An Initial Visual Analysis of German City Dashboards

C. Huber[1,2] T. Nagel[1] and H. Stuckenschmidt[2]

[1]Mannheim University of Applied Sciences, Germany
[2]Data and Web Science Group, University of Mannheim, Germany

Abstract

City dashboards are powerful tools for quickly understanding various urban phenomena through visualizing urban data using various techniques. In this paper, we investigate the common data sets used, and the most frequently employed visualization techniques in city dashboards. We reviewed 16 publicly available dashboards from 42 cities that are part of German smart city programs and have a high level of digitization. Through analysis of the visualization techniques used, we present our results visually and discuss our findings.

CCS Concepts

• ***Human-centered computing*** → ***Visualization;***

1. Introduction

City dashboards are a common way to visualize the current state of various urban aspects. These dashboards consist of a set of user interface widgets containing text, graphics, and visualizations. Governmental statistics on education, public health, or the environment can be combined with live data such as air quality, public transit, or traffic congestion [Mat15]. The data displayed in the city dashboards is sourced from diverse origins, including administrative records, open data portals, and real-time sensor data collected from the respective municipalities [Kit14].

Visualization dashboards are widely used in practice, ranging from business intelligence [RCB09], to industrial facilities [GDW*21], to health care monitoring [ERB*20]. Dashboards have been described as systems showing information in a visual manner for rapid access to support timely decisions [Few13]. Established purposes of dashboards in enabling analysis and supporting strategic, tactical and operational decision-making have been extended to include communication and education [SCB*19]. Typically, public dashboards are aimed towards a general audience, and need to adapt to a wide range of visualization literacy and domain expertise [SCB*19]. In the case of dashboards showing urban data, audiences include citizens and other stakeholders. The two aims of communication and decision-making are not mutually exclusive: For instance, citizens may want to learn about the state of the traffic in their city, and then decide to adapt their behavior by avoiding a congestion.

Young et al. [YKN21] studied different user groups with varying domain knowledge and data literacy skills in the context of city dashboards. They conclude that city dashboards should be designed in such ways that they match their intended audience, and recommend employing visualizations of different complexities. Similarly, Li et al. analyzed the gap between people's needs and the information provided on Corona dashboards and highlighted the importance to select visualizations appropriate for the types of data and the audience [LWCG22]. In an analysis of British city dashboards, Gray, O'Brien and Hügel argue for the need for further investigating the potential of visualizations [GOH16]. Collecting dashboard design patterns including the use of layout, visualizations, and interactions provided helpful for both novice and advanced designers [BFA*22]. Thus, with our analysis of how city dashboards are currently being designed in practice, we are providing an important first step to better understand how visualizations are being employed in contemporary urban dashboards. We investigate which visualization techniques are being used (RQ1), how frequently they appear (RQ2), and if and what techniques exist which are specific to city dashboards (RQ3). This approach allows us to collect visualization examples, providing a foundation for developing effective and informative visualizations in the context of smart cities.

Recently, there has been a major push by federal agencies for smart city initiatives in Germany [BR]. Our contribution lies in the collection and description of German city dashboards, the analysis of the different visualizations techniques employed, and the extension of a widely used taxonomy aimed at practitioners creating visualizations for the public.

2. Methodology

We investigated existing collections of smart cities, government digitization projects, and urban data initiatives to seed the list of cities under investigation. We chose 42 cities from having urban data platforms [Bit21] [Bit] which we deem a prerequisite for data-driven dashboards, and added the five largest cities by population, as well as the city of Mannheim where our smart city project is

DOI: 10.2312/evp.20231056

based in. We employed a set of search queries and collected existing dashboards. To qualify, they had to (a) be publicly accessible, to (b) focus on one city, and to (c) employ at least two visualizations. We chose criterion (b) to exclude state or region-based dashboards, and (c) to exclude non-dashboard visualization systems, such as geo-information portals.

The matching urban dashboards were examined in detail. To systematically collect visualization techniques, we opted to use an existing taxonomy. While these exist both in practice (e.g. [Dat21]) and textbooks (e.g. [Wil19]), we chose the Visual Vocabulary providing an overview of visualization techniques [Fin]. It categorizes the techniques by their main purpose, ranging from Change over Time, to Spatial, to Part-to-whole. However, none of these taxonomies specifically designed for dashboards. Hence, we extended the Visual Vocabulary by a new category specifically suited for dashboards. For analyzing the arrangement of the widgets, we used the Page Layout category from Bach et al.'s dashboard design patterns [BFA*22].

3. Results

From the 42 inspected cities, 16 provide a city dashboard available to the public. We summarize the layout, and visualization techniques of these dashboards (see Fig. 1). Only six out of 16 dashboards are multi-thematic and use multiple data sets.

Tiles and Layout. Each dashboard consists of multiple tiles, varying in size and visually distinct, each featuring typically one visualization representing a single data set. Nearly all dashboards (15/16, 93%) are multi-topic, and combine tiles of different data sets in one view. All tiles of the dashboard of Heidelberg show data of a single topic, but enable to switch the whole dashboard to a different topic. Two dashboards contain a single tile showing data from multiple sources, by providing a gallery to page through different topics. 13 out of the 16 dashboards "fit on a single screen" [Few13] with the other two providing further views either by scrolling or through tab interactions. All dashboards but one use an open layout, with Wolfsburg using a grouped layout [BFA*22]. Only Heidelberg uses a single-themed dashboard, with all tiles showing different but linked visualizations of the same data set. For instance, highlighting an item in one view affects the other views. However, none of the other dashboards provide any coordinated views. We also coded the positions and dimensions of each tile to identify the layout and space occupied by each visualization. It was found that maps occupy more space per tile compared to KPIs, but are only used 1–2 times per dashboard compared to 1-25 KPI tiles per dashboard.

Dashboard Specific Visualizations. Since not all visualizations extracted from the dashboards could be matched to a technique of the Visual Vocabulary, we added a new category, Key Performance Indicators (KPI) containing three techniques: Indicator, Indicator Matrix and Gauge. Indicator consists of a textual data value, Indicator Matrix is a collection of indicators within the same widget, and Gauge is a semicircle scale with a pointer to the current value. These simple techniques showing a single value are widely used, and have been referred to by various names (e.g. Scaled-up Number or Angular Gauge), or might have other closely related techniques such as Progress Bar or Pictorial Fraction Chart [Dat21]. Extending the Visual Vocabulary by this category allowed us to collect all visualizations employed in city dashboards.

Visualization Use. The most common visualization categories are KPI (87 occurrences on 15 dashboards), change over time (67 on 14), and part-to-whole (23 on 8). The most frequently used techniques are indicator (68 on 13 dashboards), line (37 on 7), column-timeline (25 on 7), doughnut (12 on 4), indicator-matrix (12 on 5), and dot-density (11 on 10). Overall, the number of different techniques being used on single dashboards varies widely and ranges from 3 to 8 techniques. 13 dashboards use the same technique multiple times for different data (e.g. Bad Hersfeld or Kiel), and three use each technique only once.

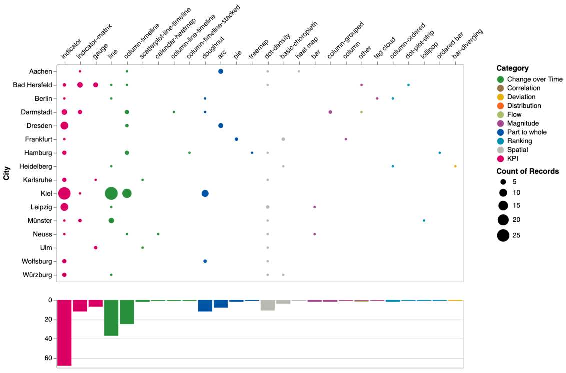

Figure 1: *Usage of visualization techniques in the analyzed city dashboards. Each circle indicates the use of a technique, with its size representing the number of occurrences. The histogram on the right shows the frequency distribution over all dashboards. Color represents the category of the visualizations.*

4. Conclusion and Future Work

We have collected and analyzed visualization techniques employed on publicly accessible urban dashboards from Germany cities. Even though only 16 dashboards matched our criteria, our analysis showed a wide mix of diverse visualization techniques being used. Simple visualizations showing a single value have been used most frequently, with time series data second.

The dashboards typically use diverse data sets, and their visualizations are mostly not coordinated. This seems to indicate an opportunistic, technology-driven development. Employing a human centered design (HCD) process might result in city dashboards more aligned to the needs of the citizens [YKN21, VZDY21].

While our initial analysis is but a first step, we hope our results can be used in HCD activities. Cepero et al. suggested guidelines for city dashboards visualizations derived from literature [CMM22]. We imagine our data set to inform such design guidelines on real-world usage to reflect best practices. Through our coding sheet, the matrix visualization, and the screen space analysis, creators, as well as others, can use the examples of potential techniques for urban data dashboards.

References

[BFA*22] BACH B., FREEMAN E., ABDUL-RAHMAN A., TURKAY C., KHAN S., FAN Y., CHEN M.: Dashboard Design Patterns, Aug. 2022. arXiv:arXiv:2205.00757. 1, 2

[Bit] BITKOM E.V.: Smart City Index 2022 | Studie 2023 | Bitkom e.V. https://www.bitkom.org/Bitkom/Publikationen/Smart-City-Index-2022. 1

[Bit21] BITKOM E.V.: Bericht: Smart-city-atlas | bitkom e.v, 29.06.2021. URL: https://www.bitkom.org/Bitkom/Publikationen/Bericht-Smart-City-Atlas. 1

[BR] BUNDESMINISTERIUM DES INNERN, FÜR BAU UND HEIMAT (BMI), REFERAT SW III 2 – SMART CITIES: Smart Cities: Stadtentwicklung im digitalen Zeitalter. https://www.bmwsb.bund.de/Webs/BMWSB/DE/themen/stadt-wohnen/staedtebau/smart-cities/smart-cities-artikel.html. 1

[CMM22] CEPERO T., MONTANÉ-JIMÉNEZ L. G., MAESTRE-GÓNGORA G. P.: Data Visualization Guide for Smart City Technologies. In *Electronic Governance with Emerging Technologies*, Ortiz-Rodríguez F., Tiwari S., Sicilia M.-A., Nikiforova A., (Eds.), vol. 1666. Springer Nature Switzerland, Cham, 2022, pp. 176–191. doi:10.1007/978-3-031-22950-3_14. 2

[Dat21] DATA VIZ PROJECT:, 03.11.2021. URL: https://datavizproject.com/. 2

[ERB*20] ELSHEHALY M., RANDELL R., BREHMER M., MCVEY L., ALVARADO N., GALE C. P., RUDDLE R. A.: QualDash: Adaptable Generation of Visualisation Dashboards for Healthcare Quality Improvement, Sept. 2020. arXiv:arXiv:2009.03002. 1

[Few13] FEW S.: *Information dashboard design: Displaying data for at-a-glance monitoring*, second edition ed. Analytics Press, 2013. 1, 2

[Fin] FINANCIAL TIMES: Visual vocabulary. URL: https://ft-interactive.github.io/visual-vocabulary/. 2

[GDW*21] GOODWIN S., DKHISSI Y., WU Q., MOYLE B., FREIDIN K., LIEBMAN A.: Informed Dashboard Designs for Microgrid Electricity Market Operators. In *Proceedings of the Twelfth ACM International Conference on Future Energy Systems* (New York, NY, USA, June 2021), E-Energy '21, Association for Computing Machinery, pp. 406–411. doi:10.1145/3447555.3466604. 1

[GOH16] GRAY S., O'BRIEN O., HÜGEL S.: Collecting and visualizing real-time urban data through city dashboards. *Built Environment 42* (2016), 498–509. 1

[Kit14] KITCHIN R.: The real-time city? big data and smart urbanism. 1–14. doi:10.1007/s10708-013-9516-8. 1

[LWCG22] LI X., WANG H., CHEN C., GRUNDY J.: An Empirical Study on How Well Do COVID-19 Information Dashboards Service Users' Information Needs. *IEEE Transactions on Services Computing 15*, 3 (May 2022), 1178–1192. doi:10.1109/TSC.2021.3114673. 1

[Mat15] MATTERN S.: Mission control: A history of the urban dashboard. *Places. The Journal of Public Scholarship on Architecture, Landscape and Urbanism* (2015), 1–20. 1

[RCB09] RASMUSSEN N., CHEN C. Y., BANSAL M.: *Business Dashboards: A Visual Catalog for Design and Deployment*. John Wiley & Sons, Hoboken, N.J, 2009. 1

[SCB*19] SARIKAYA A., CORRELL M., BARTRAM L., TORY M., FISHER D.: What do we talk about when we talk about dashboards? *IEEE Transactions on Visualization and Computer Graphics 25*, 1 (2019), 682–692. doi:10.1109/TVCG.2018.2864903. 1

[VZDY21] VORNHAGEN H., ZARROUK M., DAVIS B., YOUNG K.: Do City Dashboards Make Sense? Conceptualising User Experiences and Challenges in Using City Dashboards. A Case Study. In *The 22nd Annual International Conference on Digital Government Research* (2021), DG.O'21, ACM, p. 219–226. URL: https://doi.org/10.1145/3463677.3463695, doi:10.1145/3463677.3463695. 2

[Wil19] WILKE C. O.: *Fundamentals of Data Visualization*. O'Reilly, 2019. 2

[YKN21] YOUNG G. W., KITCHIN R., NAJI J.: Building city dashboards for different types of users. *Journal of Urban Technology 28*, 1-2 (2021), 289–309. doi:10.1080/10630732.2020.1759994. 1, 2