A Business Intelligence Dashboard for the Phone:
Small-scale Visualizations Embedded into a
Mobile Analysis and Monitoring Solution

Nils Höll[2] 🆔, Shahid Latif[1] 🆔, and Fabian Beck[1] 🆔

[1]University of Bamberg, Germany
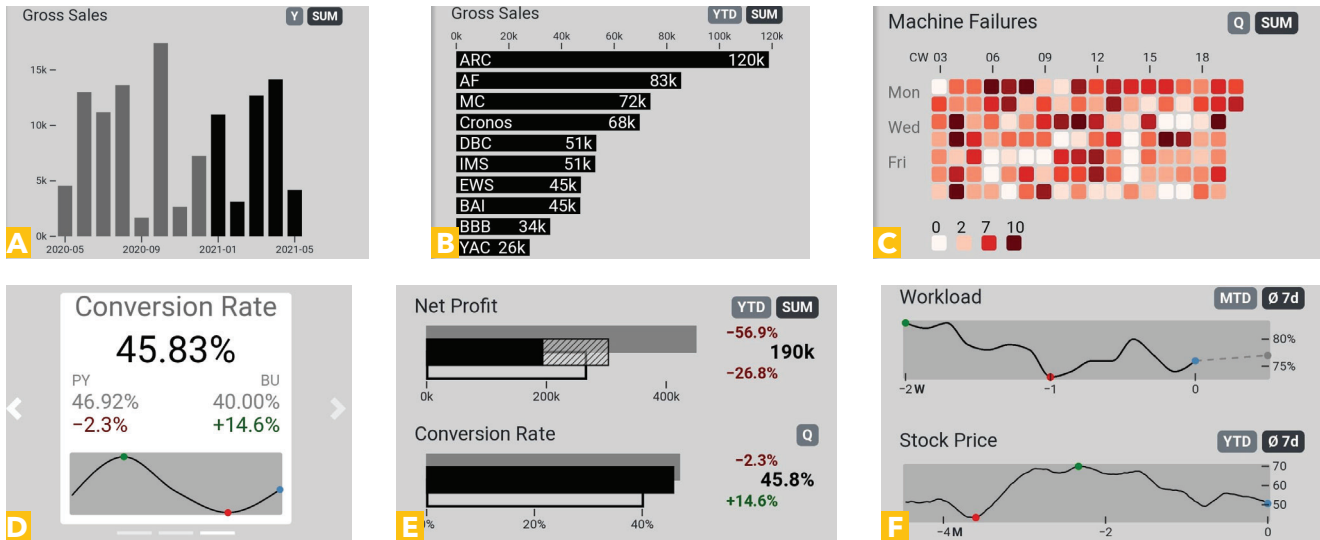[2]University of Duisburg-Essen, Germany

Figure 1: *Six different small-scale visualizations designed and optimized for phone displays. (A) Bar chart, (B) column chart, (C) calendar, (D) carousel of KPITiles, (E) KPIBars, and (F) time series.*

Abstract

Although smartphones have become ubiquitous, most of the visualization applications are still designed for large-screen devices. In a business intelligence context, dashboard solutions for monitoring key performance indicators and performing simple analysis tasks can profit from being available on the phone. We identify usage scenarios and design requirements by interviewing 20 business experts. Our solution adapts existing diagrams and proposes novel visualizations for the small-screen environment, and integrates them into an easy-to-use visual dashboard.

CCS Concepts
• *Human-centered computing* → *Information visualization;*

1. Introduction

The term *dashboard* refers to a visual display that provides relevant information at a glance and facilitates monitoring critical aspects [Few13]. Nowadays, dashboards are utilized in almost every industry to support data-driven decision-making [SCB*19]. How- ever, the dashboards are dominantly limited to personal computers or other larger-screen displays. But as users of these dashboards— particularly executives and managers—are traveling frequently or might not have access to their desktop setup during meetings, there is an expected demand for mobile availability of the dashboards.

Whereas the idea of porting business intelligence dashboards to smartphones has been proposed earlier [Ben08; AH10b; CCS12; BCAF13], we look at this challenge closely, and suggest a business intelligence dashboard for the phone. Our focus is on designing expressive small-screen visualizations and their integration into specific monitoring and analysis use cases.

In a business intelligence context, the performance of a business is usually monitored through a set of key performance indicators (KPIs). To establish the exact usage scenarios and need for mobile dashboards, we conducted interviews with 20 experts working in different roles across thirteen companies. To support the identified scenarios, we developed a mobile dashboard solution for modern smartphones (4.5–6.7 inch displays). While the selection of KPIs depends on the specific use case, we restrict ourselves to a set of five to six most relevant KPIs that can be realistically visualized on a smartphone. We adapt existing visualizations and design new ones for small screens. Figure 1 shows six different visualizations that we integrate into the dashboard.

2. Related Work

The term *mobile business intelligence* refers to the use of business data on mobile devices. Peter et al. [PITP16] performed a qualitative study using various modes of user engagement and found that the quality of mobile business intelligence applications influences their usage. Bensberg [Ben08] provided a technical basis and a process-oriented frame of reference for realizing mobile business intelligence. Airinei and Homocianu [AH10a] investigated existing mobile business intelligence dashboard applications and highlighted challenges regarding the limitations of the mobile operating systems, poor modes of input and lack of an easy-to-use user interface, and hardware limitations. Similarly, Brodzinski et al. [BCAF13] describe challenges related to small screens: overlapping virtual keyboards leaving little space to see while typing and imprecision in touch interactions. However, these limitations were discussed for previous generations of mobile devices, but might not be a bigger concern anymore for the latest devices.

Existing research has explored various visualizations for mobile settings [LBC*21]. For instance, Noirhomme-Fraiture et al. [NRCC05] discuss different possible interactions, visualizations, and limitations of mobile information systems with a focus on stock prices. They suggest minimizing screen transitions and interactions, as well as preferring vertical scrolling to horizontal. *MobileVis* [Ros14] is a platform that provides a variety of options for diverse mobile visualizations, best practices, and design guidelines. Regarding characteristics of mobile visualization [LBC*21], our approach can be described as a solution for *phone-sized*, *carryable* displays working with *connected data* (with caching) not being related to display movement (*no change*), intended to be used for viewing timespans in the range of *minutes*, allowing *simple view specification*, and made to be shared among *larger groups* (i.e., all manager of a company). We have considered major aspects of responsive design for mobile visualization [HAB*21] including appropriate *scale* of the visualizations, both supporting portrait and landscape *aspect ratios* in a *layout* designed for small screens, providing different *levels of detail* and using mobile-friendly *interactions* (cf. Section 4).

3. Scenarios and Requirements Analysis

To establish concrete usage scenarios for mobile dashboards and derive requirements, we conducted semi-structured interviews with 20 experts from 13 companies across 7 business areas. These companies range from small (6 employees) to large (144,000 employees), but with a focus on medium-sized companies (*median* = 2000). The interviewed experts hold different positions, including managing directors (6), business intelligence consultants (4), project managers (3), vice presidents (sales or manufacturing, 3), and others (4). Each interview lasted anywhere between 30 and 60 minutes (*median* = 40). We asked questions about *reporting and business intelligence* (e.g., KPIs, data currency, challenges in existing reporting workflow), *mobile dashboards* (e.g., need, usage, level of detail, analysis tasks), and *application requirements* (e.g., offline use, notifications, sharing). We analyzed interviews through assigning descriptive codes and categorizing those codes. We gave importance to frequent codes and discarded the codes that only appeared once or twice. The experts are labeled as E0–E19; E0 acted as a pilot—answers of E0 were used to design the interview questions, but are not summarized in the following. The complete list of interview questions and more details on the participating experts are included in the supplemental material.

A first group of results concerns the relevant usage scenarios that the participating experts envisioned, which we broadly categorize into three high-level scenarios.

(S1) Personal access: Fifteen experts mentioned the need of an easy and personal access to the underlying data. While complex and versatile analysis platforms are designed for trained users, they are not suitable for occasional users. This can lead to inefficiencies and errors due to misconfigurations of, for instance, data filters (E2, E5, E7, E9). Having quick access via pre-configured measures enriched with intuitive visualizations could increase efficiency and avoid such problems (E14). Easier access to data can also lead to better transparency and visibility of personal targets (E5).

(S2) Monitoring: Viewing real-time data for short-term reactions to certain events was also considered consistently as relevant. For example, failures in machines, deviations in product quality, or sick leaves are events that need to be immediately reported to the manager. Fourteen experts highlighted the importance of such a scenario. E15 referred to it as a *"portable control center"* that would inform a user about critical business events that require interruption. The mobile aspect is especially important here as employees need to travel between manufacturing plants and might not be able to operate a laptop on a production floor (E11, E14, E15, E17).

(S3) Meeting preparation: Staying up to date with the customer data is a critical part of meeting preparation, especially for sales employees (E1, E4, E7, E9, E12, E13). E19 mentioned potential problems with outdated customer data when working remotely, as their current tool requires a laptop with stable internet connection. With a smartphone, E19 said, such issues can easily be overcome. Five experts also pointed out the ease of conducting quick meetings with the availability of a dashboard on the phone.

Orthogonal to the usage scenarios, we derive 16 requirements (R1–R16) for realizing dashboards supporting the aforementioned

scenarios. (The number in the parenthesis refer to the frequency the requirement was mentioned in our interviews.)

(**R1**–**R5**) Visualization requirements: The main requirement of the dashboard is to provide an **overview** (16, **R1**) of important KPIs. Arranging information according to entities (e.g., products, customers), **entity-specific dashboards** (8, **R2**) can focus on a few critical KPIs filtered to a point of interest. **Trend lines including forecasts** (20, **R3**) were frequently mentioned for observing current or foreseeing future developments. A related requirement is to perform **deviation analysis** (14, **R4**) for comparing values against targets or historical values. To avoid that users losing track of what information they are currently viewing, it is important to provide **context** (6, **R5**) for the visualized information.

(**R6**–**R8**) Interaction requirements: A standard interaction requirement for a mobile dashboard is **drill-down** (9, **R6**). To closely analyze different segments of a time series, **time span selection** (3, **R7**) is required that can be either used to monitor a KPI over a week (E2) or detecting seasonal patterns in several weeks, months, or years of data (E6, E12, E19). The ability to **filter** (5, **R8**) data items—through sorting or searching—is also important to keep the long lists of data manageable on a small screen.

(**R9**–**R11**) Workflow requirements: Having options to **share and collaborate** (18, **R9**) is also particularly relevant for users in a mobile scenario. Particularly for usage scenario S2, **push notifications** (14, **R10**) can inform the user about critical events, even when the dashboard is not in active use. **Personalization** (13, **R11**) helps tailor the mobile dashboard for a user and is relevant for scenario S1.

(**R12**–**R16**) Non-functional and technical requirements: One main consideration is a good **usability** (8, **R12**) of the mobile dashboard. The design should be intuitive and hassle-free (E3, E10), configuration should be minimized (E9), and should be close to other mobile applications (E18). Other requirements include **offline usage** (9, **R13**) in places where network connection is not available and **cross-platform availability** (9, **R14**). Lastly, experts also described **application security** (7, **R15**) and **performance** (2, **R16**) as two general requirements.

4. Mobile Dashboard Design

To address the scenarios (S1–S3) and requirements (**R1**–**R16**), we have designed a mobile dashboard application. The application has been implemented using Node.js, Typescript, and D3.js as a *progressive web app*—a platform-independent web application with closer integration into mobile devices (**R14**). It inherits security through HTTPS (**R15**), caching for better performance and offline usage (**R13**, **R16**). We target modern smartphones with screen sizes of 4.5–6.7 inch diagonal [21; 19]. Although the dashboard application can be used in landscape mode and provides transitions, we have optimized the visual design for the portrait mode, typically used in about 80% of the time [Red17].

As recommended for mobile applications [SHH*15], a navigation bar is located at the bottom. It allows switching to the previous view, returning to the overview page, and getting hints about the active visualization. The default page (Figure 2, left) provides an overview of the most important KPIs as a slideshow (*KPITiles*),
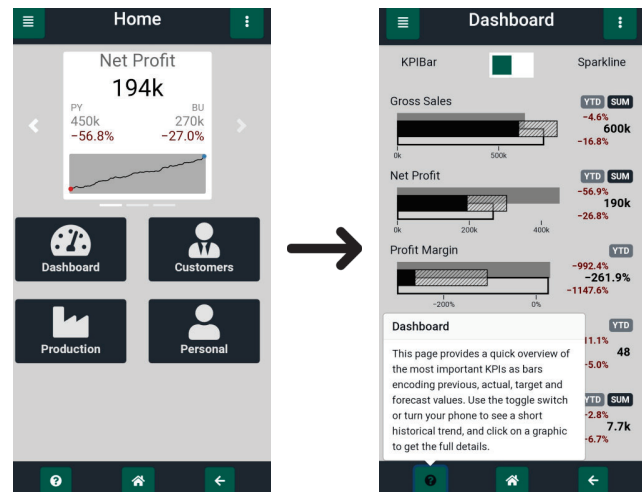

Figure 2: *The interface of the mobile dashboard: (left) landing page with carousel of KPITiles and options to drill down to entity-specific dashboards; (right) dashboard for getting an overview of 5 KPIs with an option to switch between aggregated values (KPIBar) and temporal evolution of values (KPISparkline).*

along with entity-specific dashboards, each consisting of a list of four to six KPIs relevant to a specific aspect of data. We designed individual visualizations for the KPIs (Figure 1). While most of these visualizations are well-established in literature and practice, a challenge was to adapt them to small-screen displays. Throughout the visual design, we reduced the amount of visual objects to avoid visual clutter, yet keeping the visualization understandable (**R5**). Similarly, a minimal set of colors (grayscale colors to encode values) has been chosen according to international business communication standard [HF17]; bright colors are only utilized to highlight specific points or deviations [Ber16].

Bar charts (Figure 1 **A**) are probably the most frequent visualization used in business intelligence. Since horizontal space is limited on a smartphone, we use **column charts** **B** [Ros14] with horizontal bars; they also enable placing labels and even exact values inside the bars. It only requires standard vertical scrolling to display many categories. However, for time series data, it is still recommended to use charts with vertical bars and time from left to right [HF17]. To mark time spans, we use industry-standard abbreviations like Y (one full year) and YTD (year to date) as labels with a light gray background. Other labels with darker background, like SUM, show whether the data is aggregated over time. While, in some cases, highly aggregated time series on a quarterly or monthly level are sufficient, interpretation of other KPIs requires analyzing finer temporal granularity. Bar and line charts allow visualizing such time series, but do not show calendar-related seasonality (e.g., the same days of a week are harder to compare). A **brick wall** or a **calendar visualization** **C** is an information-rich, space-efficient representation [NRCC05], which can provide an overview of one KPI within a calendar-based layout (**R1**). The organization of days of the week in rows makes it easier to see weekly patterns.
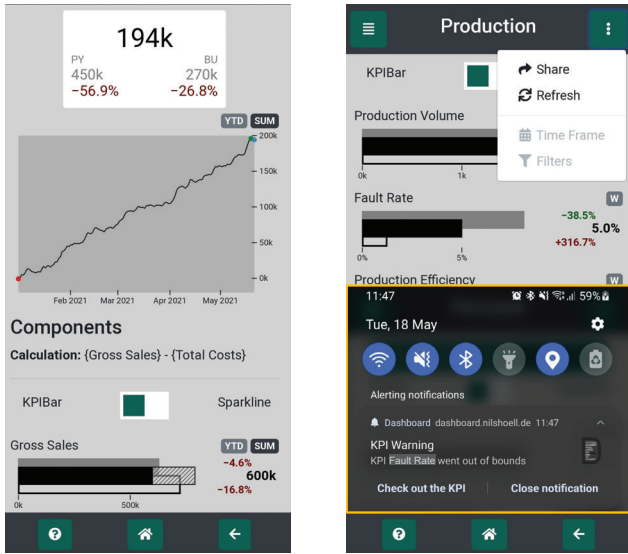
Figure 3: *The detail page of a KPI activated by clicking on a KPI-Tile (left); notification and sharing options (right).*

As a more specialized visualization, we designed a carousel of **KPITiles** D to provide an overview of important KPIs (**R1**), which users can swipe trough. Each tile displays two reference values (e.g., PY – previous year, BU – business target) along with a small timeline of the KPI. In contrast to regular dashboards, a carousel of KPIs should work better on a small screen, compared to placing them side-by-side on one screen. To offer better comparison and more detailed deviation analysis (**R4**), we suggest **KPIBars** E. Each displays the current value of a KPI along with relevant reference values. While being inspired from *bullet graphs* [Few13], we believe that distinct bars instead of symbols better support comparison at a glance. Placing the solid black bar with the current value over the others emphasizes its importance while improving space efficiency. The top comparison bar in light gray represents the value of the previous period, while the future-oriented target value is shown at the bottom as an outlined bar. The semi-transparent forecast value appended to the right of the solid bar makes it easy to assess the anticipated value of a KPI in comparison to its target. The labels on the right show the absolute value of the current KPI, with percentage deviations to previous and future values (appreciating values in green, depreciating values in red). To perform the trend analysis (**R3**), **KPISparklines** F display longer time series with simplified axis labels. We mark the current time as 0 and show earlier weeks, months, or years with negative numbers (e.g., -2W, -4M, -Y). Additional symbols like ∅ 7d denote the 7-day moving average; the dotted portion of the line shows the prediction according to the moving average (**R3**). Red, green, and blue dots mark the minimum, maximum, and current value of the KPI in the displayed interval. Multiple *KPISparklines* are stacked on top of each other to provide a temporal overview of several KPIs.

We have used standard interactions such as scrolling, tapping, swiping, and long-tap. To explore details of a specific KPI (**R6**), users can tap on it. The detail page that opens (Figure 3, left) con-sists of a *KPITile*, followed by an enlarged *KPISparkline* and components of the KPI as *KPIBars*. Since *KPIBars* and *KPISparklines* display complementing aspects, users can switch between them using a toggle switch, or rotate the phone to landscape mode to view them both at once. A long tap on any visualization opens up details about a KPI (e.g., the units of measurement, formula, and a description). Other features, like sharing (**R9**) and setting up alerts (**R10**), are available in context menus (Figure 3, right).

5. Discussion and Conclusion

We presented a dashboard solution designed for modern smartphones that allows business professionals to monitor and analyze key performance indicators. For this application study, we first interviewed 20 professionals to find the most relevant usage scenarios and requirements. The main contributions in developing a mobile solution were adapting and designing viable visualization for the small-screen setup, as well as integrating them into different dashboards and a workflow that matches the intended applications.

Whereas our approach already provides solutions for most of the requested features (**R1**–**R4**, **R10**, **R11**, **R12**–**16**), not all requirements could have been fulfilled completely yet. Requirements **R5**, **R6**, **R8**, **R9** are only partly satisfied, and requirements **R7**, **R11** are not implemented. While every visualization already provides some context (**R5**), the more complex visualizations like *KPIBars* could still profit from additional annotations. While the drill-down (**R6**) is a powerful feature to explore details regarding a particular visualization, the interactions between one view to another and then going back to the original view might not yet feel as smooth. The ability to filter (**R8**) and sort data should also be extended to filter not only a single item but multiple items or to see, for instance, good and bad performing items. Finally, the share and collaborate (**R9**) feature only supports sharing the current view with other users and does not allow adding personal annotations. Our current version does not allow selecting various levels of temporal granularity (**R7**) and the personalization of the mobile dashboard (**R11**), but these features should be relatively straightforward to implement.

Showcasing and discussing our solution with an expert (an executive working in a financial department who was not participating in the initial interviews) has demonstrated that the dashboard can be leveraged in the targeted scenarios (S1–S3). The expert reviewed four specific application examples covering these scenarios and provided feedback. For instance, a manager can quickly access relevant KPIs through *KPIBars* and *KPISparklines* whenever required, and share the respective view to discuss an issue. In a mass production monitoring scenario, a production expert can regularly monitor the efficiency, fault rates, and incidents that could halt the production process. All time-based visualizations and push notifications are a critical feature in this case. A sales person who travels to meet a client can drill down to the client of interest to recall the respective sales (S3). In the future, dashboards more tailored to a specific use case, however, could even provide richer insights.

References

[19] *US Smartphone Sales by Display Size 2017-2019*. Statista. 2019. URL: https://www.statista.com/statistics/1042669/us-smartphone-sales-by-display-size/ (visited on 10/13/2020) 3.

[21] *Compare Phone and Tablet Sizes Side by Side*. Phone Sized. 2021. URL: https://phonesized.com/compare/#1447,1582,1583,1669,1668,1566,1329 (visited on 04/27/2021) 3.

[AH10a] AIRINEI, DINU and HOMOCIANU, DANIEL. *The Mobile Business Intelligence Challenge*. ID 2381814. Social Science Research Network, 2010. URL: https://papers.ssrn.com/abstract=2381814 (visited on 12/11/2020) 2.

[AH10b] AIRINEI, DINU and HOMOCIANU, DANIEL. "The mobile business intelligence challenge". *Economy Informatics* 10.1 (2010). URL: https://ssrn.com/abstract=2381814 2.

[BCAF13] BRODZINSKI, JAMES, CRABLE, ELAINE, ARIYACHANDRA, THILINI, and FROLICK, MARK. "Mobile Business Intelligence". *International Journal of Business Intelligence Research* 4.2 (2013), 54–66. DOI: 10.4018/jbir.2013040104 2.

[Ben08] BENSBERG, F. "Mobile Business Intelligence". *Erfolgsfaktoren des Mobile Marketing*. 2008, 71–87. DOI: 10.1007/978-3-540-85296-4_5 2.

[Ber16] BERA, PALASH. "How Colors in Business Dashboards Affect Users' Decision Making". *Communications of the ACM* 59.4 (2016), 50–57. DOI: 10.1145/2818993 3.

[CCS12] CHEN, HSINCHUN, CHIANG, ROGER H. L., and STOREY, VEDA C. "Business Intelligence and Analytics: From Big Data to Big Impact". *MIS Quarterly* 36.4 (2012), 1165–1188. DOI: 10.2307/41703503 2.

[Few13] FEW, STEPHEN. *Information Dashboard Design: Displaying Data for At-a-glance Monitoring*. 2. ed. Analytics Press, 2013 1, 4.

[HAB*21] HORAK, TOM, AIGNER, WOLFGANG, BREHMER, MATTHEW, et al. "Responsive Visualization Design for Mobile Devices". *Mobile Data Visualization*. 2021, 33–66. DOI: 10.1201/9781003090823-2 2.

[HF17] HICHERT, ROLF and FAISST, JÜRGEN. *International Business Communication Standards: Conceptual, Perceptual, and Semantic Design of Comprehensible Business Reports, Presentations, and Dashboards*. 1.1. CreateSpace Independent Publishing Platform, 2017. 168 pp. 3.

[LBC*21] LANGNER, RICARDO, BESANÇON, LONNI, COLLINS, CHRISTOPHER, et al. "An Introduction to Mobile Data Visualization". *Mobile Data Visualization*. 2021, 1–32. DOI: 10.1201/9781003090823-1 2.

[NRCC05] NOIRHOMME-FRAITURE, MONIQUE, R, FRÉDÉRIC, CHITTARO, LUCA, and CUSTINNE, GRÉGORY. "Data Visualizations on Small and Very Small Screens". *Proceedings of Applied Stochastic Models and Data Analysis*. 2005 2, 3.

[PITP16] PETERS, TWAN, IŞIK, ÖYKÜ, TONA, OLGERTA, and POPOVIČ, ALEŠ. "How System Quality Influences Mobile BI Use: the Mediating Role of Engagement". *International Journal of Information Management* 36.5 (2016), 773–783. DOI: 10.1016/j.ijinfomgt.2016.05.003 2.

[Red17] REDDY, RAHUL. *Smartphone vs Tablet Orientation: Who's Using What?* ScientiaMobile. 2017. URL: https://www.scientiamobile.com/smartphone-vs-tablet-orientation-whos-using-what/ (visited on 03/30/2021) 3.

[Ros14] ROS, IRENE. *MobileVis*. 2014. URL: http://patterns.mobilev.is/ (visited on 11/17/2020) 2, 3.

[SCB*19] SARIKAYA, ALPER, CORRELL, MICHAEL, BARTRAM, LYN, et al. "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.

[SHH*15] SHITKOVA, MARIA, HOLLER, JUSTUS, HEIDE, TOBIAS, et al. "Towards Usability Guidelines for Mobile Websites and Applications". *12th International Conference on Wirtschaftsinformatik*. 2015, 15. eprint: https://aisel.aisnet.org/wi2015/107 3.