An Empirical Study of Technical Debt in Open-Source Software Systems

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What is Technical Debt

- In 1992, Ward Cunningham described technical debt as writing immature or "not quite right" code in order to ship a new product to market faster.
- **Technical Debt consists of:**
  - **Principle:** measures the cost or effort for eliminating technical debt .
  - **Interest:** measures the extra cost or effort over some period of time incurred for NOT eliminating the technical debt.

Why Do We Take Technical Debt

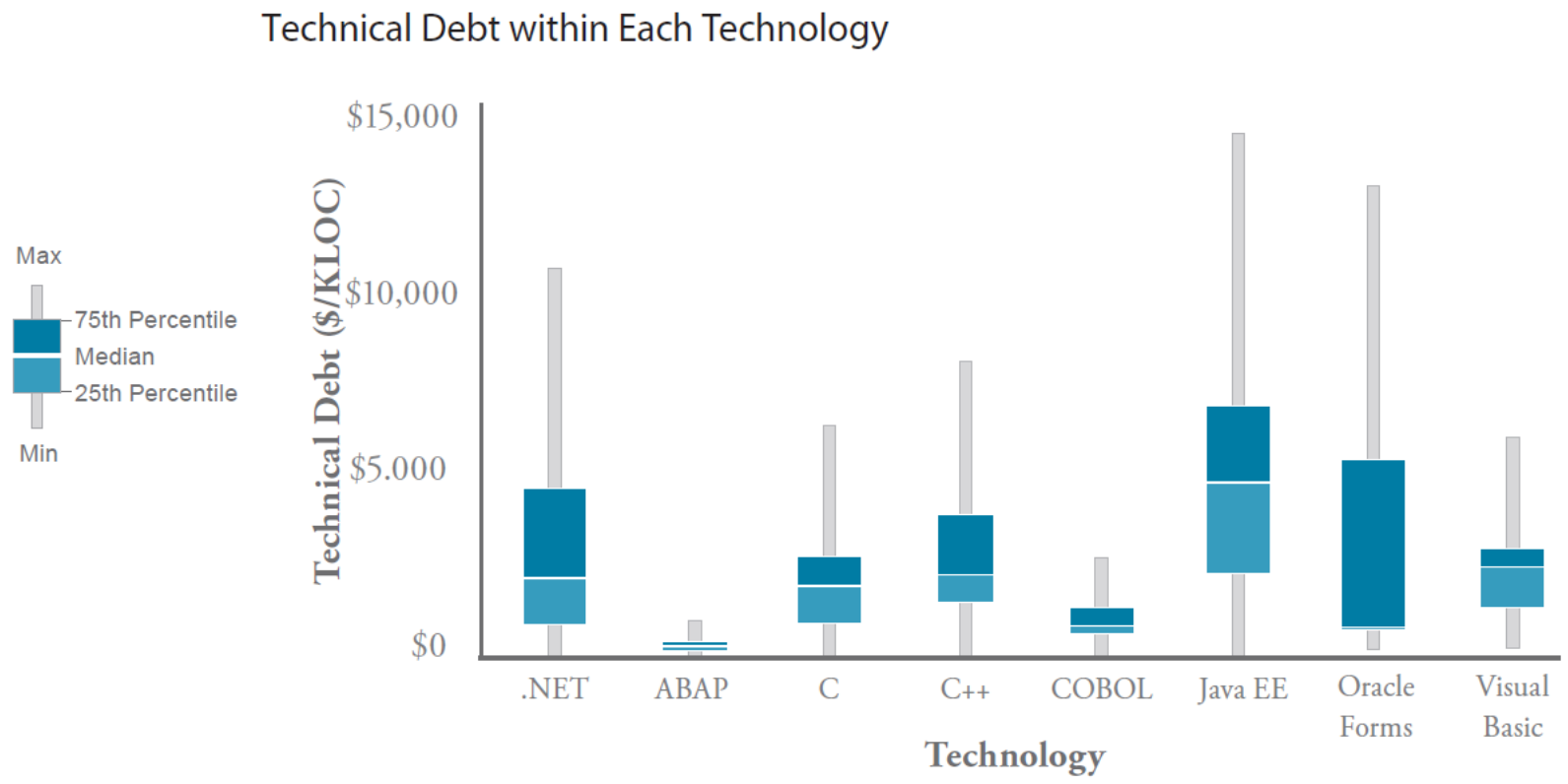
- Release faster.
- Decrease current release cost.
- Gather more information.
- Delay decisions.

Technical Debt Consequences

- Increased time to delivery.
- Increased number of defects.
- Raising maintainability cost.
- Decreased customer satisfaction.

- Based on the analysis of 1400 applications containing 550 million lines of code submitted by 160 organizations, the average Technical Debt per LOC of $3.61.

http://www.castsoftware.com/resources/resource/whitepapers/cast-report-on-application-software-health?gad=RLP&EID=e304258b-d795-4c50-93a9-1de71853cd3e

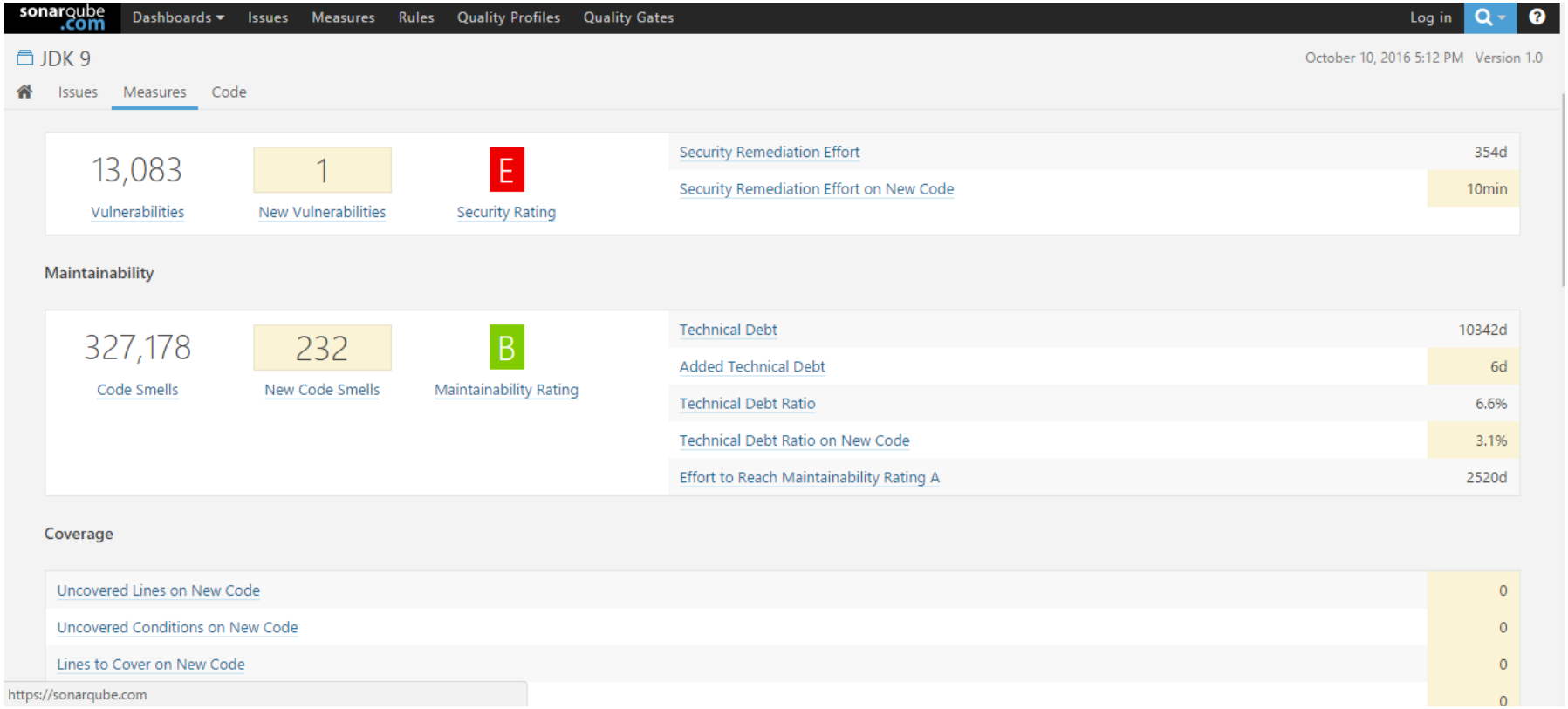


The average cost of Java apps was even higher: $5.42 per line of code.

http://www.castsoftware.com/resources/resource/whitepapers/cast-report-on-application-software-health?gad=RLP&EID=e304258b-d795-4c50-93a9-1de71853cd3e

- **Research Question #1:** Does the size of the source code relate to the total technical debt and the technical debt density.
- **Research Question #2:** Do the total technical debt and the technical debt density in a software vary among domains?
- **Research Question #3:** Do system development and management decisions including number of commits, releases, branches, and contributors relate to the total technical debt and the technical debt density?

Technical Debt Calculation



- Technical Debt= Technical Debt(in _man _ hours)

- Technical Debt Density= Technical Debt(in _man _ hours)/LOC

Data Collection

- More than one official releases.
- Latest stable release source code is available.
- Software system falls under one and only one domain.
- The programming language is only java.
- Well-presented in the community.
- Active Git repository.

Data Collection

Apache Software Foundation (Java)

TABLE I
CHARACTERISTICS OF SYSTEM DATA SOURCES

Domains	Number of systems	Average LOC
Big Data	16	44992
Database	13	52610
Library	35	113612
Network Server	9	20624
Web Framework	11	31164
XML	7	51569

Data Analysis - (1/3)

- Evaluation on size hypothesis (RQ#1)
  - K-means Cluster analysis
    - Help to find pattern in the data based on their similarity.
    - We cluster them based on the size of systems using a clustering algorithm
      - Examine whether total TD and TDD differ significantly among each cluster

Results on Size Hypothesis

- **Larger systems** have more technical debt in total but less technical debt density while **smaller systems** have less technical debt in total but higher technical debt density

TABLE III
CLUSTER MEANS

Cluster	Technical Debt	LOC
1	2074.1818	120362.64
2	346.2475	18070.42

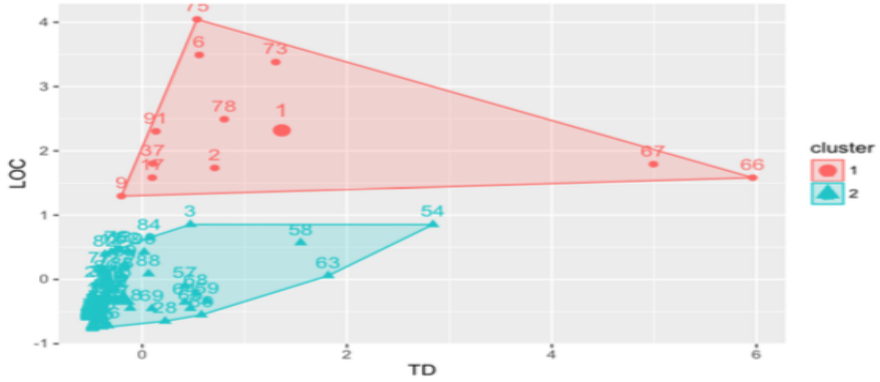


Fig. 1. 2D representation of the cluster solution of Technical Debt

TABLE IV
CLUSTER MEANS

Cluster	Technical Debt Density	LOC
1	19.48511	120362.64
2	20.06992	18070.42

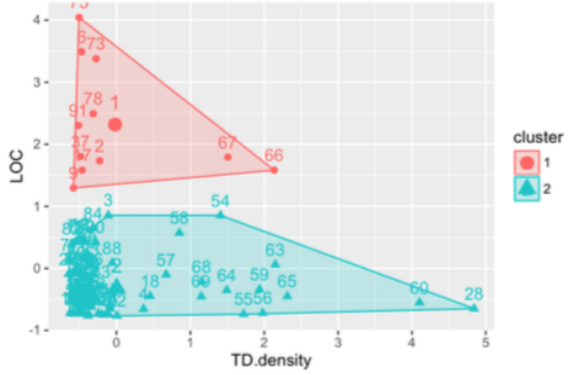


Fig. 2. 2D representation of the cluster solution of Technical Debt Density

Data Analysis - (2/3)

- Evaluation on domain hypothesis (RQ#2)
  - We perform various statistical analysis
    - Levene's Test.
    - Welch ANOVA.
    - Games-Howell Test.

Results of Levene's Test

- Unequal variances (F = 6.117, p = 6.912e-05) for TD and unequal variances (F = 4.9892, p = 4.695e-04)for TDD.
- Since the p-value of Levene's test is less than 0.05, we concluded that the variances of the six domains are significantly different.
- These unequal variances suggest that we cannot use one-way ANOVA (violate one of the assumptions for one-way ANOVA)
- Welch ANOVA is used in this case.

Results of Welch ANOVA

- An alpha level of 0.05 is used.
- Total technical debt of six domains
  - *Welch's F*(5, 23.508) = 4.2964 with *P*= 0.006408
    - (Not all domains have the same TD)
- Total technical debt density of six domains
  - Welch's F(5, 25.47) = 5.2781 with *P* = 0.001848
    - (Not all domains have the same TDD)

Games-Howell Test

- What about unique pairwise comparison? => Games-Howell Test

Results

- Library and Big Data have significantly different TD at 0.1 level of significance, not significant for other comparisons.
- Many pairwise appear to have significantly different TDD at the 0.1 level of significance:
  - XML with Network
  - Web Framework with Network
  - Web Framework with Big Data
  - Database with Big Data

Data Analysis - (3/3)

- Evaluation on system development and management decisions hypothesis (RQ#3)

- Pearson Correlation Test
- Significance level is set to 0.05 Confidence level=95%

Results of Pearson Correlation

Technical Debt

CORRELATION COEFFICIENTS MATRIX BETWEEN TOTAL TECHNICAL DEBT AND SYSTEM DEVELOPMENT AND MANAGEMENT DECISION FACTORS

	N	R-value	p-value
Number of Branches	91	.05071	.63308
Number of Releases	91	.26114	.01241
Number of Commits	91	.51619	1.63135e-7
Number of Contributors	91	.12618	.23335

Results of Pearson Correlation

Technical Debt Density

CORRELATION COEFFICIENTS MATRIX BETWEEN TECHNICAL DEBT DENSITY AND RESEARCH QUESTIONS FACTORS

	N	R-value	p-value
Number of Branches	91	-0.04658	.66108
Number of Releases	91	.12826	.22567
Number of Commits	91	.17108	.10493
Number of Contributors	91	-.02188	.83688

Conclusion

- We examined 91 Apache Java OSS projects.
- We employed various statistical methods to investigate how TD and TDD relate to different system characteristics, development, and management decisions.
- The size of software system and its domain can impact its TD and TDD significantly.
- Number of system releases and commits have a significant positive relationship with TD.
- Results show no significant relationship between TD and the number of contributors and branches.
- No significant relationship between TDD and any of the system development and management decisions.

Future Work

- Further the study to understand the reasons behind these relations.
- Goal: provide guidelines for decision makers to help them study the tradespace by providing what factor(s) introduce more TD to the system and the quality per capita in the systems.