Seeing the Forest for the Trees: Group-Oriented Workforce Analytics

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Abstract. Workforce analytics brings data-driven methods to organizations for deriving insights from employee-related data and supports decision making. However, it faces an open challenge of lacking the capability to analyze the behavior of employee groups in order to understand organizational performance. This paper proposes a novel notion of work profiles of resource groups, informed by the management literature, for characterizing resource group behavior from multiple aspects relevant to workforce performance. This notion is central to the design of a new, systematic approach that supports resource group analysis by exploiting business process execution data. The approach also provides managers and business analysts with an intuitive means of group-oriented resource analysis by applying visual analytics. We demonstrate the applicability of the approach and usefulness of the proposed notion of resource group work profiles using real datasets from five Dutch municipalities.

Keywords: Workforce analytics · resource groups · process mining · event logs · visual analytics

1 Introduction

Achieving excellent business process performance within the management of operations is a demanding and crucial challenge for any organization to maintain competitive advantage. The prevalence of information systems has led to many data science applications supporting analyses of organizational performance to address this challenge. Business processes are often at the core of such analyses as they describe how resources of an organization (employees, machines, systems) are connected with each other [3]. The focus of business process analytics is often on the control-flow perspective and process design. However, the aspect of how employees work together in processes to achieve efficiency is also important [21].

Employees are the key resources of an organization. Not only their individual but also collective performance as different units or teams has a direct impact on the outcomes delivered by the organization [33]. Data science applications in this regard are termed *workforce analytics*, which aim at extracting insights from analyzing employee-related data and thus support evidence-based

decisions on human resources [23]. The success of Google's Project Oxygen and other leading-edge enterprises illustrates the value of workforce analytics as an important organizational capability to improve resource planning and performance evaluation. However, as workforce analytics receives growing attention, several challenges have been identified regarding its current practice [20]. One of these challenges concerns the absence of group-level analysis pivotal to strategy execution and organizational effectiveness. For example, current workforce analytics has not yet enabled consistent comparisons across internal groups within organizations [12].

Our research aims to explore a possible solution to improving organizations' capability to conduct group-oriented workforce analytics by systematically exploiting business process execution data. The *motivation* is two-fold. First, business processes often cut across functional boundaries in an organization and collectively involve employees from different functional units to deliver outcomes to customers [18]. The end-to-end nature of processes makes it viable to analyze and compare different resource groups by linking their performance with process outcomes. Second, data recording actual process execution is readily available in many organizations in the form of event logs. With time-stamped information on process instances (e.g., an insurance claim), process activities, and relevant organizational groups (e.g., a group of claim processors), event logs can serve as a valuable and objective data source complementary to survey data commonly used by current workforce analytics in practice [23].

Process mining is the field that studies data-driven process analytics using event logs. With regard to human resources in organizations, the state-of-the-art literature focuses on analyzing individual resources or discovering the formation of resource groups. Studying human resources at the group-level to extract insights on how resources work in groups and how resource groups perform in business processes is underexplored. This leads to the following research question for workforce analytics in process-related digitalization: *how to utilize process execution data for analyzing the behavior of resource groups working in business processes?*

In this paper, we propose a novel notion of *work profile of resource groups*, drawing on relevant studies in the management literature. It comprises an extensible set of quantitative measures for characterizing resource group behavior from multiple aspects, including workload, performance, goal achievement, participation, distribution, and collaboration. Based on this notion, we develop an approach to identify and analyze resource groups' work profiles using event log data. The approach provides managers and business analysts with an intuitive means of group-oriented resource analysis by applying visual analytics. We demonstrate the applicability of the implemented approach and usefulness of the proposed notion of resource group work profiles by analyzing real event logs from five Dutch municipalities.

Our research contributes to addressing the gap of resource-group level analysis in business process management research on a conceptual and also methodological level. From a practical perspective, our research provides the possibility

of strengthening an organization's process-oriented capability in terms of coordinating groups to increase efficiency.

The paper is organized as follows. Sect. 2 reviews existing literature related to resource group analysis. Sect. 3 proposes the notion of work profiles of resource groups. Sect. 4 presents the design of an approach for identifying and analyzing work profiles. Sect. 5 discusses results and findings from evaluating the approach over real-life datasets. Sect. 6 concludes the paper and outlines future work.

2 Resource Group Analysis: Theory and Related Work

The organization of employees in terms of teams or groups and the comparison of their collective performance constitute important topics in management [16]. A team is formed by engaging individuals in collective work with joint effort, whereas a group only represents individuals tied together by certain criteria, not necessarily working jointly [26]. For example, there can be employees from a function-oriented group who work together with those from other function-oriented groups in a team performing a particular process, but having limited interaction with their own group members. In this work, we focus on groups rather than teams.

Groups of employees can be characterized by the interaction between group members. This is addressed by the interactionist theory of behavior, which states that the interaction between individuals in a group determines the performance of the group [24]. Malinowski et al. [22] provide a comprehensive overview of the challenges regarding decision support to identify influencing factors and the related concepts. Next to a person-job fit and a person-vocation fit, individuals interact with their group members, and thus a person-group fit has to be ensured. Whether all group members have an adequate person-group fit can be determined from their interaction and performance [22]. Hence, there are two levels of workforce analysis — group performance and interaction within a group, i.e., the way a group is organized internally.

Within management research, much work has focused on defining general practices while neglecting individual interactionist fits in a group context [14]. An example of such a general practice would be the grouping of employees around the processes they are involved in rather than around the types of tasks they perform. Other general practices state that high performance groups should have, e.g., clearly defined goals, aligned values, and adequate collaboration [8]. In particular, the collaboration aspect remains opaque in such work. The problem with such practices is that they are based on generic assumptions and may not be the best for a specific organization or parts of it. Research in the field of psychology includes individual differences, perceived psychological states regarding various dimensions and aspects, e.g., group cohesion [9]. However, such psychological aspects are often subjectively measured through questioning, conducted sporadically. Hence, these aspects are not considered in this article as focus is on objective measures using process data. Moreover, organizations nowadays are required to be flexible as they are faced with dynamic and ongoing changes of

the environment [32]. Organizational structures need to reflect this by being able to evaluate groups on an ongoing basis — providing data on group comparisons.

Group performance is typically described from a measurement perspective without specifying how to gather and analyze data. Brignall and Ballantine [5] review different performance management models and point out that the utilization of human resources is an essential aspect. The literature reviews conducted by Haynes [13] and Bortoluzzi [4] discuss the measurement of productivity in organizations and identify certain productivity indicators, e.g., working hours, time to completion, and amount of satisfactory outcomes vs. errors. Gibson et al. [10] review the existing measures of group effectiveness in the literature and conduct interviews in several multinational organizations, summarizing five dimensions for measuring the "outcome effectiveness" of groups. Charlwood [6] reports the results from a literature review that identifies theory and evidence on the use of Human-Capital metrics by organizations. The review extracts more than 600 Human-Capital metrics from the literature describing workforce characteristics and the evaluation of workforce efficiency.

With regard to the internal organization of the group, first there are approaches which consider the interaction between groups referring to handovers in processes [21], role descriptions and expertise [1], or communication and control structures [11]. Second, approaches using business process execution data to study human resource groups can be categorized into two topics. One concerns using event logs for analyzing the formation of resource groups, e.g., Schönig et al. [28] propose an approach that uncovers the composition rules of human resource groups in process executions, and Appice [2] proposes a method that reveals the construction and destruction of organizational groups over time using event logs. The other topic concerns the discovery of organizational groups (e.g., [30]), which aims at extracting the grouping structures around resources. Third, there exists research (e.g., [17,25]) focusing on analysis of individual resource behavior by building resource "profiles" from event logs, which represent objective descriptions of how individual resources were involved in process execution. However, it still remains an open question as to what and how to characterize the behavior of resource groups working in processes.

3 Work Profile of Resource Groups

Drawing on the theoretical and conceptual background in the prior section, this section presents the notion of *work profile of resource groups*. A work profile of a resource group can be defined as a collection of *indicators* used to measure different *aspects* of that group of resources in terms of their interaction with relevant work. As with any indicators related to performance, the measurement of indicators includes a connection to time, i.e. a time interval (between t_1 and t_2) in which the respective performance of a group is measured [6]. By specifying the relevant interval, work profiles can reflect the fact that the performance of resource groups is often dynamic due to having shifts and turnover. Hence, the definition of a work profile is as follows:

Definition 1 (Work Profile of a Resource Group). *Let RG be a set of resource group identifiers, $\mathcal{T}$ the universe of timestamps, and $[t_1, t_2)$ a half-open time interval with $t_1, t_2 \in \mathcal{T}$ and $t_1 < t_2$. Let $\mathcal{I}$ be a set of names for possible indicators. Given a resource group $rg \in RG$, $WP = (rg, t_1, t_2, \mathcal{I}, \sigma)$ is a work profile for the resource group during time period $[t_1, t_2)$ where $\sigma : \mathcal{I} \to \mathbb{R}$ specifies the quantified measures of the indicators.*

The definition provides a general representation of indicators measuring different aspects of a resource group over a specific time-frame. By reviewing the management literature, we identified a number of relevant studies [4,5,6,10,13] which can inform the proposal of a resource group's work profile useful for workforce analytics. The indicators refer to the input-throughput-output view on processes [7]. Performance regarding input-output can be measured with indicators related to productivity and efficiency. Whether a specific output is achieved is referred to as goal achievement. Finally, the throughput is reflected by the summation of employee workload in a group. As a result, we present a collection of three general aspects and associated indicators, focusing on a resource group in its entirety.

- ***Workload*** [5]: *What and how much work is a resource group involved in?*
  - allocation – overall amount of work allocated to the group
  - assignment – amount of the group's workload assigned to specific work
  - relative focus – % of the group's workload assigned to specific work
  - relative stake – amount of contribution by the group to specific work
- ***Performance*** [4,6,10,13]: *How does a group perform?*
  - amount-related productivity – amount of work completed by the group
  - time-related productivity – time needed by the group to complete work
  - efficiency – amount of satisfactory work produced by the group
- ***Goal achievement*** [4,10]: *To what extent does a group adhere to goals?*
  - effectiveness – % of established goals accomplished by the group

In this research, we also consider how resource groups interact with work in terms of their involvement in business process execution captured by process event logs. This theoretical focus is reflected in the following aspects and indicators, which measure how group members interact with relevant work in a process, and with each other.

- ***Participation*** [4,6]: *How do group members commit to work?*
  - attendance – number or % of members in the group committing to work
- ***Distribution*** [4]: *How is work distributed over group members?*
  - member load – amount of work allocated to individual group members
  - member assignments – amount of members' workload allocated to specific work
- ***Collaboration*** [6]: *How is the collaboration among group members?*
  - cooperation – extent of collaboration between group members

The above collection of six aspects and associated indicators can be used to form the structure (or template) of a group's work profile for group-oriented analysis. Note that the term "work" here refers to either activities (tasks) or cases of a business process. Analysts can build their own sets of indicators according to different problems and contexts. However, to enumerate a comprehensive, universal set of aspects and indicators would be unrealistic [6] and is beyond this paper's scope.

4 Identifying and Analyzing Work Profiles

We introduce the design of an approach for identifying and analyzing work profiles of resource groups using process event log data. Fig. 1 depicts an overview of the proposed approach consisting of two main phases.

4.1 Identifying Work Profiles

Identify resource groups. The starting point is an event log. As a minimum requirement, the input event log should provide information on cases (instances of process execution), activities, resources, and time. These are satisfied by many event logs as they often record case identifiers, activity labels, resource identifiers, and timestamps as the basic event attributes. Additionally, the input event log may also carry an attribute indicating the group identities of resources.

Given such an event log, the first task is to identify different resource groups. This is straightforward when a group identity attribute is present in the log. Otherwise, organizational group discovery (e.g., [30]) can be applied to extract group identities of resources. In either situation, one can determine the number of resource groups, their members, and thus the associated event data in the log.

Map events onto multiple dimensions. Event logs contain complex and multi-dimensional data capturing the information on various perspectives of process execution. Consider an example of an insurance claim process: a manager (organizational dimension) is in charge of the final review of a claim (activity dimension), and several groups are formed to work on different weekdays (time

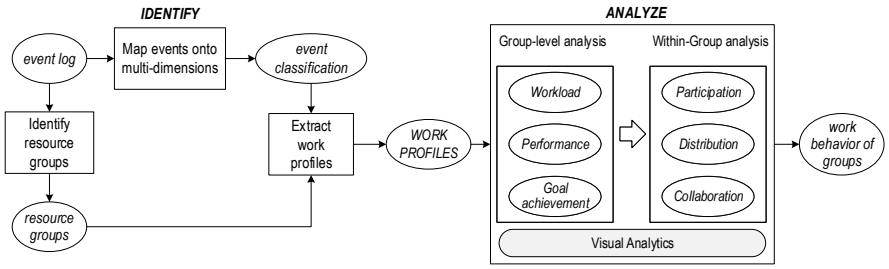


Fig. 1: Overview of the approach to identifying and analyzing work profiles

dimension) to serve customers lodging different types of claims (case dimension). Moreover, from the perspective of resource groups, members in the same group are likely to share common characteristics, e.g., all managers conduct reviews, despite that they may be specialized in handling certain types of claims.

To study the work behavior of resource groups in process execution, we organize events into classes of events based on different dimensions (such as case, activity, time dimensions). Depending on the purpose of an analysis and available information in the input log, analysts can specify different case types, activity types, and time types. For example, to compare the performance of employee groups on different weekdays, seven time types may be defined (e.g., "Monday", "Tuesday"). Consequently, ("car insurance claims", "contact", "Friday") refers to all events on Fridays concerning the work behavior of employees when they contacted customers that had lodged car insurance claims.

Based on the classification of events according to various process dimensions, indicators of work profiles can be calculated respectively. It therefore enables more targeted analyses on the work behavior of groups. For instance, given case type "gold customer" and activity type "contact", ("CityS.", 2020-09-27, 2020-10-25, attendance, 60%) indicates to HR analysts that 60% of members in employee group "CityS." worked on contacting gold customers between September and October 2020.

Extracting work profiles. We describe the pre-defined work profile indicators (Section 3) that can be directly extracted given a typical event log with essential information recorded. Note that all indicators are measured given a resource group and a time interval (see Definition 1).

Workload: The indicators of group workload capture the amount of different types of work carried out by a resource group. With respect to an event log, the amount of work can be quantified by considering either the number of activities (which can be inferred from the event number) or the number of cases (which can be inferred from the case identifiers).

- allocation is measured by the total number of activities conducted by a group, or the total number of cases involving the group;
- assignment is measured by the number of activities conducted by a group that are specific to some case type, activity type, and time type, or the number of cases involving a group that are specific to some case type;
- rel_focus measures the assignment of specific activities or cases to a group, compared with the total allocation to the group;
- rel_stake measures the assignment of specific activities or cases to a group, compared with the total number of activities or cases of the specific types.

Performance: The indicators of group performance can be quantified by considering activities and cases *completed* in a given time interval. Note that they are different from the workload indicators which do not consider completion.

- amount-related productivity is measured by the total number of completed activities or completed cases by a group;

- time-related productivity is measured by the average time taken by a group to complete an activity or a case;
- efficiency extends amount-related productivity by including some normative predefined criteria. For example, an analyst can specify that only cases completed within 10 days are considered "satisfactory", and therefore efficiency will be calculated based on the number of satisfactory cases by the group only.

Goal achievement: The effectiveness indicator measuring the *goal achievement* of a resource group can be quantified based on other aspects and their indicators. For example, when two goals are established in terms of the maximum amount of allocation (measuring workload) and the minimum level of efficiency (measuring performance), the effectiveness of a group can be measured by considering whether the group accomplishes these goals, respectively.

Participation: The indicator attendance can be quantified by considering the occurrences of group members carrying out activities or cases. Note that the measure may only be a rough estimate since an event log may not accurately capture the time when employees start working on a process.

- attendance is measured by the number of member resources in a group who originated at least one event (for a relevant activity or case).

Distribution: The indicators for distribution are defined over group members by calculating the portion of workload of the group. Thus, the following indicators consider a given resource in a group.

- member_load is measured by the number of activities conducted by a resource. Therefore, the sum of member_load across all members of a group should be equal to the allocation of the group (measured by activities);
- member_assignment is measured similarly to member_load, but using case types, activity types, and time types to characterize the work by different dimensions.

Collaboration: Quantifying the extent of collaboration among employees using event logs can be challenging since (1) event logs usually do not capture the communication between employees and (2) the way how collaboration happens in different processes and organizations may differ. In the following, we discuss a possible estimate of cooperation based on how frequently group members transfer work between each other in process execution (known as handovers).

- cooperation within group members can be estimated by the density of handovers of work between group members [31].

4.2 Analyzing Work Profiles

Building on work profiles extracted from event logs, different data analytics techniques can be applied to discover patterns from the measurement of indicators. In our approach, we discuss the use of visual analytics as an intuitive and proven means [15] for analyzing work profiles.

Following the definition of work profiles and the relevant aspects and indicators, we consider the following requirements for visually analyzing work profiles:

- Users should be able to interactively extract work profiles related to different time intervals in an event log and at different granularity (e.g., daily, monthly), thus be able to track changes of work profiles over time;
- Users should be able to have an integrated view of interrelated indicators (e.g., allocation and assignments) to derive findings on interactions between different aspects (or dimensions);
- Users should be able to compare indicators measured among different groups at different times; and
- Users should be able to correlate indicators of group-level analysis with those of within-group analysis to obtain a holistic view on groups' work behavior.

Based on these requirements and guided by the general principles in visual analytics [19], we developed a design composed of several types of charts combined with interactive filters. The design aims at providing an integrated and purposeful visualization on multiple aspects of a resource group's work profiles.

The design includes the following. (1) A *stacked area chart* and a *line chart* are chosen for analyzing workload and performance, considering their advantages in capturing indicator values as time-series and showing the evolution patterns. For these two charts, interactive filters are embedded to allow users to explore the workload and performance indicators at different times and at different levels of granularity. (2) A *heatmap* is used for supporting the analysis on workload and distribution with regard to different case, activity, and time types, for its usefulness in simultaneously presenting values related to two-dimensional data attributes. (3) A *stacked bar chart* is used for intuitively presenting the attendance of group members with respect to group size. By connecting different charts using the same set of interactive filters, users are provided with an overall picture of work profiles of resource groups in a selected time interval of interest.

The design shows a possible way of applying visual analytics to analyze work profiles. While the aspects and indicators of a work profile may be further extended, other visualization techniques can also be adopted accordingly.

5 Evaluation

The purpose of our evaluation is to demonstrate how the proposed approach can be used for resource group-oriented analysis. To this end, we have developed a prototype with interactive visualization, built upon Vega-Lite [27], as a realization of the design of the approach in Sect. 4. The tool is publicly available (`https://royjy.me/to/gwp-demo`). Fig. 2 and Fig. 3 illustrate the prototype's interactive visualization interface.

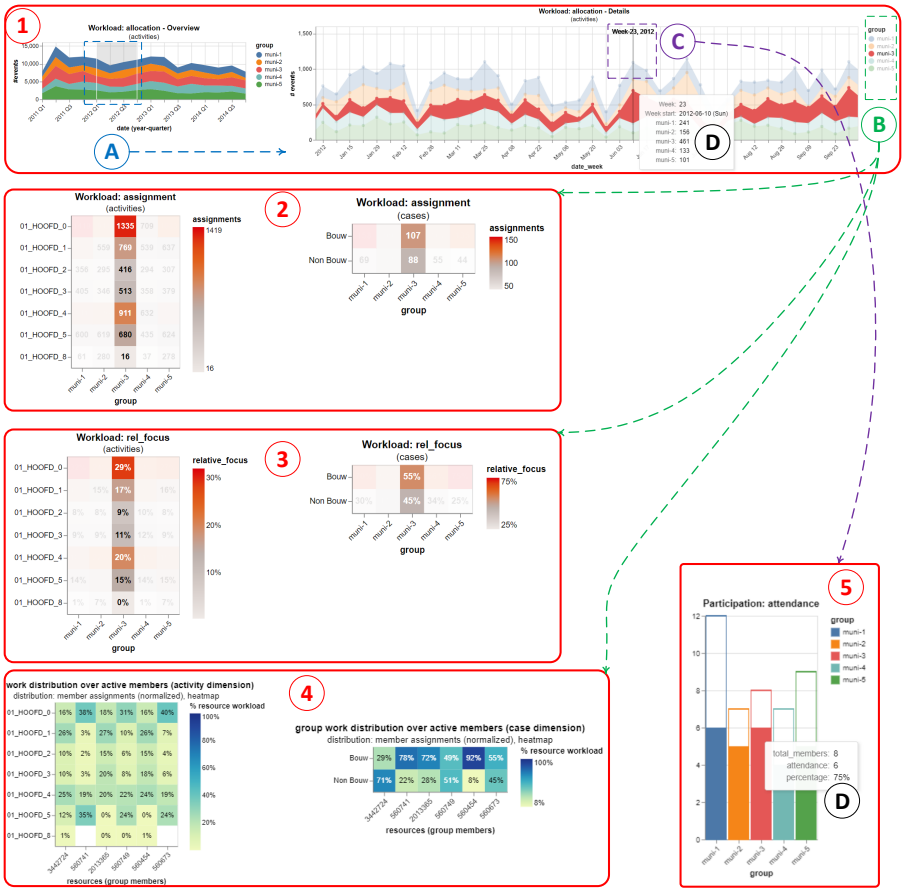


Fig. 2: Annotated screenshots of the prototype's interactive interface for analyzing work profiles regarding workload, participation and distribution. The numbers mark different views: (1) workload by allocation; (2) workload by assignment measuring either activities or cases; (3) workload by rel_focus measuring either activities or cases; (4) distribution by member_assignment; (5) participation by attendance. The views respond to user interactions simultaneously: (A) selecting a time interval and zoom-in; (B) highlighting specific groups; (C) focusing on a specific time period (week); and (D) showing specific numbers via a tooltip

5.1 Design of Experiments

We conducted an evaluation by experimenting on a real-life dataset[4] with five event logs. The event logs record a process of handling building permit applications in an approximate four-year period, and contain typical event attributes satisfying the minimum requirements on an input event log (Sect. 4.1). Note that the event logs only record the end timestamp for each activity conducted

[4] BPIC 2015: https://data.4tu.nl/collections/BPI_Challenge_2015/5065424/1

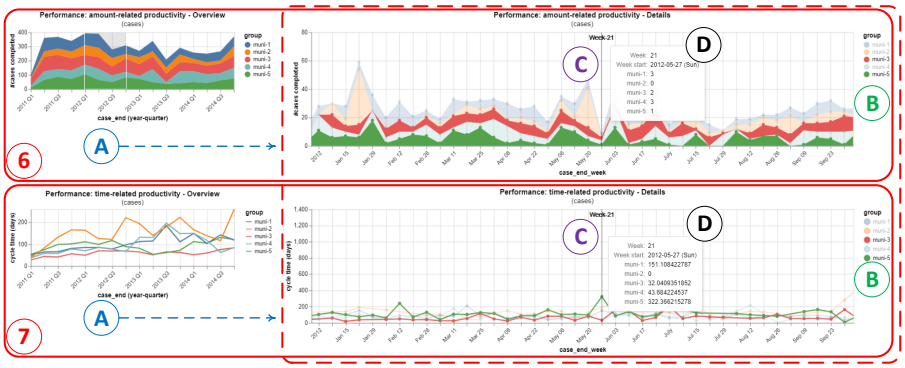


Fig. 3: Annotated screenshots of the prototype's interface for analyzing work profiles regarding performance. Views of (6) amount-related productivity and (7) time-related productivity respond simultaneously to user interactions (A–D)

in the process. Therefore, only activity occurrences can be considered in the subsequent analysis, not the activity duration time.

Still, this dataset can serve as a representative example of how our approach can contribute to workforce analytics centered around resource groups. This is because the dataset captures how an identical process was performed in five different municipalities, and thus representing scenarios where *different resource groups participate in executing the same process*. Moreover, the process owners raised a few questions originally, with a particular focus on the differences between the municipalities' performance and the roles of their employees. Given this context, we consider each municipality as a separate resource group in our experiments[5], and apply the approach to extract and analyze their work profiles.

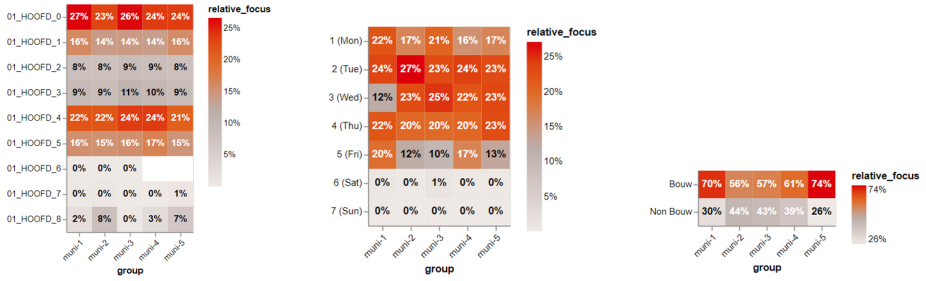
5.2 Group-level Analysis

We first conduct the group-level analysis and focus on the workload and performance aspects, motivated by one of the process owner's original questions: *Where are differences in throughput times between the municipalities and how can these be explained?* For simplicity, we refer to the five municipalities (i.e., the resource groups) by short names, e.g., "muni-1" denotes the first municipality.

Workload analysis. We organize cases and events by three process dimensions (activity, time, case) to compare the workload of resource groups. Fig. 4 shows the visualization of group workload in regard to different activity, time, and case types. The five groups exhibit very similar patterns in terms of assigning their group workload according to different types of activities (Fig. 4a). Slight differences can be observed as neither of muni-4 nor muni-5 has worked on activities of type 6. Also, employees from muni-2 and muni-5 seem to have committed to

[5] Experiment details: `https://git.io/Jq9uC`

more workload in executing activities of type 8. These groups also show similarities regarding the types of cases they processed (Fig. 4c), as the majority leaned towards handling the construction-related applications ('Bouw'), especially muni-1 and muni-5. An interesting observation can be made regarding the weekday pattern shown in Fig. 4b. Muni-1 differs from others as it had only 12% of its total workload assigned on Wednesdays. In the meantime, muni-2, muni-3 and muni-5 seem to form another cohort as Fridays were their least busy day. This observation may link to different arrangements of office hours in the groups.



(a) activity types (b) time types (c) case types

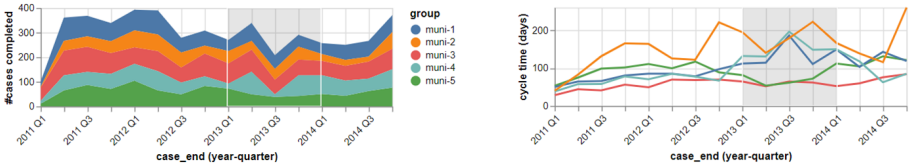
Fig. 4: Workload of the groups measured by rel_focus in 2011–2014

Performance analysis. Fig. 5 presents an overview of group performance by calculating indicator amount-related productivity and time-related productivity for different year-quarters. For analyses in this part, we base our observations on work profiles starting from 2012 Q1, since we only included cases started after 2010-12-31 in our evaluation, and hence the numbers related to case completion in 2011 may not reflect the actual performance[6].

From Fig. 5a we can see that five groups follow a highly similar pattern in terms of amount-related productivity (as the number of completed cases) — most of the cases were completed in Q1, followed by that in Q4 and Q3, while the least throughput happened in Q2. Compared across years, 2012 saw the most completed cases. The groups' performance decreased in 2013 and went slightly higher in 2014. An observation worth mentioning is that muni-4 had a sudden increase of performance after 2013 Q1 until 2014 Q2, and later dropped to the same level as the other groups.

Fig. 5b provides another perspective on group performance visualizing time-related productivity. Note that it is calculated by the average cycle time of completed cases, hence the performance is high when the value is low, and vice versa. We can see that muni-3 delivered steadily high performance in terms of shorter cycle time. Muni-5 also had a relatively consistent level of performance, which slightly improved during the year 2013. The performance of muni-2 changed across the four quarters, while within each year it follows a pattern: starting low in Q1, improving in Q2, and gradually decreasing towards the end of a year (Q3

[6] The mean case cycle time in the dataset is 91.1 days (std. 105.8 days).



(a) amount-related productivity (cases) (b) time-related productivity (cases)

Fig. 5: Performance of the groups in 2011–2014

and Q4). This highlighted pattern of muni-2 would be interesting to investigate, as this group is not unique in terms of amount-related productivity.

Meanwhile, the spike of case cycle time in muni-1 and muni-4 in 2013 also deserves further attention. With our previous observation on the increase of throughput of muni-4 in the same period, we selected the interval of 2013 and used the detailed view to drill down the performance values of muni-4.

Fig. 6 depicts the visualization. The upper view clearly shows four sharp increases of amount-related productivity. In each of the four weeks, muni-4 completed significantly more cases (more than 30) compared to all other groups (less than 10). This explains the spike in the overview (Fig. 5a) and may link to the existence of batching behavior of muni-4. Interestingly, the increase of amount-related productivity seems unrelated to the group's time-related productivity as shown in the lower view. Cross-checking the same weeks in the two charts, we can see that the potential batching completion did not directly link to a significantly longer case cycle time of muni-4.

5.3 Within-Group Analysis

We proceed to analysis at the group-member level, motivated by another question raised by the process owner: *What are the roles of the people involved in the various stages of the process and how do these roles differ across municipalities?*

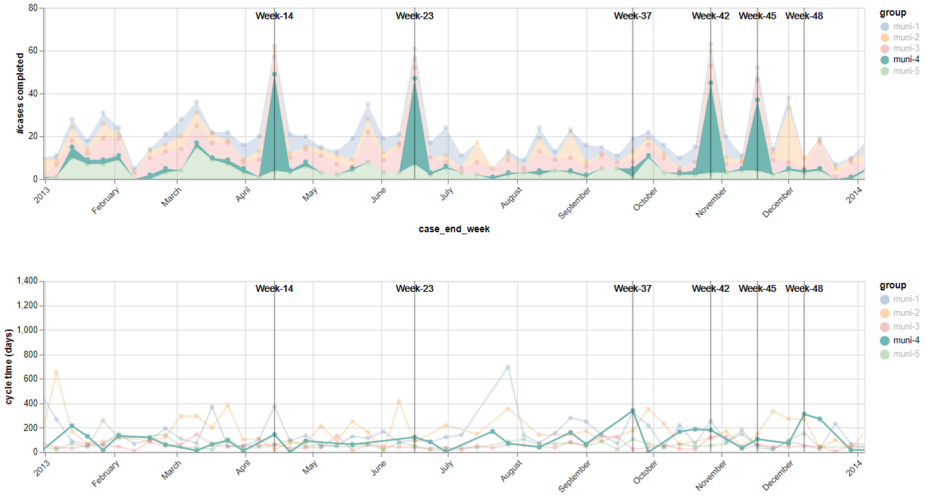
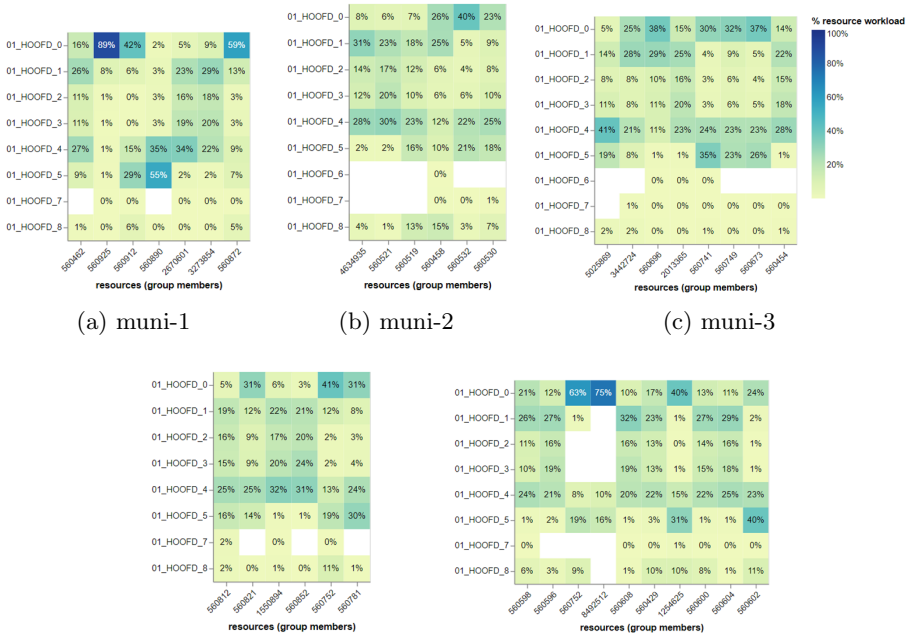


Fig. 6: Muni-4's performance by amount-related and time-related productivity

Following the question, we analyze the distribution within each group and focus on the most active members.

Distribution analysis. Fig. 7 presents how individual resources within each group handled different types of activities distributed to them, which reflects the involvement of resources at different phases in the process. Comparing across the columns in the heatmaps, we noticed two major patterns in all five groups, which are more significant in muni-4 and muni-5. There exists a cohort of resources focusing primarily on the executions of activities of type 0, 4, and 5, while they seldom carry out activities in the middle of the process (type 1, 2, and 3). Also, there is another cohort of resources that exhibits a different pattern as their workload was mostly on executing activities from phases in the middle (type 1, 2, 3, and 4) in a balanced manner. This second cohort of resources was less involved in executing activities of type 0 and 5. The two different yet possibly complementary patterns may relate to two business roles in the process.

The heatmaps also highlight patterns unique to some municipalities. For example, resource '560925' in muni-1 carried over 89% of its total workload in executing activities of type 0, and 8% in conducting activities of type 1. The resource was rarely involved in activities during the later phases in the process. While such a pattern is not observed in the other groups, it implies that in muni-



(a) muni-1 (b) muni-2 (c) muni-3

(d) muni-4 (e) muni-5

Fig. 7: Distribution within each of the five groups (2011–2014) measured by member_assignment in terms of activity types. The values have been normalized by member_load of each individual for role analysis

1 there was a specific role for dealing with the initial processing of the received applications. As another example, resource '8492512' in muni-5 only executed activities of type 0, 4, and 5 in the four-year period, and may have acted as a specialist supporting the first major role identified before (i.e., focused mainly on activities of type 0, 4, and 5).

Summary. The above analyses on group work profiles using visual analytics reveal interesting patterns regarding how five different resource groups worked on the same process, and identify areas that require further investigation. While we do not aim at a thorough case study on these municipalities, we demonstrate how the proposed notion of work profiles and the approach to identifying and analyzing them can contribute to answering questions related to group-oriented workforce analytics, through utilizing event logs.

6 Discussion, Implications, and Conclusion

Our study is inspired by research on analyzing resource group characteristics and on mining individual resource behavior. The results of demonstrating the proposed approach show that it can be applied successfully and provides interesting insights with regard to workforce analytics. Compared to prior work, we provide an approach that is based on theory and a subsequent conceptualization on the group level. It allows the use of a minimum of information from event logs to enable relevant workforce analysis on the group level and describes how visual analytics can be used to support the analysis.

Our research has several theoretical implications. First, we contribute to the discussion of connecting human resource management to the domain of BPM [29]. We introduce the interactionist theory to the domain of analyzing groups in a BPM context and demonstrate how it is relevant for workforce analytics for group performance and organization. We show how performance indicators can be connected with interactionist-related parameters, using process data to extract knowledge about how interaction leads to performance. Second, our research provides insights on workforce analytics in the context of business processes by conceptualizing the notion of work profiles of resource groups. As such, we provide a better understanding of how such an organizational capability can be fostered to enable high performance. The conceptualization of work profiles allows the characterization and comparison among different groupings of employees over time. Such information is important to continually evaluate existing organizational structures which might not reflect optimal interaction between employees and have to be adapted. Hence, measuring and managing resource groups is an important organizational capability as organizations continuously have to decide how to group employees to adapt to changing requirements. Third, we provide an analytical approach using actual process execution data that can be used to determine the performance of groups over time and identify possible root causes related to the internal group interaction for the performance observed. Fourth, we show how the analytical results on the group level can be visualized.

From a practical perspective, process managers and analysts can benefit from the research outcomes which enable them to use event log data to objectively evaluate work behavior of their resource groups. The analysis can pinpoint the areas of interest across different periods, different levels of resources, and different process dimensions. The use of visualizations facilitates the interpretation of analysis results in daily operations.

As with any research, our work is subject to limitations. First, the dataset used in the evaluation only records end timestamps. Richer insights can be derived if both start and end timestamps are recorded. Second, the proposed indicators are based on standard event log information. While this allows for broad applicability, other attributes, e.g., capturing the collaboration aspect of human resource groups, can be defined and exploited to derive additional insights. Third, factors related to other aspects of the interactionist theory, e.g., psychological factors, can be taken into consideration. For this, however, data sources beyond event logs need to be included.

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