Hierarchical Economic Planning of the Inspection Process

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1 INTRODUCTION

Inspection is an effective but expensive method to find defects in software products and to determine product quality early during software development [8, 10]. The application of inspection in a project can be viewed both as a technical quality assurance method and as an investment to get feedback on the actual product quality and to save future rework cost.

Raffo *et al.* [11] introduced a model for the cost of *defect potential*, that is the set of costs incurred by the potential of defects in a product. They argue that defect potential impact should be used to evaluate the option of applying certain quality assurance activities: Quality assurance is not carried out due to the known presence of certain defects, but due to the potential impact of unknown defects in a development product. According to this view quality assurance activities such as inspection provide some coverage for the risk of defect potential. The defect potential depends on the kind and size of the product as well as on the range of possible defects in the product and the impact of these defects on the project outcome.

In inspection practice the inspectors on the team often just receive a product and a checklist with the goal to find as many major defects as possible. The inspectors then have to decide by themselves what defect detection tasks to carry out on what portion of the product. The result is a list of defects; but usually there is no feedback on the actual coverage of the defect potential of the product, that is which parts of the product have been checked with which defect detection task. Thus there can be no realistic evaluation on the actual benefit of the inspection with respect to the defect potential, which was the initial reason to carry out quality assurance.

Further defect detection activities usually can not be exhaustive for development products in a typical project due to considerable product size and scarce availability of skilled inspectors' work time. Thus the best application of the available resources on product scope and possible detection activities has to be planned diligently.

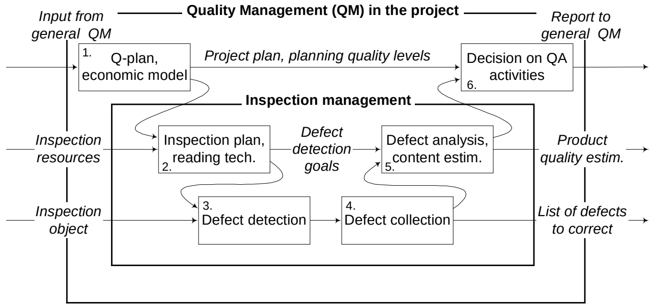
In this position paper we introduce a process framework for planning and evaluating an inspection with respect to defect potential coverage. In this framework we identify three hierarchical levels of key questions for a prospective inspection, which consider economic issues from the point of view of the persons involved in an inspection.

The paper aims at a more rational treatment of inspection planning by raising awareness for the importance of economic modeling of process decisions for inspection as an example for quality assurance activities in general.

2 A PROCESS MODEL FOR INSPECTION DECISIONS

In the following we assume a software development project, in which the question arises, to what extent to apply quality assurance (QA) to a work product, e.g. a requirements or design document. Figure 1 presents a process framework for the study of software inspection that consists of two main parts (large boxes): *Quality management* in a software development project as context for a possible inspection and *inspection management*, if an inspection is actually conducted.

Figure 1. Software inspection process framework [5].



The two parts contain six process boxes, which are passed sequentially: The left three boxes model represent planning stages for the inspection on a more and more detailed level, the corresponding three boxes on the right side represent processes for analysis of the actual inspection result and provide feedback to the planners.

Process 1 defines the inspection context in a quality plan (Q-plan) that contains planned quality levels for specific products as part of the project plan based on an economic model that incorporates assumptions of the organization or the project manager on the value of defect potential in general and defect potential covered by a quality assurance activity (see also [1]). Result is the decision whether or not to use inspection as QA activity.

If inspection is chosen, process 2, inspection planning, considers in this context available resources, the prospective size of the product to be inspected, and the set of target defects for best coverage of the main defect potential. With this input the project manager has to decide how many inspectors to take, which inspection

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techniques to apply, and how to distribute the responsibility for finding defects among the inspectors.

Defect detection in an inspection can be supported with techniques that guide the inspectors through the inspected document and tell them what to look for and how to perform the quality checking. These techniques are commonly referred to as reading techniques [2]. A reading technique can be defined as a series of steps or procedures that help an inspector perform the defect detection activity of an inspection. In this way it supports an inspector in acquiring a deep understanding of the software artifact. A major characteristic of a reading technique is the responsibility that it assigns to inspectors. The responsibility may be general, to identify as many defects as possible, or specific, to focus the inspector's attention on a limited set of issues. According to this criterion, a reading technique can be general, like a checklist that lists all the defect types or symptoms to look for, or specific, like scenario-based reading that uses procedures to detect specific classes of defects.

In an inspection team, procedures with general inspector responsibility often lack inspector coordination and lead to a waste of effort among inspectors or gaps in the coverage of the inspected document. These effects result in low inspection cost-effectiveness. Systematic approaches with specific inspector responsibilities, on the other hand, provide coordination, avoid gaps in the coverage, and, thus, are expected to increase the overall cost-effectiveness of the inspection [2, 9, 10].

Processes 3 and 4 cover the inspection activities defect detection and collection. First inspectors apply their assigned inspection techniques to a concrete inspection object and generate an individual defect list, then these lists are gathered, true defects identified and forwarded to the author for the consecutive correction of the defects.

The actual conduct of the inspection by the inspector has of course significant impact on the actual result of the inspection: The inspection process quality and the data available for determining the remaining defect potential. Thus the communication of the project manager's *intent* on what is important information for their further project planning to the individual inspector for his activity decisions is as important as the *feedback* to project management what the inspectors actually did during inspection to cover product parts with certain quality assurance activities.

Processes 5 and 6 represent post-inspection data evaluation steps for further project planning [7]. The data analysis of the team defect list, which contains information on which inspector found which defect, prepares statistics as input to the estimation of remaining defect potential, which can be compared to defect detection goals for the target defect groups. With input from the original project plan, the Q-plan, and the economic model in the project as well as estimates on the remaining defect potential in the inspection object a decision on further development and quality assurance activities in the project can be planned.

3 MANAGEMENT DECISIONS DURING INSPECTION

There are three levels according to the managerial and technical viewpoints on the inspection process:

Level 1 (processes 1 and 6): The consideration of inspection by the project manager as possible method to extract information on the actual current status of a development product, and (if an inspection is actually conducted) the use of this information for further project planning.

Level 2 (processes 2 and 5): If project management decided to conduct an inspection, inspection management (which may or may not be identical with project management) has to choose one of many possible inspection designs and prepare inspection materials accordingly. After inspection the analysis of actual results gives a first feedback in relation to the planned results.

Level 3 (processes 3 and 4): The individual inspectors on the inspection team receive guidelines and inspection material from inspection management. As the variation of the performance potential of inspectors is considerable, the individual inspector has to find out whether he can carry out all the process steps for the product under inspection in the available inspection time slot, and if not, what actually to do.

These three levels of planning and analysis activities are present in all inspections, but are often not considered explicitly. In the following we focus on the planning questions identified in the process steps 1 to 3 in the above framework. For each step we define the major question asked as well as the respective technical and economic assumptions and variables.

3.1 Whether or not to conduct an inspection

The major question of the project manager in process 1 is, which QA approach to take, e.g. inspection or testing, and to set a goal for the application of the chosen approach in terms of defect potential coverage. Results of this step are apart from the selected QA approach a range of intensity for the application of the approach, e.g. constraints for schedule, resources, and budget.

Important inputs to the above question are assumptions on the context of QA: the project size and quality/value priorities in the project plan, assumptions regarding the defect potential of the development processes prior to and following QA. Further there need to be general assumptions on the effectiveness ranges of QA approaches to cover certain areas of defect potential.

From an economic point of view the trade-off of the application inspections has to be assessed against the use of other development and QA activities, which compete for common scarce resources [1]. In an experiment on the impact of defect detection techniques for inspection [4] we modeled the cost and benefits of an actual inspection with direct and indirect cost for searching and inspection planning, and benefits based on saved rework for the defects found during inspection (see the appendix for a model overview). This approach worked fine, since the product under inspection contained a substantial number of defects, but left open the question of the value of checking a product, which does not contain many defects.

The notion of defect potential presented by Raffo *et al.* [11] with a cost framework for the comparison of development process alternatives helps to consider the total cost of a QA activity for the project. In this framework [11] we focus on the cost of searching for products. Although the framework considers QA costs as fixed regarding the number of defects found, we see costs during planning as variable costs, since they depend on the assumption of the defect potential coming from the product quality, notation and size, as well as on the actual investment of time into inspection.

For the question at hand the project manager needs a model that contains the assumption on the technical effectiveness of QA approaches to cover a certain defect potential and the relative cost for defined levels of coverage. These model parts will use empirical input from expert opinion, empirical data from literature or in-house experience.

3.2 Operational inspection planning

After the decision for an inspection has been taken, for operational inspection planning the inspection manager has to decide among a variety of inspection designs. In the case of inspection different defect detection techniques, e.g. a general checklist or a systematic reading technique like scenario-based reading [2], have to be ranked according to the goals and resource constraints from step 1 and planned on a more detailed level.

The inspection planner, usually the project manager, needs an assessment of the document to be checked in order to set expectations for the necessary checks, probable level of defect potential, and the time range necessary for inspection.

An important parameter is the level of performance of the candidates for the inspection team. This individual level of inspection effectiveness can vary considerably with the defect detection technique applied and time available for inspection. The planner has to determine whether a useful inspection is feasible with the inspectors at hand.

The inspection planner needs some simple rules of thumb to calculate for the normal case, worst case, and best case, how much inspector time he/she will need, and what can be expected as result. For this we need to understand main factors of inspection and their relationship with inspection performance indicators, ideally based on data and simulations from local experiments to assess the probability distributions and the sensitivity of the most important factors [3].

From this planning for best and worst cases the inspection planner can determine the range of team sizes, necessary inspector capabilities, and decide which inspector roles will need a backup, which detection aids to provide, and what training to administer prior to inspection.

From the economic perspective the ranking of alternative inspection designs narrows the set of costs to be determined to costs for searching and the associated effectiveness for defect potential coverage. An important output is to translate the goals and constraints from step 1 according to the tasks of the individual inspectors so they can understand the overall priorities of the inspection, in which they take part (with explicit goals, but also by assigning specific procedures for document parts).

3.3 Individual time planning of an inspector

The question for the individual inspector is whether his time available for inspection will be sufficient to execute all tasks prescribed, and, if not, which tasks to execute primarily. For these decision and planning activities the inspector needs to understand the overall goal of the inspection and his part in it. Further, at any time during inspection he needs to find out how much time his remaining tasks will most likely take him.

An important general question is how much information to give to an inspector, so he is not burdened with information he does not need for his tasks, and yet can make an informed local decision, which will not go against the overall inspection goals from steps 1 and 2. For inspection research this means to find out, which factors are most important for performance in a given inspection situation and to devise different scenario strategies for the normal case, for worst cases, where something seriously goes wrong, and for optimal cases, where an inspector exceeds the expectations of the scenario designers.

The (technical and economic) result of the inspection includes the actual effort applied, the set of defects found, and the defect potential covered in relation to the original goal of inspection (document coverage and actual tasks applied). This feedback from inspector reports on their defect detection tasks is essential to analyze the actual product quality and remaining defect potential.

4 FURTHER WORK

Some reflection on the framework for hierarchical economic planning of the inspection process presented in this paper brought up the following issues for further work.

The framework promotes conscious planning of project value and translation for different roles in the development and QA process for rational communication of goals, constraints, and results between roles in the inspection process. This needs common approaches to describe the cost and value of a project for comparison of a set of QA approaches in general and inspection designs specifically. The framework in [11] is a good start, but needs to be refined for the average project manager to tackle the planning tasks described above.

Next steps to take are to identify and collect data to assess defect potential coverage in empirical studies. Further the technical and economic uncertainties are to be modeled starting with the assumptions of the project manager on context, input and output factors, which can over time be refined with empirical data input.

A crucial aspect is the correct translation and communication of economic high-level goals to the coordinated detailed application of inspection tasks. This needs empirical research on the relationships of input and output factors for a inspection designs in well-defined contexts. With this information the uncertainty of actual technical inspection performance variation of inspectors and inspection tasks with a given product can be modeled [3, 6].

Lastly the uncertainty of economic variables like future costs and benefit needs to be modeled in a balanced scientific and pragmatic way, which makes them readily usable for the project managers, who are in practice the target audience of these models.

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APPENDIX

For your convenience a cut from section 2 in [4], which can be a reference to the paper in the proceedings.

Table 1 defines variables of a cost-benefit model for one inspection cycle out of a series with the economic indices net gain and return on investment. The proposed model extends a prior cost-benefit model [2] which used only direct costs.

Table 1. Variables for economic model of inspection.

t	Index of an inspection cycle (1, 2).
m	Number of defect severity classes, e.g., 2 for major and minor defects.
s	Severity level of a defect class (1, 2, …, m).
N_t^s	The number of actual defects in class *s* before inspection cycle *t* (estimated in practice, known in the experiment).
D_t^s	The number of defects in class *s* found by a team in inspection cycle *t*.
B^s	The expected increased cost of removing a missed defect via the downstream processes, that is the estimated benefits from finding a defect in class *s*.
DC_t^r DC_t^m	The direct cost of inspection cycle *t* in staff hours, i.e., the effort for individual reading (denoted by the index *r*) and the effort for the team meeting (denoted by the index *m*).
IC	Indirect costs of an inspection.
TC_t	The total costs of inspection cycle *t*, i.e., the sum of direct and indirect costs.
G_t	Net gain for inspection cycle *t*, i.e., the sum of benefits minus the sum of all costs for this cycle.
ROI_t	The return on investment for inspection cycle *t*, i.e., the net gain per invested cost unit.

2.2.1. Cost of an inspection cycle. Costs of an inspection are indirect and direct costs. Indirect costs come from deciding to conduct an inspection (and not from the effort of the inspectors involved); they include costs for inspection planning and the delay of the project. Further so-called opportunity costs may arise, since the inspectors cannot do other work that would have been more beneficial than their contribution to inspection. The estimate of these costs depends to some extent on the organizational environment of the project. In this work we assume the indirect cost of an inspection to be a fixed value, *IC*, for a given project. We assume no opportunity cost, i.e., that the inspectors do their most valuable job when inspecting.

Direct costs vary with the number of persons involved in the inspection and the effort they invest into inspection for reading and meetings. For the direct cost we set up the effort for individual defect detection and the effort for creating the team defect list (see eqn. 1).

$$TC_t = IC + DC_t^r + DC_t^m \qquad \text{(eqn. 1)}$$

$$ADC_t = \left(DC_t^r + DC_t^m\right) \Big/ \sum_{s=1}^{m} D_t^s \qquad \text{(eqn. 2)}$$

$$G_t = \sum_{i=1}^{m} \left(B^i \cdot D_t^i\right) - TC_t \qquad \text{(eqn. 3)}$$

$$ROI_t = G_t / TC_t \qquad \text{(eqn. 4)}$$

There are two kinds of decisions regarding reinspection: First there is the decision on project level whether or not to schedule a reinspection. For this decision all costs are to be considered, which affect the project, which includes indirect costs. After the decision for a reinspection has been taken, for inspection planning there is the decision among a variety of inspection designs. For this decision only direct costs need to be considered as indirect costs are by definition similar for all designs. Thus to compare the performance of different teams for an inspection cycle *t* the average direct cost for a defect is a useful indicator (see eqn. 2).

2.2.2. Benefit of an inspection cycle. Benefits come from estimated savings of rework, if a defect has to be detected and removed later in development or operation. The project manager or developer must estimate the benefit of a defect. This benefit from savings depends on the severity of the defect and the impact it would have had on the development project, which may vary with the development phase in which the defect would have surfaced.

In this work we distinguish 4 severity levels of defects depending on the additional effort to find and fix a defect in a given class, if it is not found during inspection. The rationale is to use enough defects classes to allow expressing the magnitude of impact they have on development, while restricting the number of defect classes to a variety that can readily be understood, used, and retained by an inspector who has to classify defects. The benefit differences between the defect severity levels should be in a range that helps inspectors and managers to consistently assign a defect to a severity level, e.g., benefits of neighboring classes should differ at least by a factor of 2.

There are several approaches to determine the benefit for a defect of a given severity class.

- The simplest approach is to assign each defect class a single benefit value [2].
- Another approach is to assume for each class a probability distribution of benefits. This can be, for example, a triangle distribution for best, most likely, and worst cases. The expected benefit for a given defect is determined from this benefit distribution.
- A more sophisticated approach includes estimates on the benefit for several development phases, e.g., an early phase, where the impact of a defect is rather low (e.g., in-house design). While in a later phase the impact is much higher, since more rework is necessary and more people are involved (e.g., operation at the customer).