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Article

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OPERATIONS, INFORMATION & TECHNOLOGY | RESEARCH ARTICLE

Radiology demand and capacity: A stochastic analysis based on care pathways

L. Sibanda^{1,2*}, P. Engel-Hills¹ and E. Hering¹

Abstract: The definition of (care) pathways, their advantages and disadvantages and the associated theories since the 1950s have been reported. Important in the definitions is that clinical care pathways are defined for a single examination process and that variances in clinical examination or clinical setting introduce variances in the clinical pathway. The objective of this study was to provide stochastic evidence necessary to establish a radiology care map that has “the right people, doing the right things, in the right order, at the right time, in the right place, with the right outcome”. Following a rigorous ethics approval process, data was collected from all consenting departments, radiographers (in their individual professional capacities) and a random sample of patients through document review, interview and observational research approaches. The outcome of the study supports blurring the scope of practice boundaries and timely execution of radiography examinations. However, there remains the need for further research to map care pathways for other radiology procedures and patients whose care is more variable and less standard.

Subjects: Instructional Communication; Organizational Communication; Technical Communication; Health Communication; Continuing Professional Development; Allied Health

Keywords: process activity; functional activity; integrated care; care pathway; clinical pathway

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PUBLIC INTEREST STATEMENT

Long waiting time for radiology service is a common and undesirable situation that affects many people in their lifetime. Faced with this problem, all too often, organisational restructuring and re-deployment of resources do not always result in reduced waiting times. This article explores the radiology care pathways, based on data gathered using interviews, observation and document reviews. This data was used to explain observed service transaction times for radiology patients in order to improve capacity planning. It was found that capacity planning was not preceded by solutions of basic work problems. However, the gravity of the situation was alleviated by informal and unofficial adoption of some radiologist duties by radiographers. Clearly, this outcome supports blurring the scope of practice boundaries and timely execution of radiography examinations. Understanding these practice dynamics can improve care pathways.

1. Introduction

Engagement in evidence based decision-making approaches is an important part of policy formulation aimed at enhancing efficiency and cost-effectiveness (ZMFED, 2013). In this approach, it is pertinent that patient care pathways are explicitly defined. Drawing from literature regarding definitions of clinical care pathways, a radiology care pathway may be defined as the process a patient follows from the time of referral for a radiology examination until the time the patient is dismissed from the radiology department (Daniel & Alan, 2006; Vanhaecht, De Witte, & Sermeus, 2007). These authors explain that processes comprising patient care pathways are used internationally to guide evidence-based health care in order to provide efficient services albeit concerns that all too often, a clinical care pathway is defined for single examination process. This leads to an element of confusion regarding what constitutes a clinical pathway in respect of activities and personnel involved. Hypothetically, it is logical that activities forming radiology care pathways may differ from patient to patient because patient demands and therefore flow times, equipment used, radiographer experience as well as institutional exposure guidelines may differ across radiology settings. Noting the difference between patient factors associated with acute and elective care, it might be expected that patient factors will lead to variances in the specific path each patient would follow within a radiology department. It is key to note that elective care is not life threatening in the medium term and therefore, allows for planning latitude that provide the radiographer with some control over the start time of care though within reasonable reliability margins.

Vanhaecht et al. (2007) outline defining characteristics of care pathways as embracing appropriately sequenced, patient specific and evidence-based goals with key elements of care that recognise synergy among team members. With respect to a plain radiology patient care pathway, the aforementioned defining characteristics of care pathways are indeed consistent with the main outcome measure of a radiology care pathway thus enhancing care across the continuum. This is consistent with concepts from the field of Health Operations Management (HOM), defined by Vissers and Beech (2005) as the analysis, design, planning and control of all activities necessary to provide a (radiology) service to (patients as) clients. These authors as echoed by Schrijvers (2009) as well as Schrijvers and van Hoorn (2012) explain that challenges are bound to arise if care pathways are not based on capacity planning of resources. The use of demand to capacity ratios for mapping patient care pathways has been identified by the United Kingdom National Health Service (UKNHS) as prerequisite for policy formulation aimed at optimising resource deployment and utilisation (UKNHS, 2005). Work done to clear bottlenecks in patient care pathways; to understand the magnitude and variation mismatches in demand and capacity and to smooth these variations, where possible, has been reported for the United Kingdom's National Health Service using demand to capacity ratios and this was fundamental for "Lean thinking" (UKNHS, 2005). Studies conducted by the UKNHS (2005) explain how evidence-based approaches can be used to map radiology clinical care pathways and also how to use the relationship between demand and capacity to explain workloads and therefore patient waiting times. Figures 1–3 are illustrative displays for a bottleneck activity, process activity and a functional activity as defined by UKNHS (2005). This aforementioned literature, although limited to high income countries, formed the impetus for the study of care pathways for low income environments.

The objective of the exploratory study reported here was to establish the nature of activities in the plain radiology patient care pathway so as to provide stochastic evidence necessary to establish a radiology care map that has "the right people, doing the right things, in the right order, at the right time, in the right place, with the right outcomes".

Figure 1. Illustrative display of a bottleneck activity.

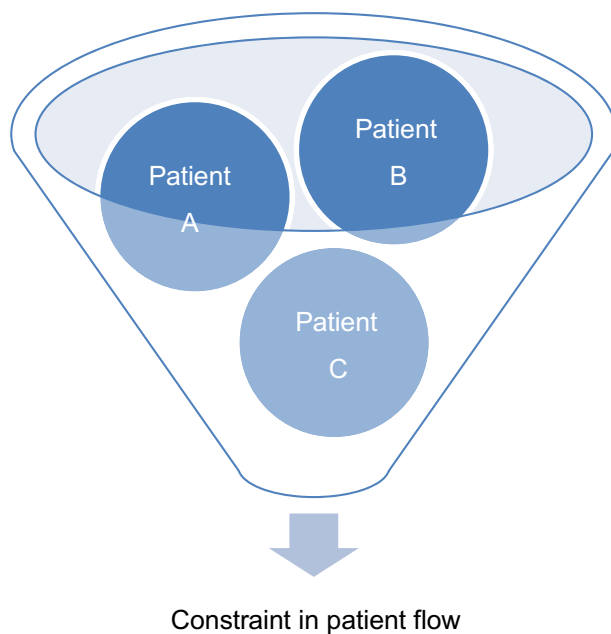


Figure 2. Illustrative display of process activities.

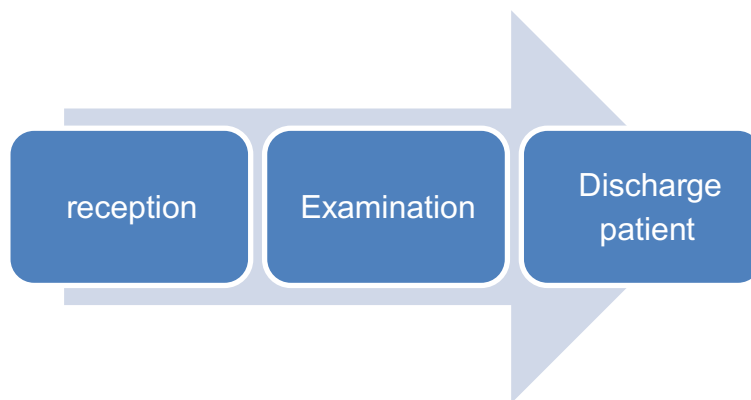
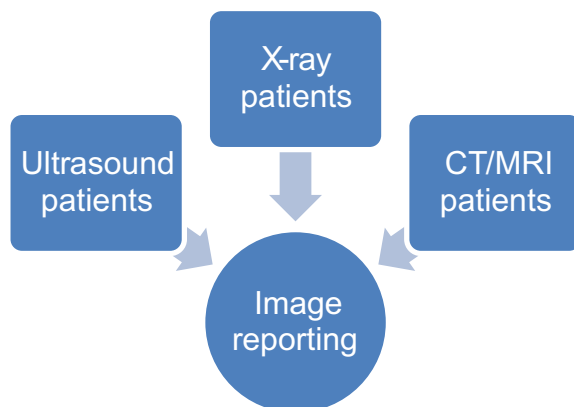


Figure 3. Illustrative display of a functional activity.



There is no literature that was identified with respect to radiology demand function. However, the use of well documented operations research/economics demand function methodologies as a framework for developing radiology analogue of a demand function was considered appropriate in ensuring the validity of this study. The function is the mathematical expression of the relationship between the number of radiology examinations demanded and those factors that affect the willingness and ability of a patient to access the examination. On the left side is the utilisation or demand for radiology services (Q_d) while on the right side is a function that manipulates labour drivers to give the observed demand for radiology services. In this way, if Q_d denotes the number of radiology examinations demanded, E is the amount charged for the examination, P_{rg} is the amount charged for a substitute or complementary examination, Y is the income of a patient then we can write the notation:

$$Q_d = f(E; P_{rg}, Y) \quad (1)$$

In this example, the semi-colon in the list of arguments for this demand function notation means that a demand equation may be written as:

$$Q_d = 1.1Y - 4P_{rg} - E - \text{constant} \quad (2)$$

The constant is the repository of all relevant non-specified factors that affect demand for radiology examinations, E is the fee for the examination and the coefficient for the cost is negative. In essence, the coefficients will be positive whenever a variable has a positive impact on demand and negative otherwise. If for example, P_{rg} denoted a complementary examination, the coefficient of its fee would be negative and if it were a substitute examination, the coefficient of its price would be positive while on the contrary, income (Y) has a positive coefficient.

2. Data collection procedures

Data collection was preceded by a rigorous ethical consideration process to get consent from departments, radiographers and patients. This was followed by ethics clearance from the Medical Research Council. A data collection instrument designed drawing from similar studies and piloted at the research sites by the researchers to come up with final item analysis was administered by the researchers as non-participant observers in all participating departments. This study was multicentred with a design guided by an abundance of literature on methodologies for patient care pathways. A predetermined random sample of patients drawn from consenting departments (proportionately distributed across examinations at each site) was observed from the time they arrived at the radiology reception area until they were dismissed from the radiology department (Daniel & Alan, 2006; Schrijvers & van Hoorn, 2012; UKNHS, 2005; Vanhaecht et al., 2007; Vissers & Beech, 2005). Consistent with literature, the objective was to document all instances where the patient moved from one personnel member to another (handoffs) and activities performed by radiology staff in respect of patients at each handoff (Schneider, 2011; Sibanda, Engel-Hills, & Hering, 2014). At each stage in the patient care pathway, documentation of patient activities recorded who they were involved with, equipment used and the amount of time taken for each activity (Daniel & Alan, 2006; Schneider, 2011; Schrijvers & van Hoorn, 2012; Sibanda et al., 2014; UKNHS, 2005; Vanhaecht et al., 2007; Vissers & Beech, 2005). Documentation also included the total number of radiology referrals from all sources at each of handoff (UKNHS, 2005). The observations were triangulated by prospective questionnaire and interview data which further sought to interpret the observations.

The data collection process was complex in that there were huge variances in anatomical regions involved, the examination techniques, expertise and curricular background of radiographers, type of equipment and patient/pathological characteristics as well as diversity in activities of the radiographers. Care was therefore taken with respect to inter-equipment, inter patient, inter-operator and inter-pathology variability in the measurements. To accomplish this task, the anatomy was divided into four categories namely: appendicular, axial and skull, chest region and others. Central tendency

with respect to service transaction times associated with these regions were established from a calculated multicentre quota sample of patients examined by various radiographers on various available X-ray machines (Schneider, 2011; Sibanda et al., 2014; UKNHS, 2005). These measurements were corroborated by interview results in respect of views of radiographers about the time estimates per patient as well as explanations for the observed data. Weighting these times across examinations, equipment, patients and radiographers allowed the determination of how service characteristics affected the duration and nature of the service transaction time for patients per anatomical region across the data collection sites.

3. Data analysis

The determination of radiology departmental activities involved an account of flexible activities that were performed at any time (e.g. damp dusting, filling and replenishing of drugs and accessories) as well as activities that were performed on a rigid demand (e.g. examining a patient, disinfection after examination, image evaluation and interpretation). Consistent with Sibanda et al. (2014) and Schneider (2011), these were categorised as controllable work-activities that were flexible in their timing and uncontrollable work-activities that required rigid timing. By this definition it was therefore appropriate to consider controllable activities as activities that afforded radiographers time latitude to perform the activity (Schneider, 2011). Notably, though, this latitude did not mean there was an open-ended window period. With this in mind, controllable-work windows were variable in length depending on the nature of the activity (Schneider, 2011).

The criterion adopted for this study was that if a patient's clinical journey in the radiology department had a mixture of controllable and uncontrollable characteristics, this essentially meant the journey was uncontrollable. Using this framework, the task was to map the plain radiology patient care pathway noting activities done, equipment and personnel capacity (Schneider, 2011; Sibanda et al., 2014; UKNHS, 2005, 2006). The equipment and personnel involved as well as the number of patients entered to calculate demand was based on the central tendency for the five sites. Activity time used in this study was an arithmetic mean for the research sites obtained by a survey approach. These activity time values for individual activities represent an average of values obtained by observational and interview approaches per examination. The final mean activity service transaction time, together with associated standard error of the mean were calculated by adding the aforementioned activity times associated with each examination and averaging across examinations.

Calculated staff and equipment capacities represented the total number of resources available at any given time at the five sites. With no official time series records on staff and equipment numbers, observed numbers for year 2014 and year 2015, as modulated by interview data, were used. When it came to time series data, the number of patients used for the calculations was the total number of patients for the five sites. Annual demand, defined as all radiology referrals coming in from all sources to a step in a patient care pathway (Schneider, 2011; UKNHS, 2006), was measured at the identified step by multiplying the patient numbers by the time in years it took to handle a patient at each step (UKNHS, 2006). Again consistent with the aforementioned literature, capacity was defined as the resources available to do work at each of the steps in a patient care pathway. This included all equipment and staff hours available to care for patients. Annual X-ray equipment capacity was obtained by multiplying the number of pieces of equipment by the time available to personnel with the necessary competencies to offer radiology care to patients (UKNHS, 2005). In order to ensure consistency and comparability as outlined by UKNHS (2005), demand and capacity were both measured in the same units (per year). These calculations were done using the Statistical Package for Social Sciences (SPSS Version 21). The same statistical package was used to guide the description of interview data by establishing central tendencies necessary to support inferential analysis.

4. Results

There were eleven distinct activities that were identified and observed using the check list. Table 1 is an illustration of a process template describing the process in terms of what happened to a patient at one point in time in the radiology department. The table also includes other observed activities

Table 1. Overall year on year demand/capacity ratio (DC⁸)

		Year										
		2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Compensated number of patients		50,321	55,685	38,089	43,630	25,379	16,495	41,080	38,117	54,171	50,169	48,550
Accounts	Demand	1.20	1.33	0.91	1.04	0.61	0.39	0.98	0.91	1.30	1.20	1.16
Reception desk	Demand	0.61	0.68	0.46	0.53	0.31	0.20	0.50	0.46	0.66	0.61	0.59
	Staff capacity	1.54	1.54	1.54	1.54	1.54	1.54	1.54	1.54	1.54	1.54	1.54
	DC ⁸	0.40	0.44	0.30	0.34	0.20	0.13	0.32	0.30	0.43	0.40	0.38
Actual number of patients		45,746	50,623	34,626	39,664	23,072	14,995	37,345	34,652	49,246	45,608	44,136
Waiting	Demand	0.81	0.90	0.62	0.70	0.41	0.27	0.66	0.62	0.88	0.81	0.78
	Sitting capacity	4.75	4.75	4.75	4.75	4.75	4.75	4.75	4.75	4.75	4.75	4.75
	DC ⁸	0.17	0.19	0.13	0.15	0.09	0.06	0.14	0.13	0.18	0.17	0.17
Examination	Demand	2.58	2.85	1.95	2.23	1.30	0.84	2.10	1.95	2.77	2.57	2.49
	Equipment capacity	2.14	2.14	2.14	2.14	2.14	2.14	2.14	2.14	2.14	2.14	2.14
	Staff capacity	7.91	7.91	7.91	7.91	7.91	7.91	7.91	7.91	7.91	7.91	7.91
	Staff capacity roistered	3.86	3.86	3.86	3.86	3.86	3.86	3.86	3.86	3.86	3.86	3.86
	DC ⁸ staff	0.33	0.36	0.25	0.28	0.16	0.11	0.27	0.25	0.35	0.32	0.31
Image processing	DC ⁸ roistered staff	0.67	0.74	0.51	0.58	0.34	0.22	0.55	0.51	0.72	0.67	0.64
	DC ⁸ equipment [†]	1.21	1.33	0.91	1.05	0.61	0.40	0.98	0.91	1.30	1.20	1.16
	Demand	0.87	0.96	0.66	0.75	0.44	0.28	0.71	0.66	0.94	0.87	0.84
	Equipment capacity	1.42	1.42	1.42	1.42	1.42	1.42	1.42	1.42	1.42	1.42	1.42
	Staff capacity	1.54	1.54	1.54	1.54	1.54	1.54	1.54	1.54	1.54	1.54	1.54
	DC ⁸ staff	0.56	0.62	0.43	0.49	0.28	0.18	0.46	0.43	0.61	0.56	0.54
	DC ⁸ equipment	0.61	0.68	0.46	0.53	0.31	0.20	0.50	0.46	0.66	0.61	0.59

[†]Denotes demand greater than capacity.

performed by radiographers. All centres had no resident radiologist and out of the 5 radiology departments observed, there was one centre that reported on images. Patients would leave their images behind and these would be delivered to an offsite radiologist who, upon finishing the reporting process, would forward the report and images to the referring clinician. Waiting time for these reports was never less than one day. At the time of this study the research sites had a total of 9 general radiography X-ray machines (working). The total number of filled staff posts (in service staff numbers) was: 41 radiographers but 20 radiographers on duty per shift and 15 darkroom technicians/clerks but 11 on duty per shift.

It was observed that darkroom technicians doubled as reception clerks. For the purpose of calculation of staff capacity, the observed total number of darkroom technicians plus reception clerks was therefore equally distributed between the two categories. The accounting process took an average of 12.57 min. The accounts department served the entire hospital and there was generally a queue at any given time at all research sites. Some departments had an additional cashier at the radiology department such that there were two personnel serving this queue. Out of a 118 patients observed, 108 were able to pay and proceed back to radiology reception area to register for a radiology examination. This means that 9.2% of patients were not examined because of financial issues and therefore, the number of patients recorded on the register represented 90.8% of the actual demand seen at the accounts and reception areas. Upon arrival at the radiology reception, the patients would join the queue and await their turn. For each patient, a total service transaction time (including registration time for examination) at the reception desk was on average 6.39 min. After the registration process, the patient would then join the queue in the waiting area for an average 9.34 min. The total service transaction time for plain radiology patients was 74.55 min. The examination process accounted for 39.7% of the service transaction time which was therefore, the bulk of this service transaction time (29.61 min out of 74.55 min).

In four out of five sites, it was observed that the radiographers' working day was 8–16 h and that each radiographer had 30 min tea break and one hour lunch break on each normal working day. In this regard, each radiographer was available to deliver services for six and a half hours on each normal working day. The one remaining site, was generally not busy thereby giving a flexible tea and lunch break timing. This arrangement seemed to work very well. The number of radiographers per shift was recorded from rostered radiographers. This information together with the overall yearly number of patients enabled a calculation of demand to capacity ratios (DC^R).

Overall demand to capacity ratios (DC^R) for the five research sites is displayed in Table 1. It was observed that 90.8% of patients initially seen at the radiology reception desk managed to return from the accounts department for radiology examinations. Reasons for the fallout were not investigated but it can be assumed that this was due to financial reasons. Based on the pilot statistics in which out of 118 originally seen at the reception, 108 were finally registered for the radiology procedure, the percentage number of patients seen at the reception and accounts departments as compared to registered number of patients documented in patient registers was then calculated.

The observed maximum demand to capacity ratios for all the stages were lower than expected with the minimum below 0.5. For all activity stages the central tendency of demand to capacity ratio as measured by the mean value was lower than expected (1.00) except in respect of demand to capacity ratio for examination equipment (0.996 ± 0.002) which was marginally lower than expected. In order to provide supporting evidence to explain the observed demand to capacity ratios, 400 request forms spanning from 2004–2014 were analysed. The distribution was not even across the years as availability of documents was not consistent.

It was also observed that 22% of the request forms were complete in respect of both clinical history and diagnosis. The central tendency (78%) was that referrers would indicate the examination question without supporting clinical history. Furthermore, survey results established that generally, radiographers' perspectives were that, for a long time since about year 2000, there was a cascade of

artificial negative pressures on radiology patient care pathway. According to the interviewed (84%) radiographers, these pressures (perceived as artificial) included economic sanctions, a weakening economy, equipment breakdowns and staff exodus and were always used by policy-makers to explain long waiting times for radiology services. However, it also emerged from some radiographers (15%) that waiting times were presumed consistent with increased demand due to epidemiological trends as well as overutilisation (76%) of radiology by referrers.

Generally, radiographers concurred (94%) that there was an unofficial role extension such that radiographers assumed some roles that were officially the scope of practice for the radiologists. However, none of the interviewed radiographers acknowledged having been formally trained to offer life support services, inject patients, or interpret radiology images. Furthermore, there were no continuous development programmes recorded by radiographers in line with these aforementioned activities except that radiographers were trained in-house.

Some key findings were that it was generally accepted (98%) that all radiographers were academically competent to do obstetrics and gynaecology ultrasound scans and reporting. The Radiation Protection Authority of Zimbabwe was in existence since before the data collection window period. Regulatory requirements such as ionising radiation signs, pregnancy alert and pilot exposure lamps were observed in all centres. However, justification and optimisation of exposures documents were not identified in all sites.

5. Discussion

Vanhaecht et al. (2007) defined the term “care pathway” or “pathway” as “a complex intervention for the mutual decision-making and organisation of care processes for a well-defined group of patients during a well-defined period”. Drawing from an outline by Vanhaecht et al. (2007) that provided characteristics of care pathways, this study focused on well defined goals and elements of care drawn from evidence, best practice, patient expectations for enhancement of communication with clients and linking of care processes to the sequence of activities that relate to multidisciplinary synergy. It was acknowledged that documentation, monitoring, and evaluation of variances and outcomes as well as identification, deployment and utilisation of appropriate resources are essential components of a care pathway. This is all in the interest of quality of care across the continuum, improved risk-adjusted patient outcomes, equity, patient satisfaction and optimised resource utilisation. Long patient waiting times that were evident at reception areas, accounts and patient waiting areas were potentially avoidable since observed demand to capacity ratios were generally less than one (UKNHS, 2006).

Observed handoffs in the patient pathways, although consistent across departments, could be reduced by introducing an online patient tracking system which will make available all patient information at the click of a button. Consistent with literature, the concept of utilising radiographers to undertake tasks which previously had been the role of radiologists had diffused slowly (though unofficially) across the research sites (Schneider, 2011). Although the practice by radiographers to identify pathology/abnormality by placing a dot where it is observed on images (red dotting) was acknowledged by radiographers as part of their activities, such action was however not observed across all research sites, and therefore cannot be used to explain observed service transaction times. With the global Health Services hard hit by a shortage of radiologists and these unofficially extended roles having been reported elsewhere as not in conflict with radiologists, these activities by radiographers may as well be an available solution to long patient waiting times for in low resourced environments. However, caution must be exercised to ensure that the impact of this role extension on the demand for radiology services, while easing an existing bottleneck (radiologists reporting) does not introduce an even worse new bottleneck of radiographer services. Overall, the observed pattern and rate of adoption of extended role and activities fits the observations made by Stevens, Robert, and Gabbay (1997). These researchers claimed that, in the first event, there is a tendency for new health care technologies to be introduced somewhat in an unorganised manner. It must be emphasised here that while the interview outcomes seem to support Stevens et al. (1997), second

suggestion that first technological diffusion is initially typically unorganised but occurs at different rates, factors that influenced this are subject to further investigation for these research sites.

Another issue that was investigated was the impact of completeness, accuracy and justification of radiology examinations on the demand for radiology services. There was wide spread non-compliance (78%) with the completion of radiology examinations request forms. Non-compliance potentially compromised the continuity of patient care in radiology departments in that there was possible inaccuracy of the requested examinations. Consistent with literature (IAEA, 2008; Sibanda, 2012), the most important fact was that, by virtue of being incomplete and therefore not indicated in so far as documented request information was concerned, these examinations were not justified and unnecessarily added 78% examinations to radiology demand. The impact on occupational dose and individual patient dose cannot be over emphasised. The impact of exposure guidelines as well as technology diffusion was not visible in the collected data from individual sites and neither was it visible in the overall data possibly because of the time horizon for the data.

While the outcome of this study has illustrated a rather moderate shift in practice for radiographers and that the extended roles now have a real potential to be officially embedded into practice, it would appear that challenges exist. In particular, because the existence of varied radiographer entry level qualifications (Bachelor's degree, Diploma and certificate level), matching the skills available with practice demands across different staff groups requires a review of radiography curricula. The current scenario therefore provided a challenge to capacity planning for delivery of an efficient and effective service. At the time of writing this report, the Zimbabwe National University of Science and Technology (NUST) for example, was engaged with the process of reviewing radiography curriculum. In this endeavour, the Allied Health Professions Council (AHPC) of Zimbabwe and the Radiographers' Association of Zimbabwe (RAZ) have also initiated the process to redefine scope of practice for radiographers. In this regard, it would seem that the adoption and diffusion of extended roles in radiography will continue for some time until these institutional policies are well aligned to each other. If this does not happen, the pressure is bound to continue together with a growing demand for radiology services (Department of Health, 2000). Suffice it to say, if the scope of practice is not redefined soon, these factors will play a pivotal role in accelerating the introduction planned and systematic extensions to promote quality service.

It is evident that the scope of practice for radiographers is a topical issue and that blurring role boundaries within multidisciplinary environments requires that the radiography education be responsive to the observed demands of practice in order to meet changing priorities. However, as suggested by Schneider (2011), ways will have to be identified to cater for those radiographers already in practice, to enable the development of competences over and above those learnt during pre-registration education and training. With respect to training institutions, opportunities also exist for supporting and enabling the widening scope of practice. Institutions will have to be proactive in responding to the need and revising the content of pre and post registration education.

Turning the focus to improvement methodologies, in a radiology perspective and consistent with previous research in other disciplines, activities done by radiographers were looked at using a "bottleneck" concept (Sibanda et al., 2014; UKNHS, 2005). In the study, identification of areas where patients' natural flow was constrained was a prerequisite to prescribing efficient and equitable distribution of resources as well as their utilisation. Using this concept, calculated demand to capacity ratios for the research site revealed that all but one (equipment capacity) of the observed activity stages were significantly over capacitated. Based on statistical evidence, for the majority of handoff stages there was under utilisation of resources. Consistent with literature, the patient care pathway itself had activities that fell into two types: process activities and functional activities. The examination process took the longest time to complete and was therefore identified as the "rate limiting step or task" in a radiology patient care pathway (UKNHS, 2005).

Despite reports by the ministry (ZMOHCC, 2009) regarding poor staffing levels, the radiology sector was actually over capacitated in so far as demand to capacity ratios can show. This was made more evident by noting that even when staff capacity was calculated based on half the observed established number of radiographers, (where half the number of radiographer establishment formed the shift at any given time) the staff capacity was found to be still above demand. This is evidence that even when half this number was in service, the sector was still over staffed. However, the results show that for most of the years, there was under-capacity in respect of X-ray equipment and this could provide answers to explain the existence of observed long waiting times. This was enough statistical evidence to recommend that the ministry should, at least in the short to medium term, focus its investment on radiology equipment and, instead of increasing radiographic staff capacity, focus on redeployment to solve observed variation mismatches in demand and capacity. Consistent with literature (UKNHS, 2005), activities such as image processing were typically functional bottlenecks with a potential to cause waits and delays for patients from several sources (radiographers) thereby causing disruption to the natural flow of radiology patient care processes. This delay was however not visible, possibly because the processing area had over-capacity relative to the demand for processing services. Image reporting is another example of a process activity but was not assessable in this study because images were delivered to a radiologist who had over a day to report on them.

Literature explains that such circumstances result in demand that is not promptly dealt with thereby resulting in a backlog (UKNHS, 2006) so much so that when it comes to execution of activities latitude windows for the individual activities, would be oversubscribed. In this study, it was observed that when departments started work, patients were already waiting and that queues would build up during tea and lunch breaks. Due to the fact that capacity generally surpassed demand, it can be concluded that these queues were mostly as a result of a mismatch between variation in demand and capacity. Elsewhere, it has been shown by many researchers that under similar conditions queues are as a result of the right people not always being available to deal with the demand in a timely manner (Gahan, 2010; Hobson, 2007; Lee & Silvester, 2004; Lodge & Bamford, 2008; Martin, Sterne, & Gunnell, 2003; Silvester, Lendon, & Bevan, 2004; Taylor & Shouls, 2008). Drawing from this literature, it means that every time demand exceeded capacity, a queue resulted and demand was subsequently carried forward. However, on the contrary, every time capacity exceeded demand, the extra capacity was filled from the backlog and this may explain the observed intermittent queues (Martin et al., 2003; Silvester et al., 2004).

Generally, throughout the plain radiography patient care pathway, capacity remained higher than demand for plain radiology services. In this study, the central tendency for equipment demand/capacity ratio was 0.996 ± 0.002 which was not significantly different from expectation (1.00). However, this means that there was insufficient room to accommodate flash variations in demand. This observation is despite the concerns by the Ministry of Health and Child care in which concerns were raised regarding the capacity of radiology human resources (ZMOHCC, 2009). The observed waiting time for radiology examinations was consistent with literature where these times were cited as the source of patient dissatisfaction (Taylor & Shouls, 2008).

The methodological approach adopted in this study took account of the variability of activity time as an indicator of demand by averaging activity time based on the variability of patient factors, personnel proficiency and examinations at the research site. This approach compensated for the fact that activity time varies depending on variables such as co-operation of the patient, age of the patient, the radiographer and the pathology investigated. Furthermore, the research focus was general radiography patients and observed patients placed similar demands on departmental resources. Gathering both the number of patients and the number of examinations was a plus for this study as previous researchers had recommended that this approach provides a more accurate estimate of activity and therefore demand (Gahan, 2010; Hobson, 2007; Lee & Silvester, 2004; Lodge & Bamford, 2008; Martin et al., 2003; Silvester et al., 2004; Taylor & Shouls, 2008). Although radiographers were assumed to be “interchangeable”, it is acknowledged that the use of activity

time gathered in one year, as a basis for calculations for all the years, introduced cohort errors. Again, this study did not include demand encountered outside normal working hours although contrary to other researchers, the data-set did provide the ability to determine whether a drop in demand for one research site was picked up by other providers in the same catchment area (Sibanda et al., 2014).

In order to provide more insights into the observed labour scheduling, observed activities were further classified based on timing. The nature of observed activities was such that some activities were performed at any time while other activities were performed upon demand. Of particular note is that radiographers were involved in occupational health and safety activities which were additional to what was measured in this study. This included routine hazard prevention measures such as daily damp dusting (disinfecting door handles, cassettes and equipment for example) as well as on demand infection control. The observed protocols were that routine infection control was done first thing in the morning or at the end of the day's work or in between examinations when demand allowed. This means that the scheduling of such activities was essentially controllable by radiographers. In other words, it allowed time latitude so that it could be done at the convenience of the radiographers. Some of these controllable activities were done monthly with examples being such activities as archiving and replenishing of emergency drugs and accessories. By this definition, controllable work afforded radiographers time latitude in which they could perform the activity. Importantly, though, these activities had to be performed within a window period. As such, controllable-work windows could vary in length depending on the nature of the activity: replenishing of emergency drugs at the research sites had documented latitude of months which was quite reasonable when considering expiry dates and rates of usage. It strongly recommends that these activities be investigated to see if they can account for the balance in human resource capacity.

There were other activities that did not allow radiographers to be flexible in their scheduling. These were particularly elaborate and on busy examination schedules. As an example, examining a patient, disinfection after examining patients with open wounds, image evaluation and interpretation as well as communication of findings were certainly "uncontrollable work" as they were rigid in their timing. Importantly, when a patient had been examined and there was another patient waiting for the services, room preparation was mandatory at the end of the examination. Therefore, the criterion was that if a patient's clinical journey had a mixture of controllable and uncontrollable characteristics, the journey was classified as uncontrollable. This was appropriate as once the examination process for the patient had been initiated, it had to be finished in as short a time as possible. There was also some evidence from literature that the duration of a patient's stay in a radiology department can be shortened by starting activities sooner or increasing parallelism (Mould, 2009; Tennat, 2001). The approach adopted in this study can best be described by The Theory of Constraints (Cox & Schleier, 2010; Goldratt & Cox, 2004). Consistent with Goldratt and Cox (2004) as well as UKNHS (2006), the focus of this study was on bottlenecks that had to be passed before the radiology process could continue. Because bottlenecks created rate determining stages on the capacity of a system, it was befitting to embrace Goldratt and Cox's (2004) view that a bottleneck solution was an overall process solution. This view was also shared by many other researchers who went a step further to identify the actual problems in patient care pathways (Gahan, 2010; Hobson, 2007; Lee & Silvester, 2004; Lodge & Bamford, 2008; Martin et al., 2003; Silvester et al., 2004; Taylor & Shouls, 2008).

6. Conclusions

In conclusion, generally the observed radiology departments were over capacitated in respect of human resources with demand to capacity ratio significantly less than one for all steps in the patient care pathway. However, equipment resources for conducting examinations were just under capacity. The observed queues and waiting times allowed the radiology departments to appear busy and in need of more resources yet in reality virtually all stages had capacity that surpassed demand. Guided by interview and questionnaire results, it can be concluded that inconsistencies between demand

and capacity was evidence that, beginning with lack of evidence to guide policy formulation; there was a cascade of assumptions on radiology patient care pathway which included beliefs that economic sanctions, a weakening economy, overutilisation of radiology and staff exodus were responsible for long waiting times for radiology services. Because activities that happened in the examination rooms had the greatest negative impact on service transaction time for radiology patients, it can be concluded that major gain would come from directing future research into this focal point.

6.1. Managerial and academic implications

Plain radiography formed the bulk of the work for radiographers in the observed departments and therefore an observed reserve staff that was equivalent to the number of radiographers manning the department at any one time was rather too high for a low income economy even when other hidden duties are taken into consideration. Generally, the observed plain radiology patient care pathway had four functional activities and seven process activities. Out of an observed eleven activities, four were controllable while seven were uncontrollable. Important in the findings of this study is that, role extension is now unavoidable, curricula and regulatory bodies must respond by aligning themselves to this development. To our knowledge, this is the first attempt to present factors impacting on demand to capacity ratios together with radiology when it comes to multicentre analysis. Finally, with regard to the practical standpoint, since the observed demand to capacity ratios were generally significantly below one, policy formulation towards resource management requires review.

7. Limitations and recommendations

In the light of these research findings, it is recommended that Health Operations Management concept of care pathways described in literature as the analysis, design, planning and control of all steps necessary to provide a service to a patient (Vissers & Beech, 2005), be considered by the National Health Service. Background literature to this study and the outcome of this study provide guiding evidence to this policy formulation. Furthermore, the care plan for individual patients will require managers to look at patient examination planning, protocols, patient group planning and control some of which is already being practiced in the National Health Services. However, because this would still leave a gap in capacity planning of professionals, equipment and space, it is recommended that forecasting and planning ahead for the number of patients to be treated and care activities be carried out as well as utilisation of long-term strategic planning by policy-makers to improve service transaction times for radiology patients. Connecting all activities within the patient care pathway, this study has shown how the duration of a patients' stay in a radiology department can be shortened by starting activities sooner. Consistent with literature (Gahan, 2010; Goldratt & Cox, 2004; Hobson, 2007; Lee & Silvester, 2004; Lodge & Bamford, 2008; Martin et al., 2003; Silvester et al., 2004; Taylor & Shouls, 2008), it is recommended that policy-makers focus on the fact that in any process bottlenecks occur that must be passed before the process can be continued.

It is also recommended that the National Health Service focus its efforts on reducing the variation mismatches in the system by managing the capacity to meet the peaks and troughs in demand. Consistent with lessons drawn from the aforementioned literature, this can be achieved through evidence-based redeployment of resources before even thinking of new acquisitions or raising staff establishments. Investment should focus on reinstating existing X-ray examination rooms and human resource management. Further research must focus on what is causing the peaks and troughs in the demand and capacity in order to redeploy radiology staff to match the variations. Evidence-based selection of Continuous Professional Development (CPD) activities is strongly recommended

in order to foster immediate academic and technical skills of radiology staff towards an understanding of time management and reflective practice. There is a need for the radiology staff to appreciate what they can do as radiology departments to solve the problems before even looking beyond to the ministry for external solutions.

Observed service transaction times as well as demand to capacity ratios demonstrated that the radiology sector could still take up an increased number of patients without the need for additional staff. However, the study was limited in that it did not explore the timeline for this window period in which the status quo of staffing levels can remain valid. To achieve this, an exploration of variables that model radiology demand (those that have a correlation or causal relationship with patient numbers) can be explored in order to establish foundations for a model to estimate the associated time line that the radiology sector would require to review staff establishments. The main outcome measure of this proposed study would be a statistically substantiated proposition regarding a relationship among those identified labour drivers as well as whether the aforementioned drivers are themselves time-variant or time-invariant (Malkowski, Hedwig, Parekh, Calton, & Sahai, 2007). The established radiology patient care pathways can be summarised into two models: a standard process which represents patients who followed the most common process among the observed participants (Figure 4) and a direct interpretation process which represented those patients who followed the less popular examination process (Figure 5).

Figure 4. Common radiological patient care pathway.

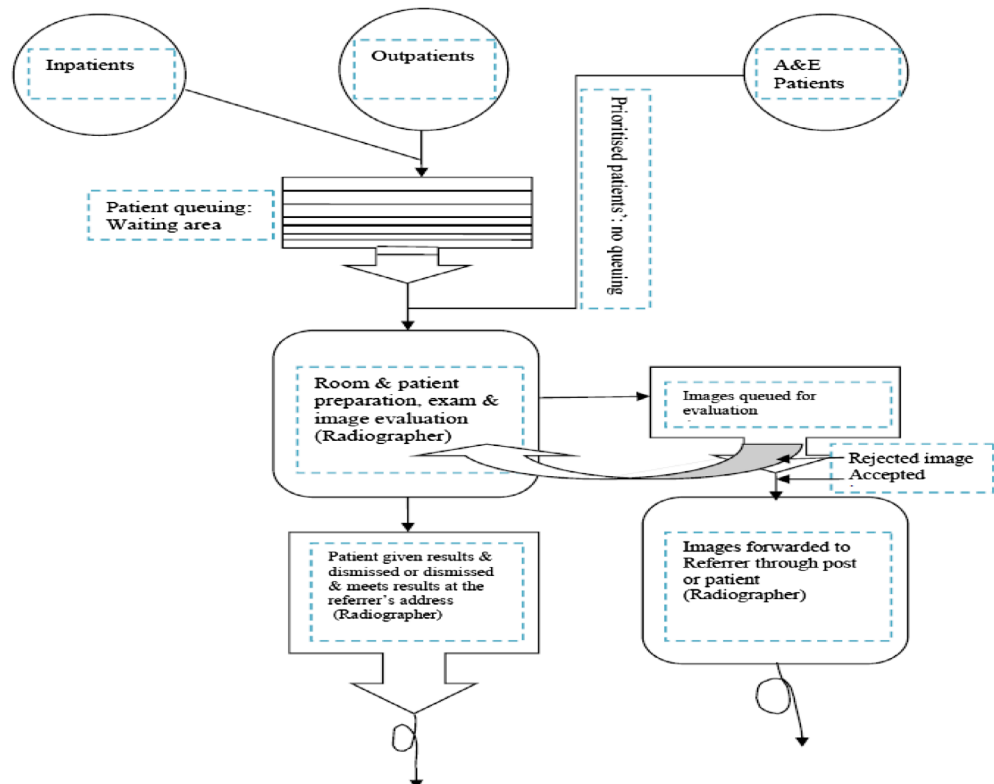
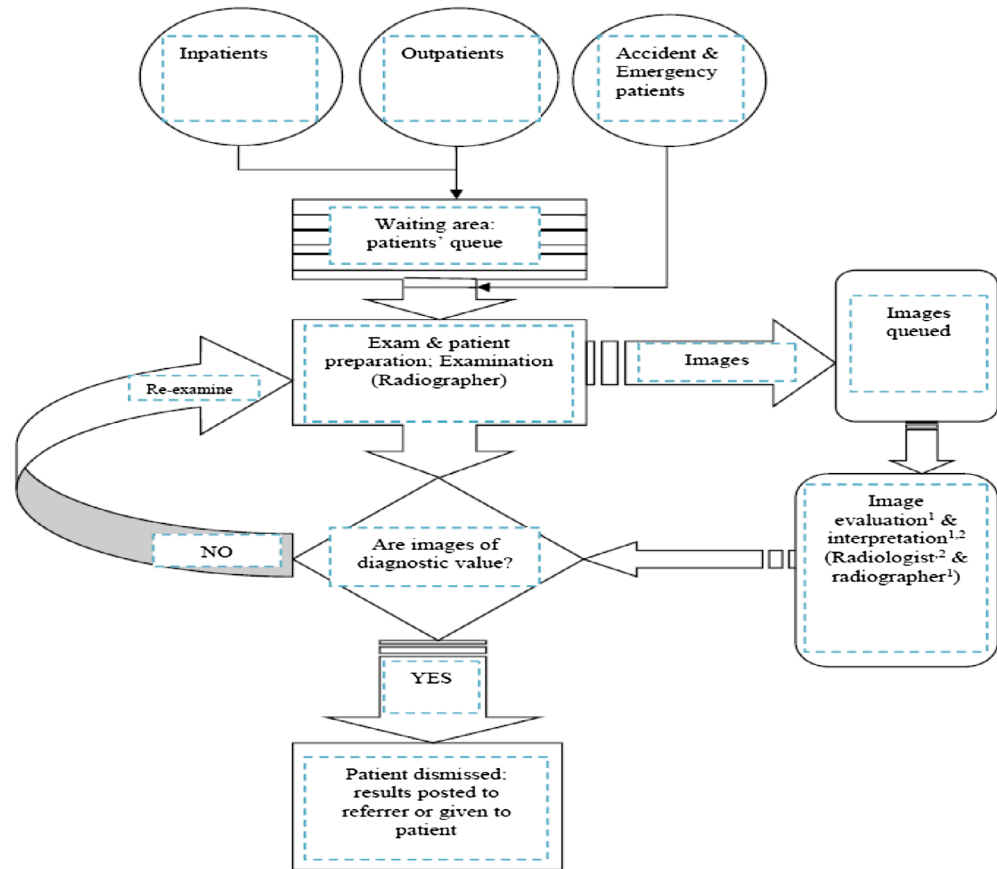


Figure 5. Patient care pathway with image reporting.



The less popular pathway yet recommended (Figure 5) had elements that needed formalisation, training and regularisation. The established practice was towards less and less direct supervision of radiographers during radiological procedures. It can be concluded that because of the acute shortage of radiologists, radiographers have gradually, unofficially and by default extended their roles towards full evaluation and interpretation of plain radiology images. This was however without the much needed formalisation, training and regularisation. Emerging from this research outcome are opportunities for an Internet-based health system (e-Health) to promote paperless online operations and teleaccess to specialist services especially for remote communities. Generally, radiographers are trained in e-Health from undergraduate level.

These observed pathways are both similar to what was reported by Schneider (2011). The recommended pathway (Figure 5) requires that curricula and continuous professional development issues be attended to as prerequisites issues.

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