DRIVERS OF QUARTERLY WEBSITE DELIVERY

STAT 502 Final Project

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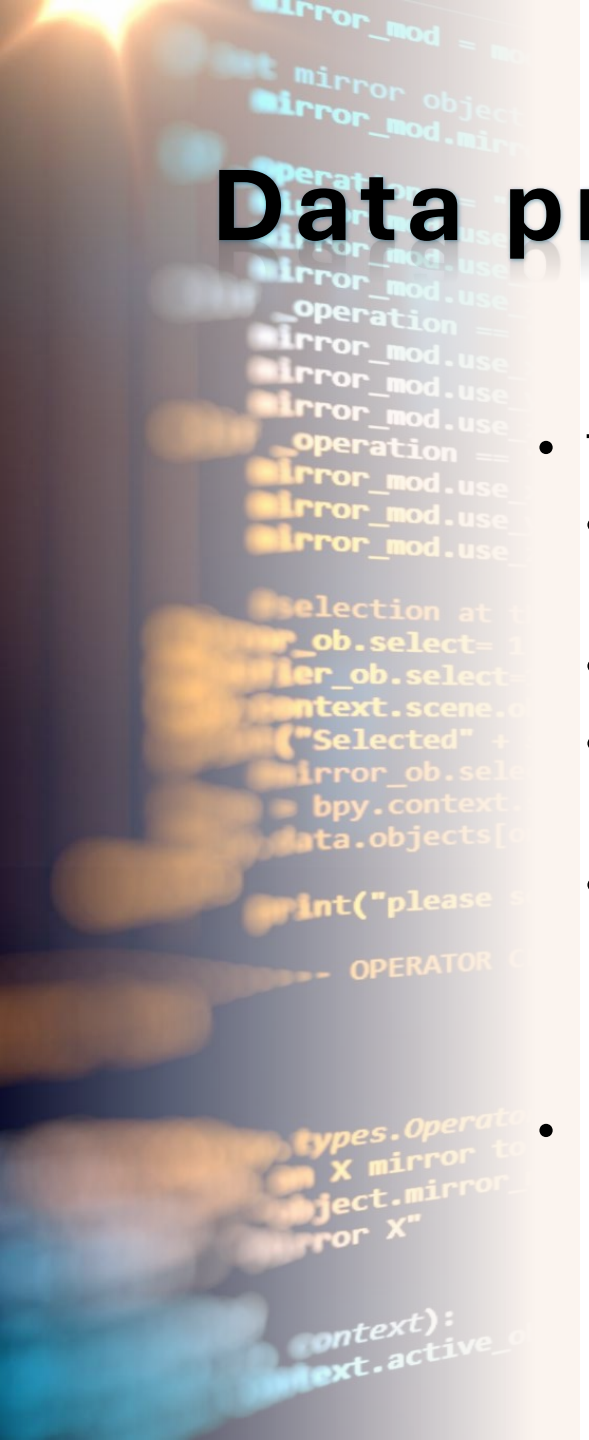
Introduction

With digital demand rising, website teams face varying workloads, experience levels, and process efficiencies. We analyze eight quarters of data from 13 three-person teams (2001 Q1–2002 Q3) using linear mixed-effects models to quantify how backlog, team experience, and a mid-2002 process change impact quarterly delivery. Our results offer clear, data-driven guidance for optimizing team structure and workflows.

Research Hypotheses

Hypothesis	H0	H1
H1 (Backlog)	Backlog level has no effect on websites delivered.	Higher backlog leads to more websites delivered.
H2 (Experience)	Team experience has no effect on websites delivered.	Higher experience leads to more websites delivered.
H3 (Process)	The 2002 process change has no effect on websites delivered.	The process change increased websites delivered.
H4 (Backlog × Experience)	The effect of backlog is the same regardless of experience level.	The effect of backlog depends on experience level.
H5 (Three-way interaction)	The effects of backlog and experience are not moderated by the process change.	The process change moderates the effect of backlog or experience on delivery outcomes.

Data processing



- Transform data:
  - **Websites Delivered**: response variable, the number of websites delivered.
  - **Backlog**: the number of pending projects)
  - **Experience**: the average team experience in months
  - **Process Change**: whether the team was affected by the process redesign in 2002.

→ **two-level factors** (high or low)

- Delete Team 12 → balanced data

Methodology

Part 1 Models

Without process change

- Model 1: BackGroup × ExpGroup
- Model 2: BackGroup + ExpGroup

Part 2 Models

With process change

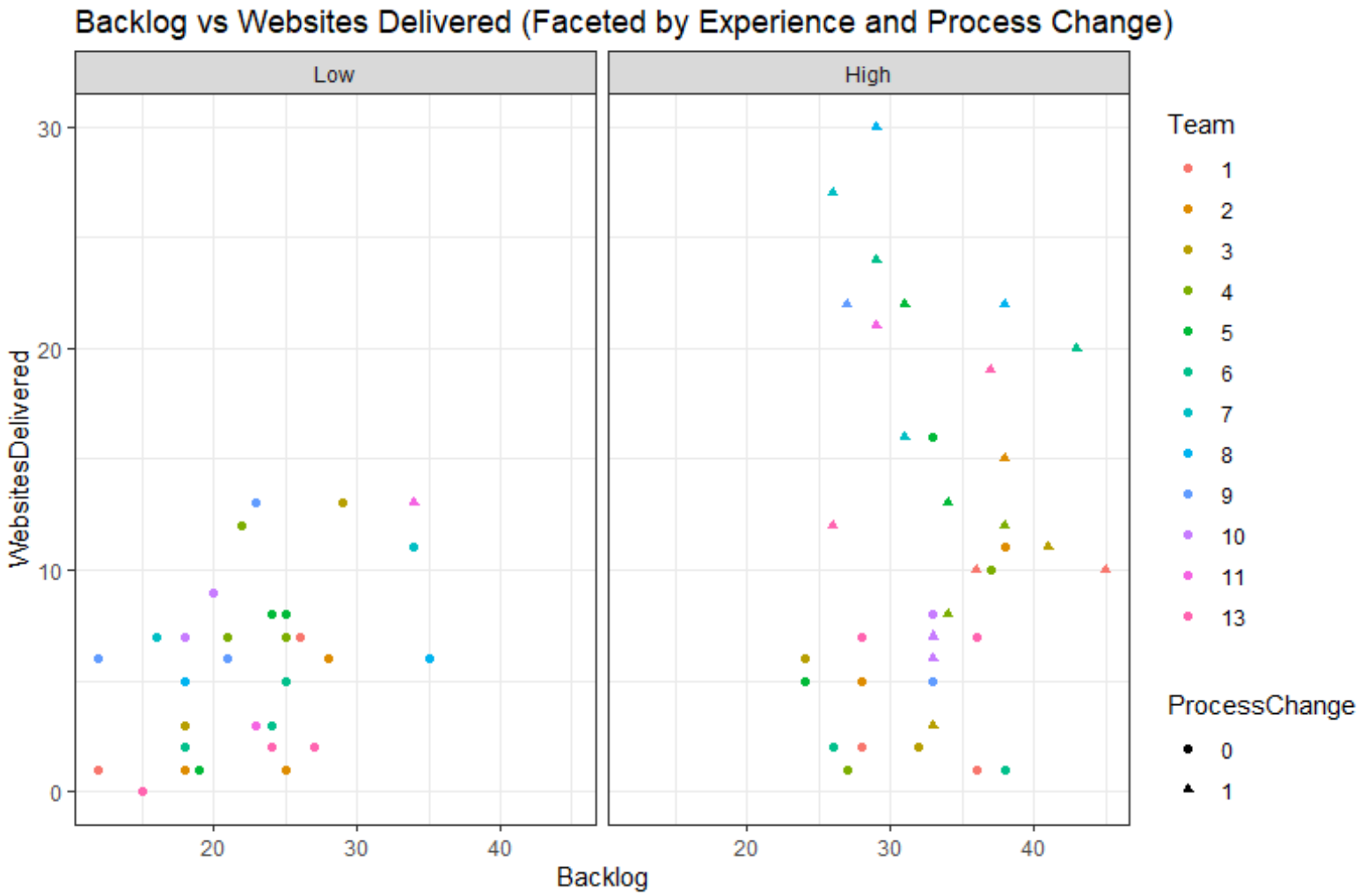
- Model 1: BackGroup × ExpGroup × ProcessChange
- Model 2: BackGroup + ExpGroup + ProcessChange

Data Analysis | EDA

- **Backlog**:
- positive correlation

- **Experience**:
- high-experience teams delivered more websites

- **ProcessChange**:
- Higher output with process change



Data Analysis | Model Selection

- **P-value > 0.05**:
- the interaction model is not significantly better than the one without interaction.

- **AIC & BIC**:
- the additive model had lower AIC and BIC

→ **Additive model**
As final model

Output of likelihood ratio test:

```
Data: x
Models:
model_proc_add_ML: WebsitesDelivered ~ BackGroup + ExpGroup + ProcessChange + (1 | Team)
model_proc_inter_ML: WebsitesDelivered ~ BackGroup * ExpGroup * ProcessChange + (1 | Team)
                     npar    AIC   BIC  logLik deviance  Chisq Df Pr(>Chisq)
model_proc_add_ML       6 440.92 454.5 -214.46   428.92
model_proc_inter_ML     9 440.54 460.9 -211.27   422.54 6.3846  3    0.09433 .
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Data Analysis | Model Result

- **REML Criterion:**
- 420.1

- **Random Effects:**
- Team intercept variance = 3.35

- **Fixed Effects:**
- ProcessChange: $\beta = 9.15$ ($p < 0.001$)
- BackGroup: $\beta = 0.95$ ($p = 0.550$, n.s.)
- ExpGroup: $\beta = 0.28$ ($p = 0.829$, n.s.)

```
> summary(model_proc_add)
Linear mixed model fit by REML. t-tests use Satterthwaite's method ['lmerModLmerTest']
Formula: WebsitesDelivered ~ BackGroup + ExpGroup + ProcessChange + (1 |      Team)
   Data: x

REML criterion at convergence: 420.1

Scaled residuals:
    Min      1Q  Median      3Q     Max
-2.3406 -0.6509 -0.1856  0.5876  2.5620

Random effects:
 Groups   Name        Variance Std.Dev.
 Team     (Intercept)  3.35    1.830
 Residual             23.56    4.853
Number of obs: 71, groups:  Team, 12

Fixed effects:
               Estimate Std. Error      df t value Pr(>|t|)
(Intercept)      5.3002     1.0299 25.5322   5.146 2.41e-05 ***
BackGroupHigh    0.9594     1.5969 60.0937   0.601    0.550
ExpGroupHigh     0.3480     1.6037 61.2937   0.217    0.829
ProcessChange1   9.1518     1.6300 59.2273   5.615 5.53e-07 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Correlation of Fixed Effects:
            (Intr) BckGrH ExpGrH
BackGropHgh -0.186
ExpGroupHgh -0.333 -0.427
ProcssChng1  0.007 -0.337 -0.367
```

Data Analysis | Model Result

- **ANOVA (fixed effects):**
- ProcessChange: significant
  $F(1,59.23)=31.53$
  $p < 0.001$
- BackGroup: not significant
- ExpGroup: not significant

```
> anova(model_proc_add)
Type III Analysis of Variance Table with Satterthwaite's method
              Sum Sq Mean Sq NumDF  DenDF F value    Pr(>F)
BackGroup       8.50    8.50     1 60.094  0.3610    0.5502
ExpGroup        1.11    1.11     1 61.294  0.0471    0.8289
ProcessChange 742.61  742.61     1 59.227 31.5250 5.527e-07 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

- **RANOVA (random effects):**
- Team: not significant
- Removing the team intercept gives $\chi^2 = 1.58$

```
> ranova(model = model_proc_add)#Anova for random effects
ANOVA-like table for random-effects: Single term deletions

Model:
WebsitesDelivered ~ BackGroup + ExpGroup + ProcessChange + (1 | Team)
            npar  logLik    AIC    LRT Df Pr(>Chisq)
<none>         6 -210.04 432.09
(1 | Team)     5 -210.84 431.67 1.5849  1     0.2081
```

Data Analysis | Assumption Test

- **Residual Q–Q Plot:**
- align along the diagonal line with minor tail deviations
  → acceptable normality

Data Analysis | Hypothesis Test Summary

	Hypothesis test result
H1 (Backlog)	P-value>0.05, cannot reject H0, indicating the Backlog level has no effect on websites delivered.
H2 (Experience)	P-value>0.05, cannot reject H0, indicating the Team experience has no effect on websites delivered.
H3 (Process)	**P-value<0.05, reject H0, indicating the process change increased websites delivered.**
H4 (Backlog × Experience)	P-value>0.05, cannot reject H0, indicating the effect of backlog is the same regardless of experience level.
H5 (Three-way interaction)	P-value>0.05, cannot reject H0, indicating the effects of backlog and experience are not moderated by the process change.

Conclusion

- **Modeling Result**
  - **Part 1 (without process change)**:
  - in the main effects model, both **backlog** and **experience** were significant

  - **Part 2 (with process change)** :
  - only process change is significant

→ **process change** had the strongest impact on productivity outweighing the effects of backlog or team experience

↓

Prioritize process improvements for rapid productivity gains

- **Future Analysis Recommendation**:
- ProcessChange is available → ProcessChange-only model

- ProcessChange is unavailable → main effects model (backlog + experience)

THANK YOU!

Drivers of Quarterly Website Delivery

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