

# Value Stream Mapping Requirements for Optimizing Information Flows in Hospitals

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**H**ospitals face increasing staff shortages while simultaneously advancing the digitalization of patient data and clinical processes. To achieve sustainable workload reduction, however, information and communication processes must be optimized alongside the introduction of digital technologies. Existing approaches to modeling information flows, particularly adaptations of value stream mapping, do not adequately account for the specific characteristics of hospital processes. This paper aims to identify the requirements for modeling information flows in hospitals and to adapt conventional value stream mapping accordingly. Interviews with clinical staff, with subsequent observations of workflows, were done to gain insights into hospital communication pathways. Based on these findings, requirements were structured using the MoSCoW method, relevant evaluation metrics were defined, and adaptations for value stream mapping were made.

[Keywords: Value Stream Mapping, Hospital, Information Flow, Analysis]

## 1 Introduction

Across the globe, populations are aging, and multimorbidity is becoming more common, increasing pressure on healthcare systems and hospitals [1]. At the same time, hospitals face growing staff shortages and rising costs [2]. This combination leads to an increasing workload for healthcare professionals. Digital technologies have the potential to reduce staff workload and improve efficiency. The increase in available data also has the potential to increase staff mem-

bers' satisfaction [3]. However, hospitals often lag behind other industries in adopting new technologies [4] in part due to low compatibility with the current workflows, slow progress in standardization, and unwillingness of healthcare providers to invest without proof that those investments reduce costs [5]. When technologies or process optimizations are introduced, they are typically implemented within individual departments rather than across entire hospitals. This "island approach" optimizes local processes while providing little transparency regarding interdisciplinary workflows [6]. As a result, communication and information exchange between departments remain fragmented. Although German hospitals are currently transitioning to digital patient records, sustainable digitalization requires not only new technologies but also the adaptation, optimization, and standardization of hospital information and communication processes [7]. A holistic understanding of information exchange is therefore essential. Process models can help identify where information originates, how it is transferred, what information is transferred, and where it is required. While many modeling approaches exist, including the widely used value stream mapping (VSM), they primarily focus on the flow of materials or people. Information flow is generally treated as a secondary aspect, despite being central to operations. Moreover, hospital processes are highly variable and differ fundamentally from the standardized workflows typically addressed by lean management approaches.

This paper investigates how information exchange in hospitals can be modeled and how value stream mapping can be adapted for this purpose. It reviews the current state of information flow modeling and lean management in hospitals, derives requirements and evaluation metrics for a suitable modeling approach, and proposes adaptations of VSM to better reflect hospital-specific conditions.

## 2 State of the Art

Lean management, and specifically value stream mapping, is a widely accepted analysis method used in most industries to help identify weak points in the current processes. It helps simplify processes and identify aspects that do not generate value and how to reduce these. As such, hospital environments could greatly benefit from VSM application, and while it has been applied in the hospital environment, VSM has yet to find real purchase [8], [9], [10]. The main use cases are in individual departments, such as the pharmacy [11], not the hospital as a whole or the interaction between departments [12]. Misra et al. [8] examined what is hindering the adoption of lean management in hospital environments, identifying four main factors: poor knowledge of lean, current management practices, the hospital organizational structure, and employee resistance. Current management practices include a lack of management support and too little time and resources. The problematic organizational structure is identified as stemming from the low-level of interdepartmental optimization. Akmal et al. [10] undertake a similar examination and come to the conclusion that there are three main reasons for resistance to lean implementation in hospitals. The first is the loss of power and autonomy that physicians feel through the organizational shifts that often occur. A lack of familiarity and motivation to implement lean is identified as another issue. The third reason for resistance stems from the manufacturing background of lean and the framing of terms, feeling that these are not applicable or even detrimental to a hospital use case. Alogla [9] comes to similar conclusions and argues that, specifically for VSM, the largest hurdle is the flawed adaptation from classic VSM terms into the hospital environment. This, for example, makes it difficult to define what value is or who the customer is. Their paper proposes initial terminology and definitions to more effectively apply VSM in hospital environments. They argue that the patient is not only the customer but also the product. The state of the patient is the raw material that is transformed into a more desirable state. Adapting terminology helps both management and medical staff work together more effectively, rather than feeling like they are on opposing teams. Hospitals present specific conditions [9], [10], and to ensure VSM is successfully adopted in hospital environments, its core ideas must be tailored to the environment in which they are used to foster understanding and collaboration.

Over the last few years, multiple researchers have proposed ways to adapt classic modeling systems to accommodate the ever-growing importance of data. Value stream mapping is no exception, with multiple papers [13], [14], [15], [16], [17], [18] [19] delving into the adaptation and application of VSM for the flow of information. Roh et al. [13] have proposed a variation they call information stream mapping (ISM). This includes not only suggestions for changes to the mapping itself, but also builds on the work of Meudt et al. [14] on how to view the classic “7

wastes” when applied to the flow of information. Unnecessary Motion, for example, is defined as the search for information and the combination of information from varying sources. [13] defines five key performance indicators (KPIs) with which these wastes can be identified, they are:

- Level of automation: ratio of fully automated information transfers to the total number of information transfers.
- Centrality index: Number of information transfers to a central IT system over the total number of information transfers.
- Real-time capability: One minus the quotient of the number of information transfers in real-time, divided by the number of total information transfers.
- Media disruptions: The sum of information transfers from digital to paper based and oral to paper based, divided by the total number of information transfers.
- First pass yield of information: One minus the quotient of the number of transfers for which further questions were required over the total number of information transfers

Busert et al. [15] take it a step further, arguing that the additional aspect of information quality must be measured to sufficiently be able to evaluate the flow of information. They define the quality of information through three additional KPIs:

- Granularity: The degree of detail with which the information is given.
- Actuality: How up-to-date the information is or how frequently it is supplied.
- Accuracy: The correctness and completeness of the information.

Bega et al. [16] also examine the adaptation of VSM for information flow, focusing on the visualization of the media origins of information and the transfer method. Although very extensive, they acknowledge that these additions make the model harder to understand, making it difficult for complex applications. Example applications are given in the paper from Hartmann et al. [17]. They apply information flow analysis to 13 companies across various technology industries and 1 maintenance company. Focusing on how hindrances in the information flow correlate to the value stream. Mesiter et al. [18] is another example, suggesting a KPI framework by which information logistics waste can be identified in the digitalization of company processes. The work from Muehlbauer et al. [19] suggests a methodology with which the data maturity of logistic operations can be analyzed to evaluate potential.

The work in these papers lays a solid foundation for adapting VSM to information flow, but the application use cases remain limited. The test cases were applied in manufacturing companies, and aspects such as the experience and knowledge of employees were not considered. The papers that do have hospital application take the first steps toward recognizing the problems hindering VSM adaptation and offer suggestions for adaptation to the specific use case. However, their focus is on classic VSM, analyzing how to better depict the patient's flow through the hospital. The application of VSM in hospitals still lags behind the industrial applications [12], which have recognized the flow of information as a vital aspect of modern processes [13]. As such, research needs to not only look at applying classic VSM to the hospital environment but also start analyzing the flow of information so that hospital applications can catch up to industrial standards.

### 3 Methodology

The methodology of this paper consists of 4 parts, the first two of which are interviews and observations conducted in a hospital to gain an overview of what communication and information exchange actually look like. All interviewed staff members and observed patients agreed to the taking of notes, and no personal data, beyond their role or diagnosis, was recorded. Interviews and observations consisted solely of non-interventional studies, and all information gathered was kept anonymous. According to institutional guidelines, no formal ethical approval was required. Using the information gained from these two steps, a list of requirements is generated that can be used to ensure an adapted VSM can be applied to the hospital. Finally, adaptations to common terms are proposed and discussed, along with KPIs to evaluate information-flow processes in a hospital. An overview of the applied methodology can be seen in Figure 1.

To gain insight into the information exchange in hospitals, a university clinic in Germany is regarded as a use case. The particularity of a university clinic is that it not only provides patient care but also educates physicians. This means there is a high level of staff turnover, as physicians in training only stay for a limited time. Additionally, there is a large variation in employees' skills and experience. To begin, interviews are conducted to gain a general overview of communication processes in the hospital. Aiming to understand what information is exchanged and how, as well as how staff members view that exchange. Notes are taken throughout. Each staff member is interviewed by two people simultaneously, and afterward, the two interviewers compare notes to ensure the discussed aspects are understood correctly. If any points differ, the corresponding staff member is contacted again to clarify. The interviews are semi-structured, and starting questions are kept general, asking the staff members to describe their daily work and how

they communicate and acquire data. Follow-up questions are based on the answers given and focus on identifying staff members' needs for a successful exchange of information, as well as any aspects that play a key role in the process or cause deviations. The interviews provide the necessary base context to understand the requirements a model must have to reliably depict hospital processes. However, as medical staff members may not be able to reproduce all relevant information during an interview, observations are also performed to gain a more thorough understanding. The objective of this study is to establish a stable base foundation of adaptations that are needed, not to account for all possible edge cases. Consequently, the scope of observation is a single representative process that covers a wide base of interactions. This allows for methodological simplicity while also enabling an in-depth analysis. The process chosen for the observations is the preoperative ambulant patient admission. In its core, this process is about gathering necessary information on the patient so that the responsible physician can decide whether an operation can be performed and what deviations may be necessary. As such, this process focuses on the exchange of information among multiple parties within and outside the chosen ward, ensuring that a wide range of communication options can be observed. The process steps are highly standardized, but deviations still occur that need to be resolved. This ensures that a stable base understanding is established, but also that deviations, typical of a hospital environment, can be taken into account. The chosen process is observed over two days by two people following the relevant staff member. During the observations, the general actions are noted, but special focus is given to any steps involving the acquisition or exchange of information. Specifically noting which information is given or received from which source using which form of media. Before the official observations begin, the staff member is asked to clarify the standard workflow as it should occur without interferences or problems. This provides a baseline against which observers can identify deviations. If the staff member mentions regular deviations that occur, then these are also noted. During observation, when patient contact occurs, the observers explain their presence and ask permission to observe. The only patient data recorded is the diagnosis. This is necessary to differentiate the processes of the different pathologies. The process steps the staff member goes through for each patient are recorded, specifically those that require information exchange and the manner in which the physician obtains or shares this information. If steps or exchanges are unclear, questions are asked when the patient is not present. As with the interviews, the two observers compare notes afterward, and differences are discussed and, if needed, clarified with the staff member.

The information gathered through interviews and observations is compiled to create a list of requirements for the model. To create this list, the gathered information is used and analyzed in three steps. The first step is to clarify the model's goal by asking: What should the model be used

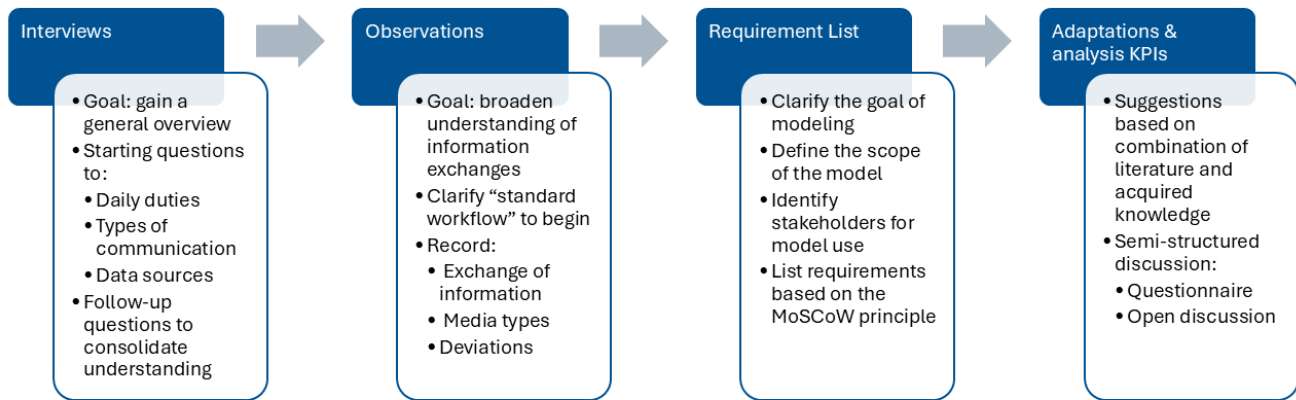


Figure 1: Overview of the steps of the applied methodology.

for? Who is supposed to use the model? And what level of detail should the model give? The second is defining a clear scope, which includes start and end points and the aspects to depict. The third step is to identify which stakeholders would use the model and what information they would be interested in. Combined with the notes taken during interviews and observations, the information is used to create a list of requirements based on the MoSCoW principle. This method ranks requirements according to “Must have”, “Should have”, “Could have”, and “Will not have”. “Must have” refers to functional requirements that are necessary for the model to achieve its goal. If any of these requirements are not met, the model is unusable. “Should have” requirements are aspects important to the model’s usability and quality. These are strongly based on the information needed by the identified stakeholders. “Could have” is an aspect that would increase the quality of the model, but is not necessary for usability. “Will not have” constitutes anything that lies outside the defined scope.

Next, adaptations to the principles of classic VMS are made based on the suggestions from [8], [9], [10] and the knowledge gained during the interviews and observations in the hospital. Additionally, KPIs for identifying waste are defined to ensure the models created can be used effectively. The KPIs were taken from the current state of the art, specifically [13] and [15] and, where needed, adapted for the hospital use case. In the final step, the chosen KPIs and suggested adaptations are evaluated and discussed with a group of four scientific researchers focused on the optimization and modeling of logistic processes. This discussion is semi-structured with the goal of gaining a first input on whether the adaptations still keep the core idea of VSM. First, the newly defined terms and KPIs are explained, along with an overview of hospital processes. Then a questionnaire is handed out, in which the terms and KPI are evaluated on applicability, usability, and comprehension. Com-

prehension was chosen because management positions in hospitals are frequently held by medical staff with limited lean experience who should still be able to understand the model’s results. Applicability verifies that the adaptations made are considered sensible for the hospital environment. Usability is checked to verify that any adaptations made still fulfill the core goal of VMS. Afterward, an open discussion was started to gain more in-depth feedback and input on the adapted definitions. Although the evaluation of comprehension focuses on the medical professionals, the validation is initially performed with logistic researchers, as their base understanding can allow them to give feedback even if explanations or definitions are confusing. This feedback can ensure that later validation with medical professionals begins at a higher level of comprehensibility, allowing for more substantive feedback from these key stakeholders.

#### 4 Results

The interviews at the German university hospital took place on a surgical ward. The head nurse of that ward was interviewed, as were a surgeon and a physician. Each interview lasted about an hour. When the interviews were completed, the observations took place over two separate days. At the beginning of the first day, the physician responsible for admissions was asked to summarize the typical workflow. The process begins when the patient arrives at the outpatient admission. Here, the physician decides which information is needed. For the usual types of visceral surgery, the patient needs to have their blood tested, visit the ear, nose, and throat doctor (ENT), have an electrocardiogram (ECG), and get the go-ahead from the anesthesiologist. Afterward, the patient returns to the outpatient admission, where the physician reviews all gathered information, conducts a risk assessment, and finally counsels the patient on their upcoming operation. In the final step, all patient information is

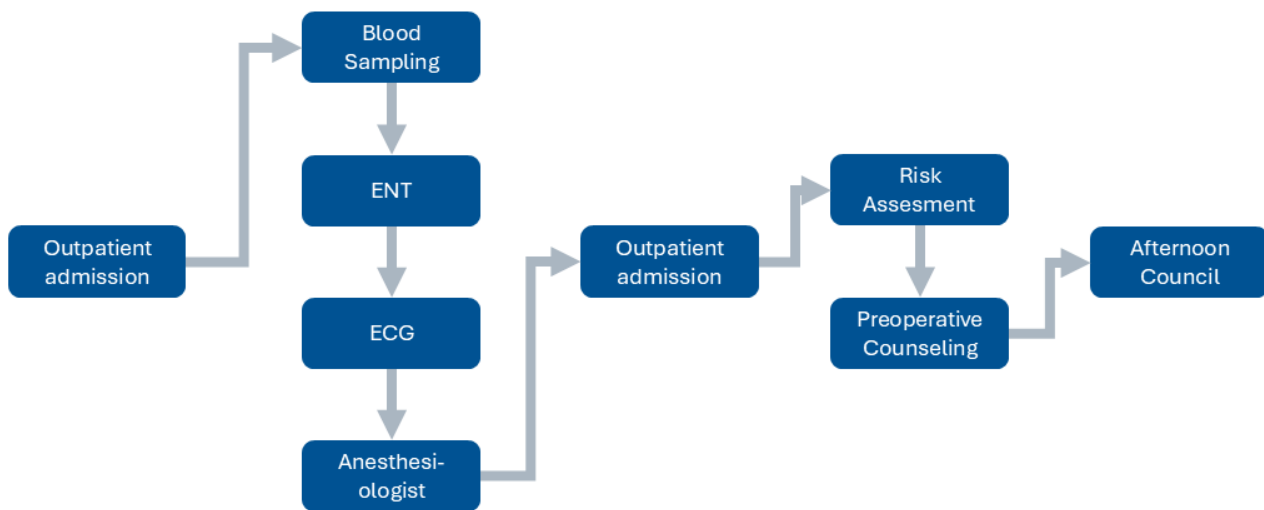


Figure 2: General process steps of the ambulatory preoperative outpatient admission.

presented to the responsible head surgeon at the afternoon council, who ultimately decides whether and how the patient will undergo surgery. The summary of the process is shown in Figure 2.

After receiving the general overview, the observations were conducted from the physician's perspective, as the physician is responsible for ensuring that all relevant data is accounted for. In total, the process was observed six times. Four of the observed processes only had minor deviations from the typical workflow described above. One of which was with a patient who had limited German language skills. The two deviations included one patient who was not registered in the system upon arrival and one patient who experienced a medical emergency during blood sampling. The missing registration was remedied by calling the corresponding department and clarifying the reason. In this case, the registration had been forgotten, and the call resulted in the patient's information being included in the system. However, because the system takes a while to update, the necessary stickers for the blood samples could not be printed immediately, further delaying the process. In the case of the medical emergency, immediate support from nurses was required, which required them to drop any work they were currently doing. The emergency delayed this patient's process and the following patients'. The incident also called for additional testing and was noted by the physician later in the risk assessment.

Over the course of the interviews and observations, the following aspects were noted that should be taken into account when adapting a modeling language for hospital application:

- Patient data is saved in a digital system, but most diagnostic information comes from physicians' letters, which are only scanned into the system.
- Physician's letters are not standardized, and due to the scanning process, it is currently not possible to search for specific information over multiple documents.
- If data is missing or unclear, the most efficient way to gain the needed information is to call the responsible staff member.
- Physicians receive multiple calls per hour, causing constant disruptions to their work.
- The physician in charge of the preoperative ambulant patient admission must assess the operational risk of the patient; this assessment is made based on the impression the physician has of the patient.
- Experienced physicians can better judge a situation and make decisions with missing information than a physician in training or at the beginning of their career.
- The amount of information required at the afternoon council and the total time it takes is strongly dependent on the head surgeon present and their personal decision-making process.

The interviews and observations were analyzed in three steps as explained in section 3 with the following results. The model has two goals: the first is to help physicians and nurses clarify the communication process in a hospital environment. The second is to help management identify bottle-

|                                       | Requirement                                                         | Reasoning                                                                                                                                         |
|---------------------------------------|---------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------|
| The model <b>must</b> be able to...   | ...represent different types of media.                              | Hospitals rely on a wide range of technologies and communication types.                                                                           |
|                                       | ...represent the transition between different types of media.       | Communication in hospitals is handled through a wide range of media forms and requires the information to be constantly reprocessed.              |
|                                       | ... represent the completeness of the information.                  | Missing information causes disturbances and deviations in the process.                                                                            |
|                                       | ... show person-specific information.                               | Individual experience and knowledge of medical staff play a large role.                                                                           |
|                                       | ... make it clear where the information comes from.                 | The goal is to increase transparency, and the medical staff needs to know where the information originated in case of questions.                  |
|                                       | ... make it clear where specific information is needed.             | The goal is to increase transparency, and the medical staff needs to understand who is dependent on their information.                            |
|                                       | ... use uniformly defined symbols, colors, and structure.           | The model needs to be easy to understand and comparable.                                                                                          |
| The model <b>should</b> be able to... | ...account for employee experience and knowledge.                   | Individual experience and knowledge of medical staff play a large role.                                                                           |
|                                       | ... be understandable, even for people with limited VSM experience. | Medical staff are key stakeholders and do not necessarily have lean experience.                                                                   |
|                                       | ...represent time requirements.                                     | Important KPI for management.                                                                                                                     |
|                                       | ...represent the information content at different levels.           | Different depths of information are needed for different process steps.                                                                           |
|                                       | ...identify triggers for information exchange.                      | The goal is to increase transparency of the processes.                                                                                            |
|                                       | ...represent or highlight deviations from the process.              | Management wants to understand where common deviations occur.                                                                                     |
|                                       | ...visualize bottlenecks.                                           | Management wants to understand what steps cause delays and cost time.                                                                             |
| The model <b>could</b> be able to...  | ... be scalable, to depict connections between processes.           | Extensions increase transparency and understanding.                                                                                               |
|                                       | ...represent patient risk assessments.                              | An important piece of information, yet very difficult to fully quantify.                                                                          |
|                                       | ...represent different sources of information.                      | Each department uses different technologies and software, which are not necessarily compatible with those of other departments, causing friction. |
| The model <b>will not</b> ...         | ...show how information is collected.                               | Focus is on communication processes, thus the exchange of information.                                                                            |
|                                       | ...depict the flow of materials or people.                          | Focus is on communication processes, thus the flow of information.                                                                                |
|                                       | ...be created by medical staff members.                             | The workload for medical staff should not be increased.                                                                                           |

Figure 3: List of model requirements with short explanation.

necks and areas of waste. As such, the main stakeholders are medical staff members, especially physicians, and hospital management, which often have a medical background. The former is most interested in understanding where they can find the information they need and who relies on the information they have. The second group is interested in identifying why processes deviate and how to minimize these deviations. The model needs to have relatively detailed information about the receivers and transmitters of information, since this is often person-specific, and it also needs to show a wide range of transmission types. However, since the goal is not to show how information is created, such aspects do not need to be described in great detail. Additionally, the scope is set to only depict the flow of information. This means the path the information takes should be followed, which is not necessarily the path the patient takes. The model only needs to depict individual closed processes to begin with, not all processes that can occur for a patient. A closed process is defined as the creation of a single data packet, such as ambulatory preoperative outpatient admissions.

Using this information, requirements for an adapted VSM method are considered and prioritized according to the MoSCoW method. A few chosen requirements will be explained here, and a summary of all requirements can be found in Figure 3. For the modeling of VSM in a hospital environment, one example of a “Must-have” requirement is that the model is person-specific. As employee experience plays a large role in their decision-making process, it is important that the model can be depicted at a level where indi-

vidual people are taken into account. If this level of detail is not given, then the model will have problems being applied to the hospital context. Building on that, a “Should have” requirement is that employee experience and knowledge is accounted for. This is an important aspect that can greatly influence whether a disturbance occurs or not, and is thus vital for the usability. A further “must-have” requirement is that the model must clearly depict which medium is used for the transfer of data, as well as any media changes needed to process the data. This aspect is important as, depending on the media, different volumes of information can be acquired at different levels of accuracy and in different time spans. Additionally, media changes occur very frequently in the hospital setting. If these aspects cannot be depicted, then vital clarity over the information flow is lost.

Besides defining the requirements for VSM in a hospital environment, it is also important to adapt the definitions of classic VSM to fit the application. The first important aspect in creating a VSM is the definition of the product. When dealing with the exchange of information in hospitals, the product should be defined as the patient information. Patient records pass through various hospital departments, sometimes corresponding to the patient’s movement, and at other times to only a part of the patient, such as a blood sample. At each process step, the patient records are either supplemented or further processed until they are deemed sufficiently complete to support a decision, at which point the process is complete. A process step in the hospital is defined as any step where data is stored, exchanged, or otherwise processed. This corresponds to the “must have” re-

quirement, that the model must be person-specific, and the “will not” requirement that data collection is not modeled.

When data collection is viewed as the product, the classic definition of supplier and customer becomes more difficult to apply but less vital. Instead, identifying the stakeholders and their needs gains importance. Stakeholders can still be loosely divided into those supplying information and those receiving the final product (i.e., the collection of data), but the same stakeholders can belong to both categories. For example, the patient supplies the material for data collection, their body, but also requests the final product, the information to their medical condition. To identify what is vital in the information flow, it is important to determine which initial data is provided by the stakeholders and which information is needed, to what degree, by any or all stakeholders in the final data package. In a hospital environment, defining the boundaries of the system is also a vital aspect. Depending on what treatment a patient requires, multiple data packages are created from the same patient. For example, the data package needed to ensure a patient can be operated on is one product, and the data package needed to ensure a patient can be released from hospital care is a second product. Both packages have different stakeholders that supply the initial input and different stakeholders requiring the completed data, although the patient is the same. As such, the terms “providing stakeholder(s)” and “requesting stakeholder(s)” better fit the application. As all decisions regarding which data is required and when the patient should go through the process are based on the diagnosis, this can be viewed as the production planning. An overview of important terms can be found in Table 1.

Table 1: Adapted VMS definitions

| Term                      | Definition                                                                                                      |
|---------------------------|-----------------------------------------------------------------------------------------------------------------|
| Patient records           | The product that is created through the process.                                                                |
| Process Step              | An action where data is stored, exchanged, or otherwise processed.                                              |
| Providing Stakeholder(s)  | The person or group providing the starting input of the process.                                                |
| Requesting Stakeholder(s) | The person or group that requires the patient data.                                                             |
| Diagnosis                 | The plan that sets the process into motion and signals to the providing stakeholder that information is needed. |

A critical aspect of the model is the KPIs by which the process can be evaluated. To evaluate information processes for waste, the five base measurements from Roh et al.[13] are taken with two adaptations:

- Level of automation ( $la$ ):  

$$la = \frac{\sum_i i_a}{i}$$
 $i_a$ : automated information transfer  
 $i$ : number of total information transfers
- Centrality index ( $ci$ ):  

$$ci = \frac{\sum_i i_c}{i}$$
 $i_c$ : information transfers from a central IT system
- Real-time capability ( $rtci$ ):  

$$rtci = 1 - \frac{\sum_i i_{nr}}{i}$$
 $i_{nr}$ : non-real-time capable information transfers (longer than a few minutes)
- Media disruptions ( $mdi$ ):  

$$mdi = \frac{\sum i_{d,o,k \rightarrow p} + \sum i_{d,p,k \rightarrow o} + \sum i_{p,o,k \rightarrow d}}{i}$$
 $i_{d,o,k \rightarrow p}$ : information transfers from digital, oral, or knowledge to paper-based  
 $i_{d,p,k \rightarrow o}$ : information transfers from digital, paper-based, or knowledge to oral  
 $i_{p,o,k \rightarrow d}$ : information transfers from paper-based, oral, or knowledge to digital
- First pass yield of information ( $fpy_i$ ):  

$$fpy_i = 1 - \frac{\sum_i i_q}{i}$$
 $i_q$ : information transfers where further questions are needed

The first adaptation is made to the centrality index. It is adjusted to view the hospital process as pull-oriented rather than push, by changing the definition from the number of information transfers **to** a central IT system to the number of information flows **from** a central IT system. The second change is in media disruptions to include a wider range of changes in the media. As informed during interviews, digital information will often be printed, supplemented, and then scanned back into the system. Missing data is almost always acquired orally, and then the documentation is completed either on paper or digitally. Additionally, employees' experience plays a role, and their evaluations can be documented. This constant change in media costs time and can also lead to information loss. To sufficiently capture this aspect, all media changes are counted that start from either digital, paper-based, oral, or person-specific knowledge and end as either digital, paper-based, or oral information. Information that ends as personal knowledge is not counted, as it does not affect the current process and can not be observed.

Whilst [13] creates a good base, the quality of information also plays an important role in the hospital environment. This is something that Busert et al. [15] build upon. They suggest using granularity, actuality, and accuracy to

evaluate quality. The actuality of the model can be grouped with the KPI "real-time capability", as this evaluates the frequency with which the information is updated. Regarding accuracy, the model in a hospital setting is not meant to evaluate the quality or correctness of medical professionals' work; as such, we assume that all information exchanged in the process is correct. Thus, the accuracy aspect would only evaluate whether information is lost or incomplete. Lost information is already covered by the first pass yield of information, and evaluating incompleteness can also be done with the third aspect, granularity, which looks at the degree of detail of the information. However, evaluating the granularity of only the information is insufficient, as the required granularity varies for each process step and may also depend on the level of experience employees have. Thus, the evaluation should not depend solely on the granularity of the information itself but on whether the given granularity matches the granularity needed. If the granularity given is lower than needed, then the information is incomplete. If the granularity is higher than needed, then we have more information than will be used, which is an additional form of waste. Last but not least, to evaluate waste, the aspect of value-added time should not be neglected. If we view patient information as the product, then the value-added time is the time spent gathering information about the patient. This includes, but is not limited to, time spent undergoing tests on the patient and general interactions with the patient. In the end, we have 7 KPIs by which a hospital's information flow can be analyzed: level of automation, centrality index, real-time capability, media disruption, first-pass yield of information, granularity, and value-added time.

To gather input on the applicability, usability, and comprehensibility of the definitions and chosen KPIs, a semi-structured group discussion with four scientific researchers in process logistics was conducted. Discussing the adaptation solely with scientific researchers was chosen as a first validation step due to their familiarity with lean management. Having background knowledge enables them to provide informed feedback on whether the adaptations still fit the general VSM purpose. It also allows them to more easily understand the definitions and give feedback on the comprehensibility and the level of revision needed. Due to the small group size and focus on researchers in the logistics field, the input is naturally biased, but it is a solid first step that can be built on in further work. In future work, the feedback from the first validation phase shall be used to review the current adaptations and identify additional aspects that require adaptation. Once this feedback is integrated, then a second round of validations shall be performed that includes medical personnel. Defining patient information as the product was considered a sensible decision for applicability, usability, and comprehensibility. The definitions of customer and supplier caused a more in-depth discussion, with the final consensus that an individual approach, depending on the use case, is the most sensible option. Care should be taken, though, to ensure that this approach is made more compre-

hensible, and further guidelines are needed to make the application as homogeneous and easy to apply as possible. The evaluation of the KPIs was overall positive across all three evaluation criteria, but three main points emerged. The first discussion point was whether using real-time capability as a KPI is necessary in a hospital environment. There is rarely a need to provide information in real time, as long as the patient is not in a critical condition. The real importance is in ensuring that the most current information is available when needed. This would shift the focus away from the real-time aspect and towards checking whether the information is always up to date when needed. In most cases, information is needed at a certain point, and if it is not available, wait times increase; if it is outdated, it requires new tests and additional process steps. Either way, it is not necessary for information to be immediately transmitted; it needs to be immediately available. The definition of this KPI should be adapted to reflect this need. Another discussion point was the granularity. The main concerns were the increased model complexity and uncertainty about how to measure this KPI. This is, however, also the most abstract KPI for participants to imagine. Further explanation of the use, as well as clearer guidance on how to measure and evaluate this KPI, should be provided to improve comprehension. The definition of value-added time was also viewed critically. The main concern is how well an observer can measure the time spent gathering and processing relevant data, since data gathering is very broad and can be interpreted or performed in many different ways. It was suggested that further narrowing of the term's definition will be needed to ensure this KPI can be applied sensibly to a process in a hospital environment.

## 5 Conclusion

This paper investigated how VSM can be adapted to model information exchange in hospital environments. While existing approaches provide a strong foundation, they do not adequately take into account the unique aspects of the hospital environment. Based on a literature review, interviews, and observations of a preoperative outpatient admission process, requirements for hospital-specific information flow modeling were identified and translated into adapted VSM definitions and seven KPIs for analyzing the process and identifying information-related waste.

The proposed approach extends existing work by treating patient information as the central product, outlining requirements for successful adaptation, and accounting for aspects such as employee experience. Initial evaluations with scientific researchers indicated that the proposed concepts are generally applicable and understandable, while also highlighting the need to further the scope of granularity and value-added time, as well as reevaluating the relevance of real-time capability in a clinical setting. The initial evaluation was done with a small group, which carries a high

level of bias. As mentioned, future work should integrate feedback from the initial evaluation, and a second round of validation should be conducted with further lean experts and, more importantly, medical professionals. Future work should also include creating more in-depth building blocks and validating all adaptations through application to a hospital process.

## REFERENCES

- [1] S. Mercer, J. Furler, K. Moffat, D. Fischbacher-Smith, and L. Sanci, *Multimorbidity: technical series on safer primary care*. World Health Organization, 2016.
- [2] E. Kuhlmann, M. Falkenbach, M. G. Brînzac, T. Correia, M. Panagioti, B. Rechel, A. Sagan, M. Santric-Milicevic, M.-I. Ungureanu, I. Wallenburg *et al.*, “Tackling the primary healthcare workforce crisis: time to talk about health systems and governance—a comparative assessment of nine countries in the who european region,” *Human resources for health*, vol. 22, no. 1, p. 83, 2024.
- [3] C. Haid, O. Berchtel, N. Wagner, and J. Fottner, “Development of human-centered scheduling in logistics,” *Logistics Journal: Proceedings*, no. 20, 2024.
- [4] M. Beaulieu and O. Bentahar, “Digitalization of the healthcare supply chain: A roadmap to generate benefits and effectively support healthcare delivery,” *Technological forecasting and social change*, vol. 167, p. 120717, 2021.
- [5] A. Gleiss and S. Lewandowski, “Removing barriers for digital health through organizing ambidexterity in hospitals,” *Journal of Public Health*, vol. 30, no. 1, pp. 21–35, 2022.
- [6] C. Amato, L. McCanne, C. Yang, D. Ostler, O. Ratib, D. Wilhelm, and L. Bernhard, “The hospital of the future: rethinking architectural design to enable new patient-centered treatment concepts,” *International journal of computer assisted radiology and surgery*, vol. 17, no. 6, pp. 1177–1187, 2022.
- [7] A. B. Ledford, G. Harris, and G. Purdy, “Implementing a complete digital thread: The need for data element mapping and analysis,” *IEEE Open Journal of Systems Engineering*, vol. 1, pp. 139–152, 2023.
- [8] R. Misra and S. Fernando, “Organisational barriers to the lean management approach in healthcare,” *Sage Open*, vol. 16, no. 1, p. 21582440251413494, 2026.
- [9] A. Alogla, “Revisiting lean healthcare: adopting value stream mapping from manufacturing,” *Frontiers in Health Services*, vol. 5, p. 1613756, 2025.
- [10] A. Akmal, J. Foote, N. Podgorodnichenko, R. Greatbanks, and R. Gauld, “Understanding resistance in lean implementation in healthcare environments: an institutional logics perspective,” *Production Planning & Control*, vol. 33, no. 4, pp. 356–370, 2022.
- [11] C. P. A. Tirta and M. Arini, “Lean–visual management integration in hospital information systems to sustain pharmacy performance under high workload,” *Media Publikasi Promosi Kesehatan Indonesia (MPPKI)*, vol. 9, no. 2, pp. 369–378, 2026.
- [12] J. A. Marin-Garcia, P. I. Vidal-Carreras, and J. J. Garcia-Sabater, “The role of value stream mapping in healthcare services: A scoping review,” *International*

*journal of environmental research and public health*, vol. 18, no. 3, p. 951, 2021.

- [13] P. Roh, A. Kunz, and K. Wegener, "Information stream mapping: Mapping, analysing and improving the efficiency of information streams in manufacturing value streams," *CIRP Journal of Manufacturing Science and Technology*, vol. 25, pp. 1–13, 2019.
- [14] T. Meudt, J. Metternich, and E. Abele, "Value stream mapping 4.0: Holistic examination of value stream and information logistics in production," *Cirp Annals*, vol. 66, no. 1, pp. 413–416, 2017.
- [15] T. Busert and A. Fay, "Information quality focused value stream mapping for the coordination and control of production processes," *International Journal of Production Research*, vol. 59, no. 15, pp. 4559–4578, 2021.
- [16] M. Bega, P. Sapel, F. Ercan, T. Schramm, M. Spitz, B. Kuhlentötter, and C. Hopmann, "Extension of value stream mapping 4.0 for comprehensive identification of data and information flows within the manufacturing domain," *Production Engineering*, vol. 17, no. 6, pp. 915–927, 2023.
- [17] L. Hartmann and J. Metternich, "Waste in value streams caused by information flow: An analysis of information flow barriers and possible solutions," *Procedia Manufacturing*, vol. 52, pp. 121–126, 2020.
- [18] F. Meister, P. Vogl, J. Schilp, A. Hohmann, and R. Daub, "Model-based framework for lean information logistics in digital production," *Procedia CIRP*, vol. 118, pp. 80–85, 2023.
- [19] K. Muehlbauer, M. Wuennenberg, S. Meissner, and J. Fottner, "Data driven logistics-oriented value stream mapping 4.0: A guideline for practitioners," *IFAC-PapersOnLine*, vol. 55, no. 16, pp. 364–369, 2022.

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