Envisioning Healthcare Work: Models for Prospective Evaluation of New Systems

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ABSTRACT
When healthcare organizations plan the introduction of advanced health information systems, they need to envision future use. In this paper we describe four different ways of modeling the flow of information in a healthcare context: normative, indicating how information should flow; descriptive, indicating how information does flow now; formative, indicating how information could flow; and projective, indicating how information will flow with a specific new health information system. All approaches must work together for analysts to envision future use effectively. We illustrate the above distinctions with a case study based in the Department of Diagnostic Radiology (DDR) in a major tertiary hospital. DDR personnel were considering the introduction of software to help them schedule patient porterage (transport) services to, from, and within the department. Our prospective evaluation method let personnel see advantages and disadvantages of different ways of deploying the porterage software and led to the specification and design of the ValuesViewer™ application.

Categories and Subject Descriptors
D.2.1 [**Software Engineering**]: Requirements/Specifications – *elicitation methods, methodologies, tools.*

H.5.3 [**Information Interfaces and Presentation**]: Group and Organization Interfaces – *Evaluation-methodology, organizational design.*

General Terms
Design, Human Factors,Verification.

Keywords
Prospective evaluation, stakeholders, priorities and values, observation, interview, cognitive work analysis, work modeling.

1. INTRODUCTION
It is well-known that people have great difficulties to envision the impact of a proposed system in a future that is vastly different from the present; there are specific biases when dealing with uncertainties and risks…as well as an inability to play through the implications of a number of interacting features, especially where multiple agents are involved or multiple changes are happening simultaneously.[1]; p. 66

The health informatics literature abounds with reports of unsuccessful implementations of health information systems [2, 3, 4] which could be considered, in part, to be failures to envision future use effectively. However, not all "unintended consequences" can be anticipated [5]. In many cases, unfortunately, an attempt is not even made to analyze the consequences of introducing a new technology on a work context, or to consider the adaptations to workplace roles and responsibilities that would be needed for an organization to "realize" the business objectives of introducing the technology.

In this paper we argue that four qualitative different ways of modeling human work must be used if we are to meet the challenges referred to in the opening quote, and if we are to perform effective prospective evaluations of the impact of health ICT. Our case study is the proposed introduction of porterage dispatch software (software to dispatch porters to collect and transport patients within the hospital) into the Department of Diagnostic Radiology (DDR) in a major tertiary hospital.

2. BACKGROUND
In this section we introduce normative, descriptive, formative, and projective modeling as elements of the foundation for the prospective method we are developing. Then we provide the background to the DDR case study. We employ the above terms as used in human-system interaction modeling and especially Cognitive Work Analysis (CWA) [6]. The terms *normative* and *descriptive* have been used in many other contexts – for example in decision theory and in philosophical ethics. Moreover, the term *formative* can refer to evaluation that tests a design. Following CWA, however, formative is added to normative and descriptive as a third approach to specifying activity [6]. Finally we add the *projective* level for the specific purposes of this research.

Normative. The business case for introducing healthcare ICT into an organization, or into part of an organization, is usually represented in a normative model. It is the organization's vision of how its clinical and business goals might be enabled and assisted through ICT. The normative model is therefore the vision of how the process *should* work. Business Process Modelling Notation (BPMN) embodies such a vision. Normative models such as those built in BPMN are often developed by business analysts or industrial engineers, on the basis of performance data, surveys,

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focus groups, and interviews with stakeholders or senior clinical governance groups. As a result, normative models are seldom rich in nuances of how contingencies and disturbances are handled [7].

Descriptive. A descriptive model provides a representation of how a business function works at present. It is therefore a representation of how the business *does* work now. It is developed primarily by ethnographers, human factors psychologists, cognitive engineers, or other analysts who observe and analyze actual work. A recent example is the narrative networks used by Dourish and colleagues [8]. Descriptive models are rich with information about how workers manage contingencies, disturbances, and unintended consequences [8, 9], and the artifacts they use to "finish the design" of their workplace [10].

Formative. A formative model is a representation of the constraints that shape work activity, rather than of work activity itself [6]. It is therefore a model that identifies boundaries for how health information processes *could* sensibly work. For example, if we know the professional and workplace priorities and values of different occupational groups within healthcare, and the basic functions that must be performed, then there may be many workplace arrangements that are consistent with those priorities, values, and functions [11].

Formative models are generated through document analysis, interview, critical incident analysis, and direct observation. Analysts move beyond the details of actual work to the deeper motivations and systemic constraints that shape people's work, such as enduring professional priorities, or transient constraints imposed by habit, convention or technology. Formative models are more fundamental than scenario-based design as used by interaction design for envisionment [12]. Formative models also define possibilities for work activity rather than prescribing normative methods of work.

Projective. A projective model is a projection of future health information processes and work practice that carries enough detail that it can be assessed against elements of formative models such as professional priorities. It is therefore an attempt to identify ways that health information processes truly *will* work after the introduction of healthcare ICT

Projective modeling of this kind is the least familiar kind of modeling. Certain kinds of automated reasoning can help analysts make projections [13] or, as here, it can be done by hand.

Prospective evaluation. Prospective evaluation builds on normative, descriptive, formative, and projective modeling, to support the process of envisioning the consequences of change. All perspectives are needed to judge whether and how people will adapt in order to preserve work values and priorities. Our concern is how best to support such prospective evaluation.

2.1 Case study – porterage services

To illustrate how prospective evaluation might be performed, and how it might build on normative, descriptive, formative and projective modeling, we use a case study of porterage services performed within the radiology and imaging department (DDR) in a large local tertiary hospital.

Porterage services are the everyday transport of patients between different areas of the hospital, as may happen when a patient is discharged from one unit to another, or moved temporarily from their home unit to a test or procedure area and then returned.

In most areas of the hospital we studied, porterage services are handled by controllers in a central control room with the help of a porterage dispatch software application. Nurses or administrators in different hospital units log requests for porterage into the software. Thirty minutes before the porterage is needed, the request for porterage appears on the controller's screen in the control room. At the right time, the controller uses the software to assign an available porter to the job and the software alerts the porter via a pager.

The porterage software runs in most areas of the hospital but the DDR has its own "dedicated" porters instead. A porterage supervisor physically located in the DDR uses a paper-based system to track porterage requests and to dispatch porters

Hospital management was keen to extend use of the porterage software to the DDR, so bringing all porterage services into the one system. The porterage software stores porterage dispatch and arrival times, which gives management the ability to collect statistics on overall system performance, to move resources where they are needed most, and to provide evidence for claims about performance of the porterage system. In this fashion porterage managers can monitor porterage efficiency and manage hospital-wide porterage resources more effectively. However, DDR personnel expressed concerns about the impact on their workload, and about disruptions to the efficient flow of patients into and out of the unit and between areas of the unit if the paper-based system were replaced by the software.

2.2 Goal of study

Accordingly, the goal of our study was to perform a prospective analysis of the impact of the porterage software on the DDR. The prospective analysis was intended to provide a basis for discussions and negotiations between the parties involved about whether, when, and how the porterage software would be implemented. Although we wanted the method to make substantively correct projections, at this point our principal concerns were to ensure that the prospective evaluation process was coherent and complete, and to test whether its findings resonated with the stakeholder groups in DDR.

3. METHODS

3.1 Participants

The study was performed with the approval of the hospital's Human Research Ethics Committee (IRB) and with the agreement of DDR and porterage management. Interviewees were three people from DDR and two from porterage management. In addition we observed the work of several porters, radiographers, nurses, and administrators within the DDR.

3.2 Data collection

The project was introduced to the department as a neutral research project focused on how to do prospective analysis of the impact of health ICT. Two analysts (an experienced ethnographic field researcher and a psychology graduate) conducted major observation sessions over 15 separate days in different areas of the DDR, and conducted five interviews with key personnel.

Observations were performed in the porterage control room, in various areas within the DDR including the porterage supervisor's desk, and by shadowing porters performing their duties. Observations were also made in another unit of the hospital that used the porterage software for porterage services. Interviews were conducted with the manager of porterage support services, the director of operational services, senior radiographers, and with porters themselves. Written notes were made.

In addition, documents, statistics, and artifacts connected with the scheduling of patient tests and porterage services were collected. Floor plans and work layouts were collected, and photographs were taken of all major operational areas.

3.3 Analysis of data

Data collected were analyzed in six major steps, shown in Figure 1 and listed below. The steps were designed (1) to help us determine what each of the different groups of professionals ("stakeholders") cared about most (each stakeholder group's "priorities and values") and (2) to evaluate how some of the possible ways of implementing the porterage software would affect each group's priorities and values.

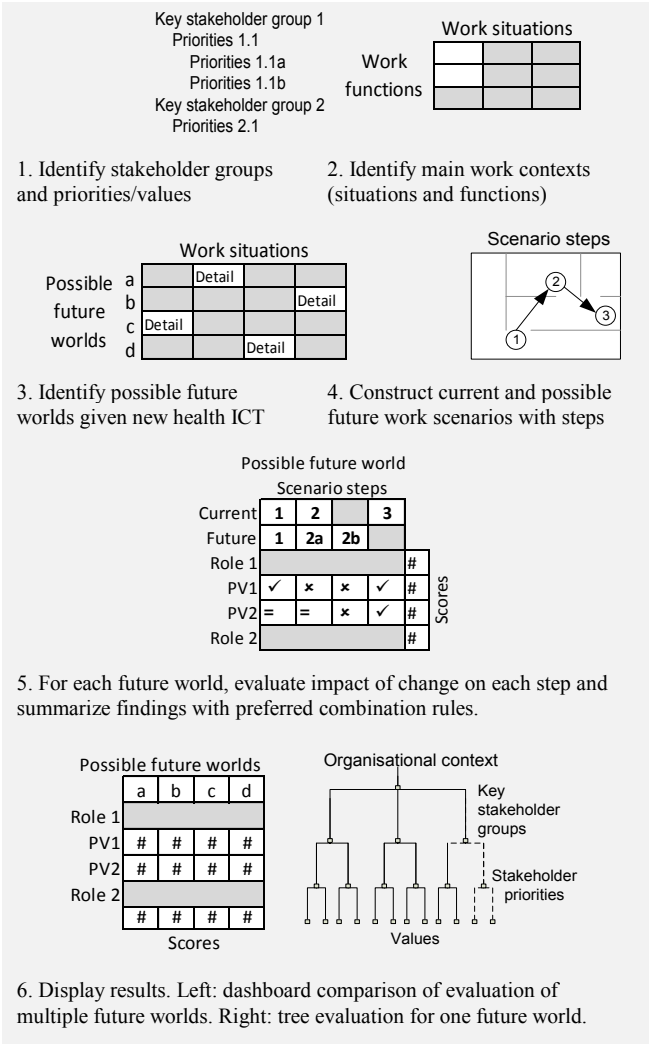

Figure 1. Icons representing the general form of the analyses produced at each step of the prospective evaluation process.

After each step in the list below, where relevant we list the key data source plus an indication of the general kind of modeling the step relied upon—normative, descriptive, formative, or projective.

1. Determine key stakeholder groups (people with similar interests) and determine their priorities and work values (from interviews). (*Normative* and *Formative*)
2. Determine main work contexts – different work situations and basic work functions (from interviews and observations). (*Formative*)
3. Determine possible "future worlds" – the most likely changes to roles and responsibilities in each of the main work situations or departmental subsections when ICT is introduced (from interviews). (*Projective*)
4. On a graphical layout of departmental subsections, describe prototypical work as functional steps or phases in a scenario. Construct scenarios for current work and possible future worlds (from observations, interviews, and system specifications). (*Descriptive* for current, *Projective* for future)
5. For each possible future world, compare scenario steps for future world with steps for current world, and determine if the future change promotes or jeopardizes the different stakeholders' priorities and values. (*Projective*)
6. Display results in a dashboard-style display of the impact of all future worlds, or a tree diagram of the impact of one future world, on stakeholder priorities and values.

Space limitations prevent us from providing detailed figures illustrating the method at each analytic step. However, Figure 1 presents icons representing the *general form* of the analysis or analyses produced at each step.

4. RESULTS AND DISCUSSION

The findings from each step are given below and overall substantive findings are discussed at the end of the section. Given the constrained timeframe for performing the analysis, we made tactical decisions about where to focus our analysis.

1. Stakeholder groups and priorities/values. Using interview content, we identified three key groups of stakeholders concerned with whether DDR should have the porterage dispatch software: (1) DDR porters, (2) porterage management, and (3) nurses, radiographers, and administrative assistants working in the DDR's imaging areas and reception areas. For each group, we identified their main professional concerns ("priorities and values") and represented them hierarchically (see Figure 1, Step 1). Some priorities and values can also be seen in Figure 2, in the bottom row of the large rectangles. For example, a general priority area for porters was "patient well-being" and a specific priority within that area was "ensure appropriate medical support for patient".

2. Main work contexts. Before projecting how the DDR might fare with the porterage software, we had to identify situations in which a large number of work constraints were operating and which might be the most challenged by the software. We therefore selected critical work contexts along three dimensions, as follows.

1. We selected functions to analyze amongst the principal work functions within the department (registering radiography request, scheduling appointment, requesting porterage, dispatch of porterage, imaging functions, and so on).
2. We classified work situations by work tempo and staffing level (daytime, nighttime, weekend). Given the limited timeframe of the research, however, we focused on daytime processes of requesting porterage and dispatch of porterage as areas for further analysis (see white cells in Figure 1, Step 2).
3. The department provides various imaging services. During initial observations, we realized that there were significant differences in the way porterage was coordinated across the

different modalities. Consequently, we decided to analyze the porterage activities for four imaging services that appeared to capture the major differences in tempo, patient criticality, and coordinative complexity: General X-Ray, Computed Tomography (CT), Vascular and Interventional Radiography (V&IR) and Magnetic Resonance Imaging (MRI).

3. Possible future worlds with porterage software. Discussions with DDR personnel and projections of future work roles revealed a core uncertainty regarding who would be responsible for logging porterage jobs on the new software. These discussions suggested four (mutually exclusive) possible ways the porterage software could be implemented, each of which would entail different changes in work roles and responsibilities. Porterage requests could be logged by:

- an existing nurse for each imaging area (nurse logger)
- an existing administrator for each imaging area (admin logger)
- an existing radiographer for each imaging area (radiography logger)
- a new central administrative person in the main reception area of DDR for all imaging areas (central logger).

Combining the four imaging areas (General X-Ray, CT, V&IR, or MRI) with the four possible ways of handling the logging of porterage requests (nurse, admin, radiographer or central logger) we arrived at 16 possible future worlds to analyze (see Figure 1, Step 3). To reduce the analytic load, we selected one logger solution to analyze for daytime operations in each of the imaging areas – in other words, we analyzed in detail only four of the 16 possible future worlds in our sample, and interpolated results for the others (see white cells in Figure 1, Step 3).

4. Describe current and future world scenario steps. For each imaging area chosen for analysis, we laid out the steps taken by departmental personnel to carry out the work functions identified in Step 2. The steps were shown superimposed on a physical layout of the work area in question (see Figure 1, Step 4). For each of the four imaging areas, we developed two scenarios:

- Scenario describing how porterage functions are carried out for that area *currently*, based on our observations.
- Scenario projecting how porterage functions will be carried out in the *future*, given the new technology and the specific means for logging porterage requests that was selected for analysis amongst the four identified in Step 3.

5. Evaluate impact of change. For each of the four future worlds selected in Step 3, the analysts worked through the scenario steps (across top of Figure 1 Step 5), judging whether the change at that step would have a positive or negative effect on each and all the stakeholders' priorities and work values (at left of Figure 1 Step 5, 'roles' indicate stakeholder groups, and 'PV' indicates priorities and values for that stakeholder). A simple combination rule was used to judge the overall cost or benefit of the future world under consideration on each stakeholder's priorities and values.

6. Display impact on stakeholder priorities and values. Various visualization techniques can be used to display the results, so as to encourage discussion and negotiation amongst different stakeholder groups. The visualization technique that had the greatest impact for departmental stakeholders was the tree diagram of the impact of a future work on stakeholder priorities and values (see bottom right of Figure 1; see also the ValuesViewer™ software in Figure 2). The top node represents the organizational context of the analysis—the DDR. The next layer of nodes holds the three key stakeholder groups, and the two layers of nodes under each stakeholder group are the hierarchy of stakeholder priorities and values.

Links on the tree are colored red if they carry a priority or value that is served less well in the future world than in the current world, and green if they are carrying a priority or value that is served better in the future world. Where the effect on values is intermediate, the lines are orange.

The tree diagram let stakeholders quickly see which priorities and values were jeopardized or promoted by different future worlds in question, and showed imbalances in the advantages and disadvantages for different stakeholder groups in those worlds.

Substantive findings. Results indicated that the future world with a new central administration person logging porterage requests (central logger) best equalized the advantages accruing to porterage management and departmental workers.

Our results were presented to all stakeholder groups in the DDR. All groups expressed confidence in the process taken to arrive at the results, so we appear to have moved towards our initial goal of making the prospective evaluation process coherent and complete. Workers in the department saw that the analysis had revealed nuances of their work that had not been effectively conveyed via other means. Porterage management expressed surprise on realizing the substantial differences in work across the different imaging areas. Our report moved up to the hospital executive to consider while the decision whether, when, and how to implement the porterage software was being made.

5. CONCLUSION

As the DDR example shows, a full prospective evaluation of the impact of new ICT on complex work processes combines elements of normative, descriptive, formative, and projective analysis of work. The prospective ICT evaluation method outlined here was later presented to the governing body for all hospitals in our state, Queensland Health, as a possible method for helping to predict and manage the impact of many new eHealth programs planned for the next few years. The potential value of the method was recognized, and we are currently applying it to the introduction of an electronic medical record Viewer by Queensland Health. In the latter work, we are supplementing the method described herein with automated reasoning approaches that might ultimately form part of a mixed-initiative system for prospective evaluation of the impact of technical change.

There are many challenges to meet if our method is to succeed; here we mention six challenges. First, analysts must carefully select work situations to analyze that carry the greatest risk to patients or productivity if new health ICT is disruptive. Second, all stakeholders must be satisfied that their priorities and values are accurately represented and that the impact of work situations on those priorities and values is accurately assessed. Third, although the process leads analysts 'linearly' through details to consider about the selected situations, the process also relies on stimulating analysts' imaginative 'non-linear' responses so many possible consequences are identified. Fourth, combination rules for evaluations must be visible and manipulable; software support would help more rapid analysis and more rapid adjustment where needed, as we have started to implement with the ValuesViewer™. Fifth, the method should be validated against actual outcomes, as we are now doing. Sixth, the method should support negotiation amongst stakeholder groups on how best to implement new health ICT and resolve areas of actual or potential conflict. Future work will address these issues.

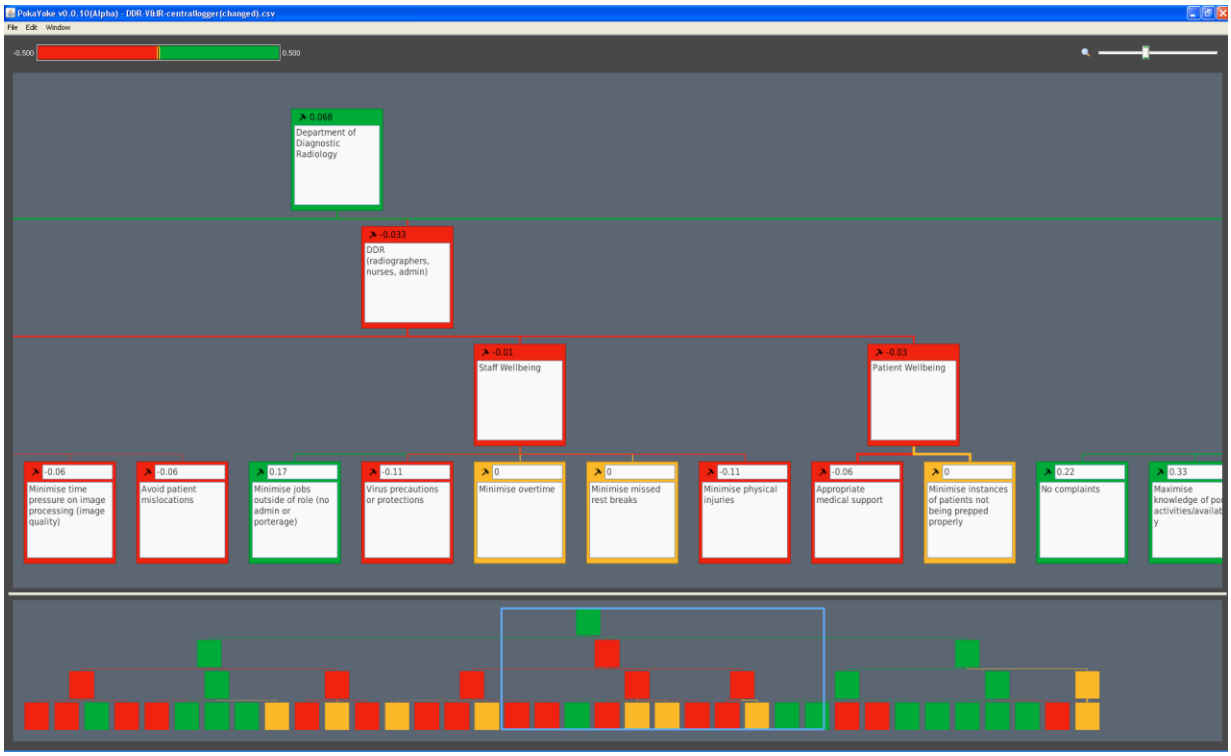

Figure 2. ValuesViewer™ software prototype for showing roll-up of priorities and values. Lower panel with small squares shows overview of values tree, with blue rectangle indicating part shown in upper panel. Upper panel with large squares shows details. Topmost node is Department of Diagnostic Radiology. Second level contains stakeholder groups ("Radiographers, Nurses, Admin" stakeholder group is visible in upper panel but others are out of view). Third level contains general categories of priorities and values (e.g. "staff well being"). Fourth level contains detailed priorities and values (e.g. "minimise overtime").

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