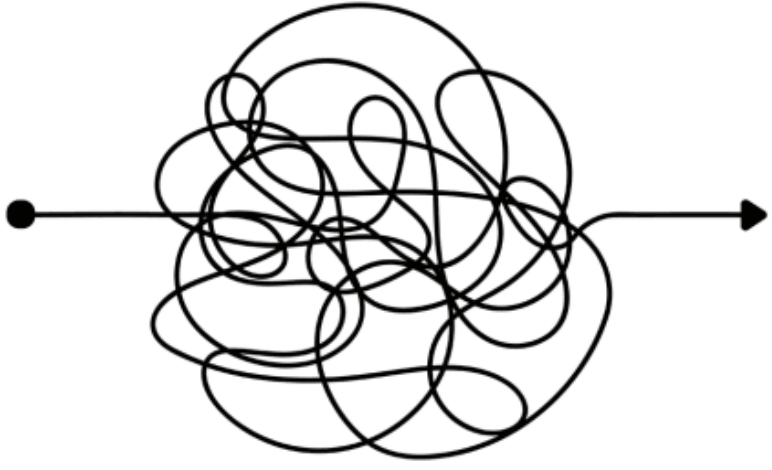
"Simplicity is the ultimate sophistication." - Leonardo da Vinci



Replication project:

The Impact of Process Complexity on Process Performance: A Study Using Event Log Data Vidgof/Wurm/Mendling (2023)

Advanced Process Mining – FSS 2024

Group 4:
Leonie Starke, Progha Labani Das, Max Frigolis, Biel Alcaraz, Frederik Röckle

Agenda

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Status quo

Authors approach

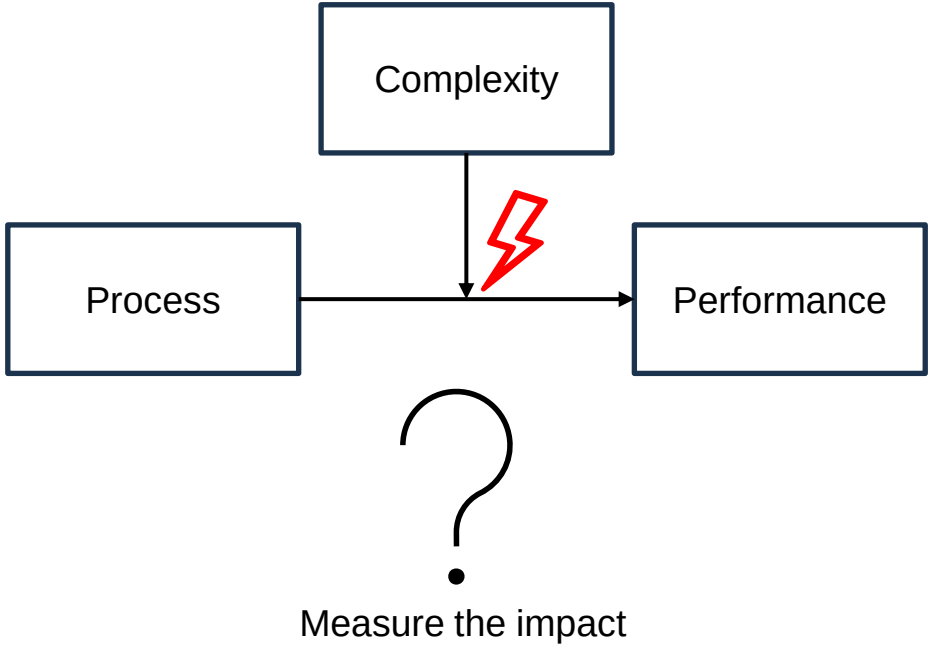
Replication Experience

Results

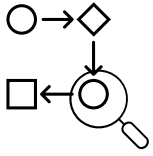
Additional Insights

Conclusion

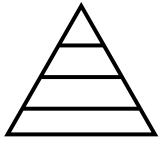
Alleged negative impact of complexity on performance



Status quo measured only by behavioral studies



Only point-spot observations of the process



Results of studies vary across hierarchy

Very subjective perception hence not reliable

Authors approach quantifies correlation by regression

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Research goal: Quantify the impact of process complexity on process performance by analyzing the relation based on event log data

Two-fold process:

1. Obtain datasets and compute process complexity metrics and throughput time

2. Conduct a statistic regression analysis to investigate the correlation between complexity and performance (throughput time)

Linear model: X (Complexity metrics) -> y (median throughput time)

Authors results explain up to 0.96 variance and high corr.

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1. Obtain data and computation of complexity metrics:
   - Use event logs from BPIC datasets from 2011, 2015 2017, 2018, 2019, 2020

2. Regression Analysis
   - Built 6 regression models with forward, backward and both selection method
   - Encoded industry domain of event log as a dummy variable

Results

R1. Best performing model reached an R-squared value of 0.969

R2. Industry dummy variable alone accounts for 80% of variance in the dependent variable

38 complexity metrics to fit throughput time

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Size:
- No. Events
- No. Sequences
- Avg Sequence length

Variation:
- No. Acyclic paths
- No. Unique sequences

Distance:
- Avg Affinity
- Deviation from random

Simple Entropy:
- Sequence entropy
- Variant entropy

Enriched Entropy:
- Enriched sequence entropy
- Enriched variant entropy

only examples

Our Replication Experience – Obtaining the datasets

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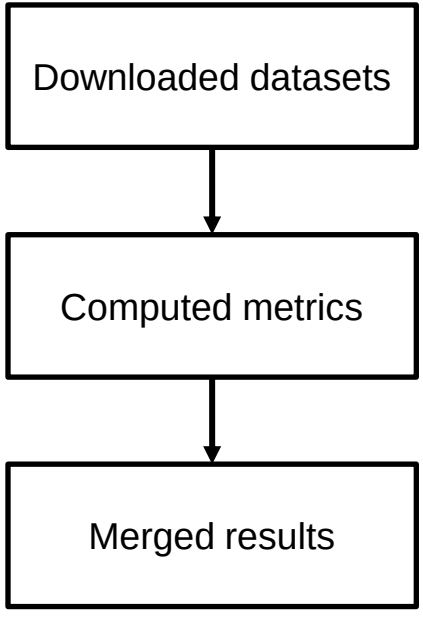


Downloaded all datasets from the TU Eindhoven website

Computed the complexity metrics and throughput time on a Azure VM 32gb ram instance with script provided by authors

Merged all metrics in one file

Our Replication Experience – the regression analysis

Built regression models

Built OLS regression models on Google Colab with statsmodels. Authors didn‘t provide any code for regression

1. With our replicated dataset

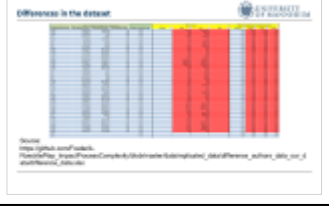
$R^2 > 0.98$

2. With provided dataset

$R^2 > 0.98$

Authors $R^2 > 0.96$

Investigated differences between datasets



Apply authors approach on new data – external validity

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1. We built a new dataset based on (BPIC 2012, Hospital Billing and Sespsi Cases)
2. Applied the same pipeline
3. Reached a similiar good R^2-value

$R^2 > 0.98$

Explanation of total variance (R2) by industry

R2. *„Industry dummy variable alone accounts for 80% of variance in the dependent variable„*

X (Industry variable) -> y (median throughput time)

```
model = sm.OLS(y,X).fit()
```

```
model.rsquared
```

```
0.26560601353812285
```

Source: https://github.com/Frederik-Roeckle/Rep_ImpactProcessComplexity/blob/master/models/Only_industry_variable_as_predictor.ipynb

Additional Insights during our replication

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methodology

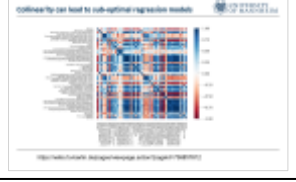
- Category groups of complexity metrics are not always aligned
- Criterias for outlier removement were not clearly specified
- Mapping of variables between paper and authors script was unclear in the beginning

dataset

- Difference between our obtained data and the one from the author in the dataset
- The authors used a dataset (finance_log) where they didn't state the origin

regression analysis

- Authors didn't provide code for regression analysis
- High correlation between some variables
- Authors didn't share their best performing model (neither variables or weights)



Conclusion

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Paper quantifies the relation of process complexity and process performance through a Linear model: X (Complexity metrics) -> y (median throughput time)

We partly replicated and extended the results of the author's work:

✓ R1.:Achieved similar R^2-scores for same data sets
=> test external validity on new data sets

✗ R2.: Only explain 0.26 instead of 0.8 variance in throughput time by the industry

Lookout from the authors: “apply dimensionality reduction techniques to find best describing variables and even use regression models for prediction”

Repo

Link to our GitHub-Repo:

https://github.com/Frederik-Roeckle/Rep_ImpactProcessComplexity

Results – computed data

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COMPUTED DATA			
Models without dummy	Remaining Variables	R-squared	
Full forward	47	0,988081	
Full backward	40	0,98815	
Full stepwise	41	0,98815	
Significant forward	18	0,988149	
Significant backward	27	0,983590	
Significant stepwise	15	0,988345	
Minimal forward	5	0,988188	here we just have 1 remainining variable for each of the 5 categories, because this is what we understood in the paper
Minimal backward	5	0,931998	here we just have 1 remainining variable for each of the 5 categories, because this is what we understood in the paper
Minimal stepwise	5	0,931998	here we just have 1 remainining variable for each of the 5 categories, because this is what we understood in the paper
COMPUTED DATA			
Models with dummy	Remaining Variables	R-squared	
Full forward	48	0,988177	
Full backward	41	0,988359	
Full stepwise	45	0,979055	
Significant forward	18	0,988149	
Significant backward	24	0,983590	
Significant stepwise	13	0,983475	
Minimal forward	5	0,988399	here we just have 1 remainining variable for each of the 5 categories, because this is what we understood in the paper
Minimal backward	5	0,931998	here we just have 1 remainining variable for each of the 5 categories, because this is what we understood in the paper
Minimal stepwise	5	0,931998	here we just have 1 remainining variable for each of the 5 categories, because this is what we understood in the paper

dataset used for that model: https://github.com/Frederik-Roeckle/Rep_ImpactProcessComplexity/blob/master/data/replicated_data/generated_merged.csv

Results – authors provided data

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PROVIDED DATA			
Models without dummy	Remaining Variables	R-squared	
Full forward	47	0,988188	
Full backward	44	0,988166	
Full stepwise	46	0,988185	
Significant forward	23	0,988188	
Significant backward	28	0,988188	
Significant stepwise	51	0,985422	
Minimal forward	5	0,988188	here we just have 1 remainining variable for each of the 5 categories, because this is what we understood in the paper
Minimal backward	5	0,931999	here we just have 1 remainining variable for each of the 5 categories, because this is what we understood in the paper
Minimal stepwise	5	0,931999	here we just have 1 remainining variable for each of the 5 categories, because this is what we understood in the paper

PROVIDED DATA			
Models with dummy	Remaining Variables	R-squared	
Full forward	48	0,9884	
Full backward	44	0,988392	
Full stepwise	42	0,988359	
Significant forward	19	0,9884	
Significant backward	26	0,988392	
Significant stepwise	10	0,974088	
Minimal forward	5	0,9884	here we just have 1 remainining variable for each of the 5 categories, because this is what we understood in the paper
Minimal backward	5	0,931999	here we just have 1 remainining variable for each of the 5 categories, because this is what we understood in the paper
Minimal stepwise	5	0,931999	here we just have 1 remainining variable for each of the 5 categories, because this is what we understood in the paper

dataset used for that model: https://github.com/MaxVidgof/complexity-data/blob/main/merged.csv

Results – our own test data

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EVALUATION DATA			
Models without dummy	Remaining Variables	R-squared	
Full forward	47	0,988149	
Full backward	40	0,98815	
Full stepwise	45	0,988184	
Significant forward	18	0,988149	
Significant backward	27	0,983590	
Significant stepwise	15	0,983475	
Minimal forward	5	0,988188	here we just have 1 remainining variable for each of the 5 categories, because this is what we understood in the paper
Minimal backward	5	0,931998	here we just have 1 remainining variable for each of the 5 categories, because this is what we understood in the paper
Minimal stepwise	5	0,931998	here we just have 1 remainining variable for each of the 5 categories, because this is what we understood in the paper

EVALUATION DATA			
Models with dummy	Remaining Variables	R-squared	
Full forward	48	0,988304	
Full backward	41	0,988359	
Full stepwise	45	0,988359	
Significant forward	18	0,988304	
Significant backward	24	0,988359	
Significant stepwise	13	0,971739	
Minimal forward	5	0,988399	here we just have 1 remainining variable for each of the 5 categories, because this is what we understood in the paper
Minimal backward	5	0,931998	here we just have 1 remainining variable for each of the 5 categories, because this is what we understood in the paper
Minimal stepwise	5	0,931998	here we just have 1 remainining variable for each of the 5 categories, because this is what we understood in the paper

dataset used for that model: https://github.com/Frederik-Roeckle/Rep_ImpactProcessComplexity/blob/master/data/test_data/generated_merged.csv

Differences in the dataset

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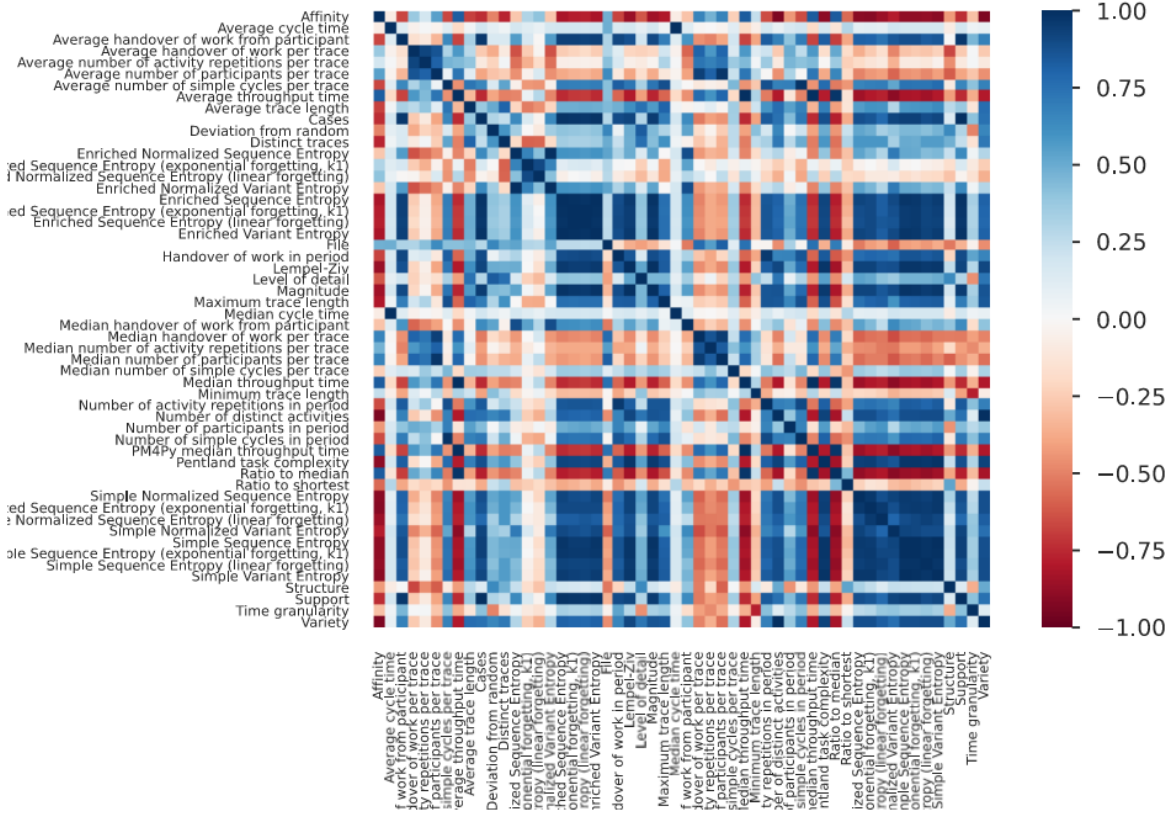
Generated Merged (Created during reproduction)					Difference Total				Difference Relative (based on original merged.csv)			
Datatype_generated_merg	Mean_generated_merg	Sum_generated_merge	Count_generated_merg	Missing_in_generated_merg	Datatype	Mean	Sum	Count	Datatype2	Mean3	Sum4	Count5
float64	11988,43445	4195952,058	350	FALSE	0	6173,565	2269719,891	6	0,00%	33,99%	35,10%	1,69%
float64	43,60835184	64017,0605	1468	FALSE	0	5,802	8813,506	6	0,00%	11,74%	12,10%	0,41%
float64	0,342302452	502,5	1468	FALSE	0	0,009	16,000	6	0,00%	2,69%	3,09%	0,41%
int64	3839,917575	5636999	1468	FALSE	0	39,867	81804,000	6	0,00%	1,03%	1,43%	0,41%
float64	0,24216328	355,4956947	1468	FALSE	0	0,002	4,245	6	0,00%	0,78%	1,18%	0,41%
int64	1049,76158	1541050	1468	FALSE	0	7,175	16874,000	6	0,00%	0,68%	1,08%	0,41%
int64	1049,76158	1541050	1468	FALSE	0	7,175	16874,000	6	0,00%	0,68%	1,08%	0,41%
int64	3127,540872	4591230	1468	FALSE	0	21,361	50251,000	6	0,00%	0,68%	1,08%	0,41%
float64	0,199122216	292,3114125	1468	FALSE	0	0,001	2,801	6	0,00%	0,54%	0,95%	0,41%
float64	0,137087137	201,2439165	1468	FALSE	0	0,001	1,813	6	0,00%	0,49%	0,89%	0,41%
float64	0,115794664	169,9865675	1468	FALSE	0	0,001	1,496	6	0,00%	0,47%	0,87%	0,41%
float64	2,514175703	3690,809931	1468	FALSE	0	0,011	31,086	6	0,00%	0,43%	0,84%	0,41%
float64	23143,07795	33974038,43	1468	FALSE	0	-96,387	-3216,217	6	0,00%	0,42%	-0,01%	0,41%
float64	940817998,9	1,38112E+12	1468	FALSE	0	-3826748,614	4280536,476	6	0,00%	0,41%	0,00%	0,41%
float64	941186177,1	1,38166E+12	1468	FALSE	0	-3828230,950	4304641,713	6	0,00%	0,41%	0,00%	0,41%
float64	1010818685	1,48388E+12	1468	FALSE	0	-4109901,562	6917205,313	6	0,00%	0,41%	0,00%	0,41%
float64	2652,425545	3893760,701	1468	FALSE	0	10,860	31922,076	6	0,00%	0,41%	0,81%	0,41%
float64	169,834471	249317,0034	1468	FALSE	0	-0,650	60,352	6	0,00%	0,38%	0,02%	0,41%
int64	9,857629428	14471	1468	FALSE	0	-0,027	19,000	6	0,00%	0,28%	0,13%	0,41%
int64	248,876703	365351	1468	FALSE	0	-0,651	533,000	6	0,00%	0,26%	0,15%	0,41%
int64	63,31675749	92949	1468	FALSE	0	-0,164	138,000	6	0,00%	0,26%	0,15%	0,41%
int64	63,31675749	92949	1468	FALSE	0	-0,164	138,000	6	0,00%	0,26%	0,15%	0,41%
float64	0,437153158	641,7408355	1468	FALSE	0	0,001	4,269	6	0,00%	0,25%	0,66%	0,41%
float64	0,437153158	641,7408355	1468	FALSE	0	0,001	4,269	6	0,00%	0,25%	0,66%	0,41%
int64	20896,47207	30676021	1468	FALSE	0	48,902	197460,000	6	0,00%	0,23%	0,64%	0,41%
float64	0,604953758	848,1451684	1402	FALSE	0	-0,001	1,701	6	0,00%	0,23%	0,20%	0,43%
float64	12,28625586	18036,22361	1468	FALSE	0	-0,024	39,045	6	0,00%	0,19%	0,22%	0,41%
int64	29603,54428	43458003	1468	FALSE	0	55,257	259070,000	6	0,00%	0,19%	0,59%	0,41%
float64	29,49208731	43294,38417	1468	FALSE	0	-0,054	96,709	6	0,00%	0,18%	0,22%	0,41%
float64	17,20583145	25258,16057	1468	FALSE	0	-0,031	57,664	6	0,00%	0,18%	0,23%	0,41%
float64	0,331149333	486,1272206	1468	FALSE	0	0,000	2,687	6	0,00%	0,14%	0,55%	0,41%
float64	0,289884327	425,5501927	1468	FALSE	0	0,0003	2,160	6	0,00%	0,10%	0,51%	0,41%
float64	120028,4514	176201766,6	1468	FALSE	0	-110,552	557217,198	6	0,00%	0,09%	0,32%	0,41%
float64	271763,2656	398948473,9	1468	FALSE	0	243,012	1988779,544	6	0,00%	0,09%	0,50%	0,41%
float64	271763,2656	398948473,9	1468	FALSE	0	243,012	1988779,544	6	0,00%	0,09%	0,50%	0,41%
float64	0,469348714	689,003912	1468	FALSE	0	0,0002	3,135	6	0,00%	0,05%	0,45%	0,41%
float64	129053,1048	189449957,8	1468	FALSE	0	-52,632	696739,193	6	0,00%	0,04%	0,37%	0,41%
int64	19002,67643	27895929	1468	FALSE	0	-7,689	102683,000	6	0,00%	0,04%	0,37%	0,41%
float64	3,65599455	5367	1468	FALSE	0	-0,001	20,000	6	0,00%	0,04%	0,37%	0,41%
float64	0,748687783	1099,073665	1468	FALSE	0	0,0002	4,795	6	0,00%	0,03%	0,43%	0,41%
float64	196609,7917	288623174,2	1468	FALSE	0	51,629	1255760,254	6	0,00%	0,03%	0,43%	0,41%
float64	204032,2981	299519413,5	1468	FALSE	0	49,103	1296571,321	6	0,00%	0,02%	0,43%	0,41%
float64	145326,8635	213339835,6	1468	FALSE	0	-22,384	838966,846	6	0,00%	0,02%	0,39%	0,41%
float64	175734,0809	257977630,7	1468	FALSE	0	-24,215	1018711,533	6	0,00%	0,01%	0,39%	0,41%
float64	0,852795576	1251,903906	1468	FALSE	0	0,000	4,964	6	0,00%	0,01%	0,39%	0,41%
object				FALSE	0	0	0	0	0,00%	0,00%	0,00%	0,00%
object				FALSE	0	0	0	0	0,00%	0,00%	0,00%	0,00%

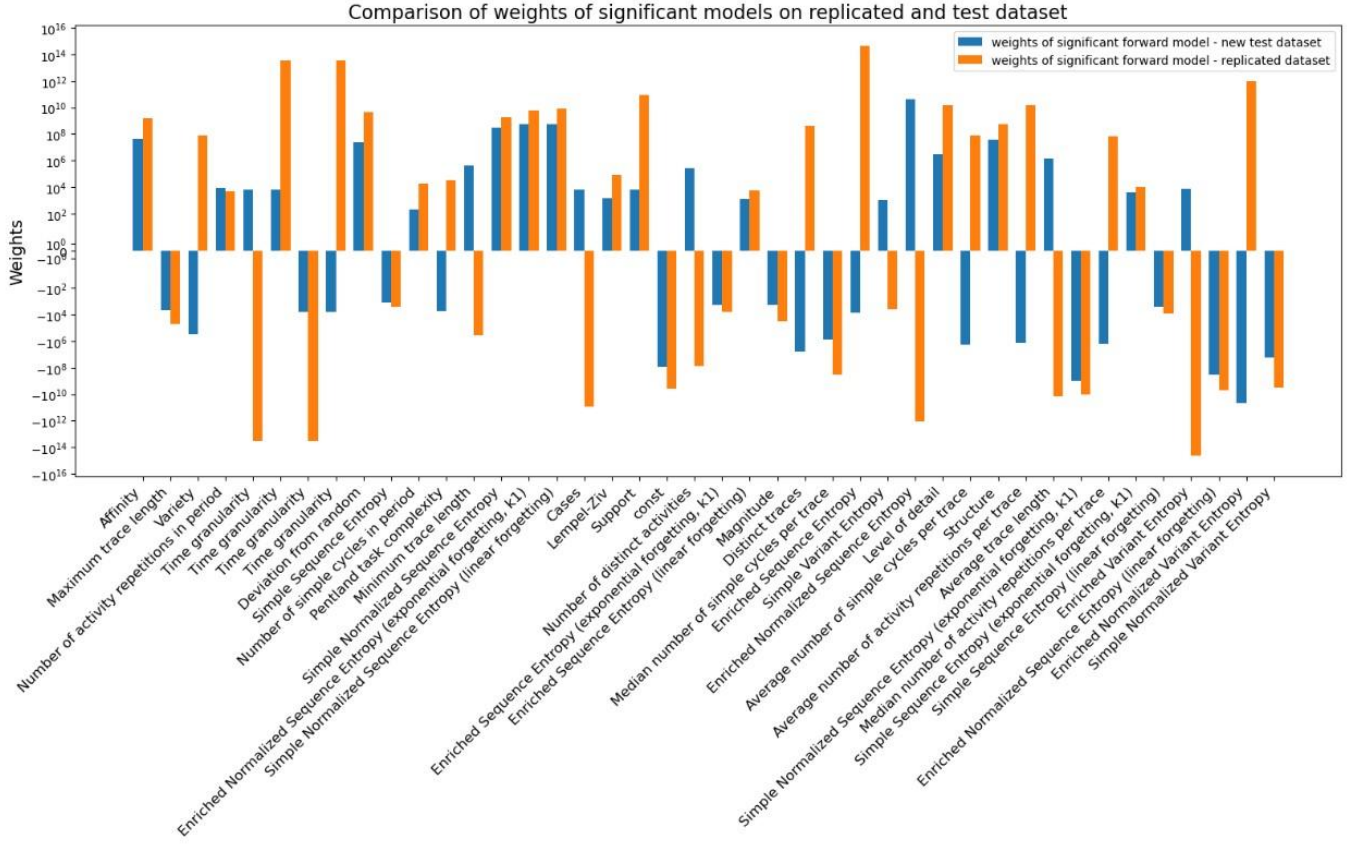
Source:
https://github.com/Frederik-Roeckle/Rep_ImpactProcessComplexity/blob/master/data/replicated_data/difference_authors_data_our_data/difference_data.xlsx

Collinearity can lead to sub-optimal regression models



https://wikis.fu-berlin.de/pages/viewpage.action?pageId=736857812

Differences in model weights



Authors linear regression models

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APPROACH

Building statistical models to explain throughput time based on process complexity. To do so, authors performed a regression analysis with the following methodology:

Two Sets:
Complexity metrics **with** and **without** *Industry*

Automated Model Selection - Based on Akaike Information Criterion with directions:
Forward - Backward - Both

Significant Variables in Model Selection - Remove variables with p-value > 0.001

Create **Minimal Models** - At most one independent variable from categories:
Size - Variation - Distance - Entropy - Generic

Authors Evaluation Process

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APPROACH

Before dealing with the main experiment, authors **preprocessed** and **prepared** the data:

	Dataset Used: 14 Publicly available real-life event logs from the BPIC

- **Splitting** into Time Periods
- Computed 38 **Complexity Measurements** / Time Period
- Computed **Median Throughput Time** / Time Period
- **Combine** all Logs into a single Dataset
- **Removal** of Outlier Periods