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Reducing unwarranted variation in healthcare service delivery systems: key issues, research challenges and potential solutions

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Abstract

There is a growing need worldwide to increase the quality and productivity of healthcare services delivery. To this end, analysing and reducing unwarranted variations in healthcare has attracted much attention in recent times. However, current modelling and simulation approaches to reduce unwarranted variations suffer from numerous limitations. Consequently, service improvement efforts have often failed to deliver expected results. This paper discusses the key issues associated with reducing unwarranted variations in hospital service delivery systems, and proposes a research framework that aims at overcoming these issues. In doing so, it highlights the need for: accurately and efficiently modelling complex service delivery systems; developing systematic knowledge acquisition approaches; and developing scalable simulation models to analyse unwarranted variations on and from care pathways.

REDUCING UNWARRANTED VARIATION IN HEALTHCARE SERVICE DELIVERY SYSTEMS: KEY ISSUES, RESEARCH CHALLENGES AND POTENTIAL SOLUTIONS

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ABSTRACT

There is a growing need worldwide to increase the quality and productivity of healthcare services delivery. To this end, analysing and reducing unwarranted variations in healthcare has attracted much attention in recent times. However, current modelling and simulation approaches to reduce unwarranted variations suffer from numerous limitations. Consequently, service improvement efforts have often failed to deliver expected results. This paper discusses the key issues associated with reducing unwarranted variations in hospital service delivery systems, and proposes a research framework that aims at overcoming these issues. In doing so, it highlights the need for: accurately and efficiently modelling complex service delivery systems; developing systematic knowledge acquisition approaches; and developing scalable simulation models to analyse unwarranted variations on and from care pathways.

Keywords: Healthcare Operations, Process Modelling, Simulation

INTRODUCTION

Improving the quality and productivity of service delivery systems has proved to be a major challenge for healthcare service providers worldwide [1-4]. A major US-based project aimed at identifying the opportunities for improving healthcare service delivery systems has highlighted that more than half a trillion US dollars of healthcare costs per year in US were associated with *overuse, underuse, misuse, duplication, system failures, unnecessary repetition, poor communication, and inefficiency* [1]. In an attempt to meet this challenge, researchers and practitioners alike, in recent times, have been paying increasing attention to reducing *unwarranted variations* (UV) in healthcare service delivery [5-8]. In US, it is estimated that UV in care among Medicare patients can account for up to 30% of healthcare costs [6]. A recent study commissioned by the New South Wales Department of Health has found "substantial variation in preference sensitive surgery rates, chronic medical admission rates and readmission rates throughout the state of New South Wales in Australia" [11; p. 1].

According to Wennberg [9], *UV in care* is care that is inconsistent with: (i) patient preferences for a particular type of care; (ii) patient treatment needs; or (iii) disparities in the supply of recourses. Published studies on UV in care have predominantly dealt with the systematic and routine collation and publication of data to highlight the geographical disparities in care in various clinical areas of national importance [5,7-8]. However,

publicising the existence of *UV in care* at the public health system level and their causes does not necessarily mean that these variations can be effectively tackled at the local health organisation level [7]. For example, a recent report published in UK on variations in healthcare has highlighted the need for developing locally focused incentives to deal with UV [7]. This paper extends the notion of UV in care to incorporate *UV in the service delivery system* towards dealing with UV at the local health organisation level. As illustrated in Table 1, UV in the service delivery systems are defined as variations in care due to care that is affected by: (i) system requirements conformance; and (ii) system related constraints. In effect, UV in the service delivery systems deals with the methods to identify and analyse UV that leads to actions for reducing these variations at the local health organisation level.

Table 1: The distinctions between UV in care and UV in the service delivery system

Types of UV / Key Characteristics	Unwarranted Variations in Care [5,7,9]	Unwarranted Variations in Service Delivery Systems (Discussed in This Paper)
Definition	Variations in care due to care that is inconsistent with: (i) patient preferences for a particular type of care; (ii) patient treatment needs; or (iii) disparities in the supply of resources.	Variations in care due to care that is affected by: (i) system requirements conformance; and (ii) system related constraints.
Scope	Publicises the existence of UV at the public-health level that affects patients care	Identifies and reduces UV at the service delivery system level (local health organisation level) that affect patients care
Examples	Patients with chronic diseases such as diabetes, living in regions with more physicians per capita will have more consultations and diagnostic tests than other regions	Patients routing issues from Emergency Department such as patients send to incorrect hospital wards from ED

To address UV at the service delivery system level, an *accurate* model of the service delivery system which represents the complex healthcare processes, characterised by collaborations among various medical specialists, complex decisions, sequential and parallel tasks is required. In this paper, we use the term 'accurate' to mean models that are *robust and detailed enough*, in the context of understanding and analysing the real world system. Developing an accurate model of the service delivery system, in turn, requires accurate mapping and modelling of the patient journey along the care process as it happens on the hospital floor. Accurate models of care pathways can then be utilised to identify and analyse UV at service delivery system level. A care pathway has been defined as "structured multidisciplinary outline of anticipated care plans which details the steps in the care of patients with specific clinical condition or set of symptoms" [10; p.133].

In this paper, UV at the service delivery system level are classified into: (i) UV *on* a care pathway (i.e. those representing the temporal dimension); and (ii) UV due to patient getting unnecessarily diverted *from* a care pathway (i.e. those representing the spatial dimension).

UV on a care pathway represents variations related to process bottlenecks, patient throughput, waiting times and resource utilisation. These types of UV are common in cases such as clinical service units (e.g. radiology), where all the patients follow similar procedures (care pathways) for diagnostic imaging. In radiology, available estimates indicate that over 50,000 patients each day seek to have their conditions diagnosed or treated using diagnostic imaging in Australia [11]; 1.5 billion imaging procedures were performed in US in 2003 [12]; and over

33 million clinical examinations were performed with diagnostic imaging in the UK [13]. The increasing need for imaging services in radiology departments can led to considerable pressure on service delivery systems resulting in longer patient wait times. However, the prohibitive costs of imaging devices severely restrict a hospital's ability to purchase additional equipment to enhance patient throughput. This makes reducing UV a viable and effective medium-term strategy for increasing the utilisation levels of such service delivery systems.

UV due to a patient getting unnecessarily diverted from a care pathway predominantly occur due to patient routing issues at emergency departments such as patients being sent to incorrect wards from the ED. Patient diversions from a care pathway can be a result of: ineffective decision making processes; unclear process steps and their interactions; conflicting performance measures for speciality units involved within care pathways; and unavailability of resources. These UV can lead to longer waiting times, delays, and lower overall productivity of the service delivery system. For example, in Australia, stroke remains the second major cause of death after heart disease with only 58% of stroke patients being admitted to the stroke unit on the day of presentation to hospital [14]. Similarly, stroke services in UK are largely inefficient due to the slower access to better stroke care, *i.e.*, diagnosis and treatment of patients are often delayed, resulting in lower benefit to patients [4].

Process improvement studies across hospitals are increasingly seen as the key to streamlining patient care services; however, to date, such studies have been few and far between [1-2]. One of the key issues associated with these improvement studies is the lack of approaches to use large amounts of heterogeneous service related data generated in hospitals (we use the term 'heterogeneous' to represent complementary types of data acquired through multiple sources). Furthermore, conflicting information and missing or unclear data adds to the difficulty in process improvement efforts. While information gathered from various sources in a hospital can be useful, currently, there is a lack of systematic knowledge acquisition and modelling, as well as performing meaningful analysis for service improvements. As a result, information available through various sources is not effectively used to enhance the understanding of the complex and dynamic service delivery processes. Developing and implementing productivity tools without a thorough understanding of service delivery processes can be incomplete and ineffective.

We present, in this paper, a framework and methodology aimed at addressing the above issues associated with UV in hospital service delivery systems. This framework has been developed as part of a broader hospital service delivery system improvement research project undertaken in UK. The paper is organised as follows: it first summarises the current approaches to dealing with UV in healthcare service delivery and associated research issues, identified through the review of extant literature. It then outlines the major research challenges in relation to addressing these issues and presents the framework and methodology aimed at meeting these challenges. The paper concludes with a note emphasising that the proposed approach and methods can be further refined and validated through future empirical studies.

CURRENT APPROACHES TO REDUCING UNWANTED VARIATIONS AND KEY RESEARCH ISSUES

This section briefly discusses and classifies previous research reported in the areas of hospital service delivery modelling, simulation-based analysis and system improvement that have been based on identifying and reducing UV. It also discusses the major research challenges, which are identified through the analysis of the limitations of the current 'state-of-the-art' approaches.

Table 2 broadly classifies literature in the area of analysing UV in healthcare at two levels, namely, the: *public-health system level* and *service delivery system level in hospitals*. Studies on UV at the public-health system level have led to the development of a series of maps or 'atlases' that highlight the variations in selected clinical areas of national importance with a view to identifying and tackling the causes or drivers of these variations [7-9]. Compared to the work undertaken in the above area, UV at the service delivery system level in hospitals has not been researched well. Therefore, the main focus of this paper is on research that deals with identifying and analysing UV at the service delivery system level originating within the hospital. Literature in the area of UV at the service delivery system level in hospitals is discussed based on the approaches that are extensively used to improve service delivery systems in general (e.g. process mapping and simulation modelling).

We will first discuss the literature in the context of (i) process mapping and (ii) simulation modelling, and then provide a specific context as it relates to (a) UV on a care pathway and (b) UV due to patient getting unnecessarily diverted from a care pathway. Process mapping is broadly viewed as a set of activities for identifying various actions and interactions involved in a particular service delivery process and its visual representation for process understanding and re-design. Simulation modelling generally refers to modelling and developing dynamic models of a service delivery system for analysing service delivery performance in the context of various "*what-if*" scenarios. Additionally, these approaches utilise various types of service delivery data and information for modelling and analysis.

These service delivery data can be: (i) quantitative; and/or, (ii) qualitative. There are various types of quantitative data, which are available in service delivery systems, such as EPR and real time tracking data. This information is generally used for developing various types of simulation modelling for analysing UV on a care pathway. The behaviour of service delivery systems under varying system parameters and scenarios can be studied using simulation modelling. It enables process improvement experts to simulate various improvement scenarios that do not yet exist for analysing UV occurring on a care pathway. Although, simulation modelling is identified to be an effective and useful technique for identifying and justifying service improvements, traditional simulation models use (over) simplified flow diagrams, which are unable to represent complex collaborative healthcare services. Furthermore, traditional simulation models relied mainly on historical system data. Thus, outputs from traditional simulation models have been often unrealistic, and generally less than 10% of the process improvement studies have involved any simulation modelling tools [28]. Therefore, a simulation modelling methodology based on an accurate service system model, complemented with multiple forms of quantitative data such as electronic patient records (EPR), historical data, and real-time tracking information is necessary for meaningfully analysing UV on a care pathway.

The qualitative data pertaining to service delivery processes are primarily gathered from clinician workshops, group debates, brainstorming or medical staff interviews. These qualitative data can be treated as procedural information or as part of systematic knowledge acquisition (KA). Procedural information is mainly related to how things are done, which is essential to any process mapping/modelling approach. KA refers to the process of gathering and documenting the procedural information for accurate process mapping. Some of the commonly used methods to identify procedural knowledge, *i.e.* KA, are based on clinician workshops. However, KA to model complex healthcare services in a hospital, based on clinician workshops, can be challenging. This is partly due to the fact that some of the important information about the service delivery system can be overlooked during simultaneous discussions with multiple staff; thereby resulting in collection of incomplete procedural data as required for accurate process modelling. A comprehensive process mapping/modelling methodology to completely and accurately model a service delivery system needs to include a detailed and systematic KA approach, to effectively gather and document procedural data.

Most of the healthcare process improvement approaches reported on in literature has involved analysing UV on a care pathway. However, there are also significant UV from a care pathway. Largely, these variations are unnecessary, and they often lead to lowering the efficiency and effectiveness of the services delivered. Traditional approaches, relying on modelling & simulating variations on a care pathway, are unable to address the problem of unnecessary variations from a care pathway. There are limited research studies that deal with the analysis and reduction of UV from healthcare services delivered in hospitals for overall system level improvements. Therefore, a modelling methodology for service variations such as role variations, which utilises a service delivery process model and real-time tracking data for identifying frequently occurring service variation patterns needs to be developed.

Reducing unnecessary variations by standardising the care delivery processes or developing & implementing an integrated care pathway (ICP) has been recognised to be an effective approach to addressing the unwanted variations [10, 29-30]. ICPs are predominantly used in hospitals to reduce and control care delivery variations [33]. Such efforts generally involve multidisciplinary communication among several speciality units in a hospital to efficiently provide care to patients. A number of research studies have worked on the creation of ICPs [29-32]. However, effectively implementing ICPs in a hospital is often associated with problems due to large variations from care pathway. For example, patient diversion from a care pathway to non-specialty medical units, which compromises the care delivered to patients, is a type of UV from care pathways. The following section details the research challenges associated with addressing the issues outlined above, and potential contributions of a proposed research framework towards addressing those issues.

Table 2: Classification of state-of-the-art approaches for healthcare process improvements

| | | | Service delivery data used | | Reducing Unwarranted Variations *on* a Care Pathway | | | | Reducing Unwarranted Variations *from* a Care Pathway | | | |
| | | | | | Qualitative data | | Quantitative Data | | Qualitative data | | Quantitative Data | |
Scope	Approach	Objective			Procedural data	Systematic Knowledge Acquisition	Historic Data/EPR	Tracking Data	Procedural data	Systematic Knowledge Acquisition	Historic Data/EPR	Tracking Data
Public Healthcare Variations	Data Analysis	Geographic Variations			-	-	[5-8]	-	-	-	[5,7,8]	-
Services Delivery System level	Process Mapping	Static Analysis (Process visualization, redesign)			[15-17]	-	[18-19]	-	-	-	-	-
					Service Delivery System Modelling			-	**Role Variations Modelling based on Tracking Data**			-
	Simulation Modelling	Dynamic Analysis	Quanti-tative data	Historic Data	[20-25]	**Discrete Event Simulation (DES) Modelling Integrated with Accurate Service Delivery System Model**			**Pathway Variations Analysis (PVA) Modelling**			-
				Tracking Data				[26]	-	-	-	-

Key Issues

PROPOSED RESEARCH FRAMEWORK AND METHODOLOGY

In this paper, we have so far emphasised the need for developing methodologies for modelling and simulation analysis of UV based on multiple types and sources of information. The overall objective, however, remains the development of methodologies for modelling & analysis of UV in the service delivery systems for process improvement. The research challenges identified in achieving this objective, which are to be addressed by using a proposed set of methodologies, are presented and briefly discussed in this section. The research framework we propose in this regard is illustrated in Fig. 1.

Accurate and efficient modelling of service delivery systems

Systematic knowledge acquisition based on the use of heterogeneous data and information to develop a robust service delivery system model is essential for identifying and reducing UV at the service delivery system level. The current approaches to service delivery system model design, predominantly, employ simplified flow charts of patient flow obtained based on on-site observations, group-based debates and brainstorming sessions, along with historical patient data. However, in most cases, this is insufficient for capturing and modelling the important interactions and relations between clinical staff, equipment and patients. The resulting models are often incomplete and, as they have a low level of information granularity, lead to oversimplified or unrealistic outputs. This is partly because some of the important information about the service delivery system can be overlooked during the unstructured discussions. Therefore, it is crucial to develop a rigorous methodology for effective qualitative data gathering for detailed and accurate process representation.

Dealing with unwarranted variations on a care pathway

The challenges associated with the analysis of this type of UV are mainly related to the development of discrete event simulation (DES) models based on oversimplified process models as input. Additionally, simplified input models assume that all the patients are following similar, if not the same, process steps in care pathways. The challenges associated with dealing with UV on a care pathway can be aggregated into two categories as follows:

a. Development of DES models for service delivery system analysis based on accurate process models is currently lacking. There is also a lack of approaches that utilise accurate static process models as necessary input for the development of effective dynamic DES models for analysing UV on a care pathway. Accurate process models help to identify and study complex interactions and relations between clinical staff, equipments and patients. The simplified input flow diagrams currently used as input for DES are not sufficiently accurate to adequately address the issues associated with UV on a care pathway such as low throughputs, bottlenecks, long waiting times and low levels of resource utilisation. Therefore, conceptual mapping between process modelling and DES simulation modelling is needed to translate accurate static process models into dynamic DES models.

b. Lack of use of quantitative data from multiple sources for building DES models: The majority of simulation modelling approaches has so far been focussed only on using historical service system data for identifying process issues related to UV on a care pathway. However, various types of service data available nowadays can be effectively used and integrated for enhanced simulations – these could include historical system

data stored in multiple IT systems and tracking data of patients, equipments and staff. To this end, again, a systematic approach is needed to define data models which can take inputs drawn from heterogeneous data together with accurate process models for DES modelling.

Dealing with unwarranted variations from a care pathway

A major challenge in this category is the lack of approaches to develop static and dynamic models for analysing UV from care pathway. Traditional approaches have mainly focussed on developing simulation models based on the assumption that the same procedures in a care pathway are followed routinely. However, due to unclear decision making steps, varying patient presenting conditions and divergence in resource availability, there are significant UV from a care pathway, which makes the improvement suggestions from conducted simulations to be often incomplete and ineffective. The secondary challenges (derived from the above) related to this type of unwanted variations in hospitals are:

a. The current approaches do not focus on the development of service delivery process models that are scalable for the analysis of UV from care pathways. There is a clear need for the representation and development of process models that are not only accurate but also scalable. The scalability of the service delivery process models is needed to: (i) model complex decision making processes embedded within the main service delivery system model; (ii) model care pathways crossing the multiple units or departments in a hospital; (iii) and generate care pathways for each role or specific service department. Furthermore, once the scalable process models have been developed for identifying UV from a care pathway, an approach is needed to integrate these process models for the performance analysis of the whole delivery system. Role activity diagram based process models are employed for accurate and scalable representation of the process.

b. Another challenge associated with the development of analytical models for simulating UV from a care pathway is incorporating or utilising various types of available service related data such as: (i) patient characteristics data related to disease presentations; clinical tests (available from electronic patient records, EPRs); and (ii) real time information about roles (available from tracking systems). Again, a systematic approach is needed to utilise these information for UV analysis.

To address the aforementioned challenges in analysing UV in the context of hospitals, involving service delivery system modelling, simulation and analysis, a research framework is proposed in this paper, while dealing with each of the research challenges. Figure 1 illustrates the proposed research framework indicating various methodologies that need to be deployed.
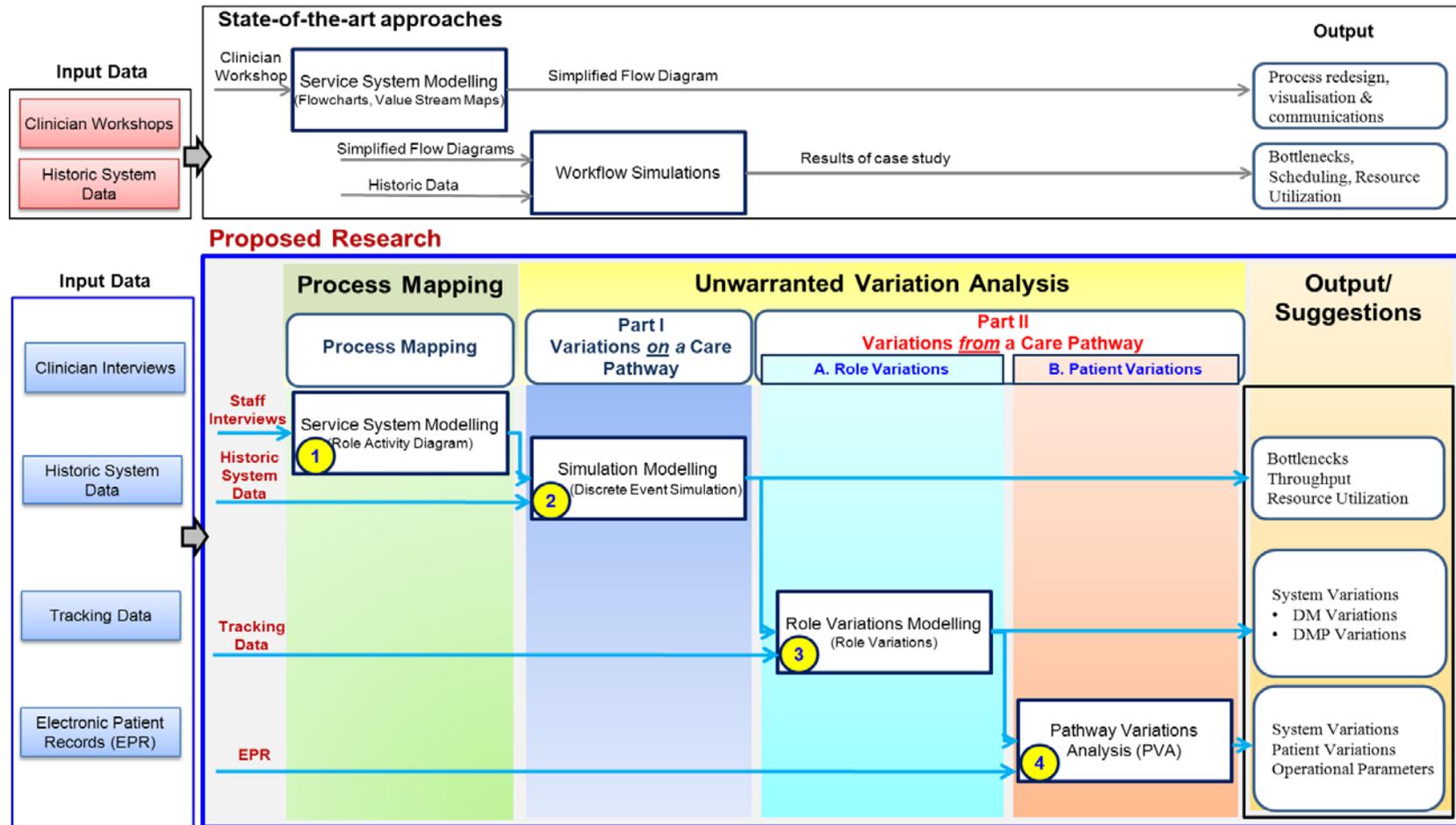
Figure 1: Current vs. proposed research on healthcare service improvements; DM – Decision Maker, DMP – Decision Making Process

The research approaches included in the above framework and potential contributions of these approaches are outlined below:

Service delivery system modelling based on qualitative procedural information

This approach aims to develop accurate and effective modelling methodology for complex healthcare service delivery processes combined with a systematic and efficient knowledge acquisition approach. The knowledge acquisition approach has capabilities for capturing, documenting, and analysing qualitative procedural information to develop process models of service delivery systems.

Modelling and analysis of UV on a care pathway using DES

The DES simulations require process models and large amount of quantitative data for simulations. However, currently there are no accurate process models which can be used for DES simulations to analyse UV on a care pathway. Therefore, this approach employs a systematic methodology for the development of dynamic simulations based on an accurate representation model of the service delivery system based on service delivery system modelling together with historical system data.

Modelling and analysis of UV from a care pathway

a. Modelling and analysis of UV of standard operating service delivery processes, specifically, role variations during a care pathway based on tracking information: The process modelling methods, largely, models the most standard process performed within the targeted service units. However, the UV from a care pathway plays a crucial role in lowering the productivity of service units, therefore, without modelling and analysing unwarranted process variations; the process improvement methods will often be incomplete. The proposed methodology identifies and models the service variations such as decision maker (role) variations and decision making (process) variations involved within the process, based on the real time tracking data.

b. Modelling and analysis of UV of standard operating service delivery processes, specifically, patient variations (diversion) from a care pathway: Pathway Variations Analysis (PVA), is proposed to model and analyse UV from care pathway. PVA aims to model crucial factors such as decision making process, decision makers, operational parameters, and inter-departmental performance measures.

CONCLUSIONS

This paper discussed the complex and challenging problem of reducing UV in hospital systems for improving healthcare service performance. The notion of UV on a care pathway and from a care pathway were introduced and discussed in some length. Research challenges related to dealing with UV in hospital service delivery systems were also identified and briefly discussed. To meet these challenges, an overall approach for accurate and scalable modelling of service delivery systems together with a suit of methods for variation analysis was proposed. In doing so, the paper highlighted the need for: accurately and efficiently modelling complex service delivery systems; developing systematic knowledge acquisition approaches; and developing scalable simulation models that can be integrated to understand

and analyse UV on and from care pathways. The proposed approach has been successfully applied in a healthcare service delivery performance improvement research project in UK, the results of which are reported in separate publications in progress. The pathway variations analysis methodology has been implemented in the stroke care pathway of a large UK hospital to reduce stroke patient diversion to inappropriate wards after Emergency department and balance the beds capacity at the hyper acute stroke unit. Proposed improvement options contributed to achieve the performance target of stroke services in the hospital. However, it would be useful that this approach and associated methods be further refined and validated through future empirical studies, to improve their generalisability.

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