Reducing Barriers to Care Delivery for Congestive Heart Failure: Agile and User-Centered Design Integration Approaches

By

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CERTIFICATE OF APPROVAL

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Reducing Barriers to Care Delivery for Congestive Heart Failure: Agile and User-Centered Design Integration Approaches

Has been approved

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Abstract

Congestive Heart Failure (CHF) is a serious and complex disorder affecting 6 million Americans.[1] While there is no cure for CHF, quality and length of survival can be impacted by optimizing medical management. This medical management though often requires the coordination of numerous specialists in multiple fields including medical, social services, transportation, referral system and last but least the patient. This level of integration and coordination requires the development of complex software that works across all these facets. Unfortunately, the development of such software is almost a poster child for a problem referred to as the Software Crisis. The Software Crisis started shortly after the invention of the computer when advancements in hardware outpaced software development. Traditionally, software projects were highly specialized, limited in scope, low-quality, delayed, over-budget, and often failed to meet the requirements of the customer.[2] Much of the resulting software was fragile resulting in further delays in updates to the software. To remedy this, a new approach for software development has evolved referred to as Agile development. Agile is an iterative development approach taking small steps toward defining a product or service that requires the direct involvement of the Subject Matter Experts (SMEs), System Engineers, Software Engineers and Quality Assurance Specialists during each iteration. An iteration within the Agile Methodology is referred to as a Sprint. After each Sprint, something is built that can be released to market. However, Agile still has problems and is better at refining rather than defining a product.[2] Another method, User Centered Design (UCD) is best at defining the requirements of a new product. UCD like Agile is an iterative process of design, test with users, refine, and repeat until the product is right.[2] With the goal of not presuming or assuming an *apriori* solution to a problem.[2] Combining Agile and UCD methodologies into a single methodology known as Agile User Centered Design Integration (AUCDI) results in a methodology that can define and refine a product for Congestive Heart Failure (CHF).

Background

Almost 6 million Americans, 23 Million Worldwide[3], are living with Congestive Heart Failure (CHF) or Chronic Heart Failure and nearly 100,000 people per year are diagnosed with CHF. CHF is a serious, long-term condition and currently has no known cure.[1] CHF is also the leading cause for hospitalization in patients aged 65 and older, meaning this problem will require more hospital resources in an aging population in countries like the United States.[4,5,6,7] Treatments for CHF include dietary modifications, close attention to weight-gain and fluid balance, and medication management.[8] Optimal treatment requires frequent contact with a medical provider and support from the whole medical management team.[4] Typical care protocols often include having patients record their weights and other vital signs at home, and to intermittently provide this information to a care team member. Models exist for coordinating care in specialized CHF Clinics but these are not available to all patients. Therefore, care pathways that involve coordination of available community resources are needed. However, the process of care coordination is often extremely time intensive and exceeds the resources available. Meaning, there is a critical need to develop better tools to support care coordination, and when possible automate care coordination steps. There are several ways software tools can help clinicians improve the coordination of the patient's needs, such as, transportation, referral status, appointments and knowing which clinics accept the patient's insurance at a glance. Software

tools can help improve the coordination of the patient needs. For example, it may be possible to streamline and at times automate the protocol for replacing the referral, and even transportation.

While tools for this may be available in most Electronic Health Records (EHRs), these systems may be awkward and cumbersome, and are frequently developed without involvement of members of the CHF care team. Currently, the most commonly used methods of software implementation and development are Waterfall and Agile. In the Waterfall method, the requirements are all defined upfront and the solution flows downstream in a sequential design process down through the steps like a waterfall. This methodology leads to high risk, uncertainty from the development team, and can be costly and slow.[7] These drawbacks are because working software is not developed until late in the project's lifecycle and once testing begins making even minor changes to the end-product becomes extremely difficult[0]. For example, some organizations (i.e., United States Department of Defense (DoD), have stated a preference for the Agile approach instead of the Waterfall approach. However, the acquisition process requires transparency in contracting with open bidding, alternative submissions, and ultimately a single award to a single bidder which is by its nature a waterfall approach.

In contrast, the Agile process is iterative. An iterative process means the requirements are not all know at the inception of the project and the end-user does not have access to the complete or entire product until the last iteration is fully developed, integrated and delivered. This allows each iteration to provide new features and functions while allowing those features and functions to improve from previous iterations. Numerous medical device manufacturers saw positive results when first implementing the Agile methodology. For example, Abbott Laboratories, reported fewer software defects, scheduling and team reductions of 20%-30% and cost savings of 35 – 50%[10]. Metronic reported that development teams found bugs earlier and products achieved higher quality, while finding team collaboration improved and work became more enjoyable[10]. GE Healthcare found the results of Agile implementation was so successful, that Ross Hughes, GE Healthcare IT's Scrum Master and Andrew Deitsch, VP and General manager for GE Healthcare IT's Imaging Solutions, to stated, "We feel that the benefits so far of our Agile adoption are worth the effort. We're now beginning the next phase of our transition by rolling out scrum globally to the rest of GE Healthcare[3]."

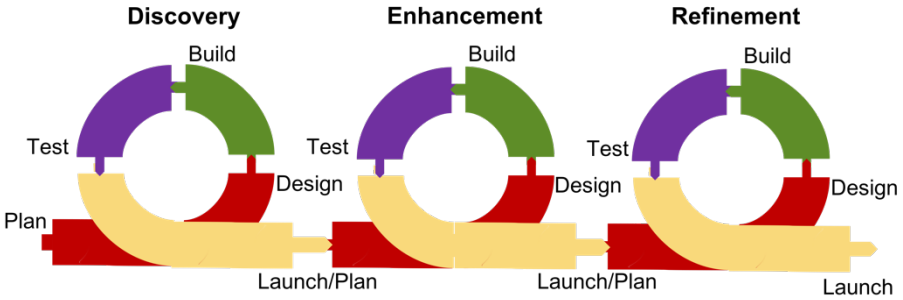

Figure 1 Agile Design Methodoloy adapated from Squiggles and diamonds and sprints[11]

In 2001, Agile, Figure 1[11], design was coined in the Manifesto for Agile Software development and sometimes known as business-driven design. Agile was designed to handle several key issues of the software crisis by advocating adaptive planning, evolutionary development, early delivery and continuous improvement. However, Agile design still has an unclear role for product design since the requirements gathering process are not well defined. This can result in

pressure to cut corners, and allows the product to be subjugated to "good enough" mentality.[2] As mentioned earlier Agile is good for refining, not defining an undeveloped product. Currently in industry, the Agile method known as Scrum is the method of choice. This process is heavily favored by managers. Scrum's design focus is having a weekly or bi-weekly meeting with the goal of producing a deliverable at the end of each Scrum Sprint. A Scrum master is assigned for each Sprint who delegates tasks and coordinates activities, however direct communication between each member in the Scrum is open and unrestricted if it aids in getting the assigned tasks done.

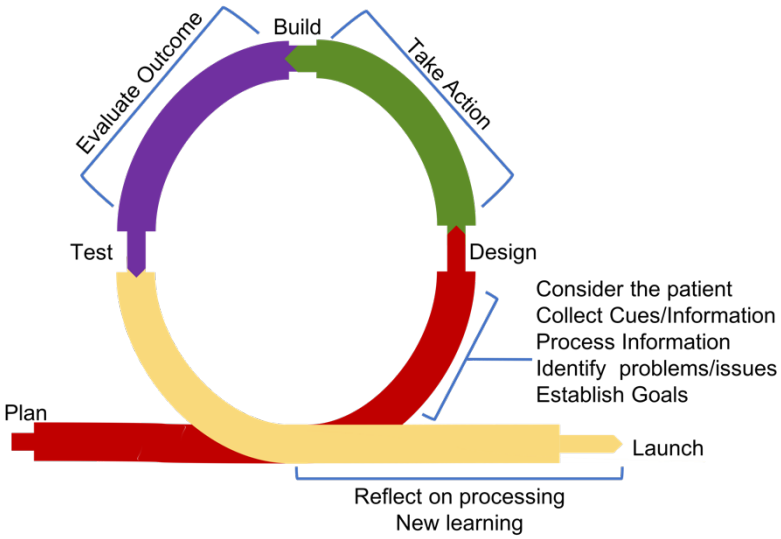

Figure 2 Clinical Decision Making vs. Agile Methodology

Seen in Figure 2[10,14], each cycle in the Agile methodology is not unlike the end-users' Clinical Reasoning cycle. Pairing the software Agile methodology to the clinicians methodology in decision making reveals the need to expand the Agile methodology to include User Centered Design methodology.

User Centered Design (UCD)

User Centered Design (UCD) is not about answering requirement alone, but also defining the requirements of the product. UCD, like Agile, requires iteration. The UCD process is design, test with users, refine, and repeat until the product is ready for release. This allows an understanding of what the user needs, and how the user likes to use the tool to help a patient suffering from CHF. A goal of UCD is to realistically or pretend to know as little about the specifics of the problem, with the aim of not limiting designs allowing new, unique, flexible and novel solutions.[2] Naturally, this sounds like a perfect match to handle what the Agile method lacks. This means as an application developer, I can make only a few fundamental assumptions about the user, such as they may be color-blind, or they like to view the graph in a different way. However, I can not make any assumptions about what information to use for patients diagnosed with CHF.

Motivation

The current project utilized data from The Clinical Information Needs of Center for Health Cares (CHC) for Hit (CLINCH-IT) research team. The goal of this project was to identify the information needs of the entire clinical team with regard to providing clinical care for patients requiring complex care management.[14] The needs range from managing treatment pathways, referrals to speacilaists, and identification of social factors (Social Determinants of Health or SoDH) that impact care. To improve the healthcare coordination of patient's diagnosed with CHF, I sought to investigate how Agile User Centered Design Integration (AUCDI) could be incorporated into the process of improving care for patients with CHF. I chose to focus on CHF after reviewing comments collected from each of the participating clinics. CHF was identified as being a complex disease in which streamlined clinical management appeared to be needed.

The basis of this project is from 2016 AMIA Design Challenge

Research Question

Identify three potential barriers to CHF care delivery that could be improved by using Agile and User Centered Design Integration (AUCDI) methodology.

Review of Data

After choosing CHF as my complex disease to focus on, I sought to identify the most important barriers to care coordination. I did this by reviewing qualitative interviews done with some of the partnering clinics involved in the CLINCH-IT project and reviewed this data to identify three barriers to the optimization of CHF care delivery that could potentially be addressed using Agile and AUCDI approaches. For this study, I reviewed the CLINCH-ITproject proposal, the team's aims, and project plan before attending one of the team's ongoing scrums. Since most groups do not incorporate every aspect of the Agile process I documented what the CHCs discussed and generated a scenario of how their clinical care team needs can be met.

Agile User Centered Design Integration (AUCDI)

AUCDI methodology requires an approach to design with as little knowledge as possible. It would be ideal to rotate between reviewing and revising over several months generating feedback on proposed ideas, what's liked and what's left desired for the best patient care in the current stage of the prototype design. As the prototype progresses, new ideas, concepts and issues will arise from these multiple perspectives. Since it can be expected that every idea discussed might not fit the scope of the project, these newly identified issues can be solved in a future scenario of the application.

Since, Human Computer Interaction (HCI) is time consuming, expensive and current day techniques are complex and intimidating, Jakob Nielsen, in 1994, coined the term, Discount Usability Engineering, as a way to ensure quality of the user interface while minimizing resource requirements. He stipulates three aspects are required: an evaluation, simplified thinking aloud (STA) groups, and a scenario.[9]

Evaluation

At the end of each sprint, Table 1 of heuristic markers are used to determine the quality of the software tool being developed and as a guideline for the development team. These markers are used by STA groups to evaluate the scenario developed in Sprint 1, Discovery, prototype developed in Sprint 2, Enhancement, and refining the prototype in Sprint 3, Refinement. The ten markers are:

Table 1 Table of Heuristic Markers

	Heuristic Marker	**Description**
1	Visibility of system status	The system should provide users appropriate and timely system feedback
2	Match Between System and Real World	Concepts and language appear naturally and logically familiar to users
3	User Control and Freedom	Users make mistakes, clearly marked “emergency exit” bypassing undesired extended dialogues
4	Consistency and Standards	Users shouldn’t worry whether different words, situations, or actions mean the same thing.
5	Error Prevention	System design should be made to prevent user error
6	Recognition rather than recall	Visible objects, actions and options to reduce user’s reliance of memory.
7	Flexibility and efficiency of use	Any level users should be cartered to and allow them to customize frequent actions.
8	Aesthetic and minimalist design	Irrelevant information competes with and diminishes relevant information’s visibility
9	Help users recognize, diagnose and recover from errors.	Error messages should indicate the problem, and suggest a solution in plain language (no code).
10	Help and Documentation	Help and documentation should be provided and easy to find.

Simplified Thinking Aloud (STA) Groups

The development team meets with what Nielsen defined as Simplified Thinking Aloud (STA) groups each sprint or stage of the AUCDI process. STA groups are real users given the scenario or prototype, and asked how they feel about the design and to think out loud.[14] Nielsen recommends using 3 to 5 users per test due to a diminishing return on benefit for larger groups shown in **Error! Reference source not found.**[14].

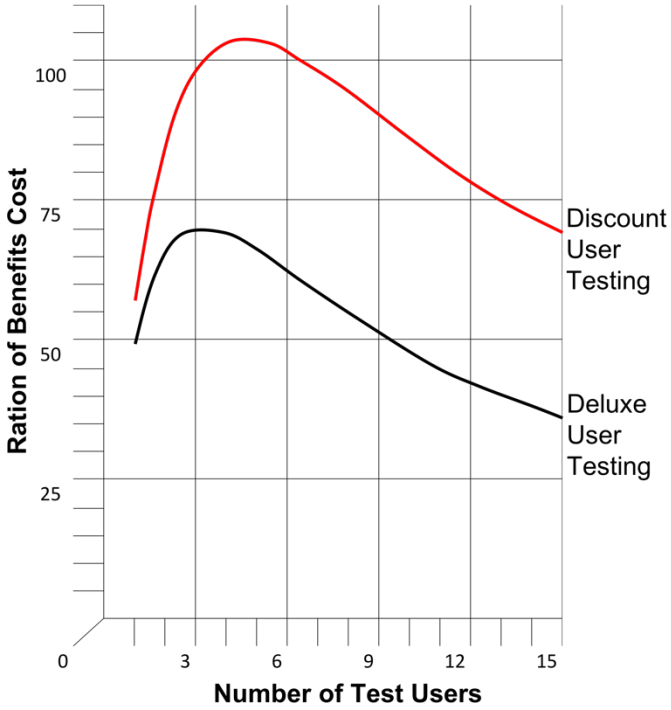

Figure 3 Cost-Benefit Trade-off curve adapted from Nielsen Jan, 1994[15]

Sprint 1 – Discovery

The Discovery Sprint focuses on defining the requirements of the problem by developing a scenario from STA group (clinician) feedback and review. A scenario isn't complete without including the standard Business Process Model Notation (BPMN) model to easily simplify and visualize a complex workflow of a business process. This helps experts cross disciplinary knowledge barriers and unambiguously communicate key concepts and knowledge with each other in a repeatable fashion. The workflow of scheduling an appointment for a patient with a specialist is depicted in Figure 7.

Scenario

Scenarios are an extreme form of a prototype with almost no features and/or functionality developed during the Discovery sprint. Scenarios are very cheap to design and implement because they need to change frequently allowing STA groups to give quick and frequent feedback on each version. Scenarios shouldn't worry about extensive backend development since they are just building the framework, or blueprint of how users describe the interface desired.

The scenario is presented to end-users for critiques of ideas and evaluation helping the team understand the scope of relevant and appropriate requirements, rather than wasting resources on assumed user requirements. Scenarios need to change frequently allowing STA groups to give quick and frequent feedback on each version on what they liked, which ones didn't they like and if any new ideas that have come to mind.

Sprint 2 – Enhancement

During the Enhancement Sprint, represented by the skeletal structure starting to gain fat and muscle through added features and adjusted workflows as concepts are discovered, tested and refined. Sprint 2 follows the same routine of two meeting cycles with end-users and development of problems discussed focusing on enhancing the scenario and turning it into a more functional

prototype. The prototype implements key ideas and concepts from Sprint 1's heuristic evaluation feedback. This sprint involves moving the initial concept to a higher fidelity that the end-users' can use to visualize a functional design and workflow.

Sprint 3 – Refinement

The Refinement Sprint is where the development team focuses on refining the design of the software application. This sprint tries to understand how different parts of the application can work together to maximize the clinicians work efficiency while minimizing the workload. Sprint 3 repeats the same routine used in Sprints 1 and 2 focusing on refining the scenario consisting of a preliminary validation of the design and initial usability assessments with representative end-users. This final step is important because it allows the reaffirmation of key concerns the clinician (end-user) may have before committing to the completion of the design and requirements phase. This helps ensure that time, energy, and costs are not spent on building superfluous backend designs before moving towards a final production of the application.

Methods

Setting

This project was completed using data provided by the organization OCHIN, a non-profit organization nationally recognized for pioneering the use of health IT to improve health care delivery and OHSU's *CLINCH-IT* Team. I was given access to qualitative interviews done with some of the partnering clinics and reviewed this data to identify three barriers to the optimization of CHF care delivery that could potentially be addressed using Agile and AUCDI approaches.

1. Review Study Aims and Project Plan

For step 1, I reviewed the CLINCH-IT project proposal, the teams aims, and project plan before attending one of the team's ongoing scrums. Since most groups do not incorporate every aspect of the Agile process I documented what the teams discussed and how the team functions. This had the added benefit of allowing me to familiarize myself with the team.

Practice Name	Geographic Location	Patients in last year
Cowitz Family Health Center (CFHC): Longview	WA: Urban	11626
CFHC: Kelso Clinic	WA: Suburban	1385
CFHC: Woodland Clinic	WA: Rural	2991
CFHC: Wahkiakum Clinic	WA: Rural	1898
CFHC: Ocean Park Clinic**	WA: Suburban	2147
Winding Waters Clinic	OR: Rural	3260
Clackmas County Health Centers (CCHC): Sandy	OR: Urban	286*
CCHC: Clackamas	OR: Urban	2498
CCHC: Oregon City	OR: Suburban	6361
CCHC: Gladstone	OR: Urban	2375
Wallace Medical Concern	OR: Urban	1022

** Patients seen in the 10 months since implementing EHR*
*** Recruited to participate, if needed*

Table 2 Characteristics of Sample Clinics

2. Identify and summarize perceived issues

Error! Reference source not found.[16], shows the characteristics of the ten Center for Health Care (CHC) organizations participating in the CLINCH-IT study. These clinics provided feedback about their work-flows, EHR feature desires and processes handling complex co-morbid patients. I reviewed the data they provided with the goal of answering the following questions:

1. What is the problem?
2. Why is it important?
3. How difficult is it?
4. Possible solutions to ask SMEs for feedback

As part of their first aim, CLINCH-IT collected videos having the clinician's walkthrough the process of their EHR activity. For step 2, I went through these videos, and identified at least three possible problems that could help improve managing the daily clinician process for both patient and the EHR. These problems were the referral status, locating a specialist, and transportation.

3. Review potential topics. Select 1

After Step 2, I identified at least one perceived issue as a main focus: Referral Status. Because of the flexible nature of AUCDI, other perceived issues were identified in the previous step and although they were not the primary focus, These perceived issues could be added later depending on the relatedness and importance of the perceived issues to solving the primary problem.

The above steps outline how an AUCDI approach was applied to identify three key problems in care coordination for CHF. These represent important preliminary steps in the development of an AUCDI-based software solution for better coordination of care in CHF. The type of approach is also generalizable and could be applied to needs assessment for other diseases requiring complex care coordination. The three key problems are referral status. finding a specialist, and transportation.

Steps for Completing this Work
If more time was available, the following scenario could be further developed into a prototype to complete a finished AUCDI based solution to the complex care of CHF.

Results

Sprint 1 Scenario

The proposed scenario was created from the implementation of the first sprint, Discovery. Figures 5-8 are the scenario developed after implementing the Discovery sprint. The scenario splits the data into three columns: Clinical, SDoH and Community. Figures 5-8 provided in the Appendix. The basis of these three columns is derived from the 2016 AMIA Student Design challenge presented by Dana Wammack, Steve Chamberlin and myself.[12]

Clinical Column (Figure 4)

The clinical column, Figure 4, shows initial solutions for the patient column derived from the CLINCH-IT interviews. The charts in the bottom-left corner should contain chronologically

oriented graphical representation tracking the patient's electrocardiogram, blood tests, stress tests, echocardiogram, cardiac catheterization, and MRIs. In addition, the application needs to:

1. **Reduce clicks to add or delete, currently: 3 clicks**. The number of clicks is reduced to two by adding a remove problem icon beside each problem listed in the Problem List. In case the remove icon gets clicked by accident, an "Are you sure?" prompt asks the user to verify the action. This increases the workers' efficiency by reduces the number of clicks by a third.
2. **Alternative Drugs.** Knowing alternative drugs covered by the patient's insurance helps the clinician quickly find an alternative treatment that is cheaper or is better for the patient.
3. **Co-morbidity (Future work)**. Patients often are plagued by one disease, but sometimes are afflicted with multiple. The icon shown in Figure 4 was added in between the Medication List and Charts. This icon, when clicked, should prompt the clinician to select two diseases they would like to observe on the patient.

Additional Features

Some additional features mentioned which aren't important to the application working, however provides customizability for the clinician to adjust the chart, list layout and color layout:

1. Multiple Themes
2. Ascending/Descending order of lists
3. Reverse x-axis in charts, dates.
4. Change Layout of Chart

SDoH Column (Figure 5)

The most effective software tools are expected to be those that incorporate SDoH into their systems. The SDoH column, Figure 5, shows initial solutions for SDoH column derived from the CLINCH-IT interviews. The SDoH column is out of the scope of this project and the main focus is the location of the referral status. The issues solved are listed below:

1. **Referral Status.** This will be added to each of the 11 SDoH markers included on clinician page. Anytime an update to the referral process occurs, it will be updated in the bottom left of each SDoH marker. Table 3 provides a list of possible Status Alerts for the scenario.

Status Alert	Action
"Made Referral"	The patient is referred to a specialist
Specialist Name, Location, Date and Time	An appointment with a specialist is scheduled
"Appointment Missed"	The patient misses an appointment
"Appointment Made"	The patient makes an appointment
"Results Pending"	Once the visit to the specialist is completed
"Results Ready"	The patient's results are ready to be viewed

Table 3 Referral Status Alerts

In case there is a no-show, reschedule, or cancelation, the calendar should update with opening slots for the scheduling patient. This helps optimize both the specialists time and facilitate care of patient suffering from CHF or other possible diseases. In order for the above scenario to work, specialists accept the application's access to their calendars, and any necessary attachments from the patient that can be updated in real-time. We are only interested in open slots, so any time slots with an existing appointment can be greyed out with no other information provided. This will help secure the patients' right to privacy under HIPPA.

2. **Patient Intake form (Future Work)** – This is the biggest bottleneck in any healthcare system and always will be. The CHF health markers tracked for patients are shortness of breath, coughing or wheezing, swelling, confusion, fatigue, weight and Nausea.[13] This is outside the scope of this project and can be finished in future work, most likely for a mobile application allowing patient input. This data can be charted chronologically so the clinician can track the patient's day-to-day health.
3. **Notes.** The application can either allow the clinician to edit or view the notes by hovering over or clicking the word "Notes". The notes should be in descending chronological order, so the clinician's is always reading the most up-to-date notes. When the notes are entered, the system automatically logs the date, clinician's name and title reducing the amount of redundant, error prone data input.

Community Column (Figure 6)

The community column, Figure 6, shows initial solutions for the community column derived from the CLINCH-IT interviews listed below:

1. **Knowing which specialists patient's insurance accepts.** The map should filter which specialists need to be displayed on the map. For example, the SDoH marker could determine which specialists need to be displayed on the map. This helps declutter icons shown on the map and corresponding legend that would otherwise overwhelm or misguide the clinician. Some diseases like CHF have special dietary needs that can help automate the filter mechanism on any food related icon. Food Security is another SDoH that affects the treatment of a patient diagnosed with CHF. So, a patient diagnosed with CHF needing to reduce their sodium intake,[3] can be filtered for restaurants serving low-sodium alternatives.
2. **Referral status.** The referral status should update in the corresponding SDoH marker when the patient schedules an appointment or sets up transportation to the specialist. See Table 3 for referral status alerts.
3. **Setting appointments.** A more in-depth view of how the map is involved in the scheduling of appintments is provided in Figure 7.
4. **Transportation.** Most patients are unaware insurance companies cover the cost of transportation to-and-from the specialist and other medical appointments. This allows us to automate filling out the insurance forms necessary for payment of the transportation. The resulting bill will include the deduction from the insurance company and reduces the time, stress, and personal costs while the clinician and patient can focus on treatment. Transportation is one of the eleven SDoH markers.

Figure 7 captures a BPMN model of the scenario's workflow for scheduling an appointment and arranging transportation. The process is initiated when the clinician logs in (green circle) which is either followed by a series of actions (boxes) or swimlane changes (yellow circle) until the process is terminated (red sphere). The specificity of the swim lanes is determined by granularity of detail the development team decides is necessary. For example, the application swim lane can be split into three more swim lanes: Clinical, SDoH and Community to provide more in-depth solution to the workflow as required.

For example, the patient Jane Doe was recently diagnosed with CHF and has been referred to a specialist. Figure 7, shows the workflow behind the process of scheduling an appointment. The clinician can use the map in the community column shown in Figure 6 to view which specialists accept the patient's insurance. Once a suitable specialist has been identified, the clinician needs to coordinate the times of the appointment, completion of tests needed prior to seeing the specialist, and results from the time of the specialist appointment. Furthermore, the patient may need assistance in arranging transportation to-and-from the appointment.

Sprint 1 Evaluation

As described previously, an evaluation of the application is done at the end of each sprint. Below, Table 4 discusses the heuristic evaluation for the scenario debeloped in the Discovery Sprint. For a description of each heuristic marker, see **Error! Reference source not found.**.

	Heuristic Marker	**Evaluation**
1	Visibility of system status	Referral status is tracked through the process updating the clinician of the patient's current status
2	Match Between System and Real World	Language and concepts are conveyed into the layout but needs further refinemint
3	User Control and Freedom	Removed an extra "click" when trying to remove a problem from the problem list. Have thought about customization
4	Consistency and Standards	A good start but needs refinement by clinician review and feedback. Further input from Referral Expert
5	Error Prevention	BPMN model shows clinical workflow and where things can be automated. Needs further refinement by clinical input
6	Recognition rather than recall	Workflow is designed to follow natural train of thought by user, further refining through review
7	Flexibility and efficiency of use	This is addressed in figure 4. Further refinement needed
8	Aesthetic and minimalist design	Minimalist design maximizes clinician information needs. Filtering techniques further reduce icon cluter on map
9	Help users recognize, diagnose and recover from errors.	Is not represented in the workflow of Figure 7 and should be addressed in subsequent sprints

	Heuristic Marker	Evaluation
10	Help and Documentation	Future development

Table 4 Heuristic Evaluation

Discussion

What I learned?

The three potential barriers to CHF care delivery are the referral process, transportation and finding a specialist that takes the patient's insurance.

Initially, the Agile approach is an improvement over the Waterfall method but still has several issues when implemented. The main issue with Agile is that if all the requirements are generally not known during the Request for Proposals (RFP), the selection process is flawed subjecting it to challenges and cost overruns. However, there are ways to have all the requirements known before the Agile process starts or breaking the Agile process into phases with the core requirements being specified before each phase. Upon further investigation, AUCDI provides a better approach towards incrementally discovering and defining requirements for healthcare applications.

The iterative AUCDI process is not unlike the approach of doctors when treating patients with chronic diseases such as CHF. The patient sees the doctor, relates their current conditions, the doctor makes some assessments and then recommends a course of action the patient must follow before the process is repeated again. Consequently, the approach of developing good software applications is not unlike the clinical process. However, in the software process the roles are different. During AUCDI, the software development team is more like the clinicians in the doctor/patient scenario. The doctors are more like the patients. The Software team listens to the doctors and makes an assessment of what needs to be done. They adjust the software and then the doctors try it until the next meeting.

AUCDI offers the promise to optimize the focus of the group on what's really missing in the communication of data as they navigate the maze of what's the problem? How do I solve the problem? and most importantly how can we best communicate what's most important to treating the problem?

AUCDI methodology does not require more developers on the team than the traditional Agile method. Although one person is sufficient enough to handle the Requirements phase of software development, it is recommended that 2-3 members on the development team should work with clinical members covering different perspectives of care. Such as, motivational speaker, clinician, referral expert, transportation, and bioinformatics, or data analyst. It would be best to have around 3-5 representatives for each member of the clinical team.

Potential and Further Research

Additional barriers are not limited to CHF but multiple complex diseases.Two additional barriers to the health care of patients coping with a complex disease are co-morbidity and home care. These two additional barriers should be the primary focus of the software tool's third iteration.

Co-morbidity

CHF and other diseases like diabetes are already complex and difficult to treat. However, what happens when the patient is suffering from two or more of these complex diseases? Another future work should include focusing on co-morbidity and how we can further inform the clinician with how these multiple diseases affect the patient at the same time, possibly indicating which ailment should be the primary focus. The use of machine learning could help identify which social determinant, or community data has a larger impact on which diseases and can also be used to help decipher symptoms to help properly diagnose the patient.

Home Care (Mobile Application)

Good healthcare of patients coping with CHF helps take care of the patient at home.[17] Another major step is creating an application that the patient can use at home. This could be done by modifying the current MyChart system or creating an entirely separate application. This allows patients to submit results on their own. The intake form shown in Figure 10 could be filled out by the patient from the mobile application. This can give the clinician an overview of the day-to-day health of the patient. Therefore, this allows the doctor to be more proactive in treating the patient by being able to contact the patient when they notice a negative trend.

Evidence

Lastly, it would be helpful to gather metrics providing data-driven evaluation to determine the significance AUCDIs has on improving the quality and efficiency of the applications being built and the care of a CHF patient. However, this research approach can take years, but the adoption of AUCDI by major corporations on a pilot program(s) could evaluate AUCDI's usefulness and effectiveness in a more timely fashion.

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Finally, thank you to all the clinicians who provided CLINCH-IT with their feedback on their experience with the current EHR system. Without their help the AUCDI methodology would not be able to work.

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Appendix

Figures

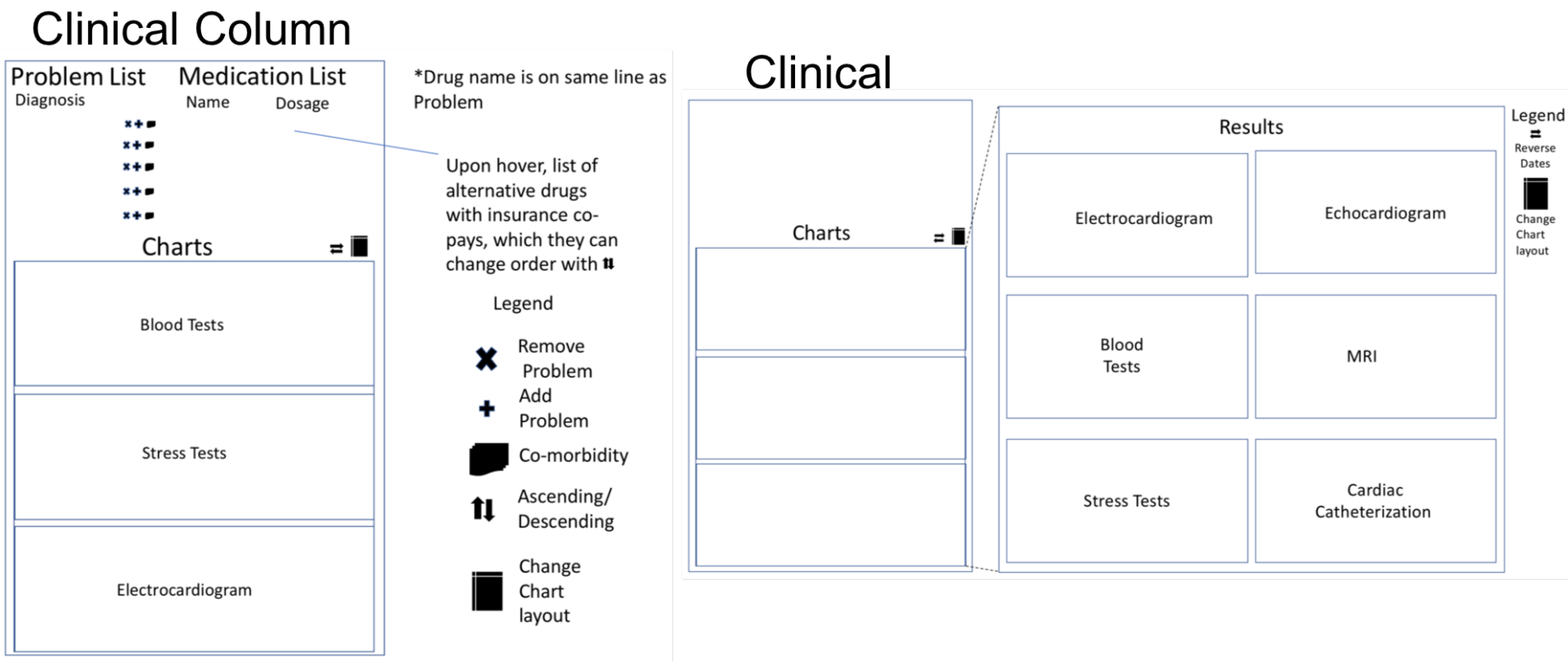

Figure 4 Clinical-Column Scenario derived from Social Vue[12]

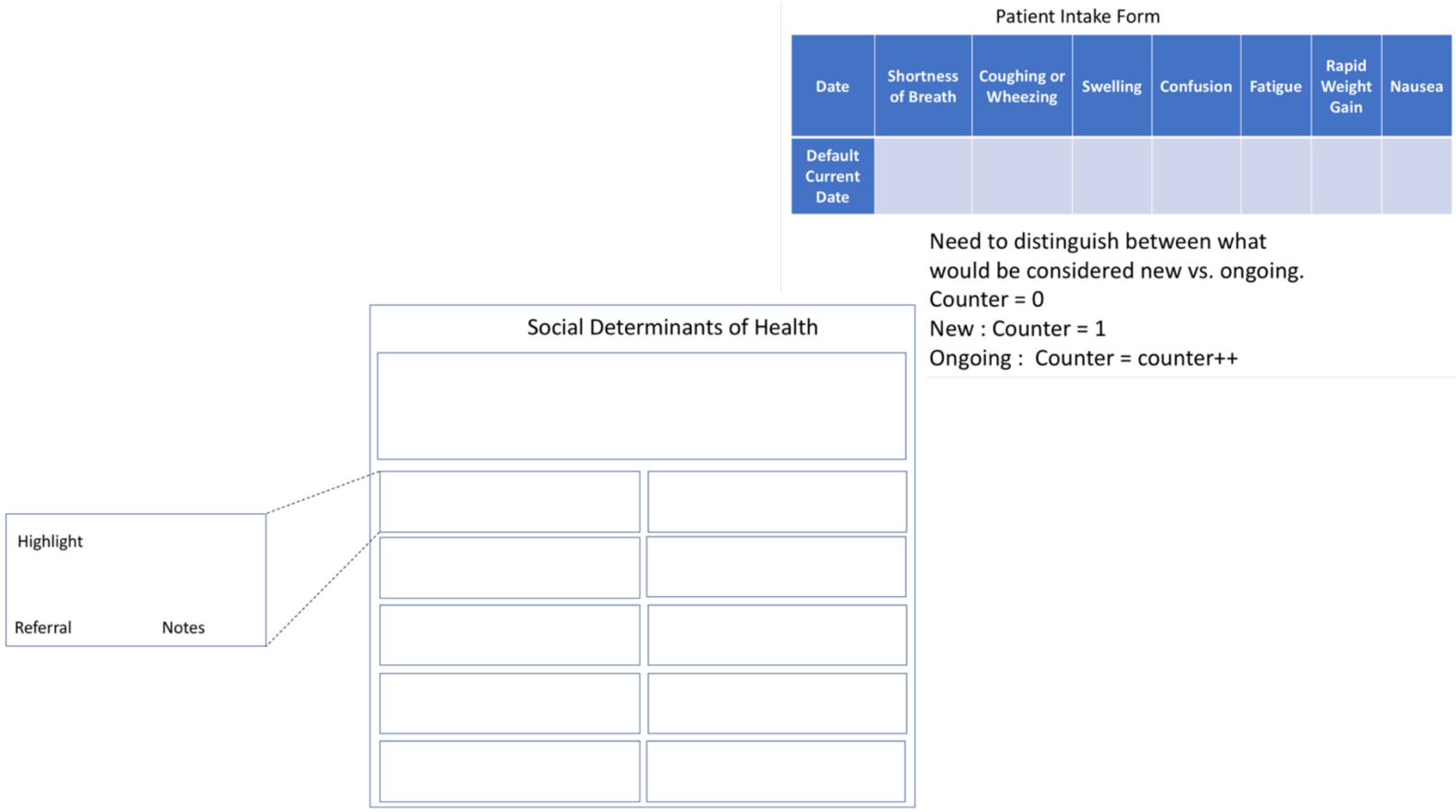

Figure 5 SDoH Column Initial Scenario derived from Social Vue[12]

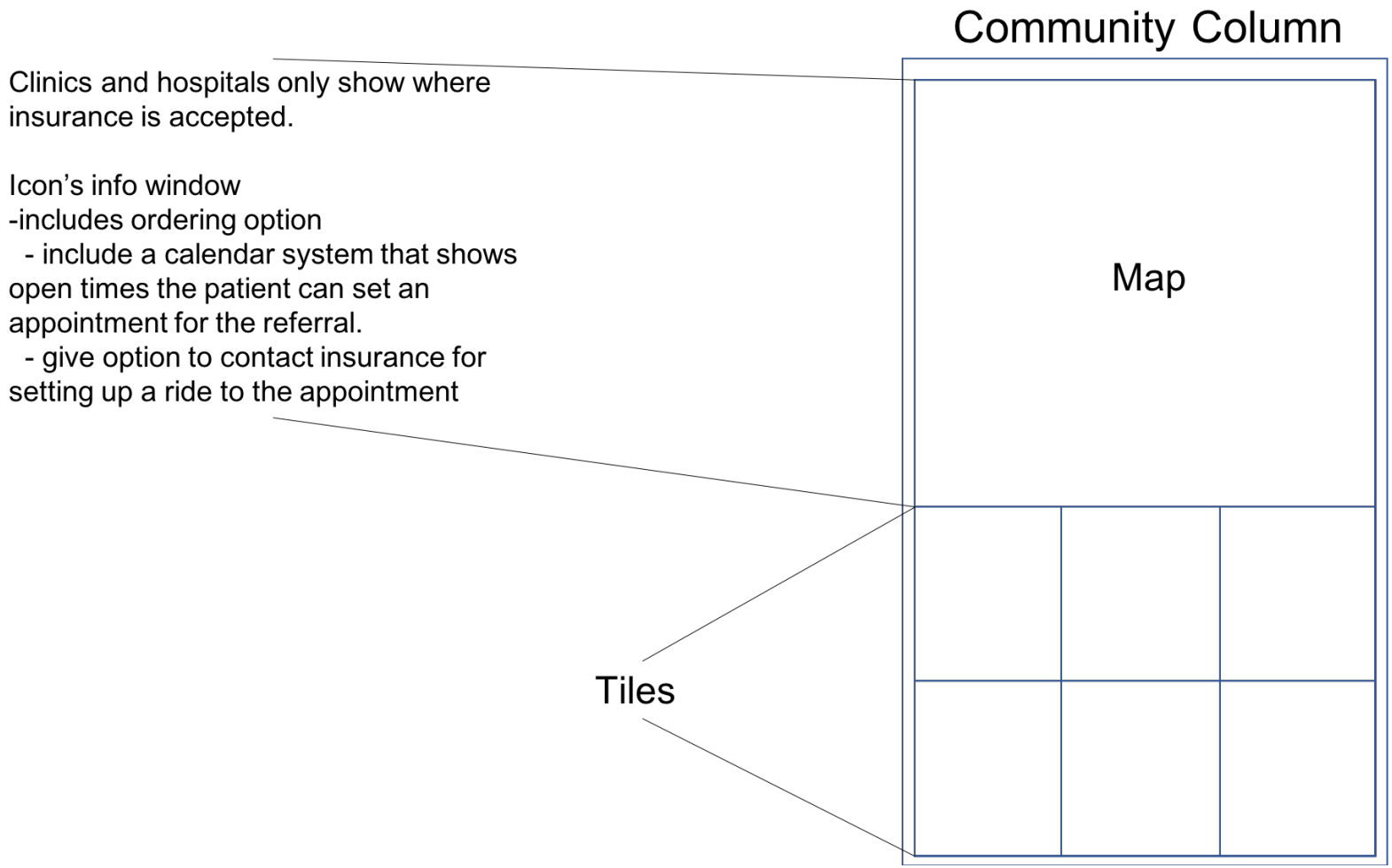

Figure 6 Community Column Initial Scenario derived from Social Vue [12]

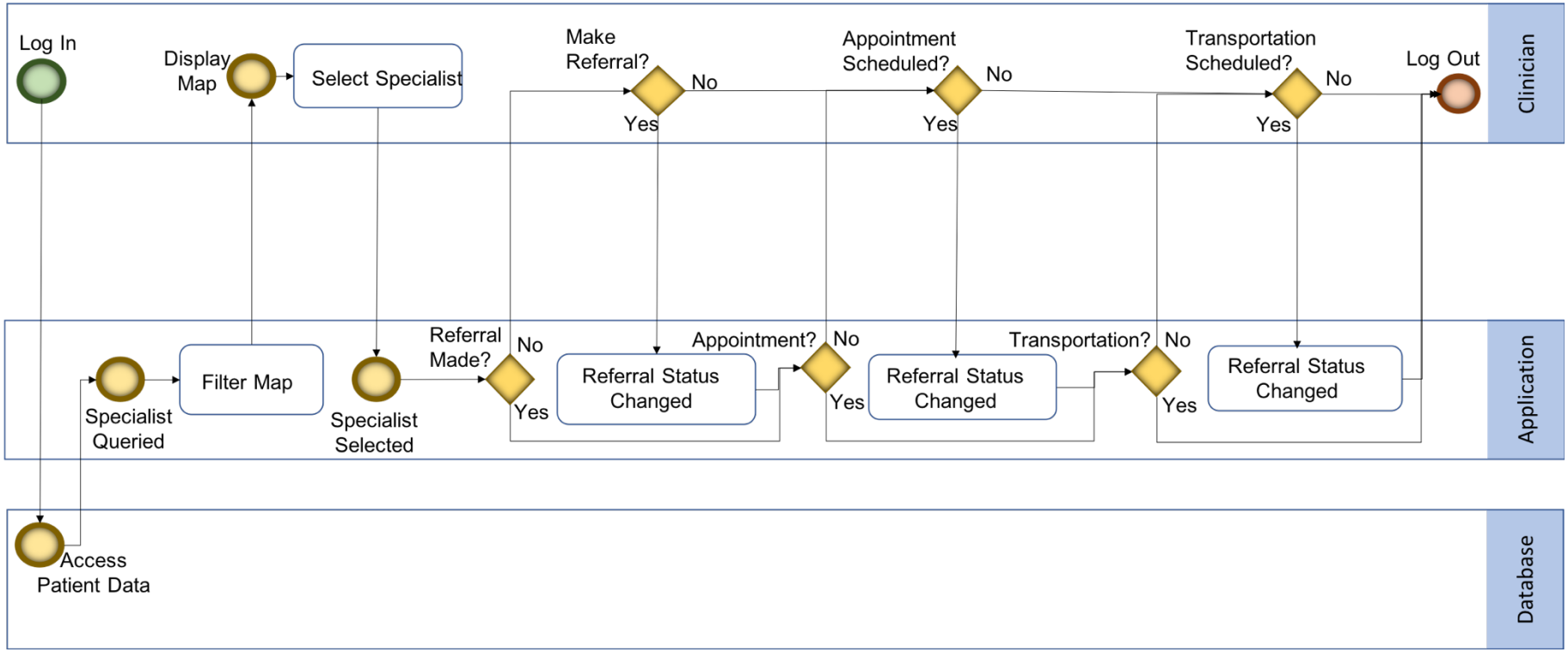

Figure 7 Business Process Model Notation (BPMN) Model of the Referral Process