Waiting in software projects: an exploratory study

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Keywords: waiting, project urgency, empirical study, re-analysis

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Austen Rainer

1. Introduction

Intuitively, there should be some connection between the behaviour of an individual and a project's ability to act. In particular the actual use of an individual's time within a project ought to have some relationship with the actual use of time at the project level. Perry et al. [1] note that there is a surprising lack of research on time-related behaviour at the individual level, and also a lack of research on the connection between an individual's actions and a project's ability to act. (Humphrey's work [2] on the Personal Software Process (PSP), and its relationship to the Capability Maturity Model (CMM) is one notable example of research that is trying to connect individual actions with an organisation's actions and outcomes.)

Bradac, Perry and Votta [3] conducted a time diary study into how a developer used their time during the development of a feature. (In the context of Bradac *et al.*'s study, a feature is the most basic unit of development for a very large software system, and represents a long-term effort.) Bradac *et al*. conducted this study in order to better understand, and ultimately try to reduce, project duration. Bradac *et al*. focused on prospects for reducing waiting in the process, and concluded that waiting was more prominent during the beginning and the end of the process. This lead Bradac *et al*. to suggest that attempts should be made to reduce blocked work in the earlier and later tasks of the process i.e. the requirements, high-level design and high-level test tasks. Bradac *et al*. also recognised that their insights into the prevalence of waiting would only really have any significance to project durations if these insights applied at a project level and not just at the level of the individual developer.

An earlier version of Bradac et al.'s paper appeared as a conference paper [4] and the findings of the paper are also discussed in [5] and [1]. The paper has also informed other research within Lucent Technologies e.g. [6] and [7].

As part of an investigation into project schedules at IBM Hursley Park [8], we sought to explore the prevalence of waiting at a higher level of the project. We investigate the progress of 'functional areas' of the projects e.g. design/code, test, marketing, finance. The projects consider these areas to be significant, as indicated by the fact that each of these areas has a representative at each of the project's status meetings. We refer to these areas as 'process areas'. (They should not be confused with the Capability Maturity Model's Key Process Areas.) As these process areas are represented at the status meetings, we consider these process areas to be one level of control below the project level. We have sought to relate our findings at the level of process areas with Bradac et al.'s findings at the level of the individual developer, and so try to address the lack of research identified by Perry et al.

In this paper, we report our re-analysis of one of Bradac et al.'s conjectures (viz. that waiting is more prevalent during the beginning and the end of the process). We also extend Bradac et al.'s analysis by investigating the prevalence of waiting at the level of the process area, and by investigating the behaviour of two other 'properties' of the project i.e. poor progress and outstanding work. We also explore other behaviour in the project (i.e. the actual start and end of project phases, project urgency and project re-plans) to try to explain the 'behaviour' of waiting, poor progress and outstanding work. A re-interpretation of our findings leads to a discussion of the implications of these findings on effort.

2. A brief re-analysis of Bradac *et al.*'s study

As already indicated, Bradac et al. conducted a time diary study into how a developer used their time during the development of a feature. They analysed a 30-month time diary of one lead designer. Bradac et al. present a number of conjectures based on their analysis of the time diary. Three conjectures interest us here:

1. "Although there may well be other factors to consider, it seems clear that one important way of improving the process is to reduce significantly the number of days in blocking states."

2. "The utility of the first conjecture depends on the degree of multiplexing within these processes. Clearly, if the global level of blocking is consonant with the behaviour of the designer at a local level, the conjecture will hold."

3. "The other thing to note… is that blocking tends to be more prevalent at the beginning and the end of the process."

Table 1 Comparison of the earlier and later parts of the process with the overall process

State	**Earlier in the process**		**Later in the process**		**Overall process**	
	f	**%**	***f***	**%**	***f***	**%**
Working	21	27.6	50	65.8	30	39
Waiting	55	72.4	26	34.2	46	61
Total	76	100	76	100	76	100

Table 1 presents frequency counts and percentages for an earlier and later part of the process, and the overall process. The data for this table was taken from time-lines presented in Bradac *et al.*'s paper, and refer to an individual's process rather than a project's process.

The earlier and later parts of the process each last 76 days. It is not clear from Bradac *et al.*'s paper where precisely in the overall process the earlier and later parts of the process occur. Also, it is not clear from Bradac *et al.*'s paper where the distinctions lie between the beginning, middle and end of the process. We assume that the earlier part of the process occurs sometime during the beginning of the process, and the later part of the process occurs sometime during the end of the process. Also the overall process for the one developer will occur within a larger overall process of the entire project.

Bradac *et al*. provide frequency counts for the earlier and later parts of the process, but only provide percentages for the overall process. To ‘recover’ the frequency counts, we have converted the percentages of the overall process to frequency counts based on the total number of days in each of the earlier and later parts of the project i.e. based on a total of 76 days. As 39% of the overall process was spent working, this can be converted to approximately 30 days i.e. 39% of 76 days. Similarly, 61% of the overall process was spent waiting and this converts to approximately 46 days i.e. 61% of 76 days.

The table suggests that there is a great deal of variation in the amount of time that can be spent blocked or working; a suggestion recognised by Bradac *et al*. Between a quarter and two-thirds of the developer’s time is spent working, and between a third and three-quarters of the developer’s time is spent waiting.

An ‘eyeball test’ of Table 1 suggests that of the earlier and later parts of the process, it is the earlier part of the process that is more like the overall process. This ‘eyeball test’ appears to undermine Bradac *et al*.’s conjecture that waiting is more prevalent during the beginning and the end of the process. As a result of the ‘eyeball test’, we proposed two hypotheses:

H_1 The frequency of waiting in the earlier part of the process is significantly different to the frequency of waiting in the overall process.

H_2 The frequency of waiting in the later part of the process is significantly different to the frequency of waiting in the overall process.

We tested these hypotheses using two-tailed chi-square ($\chi2$) tests of independence.

Table 2 Results of chi-square tests of hypotheses H_1 and H_2 (two-tailed)

		statistics				
#	**Hypotheses**	**p**	***df***	**$\chi2$**	**α**	**β**
H_1	The frequency of waiting in the earlier part of the process is significantly different to the frequency of waiting in the overall process	0.122	1	2.39	0.05	unknown
H_2	The frequency of waiting in the later part of the process is significantly different to the frequency of waiting in the overall process	0.001	1	10.556	0.05	unknown

A chi-squared test can be used to detect a difference, but in itself such a test does not indicate the direction of any difference. The results of the chi-squared test *together with* the data in Table 1 suggest a modification to one of Bradac *et al*.'s conjectures. The test results suggest that waiting is more prevalent in an *earlier* part of the process, but is not more prevalent in the later part of the process.

There are two qualifiers to our re-analysis. First, there is an empirical problem in that the data for the overall process includes the data for the earlier and later parts of the process. This undermines the use of the chi-squared test as this test really requires data from non-overlapping categories. We estimate that the earlier and later parts of the process each account for approximately 11% of all the data, and so together would account for approaching 25% of all the data. For an example of the potential impact of this empirical problem on the tests, consider hypothesis H_1: as the overall process includes the earlier process, the test would be made slightly more conservative, reducing the likelihood of rejecting the null hypothesis; by contrast, however, the presence of the later data in the overall process will make the test of H_1 slightly less conservative, increasing the likelihood of rejecting the null hypothesis. (The converse effects would be expected for hypothesis H_2.) For the moment, we recognise this empirical problem (which arises because we do not have access to the primary data), and intend to consider a correction to the tests in some future publication. (One-tailed tests would also increase the power of the tests but would not overcome the problem of over-lapping categories.)

Second, Bradac *et al*.'s data on the earlier and later parts of the process were probably chosen because they represent extremes of the process and, as a result, would provide the clearest counter-examples to the overall process. It is not clear, however, whether these extreme examples are representative of the entire earlier and later parts of the process. We are assuming that they are representative. If the examples of the earlier and later parts of the process are not representative, then we do not have appropriate data for conducting tests of hypotheses H_1 and H_2.

Given these qualifiers, we propose a revised conjecture:

> At the level of an individual designer, waiting is more prevalent during the beginning of the process than during the middle or end of the process.

As noted earlier, Bradac *et al*. qualified their conjectures, stating that:

> "…if the global level of blocking [waiting] is consonant with [equivalent to] this local level, the conjecture [on the prevalence of waiting] will hold [at the global level]."

Given Bradac *et al*.'s qualifier, we also wanted to investigate whether our revised conjecture applied at a higher level of the process.

3. Study design

3.1. Overview

As part of our investigation into project schedules at IBM Hursley Park, we sought to explore:

1. The revised version of Bradac *et al*.'s conjecture on the prevalence of waiting.
2. Bradac *et al*.'s qualifier about the global process.

We selected two projects for longitudinal case studies (in choosing the projects for study, we wanted projects which were planned to complete in approximately 12 months) and collected a variety of evidence on these two projects. Our primary source of evidence was the minutes of each project's status meetings. These meetings occurred on a weekly or fortnightly basis, and were attended by representatives of all the process areas of the project e.g. marketing, finance, design/code, testing. We also conducted interviews, and collected other forms of evidence e.g. project plans. The additional evidence allowed us to investigate other aspects of the projects e.g. the poor progress of work, outstanding work, the urgency of the project, and the planned and actual project schedule.

3.2. Research model

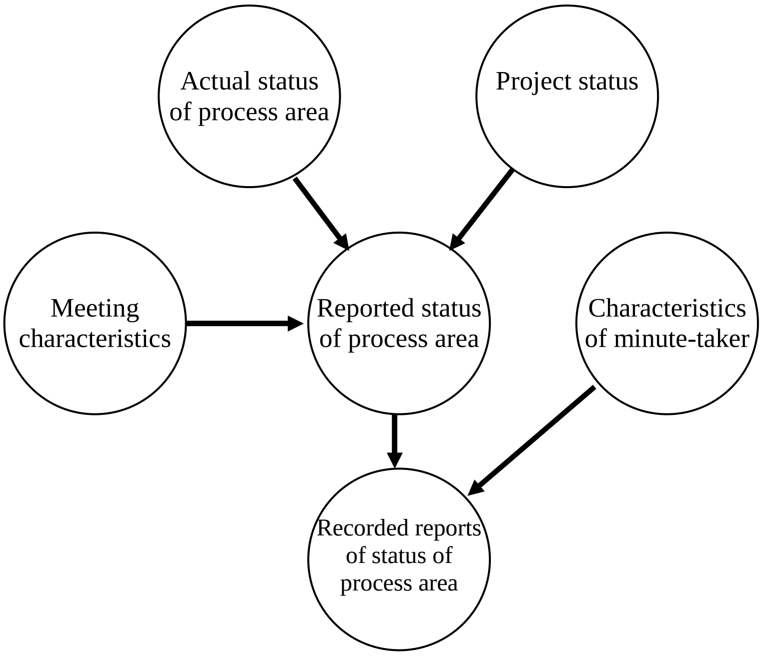

Figure 1 Possible affects on the recorded reports of process areas

Figure 1 summarises some of the main factors that might affect the reporting of waiting for Projects B and C. The results of our investigation of waiting led us to investigate other aspects of the status of process areas. We discuss these other areas of investigation later in this paper.

3.3. Definitions and measures

Bradac *et al*. do not clearly define which tasks in their study map to the beginning, middle and end of the process. They also do not clearly define the relationships between the earlier and later parts of the process and the beginning, middle and end of the process. Following a preliminary analysis of our evidence, we chose to define the beginning of the project as the planning and requirements stage, the middle of the project as the *planned* (as opposed to actual) design and code stages, and the end of the project as the *planned* test stages. We also took the earlier and later parts of the process to be equivalent to the beginning and end of the process.

As already noted, in choosing the projects for study, we wanted projects which were planned to complete in approximately 12 months. A clearly defined planned completion requires a welldeveloped plan. This means that we began to study the two projects just as the plan and requirements phases were completing (because it was then that we knew that the projects were planned to last 12 months). Furthermore, the status meetings for the projects only started to occur once the plan was complete, so we were unable to investigate the beginning of the process.

We define waiting as a state in which an individual or process area cannot start or continue work on a particular task until some other individual or process area provide some kind of input to that task. It is likely that the individual or process area that is waiting will work on some other task while they are waiting. We define outstanding work as a state where an individual or process area has not completed work that they expected to complete. We define progress of work as an indicator of the rate at which work within a task is being completed. We have measured waiting, outstanding work and progress of work by collecting frequency counts of the number of reports of waiting, outstanding work and progress of work in the minutes of the project's status meetings.

4. The prevalence of waiting for process areas

To investigate Bradac *et al*.'s qualifier about the global level of the process, and given our re-analysis of Bradac *et al*.'s conjecture, we proposed the following hypothesis:

H_3 For the process areas of the project, waiting on blocked work is significantly more frequent during the end of the project than during the middle of the project.

(Note that we were unable to investigate the beginning of the project, as discussed in section 3.3.) We tested this hypothesis using one-tailed Mann Whitney's U tests. The results of the tests are presented in Table 3. See also Figure 2 and Figure 3 for further information on the two projects.

Table 3 Mann Whitney U tests of hypothesis H_3 (one-tailed)

Project	*p*	α	β	n
B	0.0008	0.001	Unknown	46
C	0.002	0.01	Unknown	33

For both projects at IBM Hursley Park, waiting during the end of the process is significantly more frequent than waiting during the middle of the process. These results are inconsistent with our revised version of Bradac et al.'s conjecture. Partly because of these inconsistent results, we conducted some further investigation of the evidence.

5. Further analysis

5.1. Poor progress and outstanding work

We investigated two further hypotheses:

H_4 For the process areas of the project, poor progress of work is significantly more frequent during the end of the project than during the middle of the project.

H_5 For the process areas of the project, outstanding work is significantly more frequent during the end of the project than during the middle of the project.

If waiting is more prevalent during the end of the process, we might also expect more outstanding work and more poor progress in that part of the process. Outstanding work may cause waiting e.g. a developer has some outstanding work on fixing a defect which, as a result, is blocking the work of a tester. Similarly, poor progress may be due to waiting or may cause waiting e.g. the poor progress of a developer in fixing a defect leads to outstanding work and causes a tester to wait.

We tested these two hypotheses using one-tailed Mann-Whitney U tests.

Table 4 Mann Whitney U tests of hypotheses H_4 and H_5 (one-tailed)

Hypotheses	Project	*p*	α	β	n
H_4	B	0.0091	0.05	Unknown	46
	C	0.0238	0.05	Unknown	33
H_5	B	0.0197	0.05	Unknown	46
	C	0.0004	0.05	Unknown	33

Table 4 presents the results of the Mann-Whitney U tests of hypotheses H_4 and H_5. The test results indicate that:

1. Poor progress is significantly more frequent during the later part of the process, compared to the middle part of the process.

2. Outstanding work is significantly more frequent during the later part of the process, compared to the middle part of the process.

The test results of hypotheses H_4 and H_5 clearly complement the test result of hypothesis H_3. The frequency of waiting appears to be consistent with other behaviour in the two projects.

5.2. The potential effect of other characteristics of the projects

Both Bradac *et al.*'s analyses and our analyses have been structured around the concept of a beginning, middle and end to a project. (We chose to investigate the beginning, middle and end of the project because we wanted to replicate Bradac *et al.*'s study.)

The conception of a project with a beginning, middle and end does not necessarily fit well with projects that are structured in terms of project phases, or projects that are end-date driven. Put simply, project managers don't tend to organise projects into a beginning, middle and end. Consequently, we need to analyse our data from more project-based perspectives.

In addition to the quantitative data that we collected on the two projects, we also collected a large amount of qualitative data. For most of the data that we collected, we were able to plot this data according to the week in the project in which the data was generated. Often, the week in which the data was generated indicated the approximate week in which an event of some sort (e.g. an action, a decision) occurred, or was planned to occur.

Because of the nature of our qualitative data, statistical tests of hypotheses are not feasible. Instead, we present research questions to investigate the possible impact of a project's structure and status on waiting, poor progress and outstanding work:

RQ1 Is the frequency of waiting, poor progress and outstanding work related to the phases of the project?

RQ2 Is the frequency of waiting, poor progress and outstanding work related to the planned end of the project?

(We believe that these research questions are more consistent with the perspectives taken by project managers.) Figure 2 and Figure 3 plot waiting, poor progress and outstanding work against other events, for Projects B and C respectively. The events in these two figures include:

- When the product was shipped to manufacturing. This event does not necessarily indicate the end of the project. For Project B, test work continued past the week that the product was shipped and evidence indicates that fixes (and indeed some of the product's functionality) were delivered via the World Wide Web over the course of subsequent weeks. For Project C, this event does broadly mark the end of the project.
- The approximate *actual* durations of the Design/Code phase and the System Test phase.

- Some indicators of project urgency. These were statements from the meeting minutes that suggested that the urgency of the project was increasing. For example, the building of weekly and then bi-weekly increments begin, teams start to work weekends and evening shifts, daily defect meetings start. For simplicity, detailed information on the indicators of project urgency are not shown here (see [8] for more information.)
- Indications of when internal re-plans occur i.e. when adjustments are made to milestones (such as the completion of phases of work) *within* the project that do not directly affect commitments to external entities.

Both figures indicate that the increase in the frequency of waiting, poor progress and outstanding work start to occur approximately around the start of the series of re-plans, the start of the series of indicators of project urgency, and the actual start of the System Test phase. The increase in the frequency of waiting, poor progress and outstanding work then generally continues until the product is shipped to manufacturing. This pattern is more apparent for Project B than Project C. For Project B there is some indication of outstanding work remaining after the product has shipped. This is consistent with the strategy of shipping the product and then completing remaining work on the project.

Overall, the qualitative evidence supports both research questions but there is, of course, more research required here.

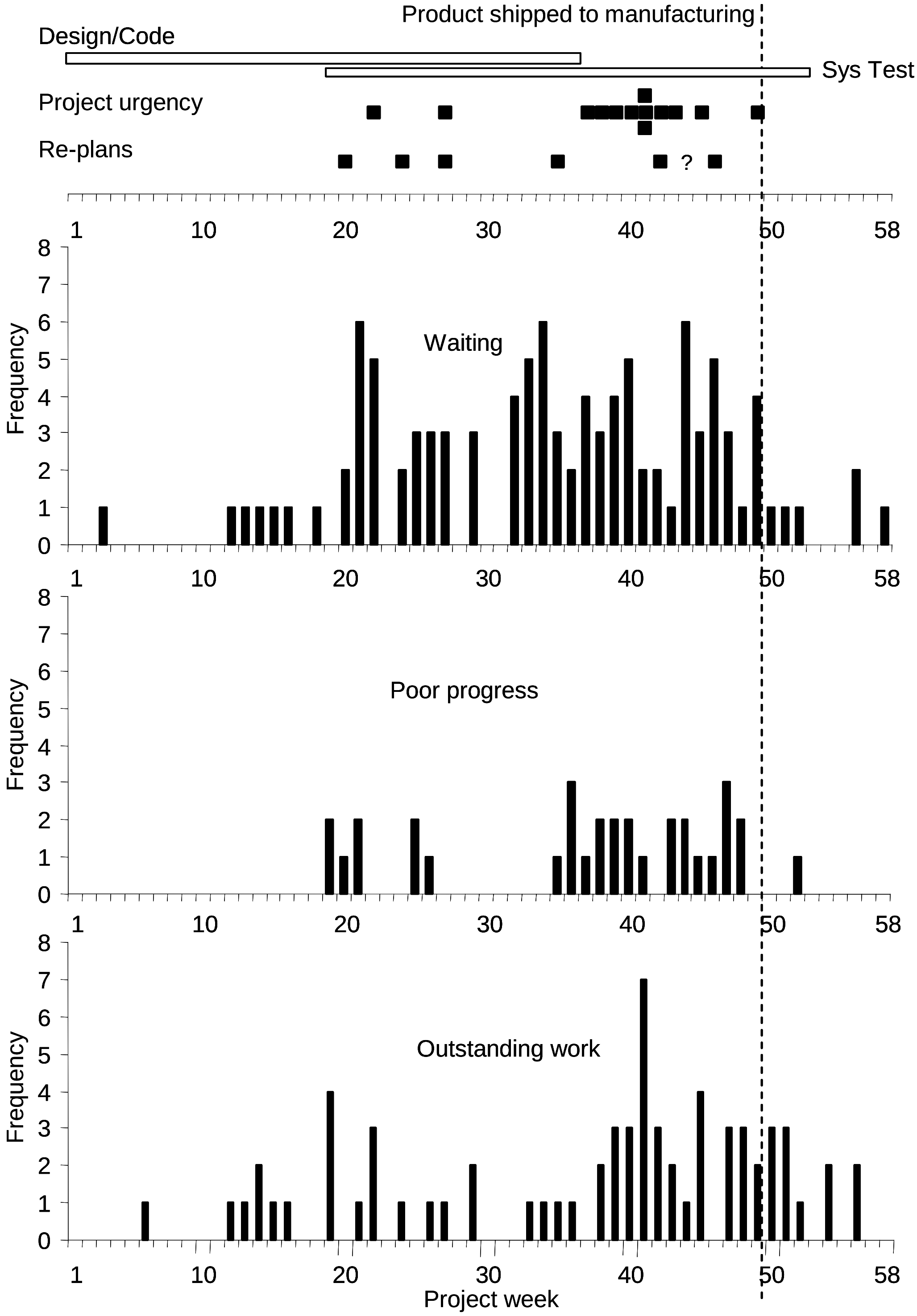

Figure 2 Waiting, poor progress, outstanding work and other 'events' for Project B

The figure plots all data against the project week number. The top 'quarter' of the figure plots various events and project phases. The '?' indicates a re-plan occurred, but it is not clear exactly when that re-planned occurred – it was sometime between week 42 and week 46. The remaining three 'quarters' of the figure plot reports of waiting, poor progress and outstanding work respectively. Where there is a frequency of zero for some weeks, this may be due to 'missing values' i.e. a project meeting did not occur during that week.

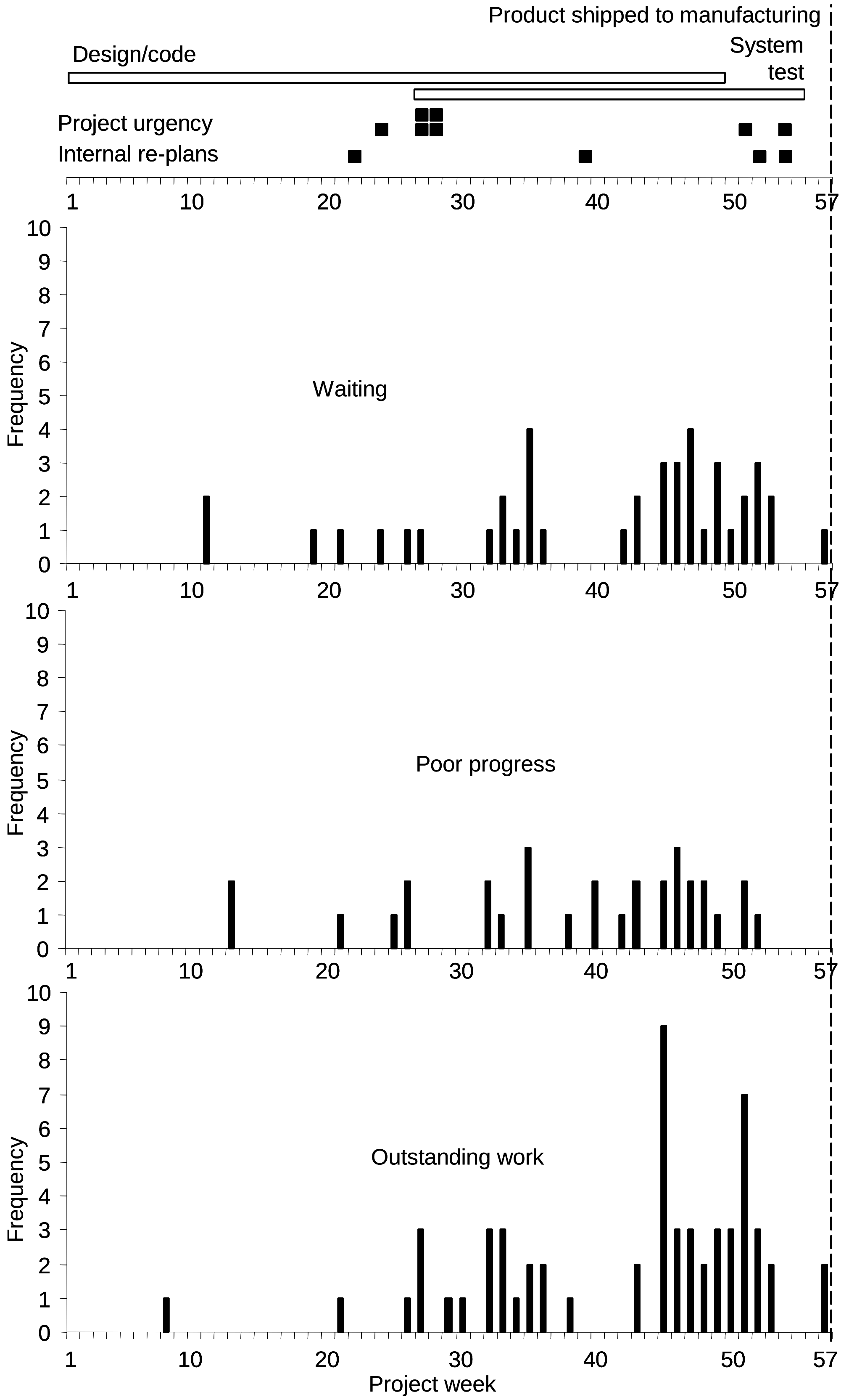

Figure 3 Waiting, poor progress, outstanding work and other 'events' for Project C

(See Figure 2 for an explanation of Figure 3.)

6. An evaluation of the observed behaviour

6.1. Summary of findings

Table 5 Results from the hypotheses and research questions

#	Hypothesis / Research question
H_3	For the process areas of the project, waiting on blocked work is significantly more frequent during the end of the project than during the middle of the project.
H_4	For the process areas of the project, poor progress of work is significantly more frequent during the end of the project than during the middle of the project.
H_5	For the process areas of the project, outstanding work is significantly more frequent during the end of the project than during the middle of the project.
RQ1	The frequency of waiting, poor progress and outstanding work appear to be related to the *actual* phases of the project.
RQ2	The frequency of waiting, poor progress and outstanding work appear to be related to project urgency.

Table 5 summarises the results from our hypotheses and research questions. Overall our results are ‘internally consistent’ (in that all of the results from the data from IBM Hursley Park are in the same direction) but are not ‘externally consistent’ (in that the ‘IBM results’ contradict our revised conjecture from Bradac *et al*.'s study.)

We have observed behaviours in two software projects that statistical analyses suggest are very unlikely to have occurred by chance. We have started to explore some of the reasons for the causes of this behaviour e.g. project urgency increasing reports of behaviour. Further research is clearly required to investigate both the causes of this behaviour and the impact of this behaviour on project outcomes. We have suggested some causal relationships between waiting, poor progress and outstanding work.

6.2. Types of process

We would expect that the actual behaviour that one observes in a time diary study should be dependent, to some degree, on the kind of process that is planned to occur. For example, if a project is planned so that it is front-end loaded (with more time allocated to design in an effort to design for quality) then one wouldn't be surprised to see more time actually spent on the front-end processes. Conversely, a back-end loaded process (where one tests for quality, perhaps with safety-critical systems) might have much more time actually spent on testing. In itself, therefore, the actual allocation of time does not indicate a problem. A problem occurs when there is a significant discrepancy between the planned and actual allocation of time. The implication is that studies of actual behaviour (e.g. time-diary studies) ought to compare the actual behaviour against the planned behaviour. This is something that neither Bradac *et al*. or we have done in our studies. (We have information on planned and actual staffing for Project B, and may be able to use this to compare planned effort with actual behaviour.) Cook *et al*. [9, 10] provide an exemplar of studies that do compare the actual and planned.

6.3. Effort

Although the details are not shown in Figure 2 and Figure 3, the indicators of project urgency are often references to increasing effort on the project (e.g. working overtime, and working weekends) or references to reorganising work in order to increase effort (e.g. converting to shift-work for testing) (see [8] for more detail). This suggests that effort increases on the projects as the projects approach their delivery dates. Such a suggestion is consistent with the Deadline Effect [11] i.e. the amount of energy and effort devoted to an activity is strongly accelerated as one approaches the deadline for completing the activity. (Boehm states that, to some degree, the Deadline Effect is the converse of Parkinson's Law i.e. work expands to fill the time available.)

7. Conclusion

This research is a response to Perry *et al*.'s recognition of the lack of research relating the individual's behaviour to the project's behaviour. We have observed behaviours in two software projects that statistical analyses suggest are very unlikely to have occurred by chance. These results indicate that there do seem to be some significant differences in the behaviour of individuals and process areas during different parts of the process. An explanation for the causes of these behaviours, and an evaluation of the impact of these behaviours on project outcomes, remains un-investigated and is the natural next step for this research. Our results are consistent with the Deadline Effect and, in the longer term, may also provide insights on other aspects of projects e.g. effort and productivity.

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