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# Improved workflow modelling using role activity diagram-based modelling with application to a radiology service case study



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## ABSTRACT

The modelling of complex workflows is an important problem-solving technique within healthcare settings. However, currently most of the workflow models use a simplified flow chart of patient flow obtained using on-site observations, group-based debates and brainstorming sessions, together with historic patient data. This paper presents a systematic and semi-automatic methodology for knowledge acquisition with detailed process representation using sequential interviews of people in the key roles involved in the service delivery process. The proposed methodology allows the modelling of roles, interactions, actions, and decisions involved in the service delivery process. This approach is based on protocol generation and analysis techniques such as: (i) initial protocol generation based on qualitative interviews of radiology staff, (ii) extraction of key features of the service delivery process, (iii) discovering the relationships among the key features extracted, and, (iv) a graphical representation of the final structured model of the service delivery process. The methodology is demonstrated through a case study of a magnetic resonance (MR) scanning service-delivery process in the radiology department of a large hospital. A set of guidelines is also presented in this paper to visually analyze the resulting process model for identifying process vulnerabilities. A comparative analysis of different workflow models is also conducted.

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## 1. Introduction

Workflow modelling of hospital processes is increasingly seen as a significant step in improving their service delivery system [1]. The development of workflow models in hospitals is a challenging task due to the complexity of the knowledge necessary in order to represent information flow, relations, interactions and collaborations occurring in the service

delivery process. In general, service delivery processes in hospitals are, to a large extent, unstructured. This is because it is largely dependent on patient outcomes along the way and care must be patient-specific. An effective workflow model will help improve process efficiency by tackling such problems as bottleneck analysis, process waste identification, capacity management, and decision making processes.

While service delivery process improvement is now often seen as key to efficient healthcare services, to date, there

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have been few process improvement studies. The traditional knowledge acquisition approaches in modelling the service delivery process has relied primarily on group-based debates such as staff workshops. The information gathered by process improvement analysis is mainly in the form of manual notes prepared during discussion which are then used in making high level process maps. This approach lacks the ability to represent the detailed steps required for improvement as important details from the workshop discussions can be missed when taking manual notes. Therefore, an approach which can reliably capture highly detailed information about process steps is required.

Workflow modelling based on a role activity diagram (RAD) is employed in this paper together with an information gathering and aggregation approach to effectively model service delivery process. The models based on RAD provide greater understanding of the decisions clinicians make about the care of their patients [2]. The development of RAD-based models helps to highlight process issues which may otherwise remain hidden, resulting in an inefficient/ineffective care delivery process. Current approaches such as group-based debates, brainstorming and workshops are the major mechanisms utilized by qualitative modelling researchers in soft operations research [3–7] and for process mapping/modelling [8,9]. These approaches have a number of limitations. They are time-consuming because they are done manually and if the information is gathered and discussed in a group, power relationships may influence the results. Therefore, a better and more systematic approach is needed. Hence, an innovative methodology is proposed in this paper, one which allows systematic information gathering and aggregation of details of the process into a single structured RAD model. The nature and extent of the details required depends on the specific situation. The general, top-level management requires a rather coarse-grained process description as they want to gain an overview of the process. On the other hand, process improvement analysts/clinicians will prefer a fine-grained process model. Fig. 1 illustrates the difference between the current literature and the methodology proposed in this paper. The traditional process mapping techniques rely largely on the manual notes of discussion workshops to visualize the high level process flow. However, the proposed methodology involves a semi-automated step (based on software tools presented in Section 4) to reliably and efficiently capture procedural knowledge before final visualization based on RADs.

The RAD-based model of healthcare processes is useful for clinicians to see the actual state of the current workflow in the hospital. This helps clinicians to improve decisions regarding patient care, where a high level view of the process is not sufficient. Clinicians must also be provided with the detailed process information to understand the interactions and relations. This will help them to review the process models and formulate their own improvement strategies.

The concepts proposed in the RAD-based methodology is complementary to the existing or ongoing data analysis techniques that seek to identify factors that lead to inefficiency in the healthcare process. In recent years, ‘lean’ healthcare, an approach aimed at providing improvements in healthcare systems, has received much attention [9]. These methods have been used for analysing patient care from start to finish,

and highlighting process problems such as process errors, work duplication, waiting/delays and information unavailability; based on the analysis of task-time which adds value as opposed to that which does not. When modelling service delivery system, these approaches analyze the most common process followed, but modelling the most standard process is only useful when the service unit has only one way of performing activities. Such systematic and controlled processes are predominant in the manufacturing sector. The lean approaches were intended for improving sequential shop floor manufacturing processes. Hospital departments, however, are fast-paced and characterized by uncertainties. Hence, using the value stream maps (VSMs) of the lean approaches tends to become too complex to accurately model healthcare service delivery due to the presence of large variations in the process steps. Therefore, a systematic approach to model and understand detailed healthcare process model subcomponents is proposed in this paper.

Another approach used to enhance operational efficiency for healthcare organizations is based on data intensive methods such as clustering, classification based on stochastic trees, and prediction based on neural networks. These techniques enable decision makers to identify patterns in clinical claims and activity-based historical data, to better identify and understand the explanatory relationships between variables that describe the operational processes [10–12]. The results of these data analytics are used to inform the decision makers about the relationship between process variables and operational performance. The major limitations of these approaches arise when there is unavailability of quantitative process data to model such systems. In addition, the data analysis model of the service delivery process, when developed with an adequate amount of quantitative data, will only highlight bottlenecks such as long patient queues for scanning. However, detailed process level information is needed to identify the causes of such bottlenecks. Thus, a complete analysis of bottlenecks requires a detailed process map.

Another method used in the area of process improvements is quantitative discrete event simulation models. These models rely on simplified qualitative models such as flowcharts to represent patient flow and historical process data [13–18]. However, qualitative models such as flowcharts (with high level process visualization) lack the ability to represent complex process relations and interactions between clinical staff, equipment and patients. This leads to incomplete and unrealistic simulation results. Therefore, this paper will also enhance the simulation modelling-based research studies by proposing an innovative information gathering method together with a detailed RAD-based process representation.

The main contributions of the proposed methodology are: the development of a systematic information gathering and aggregation methodology based on staff interviews, the use of RAD-based process models for representing information aggregated from staff interviews, the analysis of sensitive RAD structures for process problem identification and the application of the proposed methodology to a real case study from the radiology department of a large hospital.

The rest of the paper is arranged as follows. In the next section, the literature on service delivery process modelling and improvement is briefly reviewed. Section 3 details the

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