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Emerging from the Crisis:
Improving Engineering Efficiency
in Tough Times

Long version of presentations
at SPICE Days 2009 and Metrikon 2009

Emerging from the Crisis: Improving Engineering Efficiency in Tough Times

Authors

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Abstract

Increasing cost pressure, shortening innovation cycles, global competition and growing saturation in many markets demand efficiency improvement in product development. Successful organizations consider efficiency improvements an investment in their future – and in the current crisis of the world economy this need is even stronger. Many of our clients ask us whether the current situation with lots of cost cutting measures is the right time for process improvement. If done well and with good guidance on the necessary change management, process improvements will lead to quick wins and improved efficiency. Profound process improvement helps to trim RD&E specifically for the crisis. This article provides experiences and empirical evidence from such improvements in different context and companies.

Topic

Efficiency Improvement,
Experience Report

1 The need for efficiency in today's tough times

Today's market for technological products is harder than ever. Many manufacturers compete on a fluctuating and increasingly saturated market for narrow margins. Especially when the market fluctuation is running into 'hard times', many companies find themselves in a fight for mere survival – and the urgency to reduce costs and optimize profits increases.

Successively the product development comes into focus of profit optimization, since many cost drivers of the later product are defined during development, like rework due to poor quality or production costs due to uncontrolled variants. Cost reduction programs in product development often challenge their running process improvement programs, cut activities of quality assurance like peer reviews – but why? In some cases these decisions are based on gut feelings, in other cases there simply exist no objective and accepted evidences on the positive effects of such activities within an organization.

2 Process Improvement Yields Efficiency

When targeting efficiency improvement we must first understand what efficiency is and how it can be influenced. Many of the levers to enhance engineering efficiency are addressed by models such as CMMI [2] and SPICE [3,4], based on best practices of all industries conducting intense product development. Once the organization's cost drivers are analyzed and thus the levers are clear, in many cases these models present itself as a practical reference for the implementation.

2.1 Putting Efficiency Improvement into Place

The profit of an organization is the difference between its turnover (output) and its costs (input). In order to increase profits the turnover must be increased while reducing the costs. The turnover can be increased by delivering the right products and achieving a higher demand in the market. Costs can be reduced by optimizing the resources required to produce those products. Both correlate with each other, therefore the cost optimization is usually hard to find. Some cost cutting programs reduce the costs without affecting the short-term output, but harming future innovations. Reducing costs for development activities or cutting all costs which don't directly benefit the current products do reduce costs quickly. But they reduce the turnover in following periods of time and are therefore no sustainable improvement.

Efficiency is the relationship between the results achieved and the resources to achieve these results. Efficiency is "doing the things right" (while effectiveness is "doing the right things"). An efficient way of working achieves results like an effective way of working, but it keeps the necessary effort to a minimum. In the scope of development processes efficiency is productivity [1].

In a first step the cost drivers must be determined – an analysis of the current situation reveals the most relevant cost drivers. These cost drivers are the levers for effi-

ciency improvement. Levers for efficiency improvement in product development can be assigned to three categories: Products create customer value, processes describe how these products are developed and people develop products using processes. Fig. 1 depicts typical efficiency levers, which are addressed by our Vector Efficiency Check.

Most of the efficiency levers addressed in Fig. 1 match with practices of CMMI [2], ISO15504 [3] and Automotive SPICE [4]. Let's look to requirements engineering. A clearly managed communication is essential to involve all parties of both supplier and manufacturer effectively. Training improves the necessary skills to write clear and unambiguous specifications and to analyze them, which leads to a better common understanding and less recursions. Standardization of requirements and underlying tooling interfaces make sure that the practitioners always know where to find information, how to access it, and don't lose time searching for it.

This shows that CMMI and SPICE contain many opportunities for efficiency improvement. But why isn't it that easy – achieving a high capability level and the efficiency improves automatically? Why do we observe that some organizations with high capability levels still show bad market performance? Simply because reference models such as CMMI and SPICE only describe what you should do, but not how to do it. The key to success is twofold: In a first step the right approach to such models must be selected, in a second step the described practices must be interpreted in the context of the organization and implemented accordingly. Both steps are often neglected.

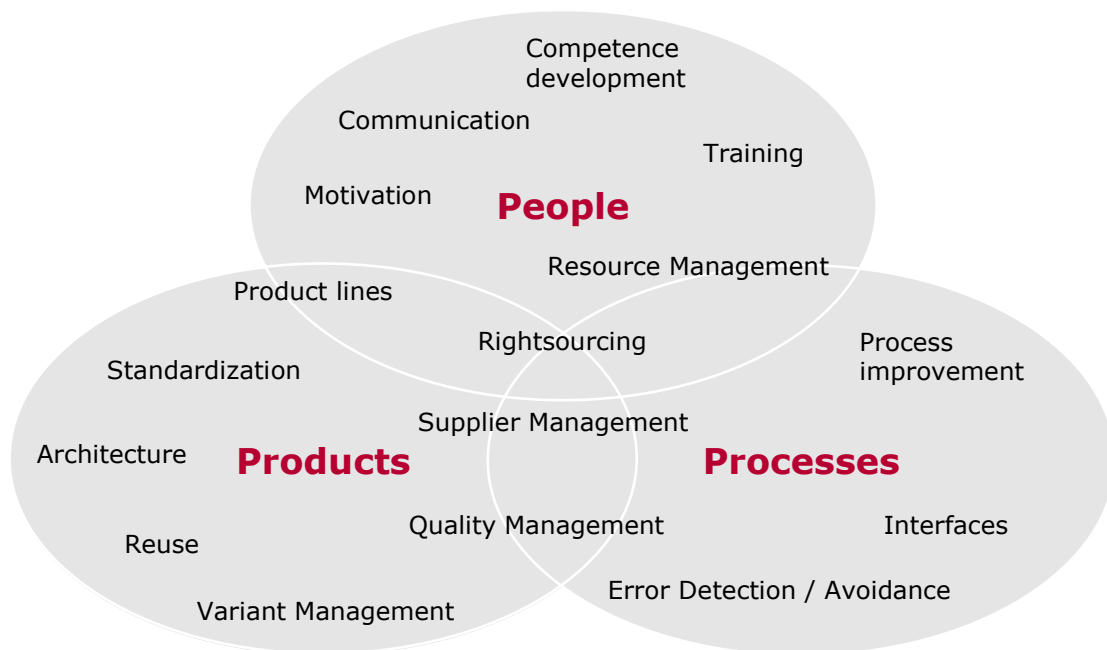


Fig. 1. Levers for efficiency improvement in product development

CMMI and SPICE provide many good practices which can be useful for efficiency improvement, if they are related to the organization's specific cost drivers. Many or-

ganizations however are narrowly focused on the process capability determination approach – at times dictated by their own management or misinterpreted market needs. The resulting process improvement programs of such suppliers bear the risk that they are based on artificial “paper” objectives, not on their own business and improvement needs. People working in such environments experience processes as a cumbersome formalism and tend to drop it in their daily work whenever possible.

Such negative examples show that a bad interpretation of such improvement models can even lead to counterproductive results. But while considering such traps and focusing on efficiency as a lead objective proves strong potential for making development organizations more efficient. Our clients profit from experience in interpreting the standard in the organization’s context and in implementing practical processes and tools.

2.2 Efficiency Improvement Practices Applied

Many of our successful clients refocused their process improvement activities due to the difficult world economic situation. They avoided to simply cut engineering headcounts or reduce development projects, and instead briefly analyzed their specific situation, then put the right priorities and then fiercely pushed those activities which best addressed the most critical cost drivers. This is a full paradigm change compared to the more traditional approach of implementing an improvement framework. It is today an objective-driven approach with incremental improvements that are tangible right at the bottom line and on a short-term basis. Here some examples recognized as high potentials for efficiency:

1. Cooperative requirements engineering. CMMI and SPICE have a strong focus on an effective cooperation between customer and supplier. Many of the practices explicitly define an active communication and common decisions. Consequently applied, both parties achieve a common understanding of the requirements and the derived design. Practically this means systematic joint walkthroughs and reviews during the early development phases. In case of difficulties like when the assignment occurs (too) late, or when resources are still bound to previous projects, a strict prioritization, a good preparation of reviewers and a strict organization of the review sessions lead to a goal-oriented and efficient execution of these activities. The initiative can emerge from any side: one of our customers, a tier 1 supplier in the automotive industry, developed a very strong drive to activate their customer. They emphasized on organizing full day meetings where they invited the customer’s component responsible and performed thorough joint reviews of the requirements and of the design. The feedback was so positive, that this good practice quickly ingrained in the team, repeating it in later phases and later projects. The customer was very happy about this approach – many valuable findings could be clarified long before the first sample had been delivered. He was also satisfied to find a strong partner who took the lead. With a globally leading automotive OEM where we supported this cooperative requirements engineering the average number of iterations (sample deliveries and SW releases) could be reduced by 25% compared to a similar line.

2. Early verification with reviews and inspections. The work product management process attribute very explicitly defines an adequate form of quality assurance of all relevant work products. Applied properly this quickly optimizes efficiency – a common

mistake is to create one comprehensive checklist for every work product and process step. The refinement of this practice means to create intuitive and effective templates and tools, which avoid most mistakes (e.g. by input validation). Then the checklists can be reduced to few questions addressing the most critical steps. The criticality shall be based on practical experience, e.g. from pilot user feedback and from lessons learned. For one of our customers we revised his “historically grown” checklist for requirement specifications. He complained that reviews using this checklist found many findings, but the majority of them were rather useless, like spelling errors or structural weaknesses. We reworked the checklist with a clear focus on content and design while removing mere formal overheads. Using the new checklist reduced the average review effort by 15% and increased the number of ‘critical’ findings detected before delivery of the first sample by 40%. As a side effect our customer observed that less review sessions were shifted because the acceptance of the new checklist was better.

3. Efficient test strategy. CMMI and SPICE require strategies for all integration and testing processes. A good test strategy comprehensively covers all product levels from unit tests to system acceptance tests. It should define an efficient usage of the (always) limited test resources to achieve defined test targets. This applies both to the supplier as to the customer as in most industries both parties perform some sort of tests. A documented test strategy is the ideal level to adjust the testing activities between supplier and customer. It abstracts the test implementation which often differs between companies. This adjustment increases the test coverage and reduces unnecessary double checks – another win-win situation. In our work supporting different car manufacturers in their quality management, we directed both the supplier and the component responsible to define ‘their’ test strategy. We agreed on some minimum structural requirements like a set of test targets derived from ISO 9126 and a definition which test level contributes to which test target. Laying both strategies side by side, both parties started a prolific adjustment of the test targets, detected several poorly covered test areas but also many unnecessary overlaps – around 35% of all tests were performed on both sides and could be reduced to a single execution without any risk! They weeded out the overlaps and could instead shift the efforts to the test targets which had poor test coverage.

3 Success factors for efficiency improvement

Organizational improvement requires change – change requires organizational change management. We have demonstrated with many clients that a well performed process improvement program leads to improved efficiency. Fig. 2 summarizes four main steps towards improved efficiency. In the following text we will use this structure to systematically introduce to practical efficiency improvement. We will combine the first two steps of cost assessment and target agreement to a phase 1, while phase 2 covers change implementation and results capitalization. This split into two phases is often done, to allow a client to see the entire picture (i.e., phase 1) and then address selected high-impact levers in a short timeframe with clear ROI (i.e., phase 2).

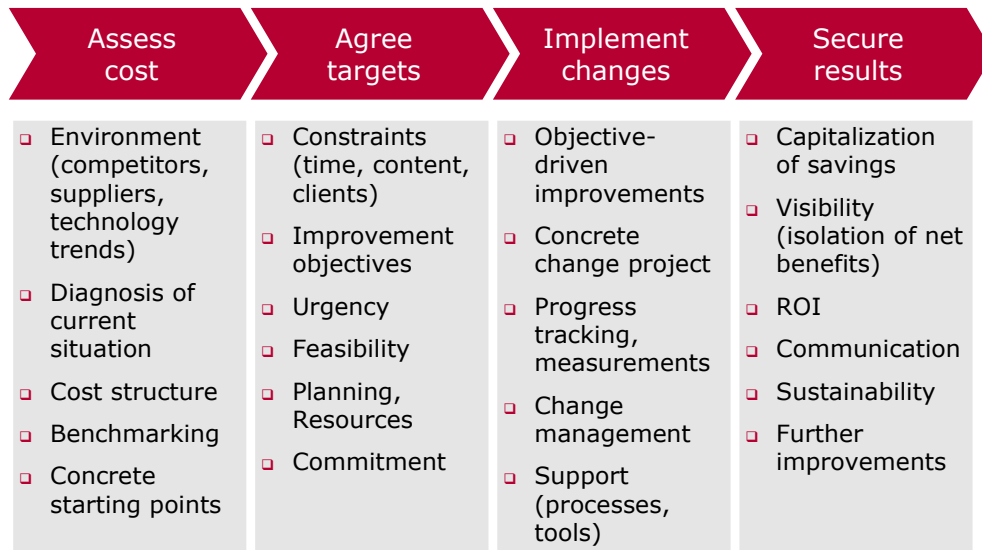


Fig. 2. Efficiency improvement in four steps

3.1 Phase one: Analysis and targets

A comprehensive analysis of the organization's specific situation is the first step. It is our experience that using one or more relevant process models (SPICE, CMMI, IEC61508) as reference offers a good systematic approach, because these models and standards cover most activities of development organizations. For instance, CMMI addresses a process management group and IEC61508 addresses specific extensions in safety relevant contexts. A careful selection of processes will address those cost drivers which are already known in the organization. Combining the systematic approach of the standard with our experience and industry benchmarks allows us to systematically determine and highlight the most critical cost drivers and thus the levers for subsequent improvements. The targets for improvement are derived from these levers. In efficiency improvement the targets must absolutely be quantitative targets in order to be able to measure their achievement. A good implementation develops business cases for each target.

3.2 Phase two: Implementation and consolidation

The implementation in the later phases is quite comparable to good process improvement projects. A specific improvement project is set up, incremental measures achieve quick wins and a strict monitoring of the targets avoids a drifting of the progress. When improving efficiency it is mandatory to quantitatively monitor the results. These measurements have to be started at the beginning of the improvement project and should demonstrate continuously the positive trend of target achievements. In efficiency improvement there is a strong focus on the capitalization of results – it is the reason why all the effort had been spent. Therefore the sponsors must demand a strict application of the improved processes and expect a better performance from their projects. This can mean, for example, to lower the effort estimations or to tighten quality criteria for milestone reviews. Then the investment pays off in a ROI comparable to typical industry benchmarks [1,5].

Implementing process improvements in the context of efficiency improvement requires excellent experience between a pragmatic interpretation of a model like CMMI and SPICE, a thorough understanding of the organization's environment and a consequent application of engineering principles to process management. Two examples:

Process descriptions: CMMI and SPICE on (maturity) level 3 require an established defined process on project and a standard process on organizational level. "Established" in this context means that processes are documented, known and applied by practitioners. Some practices from (maturity) level 2 also benefit from having standardized experience from the organizational level. Pragmatically interpreted this means: If a comprehensive process can be defined on organizational level, then there's no need that every project describes its own process and requirements, thus reducing effort for the projects. The organization's environment must be considered by embedding the processes in the existing organizational framework. This framework exists in almost all organizations and has its roots when organizations started facing ISO 9000 and their derivatives. A neat integration of the development process in this organizational framework improves its visibility. Finally, applying engineering principles means that the process description must be developed based on requirements (structural standards for a process description, addressed users, technical infrastructure), designed (process architecture), implemented (as short as possible, unambiguous and concise) and tested (reviews with practitioners, pilot projects).

Effective templates and tools: CMMI and SPICE suggest that requirements for the work products shall be defined. Do not exaggerate with many organically grown different documents across the product life-cycle because they all need to be kept consistent, thus creating extra cost. A more agile approach leads to a set of few, well designed templates and tools, integrated in the existing environment of the organization. Example: A newly created resource planning and tracking tool must be able to import the existing data of the organization's time reporting tool. The better the templates and tools are, the less explanation they require. Therefore most effort must be invested in engineering good templates. We often observe that a process definition group creates templates but never apply them by themselves – these templates create frustration and unnecessary effort for every user. Even when creating spreadsheet based rapid prototypes these should be treated like 'normal' products – they must be designed, incrementally implemented, documented and tested before they are released for general use. Well developed templates save lots of time every time they are applied.

4 Case Study: Efficiency Improvement with CMMI

4.1 The scenario

To highlight how frameworks like CMMI and SPICE are used to boost efficiency and thus contribute to cost reduction in the company, we will show a recent client case study who embarked on CMMI. Our client develops infotainment and communication components for several premium OEMs – a sector facing tough competition from mobile navigation systems, along the dimensions of feature content, quality, product

cycle-time and of course pricing. The CMMI driven efficiency improvement was introduced to the engineering department of a big Tier 1 supplier in the automotive industry. For the initial proof of concept and piloting we focused on one product line with around 300 employees.

4.2 Analysis and Targets

The client engineers products in a highly competitive market which demands both lean and flexible development combined with excellence in product strategy. His customers, the automotive OEMs, demand increasing integration of the infotainment components to related functionality, combined with a premium-level reliability and quality which the end customers can experience. Specifically, our client is expected by the OEMs a high level of quality at a competitive pricing which translates into high test coverage together with seamless integration of supplier testing with OEM system-level testing.

Due to insufficient engineering processes, in the recent past before we were called, the customer satisfaction decreased steadily, mostly due to quality issues which made necessary additional test efforts on customer's side and undermined the OEMs' trust. This inefficiency lead into a downward spiral of insufficient processes, rework and growing cost. As a direct consequence of too much rework and insufficient management processes, schedule adherence got worse, and more than 60% of all samples were delivered with more than 5 days delay, in one exceptional case the delay was even 3 months. Our client noticed that he lost several business opportunities – even from customers which had a long business relationship with him. Finally, during the last year, overtime became the standard for most engineers. Some of them worked more than 50 hours a week for the whole year. The motivation of the employees has recently been drastically impacted by too much rework and overtime.

As a first step we performed the Vector Efficiency Check. This is a fast-track checkpointing assessment together with the client looking to performance figures and results. It provides immediate answers to three key questions, namely:

- Analysis of client situation: What is client's own position?
- Assessment of client situation: What are others doing better?
- Recommendations for improvement: What should be done?

This was not trivial as the available project data initially was insufficient. We added concrete efficiency measurements such as the cost of specific process steps, cost of non-quality, late changes and rework. There were several efficiency levers, such as variant management or the cost of non-quality, insufficient product strategy, misalignment between product management and marketing, and overly high cost of non-quality. In the remaining part of this case study we will focus on the latter, specifically looking to the software development and test, as it is rather self-contained and nicely highlights how improvement frameworks such as CMMI and SPICE are used to boost efficiency with immediate ROI.

We quickly identified test as the biggest cost driver. The test efforts contributed up to 50% of the overall engineering effort, a value which compared to our benchmarks for such industry and product portfolio was overly high. Development and test cycles

used a weekly synchronization period and engineers had to deliver their best versions by Thursday so that the complete build could be automatically tested over the weekend.

To go into more depth on root causes we interviewed some test engineers. They mostly emphasized late inputs on Thursday afternoon for the weekend run. Input quality was not good so that the build and smoke tests on Friday did not run as expected. Often they had to work during the weekend with very short notification. Often test runs aborted, but at that time the specific software engineers were not readily available thus delaying entire production and test steps. We also analyzed existing data in error management system, the project planning and tracking for schedule and efforts and the test documentation such as test specifications and test reports. These documents pointed with more detail towards what we already guessed after the interviews, namely that quality gates were insufficient, and due to heavy processes, engineers skipped quality checks and rather trusted that testers would somehow identify defects.

We agreed for this part an improvement target towards reducing cost of non-quality within three months by 20% and at the same time improving test efficiency by 30% within six months. Cost of non-quality was agreed as an aggregate from the number of defects found by customer and the number of subsystems fulfilling the weekly test entry criteria. Test efficiency was calculated from the amount of performed test cases, the marginal coverage of the test sets and the effort spent on testing.

4.3 Implementation and Consolidation

Having analyzed the situation with deficiencies and underlying root causes on one hand and agreed improvement objectives on the other hand, we moved forward to implementing those changes that were most relevant for the company at this point. Fig. 3 summarizes the root causes related to test. We used CMMI which was anyway on the agenda of that company due to their OEM requests. CMMI helped in identifying appropriate engineering practices and putting them into relation. For instance it is of not much benefit to simply demand better testing, if there are insufficient resources or not enough time foreseen in a tight schedule. So it is absolutely necessary to also look to topics such as requirements engineering (e.g., who sets up coverage and test criteria), software quality assurance (e.g., how are quality gates executed), and project planning (e.g., how to best estimate the necessary effort).

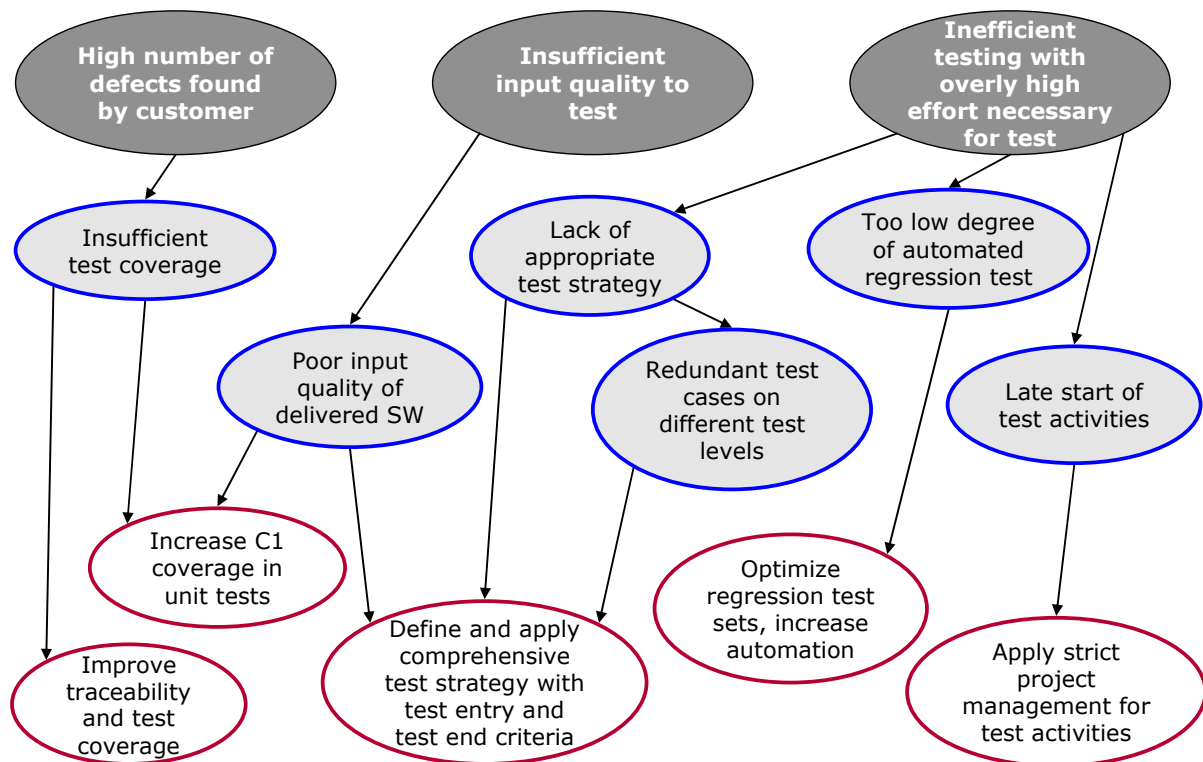


Fig. 3. Case Study: Deficiencies (grey), root causes (blue) and actions (red)

We will briefly summarize the different actions related to test and quality improvement which we implemented along this project. We have sorted the improvement actions along three symptoms which we wanted to cure, namely a high number of defects found by the customer, insufficient input quality to test, and inefficient testing. Each of the three symptoms is presented together with the related improvement actions and associated measurements for tracking the effect [1].

- High number of defects found by customer
 - Root Cause: Insufficient test coverage. Several critical customer requirements were not systematically tested
 - Action 1: Improve traceability between requirements and test specification. Close the coverage gaps with additional test cases. Measurement: Requirements coverage by tests in %, reported to customer in every release.
 - Action 2: Increase C1 coverage during unit tests. Measurement: Number of defects found by customer
- Insufficient input quality to test
 - Root cause: Poor input quality of software delivered to test.
 - Action: Define test entry and test end criteria as part of the test strategy. The project quality responsible already tracked the number of planned and performed reviews of software before start of test. It was agreed that software could only be delivered to test if a defined C0 and C1 coverage depending on complexity was demonstrated. The delivery deadline was fixed on Thursday noon. Then an automatic quick test run was performed, covering all critical

functionalities. Only if this run was successful, the weekend run was started; otherwise the developers responsible for the problematic modules had to stay until the errors were corrected. Measurement: Number of subsystems fulfilling the test entry criteria. Visibility in Monday's project cockpit chart, indicating whether the last weekend run started on time, delayed or had to be aborted.

- Inefficient testing with overly high effort necessary for test
 - Root causes: Lack of an appropriate test strategy and redundancy. Test activities started too late in the project. 40 % of the test cases were executed on more than one test level (e.g. unit test and subsystem test) which in most of the analyzed cases did not yield any benefit. The degree of test automation for regression testing was too low with too many manual tests for regression tests.
 - Action 1: A comprehensive test strategy was set up for subsystems covering all test levels from unit test to system test [1,5,6]. The challenge was that different departments were responsible for test but they agreed as it reduced their workload. This already helped immediately to reduce the double checks almost completely. By strict project management the existing scheduling of test preparation activities was enforced with explicit resource estimation and a commitment of the team leads of the test department. In a second step a test workshop was organized with the customer, where both test strategies were compared and harmonized. Also here many double checks could be reduced – our client delivered detailed test reports so that the confidence of the customer was regained. The customer itself was very glad because he also had problems getting the necessary test resources. Measurements: Effort spent on testing (plan versus actual), amount of test cases performed per subsystems and the marginal coverage of the test sets.
 - Action 2: The distribution of the existing set of test cases was optimized in a way that the number of manual test cases were reduced for the regression test level and shifted to other test levels. However, a set of around 50 manual test cases could not be shifted from the regression test level. These test cases were automated in a one-time effort. After an effort of only three person months all identified regression tests were automatic. A small team was enough to automate new regression test cases depending on a change of functionality. Measurement: Number of manual and automatic regression-test cases per week

After having implemented these actions which took around seven months, we were able to demonstrate a test efficiency improvement in terms of test effort related to development effort of slightly more than the targeted thirty percent. The cost of non-quality was reduced by almost thirty percent within the same time-frame. It took a bit longer than expected due to the duration until changes in development quality control, such as improved reviews and unit test coverage finally showed effect in testing.

5 Summary

In tough times it may be harder to raise money for improvement projects. However the urgency to improve is even stronger, because only efficiency improvement can save costs without cutting future business. Having a clear view to the own cost drivers, the improvement frameworks CMMI and SPICE offer good practices for an efficient product development process. Fig. 4 shows with data from Motorola over a longitudinal study involving different products the relationship of higher process maturity (measured by the maturity level) and reduced engineering cost for topics such as rework, defect correction or late defect detection.

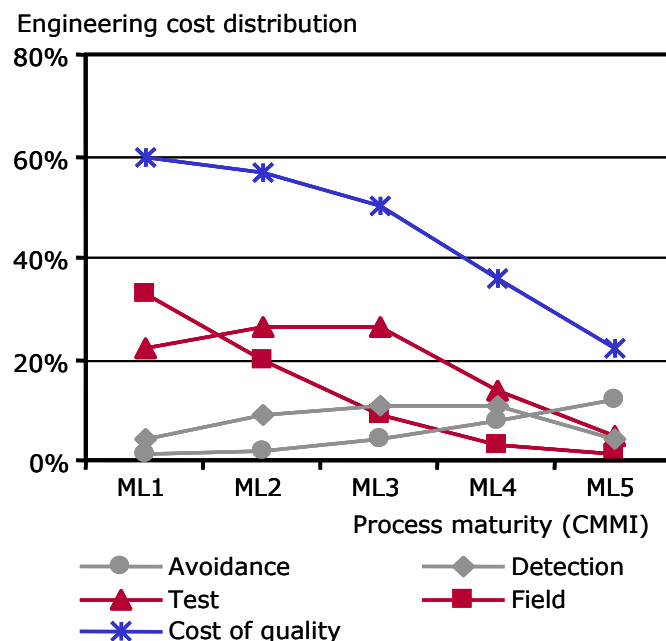


Fig. 4. Higher maturity yields to increased efficiency and thus cost reduction

The challenge is to embark on those changes which deliver a clear value – and do it right first time. Such focused approach combined with experienced change management recently helped several of our clients to achieve quick wins paired with sustainable improvements along specific cost drivers – without wasting energy. Today's tough times will determine the winners of tomorrow. It is clear that companies with insufficient efficiency such as too much rework or an overly high cost of non-quality will eventually disappear because the crisis has no place for complacency. Those who invest into lean development using state of the practice improvement models, such as CMMI and SPICE, implemented with a very well orchestrated change management based upon a clear business case and incrementally delivering tangible and sustainable results in a short period of time will achieve just-in-time bottom line impacts.

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