Abstract: Several companies have implemented extensive metrics programs to support management and improvement of their software development processes. Recent studies suggest, however, that nearly 80% of software metrics programs fail. This research focuses on the entire cycle of collecting, interpreting, distributing, and using data about an organization’s software processes. The purpose is to gain deeper insights into how a metrics program can be useful in managing and improving software organizations.

The research is conducted as action research involving a Danish software-developing company, KMD. The research is hence aimed at both the scientific and practicing communities, giving two purposes. (1) Further the scientific understanding of how data on software development are used and can be used in software management and improvement. (2) Provide useful guidelines on how to design metrics programs that become useful for managing software organizations.

Keywords: Software Metrics, Measurement, Software Management, Software Process Improvement, Management Information Systems

1. INTRODUCTION
Management of software development processes is a very difficult task. Often projects are behind schedule and the resulting applications lack quality. To perform the task managers depend greatly on different types of data, for instance written reports from project managers or software metrics like productivity, quality, adherence to schedule and budget.

Several companies have implemented metrics programs to support the managers in their decisions. However the benefits from the implementation are not as great as expected. Nearly 80% of software metrics programs fail within the first two years (Dekkers, 1999).

This research will further the understanding of how data (in particular metrics) can be used in managing and improving software development processes. This will be done by studying the collection, interpretation, distribution, and the use of data as part of managing software development processes. Decision-making is a very complex process and it is naive to think that it can be based solely on structured data as metrics. However, metrics are useful for decision making of software managers, i.e. metrics are part of the management information system for software managers.

KMD (Kommunedata) is a software company that has implemented a metrics program. The present research will be conducted as action research and will be based on the experience gained at KMD, i.e. the collection, interpretation, distribution, and use of data about software development at KMD will be studied. For further details about the combination of research and the practical work at KMD, see section 3.

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The next section presents the context of the research. Section 3 presents the method, questions, expected contributions, and limitations of the research.
2. CONTEXT

2.1. Practice at KMD

Over the last three years KMD has spent a lot of effort on implementing a metrics program. Detailed data on projects and applications are collected. Prior to the implementation of the metrics program a lot of data were already collected and used in different reports to the management.

The implementation of the metrics program has had a vast effect on the software organization in KMD where the results from the measurements are being analyzed on a quarterly basis.

As a result of the measurements the top-level management has established some improvement projects. The purpose of these projects has been software process improvement, e.g. software configuration management and estimation. Some lower level managers use the data in their decisions but there is still a lot of potential in the usage of data.

An evaluation of the current use of metrics in KMD is required to adjust the metrics program. “Since the debate on data definitions and formats can be endless, the only way to find out how to gather and analyze software data is to gather and analyze software data” (Humphrey, 1989). KMD has done that and are now ready to do the evaluation.

The use of data in software management can be divided in the following areas: Collection, Interpretation, Distribution, and Usage. This is illustrated in figure 1.

![Diagram](image)

Figure 1 Using data in software management

The area of data collection is rather well established in KMD, but the areas of interpretation, distribution, and data usage are not fully developed. All the areas are mutually dependent, e.g. if the data is not properly interpreted and distributed they are difficult to use. Likewise, if the data are not used, it is difficult to learn how the data collection, interpretation and distribution can be improved and so forth.

Part of KMD is very much aware of the benefits of metrics in management of software development processes, and they consequently spend a considerable amount of effort on this. This provides ample opportunity to study the collection, interpretation, distribution and usage of data.

This research will analyze and improve the management information system in software development at KMD with particular emphasis on the use of software metrics. The research should lead to an understanding of the criteria that will make software metrics useful in managing and improving software processes. These criteria should not only focus on the collection on data, but equally important on the interpretation, distribution, and use of these data. Examples of criteria to be considered are:

- The data should be valid and the collection of data should be economic
- Interpretations of data should represent different views and be relevant to the reader
- Data should be present and available, i.e. be at the right time and place
- The data should help covering the information needs of managers and help them focus on relevant areas for intervention

2.2. Related work

The use of data to support decision-making is wellknown from the literature as Management Information Systems or MIS (Laudon and Laudon, 1998). The general literature will be used in analyzing the specific case of software development.

To diagnose the use of data in KMD the literature of metrics will be studied. In Basili (1984) an effective data collection method for studying the software development process is described. The method is based on the Goal Question Metrics Approach (GQM). To define the metrics it is necessary to formulate the goal of the data collection and the corresponding questions (Basili, 1994). A thorough survey of the literature on metrics will be conducted during the fall. The survey will be presented in a paper.

In order to suggest improvements the work of Weinberg and Iversen will be used. Weinberg identifies six patterns for classifying organizations (Oblivious, Variable, Routine, Steering, Anticipating, Congruent). The main concern in the classification is to look for the degree of congruence between what is said and what is done in different parts of the organization (Weinberg, 1993). An organization can grow from a lower level pattern to an upper level pattern. The task of measurement should be handled differently in the various organizations. Weinberg distinguishes between first-order measurement (to build software) and second-order measurement (to tune the process of building software). An organization that is classified according to one of the first three patterns should only be concerned with first-order measurement.
In Iversen (2000) data-driven intervention in software process improvement is discussed. The general purpose of data collection is to obtain knowledge in order to gain increased insight in how to intervene in the process.

Figure 2  SPI as data-driven intervention (Iversen, 2000)

Figure 2 shows that studying some object results in data on a structured form. These data are interpreted, resulting in knowledge that can be used to intervene either in the object studied or in some other objects.

The research of Iversen focuses on software process improvement and the only subject to discussion is data collection.

In the present research the data-driven intervention is interpreted according to software processes in general. The full circle of collection, interpretation and intervention will be investigated.

3. RESEARCH

3.1. Method

Focusing on practice-related research in system development Mathiassen (1997) distinguishes between three types of approaches: Action research, practice studies and experiments. Action research involves the researchers in practice situations in close collaboration with practitioners. Experiments involve practices that are controlled by the researchers. Practice studies cover a wide variety of approaches to study systems development without active involvement of the researchers.

Action research is defined by Michael Foster (1972) as

A type of applied social research differing from other varieties in the immediacy of the researcher’s involvement in the action process and the intention of the parties, although with different roles, to be involved in a change process of the system itself. It aims to contribute both to the practical concerns of people in an immediate problematic situation and to the goals of social science by joint collaboration with a mutually acceptable ethical framework (Foster, 1972).

The primary approach of this research will be action research and to some extent experiments and practice studies. The analysis of current practices will be performed as a practice study and the improvements will be performed as experiments.

The major advantage of action research is the close integration of research and practice, allowing the researcher to gain first-hand experience while involving the practitioner in the research process. On the other hand, action research provides only limited support for structuring the research process and findings (Mathiassen, 1997).

The most important reason for engaging in an action research effort is that action research, by definition, is relevant to practitioners. However, the scope of relevance of the findings to practitioners may vary from a single organization to a whole sector, and so on (Kock, 2001).

The critique of action research is summarized in (McKay, 2001), e.g. that action research may be regarded as little more than consultancy. McKay et al argue that part of the issue concerns the way in which we currently conceptualize action research. To support a change in conceptualization they suggest a model of action research that explicitly includes both a problem solving interest cycle and a research interest cycle (McKay, 2001, p. 57).

The experience of Kock et al (2001) suggests that action research is particularly useful for the development of theoretical models, and not so useful for testing theoretical models. The purpose of this project is to build some theory of relevance to practitioners. Hence, the choice of action research as the research method seems appropriate. The subject of research method will be further elaborated in the fall after participating in a seminar arranged by Peter Axel Nielsen, Aalborg University, who has recently done some work on action research, e.g. (Avison, 1999).

Figure 3  Action Research in Reflective Systems Development (adapted from Mathiassen, 1997)

In Mathiassen (1997) it is argued that the researcher should use reference disciplines. In the present research several reference disciplines are considered, e.g. Management Information Systems, Software Process Improvement, Structuration Theory and Knowledge Management. The final choice of reference disciplines depends on the findings in the early stages of the research.
The research is organized as a practical project at KMD and a research project at the university of Aalborg. The two projects are highly interrelated. The practical project constitutes the practice of the research project, and the research project constitutes the theoretical framework of the practical project.

![Figure 4 Organizing the PhD study in two related projects](image)

The PhD-project started at 1.8.2000 and is scheduled for summer 2003. In October 2000 the KMD-project was established. The plan for the KMD-project is to analyze state-of-the-art of metrics at KMD, and from the analysis perform a range of improvements to the practice at KMD. The impact of the improvements is to be analyzed in the PhD-project. The KMD-project is scheduled for 1.10.2002.

### 3.2. Questions

Two research questions that will be addressed through the PhD study have been identified:

- What is the role of metrics in managing and improving software development? How are data collected, interpreted, distributed and used?
- How can the collection, interpretation, distribution and usage of data be improved?

The empirical study of KMD will be the foundation of the first question. The answer to the second question will be normative.

### 3.3. Contributions

The Practical Work that needs to be performed for this PhD study to be successful includes an analysis of the current use of data in management of software development processes at KMD.

As part of the project at KMD the state-of-the-art of metrics has been analyzed. The analysis is based on the following sources:

- A personal log of experience from the author who is employed at KMD and has participated in the implementation of the metrics program at KMD.
- Trace of documents with relevance to the subject (plans, minutes from meetings, email communications etc.).
- Semi-structured interviews with persons relevant to the subject.

The ideas from Soft Systems Methodology (Checkland, 1993) were used for structuring findings in the analysis and for suggesting improvements at KMD. Some of the findings are:

- There is a lot of potential in the data collected.
- There is a lot of competence and discipline on collecting and distributing data.
- The data collection is not optimal.
- Interpreting data demands a lot of time and competence.
- The data is widely used for software process improvement.
- Software management does not use a lot of the data available. It is not visible in the organization when data are actually used.
- The data do not fulfill the needs of the software management.
- The data do not express the actual problems in the organization.
- Data is not visible in the organization. In particular not to the data suppliers, and therefore the quality in data is questionable.
- The project metrics are purely focused on deadlines and resources and not on quality.

From the analysis a range of possible improvements are emerging. The improvements are directed towards all aspects of the data, i.e. collection, interpretation, distribution, and usage. The management at KMD has picked two of the improvements to be executed:

- Rationalization of the data collection to focus the effort and the attention and increase the data quality.
- Identification of project metrics to focus on quality.

As part of the research field experiments are conducted to test and assess the improvements at KMD.

The Theoretical Contributions of this PhD project is documented in a number of papers and a summary position. The papers (including reference disciplines) and their current status are:

1. “Experience from Implementing Software Metrics for Benchmarking”. The paper reports from the implementation and use of a comprehensive metrics program at KMD. The literature contains a lot of general advice on implementing a metrics program. The transformation from general advice into concrete actions is described in the paper. Furthermore, the usefulness of this kind of general advice is discussed. Reference disciplines are Software Process Improvement and theory on organizational change. The article is co-authored by PhD Peter S. Böttcher, manager of the
Software Process Improvement Unit at KMD. According to the organizer the paper is probably going to be accepted for presentation at ICSQ 2001.

2. “A Critical Look at Metrics in a Software Organization”. The paper contains a description of the analysis at KMD - the purpose, the process, and the findings. Reference disciplines are Soft Systems Methodology (Checkland, 1993) and theory on information (Pedersen, 1996). The article is co-authored by professor Lars Mathiassen, Aalborg University. He is also the supervisor of the research project. The paper is accepted for presentation at ISD 2001.

3. “Rhetorics and realities: improving software construction through metrics”. The ideas of structuration theory is used for analyzing and suggesting improvements for the software metrics program at KMD. In (Rose, 1999) the concepts from structuration theory is translated to Information Systems. The paper is co-authored by Jeremy Rose, who is presently visiting Aalborg University. The paper is submitted to IRIS 24, and will be submitted to Scandinavian Journal of Information Systems.

4. “Survey of the Metrics Implementation Literature” (in progress). The purpose of the paper is to provide an overview of the literature that has been published to date of metrics implementation, and perhaps point to a new direction for the research field. For practitioners the project may be valuable by providing an overview of what makes metrics implementation succeed or fail, as well as providing a starting point for learning about what the best practices are for implementing metrics. The paper is co-authored by Jakob Iversen, who is an assistant professor at UW Oshkosh. The paper will be submitted to a journal, e.g. IEEE Software, IEEE Transactions on Software Engineering, Computer, Journal of Systems and Software, Communications of the ACM, Information Systems Journal, or Software Quality Journal.

5. “Re-designing a software metrics program using GQM” (planned). The ideas of Goal, Question and Metrics (Basili, 1994) will be used for assessing and improving the current use of metrics at KMD.

6. “Making software metrics useful in managing and improving software organizations – A Knowledge Management Perspective” (planned). The paper will give a view of the research, e.g. the findings, and the combination of practice and research. Reference disciplines will be Knowledge Management. The article is co-authored by Lars Mathiassen.

The summary position will provide a coherent view of the research conducted, including the overall results of the improvement effort in KMD. The summary position will also address the research questions and contain the practical guidelines for other organizations to follow.

3.4. Limitations

As mentioned in section 3.1 the primary research method is action research. The research is limited to one organization, KMD. It is reasonable to question whether the findings at KMD could be generalized to other organizations. However, the software development at KMD is distributed widely across Denmark. KMD has two sites in Aalborg, one in Århus, one in Odense, and four in Copenhagen. The sites have very different traditions and culture. Actually, that is one of the problems that KMD has struggled with throughout the last decade. Hence, KMD can be viewed as several companies or cases.

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REFERENCES


