

# Using process mining to compare different variants of the same reimbursement process: a case study

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## ABSTRACT

Many organisations have procedures in place for reimbursing their employees' work-related travel expenses. This research aims to show that process mining event logs from these reimbursement processes can be valuable to organisations by performing a case study on a representative travel expense declaration and reimbursement procedure at the Eindhoven University of Technology. The focus is on comparing characteristics of the reimbursement process for domestic and international declarations. With the help of process mining, non-trivial differences are found between the occurrence frequencies of various events and the time between various steps in the processes. Through validation with the process owner, these could lead to actionable insights and therefore value for the organisation.

## Keywords

Process Mining, Comparative Process mining, Multidimensional Process Mining, Process Variant Comparison

## 1. INTRODUCTION

As in many other organisations, staff members at the Eindhoven University of Technology (TU/e) occasionally need to travel for work. The related expenses are paid for by the university, but the reimbursement has to be specifically requested by the employee. The university has therefore established procedures for both the declaration and reimbursement of these travel expenses.

At first sight, the process for the declaration and reimbursement of travel expenses at the TU/e seems similar for domestic and international trips. There is one major procedural difference between the aforementioned types of travels regarding the permissions that are required before undertaking the trip, but apart from that, the activities involved in the processes are mostly the same. However, procedures that might seem similar at first sight could show significant differences once analysed more thoroughly. That is where the area of process mining becomes relevant.

Process mining is extensively discussed in [8]. The process mining discipline can be seen as the bridge between the fields of computational intelligence and data mining on

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the one hand, and process modelling and analysis on the other. It allows doing many things through the extraction of knowledge from event logs, including process discovery, process conformance checking, and process enhancement. In other words, using process mining it is possible to (automatically) generate process models from event logs, to check the conformance of event logs to expected process flows, and to discover bottlenecks and optimisation opportunities in processes.

The application of process mining to the declaration and reimbursement process at the TU/e takes place through the use of related event data that has been published for the years 2017 and 2018 as part of a BPI challenge [9]. This event data can be segmented, after which it is possible to derive various models and statistics for each of the segments individually. Throughout the paper, the names of the activities found in the event data are written in a format that is arguably easier to read than the original names. For example, whenever an activity in the data set is named "Declaration FINAL\_APPROVED by SUPERVISOR", it is referred to in this paper as "Declaration final approved by supervisor".

This paper starts with a description of the research questions in Section 2. Then, background information on process mining and the used data set is provided in Section 3, after which related work is described in Section 4. Section 5 provides information on the methods and methodology that were used for this research, while the corresponding results are given in Section 6 and discussed in Section 7. Section 8 describes what can be concluded based on the research and in Section 9, limitations of this research and opportunities for future work are described.

## 2. RESEARCH QUESTIONS

The following research question is answered:

- 1 How does the realised process for the declaration and reimbursement of travel expenses differ between domestic and international trips?

This question is divided into two sub-questions that assist in answering the aforementioned main research question:

- 1.1 To what extent is there a difference between domestic and international trips with regards to the *activity sequences* in the mined process flows for the declaration and reimbursement of travel expenses?
- 1.2 To what extent is there a difference between domestic and international trips with regards to the *time between two consecutive activities* involved in the declaration and reimbursement of travel expenses?

It is hypothesised that declarations for travel expenses related to international trips generally represent larger amounts of money. Since larger amounts of money represent more risk, it is also hypothesised that there is a correlation between the amount of money associated with a declaration and the thoroughness and therefore duration of the checks. For that reason, the two following research questions are answered:

- 2 To what extent do declarations for travel expenses related to international trips represent larger amounts of money than declarations for travel expenses related to domestic trips?
- 3 To what extent is there a correlation between the declaration amount and the *duration of* and *average number of resubmissions in* the realised process for the declaration and reimbursement of travel expenses?

### 3. BACKGROUND

#### 3.1 Process mining

As mentioned in Section 1, various aspects of process mining are discussed in [8]. Among others, it is described that process mining starts with an event log, which includes a sequentially ordered list of events such that each event refers to an activity (a well-defined step in a process) and each activity refers to an individual case, for example, a process instance. Additional attributes can also be included in the log, such as the timestamp at which the event took place and the resource that performed the activity. An example of an event log is shown in Table 1.

If event logs are used to conduct process discovery, the concept of “representational bias” has to be taken into account. Such representational bias results from different process discovery techniques using different target graphing languages, each with its characteristics and problems [4]. Whenever a certain technique is chosen, implicit assumptions are made about the process: processes that include concepts not supported by the chosen technique will not be properly represented.

Because of this representational bias, models that were generated using process mining must be analysed based on certain properties. These properties are model fitness (how well the event log can be replayed on the model), simplicity, precision (not over-generalising the behaviour in the log), and generalisation (not over-fitting the log) [8].

Several tools are available to perform process mining. Among these tools are the commercial process mining tool Disco by Fluxicon [5], and the extensive process mining framework ProM [10]. Closely related to ProM is RapidProM, an extension for the RapidMiner software that allows the integration of ProM’s process mining functionality into RapidMiner’s analytic workflows [12].

#### 3.2 Data set

For this research, two of the five event logs that were published for the tenth International Business Process Intelligence Challenge [9] are used: `DomesticDeclarations.xes` and `InternationalDeclarations.xes`. The domestic declarations log contains 56,437 events spread over 10,500 cases, whereas the international declarations log contains 72,151 events spread over 6,449 cases. The domestic declarations log and international declarations log contain 6 and 21 attributes respectively, which includes both case- and activity-level attributes.

### 4. RELATED WORK

This research is mainly based on what is referred to in [13], [14] and [2] as *comparative process mining*, which involves the comparison of different kinds of models that were generated using process mining [13]. The papers show that comparative process mining is closely related to the notion of *multidimensional process mining*, a topic that is discussed in [3], [15] and [14].

Several papers have been written on doing comparative process mining. [13] and [14] discuss using a concept similar to that of *data cubes* in data warehousing. They propose defining dimensions for different attributes found in an event log and segmenting these dimensions based on the attribute’s values. It should then be possible to select a “cell” in the cube to get a subset of the event data for a specific set of attributes, after which this data can be used for process mining. [15] proposes a concept for increasing the level of interactivity of such multidimensional process mining.

In [11], a five-phase methodology for performing process comparison is discussed. In the case study that is mentioned in the paper, a technique described in [1] is used to detect statistically significant differences between two logs in terms of control flow and general performance. Also described is the use of a context-aware process performance analysis framework as described in [6] to find the effect of different contexts on performance.

An approach for comparing variants of processes in terms of behaviour and business rules is described in [2], and a ProM implementation of this approach has been made available.

In this case study, a combination of existing process mining and process comparison techniques are applied to event data from a representative travel expense declaration and reimbursement procedure at the Eindhoven University of Technology. The research demonstrates the applicability of process mining and processing comparison techniques to reimbursement data, adding to the idea that process mining techniques are widely applicable to various types of event data.

### 5. METHOD

The research follows an adapted version of the five-phase *Process Comparison Methodology (PCM)* introduced in [11], which is described as a “methodology for applying process comparison in practice” [11, p. 253]. The five phases are:

1. *Data pre-processing*. Translating raw data to standardised event log formats and selecting attributes of interest.
2. *Scoping*. Scoping the analysis to limit the number of comparisons that need to be performed later.
3. *Identification of comparable sub-logs*. Select variants of sub-logs that are similar.
4. *In-depth comparison*. Performing pair-wise comparisons of sub-logs.
5. *Interpretation and validation*. Interpreting the results and validating them with the process owner.

The adaptation mainly revolves around the fact that the third phase from the methodology is skipped, as it was deemed unnecessary because of this research’s focus on just two sub-logs by definition. Besides, the first phase

**Table 1. Example of an event log in which activities are assumed to be atomic, adapted from actual data used in this research.**

Activity	Date	Time	Case ID	Organisational Role	...
Declaration submitted by employee	05.04.2018	21:16:39	53348	Employee	...
Declaration approved by administration	25.04.2018	16:02:42	53348	Administration	...
Declaration final approved by supervisor	25.04.2018	16:05:13	53348	Supervisor	...
Request payment	26.04.2018	12:21:09	53348	Undefined	...
Payment handled	30.04.2018	19:31:11	53348	Undefined	...
...	...	...	...	...	...

is slightly adapted to account for the fact that the data sets are already in standardised event log formats, and the second and fifth phase saw a slight chance of focus, as clarified in their corresponding sections.

Phases 1 and 2 are described in Section 5.1, phase 3 is not performed and therefore not described any further, phase 4 is described in 5.2 and phase 5 is described in Section 5.3.

## 5.1 Data pre-processing and scoping

As the data analysed in this research was published in a standardised event log format—the XES-format [7]—the translation part suggested for phase one of the methodology was irrelevant. Nevertheless, that did not affect the need for other kinds of pre-processing, since noise removal was still required for further analyses to deliver reliable results. The noise removal steps to be performed were defined based on both domain knowledge found in the BPI challenge description and a preliminary analysis of the original data set in Disco and using ProM process discovery plugins.

Processing steps that relate to scoping the problem were also included. Scoping is phase two of the *Process Comparison Methodology*, but whereas the description of the methodology describes the goal of scoping as “limit[ing] the number of comparisons to be executed later” [11, p. 256], the goal of scoping for this research was instead to reduce the scope of the individual data sets to be compared. The reason is that there was no need to reduce the number of comparisons to be executed, since the focus of the research is, by definition, on a single comparison.

The actual processing steps and the reasons behind performing them are as follows:

1. The domestic and international data sets included 2,240 and 1,497 traces, respectively for which the first-recorded event started in 2016 or 2017. It was mentioned that the process was not fully standardised until 2018 [9], so to ensure that further analysis was not performed on logs that are inherently inconsistent because of procedural changes, the decision was made to **remove all traces that started before 01-01-2018**.
2. The international logs contain “Start trip”, “End trip” and “Send reminder” events that can take place at many different moments throughout the process, adding to the complexity of the process models while having little relevance for the proposed process analysis. For that reason, the decision was made to **remove “Start trip”, “End trip” and “Send reminder” events from the international traces**.
3. The domestic logs and international logs contain 109 and 62 incomplete traces respectively. For this research, these traces are defined as any traces that, after the previous processing steps, do not start with “Declaration submitted by employee” or “Permit submitted by employee” and/or do not end with “Payment handled” or “Declaration rejected by employee”. The decision was made to **remove all incomplete traces**.
4. The international logs include events related to the request for a permit. As the focus of this research is specifically on the declaration and reimbursement process, these events were deemed irrelevant. The decision was therefore made to **remove all events not specifically related to the travel expense declaration and reimbursement process**.
5. The domestic and international logs contain traces with events that occur only once in the respective event log. For the domestic log, that is the “Declaration for approval by administration” event, whereas for the international log, it is the “Declaration rejected by missing” event. Such events would act as noise during further analysis, especially during process discovery-related analyses. For that reason, it was decided to **remove individual traces with event types that occur only once**.
6. The domestic and international logs contain traces without a declaration number. Declarations that do not come with a declaration number seem erroneous, which is an assumption that is supported by the fact that, after traces have already been removed during the previous processing steps, traces with an unknown declaration number are declarations for an amount of 0.0. It was therefore decided to **remove all traces without a declaration number**.
7. The domestic and international logs contain traces in which the “Request payment” event is missing between the events “Declaration final approved by supervisor” and “Payment handled”. This seems strange from a control-flow perspective, as the process description explicitly mentions that the payment is “requested and made” [9]. They also show unexpected behaviour from a performance perspective, as shown in Table 2. This unexpected behaviour on two dimensions was considered enough reason to **remove traces in which the payment is handled before it is requested**.
8. The domestic and international logs contain loops because employees can choose to resubmit a declaration after it was previously rejected. These loops prove difficult to handle from a process mining perspective, which led to the decision to “unfold” the traces; to **split every trace with multiple “Declaration submitted by employee” events at those events, resulting in multiple traces that each start with the declaration being submitted**. In

**Table 2. Discrepancies in time from the final approval of a declaration to the actual reimbursement, based on whether a payment is requested or not.**

Without “Payment Request” event		
Property	Domestic	International
Abs. frequency	7	6
Mean duration	81.6 d	22.4 wks

With “Payment Request” event		
Property	Domestic	International
Abs. frequency	7,896	4,734
Mean duration	6.3 d	0.89 wks

**Table 3. Number of events, cases and case variants before and after pre-processing (B = before pre-processing, A = after pre-processing).**

Set	Events		Cases		Variants	
	B	A	B	A	B	A
Dom.	56,437	45,284	10,500	7,895	99	36
Int.	72,151	30,118	6,449	4,733	753	53

order not to lose valuable information, it was also decided to **provide each trace with an additional attribute that indicates what try the trace belongs to.**

Custom scripts to perform the processing were written in the Python programming language, subdivided into the two aforementioned categories “noise removal” and “scoping”.

Table 3 shows the effect of pre-processing on the size of the data set. Performing process discovery on the resulting data sets using the heuristic miner algorithm [16] generates models that align with the process flow described in the BPI challenge description. Figure 1, for example, shows the Petri net generated for the domestic declarations data set, with 0.9999 fitness.

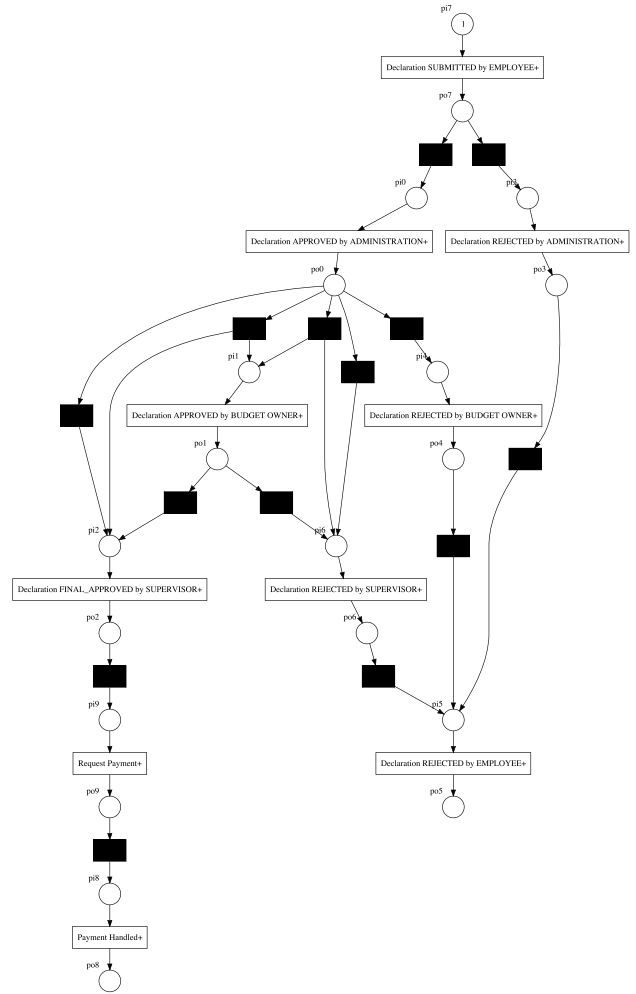
As mentioned, event traces were “unfolded” so that whenever a declaration is resubmitted, it gets its own trace. However, for some analyses, it was more efficient to use still-folded event logs. Therefore, some analyses were done using event logs for which processing step 8 was disabled.

## 5.2 Data analysis

The processes for the declaration and reimbursement of domestic and international travel expenses were compared using the ProM *Process Comparator* plugin, which is an implementation of the approach described in [1] to visualise statistically-significant differences in event logs. It provides an efficient way to distinguish disparities, taking into account both the sequence of events as well as several time-related records.

The plugin is equipped with several configuration options. The option for hiding infrequent behaviour from the visualisation was completely disabled because the analysis was preceded by pre-processing and the process model is relatively simple. The option to set the confidence level to be used for Welch’s T-test significance tests used by the plugin [1] was not used since, for this research, no reason was found to deviate from the default level of 5%.

Insights into significant differences between the two event logs that were found through the use of the Process Comparator plugin sometimes lead to the desire to perform more in-depth analyses, including the analysis of poten-



**Figure 1. Discovered process model for the pre-processed domestic declarations data set, mined using the heuristics miner [16] and visualised as a Petri net.**

tial correlations. Consequently, another Python script was written to collect relevant metadata from the event logs, such as the number of resubmissions seen for each declaration and the amount of money associated with each declaration.

The significance of the difference between domestic and international travel expense declarations regarding the average number of resubmissions/tries per declaration was determined using Welch’s T-test with a confidence level of 5%. This was considered a suitable test and matches the significance test used by the Process Comparator plugin.

## 5.3 Interpretation and validation

Since the research was performed completely independently from the process owner, it was determined that validating the results with the process owner was not feasible within the scope of this research. The focus of the fifth phase of the *Process Comparison Methodology* was therefore moved to interpretation only and the validity aspect is instead proposed as a future follow-up to this research.

## 6. RESULTS

### 6.1 Occurrence frequencies

Table 4 shows significant differences between the processed domestic and international declaration logs when it comes

**Table 4. Significant differences in the relative occurrence frequency of events between the domestic and international travel expense declarations event logs.**

Event	Domestic	International
Declaration approved by administration	91.83%	78.04%
Declaration rejected by administration	8.11%	21.88%
Declaration approved by budget owner	32.75%	28.73%
Declaration approved by supervisor	0.00%	2.35%
Declaration final approved by supervisor	89.41%	73.88%
Declaration final approved by director	0.00%	2.33%
Request payment	89.41%	76.22%
Payment handled	89.41%	76.22%
Declaration rejected by employee	10.49%	23.53%

to the occurrence frequency of events. These differences were observed through the use of the Process Comparator plugin and the diagram generated by this plugin is shown in Figure 2 in Appendix A. The frequencies are determined based on the *unfolded* event logs: the event logs in which resubmissions are considered as separate traces.

It is shown that there is a difference in the relative frequency of the “Payment handled” event, which could imply that domestic declarations are more frequently successful. Whether that is true can be determined by looking at whether the difference in the relative frequency of the “Payment handled” event, as observed for the unfolded traces, is also found for the folded traces. This is not the case. The folded traces instead show that 100% of the traces end in the “Payment handled” event.

## 6.2 Duration between events

Table 5 shows the observed significant differences in the duration between two *consecutive* events of various types, also visualised in Figure 3 in Appendix A. Meanwhile, Table 6 shows the overall average duration between the events “Declaration submitted by employee” and “Payment handled” for both data sets on a per-try and per-declaration basis. It was determined that on average, completing the process—going from “Declaration submitted by employee” to “Payment handled”—takes significantly longer in case of declarations for international travel expenses, both on a per-try basis (12d, 05:16:39.376 versus 10d, 06:50:14.472) and a per-declaration basis (14d, 23:12:50.443 versus 11d, 13:20:34.625).

## 6.3 Tries per declaration

Table 7 shows what percentage of declarations is submitted what number of times for both event logs. It is shown that the average number of retries seen for international declarations is significantly higher than for domestic declarations: 1.31 versus 1.11.

## 6.4 Declaration amounts

The average amount of money related to declarations for domestic travel expenses was discovered to be approximately 91.29, with a standard deviation of 148.77. For declarations for international travel expenses, these numbers are 806.17 and 830.82, respectively.

Correlations were calculated for the declaration amount and the number of tries, and the declaration amount and trace duration from the first to the last event. The calculations were done for the domestic data set only, the international data set only, and the two data sets combined. The calculated correlations were all in the range from 0.11–0.23, which indicates that the properties that were analysed show only very weak correlations.

## 7. DISCUSSION

### 7.1 Relations between the event occurrence frequency differences

The analysis and interpretation of the observed differences in event occurrence frequency between declarations for domestic and international travel expenses show that many of these differences are linked.

For example, it was shown that the frequency of declarations that are approved by the administration is significantly higher for domestic declarations, while the frequency of declarations that are *rejected* by the administration is significantly higher for international declarations. Whether or not the administration approves a declaration is a binary decision and the first step in the process after the declaration has been submitted. For that reason, the combination of the two observed significant differences seems sensible.

Another link can be found between the observation that domestic declarations are significantly more frequently given the *final* approval by a supervisor, the observation that international declarations are significantly more frequently given a “*regular*” approval by a supervisor and the observation that international declarations are significantly more frequently given the final approval by a *director*. Approvals happen in the order: administration, (budget owner), supervisor, (director). Since domestic declarations in the data set do not show any relation to a director, the approval that a supervisor gives to a declaration is *always* the final approval, due to which the “regular” supervisor approval never occurs for these declarations, leading to a significant occurrence frequency difference.

### 7.2 Relation between the “Payment handled” event occurrence frequency and the average number of resubmissions

The occurrence frequency of the “Payment handled” activity being higher for domestic declarations implies one of two things: either international declarations generally need to be resubmitted more frequently before they are fully approved and handled, or employees more frequently give up on their declaration completely in case of international declarations. The observation that international declarations see a higher average number of (re)tries shows that the former is true, which is further supported by the observation that 100% of the folded traces ends in “Payment handled” and none in the declaration being rejected.

### 7.3 Duration between events and resubmissions

There are seven observed combinations of consecutive events for which domestic and international travel expense declarations show a significant difference in the amount of time between one event and the other. In six of these instances, the amount of time is significantly higher for international declarations. This is in line with the observation that on average, it takes significantly longer for international travel expense declarations to go from the submission of a declaration to the payment being handled.

**Table 5. Significant differences between the domestic and international travel expense declaration logs with regards to the duration ( $\Delta T_s$ ) between two consecutive events.**

Source event	Target event	Domestic		International	
		$\Delta T_s$ mean	$\Delta T_s$ SD	$\Delta T_s$ mean	$\Delta T_s$ SD
Declaration submitted by employee	Declaration approved by administration	26:25:33.276	190:32:15.339	<u>41:45:34.062</u>	285:39:14.101
Declaration submitted by employee	Declaration rejected by administration	<u>101:27:08.074</u>	494:20:06.245	56:49:38.426	261:20:02.530
Declaration approved by administration	Declaration final approved by supervisor	45:44:36.914	72:44:08.443	<u>71:11:53.044</u>	98:57:40.746
Declaration approved by administration	Declaration rejected by supervisor	54:18:23.149	75:34:09.639	<u>100:52:12.694</u>	106:26:26.479
Declaration approved by administration	Declaration approved by budget owner	45:49:52.195	75:12:31.149	<u>76:53:27.982</u>	120:10:11.594
Declaration approved by budget owner	Declaration final approved by supervisor	68:38:25.822	58:39:48.776	<u>72:18:07.099</u>	60:31:19.259

**Table 6. Average durations ( $\Delta T_s$ ) between the “Declaration submitted by employee” and “Payment handled” events, per-try and per-declaration.**

Scope	Domestic		International	
	$\Delta T_s$ mean	$\Delta T_s$ SD	$\Delta T_s$ mean	$\Delta T_s$ SD
Single try (unfolded log)	246:50:14.472	293:16:39.376	250:43:29.616	341:15:27.000
Single declaration (folded log)	277:20:34.625	359:12:50.443	330:06:05.336	409:09:05.355

**Table 7. Number of tries in declarations for domestic and international travel expenses.**

Tries	Domestic	International
1	89.70%	74.77%
2	8.94%	20.28%
3	1.22%	4.14%
4	0.11%	0.57%
5	0.01%	0.23%
6	0.00%	0.00%
7	0.01%	0.00%
Avg. no. of tries	1.11	1.31

It could be assumed that a reason for international declarations requiring more (re)submissions and more time before they are fully approved and handled is that—as shown in the results—they have a higher value, due to which they create a larger financial risk and might be more carefully checked. However, these ideas are not supported by the calculated correlation between the amount and the number of tries and the calculated correlation between the amount and the declaration duration from the first to the last event.

## 8. CONCLUSIONS

The realised process for the declaration and reimbursement of travel expenses differs between domestic and international trips on both dimensions that were researched.

With regards to the dimension of event sequences found in the processes, it was observed that in 2018, only certain international travel expense declarations were ever approved by the director. Furthermore, it was observed that there are significant differences between domestic and international declarations when it comes to the average occurrence frequency of various events and that many of these differences are in some way linked to one another. It was also observed that on average, declarations for international travel expenses are resubmitted more frequently before their payments are handled than their domestic coun-

terparts.

With regard to the time dimension, it was observed that seven transitions showed significant differences between domestic and international travel expense declarations when it comes to the amount of time between the starting moments of two consecutive activities.

A combination of the differences in the two aforementioned categories is seen in the observed average amount of time between the moment a declaration is submitted for the first time and the moment its payment is handled. For declarations related to international travel expenses, the time between these two events is significantly longer.

With regard to the amount of money represented by declarations, it was shown that declarations for international travel expenses on average account for significantly larger amounts of money than declarations for domestic travel expenses. However, the hypothesised correlation between the amount of money associated with a declaration and the thoroughness and therefore duration of the checks was not found: the correlation between the amount of money and the number of resubmissions of a declaration, as well as the correlation between the amount of money and the total duration of the declaration and reimbursement process, was observed to be very weak.

Several more general conclusions can be drawn from this research. The first one is that process mining can provide novel insights into a process—insights that are not immediately obvious—, as was shown by the results. Also, it can be concluded that there is value in combining process mining techniques with generic statistical analysis techniques to (in)validate hypotheses derived from process mining results, as seen in the previous paragraph.

More significant, however, is a conclusion that is derived from the fact that this research provides mere statistical, non-actionable insights. That conclusion is that the importance of involving process owners or other domain knowledge experts in process mining operations should not be underestimated. Their involvement shall ease interpreting the results and lead to insights that are more action-

able and therefore more valuable to the process owner. Furthermore, it should decrease the chances of the whole operation being invalidated because of incorrect assumptions that were made.

## 9. LIMITATIONS AND FUTURE WORK

The research has led to several insights into the declaration and reimbursement process at the TU/e, especially when it comes to differences between the process for domestic and international declarations. Nevertheless, there are some severe limitations to this research and many opportunities for future research.

One limitation is related to the fact that events in the data set are considered atomic. The start time of events is shown, but the data set does not provide information about the moment at which the execution of an event finished. As a result, neither the duration of individual events nor the delay between two consecutive events can be determined.

A more severe limitation, however, is related to the absence of domain knowledge inherent in the author of this paper and a complete lack of communication with a domain knowledge expert to compensate for that shortcoming, as briefly mentioned in Section 8. It has resulted in the observations being mere statistical observations and has furthermore resulted in doubts about the noise removal and scoping that was done prior to the main analysis. It might have been too rigid. Traces were considered noise based on assumptions that have not been validated with a domain knowledge expert, and the removal of permit-related events from the international declarations data set might have meant the removal of information that would help explain some of the observed differences.

Recommendations for future work, therefore, include the suggestion to validate choices made in this research, as well as the suggestion to discuss the observations with a domain knowledge expert to potentially transform them into real, actionable insights.

Another recommendation is to explore the opportunities when it comes to doing research on the correlation between contextual properties and certain process behaviour. In this research, the correlation between the declaration amount and the duration of traces as well as the correlation between the declaration amount and the number of (re)submissions in a trace was calculated, but there are many other attributes and analyses to consider. For example, the relation between the declaration amount and specific *parts* of the process could be analysed, while there are also opportunities to look at attributes such as permit-related properties and the date at which the declaration was submitted.

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# APPENDIX

## A. PROCESS COMPARATOR DIAGRAMS

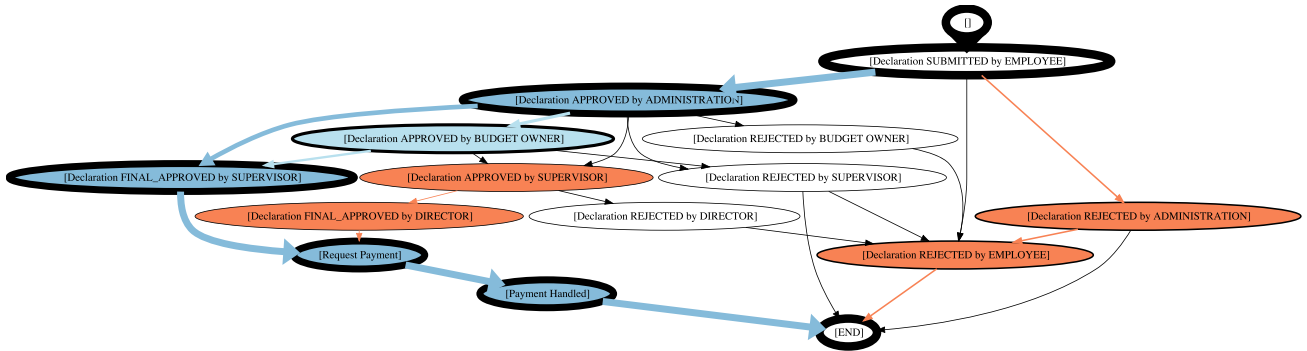


Figure 2. Process Comparator [1] diagram showing the significant differences in frequency with which certain events and transitions occur. Orange to red colours indicate that the relative occurrence frequency is larger for international declarations, whereas light blue to dark blue colours indicate that the relative occurrence frequency is larger for domestic declarations.

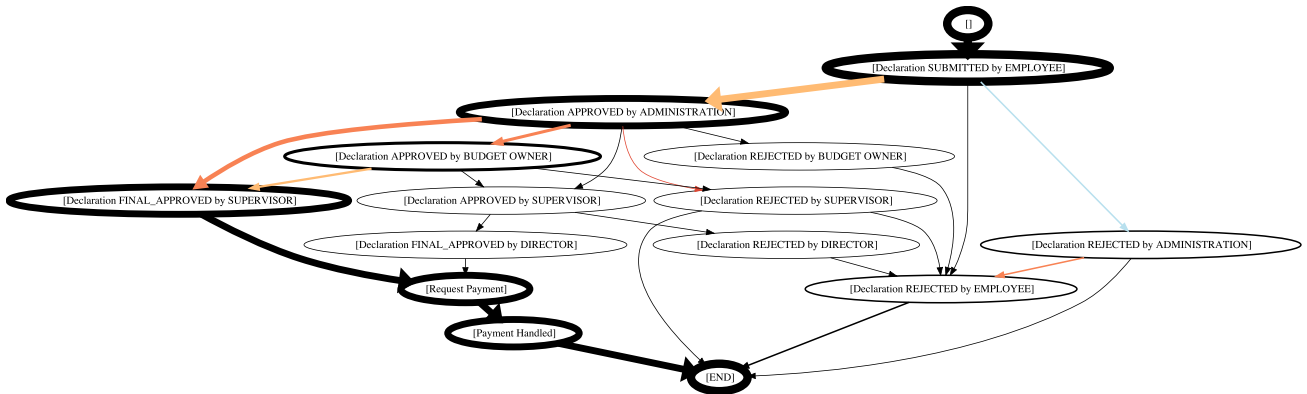


Figure 3. Process Comparator [1] diagram showing the significant differences in duration between two consecutive events. Orange to red colours indicate that the duration is larger for international declarations, whereas light blue to dark blue colours indicate that the duration is larger for domestic declarations.