study as well as suggestions for further research.

Chapter 2

Literature Review

In recent years, there has been extensive published work on various issues associated with ISO 9000 registration and its application to software development. However, almost all of these works are prescriptive or descriptive (Ebrahimpour, M., Withers, B. E., and Hikmet, N., 1997: 569-570; Haug, 1994: 1954; Atwater and Discenza 1993: 1784). These publications lack systematic measurement and multi-organization comparison and provide very little empirical evidence to what extent software process improvements have really been achieved as a result of ISO 9000 registration (Stelzer, Mellis, and Herzwurm, 1996: 1).

This literature review is comprised of three components: an examination of the empirical research on the effects of ISO 9001 registration on software development organizations, a review of the empirical research on the effects of ISO 9000 on non-software organizations, and the development of a list of variables associated with software project outcome and ISO 9001.

2.1 A Review of Empirical Research on the Effects of ISO 9001 Registration on Software Development Organizations

A 1994 study of German ISO 9001 software development organizations (Stelzer, 1995) and subsequent research on European ISO 9001 software development organizations (Stelzer, Mellis, and Herzwurm, 1996) comprise the body of empirical research on this issue.

2.1.1 ISO 9000 as an Indicator of Software Quality

This 1994 survey of the first twenty ISO 9001 registered software organizations in Germany examined the extent to which ISO 9001 registration was an indicator of the use of software quality practices (Stelzer, 1995). The study concentrated on five quality system elements: code reviews and inspections, software testing, product and process measurements, measurement of quality costs, and demonstration of quality improvements.

Based on data from 18 respondents, the study found significant variations in the implementation of an ISO 9001 compliant quality system. The research concluded that ISO 9001 registration is not an indicator of the strength of a software developer's products, processes, or its quality system. The researchers added that ISO 9001 registration is not a guarantee that the certified quality system fulfils all the requirements specified in the standard. Some of the participants in the study reported that their ISO 9001 compliant quality system did not adequately address the five quality system elements examined.

The study also found that ISO 9001 registration met the expectations of 47% of the respondents and partially met the expectations of another 53%. None of the participants in the study reported that registration to ISO 9001 was a failure.

The results of this study indicate that the value of ISO 9001 registration for software development organizations was not consistent. The researcher identified the requirement for further research.

2.1.2 Software Process Improvements Achieved through ISO 9001

The objective of this study was to gain a better understanding of the software process improvements achieved through registration to ISO 9001 (Stelzer, Mellis, and Herzwurm, 1996).

Based on data from 36 European software developers, interviews with ISO 9000 auditors, and discussions with consultants working in the software industry, the researchers identified ten key success factors for software process improvement via ISO 9000. Success factors describe the aspects that the respondents considered to be the most helpful when implementing an ISO 9000 quality system (Stelzer, Mellis, and Herzwurm, 1996: 6). The sequence of the ten factors in Table 2.1 does not indicate their importance.

Table 2.1: Success factors for software process improvement via ISO 9000	
1.	Definition and documentation of the status quo
2.	Identification of best practices
3.	Identification of business processes
4.	Simplification of routine procedures
5.	Internal audits
6.	Impetus and incentive
7.	Team spirit
8.	Workshops and regular meetings
9.	Definition of a common language
10.	Customer perception surveys

Only two of the ten key success factors identified in the study are explicit requirements of ISO 9001: 1) the definition and documentation of the status quo, and 2) internal audits. The list of success factors reveals that software organizations typically take a more comprehensive approach to achieve software process improvement than the minimum requirements of the ISO 9001 standard (Stelzer, Mellis, and Herzwurm, 1996: 8).

The research attributed several benefits to ISO 9001 registration. The majority of the software organizations reported achieving substantial improvements during the implementation of the standard. The development by software organizations of a clearly defined organizational structure and procedures helped identify and address process weaknesses. Formal customer perception surveys provided unbiased and unprejudiced feedback on the quality of a company's products and services. Internal quality audits improved job satisfaction and provided an opportunity for staff to discuss the quality system's strengths and weaknesses. These benefits and the preparation of guidelines, checklists, templates and tools led to the conclusion that ISO 9001 registration contributes to improved efficiency, shorter development times and lower costs.

Software organizations with established processes before the implementation of an ISO 9001 quality system did not achieve significant software process improvements through ISO 9001 registration. These organizations only documented the status quo and sought certification.

Although only one third of respondents could quantify the benefits of ISO 9001 registration, nearly all participants reported that they would favour implementing an ISO 9000 quality system once again.

2.1.3 Summary

Table 2.2 summarizes the empirical research on the effects of ISO 9001 registration on software development organizations.

Table 2.2: Summary of the Empirical Research on the Effects of ISO 9001 Registration on Software Development Organizations					
Year	Location of Study	Standard	Sample Size	Industry	Conclusions
<i>Stelzer: ISO 9000 as an Indicator of Software Quality</i>					
1994	Germany	ISO 9001, ISO 9000-3	18	Software	<ul style="list-style-type: none"> • ISO 9001 registration is not an indicator of product or process quality • All participants reported ISO 9001 had at least partially met their expectations • The value of ISO 9001 registration is marginal
<i>Stelzer, Mellis, and Herzwurm: Software Process Improvements Achieved through ISO 9001</i>					
1995	European	ISO 9001, ISO 9000-3	36	Software	<ul style="list-style-type: none"> • To achieve substantial software process improvement, it is necessary to implement a more comprehensive approach to ISO 9001 registration than simply satisfying its requirements • Greater benefits from ISO 9001 registration were realized by software organizations lacking established processes, explicit organizational structures, and software engineering standards and procedures • ISO 9001 registration helped save time, money and effort

2.2 A Review of Empirical Research on the Effects of ISO 9000 on Non-Software Organizations

This review of the empirical research on the effects of ISO 9000 on non-software organizations provides: a comparison of the ISO 9000 registration experiences of US and Foreign-owned firms (Ebrahimpour, M., Withers, B. E., and Hikmet, N., 1997), the costs and benefits of ISO 9000 registration (Atwater and Discenza 1993) and the effects of ISO

9000 registration on business performance (Seddon, Davis, Loughran and Murrel, 1993; Surrey University, 1992; Manchester Business School, 1995).

2.2.1 The ISO 9000 Registration Experiences of US and Foreign-Owned Firms

This research provides a comprehensive study of firms operating in the United States which have successfully achieved ISO 9000 registration (Ebrahimpour, M., Withers, B. E., and Hikmet, N., 1997). Specifically, it compares the registration experiences of 541 US-owned and foreign-owned manufacturing firms to identify the key elements associated with successful ISO 9000 registration.

The key reasons for seeking ISO 9000 registration were to achieve corporate objectives and to increase market share. Of the twenty possible areas for improvement provided by the researchers, respondents from both groups expected the highest degree of improvement as a result of ISO 9001 registration to occur in the areas of product design, product quality, communication, process design, public image, and supplier relations.

Internal quality audits, document control, design control, corrective action, and training were identified as the most demanding elements of the ISO 9000 registration process. This result is consistent with the fact that ISO 9000 registration hinges upon the development, implementation, and documentation of comprehensive systems for controlling processes.

Inadequate documentation was identified as the primary barrier to implementing ISO 9000. Poor communication was also highly rated as a barrier to implementation; however, inadequate support from top management was not a serious barrier to becoming

ISO 9000 compliant. As an explanation, the researchers suggested that all respondents had successfully registered as a result of existing senior management support. The survey results also indicate that both groups had low expectations that ISO 9000 registration would lead to improvements in productivity or market share.

The research found no significant differences between US and foreign-owned firms registered to ISO 9000.

2.2.2 The Costs and Benefits of ISO Registration

This study was based on data from 29 high technology manufacturers in Colorado Springs (Atwater and Discenza 1993). Among the research questions was an investigation of the costs and benefits of ISO 9000 registration.

Seventy-one percent of the respondents felt that the benefits associated with ISO 9000 registration were greater than or equal to its costs. Approximately half the sample reported that their ISO 9000 registration had resulted in substantial improvements to operating efficiency, customer satisfaction, competitive position, and the time required to train new employees. A third noted a significant reduction in scrap and rework. Forty-five percent reported the high cost to implement the system as well as the development and maintenance of acceptable documentation were major obstacles to ISO 9000 registration.

All the respondents cited customer requirement as their main reason for pursuing ISO 9000 registration.

2.2.3 The Impact of BS5750 Registration on Organizational Performance

Research conducted for Vanguard Consulting Inc., a consulting company in England, measured the associated costs and benefits of registration to BS5750, the British Standard Institute's predecessor to ISO 9000 (Seddon, Davis, Loughran and Murrel, 1993; Seddon, 1996). The study used seven-point Likert scales to examine the perceptions of 647 representatives from British organizations that had successfully implemented BS5750.

The study was based on the nine business indicators contained in Table 2.3. Fifteen percent of the organizations surveyed reported an improvement on all the business indicators and attributed this improvement to their compliance to the BS5750 standard. Approximately one third of the respondents reported improvements in market share and their ability to attract new customers. Sixty-nine percent reported an improvement in procedural efficiency, but the results for improvements in the measurable aspects of efficiency (costs, waste, etc.) were approximately half that value. A quarter of the respondents attributed reductions in overall costs to their registration to the standard; however, 15% of the organizations perceived costs to have worsened. Regarding the benefits of installing a quality system, 69% reported improvements in efficiency, 37% saw reductions in waste, almost half experienced improved customer service, and 31% reported improved staff motivation. Table 2.3 summarizes these findings.

Table 2.3: The Improvements and Worsening Attributed to BS5750 Registration		
	% respondents attributing improvements to BS5750	% respondents attributing worsening to BS5750
Procedural Efficiency	68.8	2.9
Error rates	54.6	1.7
Customer satisfaction	48.5	1.1
Staff attitudes	38	4.6
Wastage	37.2	3.9
Number of new customers	33.4	0.8
Market share	31.1	0.8
Staff motivation	31.1	5.3
Costs	25	15.3

The study found that the organizations that achieved the least benefit from their BS5750 registration had undertaken the initiative to address customer demand or to increase market share. The reasons for becoming BS5750 registered identified by the organizations that achieved the most value from the standard were to improve operational efficiency, customer service and the reliability of its products and services.

2.2.4 The Effect of ISO 9000 Registration on Key Business Ratios

In 1990, Lloyd's Register Quality Assurance (LRQA), an internationally accredited ISO 9000 registrar, commissioned Surrey University to research the effect of ISO 9000 registration on key business ratios such as profitability and sales (Surrey University, 1993; Seddon, 1996). A total of 222 companies from the mechanical engineering manufacturing

sector in England participated. All had been registered to ISO 9001 or ISO 9002 by LRQA. The results of the survey were compared with the 1992 industry averages.

The study examined six business ratios. The profit margins and return on capital employed (ROCE) of the ISO 9000 companies averaged more than double the industry average. ROCE relates the pre-tax profits to the long term investment in a company. On average, the sample reported 40% higher sales per employee and a profit per employee figure more than three times the industry average. Capital employed per employee, a measure of the level of investment in the company, was approximately double the industry average. And, asset turnover, a ratio of business capital investment to output, was higher. Table 2.4 summarizes these findings.

Table 2.4: A Comparison of the Business Ratios of ISO 9000 Companies and the Industry Average		
Business Ratio	ISO 9000 Companies	Industry Average
Profit margin	5.4%	1.9%
Return on capital employed	16.8%	7.7%
Sales per employee	£69,800	£47,700
Profit per employee	£3567	£900
Capital employed per employee	£21,333	£11,000
Asset turnover	145.4%	167.1%

Data were also collected on the benefits of implementing an ISO 9000 compliant quality system. The research found that 69% reported the implementation of an ISO 9000

quality system improved productivity. Approximately half reported reductions in waste and improvements to staff motivation. Forty percent saw reductions in costs and 73% reported improvements in customer service.

The survey revealed that 81% of companies obtained registration to increase market share or address their customers' demand for ISO 9000 registration.

2.2.5 The Reasons for Seeking ISO 9000 Registration and its Results

In 1995, the Manchester Business School conducted research on behalf of SGS Yarsley, an internationally accredited ISO 9000 registrar, that examined the reasons for obtaining ISO 9000 registration and its impact on businesses (Manchester Business School, 1995). A total of 1190 questionnaires were completed by ISO 9000 registered companies in the manufacturing, construction and service industries.

The driving force behind the majority of the decisions to pursue ISO 9000 registration was external pressure. Seventy-seven percent of respondents sought registration to the standard in anticipation of future customer requirement. Maintaining market share, pressure from existing customers and marketability were also identified. Internal factors included improvements to the consistency, cost reductions, efficiency and quality of operations. Table 2.5 summarizes the main reasons for seeking ISO 9000 registration.

Table 2.5: The Reasons for Seeking ISO 9000 Registration	
Benefit	Respondents who Identified this Factor
Future customer demand for ISO 9000	78%
Increase consistency of operations	65%
Maintain/improve market share	61%
Improve service quality	61%
Customer pressure	58%
ISO 9000 is a good 'promotional tool'	57%
Make operations more efficient	54%
Improve product quality	52%
Proof of Total Quality Management	34%
Cost reductions	22%

Overall, 99% of respondents claimed that they benefited from ISO 9000 registration. Better management control was identified as the most important benefit followed by the improved awareness and elimination of procedural problems. Other internal benefits included improved efficiency and better induction of new staff. ISO 9000 was also seen as a useful marketing tool, a means of improving customer service and satisfaction, and a vehicle to improve market share. Two thirds of the respondents said "keeping existing customers" was a significant benefit, although those for whom this was the only benefit were generally dissatisfied with the standard. Table 2.6 provides a summary of the benefits of ISO 9000 registration.

Table 2.6: The Benefits of ISO 9000 Registration	
Benefit	Respondents who Identified this Factor
Better management control	78%
Improved awareness of procedural problems	77%
Used the standard as a promotional tool	73%
Improved customer service	70%
Facilitated the elimination of procedural problems	69%
Improved efficiency	67%
Kept existing customers	67%
Increased customer satisfaction	67%
Aided the induction of new staff	54%
Improved market share	47%

Overall, 53% of the respondents were satisfied with the impact of ISO 9000, 26% were neither satisfied nor dissatisfied and 21% were dissatisfied. While the majority of those surveyed were satisfied with their experience with ISO 9000, the research revealed several difficulties and areas of concern. The time, volume of paperwork and costs required to implement and maintain an ISO 9000 compliant quality system were identified as the major problems with registration. Table 2.7 summarizes the common problems associated with ISO 9000 registration.

Table 2.7: Common Problems with ISO 9000 Registration	
Problem area	Respondents who Identified this Factor
Time required to write the manuals	31%
High volume of paperwork	27%
High cost of implementation	25%
Time required to complete implementation	24%
High cost of maintaining the standard	19%
Lack of free advice	18%
Lack of consistency between auditors	18%
Time spent checking paperwork prior to audits	16%
The vagueness of the standard	12%
Difficulty interpreting the standard	12%

2.2.6 Why Organizations Choose Not to Seek ISO 9000 Registration

In a second study conducted by Manchester Business School, 140 responses from organizations of all sizes were used to identify the reasons for not seeking ISO 9000 registration (Manchester Business School, 1995). The results included time commitments and the volume of paperwork, as well as the cost of implementing and maintaining the standard. Table 2.8 summarizes these findings. The researchers reported that many service sector organizations felt that ISO 9000 was not relevant and companies with less than 25 employees were particularly concerned with the costs of implementation.

Table 2.8: Reasons for Not Seeking ISO 9000 Registration	
Factor	Respondents who Identified this Factor
Too much paperwork	82%
High cost of implementation	77%
Time required to complete implementation	75%
Time required to write manuals	71%
High cost of maintaining the system following registration	68%

2.2.7 Summary

Table 2.9 summarizes the empirical research on the effects of ISO 9000 registration on non-software organizations.

Table 2.9: Summary of the Empirical Research on the Effects of ISO 9000 Registration on Non-Software Organizations					
Year	Location of Study	Standard	Sample Size	Industry	Conclusions
<i>Ebrahimpour, Withers, and Hikmet: The ISO 9000 Registration Experiences of US and Foreign-owned Firms</i>					
1996	United States	ISO 9001, ISO 9002	541	manufacturing	<ul style="list-style-type: none"> • achievement of corporate objectives and improvements to market share were the main reasons for ISO 9000 registration • improvements are expected in product design, product quality, communication, process design, public image and supplier relations • the most demanding ISO 9000 requirements are: internal quality audits, document control, design control, corrective action and training • none of the respondents identified a lack of management commitment as a significant barrier to registration • there were no significant differences between US and foreign-owned firms

<i>Atwater and Discenza: The Costs and Benefits of ISO Registration</i>					
1993	Colorado Springs	ISO 9001, ISO 9002	29	high technology manufacturing	<ul style="list-style-type: none"> • the benefits of ISO 9000 registration exceed the costs • ISO 9000 registration contributed to improvements in operating efficiency, customer satisfaction, competitive position, time required to train new employees, the amount of scrap and rework • the main barriers to ISO 9001 registration were the cost of implementation and the documentation requirements • customer demand was the main reason for pursuing ISO 9000 registration
<i>Seddon, Davis, Loughran and Murrel: The Impact of BS5750 on Organizational Performance</i>					
1993	England	ISO 9001, ISO 9002	647	manufacturing and service	<ul style="list-style-type: none"> • the most significant improvements attributed to the standard were procedural efficiency, error rates and customer satisfaction • over 15% of respondents cited increased costs as a result of registration • organizations that achieved the least benefit from registration undertook the initiative to address customer demand and to increase their market share • organizations that achieved the most benefit from registration undertook the initiative to improve efficiency, customer service and reliability
<i>Surrey University: The Effect of ISO 9000 Registration on Key Business Ratios</i>					
1990-92	England	ISO 9001, ISO 9002	222	Mechanical engineering manufacturing	<ul style="list-style-type: none"> • when compared to the industry average, ISO 9000 companies reported better: profit margins, return on capital employed, asset turnover, sales and profit per employee • the benefits of an ISO 9000 compliant quality system included improved productivity, reduced waste, decreased costs, improved staff motivation and better customer service • 81% of the sample sought ISO 9000 registration to increase their market share or meet customer demand

<i>Manchester Business School: The Reasons for Seeking ISO 9000 Registration and its Results</i>					
1995	England	1190	ISO 9001, ISO 9002, ISO 9003	manufacturing, construction, service	<ul style="list-style-type: none"> • the main reason behind the decisions to pursue ISO 9000 registration is external pressure • 99% of respondents claimed that they had experienced some benefit from ISO 9000 such as better management control • the major problems with ISO 9000 registration were the time requirements, volume of paperwork and the costs associated with the implementation and maintenance
<i>Manchester Business School: Why Organizations Choose Not to Seek ISO 9000 Registration</i>					
1995	England	140	ISO 9001, ISO 9002	all industries	<ul style="list-style-type: none"> • the main reasons for not seeking registration are: the paperwork, the high costs and time required for implementation, the time required to write manuals and the costs of maintaining the system • service companies felt the standard was not applicable • small companies were particularly concerned with the costs of registration

2.3 The Variables Associated with ISO 9001 Registration and Software Project Outcome

A list of eight variables associated with ISO 9001 registration and software project outcome was developed based on a review of the literature (Berkeley, de Hoog, Humphreys, 1990; Gupta and Wilemon, 1990; Jenkins, Naumann and Wetherbe, 1984; Jones, 1996; Stelzer, Mellis, and Herzwurm, 1996), discussions with industry experts, the ISO 9001 standard and the ISO 9000-3 guidelines on the application of ISO 9001 to software. This section discusses each of the variables and the support for its inclusion in this study.

The variables selected for the focus of this current research are: time spent planning software development projects; the amount of person-months devoted to testing, coding, maintaining project records, and conducting software design reviews and code inspections; the customer involvement in the software development process; the software engineer involvement in project planning; and project manager power.

2.3.1 Software Development Planning

Planning is the cornerstone of quality assurance (Pengelly, Norris and Higham, 1993: 375) and a requirement of ISO 9001 (ISO 9001, 1994: 4.4). Planning is deciding in advance what to do, how to do it, when to do it, and who should do it (Reifer (Ed.), 1994: 5; Humphrey, 1990: 83). A software development plan provides an overview of the project, the resources that will be used, how the project will be organized, the development schedule, how risks will be handled, how reviews will be conducted, how standards will be applied, what development methodologies will be used, and how the software will be tested (Bennatan, 1992: 140). In other words, the plan indicates how the project will satisfy performance specifications, the schedule and the budget (Rosenau and Lewin, 1984: 7). Without realistic plans, effective project management cannot be implemented (CMM, 1991: O-20).

When planning is inadequate, software developers often start with what they understand best, leaving the unknowns until later. Since unknowns have the highest risk, this progression frequently leads to trouble (Humphrey, 1989: 84). The result is often unsuccessful project outcomes.

Project planning leads to more successful project outcomes by rationalizing the process, reducing mistakes, shortening delays, securing resources and increasing intra-project coordination (Eisenhardt and Tabrizi, 1995: 89). Emphasis on project planning leads to: 1) a better understanding of the development process, 2) the elimination of unnecessary steps, 3) a more efficient sequencing of steps, 4) better use of controls necessary to satisfy quality requirements of larger and more complex software (Wilson and Sifer, 1988: 134), 5) more clearly identified staff qualification requirements and therefore a better matching of personnel to assigned tasks, 6) better organized project team interactions around a blueprint for action, 7) fewer project team misunderstandings and coordination problems, as team members can refer to the plan for common language and understanding, 8) the appearance of being competent and well organized which provides an edge in gaining resources (Eisenhardt and Tabrizi, 1995: 88-89), and 9) better risk contingencies. Software development projects are more likely to result in successful project outcomes if they are planned and implemented well (Berkeley, de Hoog, and Humphreys, 1990: 74).

2.3.2 Software Testing

The purpose of testing is to detect errors in a program and, in the absence of errors, to gain confidence in the correctness of the program (Dalal, Horgan and Kettenring, 1994: 35). Ideally, quality should be built into the software development process to ensure the correctness of the software and to prevent errors and faults from entering software requirements, specifications, designs, or code (Deming, 1986: 28; Dalal, Horgan and

Kettenring, 1994: 33; Ince, 1993: 169). Waiting until the testing phase of a project to identify and remove errors is more costly (Ould, 1990: 197) and less effective (Humphrey, 1989: 194) than improving the quality of the software earlier in the project life cycle. However, even with error prevention and detection practices early in a project, the testing phase is still essential because software that is not tested will not work (Humphrey, 1989: 191). Testing is a requirement of ISO 9001 (ISO 9001, 1994: 4.10).

Successful project outcomes are less likely when testing is relied upon as a primary method of ensuring quality. Once the software has entered the testing phase of the project, it is no longer possible to evade the consequences of careless and inadequate planning, estimating, defect prevention, and pre-test quality control (Jones, 1996: 31). Software containing many errors requires longer to test, often forcing the project manager to decide between releasing an inadequate product (Humphrey, 1989: 191) or continuing to test beyond the scheduled testing period (Smith and Wood, 1987: 101). Since testing is the last activity before release, and because schedules usually slip, testing is the activity most likely to be curtailed in favour of release (Smith and Wood, 1987: 100-101).

2.3.3 Software Coding

The typical coding process consists of: planning and software product design; coding; design reviews and code inspections after which the programmer makes any changes requested during the review; testing and the subsequent revisions to the code; and an evaluation by the team leader (Rettig and Simons, 1993: 51-52).

There is evidence that approximately 40% of software errors occur during the coding stage of the project (Smith and Wood, 1987: 15). Failure to plan for defect prevention and failure to use pre-test defect removal activities such as formal inspections becomes visible during the testing phase when many software errors are discovered and extensive rework is required (Jones, 1996: 30).

Finding and fixing errors introduced during the coding process is the most expensive and most time consuming aspect of software development, especially for large systems (Jones, 1996: 30). When one includes the costs of inspections, testing, and rework, as much as half or more of the typical development bill is spent in detecting and removing errors (Humphrey, 1989: 364).

The software coding process should emphasize the prevention of errors rather than the dependence on testing later in the life cycle to identify and correct errors (Dalal, Horgan and Kettenring, 1994: 33; Ince, 1993: 169) when the cost of removing an error is higher (Ould, 1990: 197).

To prevent the introduction of errors during the coding process, software organizations may implement software guidelines, procedures or standards (Humphrey, 1989: 158).

2.3.4 Project Record Maintenance

Project records are documented historical data on a project. Records provide repeated and objective evidence that the required quality is achieved (ISO 8402: 3.15) and that the quality system is operating properly (Bailetti and FitzGibbon, 1995: 43). A typical

software development project involves the creation of more than twenty kinds of records dealing with requirements, functional specifications, logic specifications, data specifications and other project related activities (Jones, 1996: 269).

To comply to ISO 9001, software projects must produce records for activities such as contract reviews (ISO 9001, 1994: 4.3.4), design reviews (ISO 9001, 1994: 4.4.6), design verifications (ISO 9001, 1994: 4.4.7) and test results (ISO 9001, 1994: 4.10.5). Records are a means for project managers to track changes, updates, software errors and other items that affect the evolution of software specifications, code and user manuals (Jones, 1996: 268). A proper project tracking system captures, processes and permits the review of project records such as time spent by programmers during each step of the project (Thamhain and Wilemon 1986: 79-80). This information provides a history of the project and may prove valuable during the postmortem of a module that exceeded schedule (Rettig and Simons, 1993: 52) or the planning of other projects, reviews and audits.

2.3.5 Software Design Reviews and Code Inspections

Design reviews and code inspections are more effective at finding errors in software than most forms of testing (Humphrey, 1989: 187). They also lead to the discovery of errors earlier in the project when the cost of making the corrections is far less (Humphrey, 1989: 187). Design reviews and code inspections involve the systematic review of a module of code against standards, such as specifications, in order to reveal faults and improve quality (Smith and Wood, 1987: 189). The fundamental objective of design reviews and code

inspections is to improve the quality of programs by assisting programmers to recognize and fix errors in their work early in the software development process (Humphrey, 1989: 171).

Design reviews and code inspections are conducted by personnel independent of those having direct responsibility for the work being examined (ISO 9001, 1994: 4.1.2.2). This is based on the concept that our ability to find errors in our own work is impaired since it is human nature not to see evidence that conflicts with our strongly held beliefs (Humphrey, 1989: 171). Inspections help to motivate better work. When programmers know their work will be critically examined by their peers in an inspection, they are encouraged to work more carefully either to avoid being embarrassed by sloppy mistakes or through the pride of exhibiting a quality product (Humphrey, 1989: 171).

The value of the design reviews and code inspections is usually underestimated but it is most definitely the major activity in establishing software quality (Smith and Wood, 1987: 44). The use of formal reviews and inspections before testing is an almost universal attribute of successful projects and successful software organizations (Jones, 1996: 17). Those organizations that do not use code inspections typically are not very sophisticated at software and have many failures; those organizations that use code inspections are usually fairly sophisticated, and have many successes (Jones, 1996: 17).

2.3.6 Customer Involvement in the Software Development Process

Project management involves coordinating customer involvement in the software development process (Bennatan, 1992: 3). To obtain successful outcomes, the software

development process must have built-in customer involvement (Carmel and Becker, 1995: 53). Customer involvement is especially important during the formative stages of the project (Smith and Wood, 1987: 21). During these early stages, customer involvement in the software development process results in a clearer definition of requirements and specifications for the project (Berkeley, de Hoog, and Humphreys, 1990: 73). Other examples of customer involvement include joint customer and supplier reviews of contracts, statements of work and design prototypes.

Increasing customer involvement leads to greater project success by better preempting eventual problems (Berkeley, de Hoog and Humphreys, 1990: 16) while simultaneously creating a shared responsibility for the design (Bennatan, 1992: 50). This is best illustrated through the requirements definition process. Changing requirements are a main contributor to project failure (Humphrey, 1989: 87) and often the result of poor customer-supplier communication.

2.3.7 Software Engineer Involvement in Project Planning

The number of software developers on a project team often varies according to a bell shaped (normal) distribution, with a small development team early in the project life cycle and a larger team during the middle of the project (Bennatan, 1992: 149). Involvement in the planning of a project is often confined to management (Berkeley, de Hoog, and Humphreys, 1990: 24) and marketing staff (Carmel and Becker, 1995: 53). Software developers added later in the project face a significant investment in learning (Bennatan, 1992: 14) which often leads to longer development times and schedule overruns (Brooks,

1974 :154). The inclusion of software developers in the planning of a project will move them up the learning curve sooner (Walz, Elam and Curtis, 1993: 74) and should contribute to project success.

When communication between customers and software developers is poor, the requirements definition process is often unsuccessful (Smith and Wood, 1987: 21) resulting in project failure (Humphrey, 1989: 87). Involving software developers in the project planning usually permits developers to hear the software requirements directly from the customer (Carmel and Becker, 1995: 53) resulting in fewer misunderstandings or misinterpretations of what is expected and what will be delivered. Software developers add to the project team the expertise needed to determine system requirements and the technical feasibility of the project (Berkeley, de Hoog, and Humphreys, 1990: 24), and can often provide valuable input on the estimates of development time and cost (Humphrey, 1989: 418).

2.3.8 Project Manager Power

Deficiencies of the project management function is the root cause of most software disasters (Jones, 1996: 152).

Those with project management power are the powerful linking pins who coordinate the activities of a software development team and work with senior management to create an overarching product concept (Brown and Eisenhardt, 1995: 363). Managers with this leadership and direction are often referred to as heavyweight project managers and they are key to project success (Rosenau and Lewin, 1984: 7). The

characteristics of a heavyweight project manager are summarized in Table 2.10

(Wheelwright and Clark, 1992: 194).

Table 2.10 The Characteristics of a Heavyweight Project Manager
• can influence the distribution of resources when needed
• have direct access to and responsibility for the work of all those involved in the project
• are senior managers within the organization. In some organizations they are at the same level or even outrank the functional managers.
• not only do they have expertise and experience, they also wield significant organizational clout
• have primary influence over the people working on the development effort and supervise their work directly through key functional people on the core teams
• lead and evaluate other members of the core team
• they are the persons to whom the core team reports throughout the project's duration
• rather than being neutral or a facilitator with regard to substantive issues requiring problem solving and conflict resolution, they are concept champions around which the platform product and/or process is being shaped
• they make sure that those who work on subtasks of the project understand the core concept
• they play a central role in ensuring the system integrity of the final project and/or process
• their role is carried out in a very different fashion than the lightweight project manager. Heavyweight project managers typically spend little time at their desk, talk to project contributors, and make sure that decisions are made and implemented whenever and wherever needed

The roles of a heavyweight project manager are contained in Table 2.11,

(Wheelwright and Clark, 1992: 209).

Table 2.11: The Roles of Heavyweight Project Managers	
<i>Role</i>	<i>Description</i>
Direct market interpreter	Gathers firsthand information from customers, distributor visits, industry shows, has own marketing budget, market study team, direct contact and discussions with customers
Multilingual translator	Fluency in language of customers, engineers, marketers, stylists, translator between customer experience/requirements and engineering specifications
Direct engineering manager	Orchestra conductor, evangelist of conceptual integrity and coordinator of component development; direct eye-to-eye discussions with working-level engineers; shows up in drafting room, looks over engineers' shoulders
Program manager "in motion"	Out of the office, not too many meetings, not too much paperwork, face-to-face communication, conflict resolution manager
Concept infuser	Concept guardian, confronts conflicts, not only reacts but implements own philosophy; ultimate decision maker, coordination of details and creation of harmony

Heavyweight project managers earn the respect and right to carry out these roles based on prior experience, carefully developed skills, and status earned over time, rather than simply being endowed through a designation on the part of senior management (Wheelwright and Clark, 1992: 209).

Chapter 3

The Hypotheses

The following hypotheses examine the differences in software project management practices among samples from two populations: the projects of ISO 9001 registered software organizations and the projects of software organizations not registered to ISO 9001. Data were collected on custom software projects from 20 ISO 9001 organizations and 32 non-ISO 9001 organizations. The focus of this research is on custom software projects. A custom software project is a project that leads to the development of software that meets the requirements, schedules and budgets of external or internal customers.

The measures of project outcome are: 1) project duration, 2) schedule overrun, and, 3) project manager satisfaction with the project.

3.1 Time spent planning

The software development plan defines the work and how it will be done (Humphrey, 1990: 83). Implementation of the ISO 9001 standard by organizations that develop software may result in an increased understanding and formalization of the development process, and thus, a better ability to plan projects. Project plans in ISO 9001 organizations may be more structured, more accurate, better resourced, and more closely adhered to.

Factors that may contribute to better project outcomes for ISO 9001 organizations include: project plans that better allocate project responsibilities, activities and plans that are more frequently reviewed, deviations from schedule that are identified sooner, the

anticipation and identification of contingencies for potential risks, and the definition and quantification of project activities.

Non-ISO 9001 organizations may develop less accurate plans and may not track adherence to their plans as closely. The time spent by non-ISO 9001 organizations planning a development project may result in less successful projects than the same time spent planning by ISO 9001 organizations.

In formal terms, Hypothesis 1 states that:

Time spent planning the projects of ISO 9001 organizations is associated with shorter project duration, shorter schedule overrun, and higher project manager satisfaction than time spent planning in the projects of non-ISO 9001 organizations.

3.2 Time spent testing

Software testing is defined as the execution of a program to find its faults (Humphrey, 1989: 191).

Time spent testing may be more effective for ISO 9001 organizations than non-ISO 9001 organizations. ISO 9001 organizations may conduct testing that is more independent, more thorough, more structured and better planned. Further, more successful testing may be the result of better regression testing. The testing phase of the project life cycle may be less clearly defined in non-ISO 9001 organizations. This can lead to less accurate testing plans, less adequate resources and less desirable results. The more effective testing, as expected in ISO 9001 organizations, is expected to contribute to better project outcomes.

In formal terms, Hypothesis 2 states that:

Time spent testing in the projects of ISO 9001 organizations is associated with shorter project duration, shorter schedule overrun, and higher project manager satisfaction than time spent testing in the projects of non-ISO 9001 organizations.

3.3 Time spent developing software code

Software code is defined as any set of characters representing program instructions or data in any computer language (Smith and Wood, 1987: 182).

The time spent developing software code by the software developers of ISO 9001 organizations may result in better code than the same time spent developing software code by non-ISO 9001 software developers. The code of ISO 9001 software developers is expected to be more accurate, and as a result, contain fewer errors and require less rework. The software code development phase of ISO 9001 projects may be better planned, better staffed and more structured.

Non-ISO 9001 developers may not plan the software code development phase as well, resulting in more errors and their associated costs. The time spent developing software code is expected to be more productive and result in higher quality code in ISO 9001 projects.

In formal terms, Hypothesis 3 states that:

Time spent developing software code in the projects of ISO 9001 organizations is associated with shorter project duration, shorter schedule overrun, and higher project manager satisfaction than time spent developing software code in the projects of non-ISO 9001 organizations.

3.4 Time spent maintaining project records

Records provide repeated and objective evidence that the required quality is achieved (ISO 8402: 3.15) and that the quality system is operating properly (Bailetti and FitzGibbon, 1995: 43).

The time spent maintaining project records may contribute more to project success in ISO 9001 organizations than non-ISO 9001 organizations. Through project records, ISO 9001 projects may track changes better, capture and process project performance data more effectively, provide more accurate accounts of project activities such as reviews and tests. The project records in ISO 9001 organizations are expected to provide a more accurate history of projects from which future plans, audits and project post-mortem reviews will be based. More accurate records will be used with more confidence by project managers in decision making and metrics analysis.

In formal terms, Hypothesis 4 states that:

Time spent maintaining project records in the projects of ISO 9001 organizations is associated with shorter project duration, shorter schedule overrun, and higher project manager satisfaction than time spent maintaining project records in the projects of non-ISO 9001 organizations.

3.5 Time spent conducting design reviews and code inspections

Design reviews verify the design against the requirements at specific milestones (Smith and Wood, 1987: 41). Code inspections are peer reviews of a programmer's work to find problems and to improve quality (Humphrey, 1989: 171).

The time spent on design reviews and code inspections by ISO 9001 organizations may result in better project outcomes than the same time spent on design reviews and code inspections by non-ISO 9001 organizations. ISO 9001 organizations are expected to conduct design reviews and code inspections that are more structured, more thorough, better planned and more accurately scheduled. ISO 9001 organizations may also more effectively implement the recommendations resulting from design reviews and code inspections, thus contributing to better project outcomes.

In formal terms, Hypothesis 5 states that:

Time spent conducting design reviews and code inspections in the projects of ISO 9001 organizations is associated with shorter project duration, shorter schedule overrun, and higher project manager satisfaction than time spent conducting design reviews and code inspections in the projects of non-ISO 9001 organizations.

3.6 Customer involvement in the software development process

Customer involvement in the software development process may include the active participation of the customer or their representative in the definition of a project's requirements, specifications or acceptance criteria and reviews of contracts, statements of work or design prototypes.

ISO 9001 organizations may benefit more from the involvement of their customers in software development process than non-ISO 9001 organizations. ISO 9001 organizations may benefit from a better managed interface with their clients, more clearly defined customer responsibilities, a clearer definition of customer requirements, more

frequent and formal project progress reports to customers, and more clearly defined acceptance criteria.

In formal terms, Hypothesis 6 states that:

Customer involvement in the software development process of projects in ISO 9001 organizations is associated with shorter project duration, shorter schedule overrun, and higher project manager satisfaction than customer involvement in the software development process of projects in non-ISO 9001 organizations.

3.7 Involvement of software engineers in project planning

Software engineers involved in the planning phase of projects in ISO 9001 registered organizations may have a better understanding of the project's purpose, its requirements, the acceptance criteria and the risks associated with the project. ISO 9001 projects may better address the concerns of software engineers and incorporate their suggestions and capabilities during project planning. This may result in more accurate estimates and better plans which contribute to more successful projects.

In formal terms, Hypothesis 7 states that:

Involvement of software engineers in project planning for the projects of ISO 9001 organizations is associated with shorter project duration, shorter schedule overrun and higher project manager satisfaction than the involvement of software engineers in project planning for the projects of non-ISO 9001 organizations.

3.8 Project manager power

Project manager power is a function of what a manager controls (Eisenhardt and Tabrizi, 1995: 94). Project managers with power are able to gain resources, command respect, and

break down traditional functional allegiances while simultaneously building a strong vision for the product and the project (Brown and Eisenhardt, 1995: 363).

Project manager power may result in more successful projects in ISO 9001 organizations than non-ISO 9001 organizations. This may be the result of better defined processes over which ISO 9001 project managers have power. Those with power over processes that are not clearly defined or not viewed as important have less power. More clearly defined processes will result in fewer process breakdowns and less of a project manager's time being devoted to addressing crises and more time available for proactive management. Better defined processes and fewer crises situations mean more accurate schedules, more time available for planning and process improvement and less time spent reacting, correcting and reworking. As a result, the projects of ISO 9001 organizations are expected to be more successful.

In formal terms, Hypothesis 8 states that:

Greater project manager power for the projects of ISO 9001 organizations is associated with shorter project duration, shorter schedule overrun and higher project manager satisfaction than in the projects of non-ISO 9001 organizations.

3.9 Summary of Hypotheses

The following hypotheses examine the association of software project management practices and project outcomes in samples drawn from two populations: the projects of ISO 9001 registered software organizations and the projects of software organizations not registered to ISO 9001. The three measures of project outcome are: 1) project duration, 2) schedule overrun, and 3) project manager satisfaction with the project.

1. Time spent planning the projects of ISO 9001 organizations is associated with shorter project duration, shorter schedule overrun, and higher project manager satisfaction than time spent planning the projects of non-ISO 9001 organizations.
2. Time spent testing in the projects of ISO 9001 organizations is associated with shorter project duration, shorter schedule overrun, and higher project manager satisfaction than time spent testing in the projects of non-ISO 9001 organizations.
3. Time spent developing software code in the projects of ISO 9001 organizations is associated with shorter project duration, shorter schedule overrun, and higher project manager satisfaction than time spent developing software code in the projects of non-ISO 9001 organizations.
4. Time spent maintaining project records in the projects of ISO 9001 organizations is associated with shorter project duration, shorter schedule overrun, and higher project manager satisfaction than time spent maintaining project records in the projects of non-ISO 9001 organizations.
5. Time spent conducting design reviews and code inspections in the projects of ISO 9001 organizations is associated with shorter project duration, shorter schedule overrun, and higher project manager satisfaction than time spent conducting design reviews and code inspections in the projects of non-ISO 9001 organizations.
6. Customer involvement in the software development process of projects in ISO 9001 organizations is associated with shorter project duration, shorter schedule overrun, and higher project manager satisfaction than customer involvement in the software development process of projects in non-ISO 9001 organizations.
7. Involvement of software engineers in project planning for the projects of ISO 9001 organizations is associated with shorter project duration, shorter schedule overrun and higher project manager satisfaction than the involvement of software engineers in project planning for the projects of non-ISO 9001 organizations.
8. Greater project manager power for the projects of ISO 9001 organizations is associated with shorter project duration, shorter schedule overrun and higher project manager satisfaction than in the projects of non-ISO 9001 organizations.

Chapter 4

Research Design

4.1 Unit of Analysis

The unit of analysis is a custom software project. A custom software project was defined as a project with software developed to internal or external customer requirements, schedules and budgets.

4.2 Sample

The sample is comprised of 52 custom software projects completed between October 1994 and October 1997. Only projects from organizations that design and develop software in Canada were considered for this study. The sample consists of two groups: 20 projects completed by software organizations registered to the ISO 9001 standard at the time the project was started, and 32 projects completed by software organizations not registered to the ISO 9001 standard. The registration status of the company at the start of the project defines the group in which the project is categorized; for example, organizations were classified as non-ISO 9001 if their registration occurred at any point after personnel were assigned to analyze the software requirements.

4.3 Company, Project and Respondent Selection

The researcher contacted Canadian custom software organizations included in the January 1997 Ottawa-Carleton Economic Development Corporation directory, the company

registry at Industry Canada's Strategis Internet site (<http://strategis.ic.gc.ca>), and the CanadaIT (<http://www.canadaIT.com>) Internet business directory. The services of Globus Information Services Inc. were used to identify Canadian software organizations registered to the ISO 9001 standard.

The researcher asked 162 initial contacts to confirm that their organization developed software and to provide the name of a software project manager. Many of these requests went unanswered or were directed to organizations that did not actually develop software. Upon receipt of the name of a software project manager, he or she was contacted and asked to participate in the study. Questionnaires were sent to 93 project managers who indicated an interest in participating in the study. Fifty-two useable questionnaires were returned.

Each project manager was asked to select the project to be included in this study. Projects had to be completed between October 1994 and October 1997 and had to be custom software projects.

4.4 Time of Data Collection

Data were collected between July and October of 1997.

4.5 Research Sources

The research for this study comprised an extensive review of the literature as well as interviews with ISO 9000 auditors, consultants and software project managers.

4.5.1 Literature Review

An extensive review of the literature was conducted to identify the effects of ISO 9001 registration on software development organizations, the effects of ISO 9000 on non-software organizations and the variables associated with software project outcomes and ISO 9001 registration.

4.5.2 Interviews with Industry Experts

Interviews were conducted with six industry experts. Interviewees included a prominent member of the Ottawa Valley chapter of the American Society for Quality, an expert in the Software Engineering Institute's Capability Maturity Model, an ISO 9000 and TickIT auditor, a senior manager from an ISO 9001 organization, a senior manager from a non-ISO 9001 software organizations, and a consultant specializing in software process improvement.

The interviews with the industry experts were used to improve the conceptualization and testing of the hypotheses. Industry experts were asked to identify the most significant differences in software project management between ISO 9001 and non-ISO 9001 registered organizations. The interviewees were also asked to comment on the research question, the hypotheses and software project success factors.

4.6 Data Collection Method

There are two components to the data collection package used in this research: 1) the cover letter and instructions, and 2) the questionnaire.

4.6.1 Cover Letter and Instructions

The data collection package distributed to the 93 project managers included a cover letter providing an overview of the research, assurance of the confidentiality of the responses and the name of the researcher. The name of the thesis supervisor, whom the project manager could contact with questions or concerns at any time, was also provided. The cover letter contained explicit instructions. Respondents were asked to forward any questions or requests for clarification to the researcher should they arise. Appendix B provides a copy of the cover letter.

4.6.2 Piloting the Questionnaire

The questionnaire in Appendix C was tested by two software project managers. These project managers were first asked to complete the questionnaire and then asked to provide comments. Their comments were used to produce the final questionnaire contained in Appendix D. The project managers that participated in the piloting of the questionnaire were excluded from the sample.

4.6.3 Questionnaire

Appendix D provides the questionnaire that was used for the collection of data.

Definitions of key terms were provided throughout the questionnaire.

There are seven parts to the questionnaire. The first part of the questionnaire requests project size information such as total person-months, duration and the project's software development budget. Part two asks respondents to divide the number of person-

months into project tasks. Part three identifies the participation of software engineers and clients in certain project tasks. Respondents are then asked to rank the importance to project outcome of project characteristics related to the eight hypotheses. Part five of the questionnaire is used to rate project manager power on five point Likert scales. Part six requests a rating of the project manager satisfaction that the software met the client's requirements. The final part of the questionnaire records the ISO 9001 registration status of the organization at the start of the project and concludes with an open-ended question on the differences in software project management attributed to ISO 9001 registration.

4.6.4 Data Collection

The 93 project managers that agreed to participate were sent the cover letter and questionnaire by mail, fax or email. Participants had no knowledge of the other participants in the study. A follow-up telephone call or email was sent to those who had not returned the questionnaire within three working days of its receipt. Upon receipt of the data, the researcher reviewed all responses for completeness and, if necessary, contacted the participant for additional information. The cover letter which contained contact information on the respondent was subsequently separated from the questionnaire. Prior to the creation of a SPSS data file, the coding scheme in Appendix E was used to transform the responses into useable data.

4.7 Measures

Each project manager was asked to consider a custom software project completed between October 1994 and October 1997.

4.7.1 Project Outcomes

Project Duration is measured as the number of person-months between the start and the end of the software development project. The start of the software project is the date when personnel were assigned to analyze the project's requirements. The end of the project is the date of final sign-off where the software is accepted by the client as having fulfilled the stated requirements.

Scheduled overrun was calculated as the difference in person-months between the date estimated at the start of the project for final sign-off and the date the client finally signed-off the project.

Project Manager Satisfaction with the Project consists of a rating on a 5 point Likert scale of the project manager's satisfaction that the software met the client's requirements. The scale ranges from Very Dissatisfied to Very Satisfied. The outcome of a project is ultimately determined by the satisfaction of the party that requested its development: the customer (Bennatan, 1992: 3). Obtaining responses from customers was beyond the scope of this research. Therefore, this measure of project outcome obtained the project manager's judgement of how well the customer requirements were met.

4.7.2 Project Size

Project size is the control variable for this study. Project size is measured in two different ways: 1) the total number of person-months dedicated to the software project, and 2) the approximate cost of the software developed.

4.7.3 Time Spent Planning

Time Spent Planning is measured as the total number person-months dedicated to planning the software project. Planning is deciding in advance what to do, how to do it, when to do it, and who should do it (Reifer (Ed.), 1994: 5; Humphrey, 1990: 83).

4.7.4 Time Spent Testing

Time Spent Testing is measured as the total number person-months dedicated to software testing. Software testing is defined as the execution of a program to find its faults (Humphrey, 1989: 191).

4.7.5 Time Spent Developing Software Code

Time Spent Developing Software Code is measured as the total number person-months dedicated to writing software code and implementing re-usable code. Software code is defined as any set of characters representing program instructions or data in any computer language (Smith and Wood, 1987: 182).

4.7.6 Time Spent Maintaining Project Records

Time Spent Maintaining Project Records is measured as the total number person-months dedicated to maintaining project records. Records are documented historical data on a project.

4.7.7 Time Spent Conducting Design Reviews and Code Inspections

Time Spent Conducting Design Reviews and Code Inspections is measured as the total number person-months dedicated to conducting design reviews and code inspections including formal and informal inspections, walkthroughs and peer reviews. Design reviews and code inspections and walkthroughs involve the systematic review of a module of code against standards, such as specifications, in order to reveal faults and improve quality (Smith and Wood, 1987: 189).

4.7.8 Client Involvement

Client Involvement corresponds to the active participation of clients and their representatives in software development project activities. Clients are the recipients of a product, either external or internal to the organization, including the ultimate consumer, user, beneficiary or purchaser. In the case of internal software development projects, high level management and designated users play the role of the client by specifying requirements and accepting the final product (Bennatan, 1992: 89).

Respondents were asked whether their clients were actively involved in planning, design reviews and code inspections, and testing activities. To minimize the number of

independent variables and degrees of freedom, this data was combined with the variable measuring software engineer participation in planning to create a single average measure of *Project Involvement*.

4.7.9 Software Engineer Involvement in Project Planning

Software Engineer Involvement in Project Planning is a binary variable measured by requesting from respondents whether or not software engineers were involved in the *software planning* phase of the project. Software engineer involvement in planning may include activities such as: time spent performing requirements analysis and specification development; preparing the software development plan; conducting risk analysis; preparing a high-level software design; estimating; budgeting; and, establishing commitments, policies and frameworks for decision making (Kraut and Streeter, 1995: 72).

For the data analysis, a single measure of *Project Involvement* was created by calculating the average of the *Software Engineer Involvement in Project Planning* and *Client Involvement* variables.

4.7.10 Project Manager Power

Project Manager Power is measured using 5 point Likert scales. The extent of project manager power associated with a project is determined by how extensive a role the project manager exerts in each of three areas (Wheelwright and Clark, 1992: 195):

- Influence over the distribution of resources;

- Responsible for specifications, features and layout; and,
- Direct contact with clients.

The project manager power measure is determined by calculating the average of the three responses as measured on scales ranging from Limited to Extensive.

4.7.11 Importance Rankings

Respondents are asked to rank the hypotheses in order of the most important contributor to project success to the least important contributor to project success. The number corresponding to the ranking is used to calculate the average ranking for both samples.

4.8 Data Analysis

4.8.1 The Data

For each project, the data collected included information on the characteristics of the project, a ranking by the project manager of the importance to project success of eight project characteristics directly related to the hypotheses, and whether or not the organization supporting the project was registered to ISO 9001. Table 4.1 summarizes the data collected.

Table 4.1: The Data Collected		
Characteristics	Data collected	
<i>The Supporting Organization</i>	ISO 9001 Registered?	
	If not, is the Organization Pursuing ISO 9001 Registration?	
<i>The Project</i>	Project Outcome: (dependent variables)	Project Duration
		Schedule Overrun
		Project Manager Satisfaction with the Project
	Project Size: (control variables)	Total Person-Months Dedicated to the Software Project
		The Project's Software Development Budget
	Person-Months Devoted to: (independent variables)	Planning
		Testing
		Software Coding
		Record Keeping
		Design Reviews and Code Inspections
	Project Involvement: (independent variable)	Client participation in planning, testing and design reviews and code inspections
		Software engineer involvement in planning
	Project Manager Characteristics: (independent variables)	Project Manager Power
<i>The Perceptions of Respondents</i>	Importance Rankings: (independent variables)	Time spent Planning
		Time spent Testing
		Time spent Coding
		Time spent Record Keeping
		Time spent Conducting Design Reviews and Code Inspections
		Client Involvement in the Software Development Process
		Involvement of Software Engineers in Planning
		Project Manager Power

4.8.2 Data Model

Table 4.2 describes the dependent, control and independent variables that comprise the data model for this research. Appendix F defines the variables used in the analysis of the data.

Table 4.2: The Data Model	
Component of Model	Variable
<i>Dependent Variables</i>	Project Duration
	Schedule Overrun
	Project Manager Satisfaction with the Project
<i>Control Variables</i>	Total Person-Months Dedicated to the Software Project
	The Project's Software Development Budget
<i>Independent Variables</i>	ISO 9001 Registered?
	If not, is the Organization Pursuing ISO 9001 Registration?
	Time spent Planning
	Time spent Testing
	Time spent Software Coding
	Time spent Record Keeping
	Time spent conducting Design Reviews and Code Inspections
	Project Involvement
	Project Manager Power
	Importance Rankings

4.8.3 The Analysis

The analysis included the calculation of the mean, standard deviation, variance, kurtosis, range, minimum and maximum for each group. Box plot diagrams were generated for the independent, dependent and control variables.

A correlation matrix was calculated to identify any highly correlated variables. A Spearman Rank Correlation Test was used to identify if the two groups ranked the importance of the hypotheses similarly.

A multivariate analysis of covariance (MANCOVA) model and multivariate regressions were used to test each of the hypotheses to a 95% level of significance. MANCOVA is a general univariate and multivariate analysis of covariance program. The MANCOVA model was used because the analysis involved a multiple variable comparison of two groups.

An F-test was then used to determine whether there was an overall difference between the two groups that may not have been identified by the tests on the hypotheses.

Chapter 5

Results

This chapter describes the questionnaire's response rate, the respondents, the data collected and the results of the data analysis.

5.1 Response Rate

Ninety-three project managers agreed to participate in the study. A total of 52 usable questionnaires were returned by project managers by either fax, mail or email resulting in a response rate equal to 56 percent. The reasons most frequently cited for not participating in the study were a lack of time and an unwillingness to provide the "sensitive" data requested.

5.2 Respondents

Twenty of the 52 respondents managed projects for organizations that were registered to the ISO 9001 quality standard at the time the project was started. The remaining 32 respondents comprise the non-ISO 9001 sample. Eleven of the non-ISO 9001 respondents reported that their organization was actively pursuing ISO 9001 registration or had registered to the quality standard at some point after the project had started. The ISO 9001 registration status of an organization at the start of the project was used to classify respondents into their respective group.

All the projects used for the study included the development of software to meet internal or external customer requirements; however, they varied in nature from small custom software development projects to large telecommunication software projects. There is no claim that the sample is representative of Canadian software companies.

5.3 Independent Variables

5.3.1 Descriptive Statistics for the Independent Variables

The dummy variable, which represents the ISO 9001 registration status of the organization, was crossed with the independent variables. Table 5.1 presents the range, mean, standard deviation, Kurtosis and the number of observations for the independent variables from the ISO 9001 sample. The same information for the non-ISO sample is provided in Table 5.2.

Table 5.1: The Characteristics of the Independent Variables from the 20 ISO 9001 Projects in the Sample					
Independent Variables	Range (Min-Max)	Mean	Standard Deviation	Kurtosis	Observa- tions
% Time Spent Planning	2 - 57	17	0.157	1.678	20
% Time Spent Testing	6 - 50	21.1	0.124	-0.151	20
% Time Spent Coding	10 - 100	43.1	0.261	-0.536	20
% Time Spent Record Keeping	0 - 11	5.2	0.34	-1.078	20
% Time Spent Conducting Design Reviews	1 - 17	7.4	0.04	0.275	20
Project Involvement	0 - 1	0.613	0.263	0.14	20
Project Manager Power	.20 - 1	0.787	0.204	2.777	20

Table 5.2: The Characteristics of the Independent Variables from the 32 Non-ISO 9001 Projects in the Sample					
Independent Variables	Range (Min-Max)	Mean	Standard Deviation	Kurtosis	Observa- tions
% Time Spent Planning	1 - 63	19.4	0.13	2.787	32
% Time Spent Testing	3 - 38	16.4	0.087	-0.142	32
% Time Spent Coding	5 - 83	43.4	0.196	-0.483	32
% Time Spent Record Keeping	0 - 44	6.8	0.082	14.693	32
% Time Spent Conducting Design Reviews	0 - 34	8.5	0.092	1.229	32
Project Involvement	.25 - 1	0.68	0.271	-1.248	32
Project Manager Power	.467 - 1	0.827	0.142	0.248	32

The box plot diagrams contained in Figures 5.1 to 5.7 provide a visual comparison of the independent variables for the two samples. Observations within two standard deviations of the mean are identified in the diagrams with a circle; those beyond two standard deviations are represented by stars.

Figure 5.1 illustrates a slightly higher average percentage of person-months devoted to project planning by the non-ISO 9001 sample compared with the ISO 9001 sample. The skewness of the non-ISO 9001 sample's responses is also slightly higher. There are more outliers among the ISO 9001 sample's responses.

On average, ISO 9001 respondents devoted 21.1% of their project's person-months to testing. As shown in Figure 5.2, this was approximately 5% higher than the non-ISO 9001 sample. The data were skewed for both groups.

Figure 5.3 shows very similar results for both groups in terms of the time spent coding. The data is normally distributed.

% Time
Coding

Figure 5.3: % Time Spent Coding

The time spent maintaining project records, illustrated in Figure 5.4, was higher among the non-ISO 9001 sample. Non-ISO 9001 respondents devoted an average of 6.8% of their person-months to record keeping compared with 5.2% for the ISO 9001 sample. There was a normal distribution for both samples with a slight skew for the ISO 9001 group.

% Time Record
Keeping

Figure 5.4: % Time Spent Record Keeping

ISO 9001 respondents averaged less time conducting design reviews than the non-ISO 9001 respondents. As shown in Figure 5.5, the non-ISO 9001 data is skewed while the ISO 9001 sample is normal.

The data from both samples were very similar for the project involvement variable and the measure of project manager power with the exception of a slight skew in the non-ISO 9001 data for the project manager power variable. Figures 5.6 and 5.7 provide a visual comparison of the results.

*Project Manager
Power Ratio*

Figure 5.7: Project Manager Power Ratio

5.3.2 Importance Rankings

All respondents were asked to rank the independent variables from the most important contributor to project success to the least important contributor to project success. Table 5.3 provides the average ranking for both samples as well as the difference in means and rank. The higher the number the less important the contribution. The number in brackets beside each value corresponds to its ranking.

Table 5.3: The Rankings of Project Tasks by ISO 9001 and Non-ISO 9001 Respondents			
Independent Variable	Mean and Importance Ranking for ISO 9001 Sample	Mean and Importance Ranking for Non-ISO 9001 Sample	Difference in Mean and Ranking
Time spent planning	1.9 (1)	2.531(1)	0.631 (0)
Time spent testing	4.2 (4)	4.563 (4)	0.363 (0)
Time spent developing software code	4.45 (5)	5 (7)	0.55 (2)
Time spent maintaining project records	6.8 (7)	6.406 (8)	-0.394 (1)
Time spent conducting design reviews and code inspections	3.65 (3)	4.688 (6)	1.038 (3)
Customer involvement in the software development process	4.6 (6)	3.688 (2)	-0.912 (-4)
Involvement of software engineers in project planning	3.5 (2)	4.5 (3)	1 (1)
Project manager power	6.9 (8)	4.625 (5)	-2.275 (-3)

A Spearman Rank Correlation Test was conducted to determine whether the two groups ranked the independent variables similarly. The Spearman Rank Correlation value (R_s) is calculated using the difference in rankings (D) for the 8 (N) independent variables and the formula below. For a sample size of 52, the two groups are similar if R_s is greater than 0.643.

$$\begin{aligned}
 R_s &= 1 - \frac{6(\text{sum of } D^2)}{N(N^2 - 1)} \\
 &= 1 - \frac{6(0+0+4+1+9+4+1+9)}{8(64-1)} \\
 &= 1 - 0.476 \\
 &= 0.524
 \end{aligned}$$

The calculated R_s value of 0.524 is less than the critical value, therefore, the two groups ranked the independent variables differently.

The ISO 9001 and non-ISO 9001 respondents differed most in their rankings of the contribution of project manager power, the importance of time spent conducting design reviews and code inspections, the importance of customer involvement in the development process and the involvement of software engineers in project planning. The two groups were most similar in their ranking of the time spent testing, record keeping, coding and planning.

The importance rankings by the non-ISO 9001 respondents placed project manager power and the involvement of customers in development activities higher than the ISO 9001 respondents. Time spent conducting design reviews and code inspections, the involvement of software engineers in project planning and the time spent planning were ranked higher in importance to project success by the ISO 9001 respondents.

5.4 Dependent Variables

5.4.1 Descriptive Statistics for the Dependent Variables

Tables 5.4 and 5.5 present the range, mean, standard deviation, Kurtosis and the number of observations for the dependent variables of the ISO 9001 and non-ISO 9001 samples.

Table 5.4: The Characteristics of the Dependent Variables from the 20 ISO 9001 Projects in the Sample					
Dependent Variables	Range	Mean	Standard Deviation	Kurtosis	Observations
% Schedule Overrun	-25 - 60	16.5	0.217	-0.021	20
Project Duration in Person-Months	2 - 29	14.25	9.792	-1.248	20
Project Manager Satisfaction on a 5 point Likert scale (V17)	3 - 5	4.1	0.718	-0.88	20

Table 5.5: The Characteristics of the Dependent Variables from the 32 Projects in the Non-ISO 9001 Sample					
Dependent Variables	Range	Mean	Standard Deviation	Kurtosis	Observations
% Schedule Overrun	0 - 86	17.9	0.225	2.211	32
Project Duration in Person-Months	3 - 65	12.344	12.504	9.718	32
Project Manager Satisfaction on a 5 point Likert scale	2 - 5	4.062	0.801	-0.126	32

The box plot diagrams contained in Figures 5.8 to 5.10 provide a visual comparison of the dependent variables for the two samples.

On average, the projects of ISO 9001 organizations exceeded their estimated project completion date by 16.5%. This compared with a schedule overrun of 17.9% for non-ISO 9001 organizations. One respondent from the ISO 9001 sample reported delivering a project 20% ahead of the scheduled delivery date. In contrast, the largest schedule overrun was by a non-ISO 9001 respondent whose large project took almost twice as long as scheduled. Figure 5.8 provides a comparison. The data were skewed, especially for the non-ISO 9001 sample which also contained two outliers.

The average duration of the ISO 9001 sample's projects was approximately 2% greater than those of the non-ISO 9001 sample. The ISO 9001 data produced a Kurtosis value of -1.248. This is in contrast to a Kurtosis value of 9.718 for the non-ISO 9001 sample which is clearly visible in Figure 5.9. The results were close to normal with the non-ISO 9001 sample containing three outliers.

The final dependent variable is the measure of project manager satisfaction that the software met the client's requirements. A 5 point Likert scale was used with 1 representing very dissatisfied and 5 representing very satisfied. The lowest rating of satisfaction, a score of 2, was reported by one non-ISO 9001 respondent. The data were not normally distributed and it contained a skew. As illustrated in Figure 5.10, both groups reported that they were quite satisfied that their projects met the client's requirements.

5.5 Project Size

5.5.1 Descriptive Statistics for the Project Size Variables

The total number of person-months dedicated to the project and the approximate software development budget were the measures used to control projects by size. Tables 5.6 and 5.7 present the range, mean, standard deviation, Kurtosis and the number of observations for the ISO 9001 and non-ISO 9001 samples.

Table 5.6: The Characteristics of the Project Size Variables from the 20 ISO 9001 Projects in the Sample					
Size Variables	Range	Mean	Standard Deviation	Kurtosis	Observations
Total Person-Months	4 - 960	167.85	281.233	4.457	20
Software Development Budget in Canadian Dollars	\$50,000 - 8,000,000	1176711	1938063	10.574	17

Table 5.7: The Characteristics of the Project Size Variables from the 32 Non-ISO 9001 Projects in the Sample					
Size Variables	Range	Mean	Standard Deviation	Kurtosis	Observations
Total Person-Months	1.75 - 900	90.183	174.722	15.279	32
Software Development Budget in Canadian Dollars	\$3,000 - 5,000,000	991293	1734669	1.872	29

As illustrated in Figures 5.11 and 5.12, the projects of the ISO 9001 respondents were larger than those comprising the non-ISO 9001 sample. The projects of the ISO 9001 sample were approximately 86% larger in terms of person-months with a software budget almost 19% larger.

Figure 5.11 shows the strong skew in the non-ISO 9001 sample's total person-months data; its Kurtosis value is over 15. Both variables contain several outliers.

5.6 Correlations

For this study, a correlation greater than 0.6 or less than -0.6 was considered high. The correlation values are contained in Appendix G.

A high correlation (.8536) was observed between the two control variables: total person-months and software development budget. This suggested some redundancy and the elimination of one of these variables. Since six of the respondents had not provided

budget information for their project for confidentiality or unavailability of data reasons, total person-months was the better choice as the control variable for the model.

Total person-months, software budget and project duration showed high correlations with the software development life cycle activities such as person-months spent planning, testing, coding, record keeping, and design reviews and code inspections. Similarly high correlations were observed between the life cycle activities; for example, person-months spent planning had a 74 percent correlation with person-months spent testing and a 67 percent correlation with person-months spent coding.

High correlations were observed between the measure of project involvement and client involvement in design reviews and code inspections and client participation in planning. Project manager power showed a high correlation with project manager responsibility for specifications and the project manager's direct contact with the client. Schedule overrun had an 86 percent correlation with person-months spent record keeping and a 73 percent correlation with project duration.

5.7 Differences in Software Project Management Attributed to ISO 9001 Registration

Project managers were asked whether they attribute any differences in software project management to ISO 9001 registration. Twenty-seven of the 52 respondents commented, of which 16 were from the ISO 9001 sample and 11 from the non-ISO 9001 sample.

Ten of the responses from the ISO 9001 project managers attributed process improvements to the standard. The improvements identified were: a greater emphasis on

planning, better risk analysis, more thorough testing, more emphasis on code reviews, and the formalization of software development procedures. Six respondents reported that their organization had a mature software development process prior to their ISO 9001 registration and that compliance to the standard required very few changes in the way their projects are managed.

Two of the 11 responses from the non-ISO 9001 sample attributed a more formal software development process to ISO 9001 registration. Nine project managers did not attribute any changes in software project management practices to ISO 9001 registration. Three of these respondents added that good project management did not require ISO 9001, while another argued that the increased paperwork associated with the standard is costly and does not necessarily improve project management. Of the nine non-ISO 9001 project managers that did not attribute any changes in software project management to ISO 9001, four reported that their organization was either actively pursuing ISO 9001 or had recently achieved registration.

5.8 Statistical Analysis of the Hypotheses

5.8.1 The Approach

The multivariate analysis of covariance provides the most accurate method to compare the two groups according to the hypotheses. The main advantage of a MANCOVA is its incorporation of the correlations among the variables right into the test statistic. The MANCOVA methodology constructs linear models with both continuous and discrete explanatory variables in an attempt to describe several different outcomes. In doing so, the

methodology allows one to measure the effects of the discrete variables after controlling for the continuous variables using regression. In our case, the discrete variable distinguishes whether or not a company has ISO 9001 registration. The continuous variables in this study are the measures of project size: budget and total person-months dedicated to the software project. The outcome variables are project duration, schedule overrun and project manager satisfaction with the project.

To determine whether or not there is a difference between the ISO 9001 and the non-ISO 9001 samples, the MANCOVA was used to create equations and test each hypothesis to a confidence interval of 95 percent. The test equations are provided below; the process used to derive the equations is detailed in Appendix H.

Even when tests on individual hypotheses do not detect a significant difference between two groups, a difference may be identified when the hypotheses are examined collectively. This is the case when: 1) small differences on several variables combine to produce a reliable overall difference, or 2) an unmeasured factor accounts for a significant difference. The statistical analysis concludes with a stepwise multiple regression comprising all of the hypotheses and an F-test to determine whether or not there was a significant difference between the two groups when the variables were analyzed collectively.

5.8.2 Multivariate Analysis of Covariance

The MANCOVA was conducted for the three dependent variables: schedule overrun, project duration and project manager satisfaction that the project met client requirements.

A definition of the additional variables used in the test equations is provided below.

Covariate variables, the product of two or more variables, are used throughout the analysis. These variables are represented by the letters “COV” followed by the variables comprising the product. For example, the covariate variable for the product of variable 1 and variable 2 would be: $COV_{(variable1 \times variable2)}$. The vectors (B_j) in the model are indicated in bold; variables representing single values are not bolded.

Dummy variable:

$i = 1$ if ISO 9001 sample

$i = 0$ if non-ISO 9001 sample

HYP = represents one of the measures for the hypothesis

B_0 = constant, vertical intercept

B_1 = B of the dummy variable

B_2 = B of HYP

B_3 = B of total person-months

B_4 = B of ($i \times$ HYP)

B_5 = B of ($i \times$ Person-months) = B of $COV_{(i \times \text{Person-months})}$

B_6 = B of (HYP $\times$ Person-months)

B_7 = B of Budget

B_8 = B of ($i \times$ Budget) = B of $COV_{(i \times \text{Budget})}$

B_9 = B of (HYP $\times$ Budget)

The initial model created was:

$$\text{Overrun, Duration, Satisfaction} = B_0 + B_1(i) + B_2(\text{HYP}) + B_3(\text{Person-months}) + B_7(\text{budget}) + B_4(i * \text{HYP}) + B_5(i * \text{Person-months}) + B_8(i * \text{budget}) + B_6(\text{Person-months} * \text{HYP}) + B_9(\text{budget} * \text{HYP})$$

Given the high correlation between total person-months and project budget, project budget was removed from the model to avoid the problems associated with multicollinearity. The result was the following model:

$$\text{Overrun, Duration, Satisfaction} = B_0 + B_1(i) + B_2(\text{HYP}) + B_3(\text{Person-months}) + B_4(i*\text{HYP}) + B_5(i*\text{Person-months}) + B_6(\text{Person-months}*\text{HYP})$$

If $i = 0$, then the respondent is from the non-ISO 9001 sample resulting in the following equation:

$$\text{Overrun, Duration, Satisfaction} = B_0 + B_2(\text{HYP}) + B_3(\text{Person-months}) + B_6(\text{Person-months}*\text{HYP})$$

If $i = 1$, then the respondent is ISO 9001 registered and B_1 , B_4 and B_5 measure the effects due to ISO 9001 registration:

$$\text{Overrun, Duration, Satisfaction} = (B_0 + B_1) + \text{HYP}(B_2 + B_4) + (\text{Person-months})(B_3 + B_5) + (\text{Person-months})*\text{HYP}(B_6)$$

Following the application of the MANCOVA to test the hypotheses, the variables outside the confidence interval were eliminated from the equation. Because no significant difference in project manager satisfaction was detected between the two groups, it was also removed from the model. Univariate regressions were conducted to complete the missing values from the models. Based on the values provided by the MANCOVA and the regressions, the following predictor models for schedule overrun and project duration were created for each of the hypotheses. These equations can be used to predict project outcomes.

Time Spent Planning:

$$\begin{aligned}
\text{If } i = 0: \quad \text{Duration} &= 8.949 - 9.675(\text{Planning}) + 0.0584(\text{Person-months}) \\
\text{If } i = 1: \quad \text{Duration} &= 13.701 - 9.675(\text{Planning}) + 0.013(\text{Person-months}) \\
\text{If } i = 0: \quad \text{Overrun} &= -0.213 + 5.030(\text{Planning}) + 0.075(\text{Person-months}) - \\
&\quad 0.265(\text{COV}_{(\text{Person-months} \times \text{Planning})}) \\
\text{If } i = 1: \quad \text{Overrun} &= 2.671 + 5.030(\text{Planning}) + 0.016(\text{Person-months}) - \\
&\quad 0.265(\text{COV}_{(\text{Person-months} \times \text{Planning})})
\end{aligned}$$

Time Spent Testing:

$$\begin{aligned}
\text{If } i = 0: \quad \text{Duration} &= 7.731 - 4.326(\text{Testing}) + 0.059(\text{Person-months}) \\
\text{If } i = 1: \quad \text{Duration} &= 12.657 - 4.326(\text{Testing}) + 0.015(\text{Person-months}) \\
\text{If } i = 0: \quad \text{Overrun} &= 0.06 - 3.576(\text{Testing}) + 0.045(\text{Person-months}) \\
\text{If } i = 1: \quad \text{Overrun} &= 3.345 - 3.576(\text{Testing}) - 0.002(\text{Person-months})
\end{aligned}$$

Time Spent Coding:

$$\begin{aligned}
\text{If } i = 0: \quad \text{Duration} &= 5.026 + 4.312(\text{Coding}) + 0.06(\text{Person-months}) \\
\text{If } i = 1: \quad \text{Duration} &= 9.769 + 4.312(\text{Coding}) + 0.015(\text{Person-months}) \\
\text{If } i = 0: \quad \text{Overrun} &= -3.049 + 5.468(\text{Coding}) + 0.046(\text{Person-months}) \\
\text{If } i = 1: \quad \text{Overrun} &= 0.097 + 5.468(\text{Coding}) - 0.001(\text{Person-months})
\end{aligned}$$

Time Spent Maintaining Project Records:

$$\begin{aligned}
\text{If } i = 0: \quad \text{Duration} &= 6.459 + 14.664(\text{Records}) + 0.054(\text{Person-months}) \\
\text{If } i = 1: \quad \text{Duration} &= 12.52 - 15.989(\text{Records}) + 0.015(\text{Person-months})
\end{aligned}$$

$$\begin{aligned}\text{If } i = 0: \quad \text{Overrun} &= 2.194 - 7.738(\text{Records}) - 0.007(\text{Person-months}) + \\ &\quad 0.154(\text{COV}_{(\text{Person-months} \times \text{Records})}) \\ \text{If } i = 1: \quad \text{Overrun} &= 5.649 - 55.17(\text{Records}) - 0.012(\text{Person-months}) + \\ &\quad 0.154(\text{COV}_{(\text{Person-months} \times \text{Records})})\end{aligned}$$

Time Spent Conducting Design Reviews and Code Inspections:

$$\begin{aligned}\text{If } i = 0: \quad \text{Duration} &= 5.29 + 18.333(\text{Reviews}) + 0.061(\text{Person-months}) \\ \text{If } i = 1: \quad \text{Duration} &= 0.052 + 18.333(\text{Reviews}) + 0.014(\text{Person-months}) \\ \text{If } i = 0: \quad \text{Overrun} &= -0.848 + 3.272(\text{Reviews}) + 0.046(\text{Person-months}) \\ \text{If } i = 1: \quad \text{Overrun} &= 2.356 + 3.272(\text{Reviews}) - 0.002(\text{Person-months})\end{aligned}$$

Involvement Measure:

$$\begin{aligned}\text{If } i = 0: \quad \text{Duration} &= 13.564 - 1.796(\text{Involvement}) \\ \text{If } i = 1: \quad \text{Duration} &= 12.87 - 1.796(\text{Involvement}) + 0.015(\text{Person-months}) \\ \text{If } i = 0: \quad \text{Overrun} &= 3.751 - 0.323(\text{Involvement}) \\ \text{If } i = 1: \quad \text{Overrun} &= 2.775 - 0.323(\text{Involvement}) - 0.002(\text{Person-months})\end{aligned}$$

Project Manager Power:

$$\begin{aligned}\text{If } i = 0: \quad \text{Duration} &= 5.042 + 3.498(\text{Power}) + 0.058(\text{COV}_{(\text{Person-months} \times \text{Power})}) \\ \text{If } i = 1: \quad \text{Duration} &= 5.84 + 3.498(\text{Power}) + 0.058(\text{COV}_{(\text{Person-months} \times \text{Power})}) \\ \text{If } i = 0: \quad \text{Overrun} &= 3.365 - 4.184(\text{Power}) + 0.048(\text{COV}_{(\text{Person-months} \times \text{Power})}) \\ \text{If } i = 1: \quad \text{Overrun} &= 5.006 - 4.184(\text{Power}) - 0.024(\text{Person-months}) + \\ &\quad 0.048(\text{COV}_{(\text{Person-months} \times \text{Power})})\end{aligned}$$

After controlling for total person-months, no significant differences between the ISO 9001 sample and the non-ISO 9001 sample were identified when the hypotheses were tested individually.

5.8.3 Stepwise Multiple Regression

A stepwise multiple regression was performed to measure the change to the hypotheses variables that is due to ISO 9001 registration. While controlling for total person-months and measuring the effect of the dummy variable (the ISO 9001 registration status), the main effects of all of the hypotheses and their interactions with the dummy variable were calculated. A new variable, $COV_{(i \times \text{Planning} \times \text{Person-months})}$, which is the product of the dummy variable, time spent planning relative to total person-months and total person-months (a three-way interaction), was created for this model. A definition of the additional variables used in the test equations is provided below.

- B_0 = constant, vertical intercept
- B_1 = B of the dummy variable
- B_2 = B of Person-months
- B_3 = B of Planning
- B_4 = B of $COV_{(i \times \text{Planning})}$
- B_5 = B of Testing
- B_6 = B of $COV_{(i \times \text{Testing})}$
- B_7 = B of Coding
- B_8 = B of $COV_{(i \times \text{Coding})}$
- B_9 = B of Records
- B_{10} = B of $COV_{(i \times \text{Records})}$
- B_{11} = B of Reviews
- B_{12} = B of $COV_{(i \times \text{Reviews})}$
- B_{13} = B of Involvement
- B_{14} = B of $COV_{(i \times \text{Involvement})}$
- B_{15} = B of Power

$$B_{16} = B \text{ of } COV_{(i \times Power)}$$

$$B_{17} = B \text{ of } (Planning \times Person\text{-}months)$$

Planning, Testing, Coding, Records, Reviews, Involvement, Power:

$$\begin{aligned} \text{Duration, Overrun} = & B_0 + B_1(i) + B_2(\text{Person-months}) + B_3(\text{Planning}) + B_4(COV_{(i \times Planning)}) \\ & + B_5(\text{Testing}) + B_6(COV_{(i \times Testing)}) + B_7(\text{Coding}) + B_8(COV_{(i \times Coding)}) \\ & + B_9(\text{Records}) + B_{10}(COV_{(i \times Records)}) + B_{11}(\text{Reviews}) + B_{12}(COV_{(i \times Reviews)}) \\ & + B_{13}(\text{Involvement}) + B_{14}(COV_{(i \times Involvement)}) + B_{15}(\text{Power}) + \\ & B_{16}(COV_{(i \times Power)}) + B_{17}(COV_{(i \times Planning \times Person\text{-}months)}) \end{aligned}$$

$$\begin{aligned} \text{If } i = 1 \quad = & B_0 + B_1 + B_2(\text{Person-months}) + B_3(\text{Planning}) + B_4(\text{Planning}) + \\ & B_5(\text{Testing}) + B_6(\text{Testing}) + B_7(\text{Coding}) + B_8(\text{Coding}) + \\ & B_9(\text{Records}) + B_{10}(\text{Records}) + B_{11}(\text{Reviews}) + B_{12}(\text{Reviews}) + \\ & B_{13}(\text{Involvement}) + B_{14}(\text{Involvement}) + B_{15}(\text{Power}) + B_{16}(\text{Power}) + \\ & B_{17}(\text{Planning} \times \text{Person-months}) \end{aligned}$$

$$\begin{aligned} = & (B_0 + B_1) + B_2(\text{Person-months}) + (B_3 + B_4)(\text{Planning}) + (B_5 + \\ & B_6)(\text{Testing}) + (B_7 + B_8)(\text{Coding}) + (B_9 + B_{10})(\text{Records}) + (B_{11} + \\ & B_{12})(\text{Reviews}) + (B_{13} + B_{14})(\text{Involvement}) + (B_{15} + B_{16})(\text{Power}) + \\ & B_{17}(COV_{(\text{Person-months} \times \text{Planning})}) \end{aligned}$$

$$\begin{aligned} \text{If } i = 0: \quad = & B_0 + B_2(\text{Person-months}) + B_3(\text{Planning}) + B_5(\text{Testing}) + \\ & B_7(\text{Coding}) + B_9(\text{Records}) + B_{11}(\text{Reviews}) + B_{13}(\text{Involvement}) + \\ & B_{15}(\text{Power}) \end{aligned}$$

If there were no difference between the two groups, then:

$$B_1 = B_4 = B_6 = B_8 = B_{10} = B_{12} = B_{14} = B_{16} = B_{17} = 0$$

The stepwise regression found no significant difference between the ISO 9001 sample and the non-ISO 9001 sample.

5.8.4 F-Test

An F-test was run on the full and reduced models to test the hypothesis that the two groups are the same:

$$H_0 = B_1 = B_4 = B_6 = B_8 = B_{10} = B_{12} = B_{14} = B_{16} = B_{17} = 0$$

A rejection of the hypothesis would mean that at least one of these values is non-zero.

$$F_{9, \text{ERROR d.f.}} = \frac{(\text{SSR}_F - \text{SSR}_R) / 9 \text{ variables}}{(\text{SSE}_F / (\text{Error d.f.}_F))}$$

SS = Sum of squares
 R = Regression
 E = Error
 F = Full model
 R = Reduced model

An F-test was conducted for project duration:

$$F_{9, 34} = \frac{(4475.41333 - 3439.00039) / 9}{65.83173}$$

$$= 1.7493$$

The critical value for this F-test to a five percent level of significance was 2.19.

The product of the F-test, 1.7493, was not within the critical interval resulting in the hypothesis being rejected. When all variables related to ISO 9001 registration are considered collectively, no significant difference between the two groups in terms of project duration was detected.

This test was followed by an F-test on schedule overrun:

$$F_{9, 34} = \frac{(2613.00931 - 2107.6017) / 9}{22.93581}$$

$$= 2.4484$$

At a five percent level of significance, the product of this F-test, 2.4484, was greater than the critical value of 2.19. Therefore, a significant difference between the two groups in terms of schedule overrun was identified when all variables are considered collectively.

Chapter 6

Conclusion

6.1 Summary of Findings

The objective of this research was to determine whether or not there was a difference in the software project management practices of software development organizations that are registered to the ISO 9001 standard and those that are not ISO 9001 registered. Eight hypotheses were developed based on an extensive review of the literature and interviews with software project managers, ISO 9000 auditors and consultants. To test the hypotheses, a questionnaire was sent to 93 project managers from firms developing software in Canada. Data from 20 ISO 9001 projects and 32 non-ISO 9001 projects were used in the study. Several of the results are worth highlighting.

The statistical analysis suggests that, when controlling for project size, no significant differences between the two groups could be explained by a single project characteristic related to ISO 9001 registration. The 8 hypotheses were rejected. However, when all of the project characteristics related to the hypotheses were considered collectively, there was a significant difference between the two groups related to schedule overrun.

This conclusion that there is a significant difference in software project management between ISO 9001 and non-ISO 9001 organizations in terms of schedule overrun contradicts the opinion of Capers Jones who argues that ISO 9001 registration does not appear to affect the failure or success patterns of software projects (Jones, 1995:

27). It also does not support the dissenting view that ISO 9001 registration damages an organization's performance (Seddon, 1996: 13).

Individually, some variables identified differences between the two groups; however, these differences were not necessarily attributable to the ISO 9001 registration status of the samples and may be explained by other influencing factors. The non-ISO 9001 sample spent slightly more time planning (19.4% versus 17%), record keeping (6.8% versus 5.2%), and conducting design reviews and code inspections (8.5% versus 7.4%). The ISO 9001 projects spent 21.1 percent of their person-months on testing versus 16.4 percent by non-ISO 9001 projects. The project managers of non-ISO 9001 projects had more power and influence over resources than their ISO 9001 counterparts.

The projects from the ISO 9001 sample averaged a 16.5 percent schedule overrun. This compared with a 17.9 percent schedule overrun for the non-ISO 9001 sample. Respondents from both groups were very satisfied that their projects met the client's requirements.

The two groups differed in their ranking of the importance of the eight hypotheses. The ISO 9001 group placed more importance on time spent conducting design reviews and code inspections, the involvement of software engineers in project planning and time spent planning. The non-ISO 9001 respondents attributed more importance to project manager power and the involvement of customers in development activities. The respondents from both samples were similar in their ranking of time spent testing, record keeping, coding and planning.

When asked whether any differences in software project management could be attributed to ISO 9001 registration, the ISO 9001 project managers either attributed process improvements to the standard or stated that their ISO 9001 registration required very few changes to their already mature project management practices. Two of the 11 non-ISO 9001 project managers that responded to the open-ended question also attributed a more defined process to ISO 9001 registration. However, the remaining non-ISO 9001 respondents did not attribute any changes in software project management practices to ISO 9001 registration.

An 86 percent correlation was observed between time spent record keeping and schedule overrun. A 73 percent correlation between project duration and schedule overrun suggests that the longer a project, the greater the likelihood it will exceed its schedule.

Many of the ISO 9001 respondents attributed several benefits to the more formalized processes that are associated with ISO 9001 registration. However, the effects of ISO 9001 registration on the project management practices examined in this research did not translate into differences between the projects of ISO 9001 and non-ISO 9001 organizations that participated in this study.

6.2 Limitations of the Study

The following are potential limitation to the study:

- *self-serving bias*: the project managers who reported dissatisfaction with their project's outcome may be more likely to understate their influence over the distribution of resources and the design of the software.

- *accuracy of the responses*: respondents provided information on projects completed for periods up to three years. Over time, the accuracy of the responses is likely to diminish. Further, the retrospective nature of the responses may introduce some after-the-fact rationalization.
- *measurement*: it is possible that other unmeasured factors contributed to differences in project management practices between ISO 9001 registered organizations and those not registered to the ISO 9001 standard.
- *generalizability*: the sample consists of software projects in Canadian organizations. The sample is not necessarily random. The specific findings of this study may not hold true for other organizations.

6.3 Suggestions for Further Research

The findings of this research highlight the need for further research on the effects of ISO 9001 registration. One of the conclusions of this research is that there is a difference in schedule overrun between ISO 9001 and non-ISO 9001 software organizations.

Identification of the differences and their influence on scheduling and project management would assist managers to identify the factors likely to result schedule overruns.

This study also found the two groups differed in their ranking of the importance to project success of the hypotheses, and the differences in project management attributed to ISO 9001 registration. Further research on how and why these perceptions differ would assist in identifying the process and perception changes associated with ISO 9001

registration. It may also explain why more software companies have not used ISO 9001 as a model for their quality system.

The hypotheses failed to identify differences between ISO 9001 and non-ISO 9001 organizations. Further research using more variables and a larger sample size may reveal differing results.

The software industry would benefit from research on the impact of other software project management and quality assurance models. A comparison of the differences in project management between companies using the Software Engineering Institute's Capability Maturity Model (SEI CMM) and those not using the model would be valuable.

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Appendix A: The 20 Requirements of ISO 9001

Requirement Titles	
4.1	Management Responsibility ⁵
4.2	Quality System ¹
4.3	Contract Review ¹
4.4	Design Control ¹
4.5	Document and Data Control ⁵
4.6	Purchasing ^{1, 2, 3}
4.7	Control of Customer-Supplied Product ¹
4.8	Product Identification and Traceability ¹
4.9	Process Control ¹
4.10	Inspection and Testing ²
4.11	Control of Inspection, Measuring, and Test Equipment ²
4.12	Inspection and Test Status ²
4.13	Control of Nonconforming Product ¹
4.14	Corrective and Preventive Action ⁴
4.15	Handling, Storage, Packaging, Preservation, and Delivery ¹
4.16	Control of Quality Records ⁵
4.17	Internal Quality Audits ^{2, 4}
4.18	Training ⁵
4.19	Servicing ¹
4.20	Statistical Techniques ¹

ISO 9001 elements are keyed to the following categories:

- ¹ Process Definition
- ² Process Measurement
- ³ Process Control
- ⁴ Process Improvement
- ⁵ Administrative

Appendix B: Cover Letter to Questionnaire

<insert date>

Dear Software Project Manager,

I am seeking your cooperation in the collection of data for my research on *the differences in project management practices between ISO 9001 and non-ISO 9001 software organizations*. There have been many claims regarding the benefits of ISO 9001 registration by software organizations; however, very little empirical research has been conducted to substantiate these claims. This research is supervised by Professor Tony Bailetti of the Department of Systems and Computer Engineering at Carleton University in Ottawa.

Completion of the attached questionnaire is expected to take no more than 15 minutes. To complete the questionnaire, consider a project you managed that was completed within the last 3 years. The questions pertain to the project management practices and project characteristics **for that anonymous project**. If you have difficulty answering a question, please leave it blank.

All data provided will be kept completely confidential. No link will ever be made between you, your employer or the answers you provided. This page will be detached upon receipt of a completed questionnaire.

Your cooperation is appreciated. If you require any clarification, please do not hesitate to contact me. I may be reached by telephone: (613) 591-8383, by fax: (613) 591-8384, or email: cfitzgib@ccs.carleton.ca.

In the case of incomplete responses, I may need to contact you personally. Please provide your:

Name: _____

Email Address: _____

Phone Number: _____

Place an "X" here ____ if you wish to receive a copy of the research results.

Thank you for your participation.

Most Sincerely,

Chris FitzGibbon

Appendix C: Piloted Questionnaire

Instructions

This questionnaire focuses on the project management practices of software development projects. Completion of the questionnaire is expected to take no more than 15 minutes. If you have difficulty answering a question, please leave it blank. Thank you for your participation.

Please consider a project completed prior to June 1, 1997 for which you held project managerial responsibilities.

Part I: The Project Characteristics and Milestones

1. What was the total number of work-months dedicated to the project? # _____ months
2. For the project in question, please provide the three milestones below:

____/____ **Project Start Date:** when personnel first assigned to analyze the software requirements
month/year

____/____ **Estimated Project Completion Date:** date of final sign-off and acceptance
month/year by client estimated in the initial project plan.

____/____ **Actual Project Completion Date:** date of final sign-off and acceptance by
month/year client

For the following questions, two part-time project team members are equivalent to one full-time project team member.

3. How many full-time staff (or equivalent) were part of the project team? # _____
4. How many full-time software engineers (or equivalent) were members of the project team? # _____

Part II: Project Activities

Please allocate percentages of the project's duration dedicated to the following activities. The sum of percentages may exceed 100%.

Project duration is the total effort in time required to complete the software development project. The project starts when personnel are assigned to analyze the software requirements and ends at final sign-off and acceptance by the client.

5. What percentage of the project's duration was devoted to project planning? % _____

6. What percentage of the project's duration was devoted to software testing?
Testing is defined as the execution of a program to find its faults. % _____
7. What percentage of the project's duration was devoted to software coding? % _____
8. What percentage of the project's duration was devoted to maintaining project records? % _____
9. What percentage of the project's duration was devoted to conducting design reviews and code inspections, including formal and informal inspections, walkthroughs and peer reviews? % _____

Part III: Project Participation

10. Please indicate with an X the activities for which *client representatives* (or their representatives) and *software engineers* (or their equivalent) actively participated:

Project Activity	Clients or their Representatives	Software Engineers or their equivalent
Planning		
Testing		
Coding		
Record Keeping		
Design Reviews and Code Inspections		

Part IV: Importance Ratings

On the scale below, please circle the degree of importance you attribute to the following (1 = very high, 5 = very low):

11. The importance of including *clients* or their representatives in the planning stage of the project life cycle

Very High
(extensive)

Very Low
(limited)

1
2
3
4
5

12. The importance of including *software engineers* in the planning stage of the project life cycle

1 2 3 4 5

Part V: The Project Manager

Software project management is defined as the process of planning, organizing, staffing, monitoring, controlling, and leading a software project.

On the scale below, please circle the most accurate description of the project manager for the project in question (1 = very high, 5 = very low):

	Very High (extensive)				Very Low (limited)
13. The project manager could influence the distribution of resources when needed	<hr/>				
	1	2	3	4	5
14. The project manager had direct access to and responsibility for the work of all those involved in the project	<hr/>				
	1	2	3	4	5
15. The project manager was a senior company manager	<hr/>				
	1	2	3	4	5
16. The project manager had considerable expertise and experience and wielded significant organizational clout	<hr/>				
	1	2	3	4	5

Part VI: Project Manager Power

The power of a project manager is determined by how extensive a role they take in each of the following six areas. On the scale below, please circle the most appropriate rating of the project manager's power for the project in question (1 = limited, 5 = extensive):

	Very High (limited)				Very Low (extensive)
17. Duration of responsibilities	<hr/>				
	1	2	3	4	5
18. Responsible for specifications, features, and layout	<hr/>				
	1	2	3	4	5

19. Working level contact with software engineers or their equivalent

1 2 3 4 5

20. Direct contact with clients

1 2 3 4 5

21. Influence in engineering

1 2 3 4 5

22. Influence in marketing

1 2 3 4 5

Part VII: Project Outcome

What was your degree of satisfaction that the project met the client's requirements? Please circle the appropriate rating on the scales provided (1=very dissatisfied and 5=very satisfied):

23. Satisfaction the project met the client's requirements
- Very Dissatisfied Very Satisfied
- _____
- 1 2 3 4 5

Part VIII: Conclusion

- 24a) Was the company registered to the ISO 9001 quality standard at the time the project was completed? Yes ____ No ____
- 24b) IF NO, is the company now ISO 9001 registered or is it actively working toward achieving ISO 9001 registration? Yes ____ No ____
25. Are the projects of organizations registered to the ISO 9001 quality standard better managed than the projects of non-ISO 9001 organizations? Yes ____ No ____

Please Comment: _____

In the case of missing responses, I may need to contact you personally. Be assured that your responses will be held in the strictest confidence. Please provide your:

Name: _____

Email Address: _____

Phone Number: _____

Please indicate if you would like to receive a copy of the research results?

Yes ____ No ____

Thank you for your participation!

Appendix D: Questionnaire

Instructions

Please consider a *custom software project* completed within the last 3 years for which you were the project manager. A custom software project is defined as a project with software developed to internal or external customer expectations such as requirements, schedules and budgets.

Part I: The Project Characteristics and Milestones

1. What was the total number of person-months dedicated to the project? # ____ months
2. For the project in question, please provide the three milestones below:

____/____ **Project Start Date:** when personnel were first assigned to analyze the
month/year software requirements

____/____ **Estimated Project Completion Date:** date of final sign-off by client
month/year estimated in the *initial project plan*.

____/____ **Actual Project Completion Date:** date of final sign-off by client
month/year

3. What was the approximate software development budget for this project?
\$_____

Part II: Project Activities

In question #1, you provided the total number of person-months dedicated to the project. Please provide the approximate number of person-months allocated to the following activities.

4. How many person-months were devoted to project planning?
Planning may include activities such as requirements analysis, specification development, project scheduling, risk analysis, estimating, budgeting, and establishing commitments. _____ person-months
5. How many person-months were devoted to testing? Testing is defined as the execution of a program to find its faults. _____ person-months
6. How many person-months were devoted to software coding?
Coding includes writing the code, the program instructions and implementing re-usable code. _____ person-months

7. How many person-months were devoted to maintaining project records? Project records are documented historical data on a project. _____ person-months
8. How many person-months were devoted to conducting design reviews and code inspections, including formal and informal inspections, walkthroughs and peer reviews? _____ person-months

Part III: Project Participation

For the project in question, was there active participation by software engineers and clients in the following:

9. Did *software engineers* actively participate in project planning? Yes _____ No _____
10. Did *clients* actively participate in project planning? Yes _____ No _____
11. Did *clients* actively participate in testing? Yes _____ No _____
12. Did *clients* actively participate in design reviews and code inspections? Yes _____ No _____

Part IV: Importance Rankings

13. Please rank the following project characteristics in order of the most important contributor to project success to the least important contributor to project success. Place a number from 1 (most important) to 8 (least important) beside each characteristic.

- _____ Time spent planning
- _____ Time spent testing
- _____ Time spent developing software code
- _____ Time spent maintaining project records
- _____ Time spent conducting design reviews and code inspections
- _____ Customer involvement in the software development process
- _____ Involvement of software engineers in project planning
- _____ Project manager power

Part V: The Project Manager

Software project management is defined as the process of planning, organizing, staffing, monitoring, controlling, and leading a software project.

On the scale below, please circle your degree of agreement with the description of the project manager *for the project in question* (1 = strongly disagree, 5 = strongly agree):

- | | Strongly
Disagree | | | | Strongly
Agree |
|---|----------------------|---|---|---|-------------------|
| 14. The project manager could influence the distribution of resources when needed | | | | | |
| | 1 | 2 | 3 | 4 | 5 |

On the scale below, please circle the most appropriate rating of how extensive a role the project manager took in each of the following two areas for the project in question (1 = limited, 5 = extensive):

	Limited				Extensive
15. Degree of responsibility for specifications, features, and layout					
	1	2	3	4	5
16. Direct contact with clients					
	1	2	3	4	5

Part VI: Project Outcome

As project manager, what was your degree of satisfaction that the project met the client's requirements? Please circle the appropriate rating on the scale provided (1 = very dissatisfied and 5 = very satisfied):

- | | Very
Dissatisfied | | | | Very
Satisfied |
|--|----------------------|---|---|---|-------------------|
| 17. Your satisfaction the software met the client's requirements | | | | | |
| | 1 | 2 | 3 | 4 | 5 |

Part VII: Conclusion

18. Was the organization registered to the ISO 9001 quality standard when the project started?

Yes ____ (if yes, go to question 20)
No ____

19. IF NO, is the organization now ISO 9001 registered or is it actively working toward achieving ISO 9001 registration? Yes ____ No ____
20. Do you attribute any differences in software project management to ISO 9001 registration? Please comment:

Thank you for your participation!

Appendix E: Coding Scheme

Respondent # _____

V1. _____ person-months

V2a) ____/____ Project Start Date
month/year

V2b) ____/____ Est. Project Completion Date
month/year

V2c) ____/____ Actual Project Completion Date
month/year

V3. \$_____ software budget

V4. _____ planning (person-months)

V5. _____ testing (person-months)

V6. _____ coding (person-months)

V7. _____ maintaining records (person-months)

V8. _____ design reviews and code inspections (person-months)

V9. Yes (1) _____ No (0) _____ software engineer participation in planning

V10. Yes (1) _____ No (0) _____ client participation planning

V11. Yes (1) _____ No (0) _____ client participation testing

V12. Yes (1) _____ No (0) _____ client participation design reviews and code inspections

V13a) _____ Time spent planning

V13b) _____ Time spent testing

V13c) _____ Time spent developing software code

V13d) _____ Time spent maintaining project records

V13e) _____ Time spent conducting design reviews and code inspections

V13f) _____ Customer involvement in the software development process

V13g) _____ Involvement of software engineers in project planning

V13h) _____ Project manager power

- V14. ____ PM could influence dist. of resources (1 = strongly disagree, 5 = strongly agree)
- V15. ____ PM responsibility for specs (1 = limited, 5 = extensive)
- V16. ____ Direct contact with clients (1 = limited, 5 = extensive)
- V17. ____ PM satisfaction with software (1=very dissatisfied and 5=very satisfied)
- V18. Yes ____ (1) No ____ (0) ISO 9001 registered?
- V19. Yes ____ (1) No ____ (0) IF V18 = NO, actively seeking ISO 9001?
- V20. The differences in project management attributed to ISO 9001:

Calculated Variables:

- V21. Project Duration (V2c-V2a) ____ Months
- V22. Schedule Overrun (V2c-V2b) ____ Months
- V23. Schedule Overrun as a Percentage of Project Duration (V22/V21) ____ %
- V24. Planning as a Percentage of Person-months (V4/V1) ____ %
- V25. Testing as a Percentage of Person-months (V5/V1) ____ %
- V26. Coding as a Percentage of Person-months (V6/V1) ____ %
- V27. Maintaining Records as a Percentage of Person-months (V7/V1) ____ %
- V28. Design Reviews as a Percentage of Person-months (V8/V1) ____ %
- V29. Involvement (V9 + V10 + V11 + V12)/4: ____ % (0 = no involvement)
- V30. PM Power (V14 + V15 + V16)/15: ____ % (0 = no power)
- V31. $V31 = V18 \times V1$

- V32.** $V_{32} = V_{18} \times V_{24}$
- V33.** $V_{33} = V_{24} \times V_1$
- V34.** $V_{34} = V_{18} \times V_{25}$
- V35.** $V_{35} = V_{25} \times V_1$
- V36.** $V_{36} = V_{18} \times V_{26}$
- V37.** $V_{37} = V_{26} \times V_1$
- V38.** $V_{38} = V_{18} \times V_{27}$
- V39.** $V_{39} = V_{27} \times V_1$
- V40.** $V_{40} = V_{18} \times V_{28}$
- V41.** $V_{41} = V_{28} \times V_1$
- V42.** $V_{42} = V_{18} \times V_{29}$
- V43.** $V_{43} = V_{29} \times V_1$
- V44.** $V_{44} = V_{18} \times V_{30}$
- V45.** $V_{45} = V_{30} \times V_1$
- V46.** $V_{46} = V_{18} \times V_{24} \times V_1$

Appendix F: Definition of Variables

Abbreviated Name	Variable	Measure
<i>Dependent</i>		
Duration	Project Duration	project duration = actual completion date - project start date
Overrun	Schedule Overrun	schedule overrun = (actual completion date - estimated completion date)/project duration
Satisfaction	Project Manager Satisfaction that the Project met Client Requirements	Likert scale: 1 = very dissatisfied and 5 = very satisfied
<i>Control Variables</i>		
Person-months	Total Person-months Dedicated to Software Development Activities	total person-months
Budget	The Project's Software Development Budget	project budget in Canadian dollars
<i>Dummy Variable</i>		
ISO 9001 Registered?	i = 1 if organization was ISO 9001 registered at the start of the project	
	i = 0 if organization was not ISO 9001 registered at the start of the project	
<i>Independent Variables</i>		
Planning	Time Spent Planning Relative to Total Person-months	planning = time spent planning/total person-months
Testing	Time Spent Testing Relative to Total Person-months	testing = time spent testing/total person-months
Coding	Time Spent Coding Relative to Total Person-months	coding = time spent coding/total person-months
Records	Time Spent Maintaining Records Relative to Total Person-months	records = time spent maintaining record keeping/total person-months
Reviews	Time Spent Conducting Design Reviews and Code Inspections Relative to Total Person-months	reviews = time spent conducting design reviews and code inspections/total person-months
Involvement	Involvement Measure	involvement = (software engineer participation in planning + client participation planning + client participation testing + client participation design reviews and code inspections)/4 (0 = no involvement, 1 = maximum involvement)
Power	Project Manager Power	power = (Project Manager influence over the distribution of resources + Project Manager responsibility for specs + Project Manager direct contact with clients)/15 (0 = no power, 1 = maximum power)
Importance Rankings	A respondent ranking from most important to least important of: time spent planning, time spent testing, time spent coding, time spent maintaining project records, time spent conducting design reviews and code inspections, customer involvement in the software development process, the involvement of software engineers in project planning, and project manager power	

Appendix G: Correlation Tables

The correlations for all of the main numeric variables in the study are provided in the tables below. A correlation could not be calculated between the company's ISO 9001 registration status (V18) and whether the company is currently pursuing ISO 9001 registration (V19) because the latter does not apply to organizations already registered to ISO 9001. A correlation greater than 0.6 or less than -0.6 was considered high.

The variables contained in the correlation tables are defined below.

Variables:

V1:	total person-months	V16:	Project Manager direct contact with clients (1 = limited, 5 = extensive)
V2a:	project start date	V17:	Project Manager satisfaction with software (1=very dissatisfied and 5=very satisfied)
V2b:	estimated completion date	V18:	ISO 9001 registered? (Yes = 1, No = 0)
V2c:	actual completion date	V19:	if V18 = NO, actively seeking ISO 9001? (Yes = 1, No = 0)
V3:	software budget (dollars)	V20:	open-ended question
V4:	person-months spent planning	V21:	project duration (V2c-V2a)
V5:	person-months spent testing	V22:	schedule overrun (V2c-V2b)
V6:	person-months spent coding	V23:	schedule overrun relative to project duration (V22/V21)
V7:	person-months spent maintaining records	V24:	planning relative to total person-months (V4/V1)
V8:	person-months spent conducting design reviews and code inspections	V25:	testing relative to total person-months (V5/V1)
V9:	software engineer participation in planning (Yes = 1, No = 0)	V26:	coding relative to total person-months (V6/V1)
V10:	client participation planning (Yes = 1, No = 0)	V27:	maintaining records relative to total person-months (V7/V1)
V11:	client participation testing (Yes = 1, No = 0)	V28:	design reviews relative to total person-months (V8/V1)
V12:	client participation design reviews and code inspections (Yes = 1, No = 0)	V29:	involvement measure (V9 + V10 + V11 + V12)/4
V13:	importance rankings	V30:	PM power (V14 + V15 + V16)/15 (0 = no power)
V14:	Project Manager influence over the distribution of resources (1 = strongly disagree, 5 = strongly agree)		
V15:	Project Manager responsibility for specs (1 = limited, 5 = extensive)		

Correlation Table (Variables V1 to V16 with V1 to V16)														
	V1	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V14	V15	V16
V1	1													
V3	0.854	1												
V4	0.758	0.77	1											
V5	0.826	0.742	0.614	1										
V6	0.888	0.707	0.667	0.739	1									
V7	0.67	0.414	0.485	0.533	0.599	1								
V8	0.781	0.805	0.5	0.844	0.668	0.206	1							
V9	0.051	0.034	-0.217	0.012	0.074	0.01	0.1	1						
V10	-0.127	0.022	-0.1	-0.175	0	0.024	-0.194	0.209	1					
V11	0.01	0.176	0.068	-0.149	0.033	0.029	-0.137	-0.06	0.224	1				
V12	-0.176	0	-0.191	-0.209	-0.112	-0.135	-0.107	0.136	0.326	0.111	1			
V14	-0.09	0.202	0.019	-0.312	-0.145	0	-0.266	0.084	0.104	0.219	-0.09	1		
V15	-0.365	-0.08	-0.214	-0.399	-0.309	-0.182	-0.325	0.127	0.265	0.107	0.269	0.277	1	
V16	-0.358	-0.185	-0.288	-0.409	-0.205	-0.05	-0.477	0.116	0.34	0.25	0.257	0.365	0.382	1

Correlation Table (Variables V17 to V30 with V1 to V16)														
	V1	V3	V4	V5	V6	V7	V8	V9	V10	V11	V12	V14	V15	V16
V17	-0.06	0.19	-0.11	-0.19	-0.18	-0.08	-0.05	0.04	0.03	0	0.09	0.51	0.05	0.23
V18	0.17	0.05	-0.01	0.2	0.19	-0.06	0.23	0.04	-0.11	-0.32	0.09	-0.1	-0.08	-0.08
V19	0.16	0.1	-0.06	0.09	0.14	0.23	0.09	0.27	0.11	-0.32	-0.06	0.12	0.03	0.21
V21	0.62	0.57	0.53	0.41	0.65	0.67	0.24	0.14	-0.09	-0.04	-0.14	0.06	-0.11	0
V22	0.42	0.25	0.24	0.24	0.43	0.87	-0.07	0.11	0.07	0.04	-0.17	0.08	-0.05	0.16
V23	0.03	-0.1	-0.11	-0.04	0.08	0.37	-0.2	0.19	0	-0.07	-0.13	0.06	0.04	0.17
V24	-0.24	-0.16	0.11	-0.17	-0.26	-0.13	-0.19	0.01	0.35	-0.17	0.04	-0.03	0.19	-0.03
V25	-0.04	-0.22	0.01	0.24	-0.07	-0.02	0.06	-0.04	-0.14	-0.14	-0.14	-0.21	0.04	-0.14
V26	-0.18	-0.21	-0.26	-0.17	0.73	-0.1	-0.14	-0.1	-0.05	0.03	-0.07	-0.14	0.21	0.04
V27	0.42	0.25	0.39	0.34	0.37	0.84	0.03	-0.04	0.03	0.02	-0.03	-0.03	0.02	-0.04
V28	-0.02	0.15	-0.09	0.05	-0.04	-0.11	0.27	-0.02	0.05	-0.04	0.13	0.03	0.2	0.03
V29	-0.12	0.09	-0.17	-0.23	-0.02	-0.03	-0.16	0.44	0.76	0.53	0.68	0.12	0.32	0.41
V30	-0.37	-0.05	-0.23	-0.5	-0.29	-0.1	-0.48	0.15	0.33	0.26	0.21	0.7	0.73	0.81

Correlation Table (Variables V17 to V30 with V17 to V30)													
	V17	V18	V19	V21	V22	V23	V24	V25	V26	V27	V28	V29	V30
V17	1												
V18	0.024	1											
V19	0.277		1										
V21	-0.131	0.082	0.359	1									
V22	-0.121	-0.07	0.349	0.733	1								
V23	-0.247	-0.03	0.375	0.317	0.655	1							
V24	0.039	-0.09	-0.02	-0.221	-0.159	-0.141	1						
V25	-0.342	0.221	-0.194	-0.07	-0.101	0.011	-0.04	1					
V26	-0.369	0	-0.232	-0.06	0.02	0.163	-0.346	0.103	1				
V27	-0.139	-0.113	0.2	0.505	0.716	0.425	0.092	0.032	-0.07	1			
V28	0.312	-0.07	0.292	0.017	-0.01	-0.08	0	-0.05	-0.126	0	1		
V29	0.061	-0.124	0.01	-0.08	0	-0.03	0.113	-0.192	-0.07	0	0.064	1	
V30	0.341	-0.119	0.174	-0.03	0.09	0.126	0.053	-0.132	0.058	-0.02	0.115	0.391	1

Appendix H: MANCOVA Analysis

This appendix provides the results multivariate analysis of covariance used to derive the test equations and test the hypotheses. The variables used in the model are defined and then a step-by-step walkthrough of the MANCOVA is provided.

Overrun = schedule overrun

Duration = project duration

Satisfaction = project manager satisfaction

Dummy variable:

$i = 1$ if ISO 9001 sample

$i = 0$ if non-ISO 9001 sample

HYP = represents one of the measures for the hypothesis:

Planning = planning relative to total person-months

Testing = testing relative to total person-months

Coding = coding relative to total person-months

Records = maintaining records relative to total person-months

Reviews = design reviews and code inspections relative to total person-months

Involvement = involvement measure

Power = project manager power

Person-months = total person-months dedicated to software development activities

Budget = software development budget

B_0 = constant, vertical intercept

B_1 = B of the dummy variable

B_2 = B of HYP

B_3 = B of total person-months

B_4 = B of (i x HYP)

B_5 = B of (i x Person-months) = B of $COV_{(i \times \text{Person-months})}$

B_6 = B of (HYP x Person-months)

B_7 = B of Budget

B_8 = B of (i x Budget) = B of $COV_{(i \times \text{Budget})}$

B_9 = B of (HYP x Budget)

The vectors (B_j) in the model are indicated in bold; variables representing single values are not bolded. The covariate variables in this analysis are defined below.

$COV_{(i \times \text{Person-months})}$

i x HYP:

COV_(i x Planning)
 COV_(i x Testing)
 COV_(i x Coding)
 COV_(i x Records)
 COV_(i x Reviews)
 COV_(i x Involvement)
 COV_(i x Power)

Person-months x HYP:

COV_(Person-months x Planning)
 COV_(Person-months x Testing)
 COV_(Person-months x Coding)
 COV_(Person-months x Records)
 COV_(Person-months x Reviews)
 COV_(Person-months x Involvement)
 COV_(Person-months x Power)

The model created was:

$$\text{Overrun, Duration, Satisfaction} = B_0 + B_1(i) + B_2(\text{HYP}) + B_3(\text{Person-months}) + B_7(\text{budget}) + B_4(i * \text{HYP}) + B_5(i * \text{Person-months}) + B_8(i * \text{budget}) + B_6(\text{Person-months} * \text{HYP}) + B_9(\text{budget} * \text{HYP})$$

Project budget was removed from the model because of its high correlation with total person-months. The following equation was created:

$$\text{Overrun, Duration, Satisfaction} = B_0 + B_1(i) + B_2(\text{HYP}) + B_3(\text{Person-months}) + B_4(i * \text{HYP}) + B_5(i * \text{Person-months}) + B_6(\text{Person-months} * \text{HYP})$$

If $i = 0$, then the respondent is from the non-ISO 9001 sample, resulting in the following equation:

$$\text{Overrun, Duration, Satisfaction} = B_0 + B_2(\text{HYP}) + B_3(\text{Person-months}) + B_6(\text{Person-months} * \text{HYP})$$

If $i = 1$, then the respondent is ISO 9001 registered and B_1 , B_4 and B_5 measure the effects due to ISO 9001 registration:

$$\begin{aligned} \text{Overrun, Duration, Satisfaction} &= B_0 + B_1 + B_2(\text{HYP}) + B_3(\text{Person-months}) + B_4(\text{HYP}) + B_5(\text{Person-months}) + B_6(\text{Person-months} * \text{HYP}) \\ &= (B_0 + B_1) + \text{HYP}(B_2 + B_4) + (\text{Person-months})(B_3 + B_5) + (\text{Person-months}) * \text{HYP}(B_6) \end{aligned}$$

Following the execution of the MANCOVA on the hypotheses, the variables outside the confidence interval were eliminated from the equation.

A univariate regression followed each MANCOVA to provide the value of B. The covariate variables removed for the MANCOVA were not present during these regressions. Because no significant difference in project manager satisfaction was detected, it was removed from the model. Therefore, based on the values provided by the MANCOVA and the regressions, equations for schedule overrun and project duration were created for each of the hypotheses. Each model below includes a dependent variable (Duration or Overrun), the dummy variable (i), any significant variables (Person-months, $COV_{(i \times \text{Person-months})}$ to $COV_{(\text{Person-months} \times \text{Power})}$) and a constant (B_0).

Planning relative to total person-months (Duration, i, Person-months, $COV_{(i \times \text{Person-months})}$, $COV_{(\text{Person-months} \times \text{Planning})}$)

$$\begin{aligned}
 \text{If } i = 0: \quad \text{Duration} &= B_0 + B_2(\text{HYP}) + B_3(\text{Person-months}) \\
 &= 8.949 - 9.675(\text{Planning}) + 0.0584(\text{Person-months}) \\
 \text{If } i = 1: \quad \text{Duration} &= B_0 + B_1 + B_2(\text{HYP}) + B_3(\text{Person-months}) + B_5(\text{Person-months}) \\
 &= (B_0 + B_1) + B_2(\text{HYP}) + (B_3 + B_5)(\text{Person-months}) \\
 &= (8.989 + 4.712) - 9.675(\text{Planning}) + (0.058 - 0.045)(\text{Person-months}) \\
 &= 13.701 - 9.675(\text{Planning}) + 0.013(\text{Person-months})
 \end{aligned}$$

Planning relative to total person-months (Overrun, i, Person-months, $COV_{(i \times \text{Person-months})}$, $COV_{(\text{Person-months} \times \text{Planning})}$)

$$\begin{aligned}
 \text{If } i = 0: \quad \text{Overrun} &= B_0 + B_2(\text{HYP}) + B_3(\text{Person-months}) + B_6(\text{Person-months} \times \text{HYP}) \\
 &= -0.213 + 5.030(\text{Planning}) + 0.075(\text{Person-months}) - 0.265(COV_{(\text{Person-months} \times \text{Planning})}) \\
 \text{If } i = 1: \quad \text{Overrun} &= B_0 + B_1 + B_2(\text{HYP}) + B_3(\text{Person-months}) + B_4(\text{HYP}) + B_5(\text{Person-months}) + B_6(\text{Person-months} \times \text{HYP}) \\
 &= (B_0 + B_1) + B_2(\text{HYP}) + (B_3 + B_5)(\text{Person-months}) + B_6(\text{Person-months} \times \text{HYP}) \\
 &= (-0.213 + 2.884) + 5.030(\text{Planning}) + (0.075 - 0.059)(\text{Person-months}) - 0.265(COV_{(\text{Person-months} \times \text{Planning})}) \\
 &= 2.671 + 5.030(\text{Planning}) + 0.016(\text{Person-months}) - 0.265(COV_{(\text{Person-months} \times \text{Planning})})
 \end{aligned}$$

Testing relative to total person-months (Duration, i, Person-months, $COV_{(i \times \text{Person-months})}$, $COV_{(\text{Person-months} \times \text{Testing})}$)

$$\begin{aligned}
 \text{If } i = 0: \quad \text{Duration} &= B_0 + B_2(\text{HYP}) + B_3(\text{Person-months}) \\
 &= 7.731 - 4.326(\text{Testing}) + 0.059(\text{Person-months}) \\
 \text{If } i = 1: \quad \text{Duration} &= B_0 + B_1 + B_2(\text{HYP}) + B_3(\text{Person-months}) + B_5(\text{Person-months}) \\
 &= (B_0 + B_1) + B_2(\text{HYP}) + (B_3 + B_5)(\text{Person-months}) \\
 &= (7.731 + 4.926) - 4.326(\text{Testing}) + (0.059 - 0.044)(\text{Person-months}) \\
 &= 12.657 - 4.326(\text{Testing}) + 0.015(\text{Person-months})
 \end{aligned}$$

Testing relative to total person-months (Overrun, i, Person-months, $COV_{(i \times \text{Person-months})}$)

$$\text{If } i = 0: \quad \text{Overrun} = B_0 + B_2(\text{HYP}) + B_3(\text{Person-months})$$

$$= 0.06 - 3.576(\text{Testing}) + 0.045(\text{Person-months})$$

$$\text{If } i = 1: \quad \text{Overrun} = B_0 + B_1 + B_2(\text{HYP}) + B_3(\text{Person-months}) + B_4(\text{HYP}) + B_5(\text{Person-months}) + B_6(\text{Person-months} \times \text{HYP})$$

$$= (B_0 + B_1) + B_2(\text{HYP}) + (B_3 + B_5)(\text{Person-months})$$

$$= (0.06 + 3.285) - 3.576(\text{Testing}) + (0.045 - 0.0467)(\text{Person-months})$$

$$= 3.345 - 3.576(\text{Testing}) - 0.002(\text{Person-months})$$

Coding relative to total person-months (Duration, i, Person-months, $COV_{(i \times \text{Person-months})}$)

$$\text{If } i = 0: \quad \text{Duration} = B_0 + B_2(\text{HYP}) + B_3(\text{Person-months})$$

$$= 5.026 + 4.312(\text{Coding}) + 0.06(\text{Person-months})$$

$$\text{If } i = 1: \quad \text{Duration} = B_0 + B_1 + B_2(\text{HYP}) + B_3(\text{Person-months}) + B_5(\text{Person-months})$$

$$= (B_0 + B_1) + B_2(\text{HYP}) + (B_3 + B_5)(\text{Person-months})$$

$$= (5.026 + 4.743) + 4.312(\text{Coding}) + (0.06 - 0.045)(\text{Person-months})$$

$$= 9.769 + 4.312(\text{Coding}) + 0.015(\text{Person-months})$$

Coding relative to total person-months (Overrun, i, Person-months, $COV_{(i \times \text{Person-months})}$)

$$\text{If } i = 0: \quad \text{Overrun} = B_0 + B_2(\text{HYP}) + B_3(\text{Person-months})$$

$$= -3.049 + 5.468(\text{Coding}) + 0.046(\text{Person-months})$$

$$\begin{aligned}
\text{If } i = 1: \quad \text{Overrun} &= B_0 + B_1 + B_2(\text{HYP}) + B_3(\text{Person-months}) + B_5(\text{Person-months}) \\
&= (B_0 + B_1) + B_2(\text{HYP}) + (B_3 + B_5)(\text{Person-months}) \\
&= (-3.048 + 3.146) + 5.468(\text{Coding}) + (0.047 - 0.047)(\text{Person-months}) \\
&= 0.097 + 5.468(\text{Coding}) - 0.001(\text{Person-months})
\end{aligned}$$

Maintaining project records relative to total person-months (Duration, i, Person-months, $\text{COV}_{(i \times \text{Person-months})}$, $\text{COV}_{(i \times \text{Records})}$, $\text{COV}_{(\text{Person-months} \times \text{Records})}$)

$$\begin{aligned}
\text{If } i = 0: \quad \text{Duration} &= B_0 + B_2(\text{HYP}) + B_3(\text{Person-months}) \\
&= 6.459 + 14.664(\text{Records}) + 0.054(\text{Person-months}) \\
\text{If } i = 1: \quad \text{Duration} &= B_0 + B_1 + B_2(\text{HYP}) + B_3(\text{Person-months}) + B_4(i \times \text{HYP}) + B_5(\text{Person-months}) \\
&= (B_0 + B_1) + (B_2 + B_4)(\text{HYP}) + (B_3 + B_5)(\text{Person-months}) \\
&= (6.459 + 6.061) + (14.664 - 30.654)(\text{Records}) + (0.054 - 0.039)(\text{Person-months}) \\
&= 12.52 - 15.989(\text{Records}) + 0.015(\text{Person-months})
\end{aligned}$$

Maintaining project records relative to total person-months (Overrun, i, Person-months, $\text{COV}_{(i \times \text{Person-months})}$, $\text{COV}_{(i \times \text{Records})}$, $\text{COV}_{(\text{Person-months} \times \text{Records})}$)

$$\begin{aligned}
\text{If } i = 0: \quad \text{Overrun} &= B_0 + B_2(\text{HYP}) + B_3(\text{Person-months}) + B_6(\text{Person-months} \times \text{HYP}) \\
&= 2.194 - 7.738(\text{Records}) - 0.007(\text{Person-months}) + 0.154(\text{COV}_{(\text{Person-months} \times \text{Records})})
\end{aligned}$$

$$\begin{aligned}
\text{If } i = 1: \quad \text{Overrun} &= B_0 + B_1 + B_2(\text{HYP}) + B_3(\text{Person-months}) + B_4(\text{HYP}) + B_5(\text{Person-months}) + B_6(\text{Person-months} * \text{HYP}) \\
&= (B_0 + B_1) + (B_2 + B_4)(\text{HYP}) + (B_3 + B_5)(\text{Person-months}) + B_6(\text{Person-months} * \text{HYP}) \\
&= (2.194 + 3.456) + (-7.738 - 47.432)(\text{Records}) + (-0.007 - 0.004)(\text{Person-months}) + 0.154(\text{COV}_{(\text{Person-months} \times \text{Records})}) \\
&= 5.649 - 55.17(\text{Records}) - 0.012(\text{Person-months}) + 0.154(\text{COV}_{(\text{Person-months} \times \text{Records})})
\end{aligned}$$

Design reviews and code inspections relative to total person-months (Duration, i, Person-months, $\text{COV}_{(i \times \text{Person-months})}$, $\text{COV}_{(\text{Person-months} \times \text{Reviews})}$)

$$\begin{aligned}
\text{If } i = 0: \quad \text{Duration} &= B_0 + B_2(\text{HYP}) + B_3(\text{Person-months}) \\
&= 5.29 + 18.333(\text{Reviews}) + 0.061(\text{Person-months}) \\
\text{If } i = 1: \quad \text{Duration} &= B_0 + B_1 + B_2(\text{HYP}) + B_3(\text{Person-months}) + B_5(\text{Person-months}) \\
&= (B_0 + B_1) + B_2(\text{HYP}) + (B_3 + B_5)(\text{Person-months}) \\
&= (5.29 - 5.238) + 18.333(\text{Reviews}) + (0.061 - 0.047)(\text{Person-months}) \\
&= 0.052 + 18.333(\text{Reviews}) + 0.014(\text{Person-months})
\end{aligned}$$

Design reviews and code inspections relative to total person-months (Overrun, i, Person-months, $\text{COV}_{(i \times \text{Person-months})}$, $\text{COV}_{(\text{Person-months} \times \text{Reviews})}$)

$$\begin{aligned}
\text{If } i = 0: \quad \text{Overrun} &= B_0 + B_2(\text{HYP}) + B_3(\text{Person-months}) \\
&= -0.848 + 3.272(\text{Reviews}) + 0.046(\text{Person-months})
\end{aligned}$$

$$\begin{aligned}
\text{If } i = 1: \quad \text{Overrun} &= B_0 + B_1 + B_2(\text{HYP}) + B_3(\text{Person-months}) + B_5(\text{Person-months}) \\
&= (B_0 + B_1) + B_2(\text{HYP}) + (B_3 + B_5)(\text{Person-months}) \\
&= (-0.848 + 3.204) + 3.272(\text{Reviews}) + (0.045 - 0.047)(\text{Person-months}) \\
&= 2.356 + 3.272(\text{Reviews}) - 0.002(\text{Person-months})
\end{aligned}$$

Involvement Measure (Duration, i, Person-months, $\text{COV}_{(i \times \text{Person-months})}$, $\text{COV}_{(\text{Person-months} \times \text{Involvement})}$)

$$\begin{aligned}
\text{If } i = 0: \quad \text{Duration} &= B_0 + B_2(\text{HYP}) \\
&= 13.564 - 1.796(\text{Involvement})
\end{aligned}$$

$$\begin{aligned}
\text{If } i = 1: \quad \text{Duration} &= B_0 + B_1 + B_2(\text{HYP}) + B_5(\text{Person-months}) \\
&= (B_0 + B_1) + B_2(\text{HYP}) + B_5(\text{Person-months}) \\
&= (13.564 - 0.695) - 1.796(\text{Involvement}) + 0.015(\text{Person-months}) \\
&= 12.87 - 1.796(\text{Involvement}) + 0.015(\text{Person-months})
\end{aligned}$$

Involvement Measure (Overrun, i, Person-months, $\text{COV}_{(i \times \text{Person-months})}$, $\text{COV}_{(\text{Person-months} \times \text{Involvement})}$)

$$\begin{aligned}
\text{If } i = 0: \quad \text{Overrun} &= B_0 + B_2(\text{HYP}) \\
&= 3.751 - 0.323(\text{Involvement})
\end{aligned}$$

$$\begin{aligned}
\text{If } i = 1: \quad \text{Overrun} &= B_0 + B_1 + B_2(\text{HYP}) + B_5(\text{Person-months}) \\
&= (B_0 + B_1) + B_2(\text{HYP}) + B_5(\text{Person-months}) \\
&= (3.751 - 0.975) - 0.323(\text{Involvement}) - 0.002(\text{Person-months}) \\
&= 2.775 - 0.323(\text{Involvement}) - 0.002(\text{Person-months})
\end{aligned}$$

Project manager power (Duration, i, Person-months, COV_(i x Person-months), COV_(Person-months x Power))

$$\begin{aligned}\text{If } i = 0: \quad \text{Duration} &= B_0 + B_2(\text{HYP}) + B_6(\text{Person-months} * \text{HYP}) \\ &= 5.042 + 3.498(\text{Power}) + 0.058(\text{COV}_{(\text{Person-months} \times \text{Power})})\end{aligned}$$

$$\begin{aligned}\text{If } i = 1: \quad \text{Duration} &= B_0 + B_1 + B_2(\text{HYP}) + B_6(\text{Person-months} * \text{HYP}) \\ &= (B_0 + B_1) + B_2(\text{HYP}) + B_6(\text{Person-months} * \text{HYP}) \\ &= (5.042 + 0.798) + 3.498(\text{Power}) + 0.058(\text{COV}_{(\text{Person-months} \times \text{Power})}) \\ &= 5.84 + 3.498(\text{Power}) + 0.058(\text{COV}_{(\text{Person-months} \times \text{Power})})\end{aligned}$$

Project manager power (Overrun, i, Person-months, COV_(i x Person-months), COV_(Person-months x Power))

$$\begin{aligned}\text{If } i = 0: \quad \text{Overrun} &= B_0 + B_2(\text{HYP}) + B_6(\text{Person-months} * \text{HYP}) \\ &= 3.365 - 4.184(\text{Power}) + 0.048(\text{COV}_{(\text{Person-months} \times \text{Power})})\end{aligned}$$

$$\begin{aligned}\text{If } i = 1: \quad \text{Overrun} &= B_0 + B_1 + B_2(\text{HYP}) + B_5(\text{Person-months}) + B_6(\text{Person-months} * \text{HYP}) \\ &= (B_0 + B_1) + B_2(\text{HYP}) + B_5(\text{Person-months}) + B_6(\text{Person-months} * \text{HYP}) \\ &= (3.365 + 1.641) - 4.184(\text{Power}) - 0.024(\text{Person-months}) + 0.048(\text{COV}_{(\text{Person-months} \times \text{Power})}) \\ &= 5.006 - 4.184(\text{Power}) - 0.024(\text{Person-months}) + 0.048(\text{COV}_{(\text{Person-months} \times \text{Power})})\end{aligned}$$

After controlling for total person-months, no significant differences between the ISO 9001 sample and the non-ISO 9001 sample were identified.

Bibliography

- Arter, D. R., "Demystifying the ISO 9000/Q90 Series Standards". *Quality Progress*, November 1992: 65-68.
- Atwater, J. B., and Discenza, R., "ISO 9000: Implications for U.S. Business". 1993 *Proceedings of the Annual Meeting of the Decision Sciences Institute*, 1993: 1784-1786.
- Bailetti, A. J., and FitzGibbon, C., *ISO 9001 Registration for Small and Medium Sized Software Enterprises*. Ottawa: Carleton University Press, 1995.
- Bennatan, E. M., *Software Project Management: A Practitioner's Approach*. Toronto: McGraw-Hill, 1992.
- Bennatan, E. M., *On Time, Within Budget: Software Project Management Practices and Techniques*. Toronto: QED Publishing Group, 1992.
- Berkeley, D., de Hoog, R., and Humphreys, P., *Software Development Project Management: Process and Support*. Toronto: Ellis Horwood, 1990.
- Brooks, F. P., "The Mythical Man-month". *Datamation*, December 1974: 44-52.
- Brown, S.L. and Eisenhardt, K.M., "Product Development: Past Research, Present Findings, and Future Directions." *Academy of Management Review* February 1995, p. 343-378.
- Carmel, E. and Becker, S., "A Process Model for Packaged Software Development". *IEEE Transactions on Engineering Management*, February 1995: 50-61.
- Dalal, R. D., Horgan, J. R., and Kettenring, J. R., "Reliable Software and Communication II: Controlling the Software Development Process". *IEEE Journal on Selected Areas in Communications*, January 1994: 33-39.
- Deming, W. E., *Out of the Crisis*, Cambridge: MIT Center for Advanced Engineering Study, 1982.
- Ebrahimpour, M., Withers, B. E., and Hikmet, N., "Experiences of US- and Foreign-owned firms: A New Perspective on ISO 9000 Implementation". *International Journal of Production Research*, 1997: 569-576.

- Eisenhardt, K. M., and Tabrizi, B. N., "Accelerating Adaptive Processes: Product Innovation in the Global Computer Industry". *Administrative Science Quarterly*, March 1995: 84-110.
- Gupta, A.K. and Wilemon, D.L., "Accelerating the Development of Technology-Based New Products." *California Management Review* Winter 1990, p. 24-44.
- Haug, P., "An Empirical Investigation of ISO 9000 Quality Standards, Registration Process, and Competitive Effects". *1994 Proceedings, Decision Sciences Institute*, 1994: 1954.
- Humphrey, W.S., *Managing the Software Process*. Don Mills: Addison-Wesley, 1989.
- IEEE Std-1058.1-1987: IEEE Standard for Software Project Management Plans. New York: The Institute of Electrical and Electronic Engineers, Inc., 1988.
- Ince, D. C., et al. *Introduction to Software Project Management and Quality Assurance*. London, UK: McGraw-Hill, 1993.
- Information Technologies Industry Branch *A First Review of the Performance of Canada's Software Products Industry: Establishing Benchmarks*. Ottawa: Industry Canada, November 1994.
- ISO 8402: *Quality Vocabulary*. 2nd ed. Geneva: International Organization for Standardization, 1994.
- ISO 9001: *Quality Systems - Model for Quality Assurance in Design, Development, Production, Installation and Servicing*. 2nd ed. Geneva: International Organization for Standardization, 1994.
- ISO 9000-1: *Quality Management and Quality Assurance Standards, Part I: Guidelines for Selection and Use*. 2nd ed. Geneva: International Organization for Standardization, 1994.
- ISO 9000-3: *Guidelines on the Application of ISO 9001 to the Development, Supply and Maintenance of Software*. 1st ed. Geneva: International Organization for Standardization, 1991.
- Jenkins, A. M., Naumann, J. D., and Wetherbe, J. C., "Empirical Investigation of Systems Development Practices and Results". *Information Management* July 1984: 74-82.
- Jones, C., *Patterns of Software Systems Failure and Success*. Toronto: International Thomson Computer Press, 1996.

- Kraut, R. E., and Streeter, L. A., "Coordination in Software Development". *Communications of the ACM*, March 1995: 69-81.
- Manchester Business School, *ISO 9000 - Does it Work?*. Yarsley, England: SGS International Certification Services(Yarsley), 1995.
- Mathers, M., Marshall, R., Caillibot, P., and Phipps, M., *The ISO 9000 Essentials*. Mississauga: Canadian Standards Association, 1994.
- Mobil Europe Ltd.
- Morrow, M., "ISO 9000: Survey Examines Costs, Benefits". *Chemical Week*, 1993: 48.
- Myers, W., "Debating the Many Ways to Achieve Quality". *IEEE Software*, March 1993: 102-103.
- Ould, M. A., *Strategies for Software Engineering: The Management of Risk and Quality*. Toronto: Wiley, 1990.
- Paulk, M. C., Curtis, B., Chrissis, M. B., and Weber, C. V., *Capability Maturity Model for Software*. Version 1.1 Report CMU/SEI-93-TR-24, Pittsburgh: Software Engineering Institute, 1993.
- Paulk, M. C., "The Evolution of the SEI's Capability Maturity Model for Software". *Software Process: Improvement and Practice*, August 1995: 3-15.
- Pengelly, A., Norris, M., and Higham, R., "Software Process Modelling and Measurement: a QMS Case Study". *Information and Software Technology*, June-July 1993: 375-380.
- Reifer, D. J., (Ed.), *Software Management, Fourth Edition*, IEEE Computer Society Press, 1994.
- Rettig, M. and Simons, G., "A Project Planning and Development Process for Small Teams." *Communications of the ACM* October 1993, p. 45-55.
- Rosenau, M. D., and Lewin, M. D., *Software Project Management: Step by Step*. Toronto: Lifetime Learning Publications, 1984.
- Rout, T. P., "SPICE: A Framework for Software Process Assessment". *Software Process: Improvement and Practice*, August 1995: 57-66.
- Royce, W., "Why Software Costs So Much". *IEEE Software*, May 1993: 90-91.

- Rubin, H., Yourdon, E., and Albrecht Battaglia, H., *Worldwide Benchmark Project*. Industry Canada, 1996.
- Seddon, J., Davis, R., Loughran, M., and Murrell, R., *BS5750 Implementation and Value Added: A Survey of Registered Companies*. Buckingham, England: Vanguard Consulting Ltd., 1993.
- Seddon, J., "ISO 9000 Implementation and Value-added: Three Case Studies". Vanguard Consulting: 1996.
- Shelley, C. C., "Practical Experience of Implementing Software Measurement Programmes in Industry". *Software Quality Management*, 1994: 95-106.
- Smith, D. J. and Wood, K. B., *Engineering Quality Software*. New York: Elsevier Applied Science, 1987.
- Software Quality Systems Registration Committee, *A Guide to Software Quality System Registration under ISO 9001*. SQSR, 1994.
- Stelzer, D., "Interpretations of ISO 9000 when Certifying Software Quality Systems. Findings of an Empirical Survey in Germany". Extended abstract of: "Interpretation der ISO 9000-Familie bei der Zertifizierung von Qualitätsmanagementsystemen für die Softwareentwicklung". Norbert Ruppenthal, Ulrich Sigor (Hrsg.): *Qualitätsmanagement und Software: ISO 9000 - Softwareentwicklung - Ethik - Analysen - Tools*. Beiträge vom adi QM/IT Expertentreffen 1994. Münster 1995, S. 15-31.
- Stelzer, D., Mellis, W., and Herzwurm, G., "Software Process Improvement via ISO 9000? Results of two surveys among European software houses". *Proceedings of the 29th Hawaii International Conference on System Sciences*, January 3-6, 1996.
- Surrey University, *Fitter Finance: The Effects of ISO 9000 on Business Performance*. Croydon, England: Lloyd's Register Quality Assurance (LRQA), 1993.
- Thamhain, H. J. and Wilemon, D. L., "Criteria for Controlling Projects According to Plan". *Project Management Journal*, June 1986: 75-81.
- Thompson, K., and McParland, P., "Software Process Maturity (SPM) and the Information Systems Developer". *Information and Software Technology*, June-July 1993: 331-338.

TickIT: Guide to Software Quality Management System Construction and Certification using EN 29001. London: British Department of Trade and Industry and the British Computer Society, 1992.

van Genuchten, M., "Why is Software Late? An Empirical Study of Reasons For Delay in Software Development". *IEEE Transactions on Software Engineering*, June 1991: 582-590.

Walz, D. B., Elam, J. J., and Curtis, B., "Inside A Software Design Team: Knowledge Acquisition, Sharing, and Integration". *Communications of the ACM*, October 1993: 63-77.

Wheelwright, S. C., and Clark, K. B., *Revolutionizing Product Development*. Toronto: Free Press, 1992.

Wilson, D. N., and Sifer, M. J., "Structured planning - Project Views". *Software Engineering Journal*, July 1988: 134-140.

IMAGE EVALUATION TEST TARGET (QA-3)

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