Process Mining-based Understanding and Analysis of Volvo IT's Incident and Problem Management Processes
The BPI Challenge 2013

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Abstract. Recently, there has been a strong interest in the application of innovative process mining techniques to promote evidence-based understanding and analysis of organizations' business processes. Following the trend, we analyze real life event logs of incident and problem management processes supported by Volvo IT's VINST system by using process mining and other analytical techniques. The incident and problem management logs contain 7554/2306 cases and 65533/9011 events respectively. To create relevant datasets for answering the given questions, we preprocess the logs with the help of PL-SQL and Java. The datasets are analyzed using ProM and Disco's state-of-the-art process mining capabilities, SQL, and traditional spreadsheet-based techniques. We provide evidence-based answers to the questions and demonstrate the potential benefits of process mining-based understanding and analysis of business processes. Finally, concluding remarks and limitations are discussed.

Keywords: process mining, event logs, process analysis, big data

1. Introduction

Our digital universe is rapidly growing. Because of the increasing automation of and IT support for business processes, IT systems are playing a key role in this rapid growth [2]. They are accumulating invaluable (big) data, which often records in detail which activities were executed when and by whom [9,11]. If managers extract process knowledge from the data, they can directly translate that knowledge into better process performance and decision making for process improvement initiatives [4,5,7,8].

How can we put the invaluable data to good use? Process mining provides an evidence-based approach to extract valuable insights from an organization's processes by depending on the data [8]. Through process mining, we can discover the

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actual ‘as-is’ process models depicting the way activities were performed. Process mining can verify the conformance of processes against some ‘ideal’ behaviours (e.g. as documented in standards, guidelines, and business policies) [6]. Moreover, it can also find performance issues in processes (such as bottleneck) and analyze the interaction between resources performing activities [10]. Process insights gained from using process mining and other analytical techniques can then help us precisely find process improvement opportunities [8].

The situation depicted in the BPI Challenge 2013 focuses on the incident and problem management processes supported by Volvo IT’s VINST system. The incident and problem management logs include 7554/2306 cases and 65533/9011 events respectively. We attempted to address the given questions drawn from four major issues by using process mining and other analytical techniques. To achieve this goal, we sought to understand the data and create relevant datasets for the questions. Furthermore, we tried to clarify the issues at the log data level. Specifically, to provide evidence-based answers for the questions, we aimed to address the following issues in detail:

1. Push to front mechanism
    - Defining push to front mechanism at the log data level
    - Addressing the three questions
2. Ping pong behaviour
    - Defining ping pong behaviour at the log data level
    - Addressing the two questions
3. Wait user
    - Understanding the given three questions
    - Addressing the three questions
4. Process conformity per organization
    - Defining the range of comparison in conformity
    - Addressing the given question

As noted by [1], process mining projects are typically iterative; after stakeholders provide feedback on findings, a new round of analysis is triggered. However, since we were not in contact with the stakeholders of Volvo IT, we are not able to receive any feedback on our analysis results and thus start a new round of analysis. In spite of this limitation, we believe that our answers and analysis results are plausible and thus validate the potential benefits of process mining-based analysis. We hope that our analysis results encourage an increasing number of managers to pay attention to process mining-based understanding and analysis of business processes in a big data world.

The rest of the paper is structured as follows. The next section shows which tools we used and our understanding of the data. We also explain how the two event logs were filtered and split into relevant datasets for answering the given questions. In section 3, we explain our analysis approaches and give evidence-based answers for the given questions. The final section provides the concluding remarks and the limitation of our analyses.

2. Materials and Methods

2.1 Used Tools

There are several tools used in this analysis: process mining tools (ProM and Disco), a database management system, and a spreadsheet application.

2.1.1 ProM and Disco

We chose ProM and an evaluation version of Disco (Version 1.3.6; Fluxicon) as process mining tools. We got a lot of help from Disco's capabilities like statistics, filtering function, and process map generator, which is shown in <Fig. 1>, to make a conclusion in many parts of the analysis with little effort. We also used ProM's innovative process mining techniques.

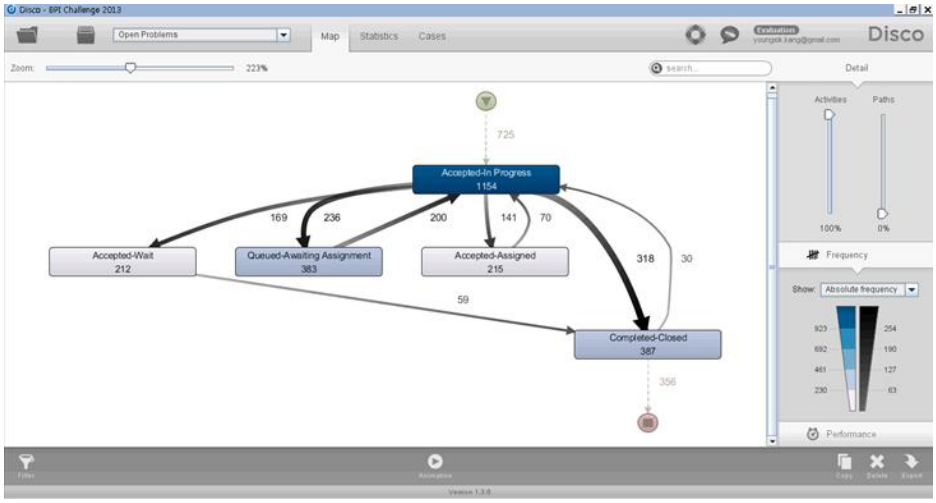


Fig. 1. Disco's process map generating function

2.1.2 Eclipse SDK and Oracle Database System

Although in general it could be said that Disco has excellent filtering functions, we sometimes needed more complicated and sophisticated preprocessing and data conversion features. That is the reason way we used Eclipse SDK(Version 4.2.2; Eclipse Foundation), the programming framework, and Oracle Database Express Edition (Version 11.2.0.1.0; Oracle).

2.1.3 Microsoft Excel

Microsoft Excel, which is well known spreadsheet application, is very useful to draw charts or graph of data. We, therefore, used Microsoft Excel(Microsoft Office 2010; Microsoft Corporation) to convey conclusion effectively.

2.2 Understanding of the Data

We received three datasets which consists of 16 attributes respectively. Some rough information of each dataset is displayed in <Fig. 2>.

Incident Management	
Event	65,533
Start Date	31.03.2010
End Date	23.05.2012
SR Number	7,554
Status	4
Sub Status	13
Action Owner	1,440
Product	704
Involved ST Function Div	24
Involved Organization	25
Involved ST	649
SR Latest Impact	4
Country	23
Owner Country	32

Problem Management(Closed)	
Events	6,660
Start Date	11.01.2006
End Date	01.06.2012
Problem Number	1,487
Status	4
Sub Status	7
Action Owner	585
Product	337
Involved ST Function Div	29
Involved Organization	15
Involved ST	324
Problem Latest Impact	4
Country	17
Owner Country	21

Problems Management(Open)	
Events	2,351
Start Date	07.11.2006
End Date	15.06.2012
Problem Number	819
Status	3
Sub Status	5
Action Owner	240
Product	139
Involved ST Function Div	26
Involved Organization	11
Involved ST	187
Problem Latest Impact	4
Country	14
Owner Country	14

Fig. 2. Rough information of the given dataset

Moreover, sub statuses are involved in one particular status and <Fig. 3> shows their correlations.

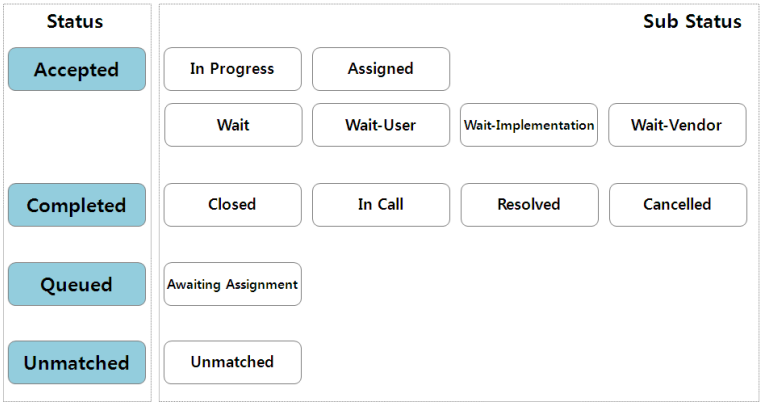


Fig. 3. Correlations between Statuses and sub statuses

There are two problem management datasets (i.e., open and closed datasets) and this means that problem management datasets are divided into two datasets. However, the incident management dataset exists as only one which includes those two concepts (open and closed). Among 7,554 incidents, 1,980 ones still remain uncompleted.

3. Analysis from the Given Questions

It is possible to draw various conclusions from one analysis using different process mining techniques. For example, it could be interesting topics to analyze social networks between action owners or to figure out every pattern of incident management process. In this analysis, however, we sought to focus on the given questions with data.

3.1 The Outline of Analysis

Through this analysis, 'SR_Number' attribute of the given data is used for case id and 'Change_Date+Time' attribute is used for time. 'Activity' could be changed flexibly in dealing with every given question and also be combined with more than two attributes. In this case, we decided to use plus sign ('+') to distinguish each attribute value. <Fig. 4>, for instance, shows the log data of an activity which consists of status and sub status combined together.

SR_NUMBER	Involved ST	Organization	Status+Sub Status	Change_Date+Time
1-739302563	D2	Org line C	Accepted+In Progress	2012-05-03 10:46
1-739302563	D2	Org line C	Accepted+In Progress	2012-05-03 10:46
1-739302563	D2	Org line C	Accepted+Wait - User	2012-05-03 11:03
1-739302563	D4	Org line A2	Queued+Awaiting Assignment	2012-05-03 11:32
1-739302563	D4	Org line A2	Accepted+In Progress	2012-05-03 11:40
1-739302563	D2	Org line C	Queued+Awaiting Assignment	2012-05-03 11:42
1-739302563	D2	Org line C	Accepted+In Progress	2012-05-03 12:17
1-739302563	D4	Org line A2	Queued+Awaiting Assignment	2012-05-03 12:43
1-739302563	D4	Org line A2	Accepted+In Progress	2012-05-03 13:21
1-739302563	D2	Org line C	Queued+Awaiting Assignment	2012-05-03 13:36
1-739302563	D2	Org line C	Accepted+In Progress	2012-05-03 14:13
1-739302563	D2	Org line C	Accepted+Wait - User	2012-05-03 14:22
1-739302563	D2	Org line C	Accepted+Wait - User	2012-05-06 13:15
1-739302563	D2	Org line C	Completed+Resolved	2012-05-11 15:35
1-739302563	D2	Org line C	Completed+Closed	2012-05-11 23:16

Fig. 4. Activity combined with a status and a sub status

Doing this analysis, it is necessary to extract data from all datasets meeting particular conditions. For example, supposing we should extract data of which organization

attribute value is ‘Org Line A2’ from dataset consisting of 15 lines, in this case only 4 shaded lines, as seen in <Fig. 5>, could be extracted.

SR_Number	Involved ST	Organization	Status	Sub Status	Change_Date+Time
1-739302563	D2	Org line C	Accepted	In Progress	2012-05-03 10:46
1-739302563	D2	Org line C	Accepted	In Progress	2012-05-03 10:46
1-739302563	D2	Org line C	Accepted	Wait - User	2012-05-03 11:03
1-739302563	D4	Org line A2	Queued	Awaiting Assignment	2012-05-03 11:32
1-739302563	D4	Org line A2	Accepted	In Progress	2012-05-03 11:40
1-739302563	D2	Org line C	Queued	Awaiting Assignment	2012-05-03 11:42
1-739302563	D2	Org line C	Accepted	In Progress	2012-05-03 12:17
1-739302563	D4	Org line A2	Queued	Awaiting Assignment	2012-05-03 12:43
1-739302563	D4	Org line A2	Accepted	In Progress	2012-05-03 13:21
1-739302563	D2	Org line C	Queued	Awaiting Assignment	2012-05-03 13:36
1-739302563	D2	Org line C	Accepted	In Progress	2012-05-03 14:13
1-739302563	D2	Org line C	Accepted	Wait - User	2012-05-03 14:22
1-739302563	D2	Org line C	Accepted	Wait - User	2012-05-06 13:15
1-739302563	D2	Org line C	Completed	Resolved	2012-05-11 15:35
1-739302563	D2	Org line C	Completed	Closed	2012-05-11 23:16

Fig. 5. Extracting events whose organization attribute value is ‘Org Line A2’

3.2 Push to Front Mechanism

This issue deals with the Volvo IT’s strategy/philosophy that most of the incidents need to be resolved by the first line support teams (mainly service desks). In general this increases work efficiency. Because the issue is only related to the incident management process, the problem management dataset was not considered for this analysis.

3.2.1 Defining Push to Front Mechanism at Log Data Level

It could be defined that the push to front mechanism operates well when incidents are closed without any involvement of support teams which are in the second or third lines. Here, we intend to set and define operational principle of push to front mechanism at a log data level.

There are records of support teams – specially, names of support teams – on incident management datasets. <Fig. 6> shows some representative examples of names of support teams out of 649 support teams total. We supposed that the support teams which don’t have any followed words like ‘2nd’, ‘3rd’, or ‘2nd 3rd’ are just in the first line: for example, ‘A14’ in the <Fig. 6>.

Involved_ST
A14
C3 2nd
L57 3rd
V13 2nd 3rd

Fig. 6. An example of names of support teams

When we make a judgment if push to front mechanism works well, only completed incidents are intended for the judgment first. It is because there is possibility for support teams in 2nd or 3rd lines to get involved in uncompleted incidents during its procedures even if it is not happened yet.

To judge whether push to front mechanism of the completed incidents works well, we should make clear the fact that there is no involvement of support teams in 2nd and 3rd lines during the procedures of incidents. <Fig. 7> shows one of the cases (incidents) in which push to front mechanism works very well.

SR_NUMBER	Involved_ST	STATUS	SUB_STATUS	CHANGE_DATE_TIME
1-740862080	N38	Accepted	In Progress	2012-05-05 0:00
1-740862080	N38	Accepted	In Progress	2012-05-05 0:02
1-740862080	N38	Accepted	In Progress	2012-05-05 0:03
1-740862080	N44	Queued	Awaiting Assignment	2012-05-05 0:03
1-740862080	N44	Accepted	In Progress	2012-05-07 11:18
1-740862080	N44	Completed	Resolved	2012-05-07 11:19
1-740862080	N44	Completed	Closed	2012-05-14 23:18

Fig. 7. A case not involved by support teams in 2nd and 3rd lines

Meanwhile, an incident requires the approval of the support team being taken over the work when it needs to switch from the current support team to other ones. For this reason, the incident remains in standby status till the support team approves when the current support team assigns a new team which will take responsibility of an incident (in other words, the status now is to be 'Queued'). You can see 'Queued' status in the part shown in red color (see <Fig. 8>). However, you are able to figure out that the attribute value of the support team has been changed from 'U3' to 'S30 2nd', although the support team in charge has actually not been changed because it's not approved yet. In this case, it can be said that the push to front mechanism operates well because there was no actual change of a support team.

SR_NUMBER	Involved_ST	STATUS	SUB_STATUS	CHANGE_DATE_TIME
1-738162073	U3	Accepted	In Progress	2012-05-02 11:18
1-738162073	U3	Accepted	In Progress	2012-05-02 11:18
1-738162073	U3	Completed	Resolved	2012-05-02 11:29
1-738162073	U3	Accepted	In Progress	2012-05-02 11:30
1-738162073	U3	Completed	Resolved	2012-05-02 11:31
1-738162073	S30 2nd	Queued	Awaiting Assignment	2012-05-02 11:43
1-738162073	U3	Accepted	In Progress	2012-05-02 11:43
1-738162073	U3	Completed	Resolved	2012-05-02 11:43
1-738162073	U3	Completed	Closed	2012-05-02 23:02

Fig. 8. A part of incident management dataset

Based on the discussion about lines involved in incidents and 'Queued' status awaiting assignment mentioned above, there are some definitions at a log data level to make a judgment if push to front mechanism works or not.

- An incident is closed without any involvement of 2nd or 3rd lines

- 'Queued' status does not include the change of support teams

Thus, based on those clear definitions given at log data level and related to the operation of push to front mechanism, we sought to give answers to those following questions.

- For what products is the push to front mechanism most used and where not?
- Where in the organization is the push to front process most implemented (field=involved organization), specifically if we compare the Org Line A2 with the Org Line C
- What functions are most in line with the push to front process?

3.2.2 Products Using Push to Front Mechanism Frequently or Not

There are 704 products related to the incident management process. Among those products, only 284 are influenced by push to front mechanism. We found a list of top 10 products which had used push to front mechanism frequently among those 284 products by using the definition we have mentioned (see <Fig. 9>). Considering only absolute frequency, the product used push to front mechanism the most is 'PROD424'. However push to front mechanism was found just in 69% of all cases related to it, 'PROD424'. On the contrary, 'PROD383' has its absolute frequency 196 and at the same time 96% out of total cases related to it show the usage of push to front mechanism.

PRODUCT	Push to front	Case Frequency	Push to front / Case Frequency
PROD424	418	605	69%
PROD660	226	267	85%
PROD383	196	205	96%
PROD253	138	190	73%
PROD455	72	76	95%
PROD235	63	77	82%
PROD267	63	99	64%
PROD236	57	76	75%
PROD716	55	59	93%
PROD494	49	88	56%

(PRODUCT: product number, Push to front: cases which work with push to front mechanism well, Case Frequency: total number of cases related to an appointed product, Push to front / Case Frequency: rates of cases related to push to front mechanism among all cases of an appointed product)

Fig. 9. Top 10 products using push to front mechanism a lot

Out of 704 products, there are 420 which have never used push to front mechanism. We selected 10 products which have many related cases among those 420 products (see <Fig. 10>). For example, there are 70 incidents related to 'PROD607'. However, they have never adopted the push to front mechanism.

PRODUCT	Case_Frequency
PROD607	70
PROD604	36
PROD295	32
PROD350	31
PROD305	29
PROD337	28
PROD54	27
PROD818	27
PROD126	23
PROD49	19

Fig. 10. Products which have never used push to front mechanism at all

3.2.3 Organizations and Function Division keeping Push to Front Mechanism well

This time, let us look into the organizations and function divisions which work with push to front mechanism well. There are 25 organizations total – including 'Other' – in the incident management process. Among those 25, there are 13 organizations working with push to front mechanism more than once. <Fig. 11> shows how the 12 organizations – not involving 'Other' – follow push to front mechanism. Although there are some organizations – like 'Org Line V8', 'Org Line G2', 'Ogr Line V10', and so on – applying push to front mechanism to every related case, it is only about less than 10 cases. Meanwhile, there is 'Org Line C' that many cases following push to front mechanism have been found and they count for 75% of all the cases. It, therefore, could be said that push to front mechanism is well followed by 'Org Line C'. On the contrary, compared with 'Org Line C', 'Org Line A2' has fairly low percentages of push to front mechanism – only 15% – shown related to cases.

Organization	Push to front	Case Frequency	Push to front / Case Frequency
Org line C	2470	3290	75%
Org line B	202	463	44%
Org line A2	188	1258	15%
Other	178	187	95%
Org line V2	29	62	47%
Org line V8	9	9	100%
Org line G2	8	8	100%
Org line V11	8	22	36%
Org line V10	7	7	100%
Org line H	6	6	100%

Fig. 11. Comparison between organizations taking push to front mechanism

Next we analyzed 24 function divisions in a similar way. There are 9 function divisions – excluding null value – which have followed push to front mechanism more than once. <Fig. 12> compares how well those 9 function divisions follow push to front mechanism. It was found that this mechanism is well followed by function divisions dealing with many incidents. In case of 'V3_2' and 'E_5', in particular, we

got surprising result that 97% and 99% of ‘V3_2’ and ‘E_5’ respectively of all cases they involved in show well fulfilled push to front mechanism.

Function_div	Push to front	Case Frequency	Push to front / Case Frequency
V3_2	2115	2180	97%
A2_1	545	790	69%
E_5	323	326	99%
NULL	253	674	38%
A2_5	23	57	40%
A2_2	22	260	8%
A2_4	9	271	3%
E_1	2	39	5%
E_6	2	102	2%
E_10	1	365	0%

Fig. 12. Comparison between function divisions taking push to front mechanism

3.3 Ping Pong Behaviour

Ideally, an incident should be resolved quickly and with minimum interference of not too many support teams. However, in reality, support teams send incidents to each other repeatedly. These phenomena are called ping pong behaviour, which definitely leads to prolonging the total life time of an incident. We can witness this behaviour in both the incident and problem management processes.

3.3.1 Defining Ping Pong Behaviour at the Level of Log Data

Ping pong behaviour denotes that support teams pass the buck to each other repetitively when they deal with an incident or a problem. For elaborate analysis, we need to define it more specifically and clearly at the level of log data. Discussion below describes how ping pong behaviour is specifically and clearly defined at the level of log data.

In 3.2, we already explained how data is recorded when incidents remain in standby status. A status value is ‘Queued’ when an incident is in standby status and the support team is changed to be recorded even if the incident is not completed yet (see <Fig. 8>). To work out these errors, we got rid of all the rows in ‘Queued’ status where incident management data sets and problem management data sets have.

We looked into the type of these behaviours first to define ping pong behaviour more specifically and clearly at the level of log data. Ping pong behaviour is considered clearly just in case both action owners and support teams have been changed. On the other hand, as shown in <Fig. 13>, there are some patterns that action owners have not been changed, but support teams. We will consider it ping pong behaviour because these types correspond to the definition of ping pong behaviour as described.

SR_NUMBER	STATUS	INVOLVED_ST	OWNER_FIRST_NAME	CHANGE_DATE+TIME
1-364285768	Accepted	V30	Frederic	2010-03-31 14:59:42
1-364285768	Accepted	V30	Frederic	2010-03-31 15:00:56
1-364285768	Accepted	V5 3rd	Anne Claire	2010-04-06 14:44:07
1-364285768	Accepted	V13 2nd 3rd	Anne Claire	2010-04-06 14:44:47
1-364285768	Completed	V13 2nd 3rd	Anne Claire	2010-04-06 14:44:51
1-364285768	Accepted	V30	Eric	2010-04-08 10:52:23
1-364285768	Accepted	V5 3rd	Anne Claire	2010-04-20 09:07:11
1-364285768	Accepted	V5 3rd	Anne Claire	2010-04-20 09:07:19
1-364285768	Accepted	V5 3rd	Sarah	2012-04-11 15:11:17
1-364285768	Accepted	V5 3rd	Sarah	2012-04-11 15:11:25
1-364285768	Accepted	V5 3rd	Loic	2012-05-03 09:10:10
1-364285768	Completed	V5 3rd	Loic	2012-05-03 09:10:12
1-364285768	Completed	V5 3rd	Siebel	2012-05-10 23:26:15

Fig. 13. In case that action owners have not been changed, but support teams

Lastly, a difficult type to judge is in case that support teams have not been changed, but action owners (see <Fig. 14>). It cannot be disregarded that these types influence on incident/problem management processes. However, we made a decision that these types are not appropriate to ping pong behaviour, based on the definition of ping pong behaviour as described.

SR_NUMBER	STATUS	INVOLVED_ST	OWNER_FIRST_NAME	CHANGE_DATE+TIME
1-364285768	Accepted	V30	Frederic	2010-03-31 14:59:42
1-364285768	Accepted	V30	Frederic	2010-03-31 15:00:56
1-364285768	Accepted	V5 3rd	Anne Claire	2010-04-06 14:44:07
1-364285768	Accepted	V13 2nd 3rd	Anne Claire	2010-04-06 14:44:47
1-364285768	Completed	V13 2nd 3rd	Anne Claire	2010-04-06 14:44:51
1-364285768	Accepted	V30	Eric	2010-04-08 10:52:23
1-364285768	Accepted	V5 3rd	Anne Claire	2010-04-20 09:07:11
1-364285768	Accepted	V5 3rd	Anne Claire	2010-04-20 09:07:19
1-364285768	Accepted	V5 3rd	Sarah	2012-04-11 15:11:17
1-364285768	Accepted	V5 3rd	Sarah	2012-04-11 15:11:25
1-364285768	Accepted	V5 3rd	Loic	2012-05-03 09:10:10
1-364285768	Completed	V5 3rd	Loic	2012-05-03 09:10:12
1-364285768	Completed	V5 3rd	Siebel	2012-05-10 23:26:15

Fig. 14. In case that support teams have not been changed, but action owners

Based on the previous discussion, we will consider all the shaded areas Ping pong behaviour. These types reflect descriptions below at the level of log data.

- Support teams have been changed.
- Exclude from the scenario that support teams have been changed while 'Queued' status are recorded.
- Ignore whether alternations to action owners only.

We will answer the questions below based on the clear definition at the level of log data on ping pong behaviour.

- What are the functions, organizations, support teams responsible for most of the ping pong?
- What products are most affected by it?

3.3.2 The Functions, Organizations, Support Teams Responsible for Most of the Ping Pong Behaviour

We, first of all, looked into ping pong behaviours shown in support teams. <Fig. 15> shows the top 20 support teams that have passed their incident. For example, through that <Fig. 15>, we could find that 'G96' handed over its incidents far more than took over from another teams. Most cases (86.6%), however, have low impact level. There could be found different features of 'D4' to 'G96'. 'D4' takes over incidents as much as it hands over although most of those cases shown on the chart below are at medium impact level at 97.3%.

Involved_ST	Hand Over	Take Over	Impact (Hand Over)			
			LOW	MEDIUM	HIGH	MAJOR
G96	1106	72	86.60%	11.90%	1.40%	0%
G97	678	817	77.40%	21.50%	1%	0%
D4	526	528	0.80%	97.30%	1.90%	0%
S42	302	37	2.30%	97.40%	0.30%	0%
D5	248	218	5.60%	94%	0.40%	0%
D8	245	191	2%	96.30%	1.60%	0%
N38	215	27	21.90%	75.30%	2.80%	0%
D2	186	163	2.20%	94.10%	3.80%	0%
G92	172	197	37.20%	49.40%	12.20%	0%
V37 2nd	161	217	0.60%	97.50%	1.90%	0%
S37	145	11	28.30%	64.10%	6.90%	0%
D7	126	111	1.60%	97.60%	0.80%	0%
G230 2nd	119	245	68.90%	30.30%	0.80%	0%
G76	118	4	11%	87.30%	1.70%	0%
G179	104	120	25%	74%	1%	0%
G40	97	120	50.50%	49.50%	0%	0%
D1	96	95	20.80%	60.40%	18.80%	0%
G22 2nd	92	134	66.30%	32.60%	1.10%	0%
G51 2nd	78	52	5.10%	70.50%	24.40%	0%
N26 2nd	76	77	1.30%	94.70%	3.90%	0%

(Involved_ST: support teams, Hand over: the number of handing over incidents to other support teams, Take Over: the number of taking over incident from other support teams, Impact(Hand Over): rates of handing over incidents to other support teams by impact)

Fig. 15. Top 20 support teams handing over their incident to other teams (incident management process)

<Fig. 16>, in this context, shows organizations and function divisions which support teams that have responsibility to ping pong behaviour – showing large frequency – belong to.

Involved ST	Organization	Function Div	Involved ST	Organization	Function Div
D1	Org line B	A2_1	G51 2nd	Org line G4	NULL
D2	Org line C	A2_1	G76	Org line C	E_5
D4	Org line A2	A2_1	G92	Org line C	E_5
D5	Org line C	A2_1	G96	Org line C	V3_3
D7	Org line A2	A2_1	G97	Org line C	V3_3
D8	Org line A2	A2_1	N38	Org line C	V3_3
G179	Org line C	V3_3	S37	Org line C	V3_3
G22 2nd	Org line A2	A2_2	S42	Org line C	V3_3
G230 2nd	Org line B	E_10	S56	Other	NULL
G40	Org line A2	A2_2	V37 2nd	Org line V7n	NULL

Fig. 16. Support teams, organizations, and function divisions which have responsibility to most of the ping pong behaviours (incident management process)

Through the same way, we analyzed ping pong behaviours related to each closed problem management process and open problem management process (see <Fig. 17, 18, 19, 20>).

Involved_ST	Hand Over	Take Over	Impact (Hand Over)			
			LOW	MEDIUM	HIGH	MAJOR
G21 2nd	28	32	7.1%	92.9%	0.0%	0.0%
G271 2nd	18	7	0.0%	22.2%	72.2%	0.1%
G181 2nd	14	18	7.1%	57.1%	7.1%	0.3%
G186 2nd	14	6	7.1%	64.3%	0.0%	0.3%
G88 2nd	14	9	14.3%	42.9%	35.7%	0.1%
G230 2nd	12	12	8.3%	58.3%	25.0%	0.1%
G165 2nd	10	13	0.0%	60.0%	10.0%	0.3%
G141 3rd	9	6	33.3%	55.6%	11.1%	0.0%
G55 2nd	7	8	0.0%	71.4%	28.6%	0.0%
G290 3rd	7	10	0.0%	28.6%	71.4%	0.0%
G92	7	4	0.0%	57.1%	42.9%	0.0%
G273 3rd	6	17	0.0%	16.7%	83.3%	0.0%
G56 3rd	6	5	0.0%	50.0%	33.3%	0.2%
G153 2nd	6	3	0.0%	16.7%	50.0%	0.3%
G167 2nd	6	4	0.0%	100.0%	0.0%	0.0%
G288 2nd	6	4	0.0%	33.3%	66.7%	0.0%
G157 2nd	5	6	0.0%	20.0%	60.0%	0.2%
M1 2nd	5	6	0.0%	80.0%	20.0%	0.0%
G138 2nd	5	2	20.0%	80.0%	0.0%	0.0%
G263 2nd	5	6	20.0%	20.0%	60.0%	0.0%

Fig. 17. Top 20 support teams handing over incidents (closed problem management process)

Involved ST	Organization	Function Div	Involved ST	Organization	Function Div
G138 2nd	Org line C	E_10	G263 2nd	Org line C	E_10
G141 3rd	Org line C	C_6	G271 2nd	Org line C	E_10
G153 end	Org line C	E_7	G273 3rd	Org line C	C_6
G157 2nd	Org line C	E_7	G288 2nd	Org line C	E_10
G165 2nd	Org line C	E_7	G290 3rd	Org line C	C_6
G167 2nd	Org line A2	A2_2	G55 2nd	Org line C	E_1
G181 2nd	Org line C	E_8	G56 3rd	Org line C	C_1
G186 2nd	Org line C	E_8	G88 2nd	Org line C	E_4
G21 2nd	Org line A2	A2_2	G92	Org line C	E_5
G230 2nd	Org line B	E_10	M1 2nd	Org line A2	A2_2

Fig. 18. Support teams, organizations, and function divisions which have responsibility to most of the ping pong behaviours (closed problem management process)

Involved_ST	Hand Over	Take Over	Impact (Hand Over)			
			LOW	MEDIUM	HIGH	MAJOR
G271 2nd	18	4	0.0%	38.9%	61.1%	0.0%
G273 3rd	7	18	0.0%	42.9%	57.1%	0.0%
G236 2nd	5	5	0.0%	60.0%	40.0%	0.0%
M1 2nd	5	5	0.0%	80.0%	20.0%	0.0%
G165 2nd	5	3	0.0%	60.0%	40.0%	0.0%
G263 2nd	4	4	0.0%	25.0%	75.0%	0.0%
G75	4	2	0.0%	75.0%	25.0%	0.0%
G134 2nd	3	3	0.0%	33.3%	33.3%	0.3%
G153 2nd	3	2	0.0%	33.3%	33.3%	0.3%
G58 3rd	3	2	0.0%	100.0%	0.0%	0.0%
G167 2nd	3	4	0.0%	100.0%	0.0%	0.0%
G55 2nd	3	3	0.0%	100.0%	0.0%	0.0%
G230 2nd	2	2	0.0%	50.0%	50.0%	0.0%
W16 3rd	2	2	0.0%	100.0%	0.0%	0.0%
G288 2nd	2	2	0.0%	50.0%	50.0%	0.0%
G143 2nd	2	3	0.0%	0.0%	100.0%	0.0%
G4 2nd	2	1	50.0%	0.0%	50.0%	0.0%
G88 2nd	2	3	50.0%	50.0%	0.0%	0.0%
G57 2nd	2	4	0.0%	100.0%	0.0%	0.0%
G119 2nd	1	3	0.0%	100.0%	0.0%	0.0%

Fig. 19. Top 20 support teams handing over their incident to other teams (open problem management process)

Involved ST	Organization	Function Div
G119 2nd	Org line C	E_8
G134 2nd	Org line C	E_7
G143 2nd	Org line C	E_10
G153 2nd	Org line C	E_7
G165 2nd	Org line C	E_7
G167 2nd	Org line A2	A2_2
G230 2nd	Org line B	E_10
G236 2nd	Org line C	E_10
G263 2nd	Org line C	E_10
G271 2nd	Org line C	E_10

Involved ST	Organization	Function Div
G273 3rd	Org line C	C_6
G288 2nd	Org line C	E_10
G4 2nd	Org line A2	A2_2
G48 2nd	Org line C	E_6
G55 2nd	Org line C	E_1
G57 2nd	Org line C	E_2
G58 3rd	Org line C	C_2
G75	Org line C	E_5
G88 2nd	Org line C	E_4
M1 2nd	Org line A2	A2_2
W16 3rd	Org line A2	A2_1

Fig. 20. Support teams, organizations, and function divisions which have responsibility to most of the ping pong behaviours (open problem management process)

3.3.3 The Products Which Are Most Affected by Ping Pong Behaviour

<Fig. 21> shows a list of top 10 products which are influenced by pong pong behaviours. 'PROD424' is a product the most deeply related to ping pong behaviour. It is related to 882 ping pong behaviours total. For incidents occurrence is as high as occurrence of ping pong behaviours, it could be said that one ping pong behaviour occurs once one incident does on average. Although 'PROD542' on the second of the list is related to ping pong behaviours less than 'PROD424', there could be found 6 ping pong behaviours when only one incidents are arose and most of its incidents show higher impact level.

PRODUCT	# of Ping Pong Behaviour (A)	# of Involved SR (B)	A ÷ B	Impact (Hand Over)			
				LOW	MEDIUM	HIGH	MAJOR
PROD424	893	882	1	75.4%	23.7%	0.9%	0.0%
PROD542	453	75	6	0.9%	96.9%	2.2%	0.0%
PROD236	243	80	3	1.6%	91.4%	7.0%	0.0%
PROD253	228	226	1	57.5%	40.4%	2.2%	0.0%
PROD698	198	140	1	57.6%	41.9%	0.5%	0.0%
PROD660	188	484	9	0.5%	99.5%	0.0%	0.0%
PROD697	177	30	6	0.0%	100.0%	0.0%	0.0%
PROD789	172	31	6	0.0%	100.0%	0.0%	0.0%
PROD455	169	81	2	71.6%	28.4%	0.0%	0.0%
PROD235	162	87	2	0.0%	98.1%	1.9%	0.0%

(PRODUCT: product number, The # of Ping Pong Behaviour(A): the number of ping pong behaviours related to relevant product, The # of Involved SR(B): occurrence of incidents, (A ÷ B), Impact(Hand Over): rates of ping pong behaviours by impact level)

Fig. 21. Top 10 products ping pong which are the most deeply related to ping pong behaviour. (Incident management process)

Each <Fig. 22, 23> shows products the most deeply related to ping pong behaviours in closed problem management processes and in open problem management processes respectively.

PRODUCT	# of Involved SR (B)	# of Ping Pong Behaviour (A)	B ÷ A	Impact (Hand Over)			
				LOW	MEDIUM	HIGH	MAJOR
PROD802	78	48	0.6	8.30%	25%	66.70%	0%
PROD97	1	27	27	0%	100%	0%	0%
PROD424	882	15	0	26.70%	60%	13.30%	0%
PROD96	13	12	0.9	41.70%	58.30%	0%	0%
PROD597	21	11	0.5	0%	18.20%	45.50%	36.40%
PROD681	1	10	10	0%	100%	0%	0%
PROD671	7	10	1.4	0%	80%	20%	0%
PROD476	5	8	1.6	12.50%	75%	12.50%	0%
PROD473	7	8	1.1	0%	62.50%	12.50%	25%
PROD350	31	8	0.3	50%	25%	25%	0%

Fig. 22. Top 10 products Ping pong which are the most deeply related to ping pong behaviour. (closed problem management process)>

PRODUCT	# of Ping Pong Behaviour (A)	# of Involved SR (B)	A ÷ B	Impact (Hand Over)			
				LOW	MEDIUM	HIGH	MAJOR
PROD802	78	34	0.4	5.90%	26.50%	67.60%	0%
PROD509	15	10	0.7	0%	100%	0%	0%
PROD350	31	8	0.3	37.50%	37.50%	25%	0%
PROD745	3	7	2.3	0%	71.40%	28.60%	0%
PROD681	1	7	7	0%	100%	0%	0%
PROD327	38	5	0.1	0%	100%	0%	0%
PROD412	8	5	0.6	0%	60%	40%	0%
PROD671	7	5	0.7	0%	80%	20%	0%
PROD494	186	5	0	0%	0%	100%	0%
PROD597	21	3	0.1	0%	33.30%	33.30%	33.30%

Fig. 23. Top 10 products Ping pong which are the most deeply related to ping pong behaviour. (open problem management process)>

3.4 Wait User

In this part, we sought to deal with questions related to abuse of 'Wait-User' which is one of the sub statuses. Dataset of incident management process on which this sub status – 'Wait-User' – is only found, therefore, becomes a target dataset. We also decided to cover status information on the analysis to be more specific. Following <Fig. 24> shows every activity found on processes when we set process activities by combining statuses with sub statuses.

Activities
Accepted+Assigned
Accepted+In Progress
Accepted+Wait
Accepted+Wait -Customer
Accepted+Wait-Implementation
Accepted+Wait-User
Accepted+Wait-Vendor
Completed+Cancelled
Completed+Closed
Completed+In Call
Completed+Resolved
Unmatched+Unmatched

Fig. 24. Names of activities found on processes (combination of statuses and sub statuses)

As shown on <Fig. 24>, the 'Wait-User' sub status is always regarded as 'Accepted' status. 'Accepted+Wait-User' hence is supposed to be the focus of analysis.

3.4.1 Our Understanding of the Given Questions

There are following some given questions related to ‘Wait-User’ sub status.

- Who is making most use of this sub status (action owner)?
- What is the behaviour per support team, function, organization etc?
- (mis)-usage per location?
- Etc.

We intend to only answer the three of the questions mentioned above excluding different possible ones. To understand these three questions, it is required to conceptualize ‘the behaviour’ in the second question. We understood this concept as the pattern of using ‘Wait-User’. Even though there are several possible interpretations of ‘(mis)-usage’ in the third question, moreover, we sought to keep on analyzing focusing on the abusive behaviour on ‘Wait-User’. The ‘Wait-User’ sub status, as mentioned above, is combined with ‘Accepted’ status and analyzed by being substituted with ‘‘Accepted+Wait-User’. Based on this understanding, consequently, we intend to deal with and make answers the following subjects.

- Action owner using ‘Accepted+Wait-User’ the most frequently.
- Each pattern of using ‘Accepted+Wait-User’ found in support team, function division, and organization.
- Locations where abuse of ‘Accepted+Wait-User’ is found.

3.4.2 Action Owner Using ‘Accepted+Wait-User’ the Most Frequently

To get answers to these questions, we counted number of uses for ‘Accepted+Wait-User’ analyzed by user. We also explored the percentages of usage of ‘Accepted+Wait-User’, considering the total number of events occurred by users, to have more validity in analysis. We, at this point, excluded ‘Siebel’, not a real action owner but only used in the system, from the analysis result.

OWNER_FIRST_NAME	WAIT_USER_CNT	TOTAL_CNT	WAIT_USER_CNT /TOTAL_CNT
Pawel	123	925	13.3 %
Muthu	80	355	22.5 %
Brecht	75	477	15.7 %
Marcin	71	688	10.3 %
Fredrik	69	585	11.8 %
Andreas	63	542	11.6 %
Katia	62	449	13.8 %
Krzysztof	56	1173	4.8 %
Emil	55	322	17.1 %
Nina	48	291	16.5 %

Fig. 25. Top 10 action owner using ‘Accepted+Wait-User’ frequently

Although ‘Pawel’ mostly uses 'Accepted+Wait-User’, ‘Muthu’ can be also recognized to use as much as ‘Pawel’ when we consider its number of events. In case of ‘Krzysztof’, meanwhile, it shows its highly placed frequency based on the absolute numerical value, whereas it shows its outstandingly lower frequency when we consider its total number of events.

3.4.3 Each Pattern of Using ‘Accepted+Wait-User’ Found in Support Team, Function Division, and Organization

We intend to call the pattern of usage of ‘Accepted+Wait-User’ as a combination of activities occurred right before and after it. Based on this definition, we found that the total number of patterns of usage of ‘Accepted+Wait-User’ was 40 (see <Fig. 26>). Before we generate this result, the uncompleted case was removed from the dataset.

Before	Target	After	Count
Accepted+In Progress	Accepted+Wait - User	Accepted+In Progress	1285
Accepted+In Progress	Accepted+Wait - User	Completed+Resolved	1160
Accepted+In Progress	Accepted+Wait - User	Queued+Awaiting Assignment	517
Accepted+In Progress	Accepted+Wait - User	Accepted+Wait - User	215
Accepted+In Progress	Accepted+Wait - User	Accepted+Assigned	195
Accepted+Wait - User	Accepted+Wait - User	Completed+Resolved	107
Accepted+Wait	Accepted+Wait - User	Accepted+In Progress	90
Accepted+Wait - User	Accepted+Wait - User	Accepted+Wait - User	88
Accepted+Wait	Accepted+Wait - User	Completed+Resolved	68
Accepted+Wait - User	Accepted+Wait - User	Accepted+In Progress	61
Accepted+Wait - User	Accepted+Wait - User	Queued+Awaiting Assignment	58
Accepted+Wait	Accepted+Wait - User	Queued+Awaiting Assignment	29
Accepted+In Progress	Accepted+Wait - User	Accepted+Wait	29
Accepted+Wait - Implementation	Accepted+Wait - User	Completed+Resolved	26
Accepted+In Progress	Accepted+Wait - User	Accepted+Wait - Implementation	20
Accepted+In Progress	Accepted+Wait - User	Accepted+Wait - Vendor	19
Accepted+Wait - Implementation	Accepted+Wait - User	Accepted+In Progress	15
Accepted+Wait - Vendor	Accepted+Wait - User	Completed+Resolved	14
Accepted+Wait	Accepted+Wait - User	Accepted+Assigned	10
Accepted+Wait	Accepted+Wait - User	Accepted+Wait	9
Accepted+Wait	Accepted+Wait - User	Accepted+Wait - User	9
	Accepted+Wait - User	Accepted+Wait - User	9
Accepted+Wait - Implementation	Accepted+Wait - User	Queued+Awaiting Assignment	8
Accepted+Wait - User	Accepted+Wait - User	Accepted+Assigned	7
Accepted+Wait - Vendor	Accepted+Wait - User	Accepted+In Progress	5
Accepted+Wait	Accepted+Wait - User	Accepted+Wait - Implementation	5
Accepted+Wait- Customer	Accepted+Wait - User	Completed+Resolved	5
Accepted+Wait - Implementation	Accepted+Wait - User	Accepted+Wait - Implementation	3
Accepted+Wait - Vendor	Accepted+Wait - User	Accepted+Assigned	2
Accepted+In Progress	Accepted+Wait - User	Accepted+Wait - Customer	2
Accepted+Wait - User	Accepted+Wait - User	Accepted+Wait - Vendor	2
Accepted+Wait - Implementation	Accepted+Wait - User	Accepted+Wait - Vendor	2
Accepted+Wait - Implementation	Accepted+Wait - User	Accepted+Wait - User	2
Accepted+Wait - Implementation	Accepted+Wait - User	Accepted+Assigned	1
Accepted+Wait - Customer	Accepted+Wait - User	Accepted+In Progress	1
Accepted+Wait - Vendor	Accepted+Wait - User	Accepted+Wait - Vendor	1
Accepted+Wait - User	Accepted+Wait - User	Accepted+Wait	1
Accepted+Wait	Accepted+Wait - User	Accepted+Wait - Customer	1
Accepted+Wait - User	Accepted+Wait - User	Accepted+Wait - User	1
Accepted+Wait - Customer	Accepted+Wait - User	Accepted+Wait - Implementation	1

Fig. 26. Pattern of usage of 'Accepted+Wait-User’ found on incident management process and its occurrence frequency

There are 649 support teams, 25 organizations, and 24 function divisions which are involved in incident management process. For we could not deal with them all in this paper, we chose two representative support teams, organizations, and function divisions of each by considering number of recorded events. We sought to answer the second question by analyzing what kinds of patterns among the 52 patterns of usage we found and how frequently the patterns are used by the selected support teams, organizations, and function divisions. As shown <Fig. 27>, we drew a graph containing events occurred in two represents of each support team, organization, and function division and rest of all events arose in organizational unit. ‘G97’ and ‘G96’ in support teams, ‘Org Line C’ and ‘Org line A2’ in Organizations, and ‘V3_2’ and ‘A2_1’ in function divisions are represents chosen for this analysis.

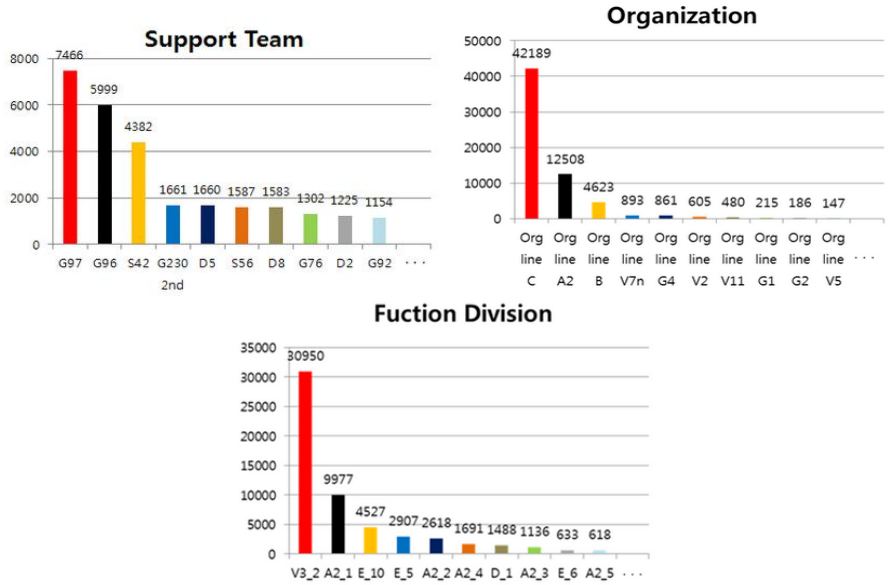


Fig. 27. Selected two representative support teams, organizations, and function divisions of each

We extracted every incident management process log from the six selected groups: two support teams, two organizations, and two function divisions. Then we compared each pattern of usage and the frequency of use by organizational units.

<Fig. 28> shows what kind of pattern the support teams 'G97’ and 'G96’ have and how frequently they use the pattern. The red parts are equally shared pattern which both two support teams have. The support team 'G97’ uses a little more pattern than 'G96’ and both teams show similar pattern-usage together.

G97

Before	Target	After	Count
Accepted+In Progress	Accepted+Wait - User	Accepted+In Progress	471
Accepted+In Progress	Accepted+Wait - User	Completed+Resolved	60
Accepted+In Progress	Accepted+Wait - User		49
Accepted+Wait	Accepted+Wait - User	Accepted+In Progress	21
Accepted+In Progress	Accepted+Wait - User	Accepted+Assigned	18
Accepted+Wait	Accepted+Wait - User	Completed+Resolved	14
Accepted+In Progress	Accepted+Wait - User	Accepted+Wait - User	11
Accepted+In Progress	Accepted+Wait - User	Queued+Awaiting Assignment	10
Accepted+Wait - User	Accepted+Wait - User		6
Accepted+In Progress	Accepted+Wait - User	Accepted+Wait	6
Accepted+Wait	Accepted+Wait - User		5
Accepted+Wait - User	Accepted+Wait - User	Accepted+In Progress	5
Accepted+Wait - Implementation	Accepted+Wait - User	Completed+Resolved	3
Accepted+Wait - Implementation	Accepted+Wait - User	Accepted+In Progress	2
Accepted+In Progress	Accepted+Wait - User	Accepted+Wait-Implementation	2
Accepted+Wait	Accepted+Wait - User	Accepted+Wait	2
Accepted+Wait - Implementation	Accepted+Wait - User		2
Accepted+Wait - User	Accepted+Wait - User	Queued+Awaiting Assignment	1
Accepted+Wait	Accepted+Wait - User	Accepted+Wait-User	1

G96

Before	Target	After	Count
Accepted+In Progress	Accepted+Wait - User	Accepted+In Progress	101
Accepted+In Progress	Accepted+Wait - User		31
Accepted+In Progress	Accepted+Wait - User	Completed+Resolved	22
Accepted+Wait	Accepted+Wait - User	Accepted+In Progress	7
Accepted+In Progress	Accepted+Wait - User	Accepted+Wait - User	5
Accepted+Wait-User	Accepted+Wait - User		4
Accepted+In Progress	Accepted+Wait - User	Accepted+Assigned	3
Accepted+Wait - Implementation	Accepted+Wait - User	Queued+Awaiting Assignment	1
Accepted+Wait	Accepted+Wait - User	Accepted+Wait	1
Accepted+In Progress	Accepted+Wait - User	Accepted+Wait	1
Accepted+Wait	Accepted+Wait - User		1
Accepted+Wait-User	Accepted+Wait - User	Accepted+In Progress	1
Accepted+Wait	Accepted+Wait - User	Completed+Resolved	1

Fig. 28. Pattern of usage of ‘Accepted+Wait-User’ ’and the frequency of use found in support teams 'G97’ and 'G96’

<Fig. 29> shows the pattern of usage and frequency of use found in organizations 'Org Line C’ and ‘Org Line A2’. We could find that 'Org Line C’ uses more patterns than ‘Org Line A2’. 'Org Line C’ uses whole patterns that were found in incident management process. Some parts of the patterns between two organizations are a little different. For example, a flow like 'Accepted+In Progress’ → ‘Accepted+Wait-User’ → ‘Accepted+Assigned’ is the fourth largest in 'Org Line C’, which is found on the list at 10 in case of 'Org Line A2’.

Org line C

Before	Target	After	Count
Accepted+In Progress	Accepted+Wait - User	Accepted+In Progress	902
Accepted+In Progress	Accepted+Wait - User	Completed+Resolved	738
Accepted+In Progress	Accepted+Wait - User	Queued+Awaiting Assignment	227
Accepted+In Progress	Accepted+Wait - User	Accepted+Assigned	165
Accepted+In Progress	Accepted+Wait - User		137
Accepted+In Progress	Accepted+Wait - User	Accepted+Wait - User	109
Accepted+Wait - User	Accepted+Wait - User	Accepted+Wait - User	59
Accepted+Wait - User	Accepted+Wait - User	Completed+Resolved	51
Accepted+Wait	Accepted+Wait - User	Accepted+In Progress	39
Accepted+Wait	Accepted+Wait - User	Completed+Resolved	32
Accepted+Wait - User	Accepted+Wait - User	Accepted+In Progress	28
Accepted+Wait - Implementation	Accepted+Wait - User	Completed+Resolved	21
Accepted+Wait - User	Accepted+Wait - User	Queued+Awaiting Assignment	20
Accepted+Wait - User	Accepted+Wait - User		18
Accepted+In Progress	Accepted+Wait - User	Accepted+Wait	17
Accepted+In Progress	Accepted+Wait - User	Accepted+Wait - Implementation	12
Accepted+Wait – Vendor	Accepted+Wait - User	Completed+Resolved	11
Accepted+In Progress	Accepted+Wait - User	Accepted+Wait - Vendor	11
	Accepted+Wait - User	Accepted+Wait - User	9
Accepted+Wait - Implementation	Accepted+Wait - User	Accepted+In Progress	8
Accepted+Wait	Accepted+Wait - User	Queued+Awaiting Assignment	8
Accepted+Wait	Accepted+Wait - User	Accepted+Assigned	6
Accepted+Wait – Implementation	Accepted+Wait - User	Queued+Awaiting Assignment	6
Accepted+Wait	Accepted+Wait - User	Accepted+Wait - User	6
Accepted+Wait	Accepted+Wait - User		5
Accepted+Wait	Accepted+Wait - User	Accepted+Wait	5
Accepted+Wait – Vendor	Accepted+Wait - User	Accepted+In Progress	5
Accepted+Wait – User	Accepted+Wait - User	Accepted+Assigned	5
Accepted+Wait – Implementation	Accepted+Wait - User		4
Accepted+Wait – Vendor	Accepted+Wait - User	Accepted+Assigned	2
Accepted+In Progress	Accepted+Wait - User	Accepted+Wait - Customer	2
Accepted+Wait - User	Accepted+Wait - User	Accepted+Wait - Vendor	2
Accepted+Wait – Implementation	Accepted+Wait - User	Accepted+Wait – Implementation	1
Accepted+Wait – Vendor	Accepted+Wait - User	Accepted+Wait - User	1
Accepted+Wait - Customer	Accepted+Wait - User	Completed+Resolved	1
Accepted+Wait - Customer	Accepted+Wait - User	Accepted+In Progress	1
Accepted+Wait - User	Accepted+Wait - User	Accepted+Wait	1
Accepted+Wait - Implementation	Accepted+Wait - User	Accepted+Assigned	1
Accepted+Wait - Vendor	Accepted+Wait - User	Accepted+Wait – Vendor	1
Accepted+Wait	Accepted+Wait - User	Accepted+Wait - Implementation	1

Org line A2

Before	Target	After	Count
Accepted+In Progress	Accepted+Wait - User	Completed+Resolved	309
Accepted+In Progress	Accepted+Wait - User	Accepted+In Progress	161
Accepted+In Progress	Accepted+Wait - User	Accepted+Wait - User	84
Accepted+In Progress	Accepted+Wait - User		48
Accepted+In Progress	Accepted+Wait - User	Queued+Awaiting Assignment	44
Accepted+Wait - User	Accepted+Wait - User	Completed+Resolved	43
Accepted+Wait - User	Accepted+Wait - User	Accepted+Wait – User	27
Accepted+Wait - User	Accepted+Wait - User	Accepted+In Progress	26
Accepted+Wait	Accepted+Wait - User	Completed+Resolved	15

Accepted+In Progress	Accepted+Wait - User	Accepted+Assigned	12
Accepted+Wait - User	Accepted+Wait - User	Queued+Awaiting Assignment	12
Accepted+In Progress	Accepted+Wait - User	Accepted+Wait - Implementation	6
Accepted+Wait	Accepted+Wait - User		5
Accepted+Wait	Accepted+Wait - User	Accepted+In Progress	5
Accepted+In Progress	Accepted+Wait - User	Accepted+Wait	4
Accepted+Wait - User	Accepted+Wait - User		3
Accepted+Wait - Customer	Accepted+Wait - User	Completed+Resolved	3
Accepted+Wait - Implementation	Accepted+Wait - User	Accepted+Wait - Vendor	2
Accepted+Wait - Implementation	Accepted+Wait - User	Accepted+In Progress	2
Accepted+Wait - Implementation	Accepted+Wait - User	Accepted+Wait - Implementation	2
	Accepted+Wait - User	Queued+Awaiting Assignment	2
Accepted+Wait - Implementation	Accepted+Wait - User	Accepted+Wait - User	1
Accepted+Wait - User	Accepted+Wait - User	Accepted+Assigned	1
Accepted+Wait	Accepted+Wait - User	Accepted+Wait - Customer	1
Accepted+Wait	Accepted+Wait - User	Accepted+Wait	1
Accepted+Wait - Implementation	Accepted+Wait - User	Completed+Resolved	1
Accepted+In Progress	Accepted+Wait - User	Accepted+Wait - Vendor	1
Accepted+Wait - Customer	Accepted+Wait - User	Accepted+Wait - Implementation	1

Fig. 29. Pattern of usage of ‘Accepted+Wait-User’ ’and the frequency of use found in 'Org Line C’ and 'Org Line A2’

In <Fig. 30>, it is possible to check the pattern of usage and frequency of use which were found in function divisions 'V3_2’ and 'A2_1’. Each division 'V3_2’ and 'A2_1’ use 33 patterns and 27 patterns respectively. The order of lists shown in those two function divisions are different each other.

V3_2

Before	Target	After	Count
Accepted+In Progress	Accepted+Wait - User	Accepted+In Progress	801
Accepted+In Progress	Accepted+Wait - User	Completed+Resolved	545
Accepted+In Progress	Accepted+Wait - User	Queued+Awaiting Assignment	104
Accepted+In Progress	Accepted+Wait - User		91
Accepted+In Progress	Accepted+Wait - User	Accepted+Assigned	66
Accepted+Wait	Accepted+Wait - User	Accepted+In Progress	38
Accepted+In Progress	Accepted+Wait - User	Accepted+Wait - User	35
Accepted+Wait	Accepted+Wait - User	Completed+Resolved	29
Accepted+Wait – User	Accepted+Wait - User	Queued+Awaiting Assignment	15
Accepted+In Progress	Accepted+Wait - User	Accepted+Wait	15
Accepted+Wait - User	Accepted+Wait - User	Accepted+In Progress	13
Accepted+In Progress	Accepted+Wait - User	Accepted+Wait - Vendor	12
Accepted+Wait – User	Accepted+Wait - User	Completed+Resolved	10
Accepted+Wait – Vendor	Accepted+Wait - User	Completed+Resolved	9
Accepted+Wait – User	Accepted+Wait - User		9
	Accepted+Wait - User	Accepted+Wait - User	9
Accepted+Wait - Implementation	Accepted+Wait - User	Completed+Resolved	8
Accepted+Wait	Accepted+Wait - User		6
Accepted+Wait	Accepted+Wait - User	Accepted+Assigned	5
Accepted+Wait	Accepted+Wait - User	Accepted+Wait	4
Accepted+In Progress	Accepted+Wait - User	Accepted+Wait - Implementation	4
Accepted+Wait	Accepted+Wait - User	Accepted+Wait - User	4
Accepted+Wait	Accepted+Wait - User	Queued+Awaiting Assignment	3
Accepted+Wait – Vendor	Accepted+Wait - User	Accepted+In Progress	3
Accepted+Wait - Implementation	Accepted+Wait - User	Accepted+In Progress	2
Accepted+Wait - Implementation	Accepted+Wait - User		2

Accepted+Wait	Accepted+Wait - User	Accepted+Wait - Implementation	1
Accepted+Wait - Implementation	Accepted+Wait - User	Queued+Awaiting Assignment	1
Accepted+Wait - User	Accepted+Wait - User	Accepted+Wait - Vendor	1
Accepted+Wait - Vendor	Accepted+Wait - User	Accepted+Assigned	1
Accepted+Wait - Customer	Accepted+Wait - User	Completed+Resolved	1
	Accepted+Wait - User	Accepted+In Progress	1
Accepted+In Progress	Accepted+Wait - User	Accepted+Wait - Customer	1

A2_1

Before	Target	After	Count
Accepted+In Progress	Accepted+Wait - User	Accepted+Wait - User	146
Accepted+In Progress	Accepted+Wait - User	Completed+Resolved	134
Accepted+In Progress	Accepted+Wait - User	Accepted+In Progress	91
Accepted+Wait - User	Accepted+Wait - User	Accepted+Wait - User	88
Accepted+Wait - User	Accepted+Wait - User	Completed+Resolved	83
Accepted+In Progress	Accepted+Wait - User	Queued+Awaiting Assignment	82
Accepted+In Progress	Accepted+Wait - User		57
Accepted+Wait - User	Accepted+Wait - User	Accepted+In Progress	33
Accepted+Wait - User	Accepted+Wait - User	Queued+Awaiting Assignment	21
Accepted+In Progress	Accepted+Wait - User	Accepted+Assigned	14
Accepted+Wait - User	Accepted+Wait - User		11
Accepted+Wait	Accepted+Wait - User	Completed+Resolved	6
Accepted+Wait - User	Accepted+Wait - User	Accepted+Assigned	5
Accepted+Wait	Accepted+Wait - User	Accepted+Wait - User	5
Accepted+Wait	Accepted+Wait - User		3
Accepted+Wait - Implementation	Accepted+Wait - User	Accepted+Wait - User	2
Accepted+In Progress	Accepted+Wait - User	Accepted+Wait - Vendor	2
Accepted+Wait - Vendor	Accepted+Wait - User	Completed+Resolved	2
Accepted+In Progress	Accepted+Wait - User	Accepted+Wait	2
Accepted+Wait	Accepted+Wait - User	Accepted+In Progress	2
Accepted+Wait - Vendor	Accepted+Wait - User	Accepted+In Progress	1
Accepted+Wait - Customer	Accepted+Wait - User	Completed+Resolved	1
Accepted+Wait	Accepted+Wait - User	Queued+Awaiting Assignment	1
Accepted+Wait - Vendor	Accepted+Wait - User	Accepted+Wait - Vendor	1
Accepted+Wait-User	Accepted+Wait - User	Accepted+Wait - Vendor	1
Accepted+Wait - Implementation	Accepted+Wait - User	Completed+Resolved	1
Accepted+Wait - Vendor	Accepted+Wait - User	Accepted+Wait - User	1

Fig. 30. Pattern of usage of ‘Accepted+Wait-User’ ’and the frequency of use found in function divisions 'V3_2’and 'A2_1’

3.4.4 Locations Where Abuse of ‘Accepted+Wait-User’ Is Found

There are 22 countries total which are involved in incident management process. In this context, we found that ‘Accepted+Wait-User’ is used repeatedly in the same case (see <Fig. 31>).

country	the number of cases	the number of repetitions									
		2	3	4	5	6	7	8	9	10~	20~
se	2894	144	56	31	11	3	4	1			
pl	1762	147	60	36	11	7	2	5		2	
us	780	26	10	2	2	1					
in	492	80	37	13	10	4	2		3		
be	482	46	23	11	3	2	3		1	2	1
br	311	13	4	2	1		1				
fr	309	20	7	3		1					
cn	101	14	3	1	2			1			
ca	66	1	1								
kr	65	4	2	2							
SE	61	2									
nl	58	7	6					2			
ru	45	3									
my	26	1									
au	25	1									
gb	22	2		1							
jp	15										
th	6										
cl	3										
pe	2										
de	2						1				
tr	1										

Fig. 31. Repetitive usage in ‘Accepted+Wait-User by country

<Fig. 31> shows the result which is sorted in descending order depending on the total number of cases. It is shown that there are the largest number of cases in ‘se’, and the smallest number in ‘tr’. In this context, it is possible that the higher a country is on the list, the more ‘Accepted+Wail-User’ is repeated. In case of 'be’, however, we could find that there are enough number of repetitions (especially there is a case repeated over 20 times) as much as ‘se’ and ‘pl’.

3.5 Process Conformity per Organization

Lastly, we focused on how much the incident and problem management processes arose in one organization conform to those in others. There is an open problems management dataset, among the given problems management, composed of uncompleted problems management. Because it is hard to say that this kind of process which is a conclusion drawn from uncompleted problems management has representativeness, we excepted this open problems management dataset from analysis. The problems management dataset, therefore, is a closed problems

management dataset. And the uncompleted incident management was removed from incident management dataset, either.

3.5.1 The Range of Comparison in Conformity

In Volvo IT, there are 25 organizations total including 'Org Line A2' and 'Org Line C'. As shown below, <Fig. 32> represents the number and rate of events related to each organization in incidents and the problems.

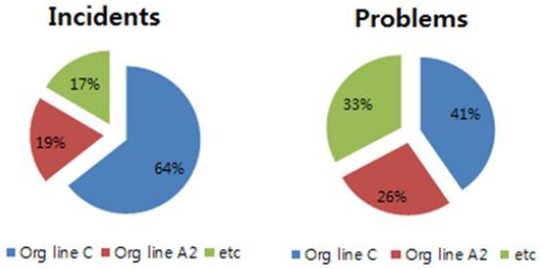


Fig. 32. The number and rate of events related to each organization in incidents and the problems

As in the figure above, over 83% of all events related to incident management is about 'Org Line A2' and 'Org Line C', which comprise more than 67% of problem management events. Consequently, we decided to consider 'Org Line A2' and 'Org Line C' as organizations which have representativeness and compare and analyze process between these two organizations: 'Org Line A2' and 'Org Line C'.

To analyze processes in different angles, on the other hand, process mining analysis helps various attributes (or combination of attributes) included in event log to be set as activities. Let us suppose, for example, there are status, support team, etc among attributes which are set as activities in incident management dataset. As shown in <Fig. 33> and <Fig. 34>, we are able to find that the two types of incident management process which set status or support team as activities show different angle each.

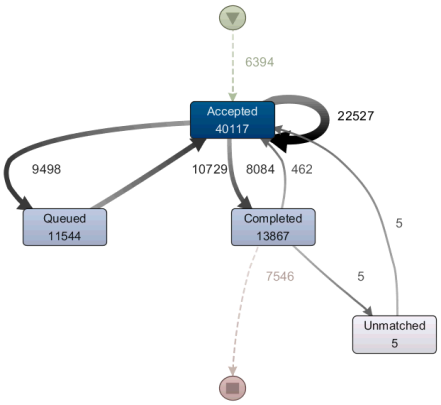


Fig. 33. An incident management process viewed from the angle of the status

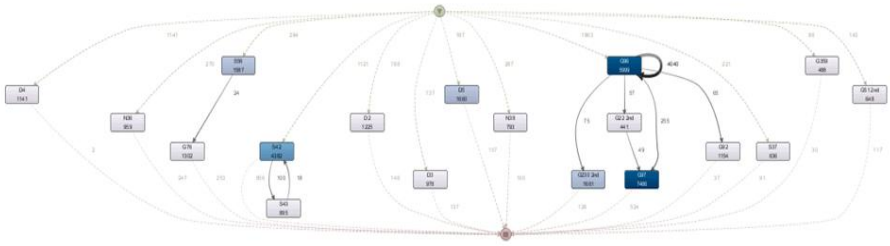


Fig. 34. An incident management process viewed from the angle of the support team

In this context, it is obvious that the processes of two organization 'Org line A2' and 'Org Line C' could also have various figures as looked from different angles. Considering angles to compare and analyze processes of two different organizations, therefore, is making a significant attempt.
However, to compare processes of two organizations, we intend to set the combination of two attributes ('status' and 'sub-status') as activities. It is because that this setting shows the most typical figure of the process.

3.5.2 The Standards of Comparing Conformity

Creating a standard of comparing conformity between two processes, we focused on the components of process model. There are differences in process model components in notations. We, therefore, chose a notation used by Disco while there are many notations of process model. This notation consists of activities representable as square boxes and flows between activities representable as arrows. Accordingly, standard to compare the processes of two organizations are supposed to be activities composing processes and flows between activities.

3.5.3 Data Extraction

To compare processes of two organizations, we extracted data from 'Org Line A2' and 'Org Line C' using the standard and range we set earlier(refer to <Fig. 35,36,37,38>).

To measure the conformity of a process of one organization to a process of the other, first of all, it was planned for two organizations to be compared each other based on the extracted data (in a structural perspective). Then we sought to compare every possible inter-organizational flows between two organizations (in behavioural perspective).

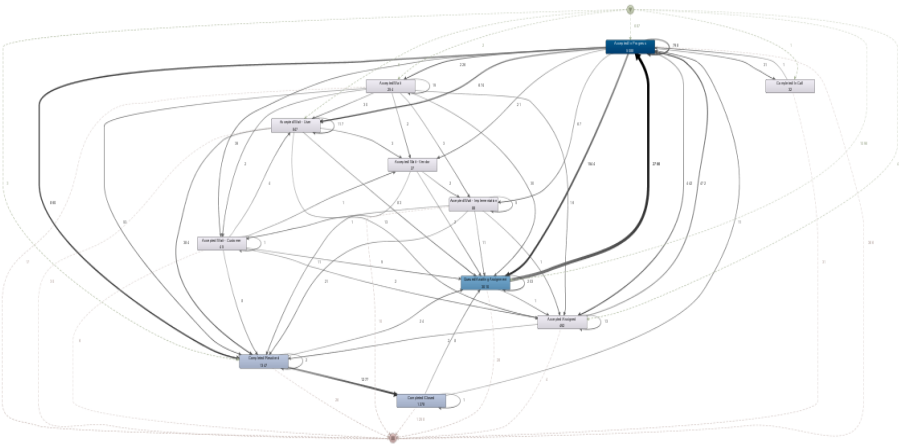


Fig. 35. Incident management processes of ‘Org Line A2’

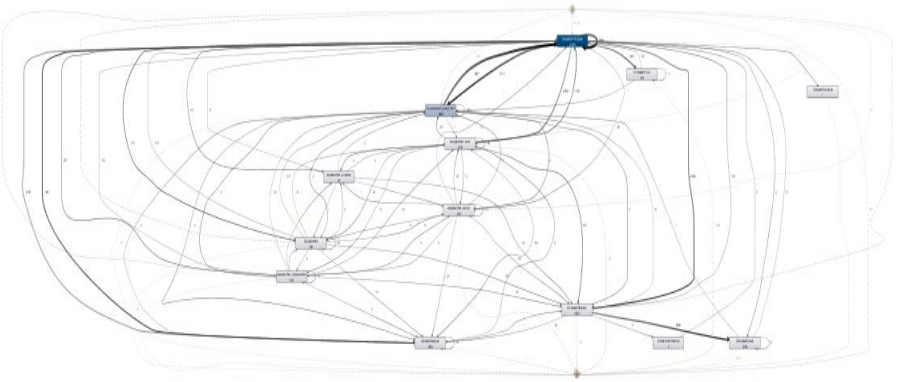


Fig. 36. Incident management processes of ‘Org Line C’

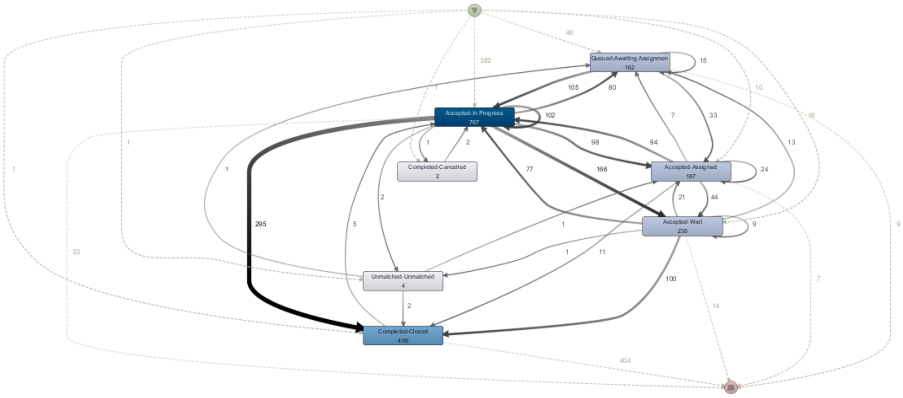


Fig. 37. Problem management processes of ‘Org Line A2’

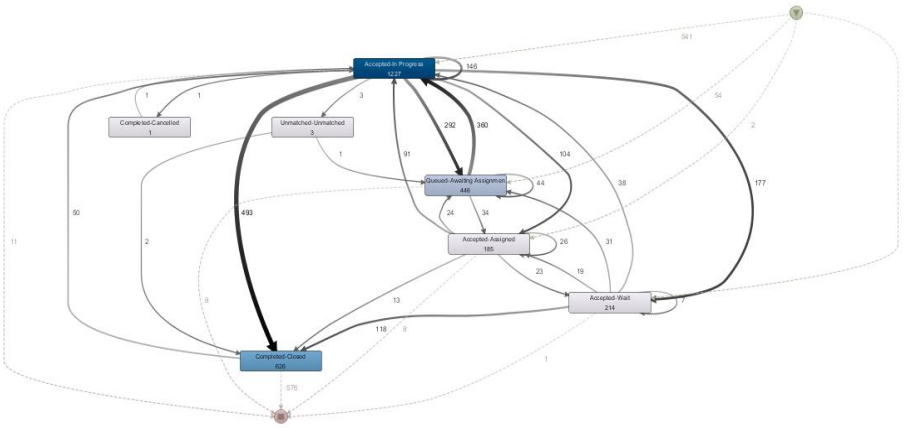


Fig. 38. Problem management processes of 'Org Line C'

3.5.4 Comparison in Structural Perspective

<Fig. 39> shows the activities composing incident management processes for two organizations and their occurrences. We observed several activities performed by 'Org Line C' which was not found on 'Org Line A2': 'Completed+Cancelled' and 'Unmatched+Unmatched'. There are differences, moreover, in occurrence frequency. For example, 'Org Line A2' and 'Org Line C' comprise 24.06% and 14.22% each of occurrence in 'Queued+Awaiting Assignment'.

Org Line A2

Value	Frequency
Accepted+In Progress	5013
Queued+Awaiting Assignment	2988
Completed+Resolved	1320
Completed+Closed	1278
Accepted+Wait-User	822
Accepted+Assigned	487
Accepted+Wait	250
Accepted+Wait-Implementation	85
Accepted+Wait-Cusomer	44
Accepted+Wait-Vendor	27

Org Line C

Value	Frequency
Accepted+In Progress	16816
Queued+Awaiting Assignment	5931
Completed+Resolved	3586
Completed+Closed	3364
Accepted+Wait-User	2678
Accepted+Assigned	2217
Accepted+Wait	779
Accepted+Wait-Implementation	311
Accepted+Wait-Vendor	236
Completed+In Call	150
Accepted+Wait-Customer	39
Unmatched+Unmatched	5

Fig. 39. Activities composing incident management processes for two organizations, 'Org Line A2' and 'Org Line C', and their occurrences

<Fig. 40> illustrates the activities composing problem management processes for two organizations and their occurrences. Differently from the incident management processes, in problem management process, the activities performed in two organizations are in conformity with each other. The percentages, moreover, of activities occurrences are about the same.

Org Line A2

Value	Frequency
Accepted+In Progress	767
Completed+Closed	409
Accepted+Wait	235
Accepted+Assigned	187
Queued+Awaiting Assignment	162
Unmatched+Unmatched	4
Completed+Cancelled	2

Org Line C

Value	Frequency
Accepted+In Progress	1227
Completed+Closed	626
Queued+Awaiting Assignment	446
Accepted+Wait	214
Accepted+Assigned	185
Unmatched+Unmatched	3
Completed+Cancelled	1

Fig. 40. Activities composing problem management processes for two organizations, 'Org Line A2' and 'Org Line C', and their occurrences

3.5.5 Comparison in Behavioural Perspective

As stated above, we sought to explore and compare the every possible process of two organizations. To explore every possible flows, we used a footprint matrix, which is usually utilized for comparing the conformity between (drawn)process models and event log in conformance checking which is one of the process mining methods.

Comparing activities composing incident management processes, we found that there are two activities, Completed + Cancelled and Unmatched + Unmatched, on 'Org Line C' only. We attempted in analysis, excluding events related to those two activities, to compare two processes in behavioural perspective. We moreover used alphabetic characters like <Fig. 41> instead of using names of activities for the convenience of expression.

A	Accepted+Assigned
B	Accepted+In Progress
C	Accepted+Wait – User
D	Completed+Resolved
E	Accepted+Wait – Customer
F	Accepted+Wait –Implementation
G	Accepted+Wait – Vendor
H	Accepted+Wait
I	Completed+In Call
J	Queued+Awaiting Assignment
K	Completed+Closed

Fig. 41. Names of activities substituted with alphabetic characters (incident management processes)

<Fig. 42> shows footprint matrices drawn from each incident management process of two organizations.

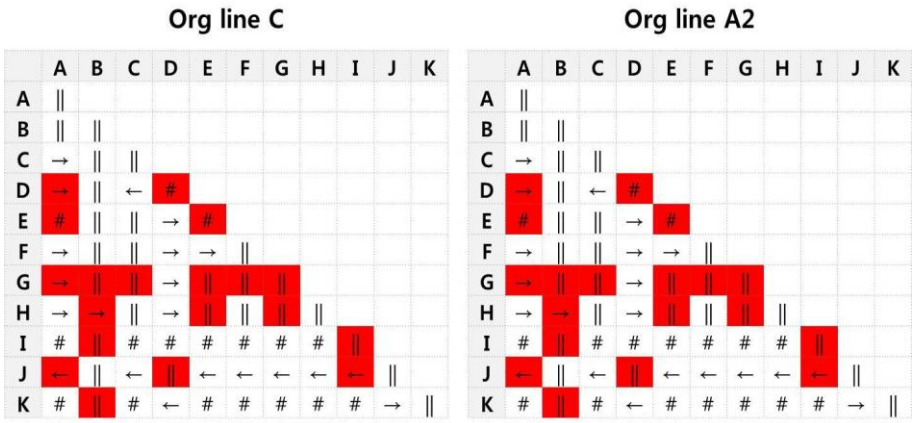


Fig. 42. Footprint matrices drawn from incident management processes of 'Org Line A2' and 'Org Line C'

There are three commonly used symbols on footprint matrix here: #, →, ||. By using these symbols, we could easily find the differences between behaviours drawn from two processes. For example, 'X # Y' means that there is no relation between activity X and activity Y in terms of execution order. 'X → Y' means that activity Y follows activity X and there is no inverse scenario. Lastly, 'X || Y' shows that activity X is performed in parallel with activity Y. That is, activity X is followed by activity Y and the inverse scenario is also possible. The red boxes above on the footprint matrices show the differences found by comparing two organizations. We could recognize the parts showing differences between behaviours of two processes.

Besides, there is another method of comparing two processes: counting flows in each case and comparing them. There is comparative outcome via this method on <Fig. 43>.

Org line A2

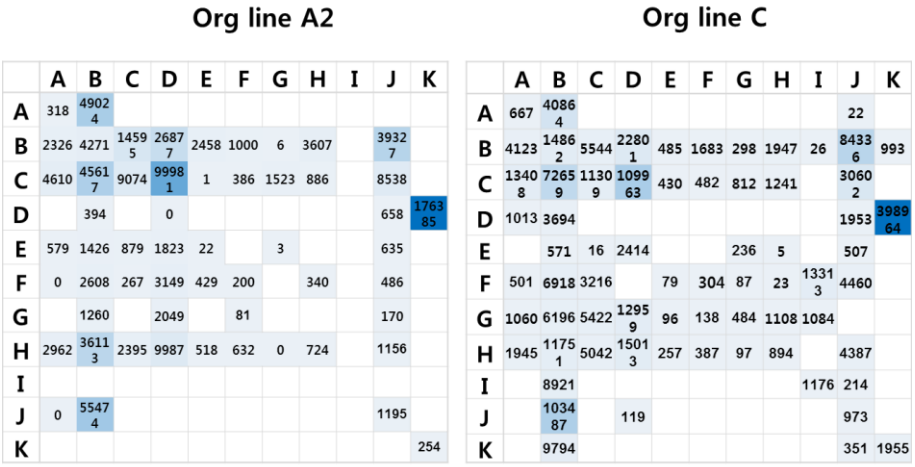
	A	B	C	D	E	F	G	H	I	J	K
A	12	472									
B	442	767	669	858	39	66	21	225		1544	
C	13	198	112	371	1	9	3	5		83	
D		18		2						23	1277
E	2	14	4	7	1		1			9	
F	1	30	8	19	1	5		1		11	
G		9		11		2				2	
H	16	81	29	52	2	3	2	19		29	
I											
J	1	2761								201	
K											1

Org line C

	A	B	C	D	E	F	G	H	I	J	K
A	73	2140								3	
B	1875	3947	2320	2370	33	275	194	713	133	4078	2
C	179	993	184	854	2	14	14	23		370	
D	18	161								53	3354
E		8	2	25			1	1		2	
F	7	97	41	91	1	12	5	1		52	
G	23	70	20	86	1	2	12	5		16	
H	42	267	102	159	2	8	9	36		121	
I		132							17	1	
J		5629		1						284	
K		75								7	8

Fig. 43. Comparative outcome of counting flows in each of two organizations (incident management process)

The last method, added to this, is to calculate the average time to make flows for each process and compare the outcome. <Fig. 44> contains the result of it.



	A	B	C	D	E	F	G	H	I	J	K
A	318	49024									
B	2326	4271	14595	26877	2458	1000	6	3607		39327	
C	4610	45617	9074	99981	1	386	1523	886		8538	
D		394		0						658	176385
E	579	1426	879	1823	22		3			635	
F	0	2608	267	3149	429	200		340		486	
G		1260		2049		81				170	
H	2962	36113	2395	9987	518	632	0	724		1156	
I											
J	0	55474								1195	
K											254

	A	B	C	D	E	F	G	H	I	J	K
A	667	40864								22	
B	4123	14862	5544	22801	485	1683	298	1947	26	84336	993
C	13408	72659	11309	109963	430	482	812	1241		30602	
D	1013	3694								1953	398964
E		571	16	2414			236	5		507	
F	501	6918	3216		79	304	87	23	13313	4460	
G	1060	6196	5422	12959	96	138	484	1108	1084		
H	1945	11751	5042	15013	257	387	97	894		4387	
I		8921							1176	214	
J		103487		119						973	
K		9794								351	1955

Fig. 44. Comparative outcome of calculating the average time to make flows for two organizations (incident management process) (in hours)

To compare problem management processes between two organizations, similarly, those methods mentioned above are used. As shown on <Fig. 45>, first of all, we used alphabetic characters instead of using names of activities which compose problem management processes, giving the convenience of expression. The following comparative methods are similar with methods used for comparing incident management processes.

A	Accepted+Assigned
B	Accepted+In Progress
C	Accepted+Wait
D	Completed+Closed
E	Queued+Awaiting Assignment
F	Completed+Cancelled
G	Unmatched+Unmatched

Fig. 45. Names of activities substituted with alphabetic characters (problem management processes)

Org Line A2

	A	B	C	D	E	F	G
A	||						
B	||	||					
C	||	||	||				
D	→	||	←	#			
E	||	||	←	#	||		
F	#	||	←	#	#	#	
G	→	←	#	→	→	#	#

Org Line C

	A	B	C	D	E	F	G
A	||						
B	→	||					
C	||	||	||				
D	←	||	←	#			
E	||	||	←	#	||		
F	#	||	#	#	#	#	
G	#	←	#	→	→	#	#

Fig. 46. Footprint matrices drawn from problem management processes of 'Org Line A2' and 'Org Line C'

Org line A2

	A	B	C	D	E	F	G
A	24	94	44	11	7		
B	98	102	166	295	80	1	2
C	21	77	9	100	13	1	
D		5					
E	33	105			15		
F		2					
G	1			2	1		

Org line C

	A	B	C	D	E	F	G
A	26	91	23	13	24		
B	104	146	177	493	292	1	3
C	19	38	7	118	31		
D		50					
E	34	360			44		
F		1					
G				2	1		

Fig. 47. Comparative outcome of counting flows in each of two organizations (problem management process)

Org line A2

	A	B	C	D	E	F	G
A	27096	183214	56103	7675	8924		
B	120371	433272	245506	372264	7234	23	0
C	60668	292871	6078	239754	27330		19
D		5604					
E	6478	163608			4893		
F		985					
G	8640			34708	3028		

Org line C

	A	B	C	D	E	F	G
A	13406	111363	21593	39121	14295		
B	48315	110520	51715	426792	25606	0	1608
C	3240	54634	878	140370	18722		
D		18653					
E	8650	146171			21705		
F		15					
G				43342	3551		

Fig. 48. Comparative outcome of calculating the average time to make flows for two organizations (problem management process) (in hours)

4. Conclusions

Real life event logs of incident and problem management processes supported by Volvo IT's VINST system were provided for the BPI Challenge 2013. The two logs include 7554/2306 cases and 65533/9011 events respectively. Furthermore, several questions derived from four main issues related to the two processes were raised. To address the questions, we tried to understand the data and create relevant datasets for the questions. Moreover, we attempted to clarify the issues at the log data level.

Although we cannot get any feedback from Volvo IT's stakeholders about our answers and analysis results, we strongly believe that the answers and analysis results are plausible because they are evidence-based. For the first issue, push to front mechanism, we clearly identified products for which the mechanism is most used. Furthermore, we found organization and function divisions that comply with the mechanism. Recall that the mechanism increases work efficiently. Therefore, based on these findings, managers are likely to find ways to improve work efficiency such as sharing best practices of push to front mechanism among organizations and function divisions.

For the ping pong behaviour issue, we found the function divisions, organizations, and support teams responsible for most of ping pong behaviour. We also identified the products which are most affected by this behaviour. These finding help managers reduce the total life time of both an incident and a problem. For example, managers may decide against purchasing products leading to severe ping pong behaviour in the future.

Volvo IT, typically, recommends its action owners not to use the 'wait user' sub status. However, action owners do not always comply with the guideline. To address this third issue, we found who are mainly breaking it and explored the pattern of using 'wait user' sub status per support team, function division, and organization. We also identified locations where abuse of the sub status is found. Based on these findings, managers may give warning to nonconforming action owners.

Finally, we addressed the final issue, process conformity per organization. After defining the range of comparison in conformity, we compared the incident and problem processes of the two organizations (i.e., 'Org Line A2' and 'Org Line C') from structural and behavioural perspectives. Based on the findings, managers may decide where they should focus on to achieve process standardization between the two organizations' processes [3]. Overall, we believe that our process insights gained from the answers and analysis results can help managers precisely identify process improvement opportunities. Therefore we strongly recommend that more managers pay attention to these process mining and other analytical techniques for better process performance and decision making for process improvement initiatives in a big data world [4,5,7,8].

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