NIST Planning Report 02-3

The Economic Impacts of Inadequate Infrastructure for Software Testing

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Summary

Electronic hardware and software are the two product categories driving knowledge-based economic growth. For decades, computer and communications equipment have been pacing information technologies (IT) with increases in speed and decreases in cost. Looking forward, software is assuming an increasingly dominant role as the driver of IT-based growth. Industry forecasts indicate that companies will allocate roughly half their IT budgets to software in order to leverage both the huge installed hardware base and new investment in computers and networks.

Virtually every business in the United States now depends on software for development, production, distribution, and after-sales support of products and services. Innovations in fields such as robotic manufacturing, nanotechnologies, and human genetics research all have been enabled by low cost computational and control capabilities supplied by computers and software. In 2000, total sales of software reached approximately $180 billion. Rapid growth has created a significant and high-paid workforce, with 697,000 employed as software engineers and an additional 585,000 as computer programmers.

Software, however, is as complex as it is unique. Few products of any type are shipped with such high levels of defects. In fact, the process of identifying and correcting defects during the software development process represents approximately 80 percent of development costs. Moreover, complexity is increasing. The size of software products is no longer measured in thousands of lines of code, but in millions. This greater complexity

along with a decreasing average product life expectancy has increased the economic costs of errors. Software non-performance is expensive. The media is full of reports of the catastrophic impacts of software failure, but these high-profile incidents are only the tip of a pervasive pattern of failure that software developers and users both agree is causing substantial economic loss.

NIST engaged the Research Triangle Institute (RTI) to assess the cost to the U.S. economy of inadequate software testing infrastructure. Inadequate testing is defined as failure to identify and remove software bugs in real time. Over half of software bugs are currently not found until "downstream" in the development process leading to significant economic costs. RTI identified a set of quality attributes and used them to construct metrics for estimating the cost of an inadequate testing infrastructure. Two in depth case studies were conducted. In the manufacturing sector, transportation equipment industries were analyzed. Data were collected from software developers (CAD/CAM/CAE and product data management vendors) and from users (primarily automotive and aerospace companies). In the service sector, financial services were analyzed with data collected again from software developers (routers and switches, financial electronic data interchange, and clearinghouse) and from users (banks and credit unions).

Costs of Inadequate Software Testing Infrastructure By Industry Group and the National Economy

Industry Coverage	Cost of Inadequate Software Testing Infrastructure	Potential Portion of Cost Reduced (i.e., Economic Benefits) from Feasible Infrastructure Improvements
Transportation Equipment and Financial Services	$5.85 B	$2.10 B
U.S. Economy	$59.5 B	$22.2 B

As indicated in the table, the annual cost to these two major industry groups from inadequate software infrastructure is estimated to be $5.85 billion. Similarities across industries with respect to software development and use and, in particular, software testing labor costs allowed a projection of the cost to the entire U.S. economy. Using the per-employee impacts for the two case studies, an extrapolation to other manufacturing and service industries yields an approximate estimate of $59.5 billion as the annual cost to the nation of inadequate software testing infrastructure.

Thus, if all software bugs could be identified and remove instantly (in real time), the combined economic benefits to the two industry groups and to the economy would be $5.85 billion and $59.5 billion, respectively. Realizing that such a "perfect infrastructure" is not attainable, industry experts were asked for estimates of a plausible reduction in delayed identification and removal of software errors. From this information, an "feasible improved infrastructure" scenario was constructed. This improved infrastructure scenario is estimated to result in a combined annual benefit of $2.10 billion to the two industry groups studied and $22.2 billion to the U.S. economy.

The path to higher software quality is significantly improved software testing. Industry now spends more than $1 billion dollars per year on software testing tools and this expenditure is projected to reach $2.6 billion by 2004. Approximately 302,000 workers are engaged in testing and debugging activities, which represents approximately one-fourth of all computer programmers and software engineers.

However, testing methods have a strong infrastructure character because generally accepted (standardized) approaches must be used to assure buyers that higher quality levels have in fact been achieved. This requirement for common use (standards) coupled with shortening technology life cycles and subsequent pressures to get new generations of software into the market place ahead of competition lead to substantial underinvestment in the infratechnologies underlying software testing.

For example, the lack of quality metrics leads companies to simply count the number of defects that emerge when testing occurs. Few organizations engage in advanced testing techniques, such as forecasting field reliability based on test data and calculating defect density to benchmark the quality of their product against others. Such advanced methods are not readily available, fully proven, accompanied by test suites, and then accepted as industry standards. Standardized testing tools, suites, scripts, reference data, reference implementations, and metrics that have undergone a rigorous certification process would have a large impact on the inadequacies currently plaguing software markets.

The complete report can be accessed at

http://www.nist.gov/director/prog-ofc/report02-3.pdf

Alternatively, bound paper copies can be requested by email from dherbert@nist.gov (refer to the title or Planning Report 02-3)