

# Automating Time-Consuming and Error-Prone Manual Nursing Management Documentation Processes

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A German regulation requires nursing managers to document patient-nurse ratios. They have to combine heterogeneous hospital data from different sources. Missing documentation or ratios that are too high lead to sanctions. Automated approaches are needed to accelerate the time-consuming and error-prone documentation process. A documentation and visualization system was implemented. The system allows nursing managers to quickly and automatically create the documentation required by the regulation. Interactive visualization dashboards assist with the analysis of patient and staff numbers. The developed method was effectively used in nursing management tasks. No changes to the information technology infrastructure were needed. The new process is around 35 hours per month faster and less error-prone. The documentation functionality automatically reads the required information and correctly calculates the documentation. The visualization functionality allows nursing managers to assess the current patient-nurse ratios before the documentation is submitted. The method scales to multiple wards and locations. It calculates the sanctions to expect and is easily updatable. The proposed method is expected to decrease nursing administration workloads and facilitate the analysis of nursing management data in a cost-effective way.

**KEY WORDS:** Data analysis, Data visualization, Government regulation, Nursing administration research, Nursing care management

**O**n January 1, 2019, a new regulation was adopted by the German Ministry of Health. The *Pflegepersonaluntergrenzen-Verordnung* (PpUGV) defines maximal patient-nurse ratios that need to be met in certain hospital divisions.<sup>1</sup> The goal of the regulation is to ensure a high quality of care in these divisions.

The fulfillment of these ratios has to be documented and reported to a public institute.<sup>2</sup> The regulation is coupled with financial disadvantages for hospitals not meeting these requirements.<sup>3</sup> Failing to meet the required patient-nurse ratios, which are computed as a monthly average, results in sanctions of up to €8500 per missed 8-hour nurse work shift. Hospitals that do not report their patient-nurse ratios on time or deliver incomplete documentation are sanctioned with a fine of up to €20 000.

The new regulation leads to increased documentation workloads for nursing managers. As data from different sources (namely, staff and patient management systems) need to be combined, the corresponding information technology (IT) systems have to be compatible with each other. If they are not, manual work is needed to extract and combine the data. Nursing management has an impact on care outcomes.<sup>4</sup> As much time as possible should be available for tasks that improve hospital care. Some nursing managers report that they spend up to 49% of their work time with deskwork.<sup>5</sup> Methods to decrease the time spent on documentation can help free up time, which can be used for tasks that have an impact on hospital care.

An additional challenge stems from the fact that the regulation can be updated every year. At the beginning of 2020, for example, new hospital divisions were added to the PpUGV.<sup>6</sup> This means that any documentation process must be flexible and easily updatable.

The PpUGV highlights two common challenges that hospital managers, and especially nursing managers, encounter in their daily routine. The first is the use of heterogeneous hospital data. Different types of data are stored in different, sometimes incompatible, systems. The manual combination

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The project was done in close cooperation of nursing management and computer science professionals. A nursing manager (M.H.) took part in the whole process. The method was used in practice to create reports. This ensured that the resulting method served nursing managers' needs and improved both speed and the documentation workflow.

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of heterogeneous data is cumbersome and error-prone. This makes it challenging to combine the data in a meaningful way. The second is that hospital care is multifaceted and often brings new requirements. These quickly changing requirements make it necessary to find and combine data flexibly and quickly.

Similar challenges are often encountered in business. One possible mitigation was found in the form of business intelligence (BI) instruments. These offer methods to combine data from different sources and visualize these data flexibly and interactively. These instruments can also be applied to hospital data.

We propose to use BI methods in nursing management documentation processes that involve heterogeneous hospital data. This approach is expected to allow nursing managers to accelerate and simplify documentation processes. The documentation of patient-nurse ratios, as in the PpUGV, serves as an example of such a process. The goal of the present study is to assess the use of BI in nursing management documentation processes that include heterogeneous hospital data.

## RELATED WORK

Germany's is not the first administration to use patient-nurse ratios as a means of quality control for hospital care. Similar measures have been used in California in the United States<sup>7</sup> and the states of Queensland and Victoria in Australia,<sup>8</sup> for example.

Patient-nurse ratios have long been an active field of research. There are numerous studies on the association between patient-nurse ratios (or nurse staffing levels in general) and patient outcomes.<sup>9–12</sup> Other studies include the effect of such ratios on nursing staff satisfaction and well-being.<sup>13</sup> Another field of research is the study of organizational changes associated with mandated patient-nurse ratios.<sup>14</sup> Whereas the effects of patient-nurse ratios are well-studied, their documentation processes are not.

On a larger scale, the integration of heterogeneous hospital data has been achieved using the concept of data

warehouses, systems that combine and aggregate many different data sources.<sup>15–17</sup> This approach requires significant installation and maintenance efforts, rendering it unfeasible for a smaller application such as the integration of two data sources for documentation. A more cost-effective solution is required, one that allows the integration of a few data sources and the generation of the required documentation. The present study does not build upon a data warehouse. Instead, a BI system is directly used as the basis for the PpUGV documentation and visualization system.

Business intelligence instruments and methods have been used in various nursing management applications. These include controlling and communication<sup>18,19</sup>; patient, disease, and population management<sup>20–22</sup>; and assessment of hospital documentation quality.<sup>23</sup> The effects of BI usage have been studied in combination with nursing decision support.<sup>24</sup> Other domains in healthcare have also seen increased implementation and study of BI systems.<sup>25</sup> More uses of BI in nursing management are expected to improve healthcare.<sup>26</sup>

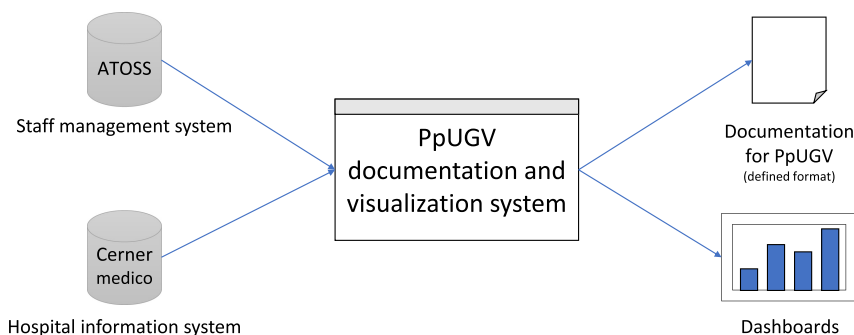
Nursing management documentation processes, however, have not been studied as a possible field of application of BI. To the best of our knowledge, this is the first study to assess the use of BI in nursing management documentation processes that include heterogeneous hospital data.

## METHODS

Process analysis was carried out in a German hospital with 650 beds. Interviews and observations with nursing and IT managers were conducted to understand the process thoroughly.

The results of this process analysis were then used to design and implement a PpUGV documentation and visualization system in the hospital. The instrument was realized as an app in the commercially available BI platform Qlik Sense (QlikTech International, Lund, Sweden). The overall architecture can be seen in Figure 1.

The requirements, as defined in the regulation, were transformed into a data model that encompasses all the data



**FIGURE 1.** The overall architecture of the proposed method. It combines staff and patient numbers to produce the required documentation, as well as interactive visualization dashboards. An overview of the corresponding process can be seen in Figure 3.

needed for the PpUGV. A load script and a collection of dashboards were designed and implemented. The load script defines how data can be imported into the data model. The dashboards are used to display the information contained in this data model in various ways.

**RESULTS**

**Manuel Process Analysis**

The output of the documentation process is defined in the regulation. It contains organizational information that must not be changed by the hospital because this information is used by government agencies to identify the hospital and its wards. Changes to this information will result in an error message when handing the documentation in. Based on the hospital's staff and patient numbers, different columns in the table must be computed. These include the monthly average number of nurses and patients, the resulting patient-nurse ratios, and the number of shifts in which the required limit was not met. The regulation defines the hospital shifts as day (6:00 AM to 10:00 PM) and night (10:00 PM to 6:00 AM). These shifts do not necessarily reflect the working hours in the hospital but are used to align the working hours in hospitals across Germany for the purposes of evaluation. This means that nursing shifts that lie across the regulation shift hours have to be distributed to the two regulation shifts proportionately, irrespective of how the nursing shifts are managed (and named) in the hospital. Patient numbers are collected only once per day and are then valid for both shifts.

The German Ministry of Health differentiates between two different types of staff members in the regulation: examined and nonexamined nurses. Although all examined staff can be included in the calculation of the patient-nurse ratios, there is a limit on the number of nonexamined staff that can be included. This maximal includable number of nonexamined staff can be calculated from the number of examined staff.

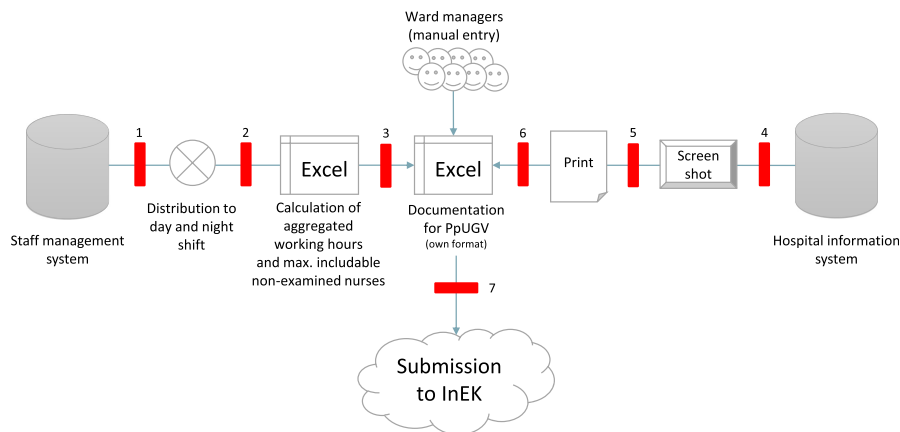
Table 1 shows the final format of the documentation. This documentation must be manually submitted to the Web site of InEK, the “Institut für das Entgeltsystem im Krankenhaus” (Institute for Hospital Reimbursement). As this Web site is provided by InEK, no changes in this part of the documentation process are possible.

The result of the analysis of the manual process can be seen in Figure 2. The data are gathered from two different sources. The first type of data describes the nurses working in each affected ward. It is copied from the staff management system (step 1). These numbers are manually divided into different positions according to the nurse types (examined and nonexamined) and day and night shifts (step 2) and then aggregated (step 3). If a nurse's shift does not entirely lie in one PpUGV shift (ie, not entirely in the range 6:00 AM to 10:00 PM for the day shift or in the range 10:00 PM to 6:00 AM for the night shift), the working time is distributed

**Table 1. An Example of the Required Documentation With Fictional Data**

Division type as in PpUGV	Division ID	Ward Type in Hospital	Ward Name	Location	Month	Shift	No. of Shifts	Average Staff No. (Examined) (EN)	Average Staff No. (Nonexamined) (NEN)	Average Patient No. (NP)	No. of Shifts in Which Limit Was Not Met	Patient-to-Nurse Ratio (PNR)	Maximum No. of Nonexamined Staff Includable in the Ratio (INEN)
Cardiology	0300	Cardiology	W1	1	January	Day	31	5.72	0.92	52.12	0	8.19	0.64
Cardiology	0300	Cardiology	W1	1	January	Night	31	4.00	0.00	52.58	0	13.15	0.71
Intensive care	0300	Cardiology	W1	1	January	Day	31	14.24	0.76	31.72	1	2.11	1.24
Intensive care	0300	Cardiology	W1	1	January	Night	31	10.00	0.00	31.72	0	3.17	0.87

The column names and cell entries were originally in German and have been translated into English. The first seven columns contain organizational information. The following seven columns contain information that is computed based on the data available in the hospital. As can be seen in the table, one ward in the hospital can be a part of multiple divisions as defined in the PpUGV; if different case types are treated there. The abbreviations are the same used in the main text.



**FIGURE 2.** Depiction of the original manual documentation process. Manual copying or calculation steps are denoted with a red bar, with the numbers denoting the step as mentioned in the main text.

according to the working hours. The working hours are used when calculating the total amount of time spent working per ward. This was done manually using a Microsoft Excel (Microsoft Inc, Redmond, WA, USA) spreadsheet. In addition, the number of maximal includable nonexamined nurses is calculated.

The second data source is concerned with the number of patients per ward. Screenshots of the hospital information system were used as the data source (step 4). These screenshots were printed out (step 5) to make it easier to work with the hospital information system. Different wards were only accessible on different pages of the system. The change between these pages was deemed too time-consuming. The needed values were manually transferred from the printed screenshots (step 6). Both staff and patient numbers were collected in one single Microsoft Excel spreadsheet that carries out the remaining calculations automatically. The format of this spreadsheet was defined by the nursing managers and could not directly be used for the required submission of the documentation. A transferring step is needed to transform the collection format to the submission format (step 7). These formats differ in the level of detail (daily vs monthly values) and their division into files (one file per ward vs one file per quarter). The data are then submitted to the InEK Web site.

Ward managers can directly modify the resulting spreadsheet. They have the option to enter the data by hand, bypassing the staff management system and the hospital information system entirely. This can be done in order to document the patient and staff numbers directly from the ward, for example, in night shifts during regular rounds.

Overall, there were seven manual copying and calculation steps in the process.

### Problems in the Manual Process

The manual process leads to several problems. First, the process is very time-consuming, taking away from the nursing

manager's limited resources. Second, the process is error-prone. Many manual copying and calculation steps can easily lead to errors in the numbers. All of the seven manual copying and calculation steps contribute to the time-consuming and error-prone nature of the process.

Third, the process does not scale. The more wards and hospital locations affected by the PpUGV, the more work time is needed to complete the documentation. With more divisions being added yearly, this steadily increases nursing managers' workload.

### Data Model

The data model was derived from the regulation text. As no mathematical formulas were included in the text, they had to be developed together with the data model. The model itself contains all the types of information that are mentioned in the regulation.

Depending on the hospital, the patient and staff information can come from a variety of sources. It can be automatically gathered from existing hospital systems. If this is not possible, it can be collected manually in Microsoft Excel spreadsheet files as a workaround. This mode of data collection is different across hospitals or sometimes even different locations and wards of the same hospital. This data model acts as an interface definition. It describes which information is needed for the PpUGV documentation and visualization system, abstracting the information from the mode of collection.

The following fields are included in the data model. First, there are the base fields that are used to match entries from the data sources. These are date, ward, location, shift, and division. Next, the fields defined by the PpUGV are the defined patient-nurse ratios and the maximal allowed portion of nonexamined nurses (MaxNEN). The remaining fields come from the input data or can be calculated from this data. These fields are the numbers of patients (NP),

examined nurses (EN), and nonexamined nurses (NEN) and the following calculated fields. These formulas have been developed from the textual description found in the regulation.

1. Maximal includable number of nonexamined nurses (INEN):

$$NEN * \frac{MaxNEN}{1 - MaxNEN}$$

2. Total number of nurses (NN), with NEN capped at INEN:

$$EN + \text{minimum}(NEN, INEN)$$

3. Minimal number of nurses needed (MN):

$$\frac{NP}{PNR}$$

4. Degree of fulfillment:

$$\frac{NN}{MN}$$

### Pflegepersonaluntergrenzen-Verordnung Documentation and Visualization System

The developed method is usable in the form of a one-click PpUGV documentation and visualization system. It automatically reads in the input data and calculates the required documentation. The corresponding process can be seen in Figure 3. A file export is triggered in the staff management system once a week. The hospital information system generates another new export file. These two export files are used as data sources.

The PpUGV documentation and visualization system automatically gathers the data and calculates the documentation. It first reads in the files that have been produced by the patient

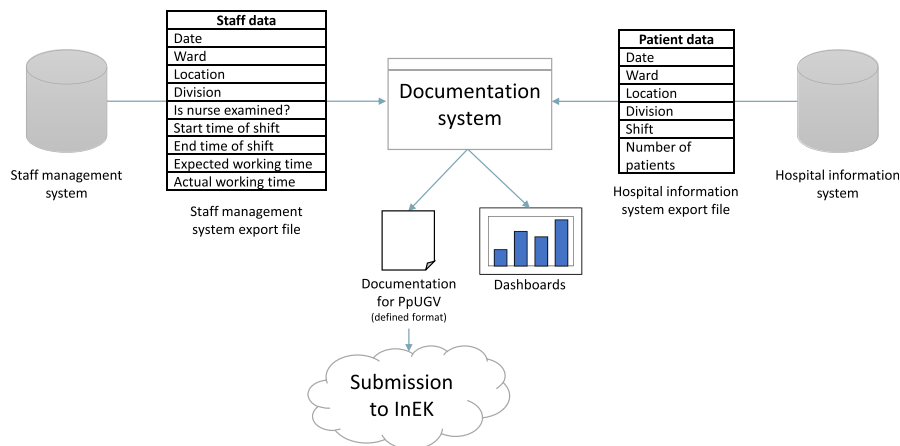
and staff management systems in the hospital or created manually. After filtering out data that are not needed (eg, data of wards that are not affected by the PpUGV), the names used in both information types are translated into joint names. As many hospital information systems use their own convention, this kind of translation is needed to ensure that entries from different systems can successfully be matched. This ensures that the data fit into the data model defined for this method. It then automatically executes the remaining calculation steps, which include distributing, aggregating, and calculating the values (steps 1 to 6 in the manual process) and the generation of the required format (step 7). All of the steps (1 to 7) in the manual process have been replaced by the load script. No further actions are required to calculate the documentation. Overall, this new process contains no manual copying and calculation steps.

The created dashboards contain various data visualization components. These dashboards can be used to analyze the nursing management data that were previously loaded, independently of the requirements of the PpUGV.

The method was validated by comparing both the manual and the automated documentation for 7 months. Overall, the differences between the automated and manual calculations were minimal, with the number of nurses being on average  $0.04 \pm 0.38$  lower with the automatic calculation, with the average taken per shift type (day and night), month, and ward. Such differences were to be expected because the automated approach performs the necessary calculations on a much more exact scale (work minutes instead of work hours). The method produced the correct documentation, which was submitted to and validated by InEK.

### DISCUSSION

Overall, the solution proved cost-effective. No changes to the IT landscape of the hospital were needed. Data exports of the existing IT systems could be used.



**FIGURE 3.** Depiction of the documentation process using the PpUGV documentation and visualization system. No manual copying or calculation steps remain.

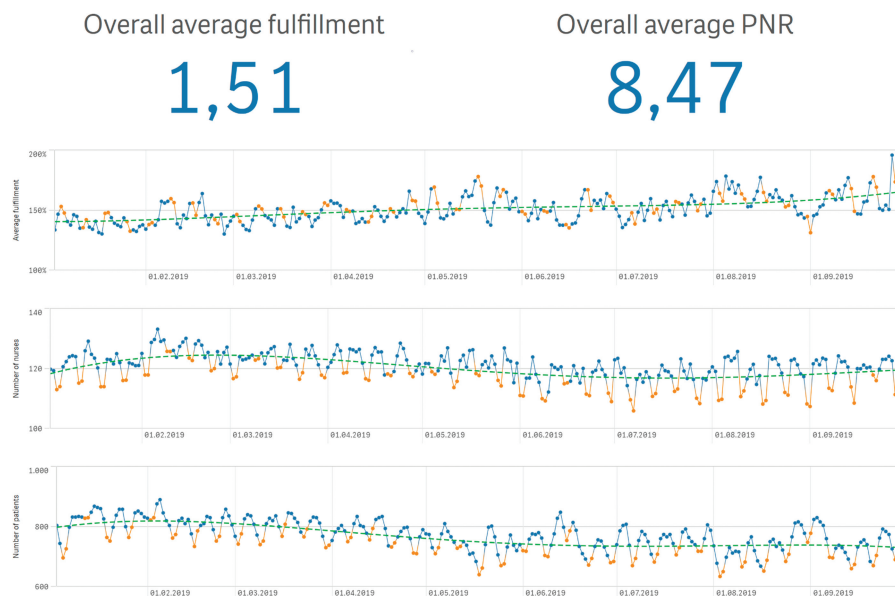
The automation of some of the required steps reduces the workload needed to fulfill the documentation requirements present in the PpUGV. Overall, the number of manual copying and calculation steps was reduced from seven to zero. The computation was completely automated. This part of the process was time-consuming and could easily lead to errors due to the high number of manual copying of numbers from one medium to another. This automation makes the process faster and less error-prone. The time savings cannot be quantified precisely because of a training effect and confounding factors that cannot be adjusted for in hospital practice (eg, interruptions). The overall time needed for the manually created report was around 40 hours per month, whereas the overall time for the automatically created report was less than 5 hours per month. The time savings are thus around 35 hours per month.

Apart from these quantitative changes, there are also qualitative changes. First, the PpUGV documentation and visualization system offers a variety of well-known visualization types. The data model includes wards, hospital divisions, dates, patient numbers, and working times. These data can be freely and interactively used to create visualizations. No programming knowledge is required. These visualizations can be used to answer various questions that arise in nursing management. Two such questions are “How are patient and nurse numbers evolving in relation to each other?” and “Is there a trend?” An example of one of the visualization dashboards can be seen in Figure 4. It is clearly visible that both patient and nurse numbers decrease considerably on

weekends (orange), but this does not have a negative impact on the fulfillment. The green trend lines (modeled as polynomials of degree 4) show interesting overall trends in the data. Both the patient and nurse numbers are affected by the main vacation times in Germany (December-January and June-August). The decline in patient numbers from January to September reflects the regular annual fluctuations, for example, due to vacation times. The degree of fulfillment increases steadily. The visualization functionality facilitates informed decision-making in nursing staff management. The date information included in the PpUGV data can be used to discover temporal trends and react to seasonal changes in the data.

The second qualitative change is that the PpUGV documentation and visualization system automatically calculates the sanctions to be expected with every report. In the case of overfulfillment, it automatically calculates the amount by which the defined limits in the regulation were exceeded. Previously, it was not clear if sanctions had to be expected before the final report was submitted. This is now calculated on a daily basis. This functionality allows nursing managers to change nurse staffing plans according to the data proactively. A screenshot of this can be seen in Figure 5.

The third change is that this new process has better overall scalability. Although the manual documentation process needed to be executed for each affected ward separately, the generation of the files, as well as the one-click report generation, are done for all wards simultaneously. Different locations of the hospital can be combined without modification.



**FIGURE 4.** A screenshot of one of the visualization dashboards with data of January to September 2019. On the top, the overall average patient-nurse ratio (PNR) and fulfillment can be seen. Both are averaged over all days and wards. Below are three line graphs showing the development of the average fulfillment, as well as the average number of nurses and patients. All graphs include green trend lines and orange marks for weekends.

Ward	Q	Month	Q	Mandated PNR	Q	Sanctions	Overfulfilment	Under- / Overstaffing
1	May			20		-6.495,31 €	3.701,03 €	0,76
2	May			20		-6.055,81 €	3.450,60 €	0,71
3	May			20		-5.925,72 €	3.376,48 €	0,69
4	May			20		-5.025,85 €	2.863,73 €	0,59
5	May			3,5		-4.992,73 €	2.844,86 €	0,59
6	May			20		-4.153,33 €	2.366,57 €	0,49
7	May			20		-2.468,44 €	1.406,52 €	0,29
8	May			3,5		-2.345,49 €	1.336,46 €	0,27
9	May			3,5		-1.962,18 €	1.118,05 €	0,23
10	May			20		1.894,78 €	-1.079,65 €	-0,22

**FIGURE 5.** A screenshot of the sanction calculation functionality. Both sanctions and the overfulfillment (in Euros spent) are shown to make these two measures comparable. If the month was overstaffed, the sanctions are below zero and vice versa. For example, ward 1 has negative sanctions because it was overstaffed according to the PpUGV. The negative sanctions give an impression of how much sanction was evaded because of this overstaffing.

This makes it easy to scale the process to different wards and locations of a hospital without increasing the manual work necessary.

Lastly, the system is easy to update. As mentioned previously, yearly changes in the regulation details are to be expected. The regulation details are stored in a configuration file that can be updated accordingly without the need to change the system itself. Changes in the allowed patient-nurse ratios, the number of nonexamined staff that can be included in the ratios, and the affected divisions themselves thus only have to be incorporated into the configuration file.

## CONCLUSION

The documentation required by the PpUGV can be time-consuming and error-prone if done manually. The PpUGV documentation and visualization system automates this process and returns the correct documentation in a fast and efficient way. Its underlying model, including the needed mathematical formulas, was derived from the regulation text. The model includes heterogeneous data from different sources, which can also be used in the visualization component via dashboards. The graphs in these dashboards can be created and queried interactively, aiding nursing managers in the analysis of their data.

The system is robust against changes in the regulation. In addition, the method is cost-effective, as no changes to existing IT systems are needed. It scales to multiple hospitals without modification.

In summary, the method improved the documentation process and had further positive impact. It allows nursing managers to use their data efficiently and interactively without larger investments.

## ETHICAL APPROVAL

No ethical approval was required because no patient data were used. Only preexisting, administrative data were used in summarized form as required by government regulations.

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