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Process mining of event logs in audit – opportunities and challenges

Miklos A. Vasarhelyi
KPMG Distinguished Professor of AIS

Pisa Summer Camp
July 8, 2019

Outline

- The CarLab
- The Mieke Project
- Tiffany's Dissertation
- Abdulrahman's Dissertation
- Work with the AICPA in the RADAR project
- Hering & Brazilian Navy
- What's next?



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Car Lab



CarLab Analytic Research

		MADS: full population testing	Process Mining	The visual audit	CarLab
GEM	Exogenous Variables audit	Cybersecurity text mining innovation	Assurance of Cybersecurity	Cybersecurity risk factors	Brazilian Stock exchange
<u>Choosing apps</u>	<u>Predictive Analytics with Weather data</u>	<u>Audit data analytics and EDA</u>	<u>Envisaging the future of audit and Big Data</u>	<u>Text Mining</u>	<u>Monitoring Unibanco's branches</u>
<u>Visualization</u>	<u>Process Mining at Gamma Bank</u>	<u>Expert System for P-Card</u>	<u>Logit regression for control risk assessment</u>	<u>Exceptional Exceptions</u>	<u>Client Retention Project</u>
<u>Litigation prediction</u>	<u>Fraud Risk Assessment using EDA</u>	<u>Detecting duplicate records</u>	<u>Continuity equations</u>	<u>Predictive Audit</u>	Credit card Default prediction
Insurance Analytics	<u>Multidimensional clustering for fraud detection</u>	<u>Rule-based selection for transitory accounts</u>	<u>Continuity Equations at HCA</u>	<u>XBRL</u>	<u>Insurance Analytics</u>
Cognitive Decision Aids	AI: Deep Learning	<u>Robotic Process Automation (RPA)</u>	<u>Intelligent Process Automation (IPA)</u>	<u>Blockchain and Smart Contracts</u>	Cluster Analysis of US States
Cybercurrency Valuation	NY City Cleanliness tweets	PIOB: what is public interest?	Continuous Audit at the Brazilian Navy	Continuous Process Mining at Hering	Deep Learning of insurance estimates

Unit Name

Content

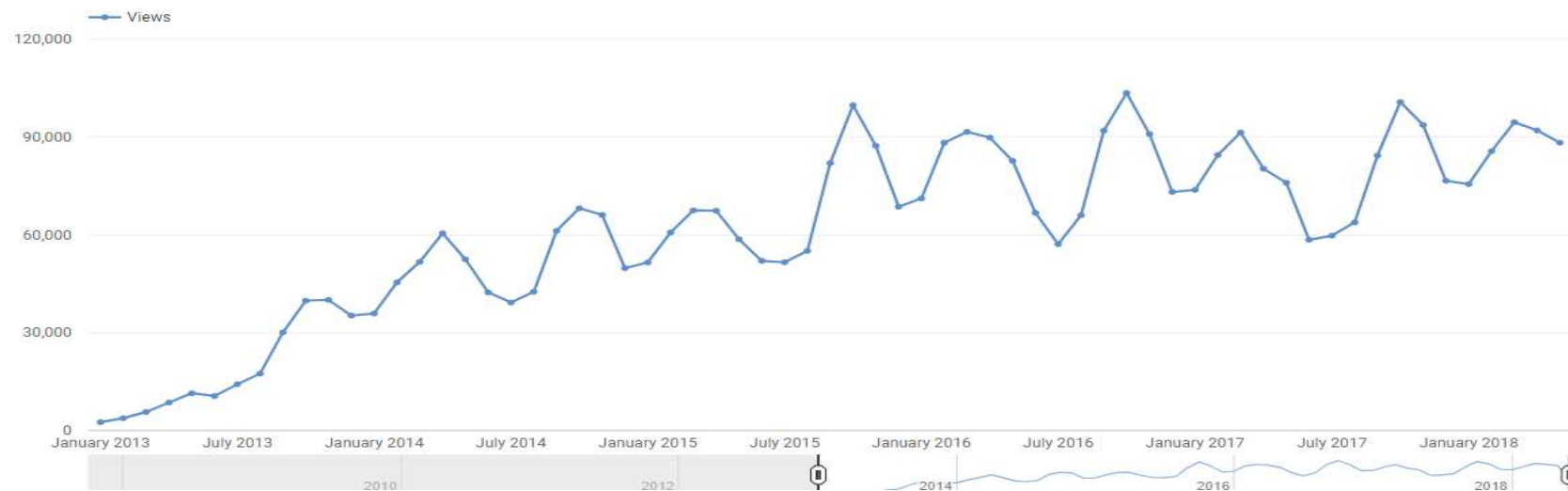
- Undergraduate, Graduate, PhD, & Audit Analytics Content**

Undergraduate	Graduate	PhD	Audit Analytics Certificate
<ul style="list-style-type: none"> • Introduction to Financial Accounting • Introduction to Managerial Accounting • Intermediate Accounting I • Intermediate Accounting II • Advanced Accounting • Auditing Principles • Management and Cost Accounting • Accounting Information Systems • Business Law I • Business Law II • Federal Taxation I • Accounting in the Digital Era • Computer Augmented Accounting • Decoding of Corporate Financial Communications 	<ul style="list-style-type: none"> • Accounting Principles and Practices • Information Technology • Government and Not-for-Profit Accounting • Advanced Auditing and Information Systems • Advanced Accounting • Corporate Taxation • Income Taxation • Income Tax Estate and Trust 	<ul style="list-style-type: none"> • Special Topics in Accounting • Survey of Accounting Information Systems • Current Topics in Auditing • Machine Learning 	<ul style="list-style-type: none"> • Introduction to Audit Analytics • Special Topics in Audit Analytics • Information Risk Management • Tutorials for Risk Management

Unit Name

Usage

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Special Topics in Audit Analytics


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1




Special Topics in Audit Analytics: Week 1- (Lecture 2: Analytics Big Data Audit Automation)

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2




Special Topics in Audit Analytics: Week 1-(Lecture 3: The Audit Ecosystem)

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Special Topics in Audit Analytics: Week 1-(Lecture 4: Audit Data Standard)

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Special Topics in Audit Analytics: Week 2-(Lecture 2)

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Special Topics in Audit Analytics: Week 3-(Lecture 1- Hypothesis Testing)

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Special Topics in Audit Analytics: Week 3-(Lecture 2- Hypothesis testing 2)

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Special Topics in Audit Analytics: Week 3-(Lecture 3 : Confidence interval)

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8




Special Topics in Audit Analytics: Week 3-(Lecture 4 -Two sample test)

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9




Special Topics in Audit Analytics: Week 3-(Lecture 5: two dependent sample test)

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10




Special Topics in Audit Analytics: Week 3-(Lecture 6: Introduce R)

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11



Special Topics in Audit Analytics: Week 3-(Lecture 7: Demonstration with R)

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Special Topics in Audit Analytics: Week 4-(lecture 1)

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The Audit Analytics Certificate Program

http://raw.rutgers.edu/audit_analytics_certificate.html

Unit Name

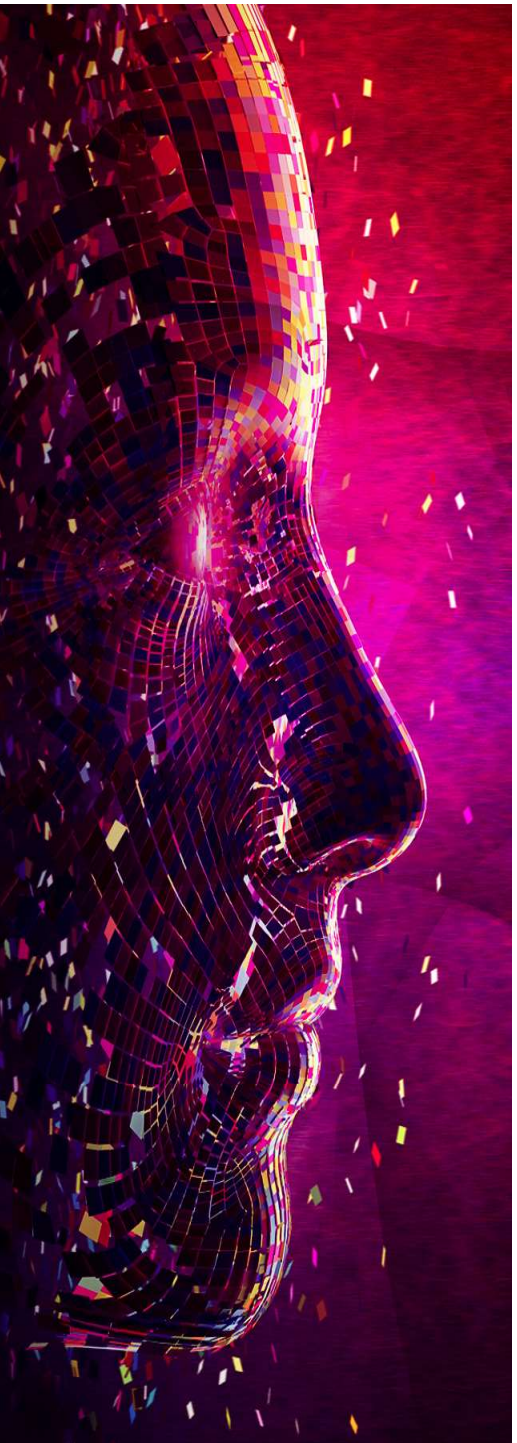


Emerging Assurance Services

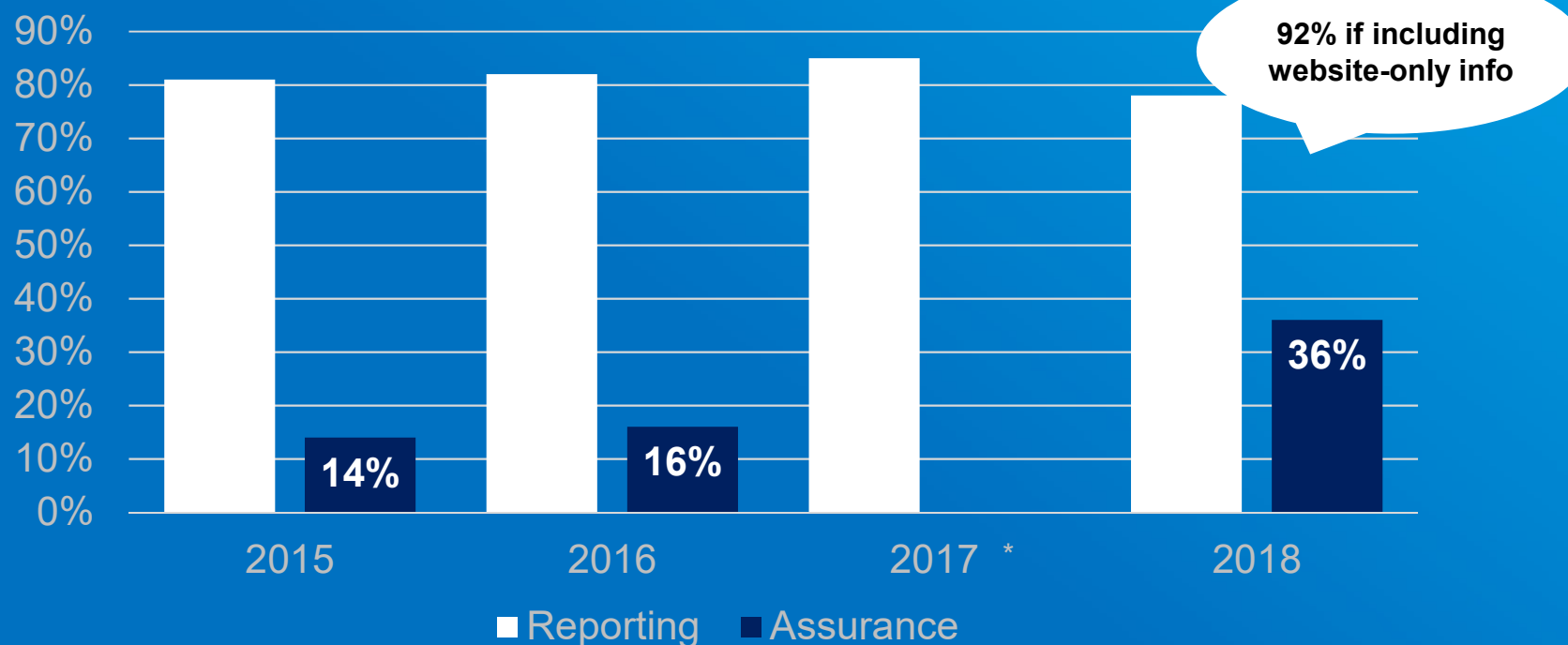
Amy Pawlicki
VP – Assurance and Advisory Innovation

Agenda Item 10
Spring Council
2019

REIMAGINE



S&P 500 – Reporting and assurance rates for Sustainability and Integrated Reporting



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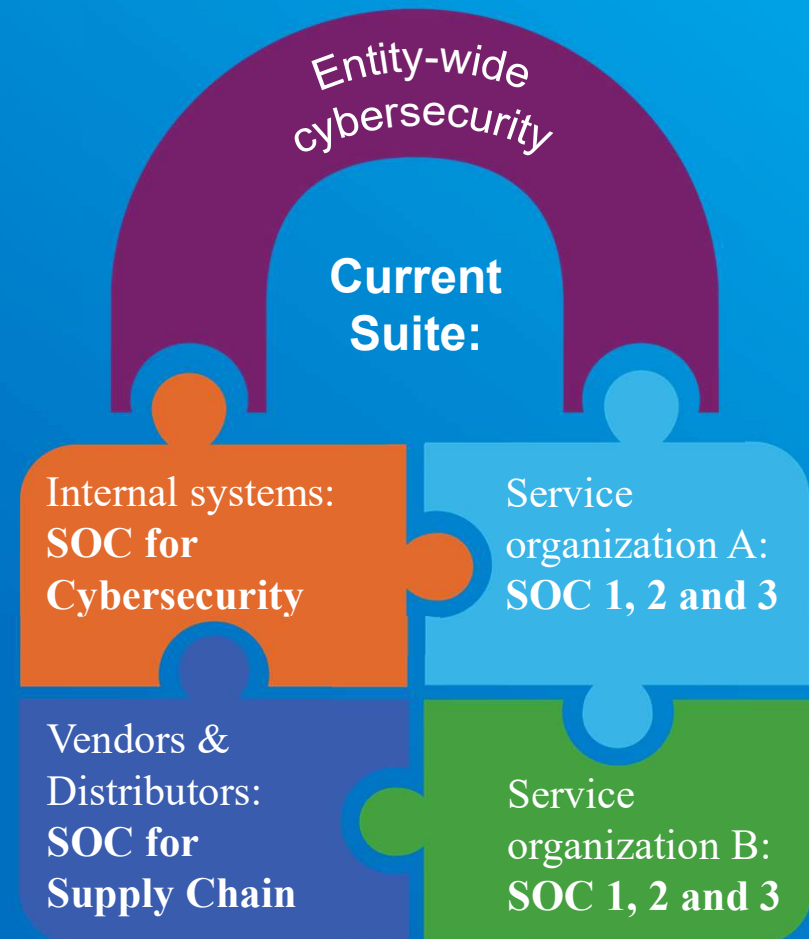
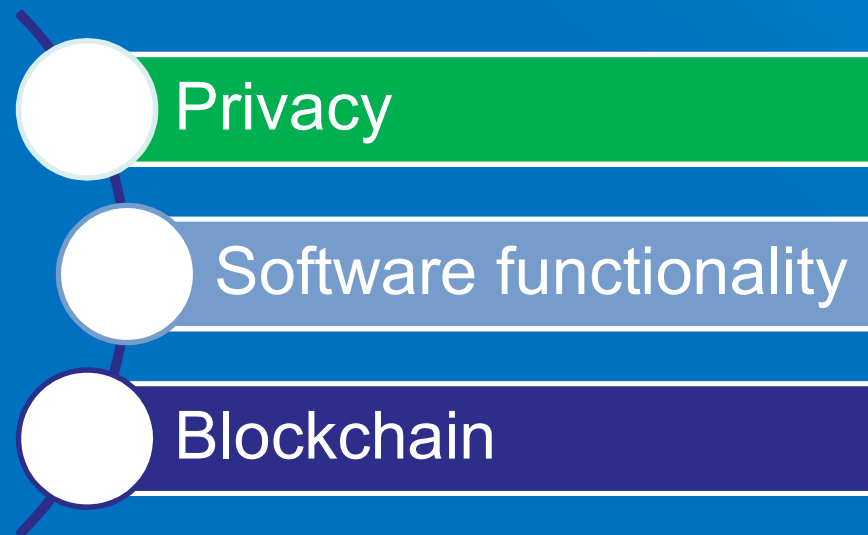
<https://www.cpajournal.com/2018/07/20/sustainability-assurance-services/> and

<https://ircinstitute.org/wp-content/uploads/2018/11/2018-SP-500-Integrated-Reporting-FINAL-November-2018-1.pdf>

*2017 assurance rates were not available

System and Organization Control (SOC) Services

New Focus Areas:



Technical Projects Related to Assurance Innovation



- Materiality considerations
- Non-ICFR internal control examinations
- Data and information integrity criteria
- Reporting on maturity models



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Process mining

Mieke Jens (Hasselt University)

Michael Alles (Rutgers Univ.)

An Example of An Event Log of an Invoice

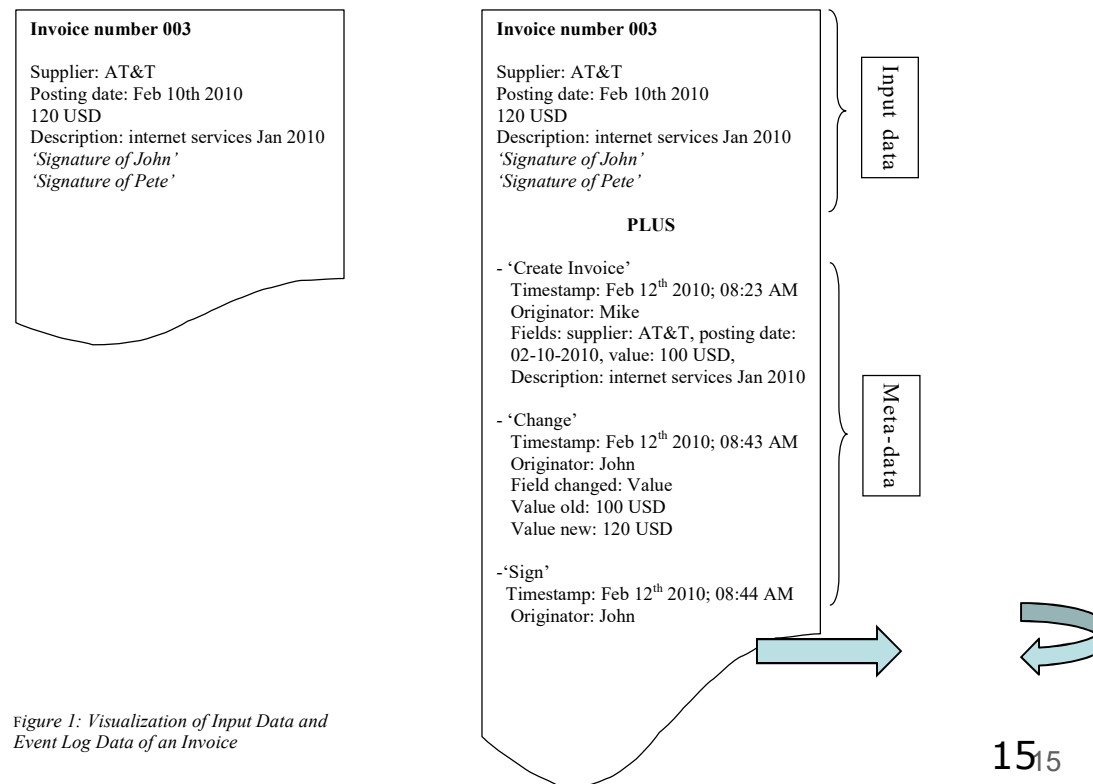
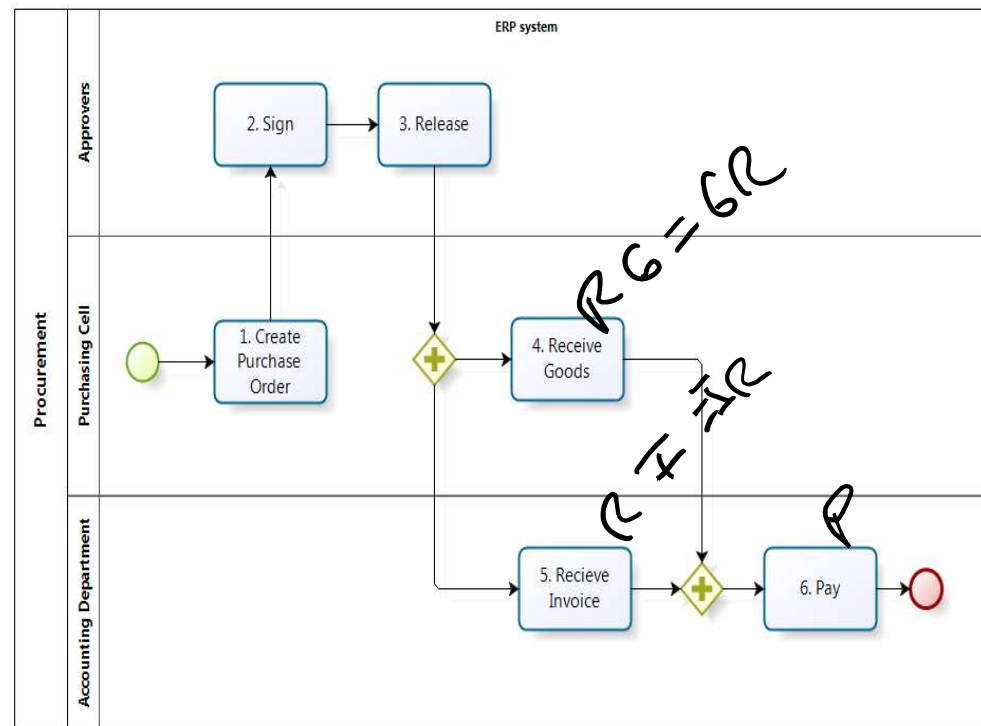
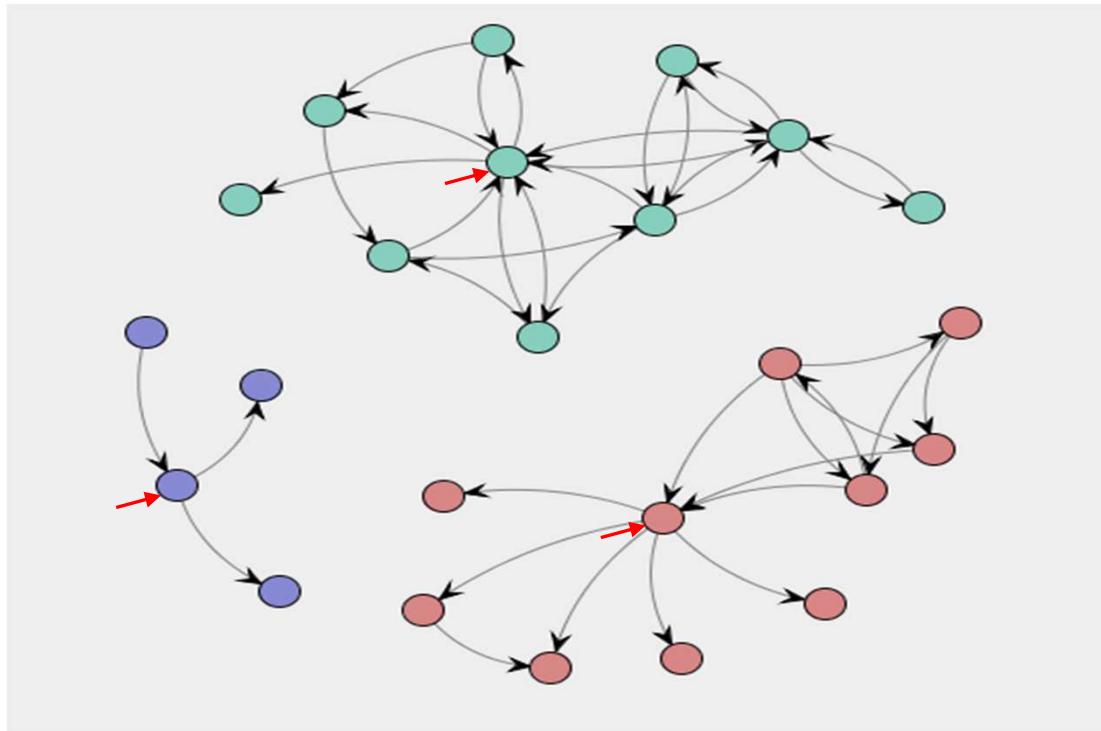


Figure 1: Visualization of Input Data and Event Log Data of an Invoice

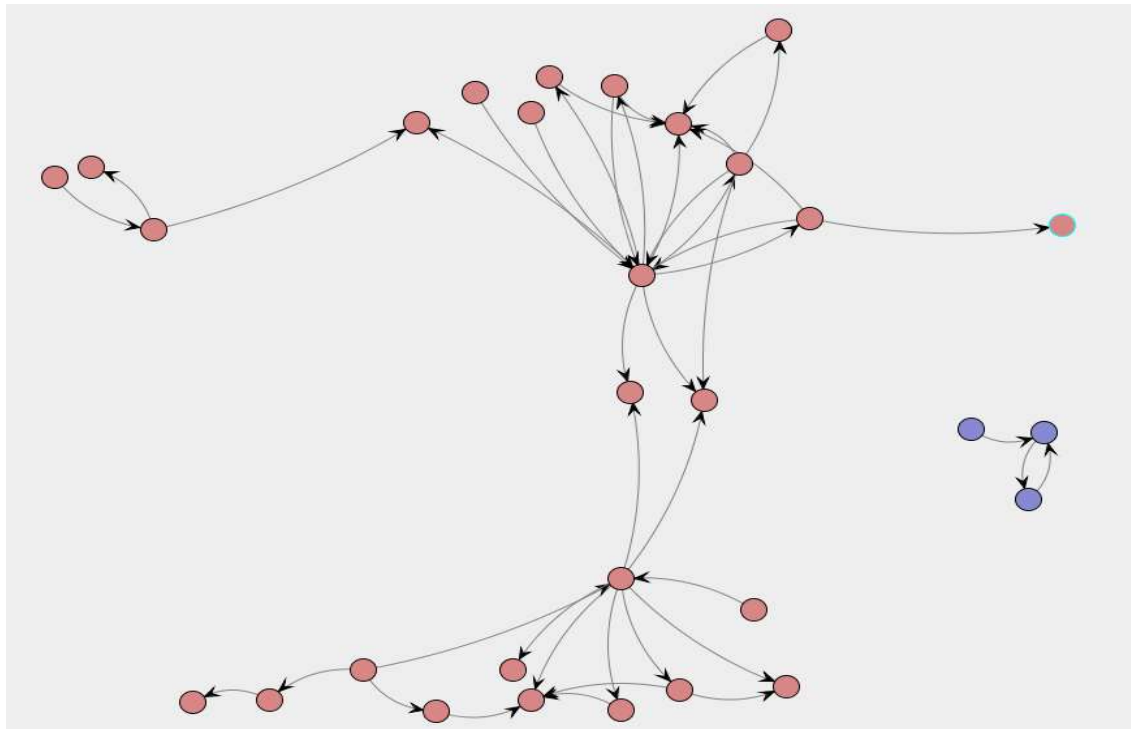
Designed (“Ideal”) Process Model



Social Network of 175 cases by three individuals violating SOD



Social Network of the 742 Cases Without *Sign* and in Violation of SOD Controls





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Exploring New Audit Evidence: The Application of Process Mining in Auditing

Dissertation Defense
Tiffany Chiu

Main Outline

- ❖ **Introduction**
- ❖ **Literature Review**
- ❖ ***Essay One:*** Process Mining of Event Logs: A Case Study
Evaluating Internal Control Effectiveness
- ❖ ***Essay Two:*** Validating Process Mining: A Framework
Integrating Auditor's Risk Assessment
- ❖ ***Essay Three:*** A Framework of Applying Process Mining for
Fraud Scheme Detection
- ❖ **Conclusion and Future Research**

Introduction

❖ Purpose

- Examine how process mining can serve as a new type of audit evidence to evaluate the effectiveness of internal control, assist auditors in their risk assessment process, and identify fraud schemes.

❖ Motivation

- Process mining - analyze business process using event log information that was automatically recorded in the accounting information systems.
- Process mining has been widely applied in computer science, engineering and management research topics. However, the application of process mining in auditing and other accounting sub-areas has just emerged.

❖ Contribution

- Findings in this dissertation contributes to auditing field by investigating how process mining can assist auditors in evaluating internal control effectiveness, assessing audit risk as well as identifying fraud schemes

Purchase Order	Sequence NO.	Activity	Resource	Variant	Timestamp
450039741940	1	Create PO	U35824	Variant 1	2007-01-10
450039741940	2	Sign	G19091	Variant 1	2007-01-12
450039741940	3	Release	U42242	Variant 1	2007-01-15
450039741940	4	GR	G35730	Variant 1	2007-01-16
450039741940	5	IR	G10849	Variant 1	2007-01-17
450039741940	6	Pay	G10849	Variant 1	2007-01-18
4500397495780	1	Create PO	U21356	Variant 1	2007-01-10
4500397495780	2	Sign	U29598	Variant 1	2007-01-11
4500397495780	3	Release	G13307	Variant 1	2007-01-12
4500397495780	4	GR	U21356	Variant 1	2007-01-29
4500397495780	5	IR	G55584	Variant 1	2007-02-08
4500397495780	6	Pay	G55584	Variant 1	2007-02-14

Literature Review (1/2)

- The idea of mining business processes was first proposed by Agrawal et al. (1998) where they developed an approach to identify business processes occurred in the system by evaluating existing logs.
- Cook and Wolf (1998) proposed the term - process discovery, and introduced a technique that develops process models by capturing current business processes.
- A large body of academic research analyzed business processes using event logs and proposed either new types of process mining techniques or a case study to evaluate or improve these techniques.
 - Bozkaya et al. (2009) proposed a process diagnostics method using process mining to help organizations understand three perspectives, namely: “how the process model actually looks like,” “how well does the system perform,” and “who is involved in the process and how.”
 - Rozinat and van der Aalst (2008) proposed a novel conformance checking approach to examine the differences between the observed business process and the designed process model.

Literature Review (2/2)

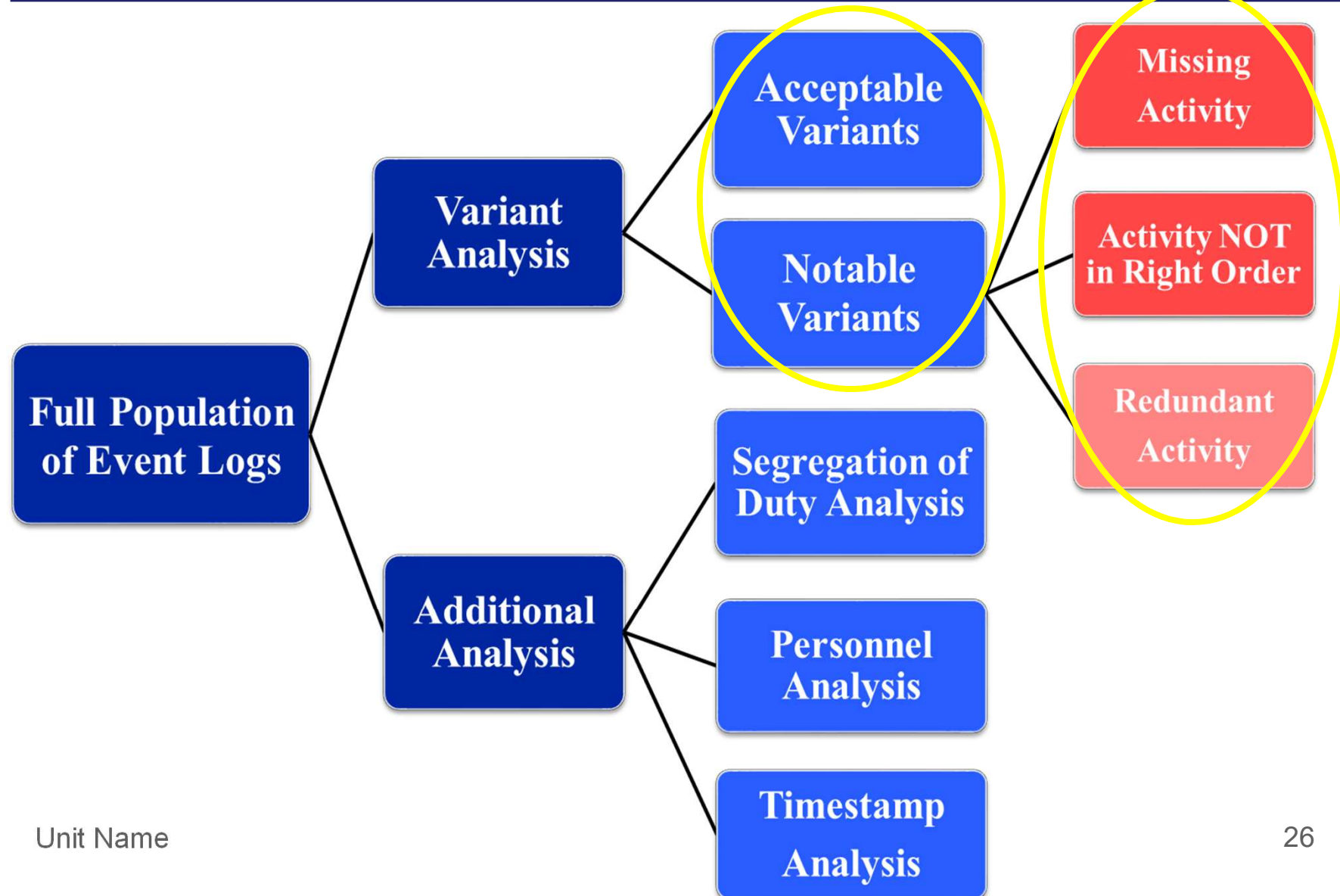
- Process mining of event logs could assist auditors in their audit work in three aspects: (1) event logs enable auditors with more data, (2) event logs are automatically logged in accounting information systems and therefore this log data is more reliable, and (3) process mining enables auditors to discover and identify an entity's business process and social network, which are less likely to be analyzed by current data analytics techniques (Jans et al. 2010; Bukhsh and Weigand 2012; Jans et al. 2013).
- Compared with using control objective information, using business process focused information in the internal control framework could improve the effectiveness of internal control evaluation (Kopp and Donnell 2005).
- Jans et al. (2014) showed that process mining techniques enable the identification of numerous transactions that are audit-relevant, including payments made without approval, violations of segregation of duty controls, and violations of company-specific internal procedures.

Essay One

Process Mining of Event Logs: A Case Study Evaluating Internal Control Effectiveness

- This paper aims at adopting process mining to evaluate the effectiveness of internal control using a real-life event log from a large European bank.
 - (1) *Variant analysis* that identifies acceptable and notable variants.
 - (2) *Segregation of duty analysis* that examines process instances and employees that violate segregation of duty controls.
 - (3) *Personnel analysis* that investigates employees who are involved in multiple potential control violations.
 - (4) *Timestamp analysis* that detects time related issues such as events performed during the weekend and process instances that have lengthy process duration.

Applying Process Mining to Evaluate the Effectiveness of Internal Control



Acceptable Variant

Category	Description
Standard Procure-to-Pay process	The variant "PO-Sign-Release-GR-IR-Pay" is the standard process in the procure-to-pay process.
Change line before sign and release	Change line occurs before sign, indicating there is approval for changing line items. <ul style="list-style-type: none"> For example: "PO-Change Line-Release-GR-IR-Pay"
Change line with the approval process	Change line occurs after sign and release, indicating there is another set of sign and release by this change line. This indicates approval for changing line items. <ul style="list-style-type: none"> For example: "PO-Sign-Release-Change Line-Sign-Release-GR-IR-Pay"
Invoice receipt (IR) and goods receipt (GR) switch places	The order of IR and GR is opposite the standard procurement process. <ul style="list-style-type: none"> For example: "PO-Sign-Release-GR-IR-Pay"

Create
Purchase
Order

Sign

Release

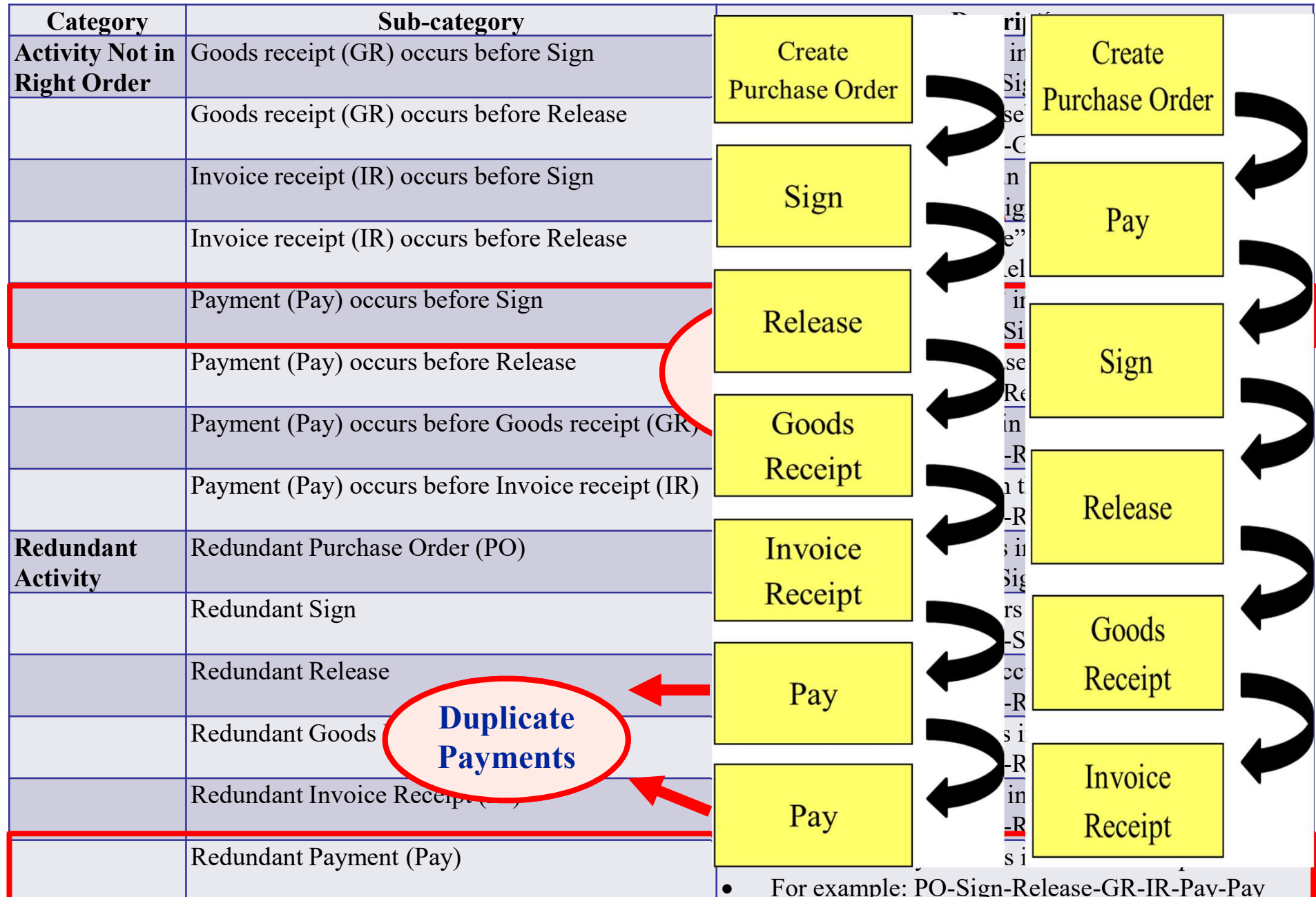
Goods
Receipt

Invoice
Receipt

Pay



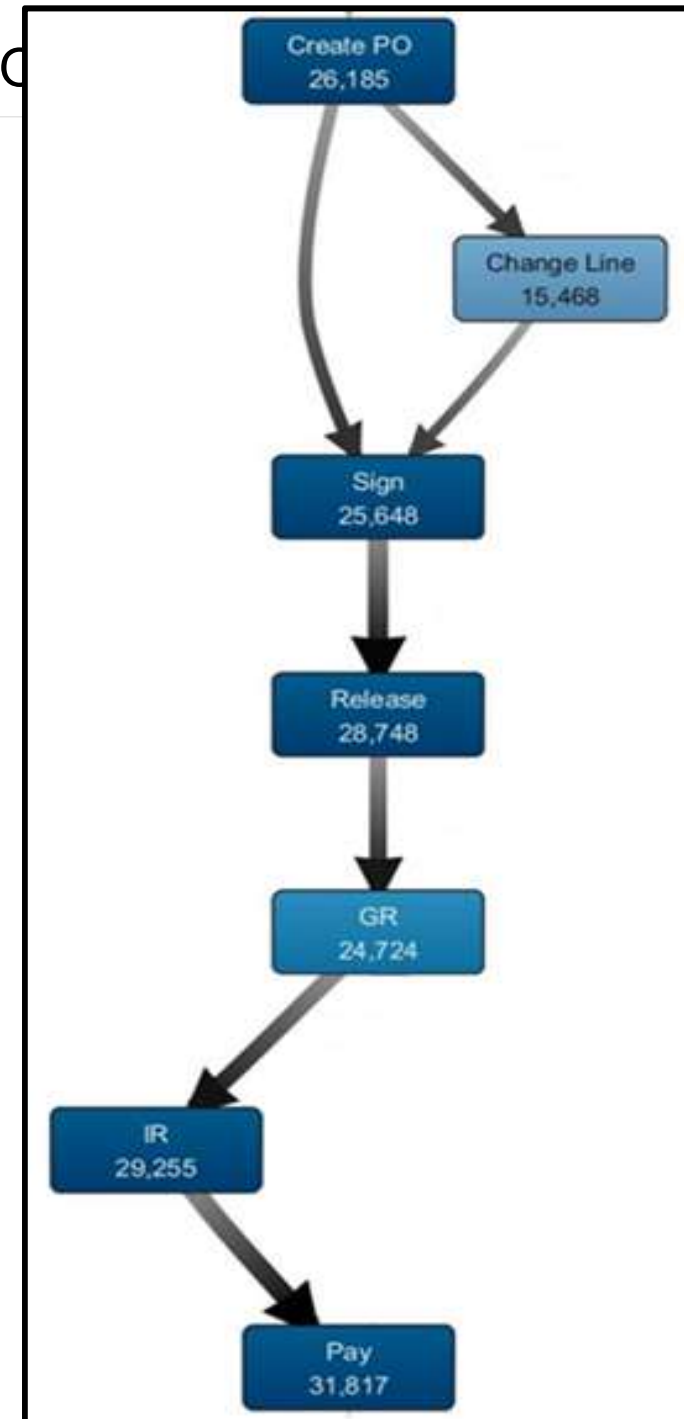
Category	Sub-category	Description	
Missing Activity	Missing purchase order (PO)	Missing activity "PO" in the business process. • For example: Sign-Release	Create Purchase Order
	Missing sign	Missing activity "Sign" in the business process. • For example: PO-Release-	Release
	Missing release	Missing activity "Release" in the business process. • For example: PO-Sign-GR	Goods Receipt
	Missing goods receipt (GR)	Missing activity "GR" in the business process. • For example: PO-Sign-Rel	Invoice Receipt
	Missing invoice receipt (IR)	Missing activity "IR" in the business process. • For example: PO-Sign-Rel	Pay
	Missing payment (Pay)	Missing activity "Pay" in the business process. • For example: PO-Sign-Rel	
	Change line without sign	In the business process, there is a change line. • For example: PO-Sign-Rel Release-GR-IR-Pay	
	Change line without sign nor release	In the business process, there is a change line after changing line. • For example: PO-Sign-Rel GR-IR-Pay	



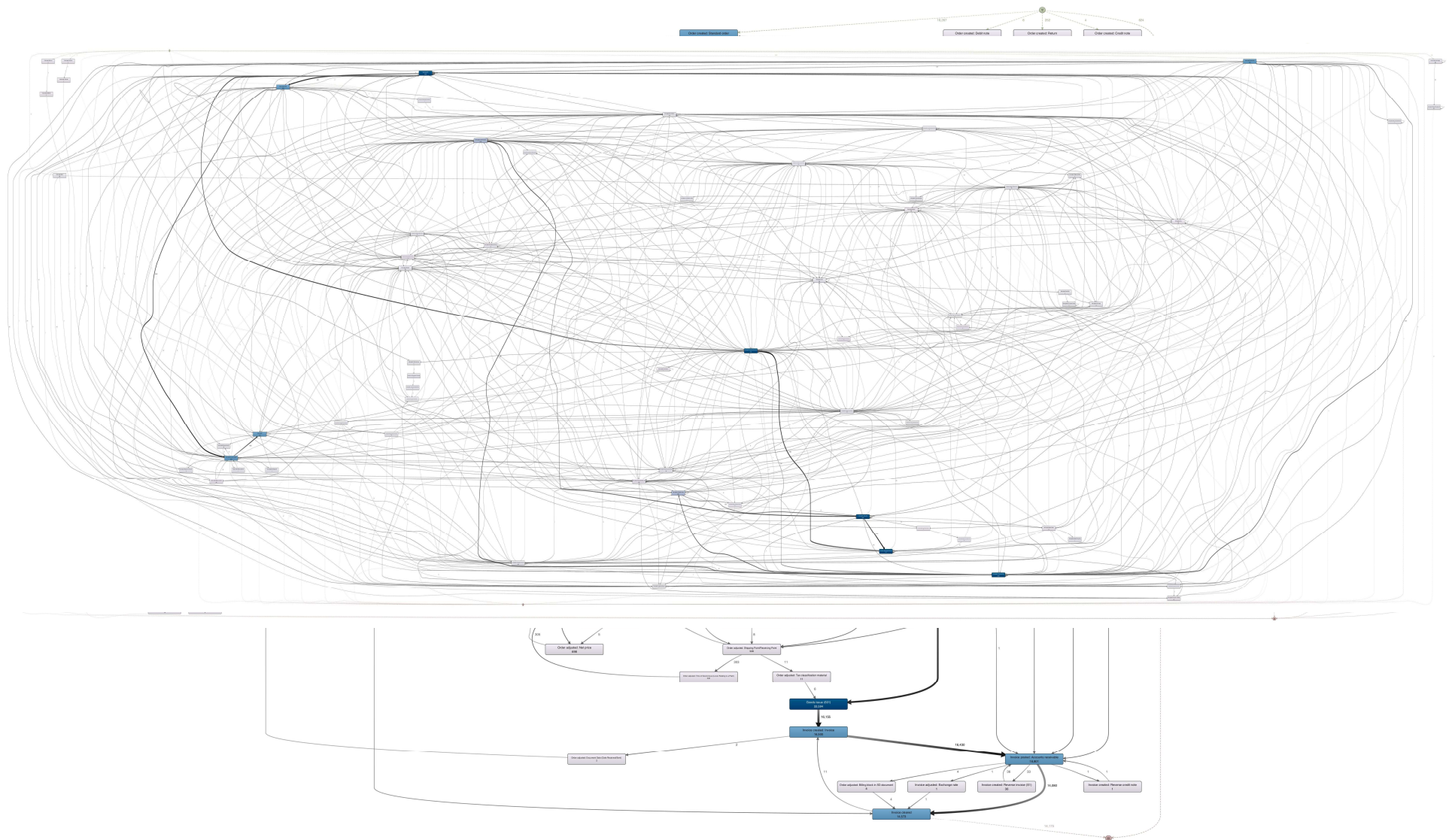
Dataset Overview

Activity	181,845
Process Instance	26,185
Activity Detail	(1) Create PO (2) Sign (3) Release (4) GR (5) IR (6) Pay (7) Change Line
Variant	980
Mean Process Instance Duration	46.2 Days
Start	01/02/2007
End	01/25/2008

Unit Name



What is Process Mining?



Variant Analysis – Results (1/4)

Variant Analysis – Overall Results

	Variant			Process Instance	
	Count	Percentage		Count	Percentage
Acceptable Variant	49	5%		19,198	73.32%
Notable Variant	931	95%		6,987	26.68%
Total	980	100%		26,185	100%

Notable Variant

	Variant			Process Instance	
	Count	Percentage (in total)		Count	Percentage
Missing Activity	551	56.22%		4,980	19.02%
Activity Not in Right Order	23	2.35%		139	0.53%
Redundant Activity	831	84.80%		2,664	10.17%

Activity Not in Right Order

Sub-category	Missing Activity	Variant Frequency	Process Instance Frequency
Goods Receipt (GR) occurs NOT after Signature (Sign)	Variant 0	Frequency	Process Instance 0
Missing Purchase Order (PO) after Release	0	0	0
Missing Signature (Sign)	40		3,443
Invoice Receipt (IR) occurs NOT after Release	3	5	3 ⁹
Missing Receipts (Receipts) NOT after Release	2	15	3
Missing Invoice Receipt (IR)	0		0
Payment (Pay) occurs NOT after Signature (Sign)	0	1	01
Change Line without signature	544		4,293
Payment (Pay) occurs NOT after Release (missing sign)	2		3
Change Line without signature nor Release	494		1,547
Payment (Pay) occurs NOT after Goods Receipt (GR)	8		8
Total	551		4,980
Payment (Pay) occurs NOT after Invoice Receipt (IR)	0		0
Unit Name			33
Total	23		139

Process Instance	Variant	Create PO	Sign	Release	GR	IR	Pay
4500400507180	Variant 674	1	21	20	1	1	1
450040050710	Variant 281	Redundant Activity		20	2	2	3
450040050720	Variant 272			0	2	2	3
450040050740	Variant 270			0	2	1	1
450040050750	Variant 269	1	21	0	Process Instance Frequency		1
450040050770	Variant 276	1	21	0			1
450040050780	Variant 275	1	21	0			1
450040050760	Variant 277	1	21	0	1	1	1
450040050790	Variant 274	1	21	0	1	1	1
4500400507100	Variant 667	1	21	0	1	1	1
450040050730	Variant 271	1	21	0	4	2	2
450039573130	Variant 775	1	13	13	11	13	13
450039757010	Variant 914	1	10	8	12	1,094	8
450039757080	Variant 922	1	10	8	1	1	2
450039757090	Variant 124	1	10	8	1	1	1
4500397570100	Variant 124	1	10	8	1	680	1
450039896140	Variant 625	1	10	8	3	3	3
450039896160	Variant 195	1	10	8	2	2	2
450039896170	Variant 195	1	10	8	2	548	2
45004035810	Variant 548	1	5	0	118	112	137
450040350910	Variant 283	1	3	0	76	70	86
450040353610	Variant 186	1	3	3	57	57	71
450040351510	Variant 400	1	455	0	129	527	117
450040318310	Variant 423	1	0	0	112	112	133
450040320910	Variant 514	1	0	0	59	60	86
450040318410	Variant 54	1	650	0	54	1,830	59
450040353810	Variant 525	1	0	0	33	33	45
45004031610	Variant 517	1	831	0	33	2,664	28
450040351710	Variant 536	1	0	0	27	27	28
450039662310	Variant 804	1	0	0	1	1	134
450039662320	Variant 805	1	0	0	1	1	77

Personnel Analysis

Segregation of Duty Analysis

	Resource Frequency	Process Instance Frequency
SOD1 (Same person perform 'Sign' and 'Release') & Missing Activity	8	8
SOD1 (Same person perform 'Sign' and 'Release') & Redundant Activity	9	11
SOD1 (Same person performs 'Sign' and 'Release') & Missing Activity & Redundant Activity	11 8	89
SOD2 (Same person perform 'Release' and 'GR') & Missing Activity	175 19	58 12
SOD2 (Same person perform 'Release' and 'GR') & Redundant Activity	21	22
SOD2 (Same person perform 'Release' and 'GR') & Missing Activity & Redundant Activity	0	0
Total	186	21
Missing Activity & Redundant Activity	205	663
Missing Activity & Activity Not in Right Order	33	129
Redundant Activity & Activity Not in Right Order	40	21
Missing Activity & Activity Not in Right Order & Redundant Activity	30	17 35

Top 10 Process Duration

Process Instances	Variant	Start Date	End Date	Duration (days)
450039593410	Variant 467	1/4/2007	1/25/2008	386
450039595410	Variant 354	1/4/2007	1/25/2008	386
450039593810	Variant 397	1/4/2007	1/14/2008	375
450039594310	Variant 660	1/4/2007	1/14/2008	375
450039597510	Variant 291	1/4/2007	1/14/2008	375
450039636610	Variant 656	1/5/2007	1/14/2008	374
450039757110	Variant 902	1/10/2007	1/18/2008	373
450039894250	Variant 583	1/16/2007	1/23/2008	372
450039673620	Variant 612	1/8/2007	1/14/2008	371
450040005720	Variant 379	1/19/2007	1/25/2008	371

Weekend Activity

	Weekend Activity Frequency	Process Instance Frequency	Resource Frequency
Create PO	465	465	1
Sign	85	85	6
Release	114	111	5
Goods Receipt	97	97	1
Invoice Receipt	33	33	2
Pay Unit Name	0	0	0
Total	794	769	10

Conclusion

- ❖ The study demonstrates how process mining can be adopted in the evaluation of internal control effectiveness.
- ❖ The results indicate that by classifying variants into acceptable/notable categories, it is possible to detect potential risks, ineffectiveness of controls and inefficient processes by using a process mining approach.
- ❖ Applying process mining to audit is a revolution that could change the way of conducting an audit.
- ❖ There are limitations associated with this study: (1) the analyses are based on procurement process. (2) Using only one event log data.
- ❖ Future research: (1) compare the categories/sub-categories of acceptable and notable variants with the organization's business rules. (2) Examine the possibility for process mining techniques to timely discover unauthorized procedures through real-time monitoring systems and subsequently reduce the occurrences of potential fraud.

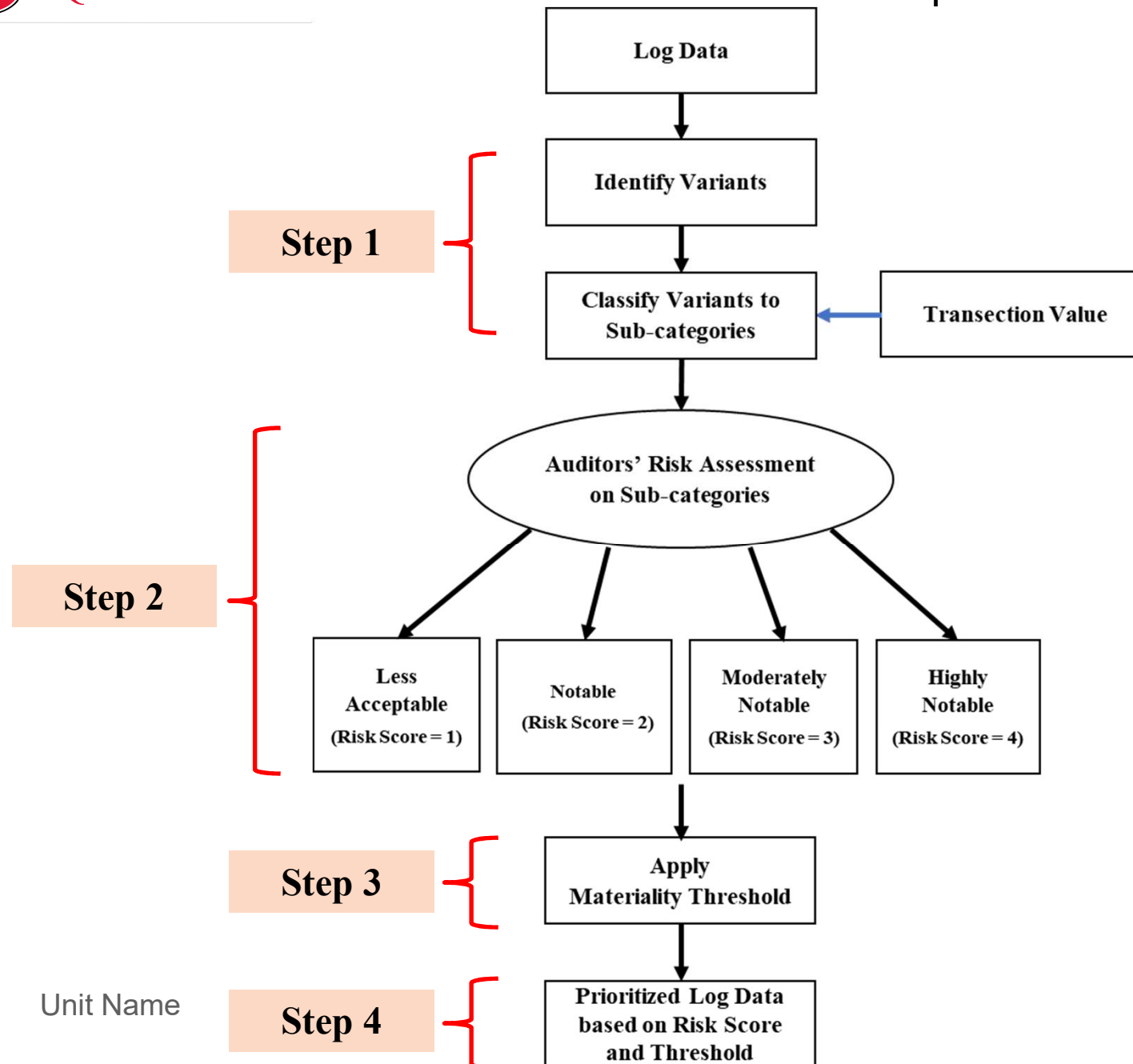
Essay Two

Validating Process Mining: A Framework Integrating Auditor's Risk Assessment

- The objective of this study is to build a framework on how auditors can utilize both routing and transaction value information when using process mining as new type of evidence in their audit work. Specifically, this framework is based on the auditor's risk assessment.
 - (1) Identify variants from the data and then classify variants into acceptable and notable variants categories and sub-categories based on different routings of the process instances.
 - (2) Risk assessment: Notable variant
 - Prior studies on audit risk assessment generally concluded that it is necessary to prioritize the identified exceptions because this could improve audit efficiency (Kim and Vasarhelyi 2012; Issa and Kogan 2014; Li et al. 2016).
 - (3) The last two steps prioritize process instances based on the sum of risk scores and the materiality threshold.

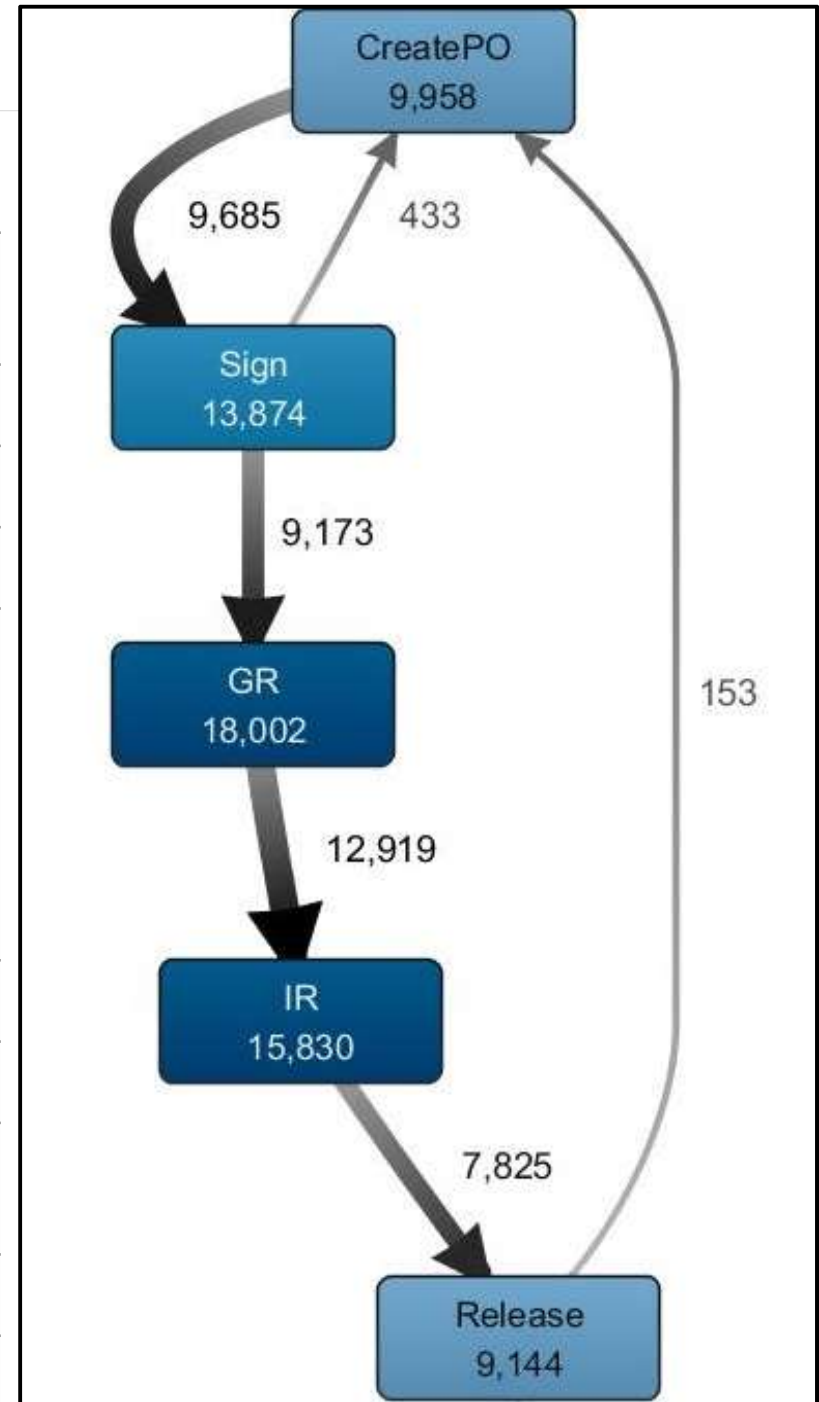
Literature Review

- Audit risk assessment refers to “identify and appropriately assess the risks of material misstatement, thereby providing a basis for designing and implementing responses to the risks of material misstatement” (PCAOB AS2110).
- Risk assessment is an important audit process which could ultimately affect audit fees, especially with the presence of serious internal control problems (Bell et al. 2001; Hogan and Wilkins 2008).
- Prior research proposed various risk detection models to achieve the goal of accurately capturing potential risks within the client’s business (Calderon and Cheh 2002; Carnaghan 2006; Chang et al., 2008).
 - Carnaghan (2006) used business process modeling to perform audit risk assessments at the business process level. The study identifies the commonly used business process modeling conventions include data flow diagrams, system flowcharts, REA models, event process chains, IDEF0 and IDEF3, UML diagrams, and business diagrams (BPMN).
 - Eilifsen et al. (2001) examined the fundamental changes in the audit process when accounting firms expand from basic financial statement audit to a new approach that includes external assurance and business risk assessment.



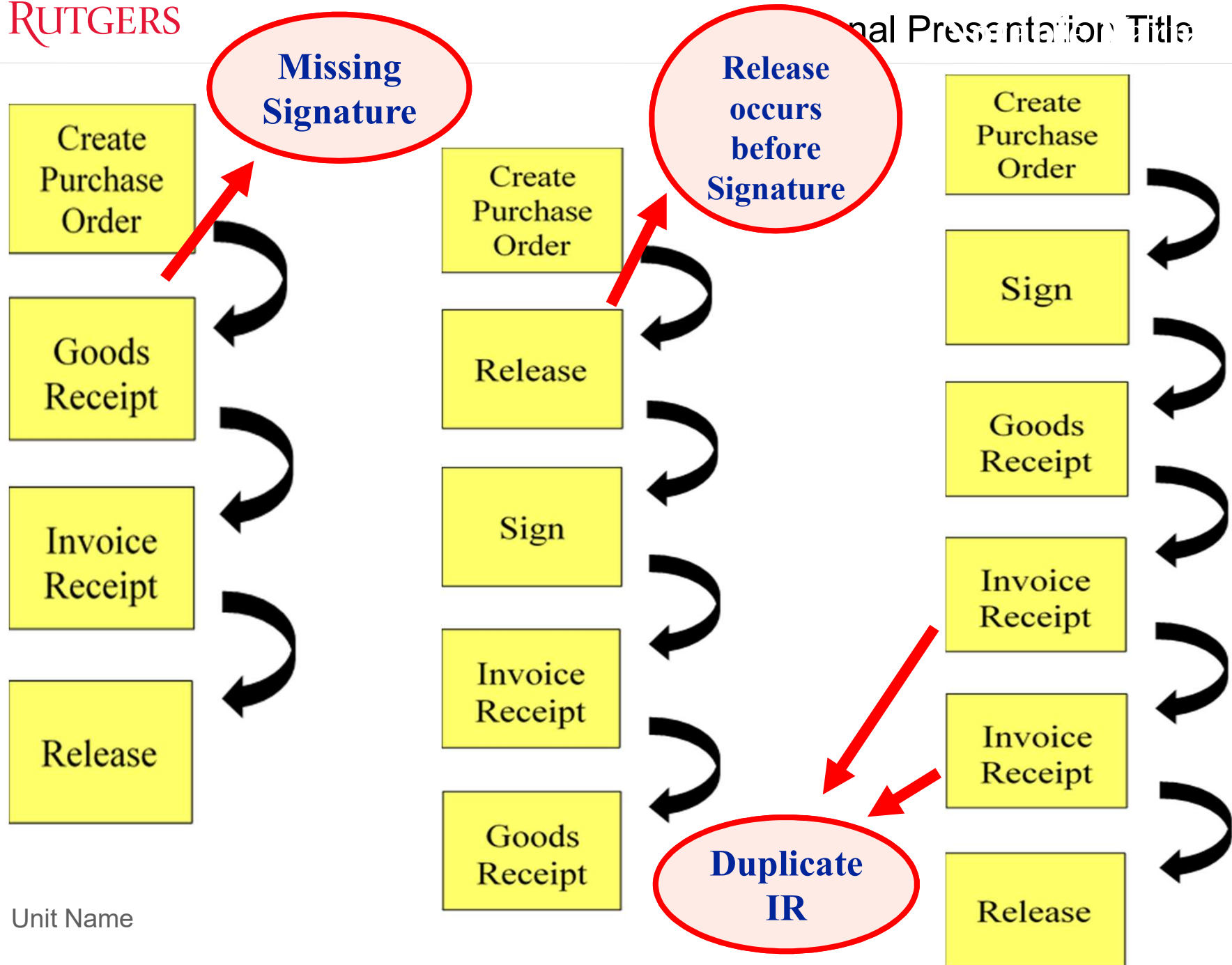
Dataset Overview

Procure-to-Pay Process – A Not for Profit Organization	
Event	66,808
Process Instance	9,187
Activity	5
Activity Detail	(1) Create PO (2) Sign (3) GR (4) IR (5) Release
Agent	237
Variant	876
Mean Case Duration	13.1 Weeks
Start	08/16/2012
End	12/02/2016



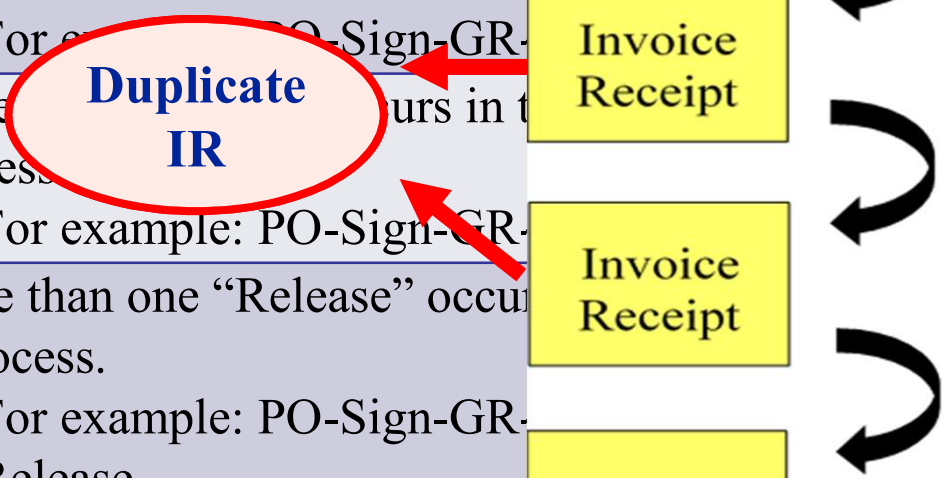
Acceptable Variant

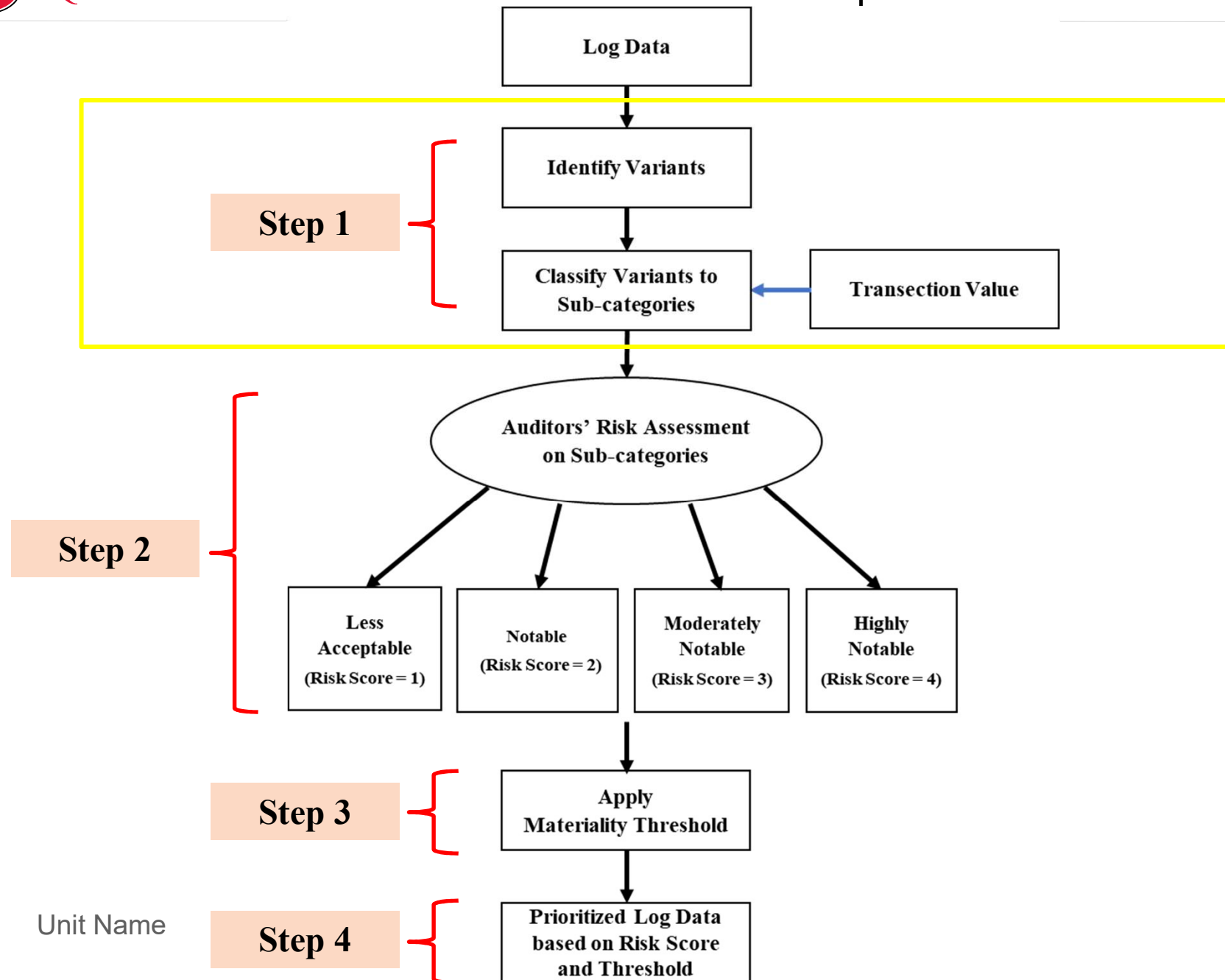
Category	Description	Create Purchase Order	
Standard Procure-to-Pay process	The standard procure-to-pay process organization is as follows:		
	(1) PO value up to \$5,000: <i>"PO-Sign-GR-IR-Release"</i>	Sign	
	(2) PO value up to \$50,000: <i>"PO-Sign-Sign-GR-IR-Release"</i>		
	(3) PO value up to \$100,000: <i>"PO-Sign-Sign-Sign-GR-IR-Release"</i>	Goods Receipt	
	(4) PO value up to \$250,000: <i>"PO-Sign-Sign-Sign-Sign-Sign-GR-IR-Release"</i>	Invoice Receipt	
	(5) PO value up to \$500,000: <i>"PO-Sign-Sign-Sign-Sign-Sign-Sign-GR-IR-Release"</i>		
Invoice receipt (IR) and goods receipt (GR) switch places	The order of IR and GR is opposite standard procurement process. • For example: "PO-Sign-IR-GR-IR-Release"	Release	



Category	Sub-category	Description	
Missing Activity	Missing purchase order (PO)	Missing purchase order in the business process. • For Release-GR-IR-R	Create Purchase Order
	Missing signature	Missing signature in the business process. • For Release-GR-IR-R	Goods Receipt
	Missing goods receipt (GR)	Missing goods receipt in the business process. • For Release-GR-IR-R	Invoice Receipt
	Missing invoice receipt (IR)	Missing invoice receipt in the business process. • For Release-GR-IR-R	Release
	Missing release	Missing release in the business process. • For Release-GR-IR-R	Sign
Activity Not in Right Order	Goods receipt occurs before signature	"GR" occurs before "IR" in the business process. • For Release-GR-IR-R	Release
	Release occurs before signature	"Release" occurs before "IR" in the business process. • For Release-GR-IR-R	Invoice Receipt
	Release occurs before goods receipt (GR)	"Release" occurs before "GR" in the business process. • For Release-GR-IR-R	Goods Receipt
	Release occurs before invoice receipt (IR)	"Release" occurs before "IR" in the business process. • For Release-GR-IR-R	

Category	Sub-category	Description	Create Purchase Order
Redundant Activity	Redundant purchase order (PO)	More than one "PO" occurs in process. • For example: PO-PO-Sign-	Sign
	Redundant signature	More than one "Sign" occurs in process. • For example: PO-Sign-Sign-	Goods Receipt
	Redundant goods receipt (GR)	More than one "GR" occurs in process. • For example: PO-Sign-GR-	Invoice Receipt
	Redundant invoice receipt (IR)	More than one "IR" occurs in process. • For example: PO-Sign-GR-	Invoice Receipt
	Redundant release	More than one "Release" occurs in process. • For example: PO-Sign-GR-Release	Release





Variant Analysis – Overall Results

	Variant		Process Instance	
	Count	Percentage	Count	Percentage
Acceptable Variant	8	0.91%	5,269	57.35%
Notable Variant	873	99.66%	3,918	42.65%
Total	876	100%	9,187	100%

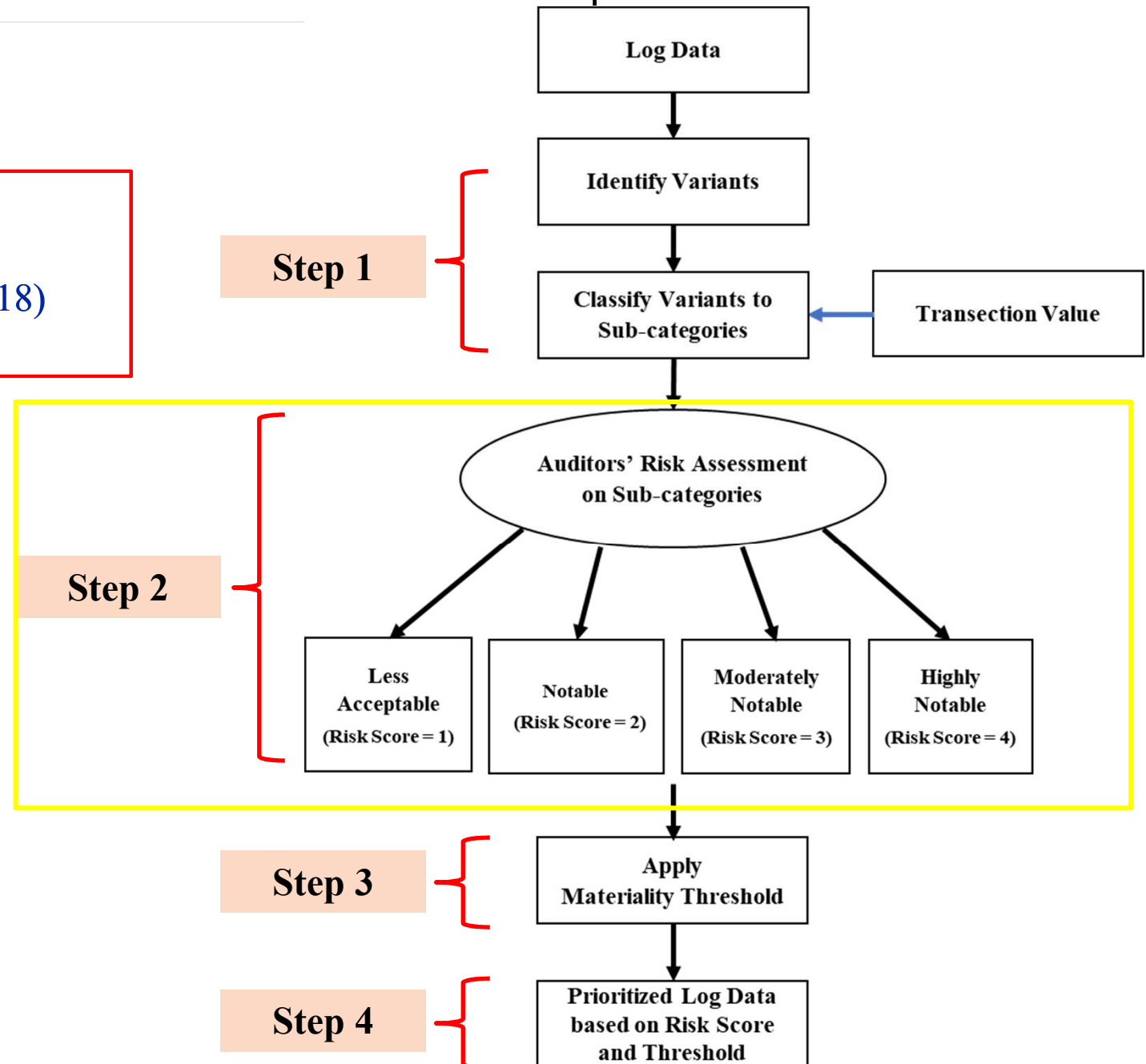
Notable Variant

	Variant		Process Instance	
	Count	Percentage (in total)	Count	Percentage
Missing Activity	248	28.31%	1,395	15.18%
Activity Not in Right Order	19	2.17%	33	0.36%
Redundant Activity	862	98.40%	2,994	32.59%

Missing Activity			
Sub-category	Variant Frequency	Process Instance Frequency	
Missing Purchase Order (PO)	0	0	
Missing Signature (Sign)	61	154	
Missing Goods Receipt (GR)	1	1	
Missing Invoice Receipt (IR)	82	1089	
Missing Release	137	201	
Redundant Purchase Order (PO)	277	576	
Total	248	1,395	
Redundant Signature (Sign)	410	1,755	
Redundant Goods Receipt (GR)	747	1,540	
Redundant Invoice Receipt (IR)	686	1,580	
Redundant Release after Goods Receipt (GR)	101	135	
Redundant Release occurs NOT after Invoice Receipt (IR)	862	2,994	
Total	12	17	
Unit Name			
Total	19	33	48

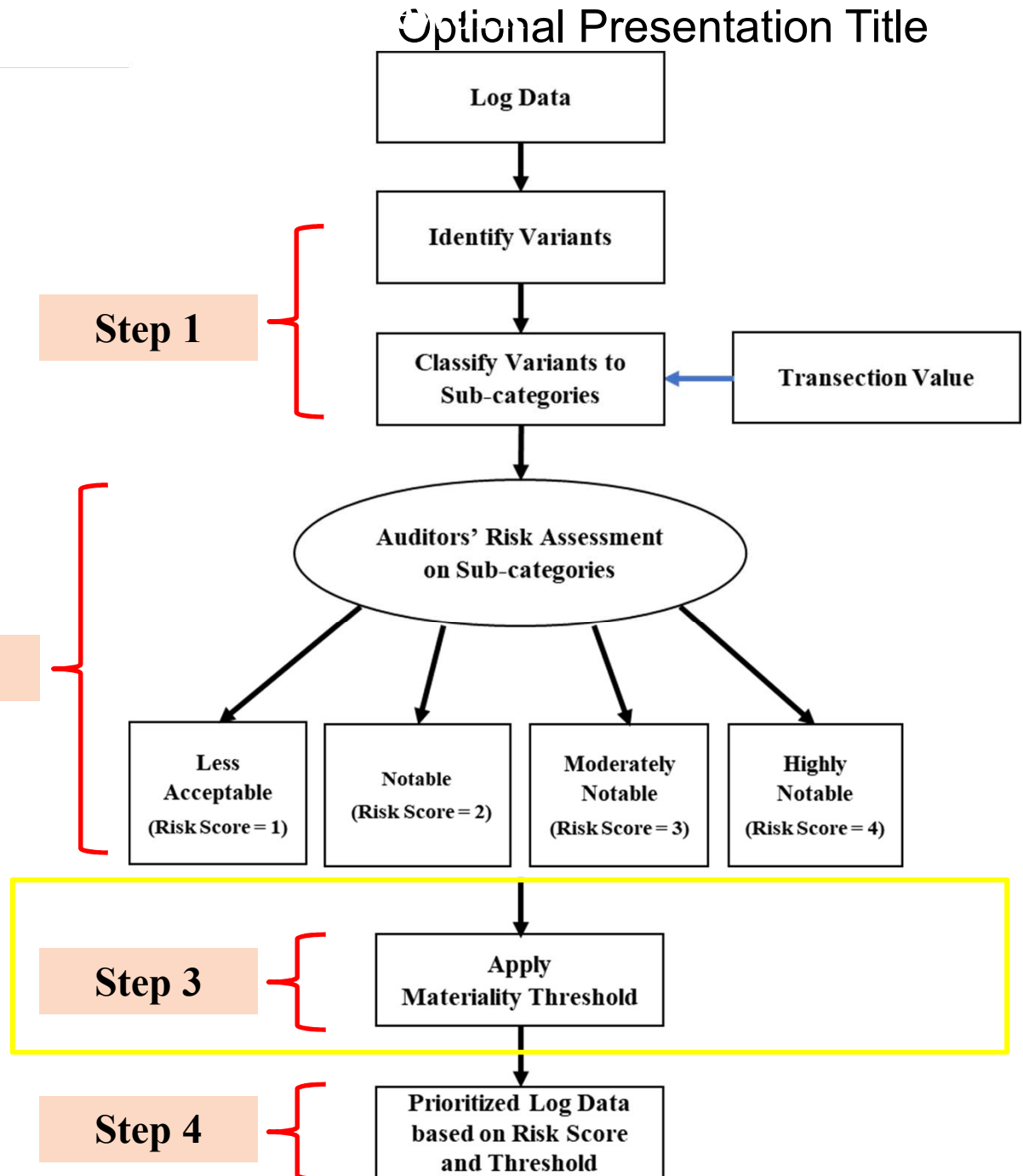
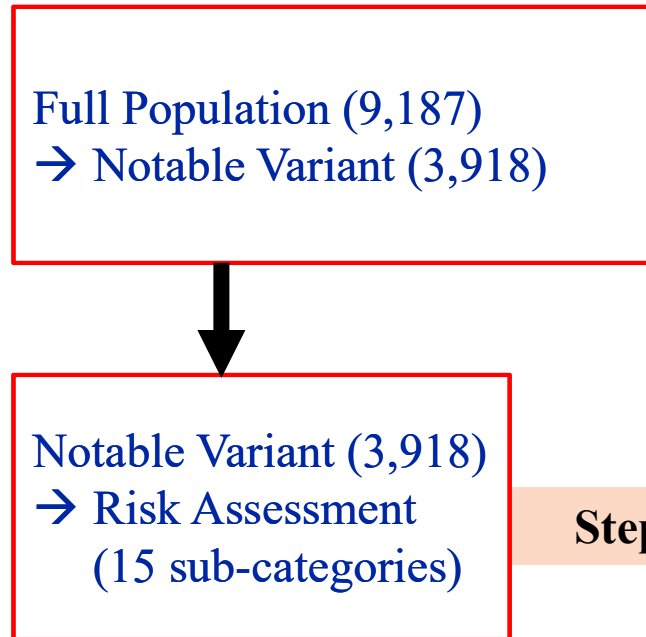
Optional Presentation Title

Full Population (9,187)
→ Notable Variant (3,918)



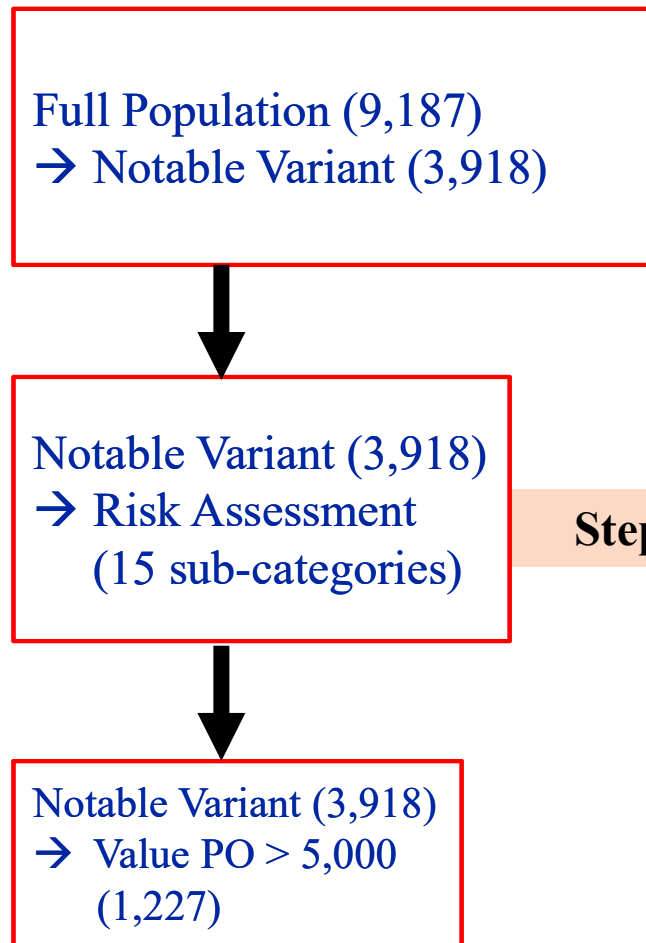
Category	Sub-category	Risk Score	Class
Missing Activity	Missing Purchase Order (PO)	4	Highly Notable
	Missing Sign	4	Highly Notable
	Missing Goods Receipt (GR)	4	Highly Notable
	Missing Invoice Receipt (IR)	4	Highly Notable
	Missing Release	4	Highly Notable
Activity Not in Right Order	Goods Receipt (GR) occurs before Sign	1	Less Acceptable
	Invoice Receipt (IR) occurs before Sign	2	Notable
	Release occurs before Sign	4	Highly Notable
	Release occurs before Goods Receipt (GR)	2	Notable
	Release occurs before Invoice Receipt (IR)	3	Moderately Notable
Redundant Activity	Redundant Purchase Order (PO)	3	Moderately Notable
	Redundant Sign	1	Less Acceptable
	Redundant Goods Receipt (GR)	1	Less Acceptable
	Redundant Invoice Receipt (IR)	3	Moderately Notable
	Redundant Release	1	Less Acceptable

Case ID	Missing Sign (4)	Missing GR (4)	Missing IR (4)	Missing Release (4)	Release occurs before IR (3)	Redundant PO (3)	Redundant IR (3)	IR occurs before Sign (2)	Release occurs before GR (2)	Redundant Sign (1)	Redundant GR (1)	Redundant Release (1)	Risk Score	Value PO
82329	1				1	1	1				1	1	15	\$5,105.00
88589			1	1		1				1	1		13	\$9,000.00
91133			1	1		1				1	1		13	\$6,438.00
78758						1	1				1	1	12	\$464,248.41
82835	1	<p><i>Process Instance 82329</i></p> <p><i>= Missing sign (4) + Release occurs before IR (3) + Redundant PO (3)</i></p> <p><i>+ Redundant IR (3) + Redundant GR (1) + Redundant Release (1)</i></p> <p><i>= 4 + 3 + 3 + 3 + 1 + 1 = 15</i></p>												62,663.00
83762	1													,468.01
84014	1													25,864.56
86159	1													22,892.06
88854	1													50,818.00
88858	1													37,210.88
89078	1			1			1				1		12	\$166,582.89
90296	1			1			1				1		12	\$9,260.90
90297	1		1	1									12	\$23,000.00
90822				1		1	1			1	1		12	\$20,825.19
81280	1					1	1				1		11	\$150,812.98
82301				1		1	1				1		11	\$60,000.00
88664				1		1	1				1		11	\$17,717.14
77865			1			1				1	1	1	10	\$39,291.63
84027	1						1	1			1		10	\$43,545.39
88830	Unit Name		1	1						1	1		10	\$96,750.00

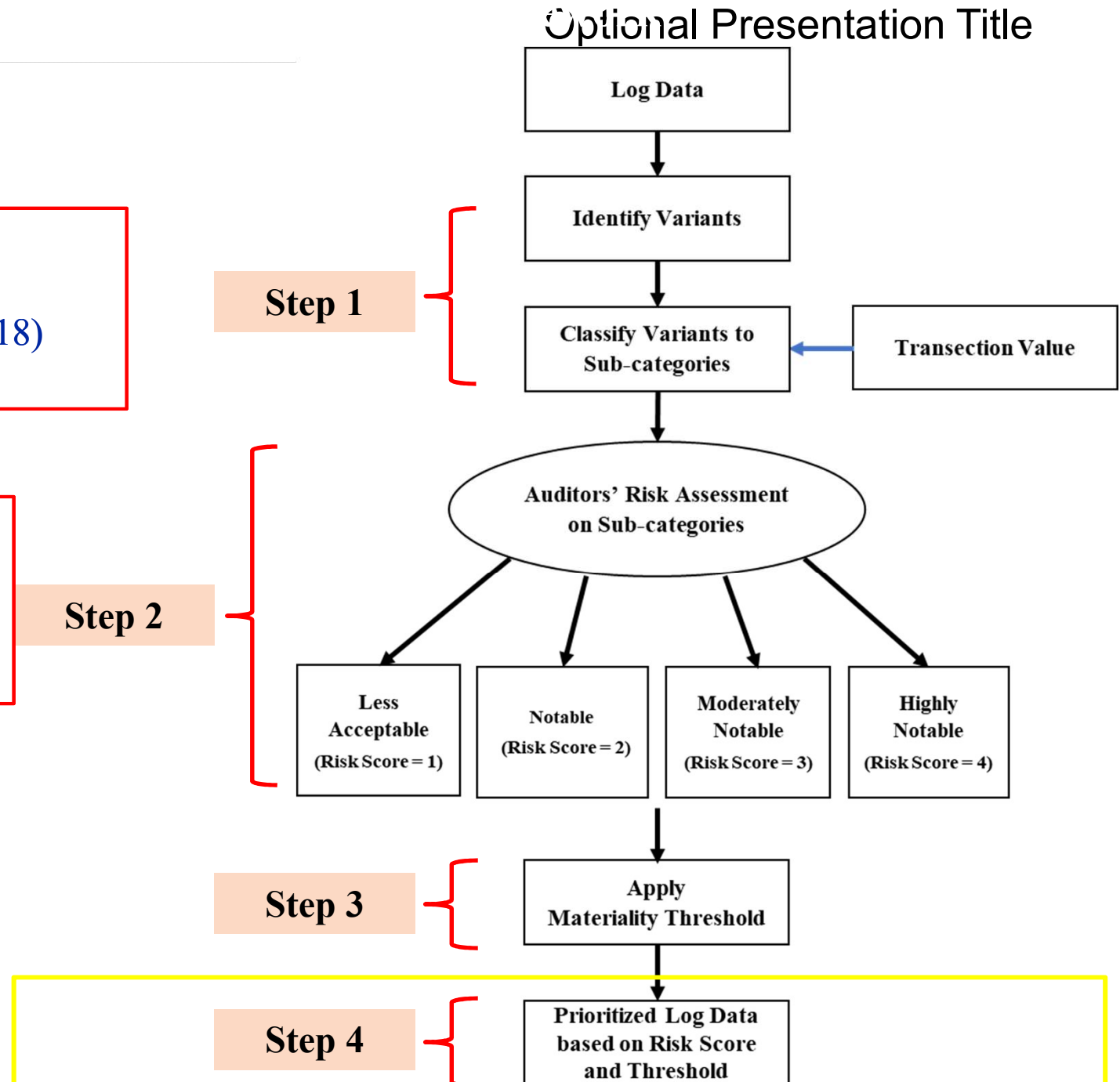


Apply Materiality Threshold

Transaction Value	Value Class	Process Instance
Less than or equal to \$5,000	Level 1	2,691
\$5,001 - \$50,000	Level 2	1,021
\$50,001 - \$100,000	Level 3	102
\$100,001 - \$250,000	Level 4	70
\$250,001 - \$500,000	Level 5	21
<i>Over \$500,000</i>	<i>Level 6</i>	<i>13</i>



Unit Name



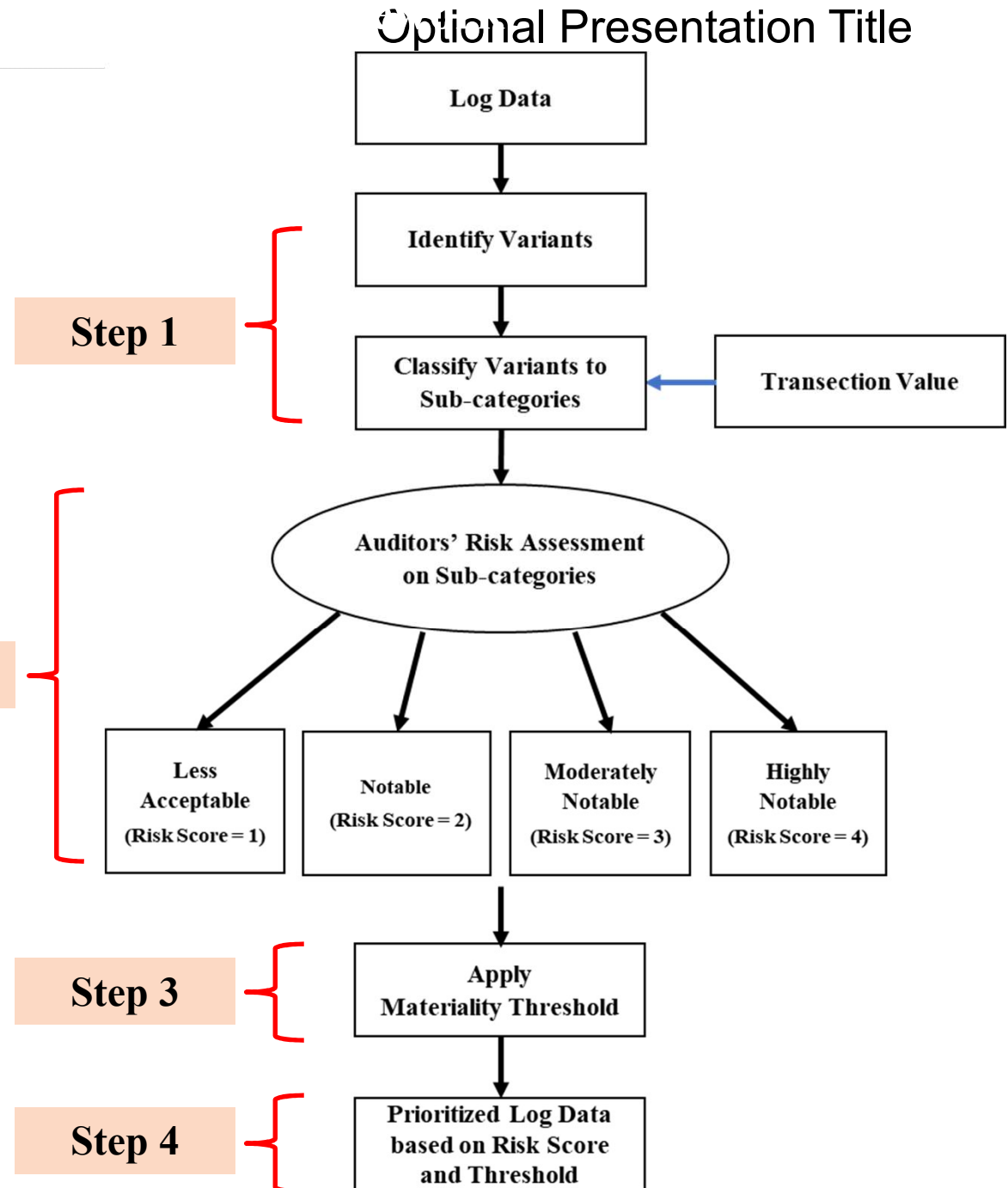
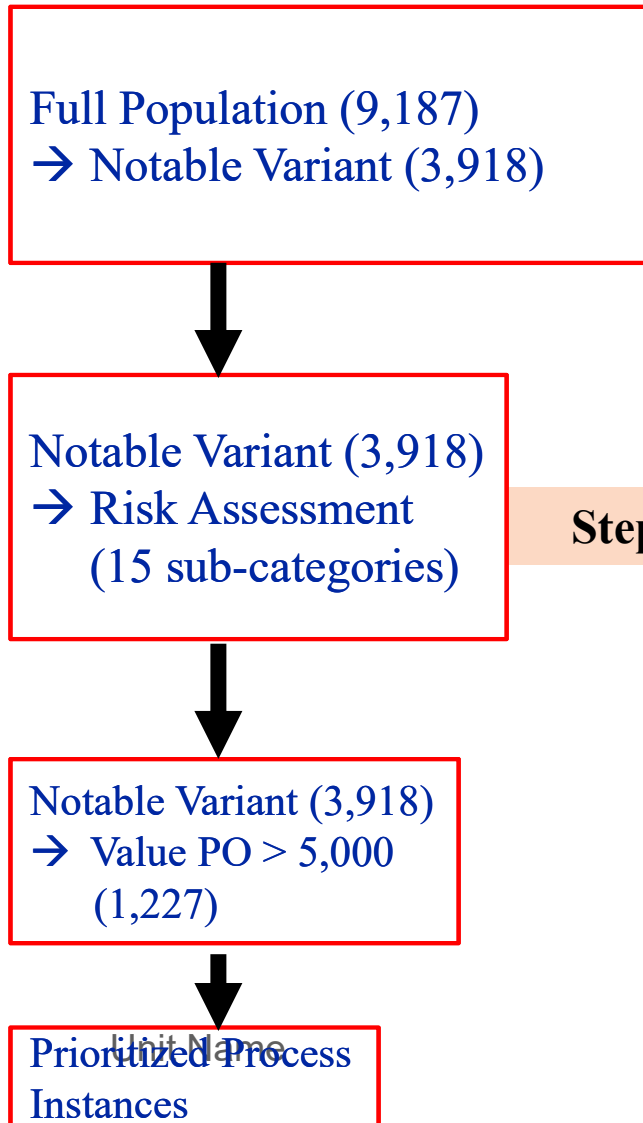
Risk Prioritization Methods

- *Method 1: Risk Prioritization based on Risk Score*
- *Method 2: Risk Prioritization based on Value Class*
- *Method 3: Risk Prioritization = Risk Score*Value PO*
- *Method 4: Risk Prioritization = Risk Score*Value Class*



Case ID	Missing Sign (4)	Missing IR (4)	Risk Score (4)	Value PO			Value Class			Risk Prioritization (Risk Score*Value Class)					Value Class
				before IR (3)	Redundant PO (3)	Redundant IR (3)	before Sign (2)	before GR (2)	Redundant Sign (1)	Redundant GR (1)	Redundant Release (1)	Risk Score (2)	Value PO		
88702			8	\$1,157,400.00	Level 6	1	1	12,481,600.00	1	1	42,963,436.00	\$1,579,094.00	Level 6		
88854			12	\$450,818.00	Level 5			60.00			60.00	\$2,177.00	Level 5		
84728		1	4	\$10,740,859.00	Level 6			42,963,436.00	1	1	42,963,436.00	\$1,579,094.00	Level 6		
88858		1	12	\$437,210.88	Level 5			60.00	1	1	60.00	\$10,740,859.00	Level 6		
80262			4	\$3,228,000.00	Level 6			12,912,000.00			60.00	\$3,228,000.00	Level 6		
82835	1		12	\$362,663.00	Level 5			60.00	1		60.00	\$3,228,000.00	Level 6		
84850	1		4	\$3,817,637.00	Level 6			12,626,800.00	1		60.00	\$3,817,637.00	Level 6		
83762	1			\$7,458.01	Level 6			12,626,800.00	1		60.00	\$7,458.01	Level 6		
88702			8	\$1,157,400.00	Level 6			12,481,600.00	1		60.00	\$1,157,400.00	Level 6		
84014	1		4	\$3,120,400.00	Level 6			12,481,600.00	1		60.00	\$3,120,400.00	Level 6		
87334	1		8	\$716,031.13	Level 6			48.00	1		48.00	\$716,031.13	Level 6		
88749			7	\$1,179,759.00	Level 6			8,258,313.00			48.00	\$1,179,759.00	Level 6		
84014	1	1	12	\$225,864.56	Level 4			48.00	1		48.00	\$225,864.56	Level 4		
89503	1		9	\$877,637.63	Level 6			7,828,738.67	1		48.00	\$877,637.63	Level 6		
89078			12	\$166,582.89	Level 6			48.00			48.00	\$166,582.89	Level 6		
87334	1			\$716,031.13	Level 6			48.00	1		48.00	\$716,031.13	Level 6		
87334	1		8	\$1,157,400.00	Level 6			12,481,600.00	1		48.00	\$1,157,400.00	Level 6		
80296	1		12	\$128,092.06	Level 4			5,728,049.04	1		44.00	\$128,092.06	Level 4		
90055				\$659,107.94	Level 6			48.00	1		44.00	\$659,107.94	Level 6		
90297	1		9	\$225,555.19	Level 5			5,570,980.92	1		44.00	\$225,555.19	Level 5		
78758		1	12	\$464,248.41	Level 5			5,570,980.92	1		44.00	\$464,248.41	Level 5		
81280			11	\$150,812.98	Level 4			44.00	1		44.00	\$150,812.98	Level 4		
88854	1		12	\$450,818.00	Level 5			5,409,816.00	1		42.00	\$450,818.00	Level 5		
88749			7	\$1,179,759.00	Level 6			42.00	1		42.00	\$1,179,759.00	Level 6		
88858			12	\$437,210.88	Level 5			5,246,530.56	1		42.00	\$437,210.88	Level 5		
84988				\$529,166.00	Level 6			42.00			42.00	\$529,166.00	Level 6		
88664			12	\$17,717.14	Level 5			5,246,530.56	11		42.00	\$17,717.14	Level 5		

~~*Risk Score Value = 0.000000 (14 process instances)*~~



Personnel Analysis

Personnel Analysis				
Resource		Process Instance		
	>5,000	Total	>5,000	Total
Highly Notable	108	150	426	1395
Moderately Notable	159	215	894	1951
Notable	15	31	8	25
Less Acceptable	164	226	1006	2819
Highly Notable & Moderately Notable & Notable & Less Acceptable	4	8	1	3

Unit Name

Irregular Process Instance

Process Instance	Variant	Timestamp	Resource	Value PO
88702	Variant 711	2015-11-25 11:06:00	ABCD1	\$11,579,094.00
84728	Variant 536	2015-01-13 12:30:00	ABCD56	\$10,740,859.00
80262	Variant 157	2014-01-28 13:21:00	ABCD1	\$3,228,000.00
84850	Variant 71	2015-01-26 12:01:00	ABCD1	\$3,174,200.00
89106	Variant 157	2016-01-08 16:24:00	ABCD1	\$3,120,400.00
88749	Variant 714	2015-12-02 14:58:00	ABCD1	\$1,179,759.00
86565	Variant 32	2015-06-25 11:06:00	ABCD56	\$1,000,000.00
91406	Variant 32	2016-07-26 13:50:00	ABCD56	\$1,000,000.00
89503	Variant 772	2016-02-12 15:13:00	ABCD56	\$877,637.63
87830	Variant 656	2015-09-28 09:02:00	ABCD1	\$789,386.75
81849	Variant 409	2014-06-02 10:44:00	ABCD1	\$780,000.00
87334	Variant 635	2015-08-18 15:05:00	ABCD1	\$716,031.13
90055	Variant 808	2016-04-07 17:21:00	ABCD56	\$659,107.94
80015	Variant 313	2014-01-08 14:37:00	ABCD1	\$551,357.88
85421	Variant 158	2015-03-24 10:22:00	ABCD56	\$550,300.00
84988	Variant 545	2015-02-09 09:00:00	ABCD56	\$529,166.63

Segregation of Duty Analysis

Segregation of Duty Analysis				
	Process Instance		Resource	
	>5,000	Total	>5,000	Total
Same person performs 'Sign' and 'GR'	5	418	12	55
Same person performs 'GR' and 'IR'	1901	8078	179	234
Same person performs 'IR' and 'Release'	1	2	4	8

Unit Name

Timestamp Examination – Process Duration (Shorter)

Timestamp Examination – Weekend Activity

Process Instance	Variant	Value PO (>5,000)	Start Date Weekend Activity	End Date	Duration (Days)
79344	Variant 2	\$5,000.00	2013-11-22 14:58:00	2013-11-22 14:58:00	0
80210	Variant 2	\$6,530.00	2014-01-22 11:58:00	2014-01-22 11:58:00	0
80290	Variant 2	\$5,600.00	2014-01-30 12:25:00	2014-01-30 14:59:00	0
80411	Variant 2	\$9,517.00	2014-02-07 10:33:00	2014-02-07 14:12:00	0
81387	Variant 2	\$6,100.00	2014-05-06 09:15:00	2014-05-06 12:42:00	0
82333	Variant 2	\$7,002.00	2014-07-02 10:33:00	2014-07-02 16:42:00	0
83241	Variant 454	\$5,167.08	2014-09-02 12:21:00	2014-09-02 13:32:00	0
83540	Variant 2	\$6,452.25	2014-09-29 14:28:00	2014-09-29 15:31:00	0
86865	Variant 2	\$25,442.00	2015-07-16 10:29:00	2015-07-16 15:29:00	0
89418	Variant 2	\$39,000.00	2016-02-04 15:21:00	2016-02-04 15:40:00	0
90503	Variant 1	\$10,000.00	2016-05-16 10:59:00	2016-05-16 14:59:00	0
90690	Variant 3	\$34,100.00	2016-05-27 08:43:00	2016-05-27 13:29:00	0

Conclusion

- ❖ This study integrates process mining into the auditor's risk assessment process by combining process mining results (the riskiness of business processes) with a corresponding transaction value (total value on the specific purchase order).
- ❖ The prioritized process mining results could improve the audit efficiency as the auditors would be able to focus on high-risk process instances with material transaction values.
- ❖ This study contributes to existing process mining and auditing research by showing how process mining can be incorporated into the audit process and the advantages of evaluating event logs when assessing risks.
- ❖ Limitations: (1) the proposed risk assessment framework is based on procure-to-pay process. (2) The results can be more generalized if the proposed risk assessment framework can be applied to multiple firms.
- ❖ Future Research: (1) identify sub-categories and assign risk scores based on different business cycles. (2) Generalize commonly used materiality thresholds.

Essay Three
A Framework of Applying Process Mining for Fraud Scheme Detection

- This paper aims at providing a framework on how process mining can be applied to identify fraud schemes and assessing the riskiness of business processes.
 - Specifically, the proposed framework captures how the patterns in process mining can be used to detect potentially fraudulent transactions.
 - This paper contributes to the existing literature by associating notable variants/activities with potential fraud schemes and then assigning risk levels, which could be used as an automatic tool to test the fraud risk of every transaction.

Literature Review

➤ Financial Statements Fraud and Fraud Type

- Accounting research on financial statement fraud and Accounting and Auditing Enforcement Releases (AAERs) includes testing hypotheses grounded in the literature of earnings management (Summers and Sweeney, 1998; Beneish, 1999; Sharma, 2004) and corporate governance (e.g., Beasley, 1996).
- Numerous measures for earnings management are created to indicate the risk of financial misstatement and fraud, such as earnings persistence (e.g., Richardson et al., 2005), abnormal accruals and accruals models (e.g., Jones, 1991; Dechow et al., 1995; Dechow and Dichev, 2002; Kothari et al., 2005), and earnings smoothness (e.g., McInnis, 2010).
- To evaluate the predictive power of the extent accrual-based earnings management measures to detect financial statement fraud, Jones et al. (2008) conducted an empirical analysis comparing ten measures (e.g., discretionary accruals, accrual quality) derived from popular accrual models and found that only the accrual estimation errors (Dechow and Dichev, 2002) and their modifications have the ability to predict fraud and non-fraudulent restatements of earnings.

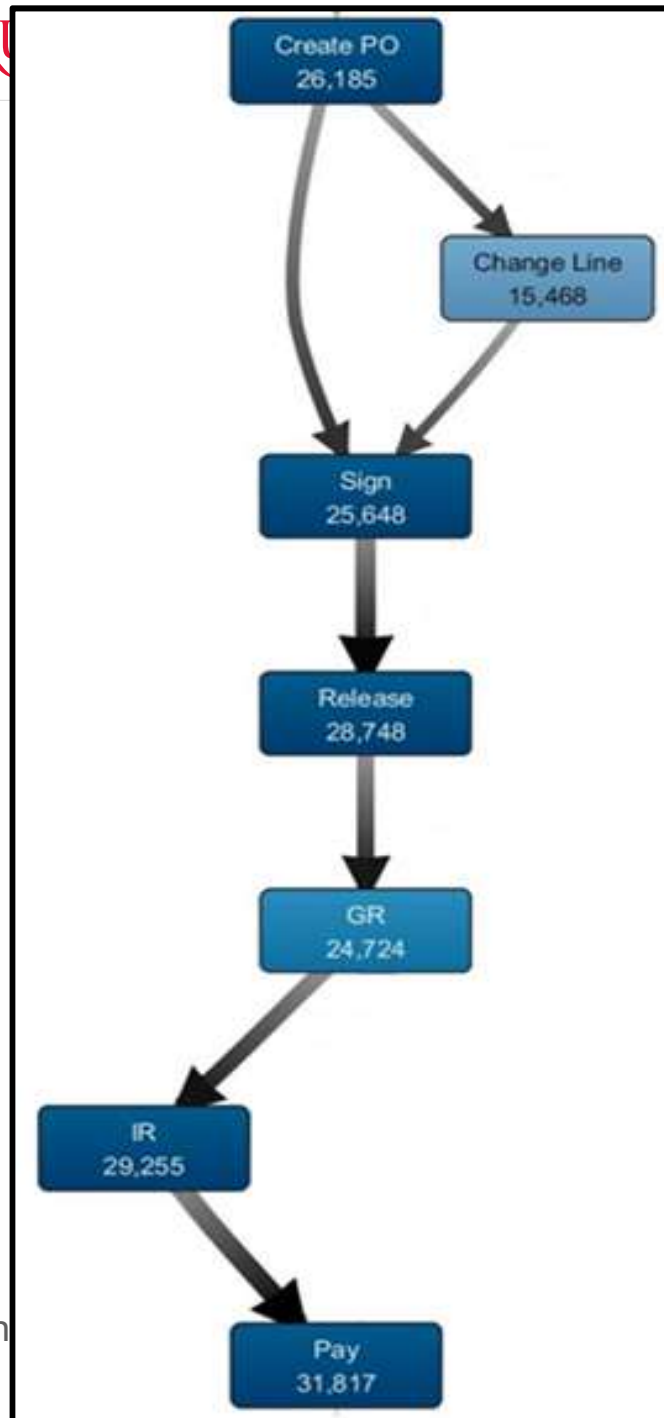
Fraud Types and Fraud Category

- Total Fraud Sample: 470 fraud firm-year observations (1994-2016)

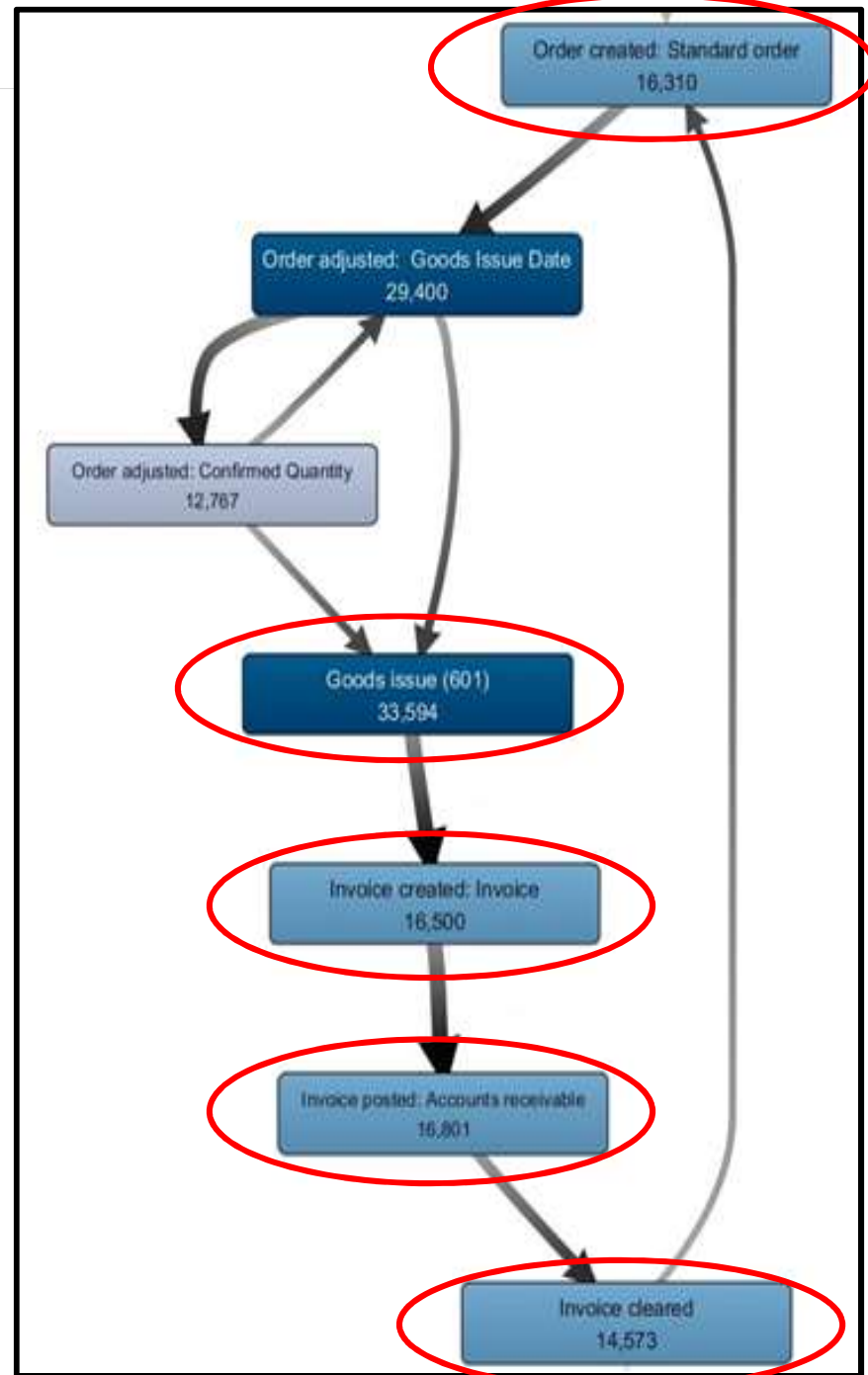
Fraud Types and Fraud Category		
Fraud Category	Frequency	Percentage
Revenue recognition issues	174	37.02%
Foreign, related party, affiliated, or subsidiary issues	150	31.91%
Liabilities, payables, reserves and accrual estimate failures	114	24.26%
Accounts/loans receivable, investments & cash issues	107	22.77%
Inventory, vendor and/or cost of sales issues	107	22.77%



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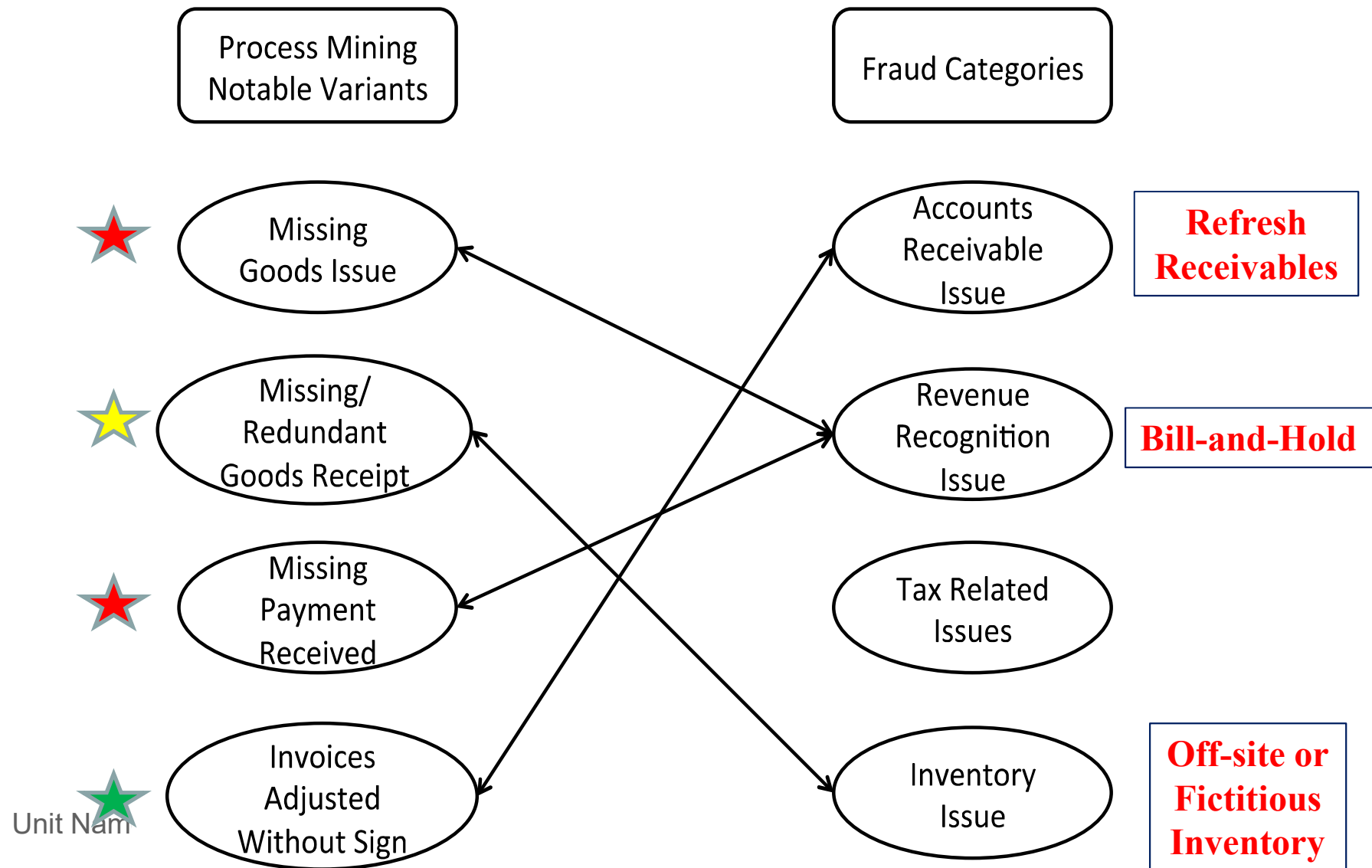
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Applying Process Mining for Corporate Fraud Detection

- To detect corporate fraud using process mining, it is necessary to understand the standard business process for accounting cycles.
 - “Order-to-cash” cycle: Order Created -> Goods Issue -> Invoice Created -> Invoice Posted -> Payment Received -> Invoice Cleared
 - “Procure-to-pay” cycle: Create Purchase Order -> Sign -> Release -> Goods Receipt -> Invoice Receipt -> Payment.
- Based on the corporate fraud schemes and the activities and variants in the event logs of an ERP system, this study identifies suspicious patterns or activities for each fraud scheme and assigns the risk levels.

Mapping Notable Variants into Financial Statement Fraud Categories



Accounting Cycle	Fraud Scheme	Notable Activity	Suspicious Pattern Example	Risk Level
Order-to-Cash	Altering Documentation	<ul style="list-style-type: none"> • Order Adjusted: Goods Issue Date • Invoice Adjusted 	Frequent occurrence of order adjusted and/or invoice adjusted activities without approval process during the fiscal year-end period	High
Order-to-Cash	Bill and Hold	<ul style="list-style-type: none"> • Goods Issue • Payment Received 	Missing goods issue and/or payment received	High
Order-to-Cash	Channel Stuffing	<ul style="list-style-type: none"> • Order Adjusted: Order Return • invoice adjusted: invoice credit note 	Frequent occurrence of order return or invoice credit note immediately after fiscal year end without an approval process	High
Order-to-Cash	Up-Front Fees	<ul style="list-style-type: none"> • Payment Received • Goods Issue • Order Adjusted: Change Goods Issue Date 	Payment received occurs before goods issue or invoice created	Low
Order-to-Cash	Failure to Record Sales Allowances	<ul style="list-style-type: none"> • Payment Received 	Missing payment received or incomplete payment	High
Order-to-Cash	Inflating the Value of Inventory	<ul style="list-style-type: none"> • Order Adjusted: Net Price 	Order adjusted without an approval process Putting in improper price comparing to the market value	High
Procure-to-Pay	Off-site or Fictitious Inventory	<ul style="list-style-type: none"> • Goods Receipt 	Abnormal goods receipt records: missing goods receipt and/or have duplicate or more than one goods receipt in one purchase order	High
Others	Fraudulent Audit Confirmation	<ul style="list-style-type: none"> • All Activities 	Matching trading partners corresponding event logs	High/ Medium/ Low
Others	Refresh Receivables	<ul style="list-style-type: none"> • Invoice Adjusted 	Invoices adjusted occurs for many transactions without an approval process	High
Order-to-Cash	Promotional Allowance Manipulation	<ul style="list-style-type: none"> • Invoice Adjusted: Cash Discount 	Many Invoice Adjusted: Cash Discount activities are entered	Medium
Others	Bribery and Corruption	<ul style="list-style-type: none"> • All Activities 	Using resource information in event logs to identify potential violation of segregation of duty controls	Medium

Conclusion

- ❖ Process mining can be a powerful fraud detection tool when auditors include the potential fraudulent patterns in their fraud detection process.
- ❖ Contribution: (1) this paper proposes a framework that links notable variants/activities in process mining with corresponding fraud schemes. (2) The proposed framework incorporates risk assessment mechanism that indicates the risk level of each fraud scheme and related notable activity.
- ❖ Limitation: this study only includes notable variants/activities in two accounting cycles and several most commonly occurred fraud schemes.
- ❖ Future research could extend the current framework by incorporating more fraud schemes and other accounting cycles when discussing how process mining can be used in fraud detection.
 - A proof-of-work (e.g. prototype) can be built to simulate the application of the proposed framework to detect certain types of fraud schemes.



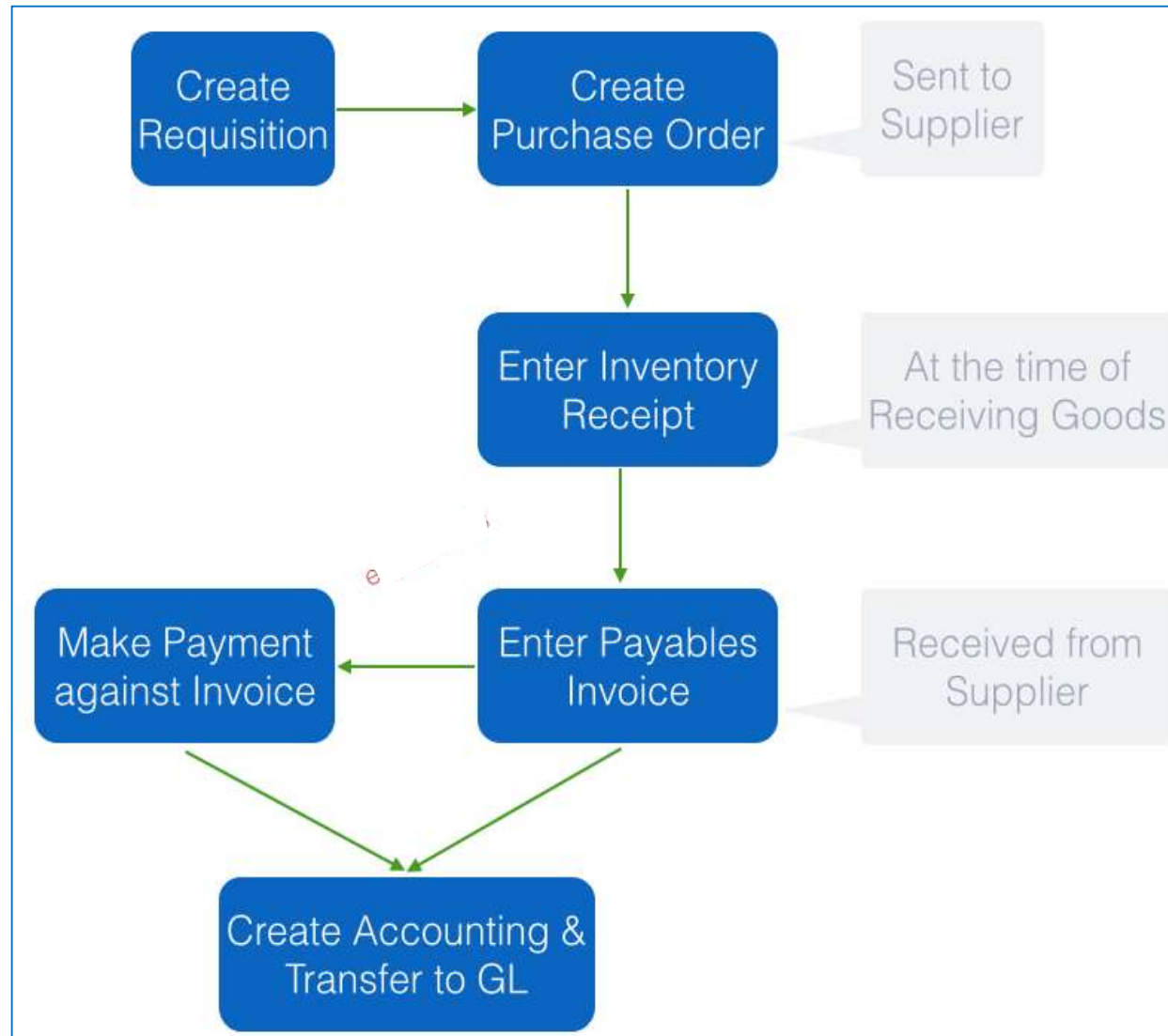
RUTGERS

Process Mining

Abdulrahman Alrefai

Information Systems



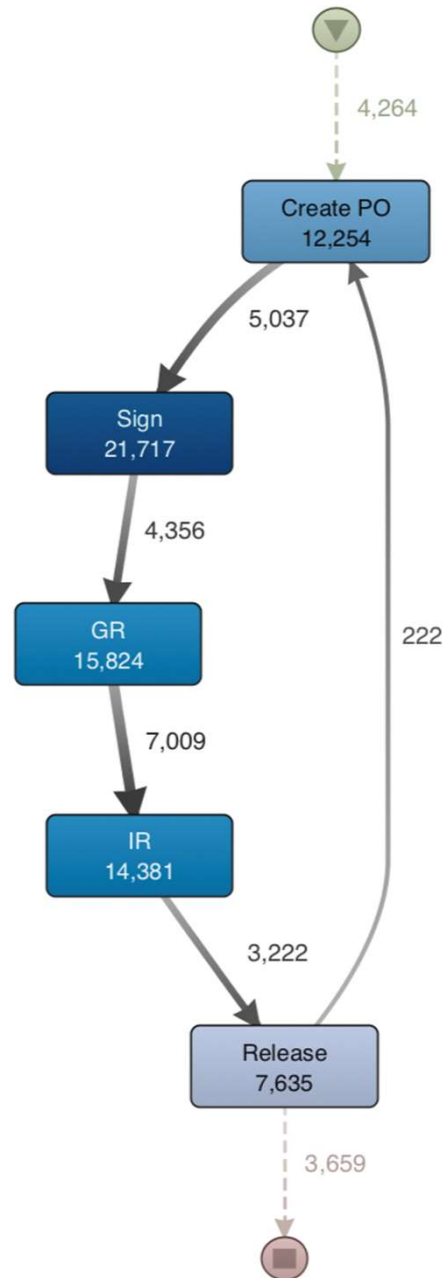


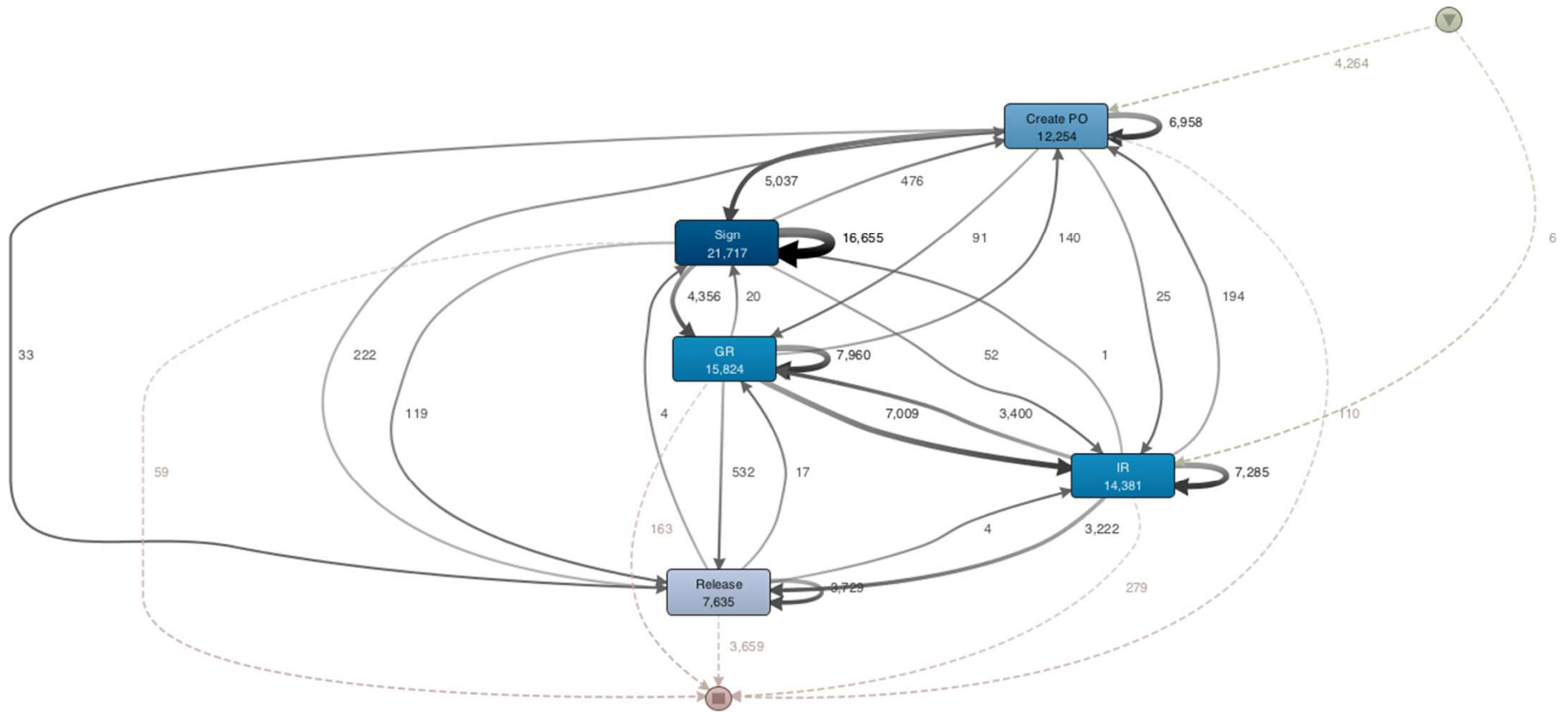
Event Log

CASE_ID	ACTIVITY	RESOURCE	TIMESTAMP	VALUE_PO	VALUE_PAY	VALUE_GR
87161	Create PO	Sandra	8/5/15 14:13	300		
87161	Sign	Sandra	8/5/15 14:14	300		
87161	Sign	Tiffany	8/7/15 10:35	300		
87161	GR	Paul	8/10/15 14:29	300		300
87161	IR	Paul	8/12/15 8:21	300	300	300
87161	Release	Amanda	7/1/16 12:08	300		
87183	Create PO	Sandra	8/6/15 11:46	14375.46		
87183	Sign	Sandra	8/6/15 11:46	14375.46		
87183	Sign	Tiffany	8/7/15 11:34	14375.46		
87183	GR	Reid	8/17/15 14:17	14375.46		14,375.46
87183	IR	Reid	9/10/15 11:31	14375.46	15,511.53	14,375.46
87183	Release	Juanita	9/10/15 14:58	14375.46		
87197	Create PO	Michael	8/7/15 10:37	864.26		
87197	Sign	Michael	8/7/15 10:37	864.26		
87197	GR	Mildred	8/7/15 12:02	864.26		864.26
87197	IR	Mildred	8/10/15 9:16	864.26	864.26	864.26
87197	Release	Kimberly	8/11/15 7:01	864.26		

What is Process Mining?

Analyze the **event log** data that exists in the information systems of a company and use that to **visualize** and **understand** what is **actually happening** in the company's processes and how they are executed in real life



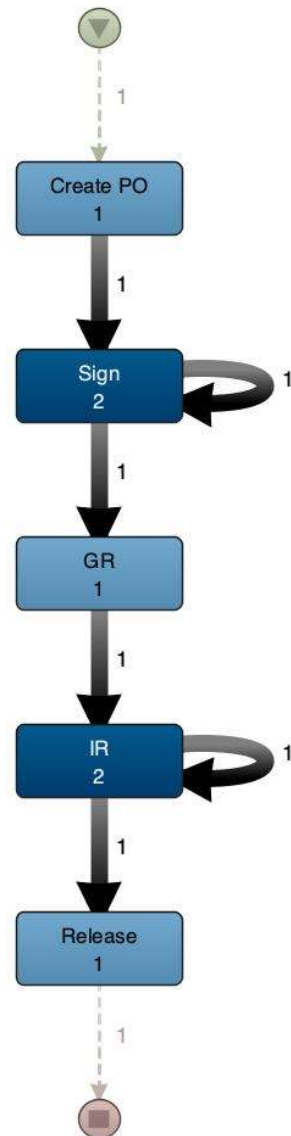


Case # 89501

Activity	Originator	Timestamp	Value PO	Value GR	Value Pay
Create PO	P1	02/12/2016 14:17:04	600.00		
Sign	P1	02/12/2016 14:17:05	600.00		
Sign	P2	02/16/2016 07:42:31	600.00		
GR	P3	02/16/2016 09:44:20	600.00	600	
IR	P3	02/17/2016 15:16:37	600.00	600	600.00
IR	P3	02/17/2016 15:17:49	600.00	600	600.00
Release	P4	02/18/2016 07:01:17	600.00		

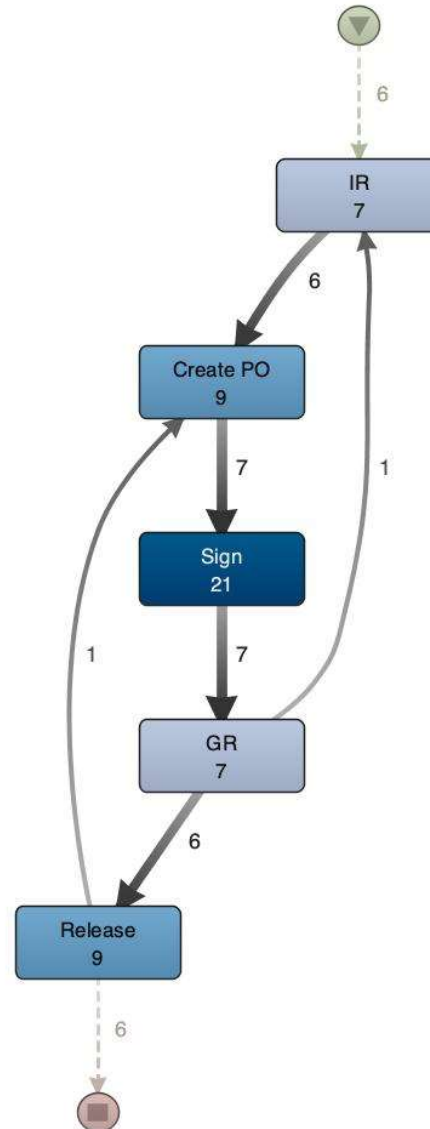
Duplicate payment suspicion





Case # 90027

Activity	Originator
IR	P1
Create PO	P2
Sign	P2
Sign	P3
GR	P1
Release	P4



	Value GR	Value Pay
5	17,784	17,783.75
5	Irregular starting activity	
5		
5		
5	17,784	
5		

Case # 89554

Activity	Originator	Timestamp	Value PO	Value GR	Value Pay
Create PO	P1	02/19/2016 12:19:01	15.71	Segregation of duty violation	
Create PO	P1	02/19/2016 12:19:01	49.00		
Sign	P1	02/19/2016 12:19:02	15.71		
Sign	P1	02/19/2016 12:19:02	49.00		
GR	P1	02/19/2016 12:20:27	15.71	15.71	3 way match violation
GR	P1	02/19/2016 12:20:27	49.00	49.00	
IR	P1	02/24/2016 11:51:45	15.71	15.71	21,783.05
IR	P1	02/24/2016 11:51:45	49.00	49.00	21,783.05
Release	P2	02/24/2016 14:26:28	15.71		
Release	P2	02/24/2016 14:26:28	49.00		

Why Process Mining?

1. ***Gaining detailed and objective information on the business process***
2. ***Obtaining high levels of assurance by examining the entire population***
3. ***Gathering strong evidence using unmanipulated data***

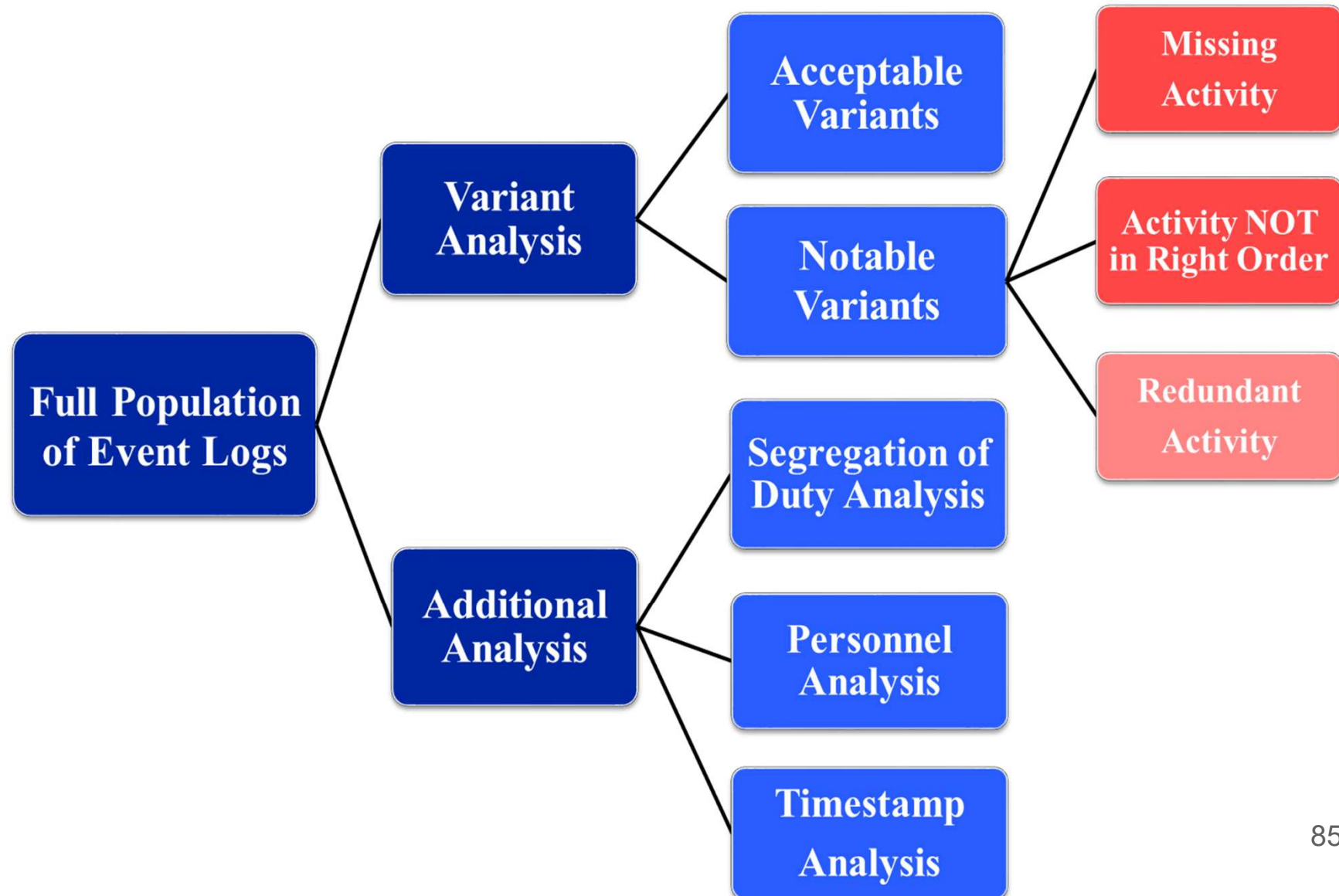


RUTGERS

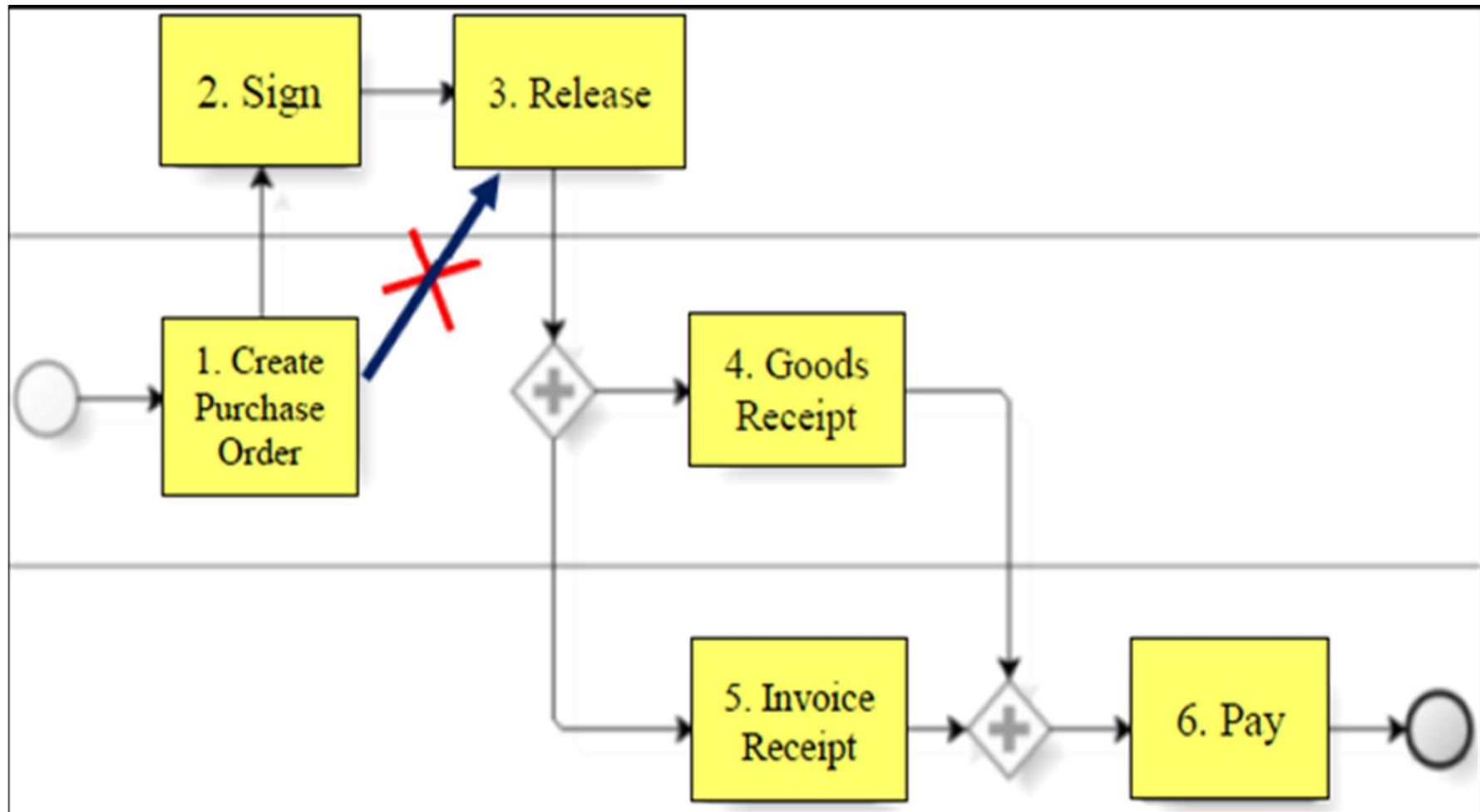
Process Mining Projects

Evaluate the Effectiveness of Internal Control (RADAR)

- This paper aims at adopting process mining to evaluate the effectiveness of internal control using a real-life event log from a large European bank.
- The evaluation is based on the full population of event logs and contains four analyses:
 - (1) **Variant analysis** that identifies acceptable and notable variants.
 - (2) **Segregation of duty analysis** that examines process instances and employees that violate segregation of duty controls.
 - (3) **Personnel analysis** that investigates employees who are involved in multiple potential control violations.
 - (4) **Timestamp analysis** that detects time related issues such as the ones performed during the weekends and process instances that have lengthy process duration.



Example of Acceptable/Notable Variants



CONCLUSIONS

Continuous Process Monitoring (Hering)

- O2C
- Match with SPED to find sales that are not recorded
- Reduce the time delay between the **occurrence** and the **analysis** of business operations related events
- → increases the **information value**

How can it be achieved?

- Develop a **novel approach** for assurance that **combines** the advantages of **continuous monitoring** with those of **process mining**
- **Actively detect** and **investigate deviations** and exceptions **as they occur** along the transaction process

Marinha do Brasil (continuous process mining)

- Piggybacking on AICPA payroll project
- Very integrated and organized information system
- Over 450 units (ships, etc)
- Over 200k employees
- Very different cycles of operation
- Continuous process mining
- Can we use the results of the prefeitura procurement system?

Thank You