



McKinsey&Company





Productivity drivers in Networking equipment software development

Numetrics R&D Analytics

■ Growing importance of SW in networking

- Insights on SW R&D productivity in networking
- Introduction to Numetrics' R&D analytics
- Numetrics offering and engagement models
- Networking/telecom OEM case studies
- Appendix

There are several trends that increase the importance of software in networking infrastructure

Trend	Description	Impact on SW in Networking
 <p>SW-defined network</p>	<p>Separate control and data planes, enabling programmability and orchestration of resources</p>	<ul style="list-style-type: none"><li>▪ Split control plane and user plane to separate the control of a data stream from the flow of data<li>▪ Abstracting a core transport node into a programmable virtual switch
 <p>Virtualization and cloudification</p>	<p>Core network functions run as software applications on top of standard hardware infrastructure with open and agile interfaces</p>	<ul style="list-style-type: none"><li>▪ Use of IT virtualization technology to run Network Functions on standard IT hardware<li>▪ Management of core network operations through virtualized instance of a service and sharing of infrastructure resources
 <p>Ubiquitous connectivity and IoT</p>	<p>Network level support for the rapid proliferation of connected devices with varying network requirements</p>	<ul style="list-style-type: none"><li>▪ OSS/BSS¹ with tailored functionality to support M2M and IoT² devices<li>▪ Built in flexibility to support complex billing models and varying traffic patterns
 <p>Real-time big data analytics</p>	<p>Embedded business optimization software including Analytics, Revenue Assurance & Fraud detection</p>	<ul style="list-style-type: none"><li>▪ OSS/BSS systems capable of quickly processing very large amounts of data to allow pattern recognition and rapid insight generation

Both OEMs and Telecom Providers are strengthening their position and focus on software capabilities

Trend

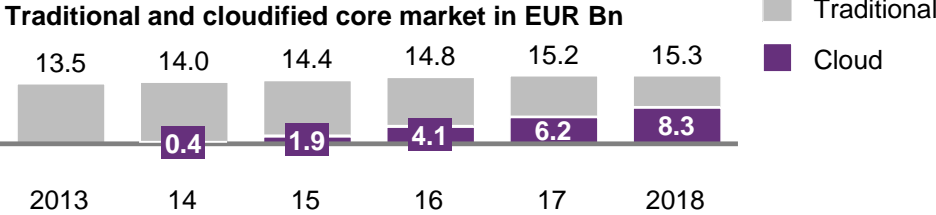
Examples

OEM increased focus on SW

- Ericsson's revenue that came from SW and services jumped from 27% in 2004 to 66% in 2014....(WSJ)
- Almost 90% of Ericsson's R&D is SW-focused according to Ericsson's head of research...(Twitter)
- 80-85% of Cisco's engineers were focused on SW and the company's R&D budget had shifted "big time" toward software innovation, according to Cisco's CEO in 2014...(crn.com)
- Ericsson acquired SW company, Envivio in a deal valued about USD 125 million...(WSJ)
- Cisco and Ericsson entered into strategic partnership to provide future-oriented networks and SW-defined network offering...(livemint.com)
- Cisco launched a SW-focused partners program in 2015...(crn.com)
- Fujitsu Acquired UShareSoft to Bolster its Cloud Business ... (Fujitsu.com)
- Intel ,Nokia, NTT and SK Telecom collaborate to fast track centrally managed 5G networks leveraging VFN and SDN... (fiercewireless.com)

Telecom provider investments

- Telecom providers are switching to SW/cloud- based functionality and cloudified core. market is expected to grow rapidly, gradually replacing the traditional core market



- Telstra to deploy Ericsson's and Ciena's transport network, introducing SDN and VFN
- SK Telecom recently launched a 300Mbps LTE-A service, planned to use OpenStack to run a software-defined network (SDN) for 5G
- Telefonica signed co-innovation agreement with ALU (Nokia) to drive adoption of NFV using Cloudband
- NTT deployed virtualized networks and is launching NFV-enabled cloud services

Telecom and networking OEMs face multiple challenges in software development

What SW is developed?

- **Virtualization and cloudification** trends are broadening the scope of software far beyond basic firmware and platform-specific networking functionality
- **Evolving requirements and required flexibility** to accommodate complex billing models and varying traffic patterns

How is SW developed?

- Transitioning to more **state-of-the-art SW practices** such as agile, continuous integration, test automation, etc.
- Using a variety of complex and “home-grown” proprietary software and verification tools which leads to **quality issues**
- **Integration challenges** due to increasing collaboration with 3rd party content / platform providers, OEMs and emerging cloud / OTA applications
- Building on top of legacy code, which is often poorly architected and not well understood
- Ad-hoc **re-use practices** due to the incremental evolution of legacy products

Where is SW developed?

- **Multiple design locations** that creates challenges in collaboration, integration and communication
- **Increasing use of outsourced SW** vendors in China, India and eastern EU

How is SW development enabled ?

- Strong “**get it done**” **mindset** limits focus on creating robust processes, practices and tools, leading to a **diversity of tools and practices** between teams
- Limited automated and mandatory **tracking of main SW quality KPI's** (e.g., test coverage) for all projects
- **Culture and work environments** not suited to attracting and retaining the best SW developers

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Numetrics' analytics and industry database have revealed several insights into Networking software development

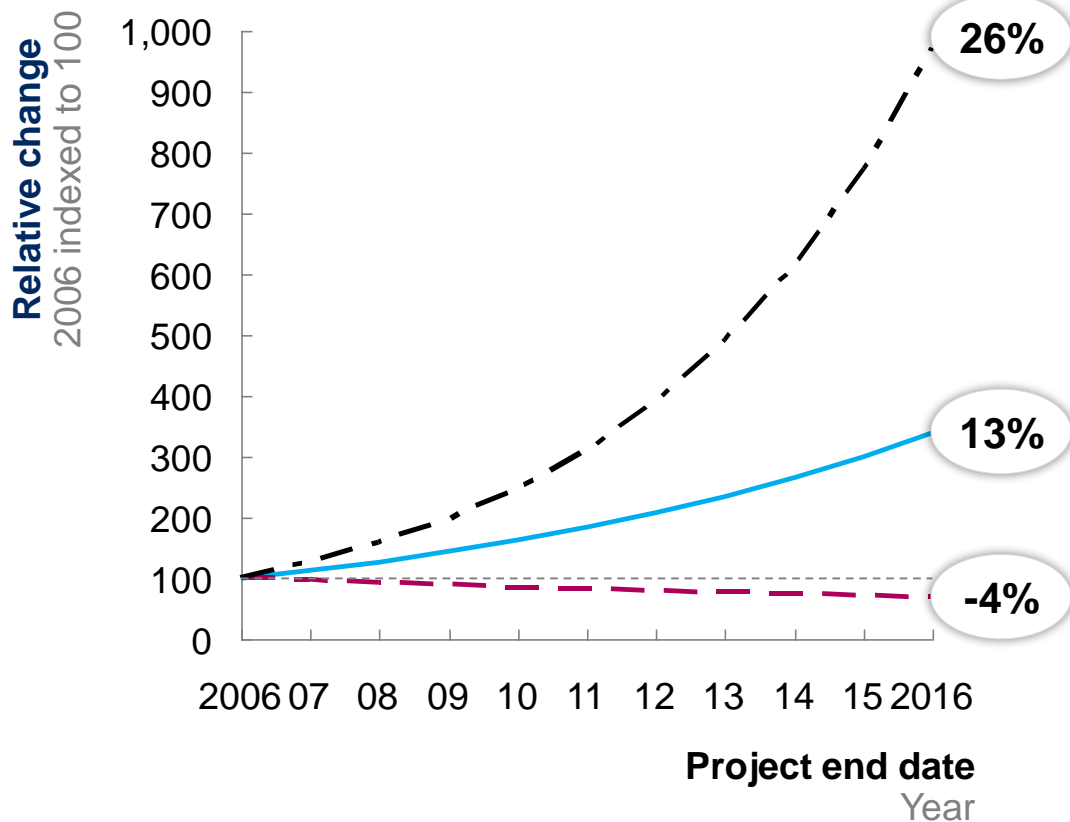
- 1 Networking SW complexity has been rising and productivity level has been declining, resulting in an unsustainable increase in required project effort
- 2 In the past 10 years, SW deliveries have been taking longer with higher slips, but at a better release quality
- 3 Networking companies successfully leverage suppliers to improve productivity and quality, but at an added cost
- 4 There is a strong correlation between SW quality, cost and on-time delivery, and the quality of client relationship
- 5 The percentage of networking projects exhibiting "good" customer relationships has been steadily rising over the last decade
- 6 Development in a new site for the 1st time significantly lowers productivity, increases cost and lowers quality
- 7 HW-dependent code (vs. application code) takes 19% more effort to develop and contains 54% more defects at release

1 Networking SW complexity has been rising and productivity level has been declining, resulting in an increase in project effort

Trends in complexity, effort and productivity

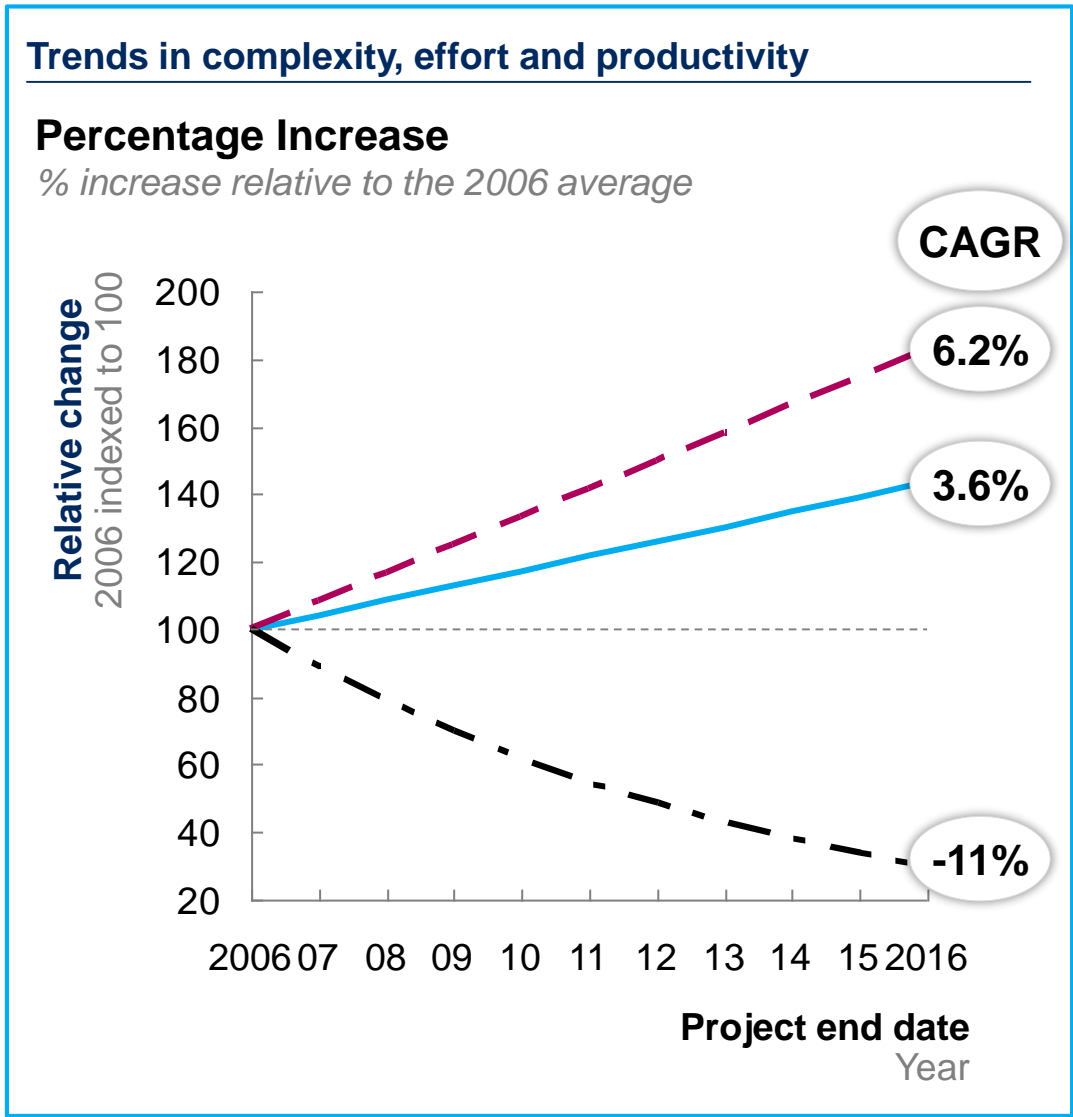
Percentage Increase

% increase relative to the 2006 average



- Since 2006, the average complexity of a SW project has increased by ~13% per year
- Productivity over the same period has been declining by ~4% per year
- The result is an unsustainable increase in total project effort of ~26% per year

2 In the past 10 years, SW deliveries have been taking longer with higher slips, but at a better release quality



— Duration
- - Slip %
- . - RD / kLoCn

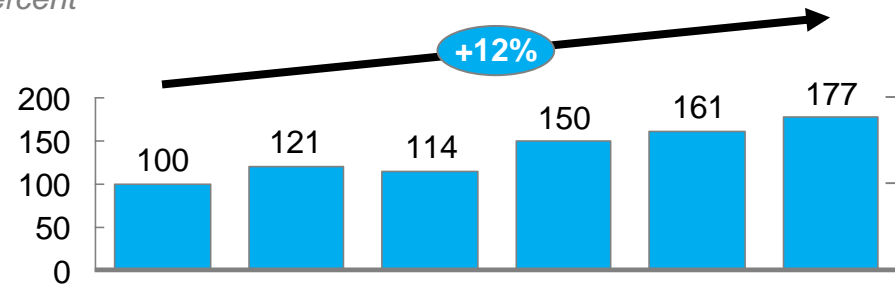


- Project duration has been increasing ~3.6% and schedule slips have increased ~6.2% CAGR over the past decade
- Release quality, measured by known residual defect density at release has been improving as residual defect density has declined ~11% CAGR

3 Networking companies successfully leverage suppliers to improve productivity and quality, but at an added cost

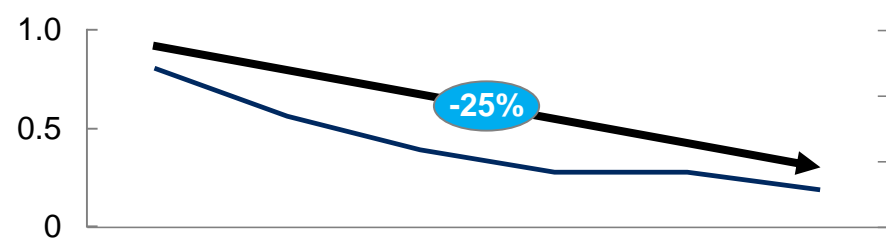
Increase in productivity due to using SW suppliers

Percent



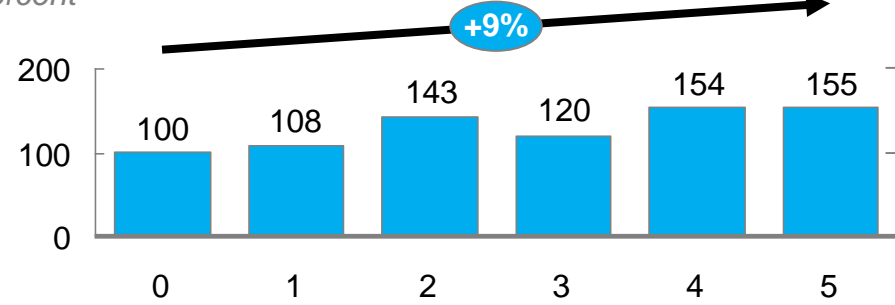
Improved quality due to using SW suppliers

Defects per KLoC



Increase in cost per complexity unit due to using SW suppliers

Percent

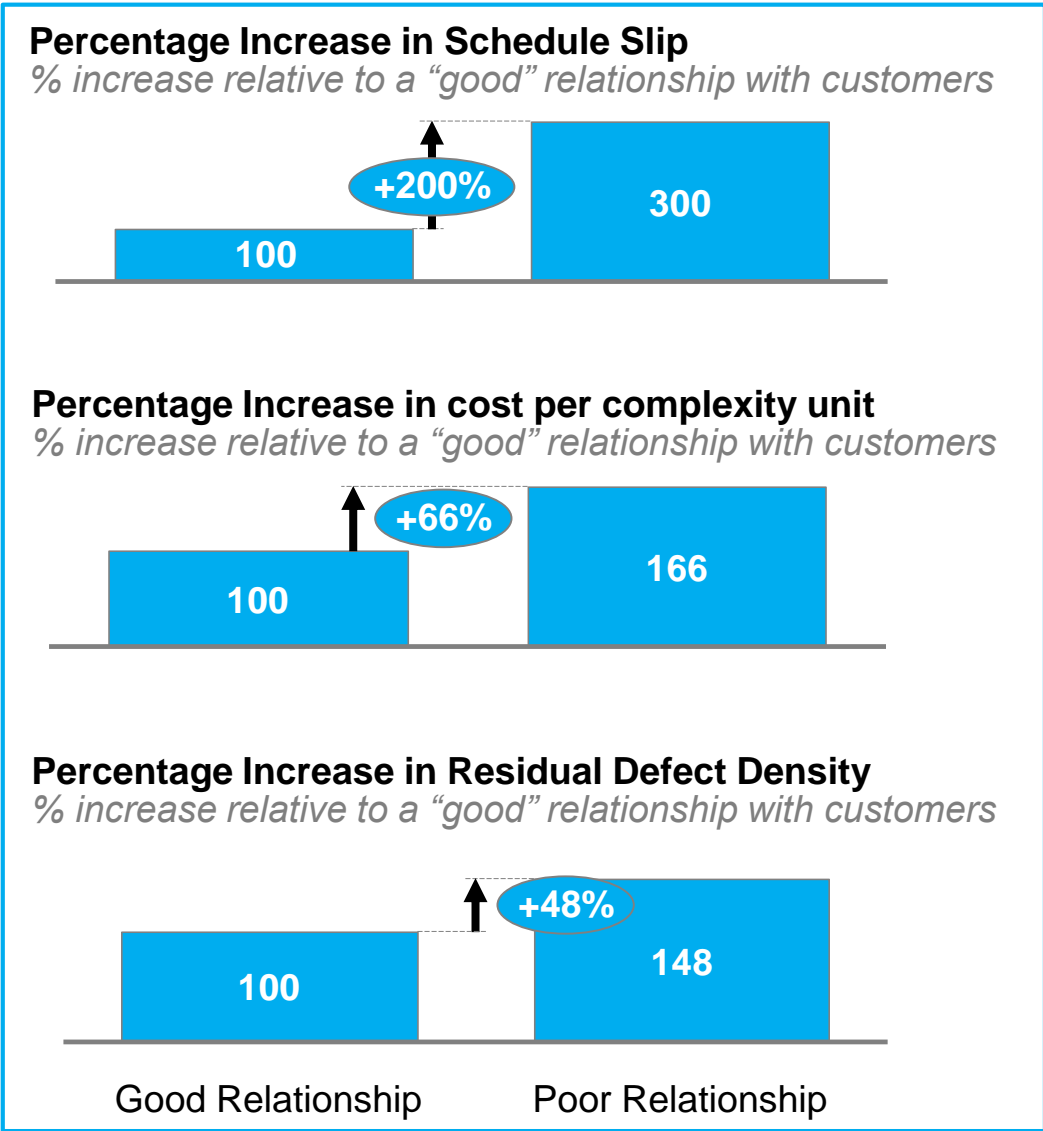


Number of SW Suppliers



- The industry has increasingly depended on 3rd-party suppliers to provide both more features and higher quality
- The telecom/networking industry has demonstrated a 12% productivity increase and 25% quality increase with each additional SW supplier used
- But achieving these results is not free. Each additional supplier adds 9% (compounded) to the cost of development

4 There is a strong correlation between SW quality, cost and on-time delivery, and the quality of client relationship



- 18% of networking project teams described their customer relationship as “poor”¹
- Deliverables with “poor” customer relationships also exhibit 48% more residual defect density², 3x more schedule slip, and incur 66% more cost per complexity unit to develop
- Although open to debate as to which is the cause and which is the effect, the data strongly suggests that improving predictability and quality will also result in a substantial improvement in customer satisfaction

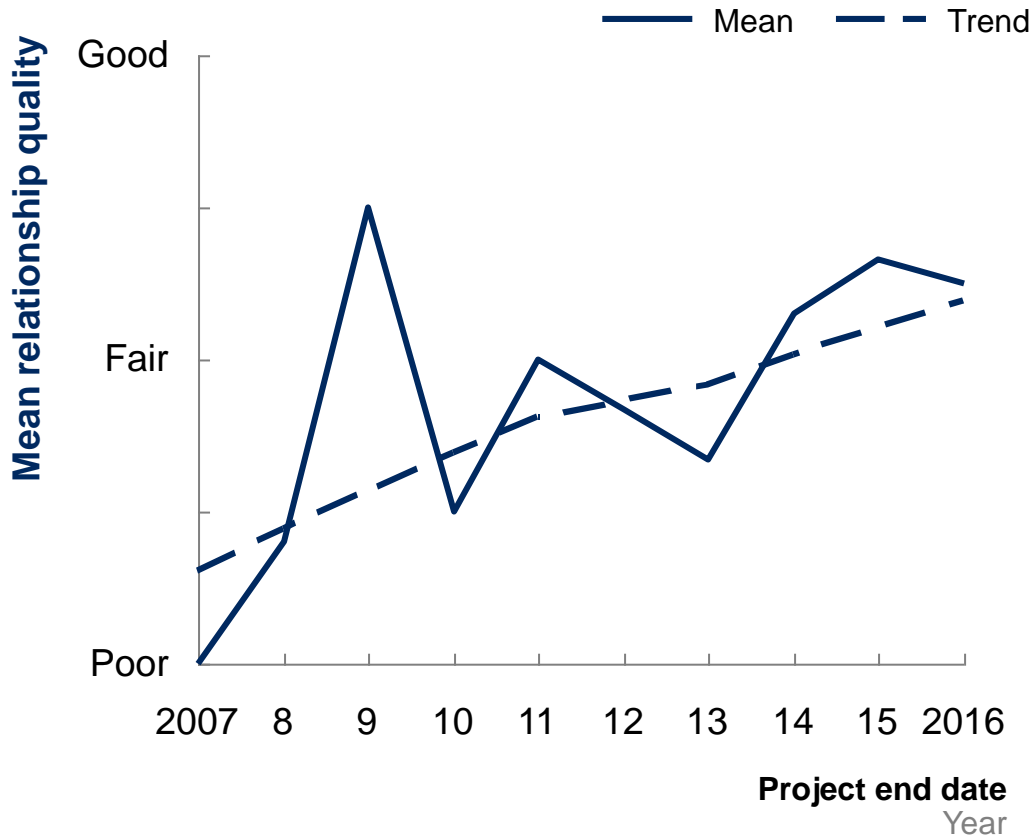
SOURCE: 465 networking-related projects in the Numetrics SW industry database 1 On a scale of poor, average and good

2 Known Residual Defects are the number of major defects that are known to exist in the software at the time of GA

5 The percentage of projects exhibiting "good" client relationships has been steadily rising over the last decade

Trend in quality of customer relationship

Average client relationship quality in each year

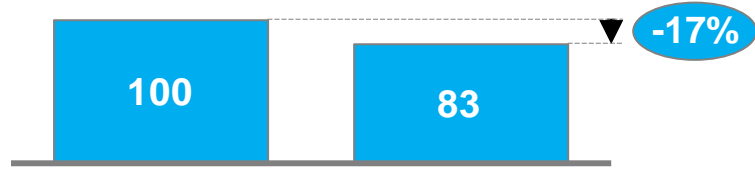


- Over the past decade, the trend in the strength of client relationships has been steadily increasing
- This trend is also strongly associated with improvements in both residual defect density and schedule predictability

6 Development in a new site for the 1st time significantly lowers productivity, increases cost and lowers quality

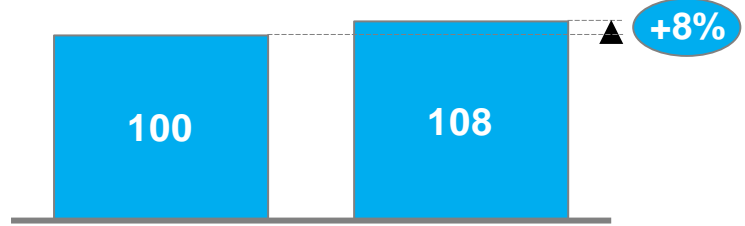
Percentage decrease in Productivity

% increase relative to a not including a new development site



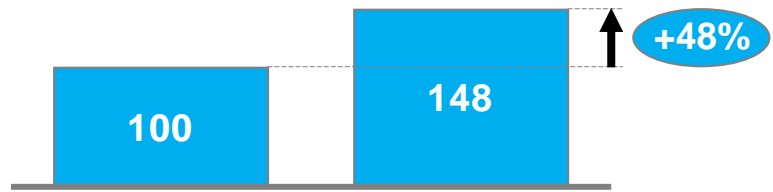
Percentage Increase in cost per complexity unit

% increase relative to not including a new development site

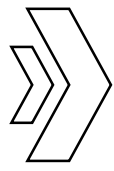


Percentage increase in Residual Defect Density¹

% increase relative to not including a new development site



No New Sites New Site

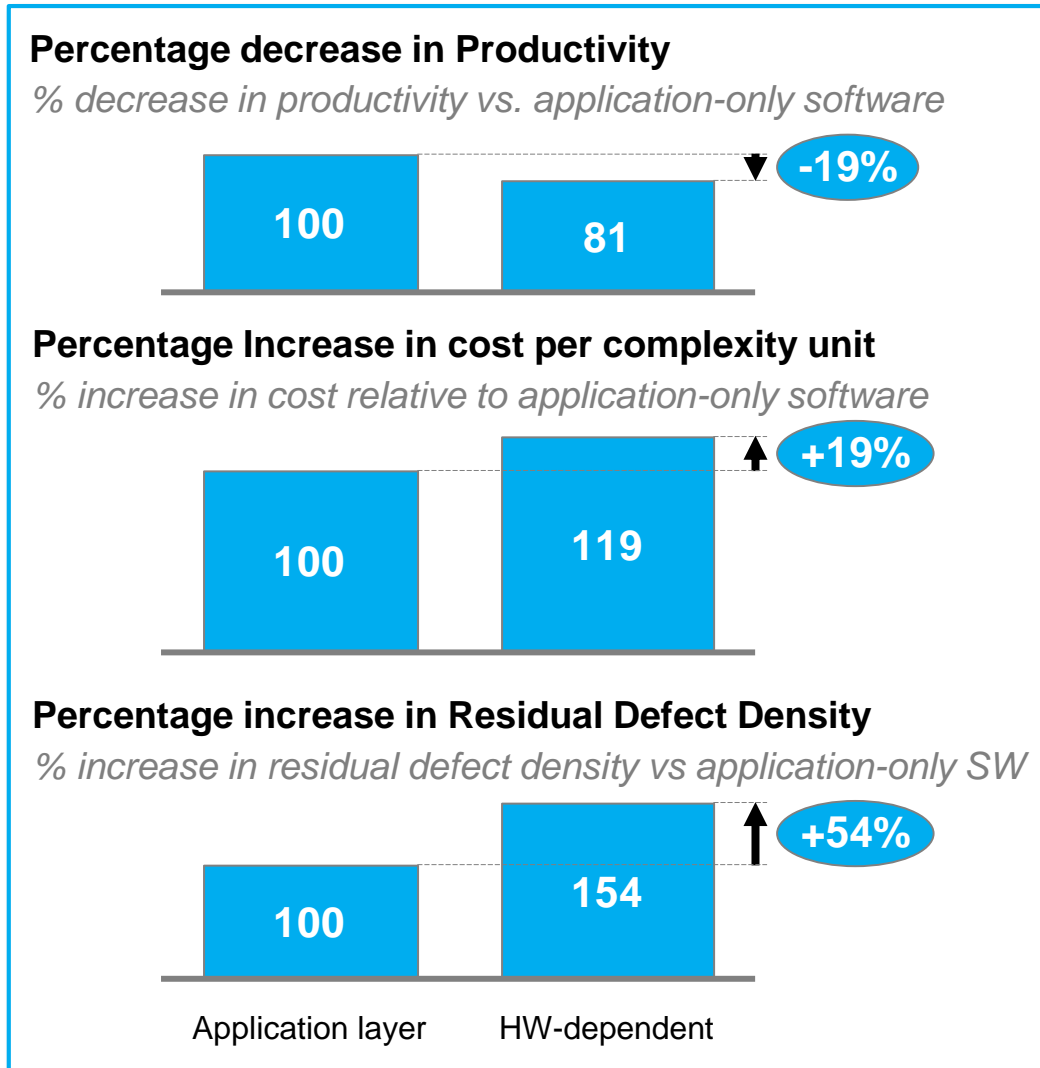


- This chart compares a variety of performance outcomes between projects that added a new development site for the 1st time vs. teams developing software in existing locations
- Opening a new development results in:
 - 17% loss of productivity
 - 8% increase in cost
 - 48% increase in known residual defect density

SOURCE: 465 networking-related projects in the Numetrics SW industry database

¹ Known Residual Defects are the number of major defects that are known to exist in the software at the time of GA

7 HW-dependent code (vs. application code) takes 19% more effort to develop and contains 54% more defects at release



- In networking applications, code that is HW-dependent (e.g. driver-level SW) is more effort intensive and more difficult to verify
- HW-dependent code:
 - Costs 19% more to develop
 - Typically contains 54% more defects per new line of code at release

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There are many questions that can be answered by leveraging analytics in R&D and project planning

Examples of questions analytics can help with

Predictability & planning

- **Project planning** – How can we have better predictability on duration, resources and cost for new projects?
- **Portfolio planning** – How can we best manage the portfolio and optimize our R&D spend?
- **Resource allocation** – How can we ensure optimal staffing and avoid resource bottlenecks?
- **Risk management** – How can we identify execution risk and early on and minimize costly schedule slips?
- **What-if analysis** – What are the cost/resources/schedule trade-offs for different project plans and scenarios?

Performance improvement

- **Performance benchmark and root cause analysis** – How does our performance vary internally? How does it compare to peers and what best practices should we adopt?
- **Improvement tracking** – How well are our improvement initiatives (e.g. Agile transformation, complexity reduction, etc.) working?
- **Informed operational decisions** – Is our outsourcing strategy working? Is our footprint harming productivity? How can we identify best practices across BUs?

Numetrics is a SaaS-based analytics solution that enables rapid improvements in IC and SW (embedded and application) development



Proven complexity measurement method

Large industry database of peer projects

Established analytics platform

Proprietary complexity algorithm successfully applied in **>400** companies



1,700+ software projects

450+ networking projects

2,000+ IC projects

40+ vertical industry segments

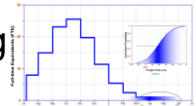
50+ operating systems

20+ programming languages

Industry Benchmarking



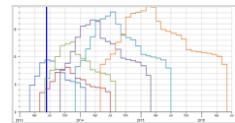
Project Planning & Estimation



Root Cause Analysis / Productivity Diagnosis



Portfolio & Resource Planning




Numetrics offers performance benchmarking, root cause analysis and project planning (predictive analytics) for SW and IC development

What is Numetrics?

SaaS-based R&D predictive analytics platform based on a **patented complexity algorithm** to provide:

 **Performance benchmarking**

 **Root cause analysis**

 **Project planning**

Where can Numetrics be applied?

- **Software (Embedded and application):**
 - **Verticals:** Automotive, Telecom, Financial, Medical devices, Industrial controls, Aerospace & Defense, etc.
 - **Operating systems:** Android, IOS, Linux, Microsoft, Wind River, TI, etc.
 - **Platforms:** ARM, MIPS, Broadcom, Freescale, IBM, Microchip, Renesas, Samsung
- **Semiconductors (ICs):** Across segments, including Analog, Mixed signal, Memory, SOC, FPGA, IP, RF

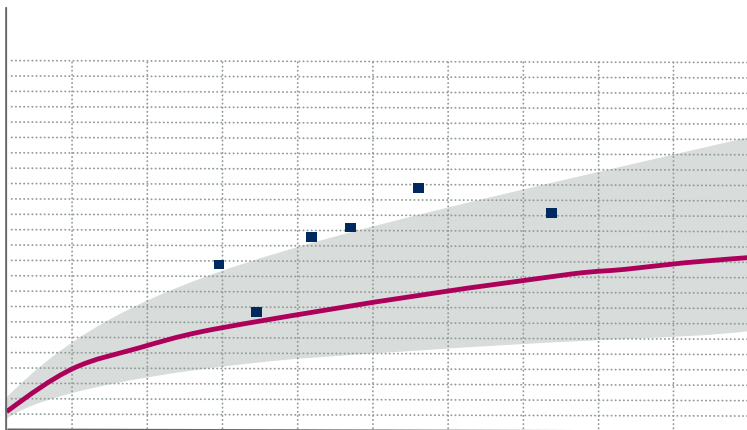
Performance benchmarking – Creates a productivity baseline to enable internal and industry benchmarking

Performance benchmarking

Create a project-level productivity baseline based on recent projects, and benchmark across multiple dimensions against a database of ~2,000 IC and 1,700+ SW projects

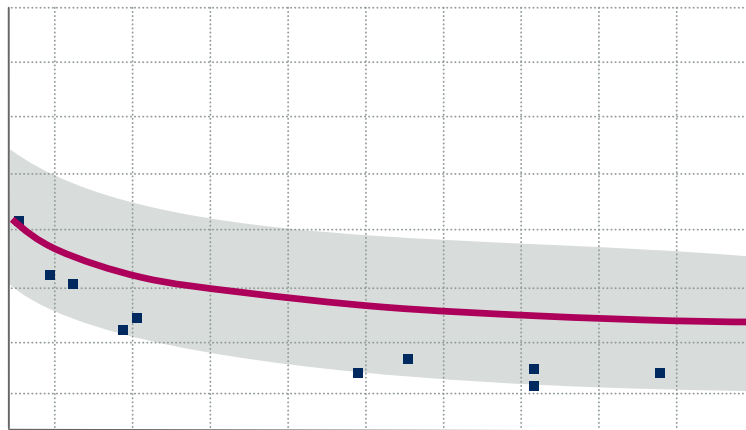
Sample outputs

Project duration Vs. Design complexity



■ Industry peers ■ Client projects

Productivity Vs. Team size

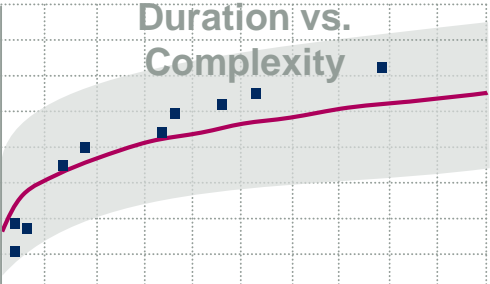


Performance benchmarking – A wide range of metrics can be benchmarked against industry peers

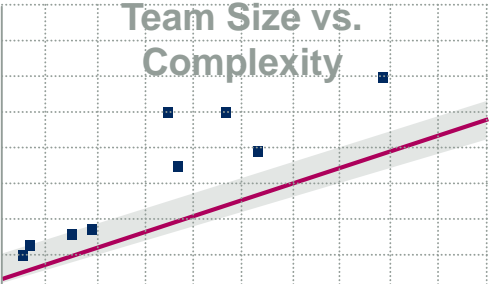
NOT EXHAUSTIVE

■ Client Software Projects ■ Band containing 50% of industry peers

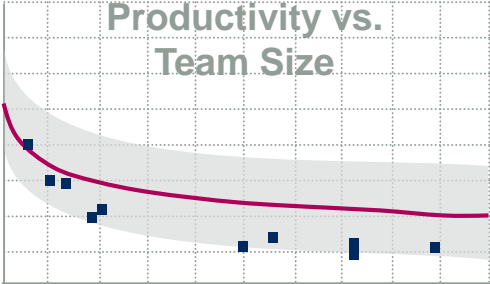
How fast can we deliver SW?



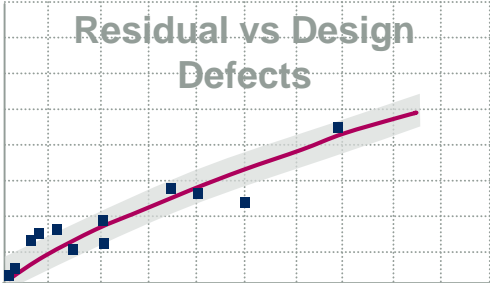
How many people do we need?



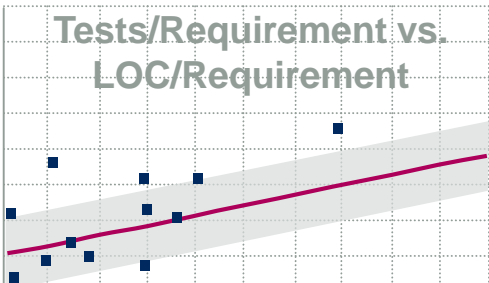
How efficient are we?



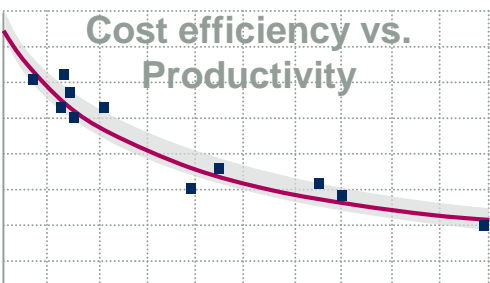
Is our verification strategy effective?



How granular are our requirements?



How cost competitive are we?



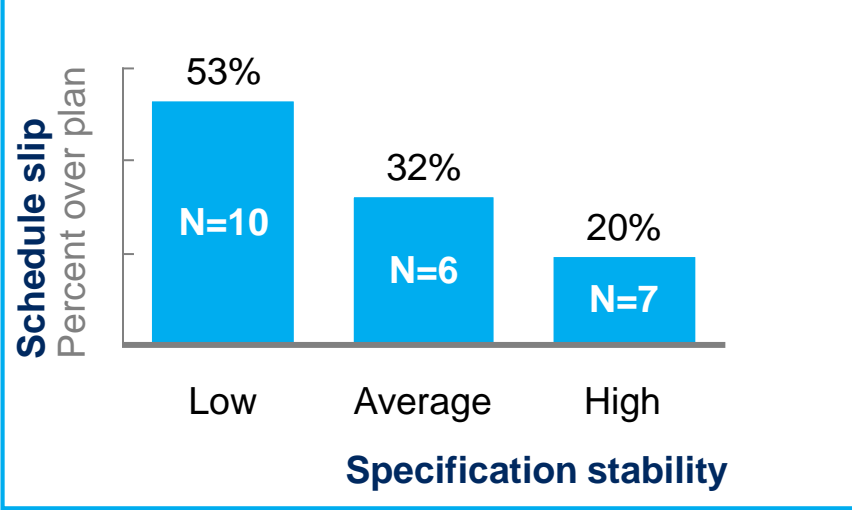
Root cause analysis – Analyzes industry database (best practices) to identify likely causes of low productivity

Root cause analysis

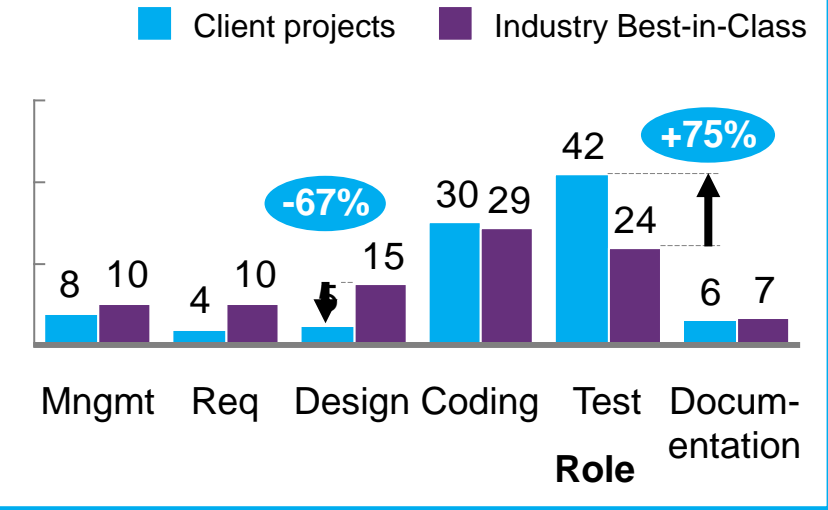
Use analytic tools to find root causes and drivers of low performance, and compare to industry best practices to determine recommended course of action

Sample outputs

Poor spec stability caused significant schedule slip



Insufficient effort during design phase caused higher test effort



Project planning – Predictive analytics generates robust project plans (resources, schedule) to identify time-to-market risks

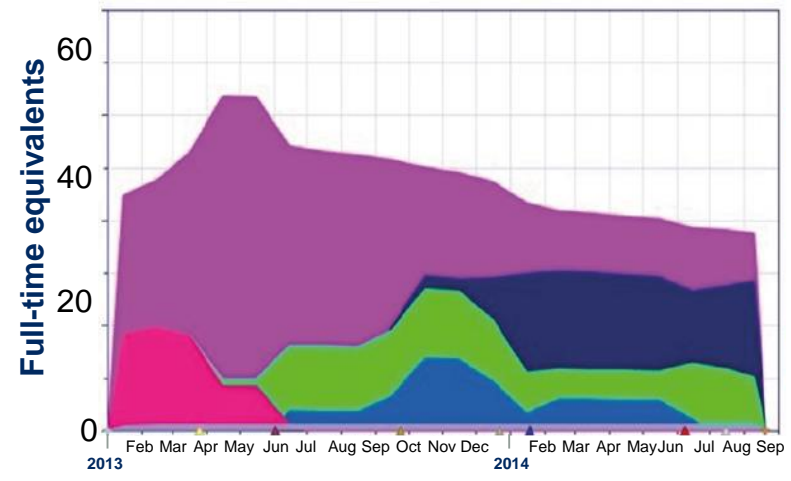


Project planning and risk assessment

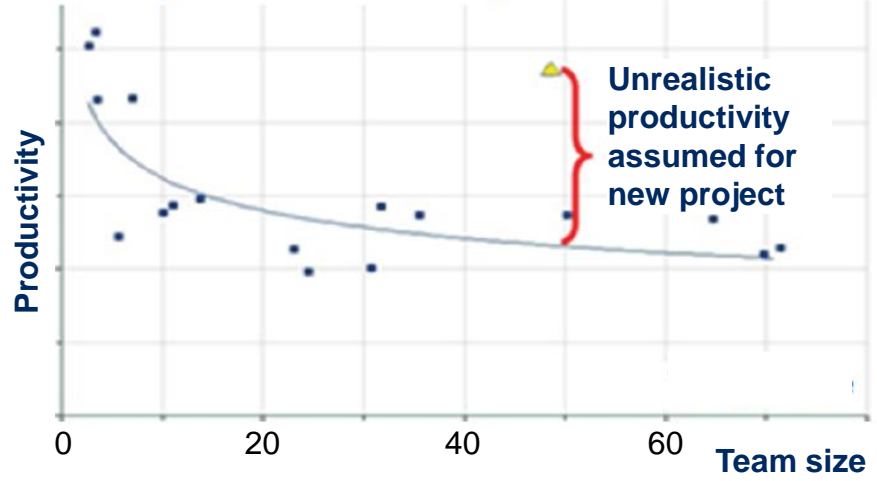
Use predictive analytics to provide better transparency to schedule and required resources at the project's outset and assess schedule risk due to unrealistic productivity assumptions

Sample outputs

Predicted staffing requirements by role and project phase

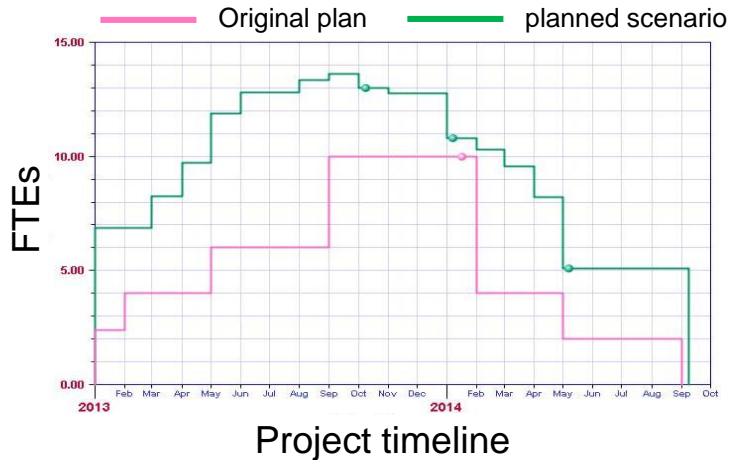


Schedule risk due to unrealistic productivity assumption



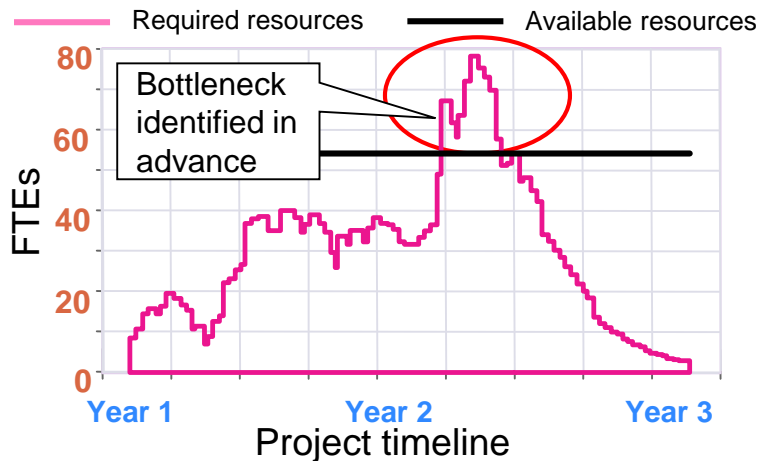
Project planning – predictive analytics is used to optimize schedule and staffing at the project and portfolio levels

“What-if” scenarios to determine tradeoffs and optimize the plan



- Planned staffing plan is plotted against the predicted resource requirements to identify gaps
- “What-if” scenarios can be run to better understand tradeoffs between specifications, resources, budget and timeline, and to determine the optimal plan for the project

Analytics on required staffing and available resources across multiple projects



- Estimated staffing requirements by role and project phase across multiple projects is compared to available resources
- Resource gaps and bottlenecks are identified early on with plenty of time to adjust staffing levels, modify scope or reprioritize projects

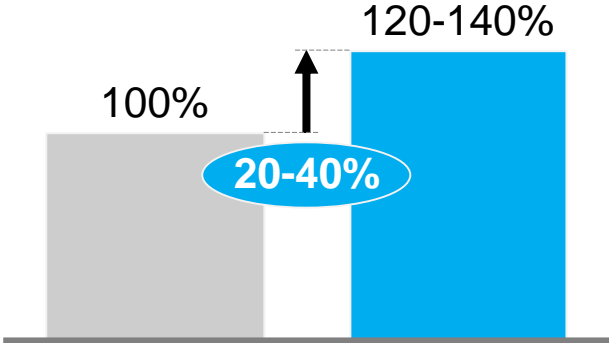
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Numetrics analytics enables step-function improvement in R&D productivity and time-to-market performance

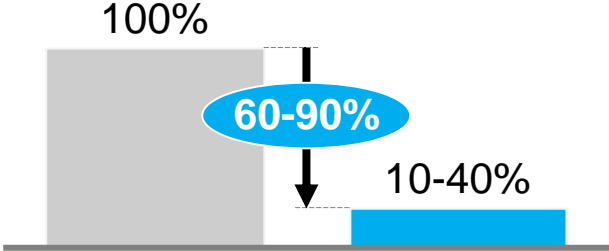


■ Before analytics ■ After analytics

R&D capacity¹



Reduction in schedule slip² (TTM)

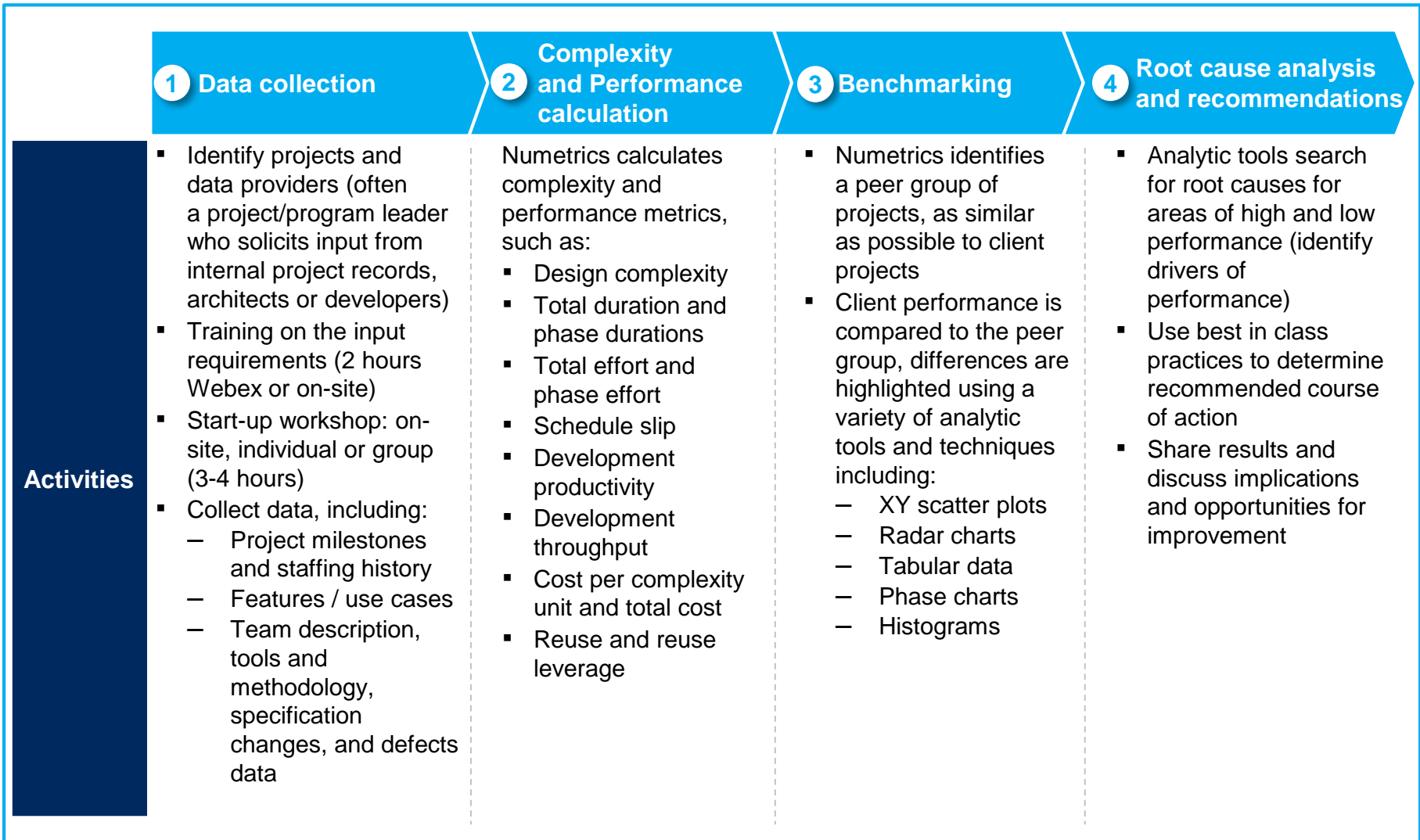


¹ R&D Capacity is measured as “complexity units per person-week”
² Schedule Slip is the amount of schedule overrun, expressed as a % of the original schedule.
 (e.g. if a 100-week project slips 12 weeks, then schedule slip = 12%)

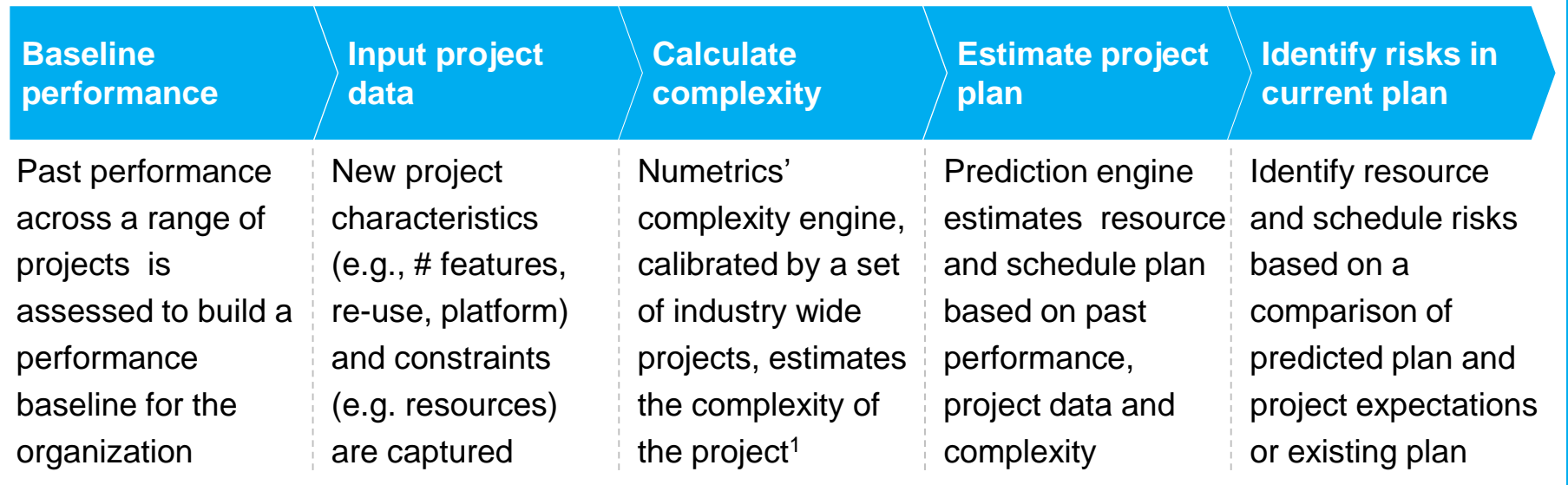
There are several ways to engage Numetrics

	Scope	Engagement model
Analytics focused diagnostic	<ul style="list-style-type: none"> 4-6 week (depending on data availability), Numetrics led diagnostic Standalone analytic assessment of 5-7 completed projects Provides a productivity baseline , industry benchmarks and analytic root cause analysis 	<ul style="list-style-type: none"> Numetrics team handles data entry, validation, analyses, and reports Client collects required project data under Numetrics' guidance and support
Deep R&D diagnostic	<ul style="list-style-type: none"> 8-10 weeks deep diagnostic, combining analytic and qualitative analyses Includes analytics focused diagnostic, complemented by qualitative tools such as surveys, project deconstruction, process mapping, interviews and workshops to provide a complete view of productivity and performance drivers May include planning of a new project to determine required resources and schedule risk 	<ul style="list-style-type: none"> Numetrics team handles data entries, validation, analyses, tailored benchmarking and reports Client collects required project data with Numetrics' guidance
Subscription	<ul style="list-style-type: none"> Embed Numetrics planning tool in the standard PD process to continuously track performance Use predictive analytics to increase TTM transparency and optimize resource allocation Includes initial benchmark and baseline creation and access to the planning tool 	<ul style="list-style-type: none"> Client trained to input project data and run reports directly using the web interface Numetrics team runs the analyses and provides insights

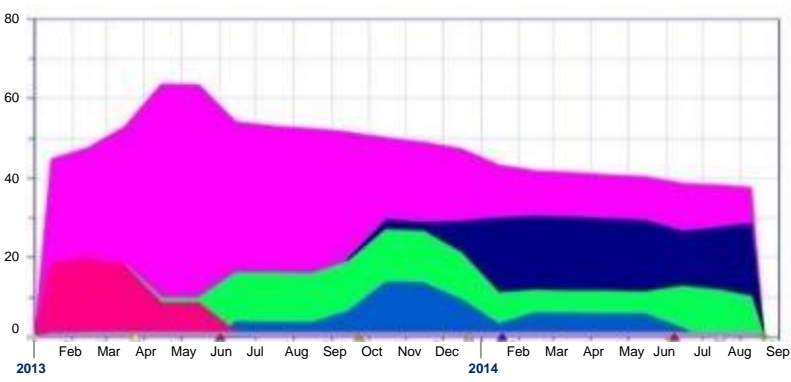
Benchmarking and root cause analysis require project data and timelines of several completed projects



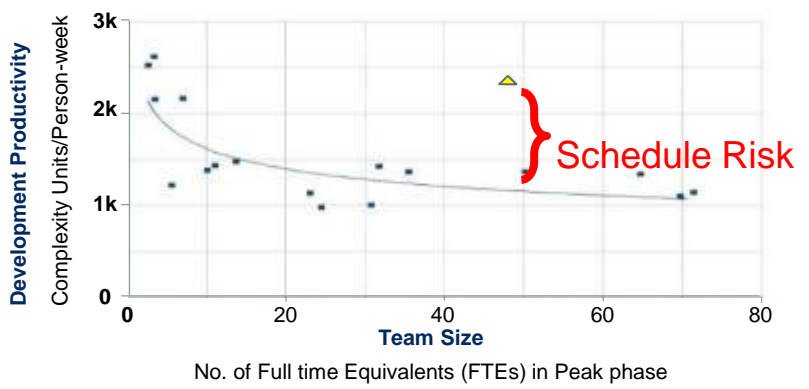
Numerics' predictive analytics can help optimize project planning and timely execution



Schedule & Resource Estimation



Schedule Risk Analysis

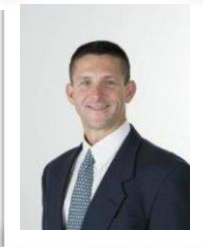


¹ Measured in Complexity Units - A metric reflecting the amount of effort the average development team will spend on the project

Who to contact to get started?



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Client case #1 – SW productivity benchmark & performance diagnostic for a telecom equipment OEM

Background

Client situation

- A global telecom company with R&D spread across 4 continents
- Recently made heavy investments in new tools and design methods, but unable to assess impact
- Great diversity of tools and practices between groups; unsure which were the “best practices” leading to the highest performance
- Looking for opportunities to improve productivity & reduce R&D costs

Engagement objectives

- Deliver ongoing performance measures as part of an executive dashboard to identify areas of best practice and teams that need help
- Quantify the ROI of recent investments in new tools & make a decision whether to roll out new capabilities more broadly
- Uncover additional opportunities for improving R&D productivity

Approach

Establish performance baseline

- Measure productivity, lead time, on-time performance and quality of multiple product lines & R&D sites

Develop performance dashboard

- Combine Numetrics’ productivity measurements and industry benchmarks with other internal metrics to create a comprehensive, standardized dashboard on R&D efficiency for senior executives

Identify best practices

- Identify improvement opportunities & best practices by comparing each baseline vs. internal and external benchmarks

Improve productivity

- Use root cause analysis techniques to uncover systemic root causes of poor performance as well as opportunities to improve

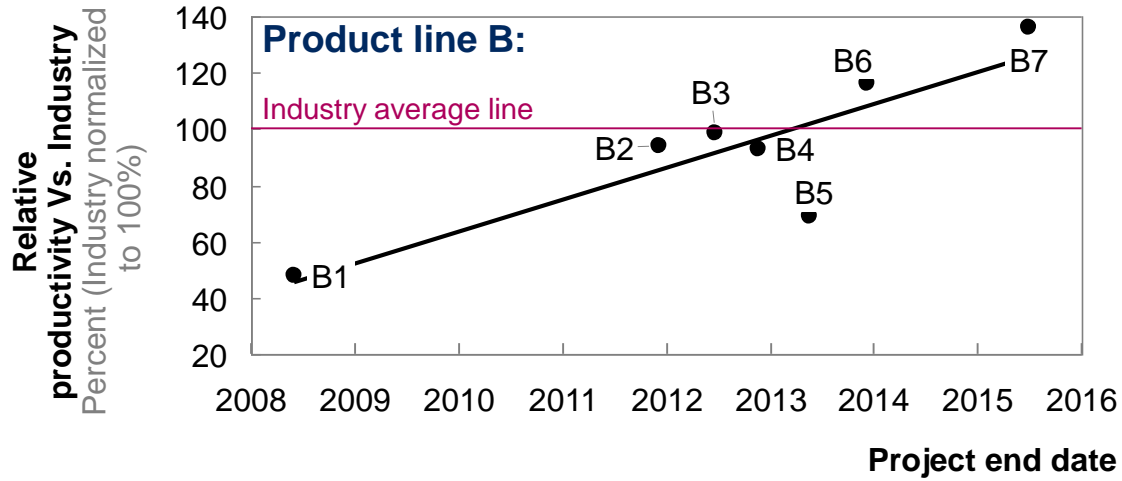
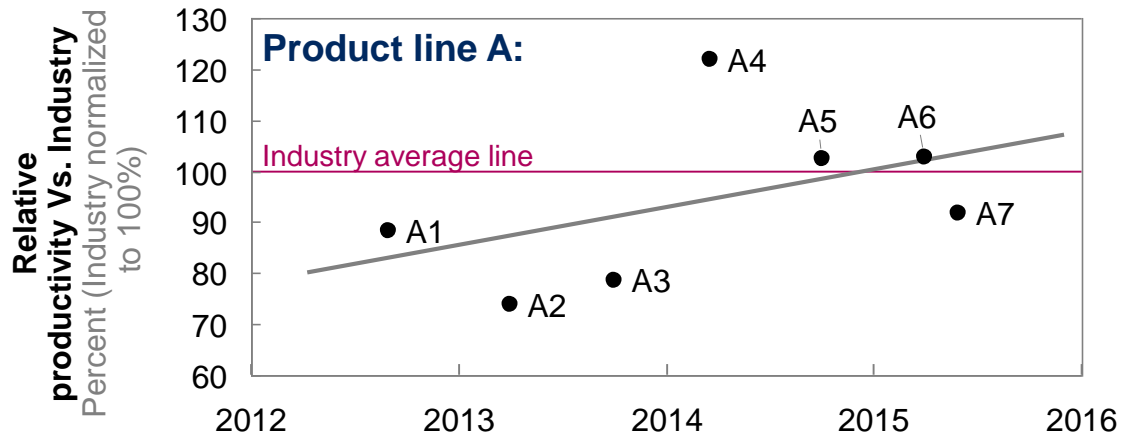
Impact

R&D productivity & transparency

- Provided a comprehensive industry benchmark across product lines and design sites
- Increased R&D transparency by establishing a performance dashboard for management
- Provided proof of the impact of recent investments in continuous integration and development methodologies, leading to a decision to standardize these practices across the company
- Enabled client to identify performance gaps and set performance improvement targets tailored for each product group
- Identified 7 actionable initiatives to improve productivity by: making changes to suppliers management, customers interactions, work allocation across sites, new release planning, prototype software approaches

Client case #1 – Continuous benchmarking showed continuous improvement and impact from Client’s initiatives

Relative productivity Vs. industry (industry indexed to 100%)



- Provided transparency by establishing a continuous performance dashboard for management
- Analytics proved that productivity was indeed improving following recent investments in continuous integration and development methodologies

Client case #2 - Software development cycle time improvement for a network equipment manufacturer

Background

Client situation

- A top tier supplier of enterprise class switches and routers
- Critical project to develop software for the next generation switching solution for secure enterprise applications
- Main concerns: New hardware platform, new functionality and a geographically dispersed development team
- Company was facing a significant loss of revenue/share to a competitor if new product is not delivered on schedule

Engagement objectives

- Develop a high integrity plan to achieve the time-to-market goal
- Assess and mitigate risks which threaten on-time product delivery

How impact was measured

- Actual cycle time was compared to the initial plan, if suggested corrective steps had not been taken

Approach

Establish capability baseline

- Measured R&D performance of teams on 4 prior generations of this switching product to establish a productivity baseline

Complexity measurement

- Estimated the new software's complexity early in the project's planning phase
- Sized each feature and change request in terms of the impact on project effort, cost and timeline

Schedule risk analysis

- Used analytics to identify high-risk execution assumptions
- Discovered underestimation of test effort required in current plan

Analytics-based planning

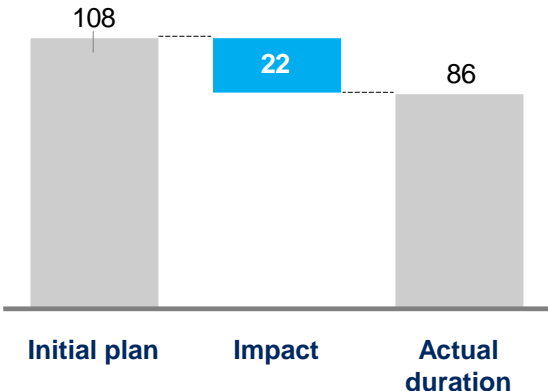
- Simulated various alternatives & developed "fact-based" cost, resource & time estimates
- Derived project and staffing plans that would meet the requirement specifications and timeline

Impact

- 4-6 months reduction in project duration and TTM slips captured through identification and mitigation of unrealistic test and verification assumptions

Impact on project duration

Weeks



"We had an intuitive feel that we consistently underestimate project effort, but it wasn't until we saw the baseline in Numetrics that we could break the cycle"

- Enterprise program manager

Client case #3 - Software development productivity and profitability improvement for a network equipment manufacturer

Background

Client situation

- A top tier networking equipment OEM with a significant software development operation
- Main concerns High product complexity, large software development and validation of resources involved, geographically dispersed development org
- Significant challenge in keeping the R&D cost low and delivering products on schedule to improve the company's profitability

Engagement objectives

- Start a lean software transformation program
- Improve R&D efficiency and drive productivity improvement initiatives

How impact was measured

- Identified improvement levers with specific targets and developed an execution plan
- Tracked productivity improvements continuously

Approach

Establish capability baseline

- Measured R&D performance and created a productivity baseline based on 26 different project teams

Benchmark performance

- Benchmarked current performance against industry peers across multiple dimensions such as project complexity, duration, team size, effort, productivity, etc.

Analytic root-cause analysis

- Performed root cause analysis to Compare client's practices to industry best-in-class
- Identified improvement opportunities and developed initiatives around levers found

Continuous improvement tracking

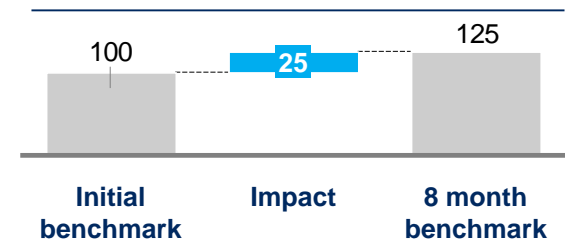
- Assessed productivity continuously to track progress of initiatives against targets

Impact

- Overall productivity improved 15-25% within 8 months, contributing to the company's bottom line and improving its overall profitability

Productivity impact after 8 months

Percent, Initial value indexed to 100%



"Numetrics delivers excellent insight into design performance indicators. The baseline comparison provides motivated design teams an opportunity to improve productivity, deliver sustainable design improvements and maximize customer perceived value"

"The program has worked very closely with the team to find root cause of our pain points, and create tangible solutions to help improve productivity"

- Growing importance of SW in networking
- Insights on SW R&D productivity in networking
- Introduction to Numetrics' R&D analytics
- Numetrics offering and engagement models
- Networking/telecom OEM case studies
- **Appendix**

Numetrics is a well-established company with a field proven sets of solutions

1998

Launch of semiconductor benchmarking solution

2001

Launch of semiconductor predictive planning solutions

2004

First embedded SW complexity model

2006

Launch of embedded SW predictive planning solution

2010

First 1,000 SW projects released in industry database

2013

Numetrics acquired by McKinsey

- Extensive database of ~2000 IC and ~1700 SW projects
- Field proven complexity estimation and predictive analytics algorithms
- Wide industry coverage including automotive, aerospace & defense, high tech, financial services, medical, etc.

The Numetrics database includes more than 300 wireless networking software projects...

Numetrics database statistics - wireless

- More than 300 wireless networking software projects
- Applications include:
 - Base stations & other network elements
 - Network management
 - 3G, 4G, LTE, CDMA
- Includes Drivers, operating system & other middleware & application layer development
- Team Sizes from 2 to 200 full-time equivalents
- Recent data (<3-4 years)



Sample Project Descriptions

- “Virtualized version of Diameter Signaling Controller for LTE networks including application-aware intelligence to optimize signaling in overload situations”
- “Basestation Layer 1 SW for dual-cell feature”
- “3G/4G baseband software”
- “Drivers for a 3G mobile baseband IC. Delivered as ROM code before tape-out”
- “UMTS Protocol stack development for 3G phones”
- “Cellular system monitors”
- “Security application for mobile device”
- “L1 and L2-L3 layers of LTE standard”
- “3G cellular modem platform”
- “Wireless voice communications terminal customized for a specific customer”
- “OA&M of mobile broadband networks.”
- “TCP/IP interface between a smart-phone and the base platform.”
- “Voice over LTE” (VoLTE) applications”

... And over 200 wired networking software projects

Numetrics database statistics - wired

- More than 200 wired networking software projects.
- Applications include:
 - Routers
 - Switches
 - Network operating systems
 - Network management
 - Security applications
- Includes Drivers, operating system & other middleware & application layer development
- Team Sizes from 2 to 200 full-time equivalents
- Recent data (<3-4 years)



Sample Project Descriptions

- “Multi Service Switch with Voice support”
- “Implementation of an L2 Switching functionality”
- “Layer 2 and 3 forwarding and processing capabilities; traffic management and local switching functionality.”
- “router/switch with support for 288 10GE ethernet ports or more”
- “Broadband Access Router with WAN Ethernet interface”
- “Security SW package for an edge router”
- “This software aggregates all the IP traffic emanating from WLANs and will put them into core network.”
- “offloading packet/data traffic from traditional network so that more BW is available for network operators for voice traffic”
- “Software includes all new operating system, networking middleware, and router application software.”

Numetrics' analytics engine is based on a proprietary "design complexity" model that normalizes productivity across projects

Design/development complexity:

- A metric representing the total amount of project effort the average design/development team in the industry would expend on the project – quantifies the true, normalized output of the design team
- The complexity model fully takes into account the stochastic nature of product development, which enables the predictive analytics engines to reliably estimate schedule & resource requirements and perform meaningful comparisons of performance metrics across different projects/designs

Complexity inputs

Software Complexity Measures

- Customer requirements
- Functional requirements
- Test cases
- Use cases
- Test types
- Lines of Code
- Architectural layers
- Number/type of components
- Reuse
- Programming language(s)
- Number of variants
- Real-time content
- Available storage space
- Number of platforms
- Platform maturity

