Analysis of Design Defect Injection and Removal in PSP

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Agenda

The Role of Defects

Our Research

The Data Set

Where the Defects Are Injected

Analysis of Design Defects

- Defect types injected during design
- When are the defects removed
- Cost to remove the defects injected in design

"Playing" with the Data

Conclusions and Future Work

The Role of Defects

- A primary goal in SPI: more efficient software development
- Software defects work against this goal
- To prevent or remove defects efficiently, we have to understand them:
  - Where and when are defects injected and removed?
  - Which defect type is most frequently injected?
  - Which type is most expensive to remove?
  - How many and which types of defects escape into unit test?
  - Other considerations

Our Research

Research goal: analyze PSP data to learn about the characteristics of defects injected during design

The Data Set

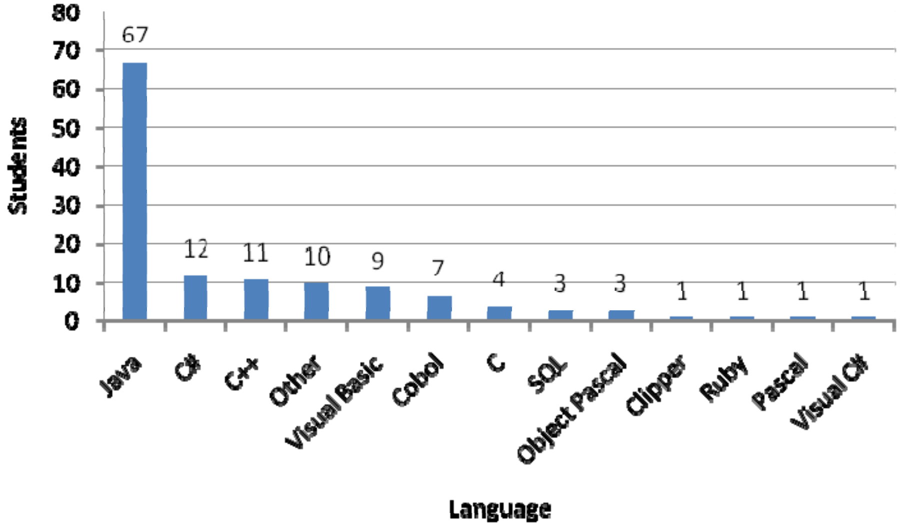
PSP 8 program course

- From October 2005 to January 2010

Only PSP2.1 was considered

- Programs 6, 7 and 8
- Threat to validity: the students who generated the data were in a learning process, so the PSP techniques may not have been well applied

The Data Set (2)



94 engineers used the Java, C++, C# and C programming languages

Reason: these languages used similar syntax, subprogram and data constructs

Threat to validity: Java, C++, and C# are OO languages but C is not and we are analyzing design defects. (Thanks, reviewers, for pointing this out.)

However, the C language was used only by 4 engineers.

The Data Set (3)

94 engineers

2 did not record any defects in the last 3 programs.

11 did not record any defects during design phase.

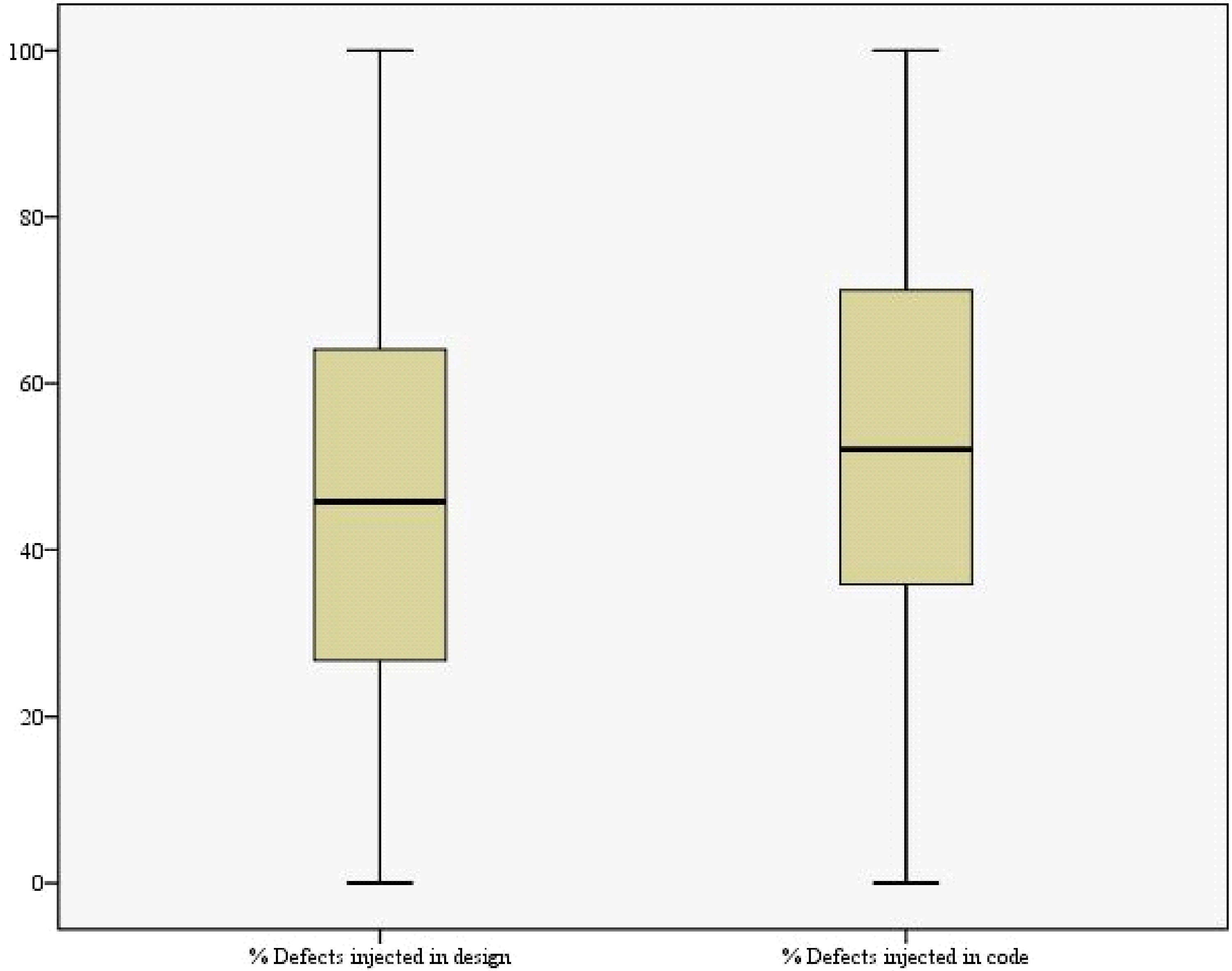
For our analysis, we sometimes use data from 92 engineers, while other times using data from 83 engineers, depending on the analysis needs.

Where the Defects Are Injected

	DLD	DLDR	Code	CR	Comp	UT
Mean	46.4	0.4	52.4	0.3	0.03	0.5
Lower	40.8	0.2	46.7	0.0	0.0	0.2
Upper	52.0	0.7	58.1	0.7	0.09	0.9
Std. Dev.	27.2	1.7	27.4	1.8	0.3	1.8

As we expected, almost 99% of the defects are injected in the DLD and Code phases.

Where the Defects Are Injected (2)



Where the Defects Are Injected (3)

The variability between individuals is substantial. For example, some engineers don’t inject defects during design and some of them don’t inject defects during code.

Future work: try to understand the characteristics of individuals exhibiting different defect injection patterns

Analysis of Design Defects

In this work, we focus on design defects.

We reduced our data set to the 83 engineers who injected design defects.

Based on our analysis, we will discuss:

- What types of defects are injected during design
- When those defects are removed
- The effort required to find and fix defects

Defects Types Injected During Design

	Docs.	Syn.	Build	Assign.	Inter.	Check	Data	Func.	Syst.	Env.
Mean	6.9	6.0	0.1	12.6	10.0	4.6	9.8	46.6	0.2	3.1
Lower	3.3	2.5	0.0	8.2	5.1	1.6	6.3	39.7	0.0	0.9
Upper	10.5	9.5	0.3	17.0	15.0	7.6	13.3	53.5	0.6	5.3
Std. dev.	16.6	16.0	0.8	20.2	22.5	13.8	16.0	31.5	1.7	10.1

To improve the detection of design defects, we first want to know which types of defects were injected during the Design phase.

Defects Types Injected During Design

	Docs.	Syn.	Build	Assign.	Inter.	Check	Data	Func.	Syst.	Env.
Mean	6.9	6.0	0.1	12.6	10.0	4.6	9.8	46.6	0.2	3.1
Lower	3.3	2.5	0.0	8.2	5.1	1.6	6.3	39.7	0.0	0.9
Upper	10.5	9.5	0.3	17.0	15.0	7.6	13.3	53.5	0.6	5.3
Std. dev.	16.6	16.0	0.8	20.2	22.5	13.8	16.0	31.5	1.7	10.1

Build and System: almost no defects of this type were found.

This may be due to the PSP course exercises:

- Small programs where the build/package is simple and the systems problems (configuration, timing, etc.) are unlikely to be present

Threat to validity: the programs of the PSP course are small.

Future work: try to find more of these defect types in TSP projects.

Defects Types Injected During Design (2)

	Docs.	Syn.	Build	Assign.	Inter.	Check	Data	Func.	Syst.	Env.
Mean	6.9	6.0	0.1	12.6	10.0	4.6	9.8	46.6	0.2	3.1
Lower	3.3	2.5	0.0	8.2	5.1	1.6	6.3	39.7	0.0	0.9
Upper	10.5	9.5	0.3	17.0	15.0	7.6	13.3	53.5	0.6	5.3
Std. dev.	16.6	16.0	0.8	20.2	22.5	13.8	16.0	31.5	1.7	10.1

Documentation, Syntax, Assignment, Interface, Checking, Data, and Environment: few defects of these types were found.

Defects of these types were injected (from 3.1% to 12.6%).

Most of the remaining defect types (except Function) are in this category.

Defects Types Injected During Design (3)

	Docs.	Syn.	Build	Assign.	Inter.	Check	Data	Func	Syst.	Env.
Mean	6.9	6.0	0.1	12.6	10.0	4.6	9.8	46.6	0.2	3.1
Lower	3.3	2.5	0.0	8.2	5.1	1.6	6.3	39.7	0.0	0.9
Upper	10.5	9.5	0.3	17.0	15.0	7.6	13.3	53.5	0.6	5.3
Std. dev.	16.6	16.0	0.8	20.2	22.5	13.8	16.0	31.5	1.7	10.1

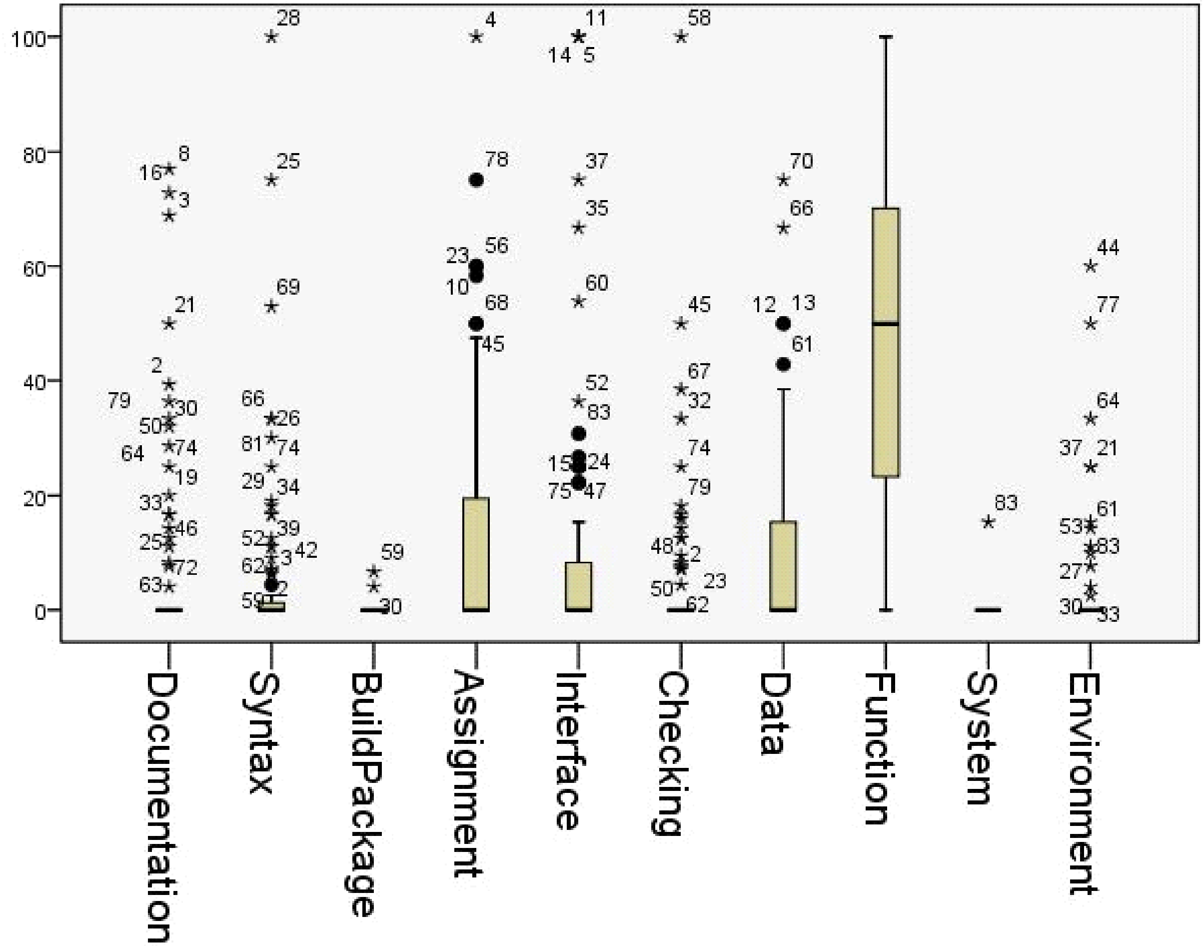
Function: many defects of this type were found.

Only defects of type Function were in this category.

46.6% of all the defects injected during design were Function defects.

Defects Types Injected During Design (4)

Variability between individuals and assignments



This suggests that individuals have different behaviors.

When Are the Defects Removed

For each engineer who injected Design defects, we identified the phases in which the engineers found these defects.

This work used a limited sample size that did not allow further analysis of removal phases.

Future work: when we get more data, examine the removal phases based on the defect types.

When Are the Defects Removed (2)

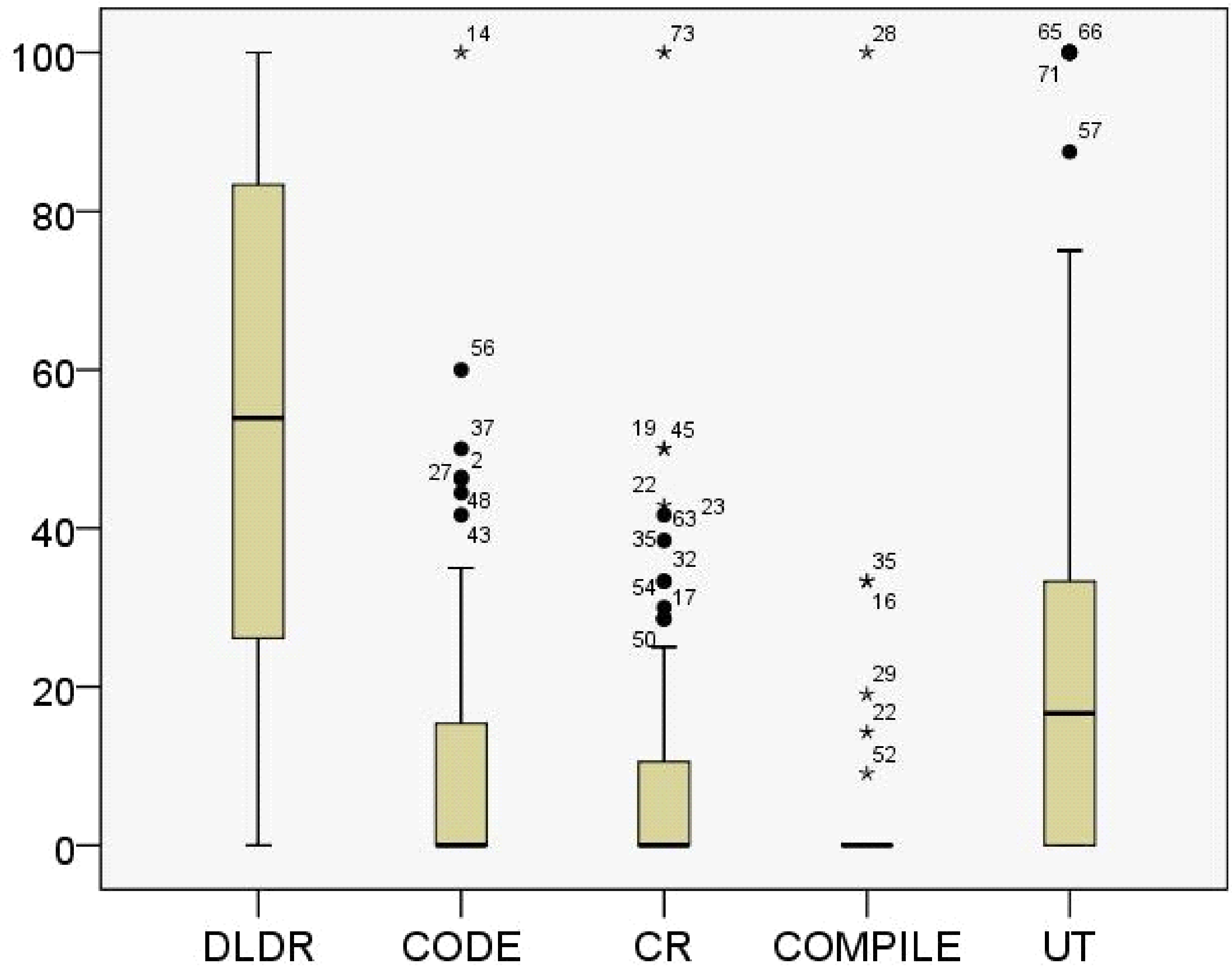
	DLDR	Code	CR	Comp	UT
Mean	53.4	9.6	8.9	2.5	25.7
Lower	45.8	5.7	5.2	0.0	19.3
Upper	61.0	13.4	12.5	5.2	32.0
Std. dev.	34.8	17.5	16.7	12.3	29.2

Half of the defects are found early in the DLDR phase.

However, one of every four defects injected during Design escapes all phases prior to UT.

- How can we improve this? We first need to know the types of defects that escape to UT.

When Are the Defects Removed (3)



Again we find a high variability between individuals.

Cost to Remove the Defects Injected in Design

We analyze the differences in cost segmented by:

- Removal phase
- Defect type

It would also be interesting to segment and analyze both the removal phase and the defect type jointly.

Unfortunately, because of limited sample size after a two dimensional segmentation, we could not perform that analysis with statistical significance.

Future work: when we get more data, examine the segmentation in two dimensions.

Cost to Remove Defects Segmented by Phase

For each engineer, we calculated the average task time to removing a design defect in each of the different phases.

Because some engineers did not remove design defects in one or more phases, our sample size varied by phase.

We excluded the cost of finding design defects in the Compile phase because we had insufficient data for that phase.

Cost to Remove Defects Segmented by Phase (2)

	DLDR	CODE	CR	UT
Mean	5.3	5.1	4.2	23.0
Lower	3.7	2.5	2.6	11.6
Upper	6.9	7.6	5.7	34.3
Std. dev.	6.6	6.7	4.1	42.0

Cost (in minutes) of "find and fix" defects injected during design segmented by removal phase

Cost to Remove Defects Segmented by Phase (3)

The cost remained almost constant during DLDR, Code, and CR.

- We expected an increased defect find and fix cost in each phase.
- The design defects that are removed during DLDR cost approximately the same as removing the ones that escape from Design into Code and those that escape from Design into CR.
- However, we are calculating phase removal costs with different defects.

Unit Test cost are almost five times higher that DLDR costs.

Cost to Remove Defects Segmented by Type

	Docs.	Syn.	Assign.	Inter.	Check	Data	Func.	Env.
Mean	5.6	4.3	7.3	5.4	4.9	11.0	9.3	10.5
Lower	3.6	1.8	1.9	2.5	2.2	2.2	6.9	3.0
Upper	7.6	6.7	12.7	8.2	7.5	19.8	11.7	17.9
Std. dev.	4.1	3.7	16.3	7.3	5.2	25.6	10.1	11.7

Cost (in minutes) of find and fix defects injected during design segmented by type

Not enough data to present Build/Package or System defects.

Three clearly different groups:

- Group 1: approximately 5 minutes cost (Documentation, Syntax, Interface, Checking)

Cost to Remove Defects Segmented by Type (2)

	Docs.	Syn.	Assign.	Inter.	Check	Data	Func.	Env.
Mean	5.6	4.3	7.3	5.4	4.9	11.0	9.3	10.5
Lower	3.6	1.8	1.9	2.5	2.2	2.2	6.9	3.0
Upper	7.6	6.7	12.7	8.2	7.5	19.8	11.7	17.9
Std. dev.	4.1	3.7	16.3	7.3	5.2	25.6	10.1	11.7

Cost (in minutes) of find and fix defects injected during design segmented by type

Not enough data to present Build/Package or System defects.

Three clearly different groups:

- Group 1: approximately 5 minutes cost (Documentation, Syntax, Interface, Checking)
- Group 2: a group only with Assignment defects

Cost to Remove Defects Segmented by Type (3)

	Docs.	Syn.	Assign.	Inter.	Check	Data	Func.	Env.
Mean	5.6	4.3	7.3	5.4	4.9	11.0	9.3	10.5
Lower	3.6	1.8	1.9	2.5	2.2	2.2	6.9	3.0
Upper	7.6	6.7	12.7	8.2	7.5	19.8	11.7	17.9
Std. dev.	4.1	3.7	16.3	7.3	5.2	25.6	10.1	11.7

Cost (in minutes) of find and fix defects injected during design segmented by type

Not enough data to present Build/Package or System defects.

Three clearly different groups:

- Group 1: approximately 5 minutes cost (Documentation, Syntax, Interface, Checking)
- Group 2: a group only with Assignment defects
- Group 3: approximately 10 minutes cost (Data, Function, Environment)

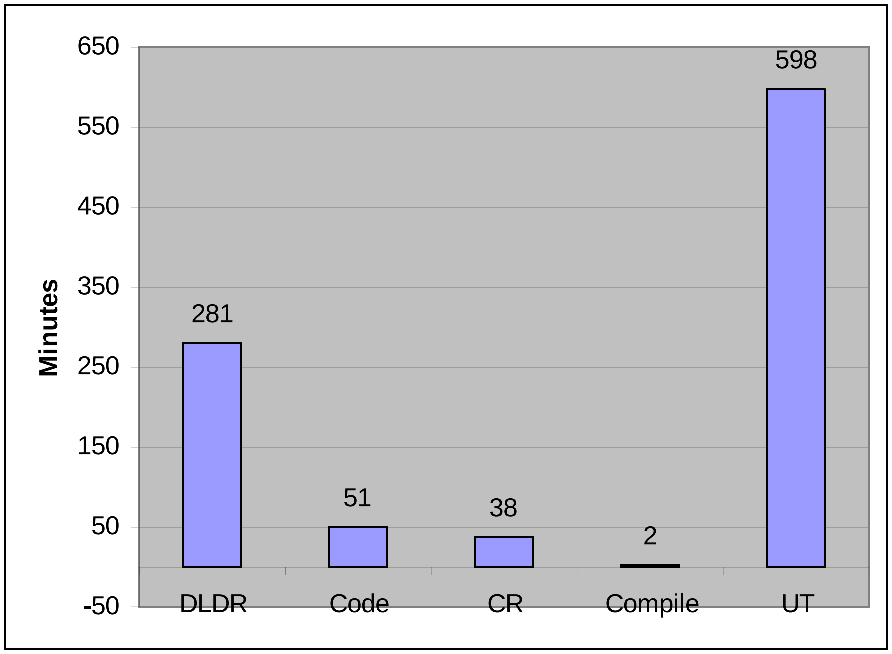
Using Data for Planning

Suppose we developed a program in which we injected 100 defects during design

Using Data for Planning (2)

100 defects injected during design

- We will find 53 in DLDR, 10 in Code, 9 in CR, 2 in Compile and 26 in UT
- Using the average cost of find and fix by phase (we assume 1 minute in Compile) we have:



We will use 598 minutes to find and fix the 26 defects that escapes all the other phases

This represents the 61% of the total time of removing the defects injected during design

Conclusions

(We observe a high variability between individuals and assignments)

Function type are the most common design defects (46%)

Function type defects are in the most costly find and fix group. (Data and Environment are also in this group)

Half of the defects injected in design are found early, in the process DLDR phase

25% of the design defects escape to UT.

Phases prior to UT have similar defect find and fix costs

Defects are 5 time more expensive to find and fix in UT than in the earlier PSP phases.

Future work

Future work was mentioned during the presentation

The most important things we are planning to do is:

- Repeat the analysis with more data
- Include an equal analysis to defects injected during coding

We hope that this new analysis will enable us to analyze improvement opportunities to achieve better process yields

Questions

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