

Department of Learning, Informatics, Management and Ethics (LIME), Medical Management Centre (MMC) Master Programme in Public Health Sciences, Health economics, policy and management (2016-2018) Degree Project, 30 Credits

Understanding variation in the 'See and Treat' process in Swedish primary care centres

A comparative analysis of process efficiency, patient volumes and patient pathways

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Master thesis for Degree of Master of Medical Science (120c) with a Major in Public Health Sciences

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Date of submission: 2018/05/08

Declaration

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The thesis <u>Understanding variation in the 'See and Treat' process in Swedish primary care centres: a</u> comparative analysis of process efficiency, patient volumes and patient pathways is our own work.

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Abstract

Background: Primary care centres (PCCs) serve as the gateway to Swedish healthcare. A See and Treat (S&T) management process has now been implemented in 4 PCCs in Sweden. Evaluation of variation between the PCCs using S&T is crucial in quality improvement in these PCCs.

Aim: This study aims to understand variation of process efficiency, patient volumes and patient pathways between PCCs which have implemented a S&T approach. It provides insights into how time resource management can be used to further refine these three dimensions in a S&T approach for primary care.

Method: The study was a retrospective observational study using multiple quantitative methods of Statistical Process Control, One-way Analysis of Variance and Process Mining to analyse the three dimensions in 4 PCCs in Sweden that implemented S&T.

Results: A sample size of 16438 was analysed. Process efficiency was improved in 3 out of the 4 PCCs whilst this improvement was sustained for 2 of these (PCC 3 and PCC 4). Patient volumes were found to be relatively stable with a degree of seasonal variation. For patient pathways, the majority of visits followed the S&T process as expected, however, a potential bottleneck was identified during completion of the digital form. Patients were more commonly triaged to the doctor than to the nurse.

Conclusion: The study has demonstrated that variation is present in the three dimensions between PCCs who implement a S&T process in Sweden. It provides an innovative methodology which serves as a comprehensive way to evaluate the process of operational management in primary care. Future studies can build on these findings through qualitative observations and interviews in PCCs implementing the S&T process.

Keywords: Primary care; Variation; See and Treat; Process efficiency; Patient volume; Patient pathway

List of Abbreviations

A&E: Accident & Emergency Department ANOVA: Analysis of Variance DTT: doctor treatment time I-Chart: Individual Chart NTT: nurse treatment time PCC: primary care centre **PM:** Process Mining S&T: See and Treat SPC: Statistical Process Control TLoS: total length of stay ToC: Time of Registration Complete ToD: Time of Diagnosis ToF: Time of First Open ToS: Time of Registration Start ToV: Time of Validation TSEF: The Theory of Swift and Even Flow TT: treatment time

WT: waiting time

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Introduction

Background

Quality improvement methods are used as a result of constrained healthcare resources and a demand for better performance (1). The definition of quality improvement has been given as "a continuous process that identifies problems in healthcare delivery, examines solutions to those problems, and regularly monitors solutions for improvement" (2). It is understood that variation is a key factor in the identification of these problems (3).

Variation in healthcare has a large influence on accessibility to services, clinical outcomes and efficient resource utilisation (3,4). More specifically, variation maybe be split into two broad categories: natural and artificial variation (2). Natural variation occurs within healthcare systems as three different forms (clinical variability, flow variability, and professional variability), which are inherent and need to be managed optimally. Artificial variation can be explained as variation which can be reduced or removed through targeted improvement. The degree to which these two broad forms of variation are present in management processes can affect delivery of healthcare services (5).

It is particularly beneficial to manage variation in primary care centres (PCCs) because they often act as the gateway to healthcare systems. Sweden is a typical example of one such system (6). If problems are present at the primary care level, then this could have knock on effects in other areas of more specialised Swedish healthcare. Given this importance, continuous evaluation and improvement of primary care services is essential. The study of variation is one method which can facilitate these needs (7). It is therefore crucial to analyse processes to understand what type of variation is occurring, and where it is happening.

Consequently, the introduction of any new management processes to PCCs in Sweden require ongoing monitoring and evaluation of variation. An example of a new management process introduced to PCCs in Sweden is that of a 'See and Treat' (S&T) approach. S&T is an operational management approach which separates processes that require different resources and activities, thus improving overall efficiency (8). The process involves triage for initial assessment of patients with minor conditions and determining subsequent patient pathways (9). In healthcare settings it has been shown to shorten waiting times and improve work efficiency, typically in Accident and Emergency Departments (A&Es), through management of the patient

flow process (10–12). The S&T approach can be adapted from A&Es for use in PCCs to help ease their paralleled problems.

Within S&T, there are different aspects which can be introduced to increase efficiency. Firstly, self-triage, where the patient's reported symptoms helps to direct their pathway, has been shown to reduce both waiting times and administrative burden (12–14). A recent report showed 50 million people per year use self-triage service globally (15). Secondly, digital systems for sharing information among health providers have recently started to play an important role in evaluating performance of primary care (16). Building upon this, the S&T approach can also be digitalised to good effect. Digitalisation can help to smooth the process of organizational management in healthcare, however, variation of utilisation may create challenges (17).

The Theory of Swift and Even Flow

The Theory of Swift and Even Flow (TSEF) may be used to help explain the mechanism of variability and the S&T process. Figure 1 conceptualises the theory; as variability of demand decreases and speed of flow increases, the productivity of a process increases (18). This concept shall be considered here with reference to variability of process efficiency measures, patient volumes and patient pathways within S&T. Thus, low variability of patient pathways and patient volumes combined with swift movement of patients through the process will increase process efficiency of S&T. Time measurements such as, total length of stay (TLoS) have previously been used as measures of process efficiency in healthcare settings (19).



Figure 1. Theory of Swift and Even Flow (18)

Previous Literature

The quality of healthcare, including primary care, is often accessed theoretically from a structure, process and outcome point of view (16,20). In healthcare settings, structure is defined as the capacity and mechanism of providing health service; process is defined as actual actions in accessing care; outcome is defined as the effects of care to patients' and populations' health status (16,20,21). In the field of evaluating S&T management, previous literature has suggested that an outcome-based approach has been the most common method for healthcare quality evaluation, such as looking at the effects of S&T on HIV and cervical cancer outcomes (22–24). However, it has been argued that a process-based approach maybe more useful to healthcare by identifying variation in care delivery (17). For example, these types of evaluation have proven useful for programs in Southern Africa which have aimed to improve cervical cancer screening (25,26). In recent decades, the benefits of a process-based approach, like pathway analysis, to evaluating healthcare quality has been highlighted (27).

However, it is challenging to establish and improve processes (28). In order to predict discrepancy of expected performance, it is of importance that a process is under a state with statistical control (29), like a health information system. In a healthcare context, timeliness is one dimension of evaluating quality care and improving process management (30). Besides, waiting times for treatment (accessibility) is emphasized as a major area for improvement in Swedish healthcare (31).

In evaluating process of S&T, existing guidelines have focused on improvement of timeliness in emergency visits and mostly were conducted within the context of the UK (10,32). Rogers et al looked at the effect of S&T in an A&E setting, finding that it reduced waiting times for patients with minor illnesses and injuries (33). However, the effect S&T has on process and variability remains to be explored fully in a primary care setting. Furthermore, S&T has yet to be analysed through patient pathways in PCCs, especially from the perspective of time resource utilization. In healthcare management, a limited amount of comparative analysis studies identified variation of using the same process structure (i.e S&T) across organizations (34). Therefore, there is a lack of evidence in improving S&T process management in a primary care context.

Rationale aim and research questions

The use of a new digital tool in PCCs in Sweden now provides a unique opportunity with time stamped data to explore the use of S&T in a primary care setting (8,35). This study aims to explore the variation of process efficiency, patient volumes and patient pathways between PCCs which have implemented a S&T approach. Therefore, the three following research questions will be explored: firstly, is there variation in process efficiency between PCCs using the S&T process? Secondly, how do patient volumes between PCCs using the S&T process vary? And thirdly, how do patient pathways vary between different PCCs using the S&T process? It was intended that the results of this study would provide insights into how time resource management can be used to further refine these 3 dimensions in a S&T approach for PCCs.

Method

The study was a retrospective observational study using multiple quantitative methods to analyse process efficiency, patient volumes, and patient pathways in 4 PCCs in Sweden that have implemented a S&T process. Process efficiency, including times resource as a main indicator, are often used for evaluation after implementing a new management programme in healthcare settings (36). Time resources used here were TLoS, waiting time (WT) and treatment time (TT). Patient volumes have previously been used to assess temporal variations in primary health care (37). Furthermore, monitoring of patient pathways may help to identify bottlenecks and evaluate real world deployment (38).

There are various methods and tools used for identifying variation of process in healthcare settings. In this study, three methods were used: Statistical Process Control (SPC), One-way Analysis of Variance (ANOVA) and Process Mining (PM). SPC has been widely used to access measures of healthcare process efficiency and the Control Chart is a frequently used tool of SPC (21,39). One-way ANOVA is a commonly used statistical method for comparing mean values obtained from different groups in clinical studies (40). It has previously been used to compare waiting times after the introduction of a 'fast track' management program for cancer patients in Denmark (9). PM has been used to gain an insight into the temporal relationship of the patient pathways (34), which the S&T process creates.

Setting and description of the S&T intervention

Since February 2014, a digital self-triage tool facilitating a S&T process has been implemented to optimize patient pathways in 14 PCCs in Sweden. The S&T process here is described with the following steps (see Figure 2): patients with simple complaints for unplanned visits can enter their own symptomatic details into the digital tool upon entry to the PCC; a registered nurse receives the electronic symptom forms through the PCC IT system and when ready, will then invite the patient to talk with them about their symptoms; in the next step the patients will be triaged by the nurse, if the nurse deems that it is necessary for the patient to then go on to see a doctor, then they will send them on, if it is not necessary to see the doctor then the patients only receive the requisite diagnosis from the nurse. Implementation of the tool may improve health management in PCCs by: reducing waiting times; increasing outpatient accessibility and decreasing administrative burden for health professionals (35).



Figure 2. Process map of the S&T process implemented in the four Swedish PCCs

Study methods

Secondary data was gained from the company which provides the digital tool facilitating S&T to the PCCs. It was collected through patient use of the digital tool and was

extracted from cloud storage to spreadsheet format. The data for each eligible centre was recorded over the course of 1 year from 05/01/2017 (the earliest date at which data was collected) until 15/01/2018 (the latest date at which data has been provided).

Eligibility criteria

A number of criteria were set in order to proceed with analyses. Firstly, only PCCs with over 6 months' worth of data were included in the analysis. This resulted in 4 out of an original 14 PCCs qualifying. The excluded 10 PCCs had a maximum of 1 months' worth of data which was not deemed sufficient enough to assess temporal variation. The second criteria were that TLoS values which were listed as over 4 hours were excluded. The majority of data points over 4 hours were anomalously long (41) (approaching 24 hours) and it was considered unrealistic that a patient would stay at a PCC for this amount of time. Thirdly, children (participants aged < 18 years) were excluded as it was thought they may not reflect correct usage of the tool.

Sample size

Data for 25051 individual patient visits from 14 PCCs was provided as secondary data. This may mean that same patient could account for more than one record if it was a separate visit. After the data was cleaned based on the eligibility criteria, the overall sample size was 16438 individual visits to the 4 PCCs, which are located in four Swedish cities: Bromölla, Norrköping, Sundbyberg and Stockholm. The final TLoS sample sizes for the PCCs were n= 3371 for PCC 1 (from 15/03/2017), n= 6724 for PCC 2 (from 05/01/2017), n= 4342 for PCC 3 (from 05/07/2017) and n = 2001 for PCC 4 (from 07/04/2017).

Data analysis

The raw data included time-stamped events (see Table 1) for individual patients as they progress through the PCC. All basic analysis and data cleaning was done using Microsoft Excel 2016. Other descriptive variables also available included patient gender, symptom types, PCC area and method by which the doctor submitted a diagnosis to the system.

Time Stamped Event	Description
Time of Registration Start (ToS)	Patient begins to enter symptoms on digital tablet
Time of Registration Complete (ToC)	Patient finishes entering symptoms on digital tablet
Time of First Open (ToF)	Nurse receives digital form and sees patient
Time of Validation (ToV)	Nurse finishes with the patient and sends them to the doctor (no diagnosis made by nurse)
Time of Diagnosis (ToD)	Diagnosis is made by either the nurse or the doctor; a proxy for patient discharge

1. Process Efficiency, patient volume analysis

The TLoS variable was considered as the time between a patient entering and leaving the PCC. Waiting time (WT) was considered to be the time between the patient first entering the PCC and when they first see a nurse and finally, treatment time (TT) was considered to be the time between when a patient first saw the nurse to when they were discharged by either the nurse or doctor, depending on the triage. Formulas by which these variables were calculated are shown below.

Variable	Definition	Method		
TLoS	ToD-ToS	SPC		
WT	ToF-ToS	ANOVA		
TT (DTT and NTT)	ToD-ToF	ANOVA		
Weekly Patient Volumes	Total patient visits per week	SPC		
Patient Pathway	Frequency and duration of patient movements	РМ		

Table 2. Variables used and their respective definitions and methods used in the analysis

A patient seeing a doctor is defined as when the patient is triaged to a doctor and has a record of the timestamp ToV. The treatment time for a patient seeing a doctor was Doctor Treatment Time (DTT). Patient seeing a nurse is defined as the patient being triaged to a nurse (i.e. not seeing a doctor for that visit) and has not record of the ToV. The treatment time for a patient seeing a nurse was Nurse Treatment Time (NTT).

Weekly patient volume was calculated for 5 day working weeks beginning the 09/01/2017 (so that each week started with a Monday). For some of the PCCs, the recording of patient visits began and ended with truncated weeks (e.g. PCC 1 data was recorded from 05/01/2017 giving only Thursday and Friday visits for the first week). It was considered that these would be unfair for comparison in the weekly analysis, so any visits which fell into truncated weeks were not included.

Once the variables of TLoS and patient volume were calculated, SPC analysis was carried out using Minitab software version 18.0 for TLoS and weekly patient volumes for the 4 different PCCs. SPC was not conducted for WT and TT as it was they were contained within TLoS. All PCCs except PCC 1 had continually recorded data from the point when they started recording. PCC 1 had no patient visits recorded from 26/06/17-14/08/17 which occurred because the PCC was closed for this period. Consequently, these weeks were removed from the analysis to provide continuous weekly patient volumes.

The control charts chosen were Individual Charts (I-Charts) as data was continuous, time ordered, over 100 individual observations and not in sub-groups (for each PCC). Anderson-Darling tests for normality were conducted for TLoS and patient weekly volume for each PCC, such that 8 normality charts were generated. For both TLoS and patient volumes, where the distribution violated a normal distribution, a Box-Cox transformation was investigated to see if this corrected the non-normal distribution. The following two rules were used to detect patterns and variation on the control charts (42–44):

i. 1 point > +/-3SD from the mean (to observe unusually high variation);

ii. 8 points in a row on the same side of the centre line (to observe shifts in variation)

Minitab software version 18.0 was also used to do to one-way ANOVA for WT, and DTT and NTT to detect any differences between the mean PCC values for these variables. A Tukey Test

was subsequently applied for statistical pair-comparison among PCCs to specifically detect which PCC means were significantly different from each other.

2. Patient pathway analysis

Patient pathway analysis was generated through the time stamped variables (ToS, ToC, ToF, ToV, ToD) by doing PM for each PCC. The four pathway maps were then compared to identify any relative differences or similarities in how the PCCs use the S&T process. PM was conducted by using Fluxicon software version 2.1.

The variables ToC and ToF only began to be recorded on July 4th 2017 meaning a more detailed map of the patient flow could be generated. Before this date patients would only be recorded as moving from ToS to ToV; the lack of granularity in the patient flow process before this date meant that visits for PM were only extracted after July 4th 2017 (until January 15th 2018). In total, 11960 samples were analysed for patient pathway analysis.

Ethical considerations

All PCCs are informed that their participations are voluntary. Only secondary data shall be used for analysis. The secondary data was recorded anonymously, and no private information of patients was recorded. Consent for use of the PCCs data was gained before their inclusion in the analysis. PCCs will be given anonymity in the results section so that better or worse performing centres cannot be identified.

Results

Process efficiency

SPC Analysis for Weekly Average TLoS

Anderson-Darling tests for normality for PCC1, PCC 3 and PCC 4 returned P-values of >0.05 showing a normal distribution (P-value of PCC 1 P= 0.348, PCC 3 P= 0.658 and PCC 4 P=0.104). However, PCC 2 deviated from a normal distribution (P-values <0.05; PCC 2 P=0.022). Although TLoS of PCC 2 was not statistically normal distribution, graphical representation of its probability plot did show a roughly normal distribution. Therefore, the control charts presented are the original TLoS values without transformation.

Figure 3 shows the I-Chart for the TLoS in PCC1. For the I-Chart the mean weekly TLoS for patients at PCC 1 was the shortest of all PCCs at 51:52 minutes. The week beginning 12 June, 2017 lies above the UCL showing artificial variation (rule 1 violation), this is followed by a sharp decrease in TLoS in the following two weeks. There is a generally decreasing trend after the TLoS rises back above the centre line.

The I-Chart for PCC 2 (Figure 4) showed a mean TLoS value of 54:47 minutes. Two shifts at different time points were observed (their performance followed rule 2 that more than 8 consecutive observations were on one side of the central line). The first occurred for 4 weeks from mid-April until mid-May, this shift lay below the central line indicating a decrease in the average TLoS. However, the second shift, which occurred from mid-October to mid-December lay above the central line, suggesting an increase in TLoS. Directly preceding the second shift there was 2 weeks of artificial variation where TLoS at the end of September and beginning of October was at its highest.

The I-Chart mean for TLoS in PCC 3 (Figure 5) was 57:37 minutes, the greatest for all PCCs analysed. A shift can be observed from late August until the middle of September, lasting for 3 weeks. This shift is below the central line demonstrating a decreased TLoS for this time period. However, the TLoS increased in an erratic manner culminating with a violation of rule 1 (artificial variation) at the start of January.

PCC 4 showed a systematic decrease in TLoS for the duration which S&T was implemented (Figure 6). At the beginning of September, when TLoS was greatest, artificial variation was observed. In contrast, there was a sustained 7-week shift below the central line at the end of the observation period from the end of November until the beginning of January. PCC 4 seemed to have reduced variation over time which suggested that the process had become more standardised over time.

a variation (above the UCL) could be observed. PCC 2 had the most artificial variation with 2 consecutive weeks. The occurrence of artificial variation across the PCCs did not appear to follow any particular pattern in terms of seasonality. PCC 1 and PCC 4 both showed decreasing variation as time progressed, although it is most evident in PCC 4. Regarding rule 2, there were 3 low shifts compared with just 1 high shift (PCC 2). Again, these shifts did not follow a seasonal pattern.



Figure 3. PCC 1 Average Weekly TLoS I-Chart (N=3371)



Figure 4. PCC 2 Average Weekly TLoS I-Chart (N=6274)



Figure 5. PCC 3 Average Weekly TLoS I-Chart (N=4342)



Figure 6. PCC 4 Average Weekly TLoS I-Chart (N=2001)

ANOVA analysis

The ANOVA P-value was >0.001 for WT suggesting that the 4 different mean values for this time period are significantly different from each other. The P-value for NTT and DTT were similarly >0.001, also suggesting that within these time periods, the PCCs had significantly different means from each other. The pairwise comparison (Tukey Test) for WT showed that all PCCs were significantly different (P<0.05) from each other (i.e none were statistically similar). PCC 4 had the highest mean value for WT with 24:24 minutes (as showed in Table 3). For the NTT, PCC 2 (28: 41 minutes) was found to be significantly greater than for PCC 1, PCC 3 and PCC 4 (P<0.05). For DTT, each PCC 3 and PCC 4 were found to be significantly different from the other 3 PCCs (P<0.05). PCC 4 had the greatest mean DTT of 56:17 minutes.

Table 3 shows that mean value of NTT was less than DTT for all PCCs. PCC 1 was consistent in that the mean values for WT (15:16 minutes), NTT (16:22 minutes) and DTT (36:39 minutes) were the lowest out all four PCCs.

The proportion of patient visits which only require NTT is similar between PCC1, PCC 2 and PCC 3 (0.21, 0.12 and 0.16, respectively) in that the values are low. Consequently, these PCCs DTT proportions are also similarly high (0.79, 0.88 and 0.84, respectively). PCC 4 differs from the other PCCs in that the proportion of patient visits which require NTT is high (0.78) and the proportion who require DTT is low (0.22).

PCC	WT		NTT			DTT		
	Mean (minutes)	Number of visits	Mean (minutes)	Number of visits	Proportion of visits	Mean (minutes)	Number of visits	Proportion of visits
PCC1	15:16	2024	16:22	415	0.21	36:39	1609	0.79
PCC 2	22:19	4145	28:41	485	0.12	38:45	3660	0.88
PCC 3	19:59	4342	20:08	679	0.16	40:58	3655	0.84
PCC 4	24:24	1449	16:59	1133	0.78	56:17	314	0.22
Total	20:29	11960	20:33	2712	1.00	43:10	9238	1.00

Table 3. Mean and sample size for WT (N=11960), NTT (N=2712) and DTT (N=9238) for all PCCs

Patient Volumes

Weekly patient volumes were analysed with SPC and results of I-Chart are shown in figures.

Three of the PCCs showed a statistically normal distribution (P-vale >0.05; PCC 1 P-value = 0.821, PCC 3 P-value = 0.383, PCC 4 P-value = 0.187). PCC 2 had a significant departure from normality in the distribution (P-value of <0.005), its probability plot showed an S-type or logistic distribution. The I-Chart for PCC 2 was therefore initially run with transformed data; however, this did not change the I-Chart results. Consequently, the results from the non-transformed data was presented here.

In Figure 7, the I-Chart for PCC 1 shows a shift of lower patient volumes at the end of May. The rest of the weekly volumes fall within the UCL and LCL. The average weekly patient volume was 101.9.

For PCC 2 (Figure 8), there was a mean weekly patient volume of 125.7 visits. From late April to early-September, the I-Chart showed that PCC 2 had a stable performance of patient volume and all data points were below the central line (rule 2). From early-September, patient volume of PCC 2 systematically increased such that artificial variation was found. However, patient volumes then stabilised around 160 visits per week (rule 2).

In PCC 3 (Figure 9), The I-Chart average was 156.3 patients per week. One data point fell below the LCL for the week beginning on Christmas day. Aside from this, weekly patient volumes fluctuated close to the mean value.

There was one shift observed in patient volumes for PCC 4 (Figure 10). This shift occurred in mid-August. The I-Chart average weekly patient volume was the lowest out of all 4 PCCs at 49.49 visits.

For all PCCs, there was only one instance of artificial variation above the UCL regarding rule 1, this was for PCC 2. There was also only one instance of artificial variation below the LCL (for PCC 3). PCC 1 and PCC 4 were similar in that neither had any evidence of artificial variation (rule 1) shown. PCC 2 showed the longest sustained low shift (rule 2). There was a clear increase in patient volumes for PCC 1 and PCC 2 towards the winter, this effect was evident but less pronounced in PCC 3 despite the drop during the week of Christmas.



Figure 7. PCC 1 Weekly Patient Volumes I-Chart (N=3260)



Figure 8. PCC 2 Weekly Patient Volumes I-Chart (N= 6663)



Figure 9. PCC 3 Weekly Patient Volumes I-Chart (N=4221)



Figure 10. PCC 4 Weekly Patient Volumes I-Chart (N= 1930)

Patient Pathway

Timestamps of patient pathways were recorded as PCCs used the digital tool in the S&T process. The expected recording of these time-stamped variables as patients moved through any given PCC using S&T is shown in Figure 11. The raw (non-averaged) TLoS data showed a right skewed distribution. Thus, the median value was considered as the real-value of duration in PM analysis.

Frequency Analysis

In this part, frequency of time-stamped events in each PCC was analysed. Absolute frequencies of all pathways were counted and marked with colour (See right of Figure 11). Bluer colour and bolder arrow of a flow means more patients went through. Actual patient flow

involved more pathways than expected, although frequencies of additional pathways were relatively small.

There were 7 various pathways in all PCCs based on their frequency. As expected (See left of Figure 11), Variant 1 (the pathway for patients triaged to see a doctor after completing digital form) and Variant 2 (the pathway for patients triaged to see a nurse after completing digital form) accounted for the majority of actual patient pathways. It seemed that Variant 1 (ToS-ToC-ToF-ToV-ToD, 84.93%, 37:33 minutes) was more popular than Variant 2 (ToS-ToC-ToF-ToD, 34.48%, 39:54 minutes). There were 5 unexpected pathways observed. Although they had a small ratio, it provided a perspective of observing actual flows. Variant 3 (ToS-ToF-ToV-ToD, 0.3%, 39:27 minutes), showed that when patients did not complete the form registration but went to see a nurse, they had a slightly longer duration (two more minutes) than Variant 1. Variant 7 (ToS-ToF-ToD, 0.02%, 22:58 minutes), followed the main flow of Variant 2 but skipped ToC and ToV, and took roughly half the duration of time of Variant 2. The rest of the pathways, Variant 4 (ToS-ToC-ToF-ToD-ToV, 0.2%, 1:26:00 minutes), Variant 5 (ToS-ToF-ToV-ToC-ToD, 0.04%, 3:12:00 minutes) and Variant 6 (ToS-ToF-ToC-ToV-ToD, 0.03%, 1:13:00 minutes) had some reversed event logs (compared to expected pathways) and a much longer duration of the whole process. In PCC1, 2, 3 and 4 the number of variant pathways present were 5, 6, 6, 5, respectively.



Figure 11. Expected variant pathways using the S&T process (Left) and Actual frequency Flow Chart of four PCCs (N= 11960) using the digital tool (Right)

Overall there were 47 visit recordings where patients took the direct pathway from ToS to ToF (see right of Figure 11), which meant they skipped the step of completing the form registration. Five visits were directly from ToC to ToD and four visits were directly from ToC to ToV, which meant the nurse might skip recoding ToF and triage patients without using the digital tool. In total, 33 reverse recordings suggest something has gone wrong with the flow order of these particular patients (24 recordings were reversed ToV and ToD, 5 recordings were reversed ToC and ToV, 4 recordings were reversed ToC and ToF). These visits of reverse recordings have been kept in the analysis as it was not clear if they were intentionally recorded as such.

The rate of reverse recordings for PCC 1, 2, 3 and 4 are 0.50%, 0.19%, 0.30% and 0.14%, respectively. PCC 1 had the greatest rate of reverse recordings, over 3.5 times the rate for PCC 4 (See Appendix PM).

As can be seen in Table 4, relative frequency of ToS, ToC, ToF and ToD for PCC 4 were slightly higher than other 3 PCCs. However, ToV of PCC 4 (6.52%) was lower than that of others, which meant that patients in PCC 4 were less likely to be triaged to a doctor. Differing to other PCCs, nurse visit (Variant 2) seemed more popular than doctor visit (Variant 1) for PCC 4 (See Appendix 1).

				Frequency		
	PCC	ToS	ToC	ToF	ToV	ToD
		N (%)	N (%)	N (%)	N (%)	N (%)
	PCC1	2024(21.19)	2018(21.13)	2024(21.19)	1462(15.31)	2024(21.19)
	PCC 2	4145(21.57)	4135(21.52)	4145(21.57)	2646(13.77)	4145(21.57)
	PCC 3	4342(21)	4323(20.91)	4342(21)	3324(16.08)	4342(21)
	PCC 4	1449(23.38)	1446(23.33)	1449(23.38)	404(6.52)	1449(23.38)
	Total	11960(21.5)	11922(21.43)	11960(21.5)	7836(14.08)	11960(21.5)

Table 4. Frequency of timestamps for 4 PCCs (N=11960)

Performance Analysis:

In the performance analysis, the location of bottlenecks in the actual S&T process was revealed. As can be seen in Figure 12, durations of all flows were counted and marked with colour. Redder colour and bolder arrow of a flow means a longer time taken, which in turn, indicated a potential bottleneck of the whole process. Reverse recordings biased the bottleneck location; thus, 33 recordings were taken out. 11927 samples from 4 PCCs were observed in the performance analysis.

The performance chart for all PCCs showed that patient flow from ToV to ToD (23:06 minutes) and that from ToS to ToF (21:06 minutes) cost the most time (See Figure 12). The treatment duration for just seeing a doctor (from ToV to ToD) in PCCs seemed longer than seeing a nurse (from ToF to ToD, 15:48 minutes). Patients who did not complete a digital form spent more time (from ToS to ToF, 21:06 minutes) on waiting for treatment before timestamp

of ToF than who completed form (from ToC to ToF, 12:30 minutes). In the S&T process, the direct pathway from ToS to ToF, which did not include a step of form registration, might be the bottleneck of the S&T process.



Figure 12. Performance Chart of four PCCs (N=11927)

Differently from the other three PCCs (See Appendix PM), the waiting duration for patients in PCC 4 who completed the form (ToS-ToC-ToF, around 17:24 minutes) was slightly longer than those who did not complete the form (ToS-ToF, around 16:12 minutes). However, it did not appear to be a significant bottleneck of the process; the main bottleneck for PCC 4 was found when from ToV to ToD (patients triaged a doctor, 41:12 minutes).

Discussion

The results from the process efficiency analysis show that PCCs who implement a S&T process can expect to have a shifted decrease in patient TLoS over a range of 2-7 months after implementation. This finding was apparent in 3 out of the 4 PCCs which were analysed. A deeper look into what time of year these low shifts occurred reveals an interesting finding. All shifts for the 3 PCCs occurred at different times of the year (PCC 2s reduction was from April –May, PCC 3s reduction was from August-September and PCC 4s reduction was from November – January) suggesting that seasonal variation is not responsible for the decreased TLoS. The low shift was only sustained for PCC 4 whilst PCC 1 held a general downward trend.

Conversely, regarding the patient volumes there is an increased winter demand demonstrated by the SPC patient volumes for PCC 2 (both rules 1 and 2), suggesting seasonal variation. For PCC 1 and PCC 3 patient volumes also appear to increase towards the winter months but within expected variability. This is in line with previous literature which has shown that seasonal demand for primary care services are 3-fold higher in winter months than summer months (37).

Therefore, any variation in patient volumes can be attributed to seasonal change rather than the S&T process. However, given the evidence that TLoS reductions do not follow seasonal patterning, it suggests that the implementation of a S&T process may help to reduce the weekly average TLoS. For PCC 4 it is evident that a statistically significant reduction in TLoS over time occurs concomitantly with a stable patient volume. This could mean that the PCC 4 has gradually learnt how to use S&T and that the process has become more standardised over time. There is evidence here in favour of the TSEF (19) : stable patient variability (demand) for PCC 4 appears to allow for a reduction in TLoS (productivity).

According to patient pathway analysis, expected pathways (patients who were triaged to see a doctor or nurse after completing the digital form) were the majority of actual patient pathways taken. This showed that actual management of S&T process has progressed as intended. There was evidence that reduced number of variant patient pathways increases productivity. PCC 1 had the joint lowest number of variant pathways which also corresponded to the ANOVA results. The ANOVA analysis showed that PCC 1 also had the lowest mean process efficiency time periods of WT, NTT and DTT.

A possible bottleneck in the S&T process was identified between timestamps ToS and ToF for all PCCs except for PCC 4. Patients skipped the timestamp of completing the self-reported form and took a longer time to proceed to ToF step than those who finished the form. It reflected that the expected pathway including the step of completing the form would smooth S&T process. For PCC 4, the possible bottleneck was identified when triaging patients to doctor treatment, but this needs more evidence for confirmation.

Based on results of both patient pathway and process efficiency analysis, a doctor visit was more frequent and took a longer mean treatment time than for a nurse visit for 3 PCCs. The finding of TT corresponded to previous research which found that time spent with a doctor was longer than with a nurse in a clinic visit (24). In contrary, PCC 4 showed this result in reverse: being triaged to the nurse was more popular than to the doctor. It is possible that this is the cause of the finding that PCC 4 showed the clearest reduction in TLoS. On the other hand, this reversal could be of concern. For example, possible causes of this could be that doctors are not using their time with patients in an efficient manner (greatest DTT from all PCCs, DTT was three-fold of NTT in PCC 4). The consequence of this may be that a greater proportion of patients are being diagnosed by a nurse than for other PCCs. An observational study would be required to fully explore why this is occurring in PCC 4.

Strengths and Limitations

One of the main strengths of the method used here has been the innovative use of both SPC and PM together to analyse the S&T process. To the author's knowledge this combination has seldom, if ever, been used in the field of primary care. This methodology has enabled the simultaneous analysis of process efficiency, patient volumes and patient pathways together. The use of these 3 parameters provides a more comprehensive approach for evaluation of management processes.

The use of timestamps has provided new ways to discover, monitor, and improve processes (45), as has been the case with the methodology used in this study. However, the use of timestamped data also highlights a limitation in that the recordings of timestamps may not have been precisely linked with patient flow events. For example, ToS was used as a proxy for the moment when a patient first entered the PCC, although the recording was made when the patient first touched the tablet to complete the digital form. Similarly, ToD was used as a proxy for when the patient left the PCC and finished their TLoS, however this timestamp was

recorded when the nurse/doctor submit the final diagnosis to the IT system. It is possible that the nurse/doctor submitted ToD an undefined amount of time after the patient had left. Therefore, it is possible that there may be a degree of error in time variable estimation due to the use of timestamp proxies.

Limitations were also apparent in the data collection period. For example, for PCC1, PCC 3 and PCC 4 data was not available for an entire year. This raises questions regarding the conclusions about seasonal variation in patient volumes (and lack thereof for TLoS). Previous literature which has specifically looked at seasonal variation has deemed it a requirement that a full year's worth of data must be collected in order to fully capture seasonal variation (37). Consequently, in order to confirm these findings, it would be beneficial to repeat this study when at least 1 years' worth of data has been collected for the PCCs being analysed.

All conclusions regarding SPC were based upon the assumption that the distributions for I-Charts were normal. Normality tests were conducted for each distribution, however the tests for TLoS and patient volume for PCC 2 did show a statistical deviation from normality. This brings up a question regarding the internal validity of the results. Yet it remains arguable that there is good internal validity as the Minitab (the data analysis package used) states that "data should be moderately normal". For the purpose of this study, the probability plots for PCC 2 were judged to be moderately normal.

Mean value of weekly TLoS was analysed for patient efficiency. Findings of using mean value of time duration in this study were corresponded to previous study of using the median value (24). However, the time periods of TLoS of PCCs showed a right-skewed distribution. The use of mean value may result in an underestimated duration of TLoS.

Regarding the bottleneck analysis, there was a limitation that the sample size of the proposed bottleneck pathway was small and thus could bring the conclusion into question. It would be beneficial to repeat the study in other PCCs to confirm the bottleneck with a greater sample size. Alternatively, an observational study focused at the entry steps (ToS-ToF) of the S&T process would also be a viable approach to clarify the location of the bottleneck.

Generalisability and Public Health Relevance

The external validity of this study is limited in scope due to the small number of PCCs which were included. 4 PCCs is not thought to be representative of all Swedish PCCs given

that in 2016 there were 1411 in total (46). These 4 PCCs represent only 4 different cities in Sweden which similarly, indicates that these findings should not be thought of as generalisable to the whole of Sweden. Yet given that this type of analysis for S&T within primary healthcare is the first of its kind, this study should be viewed as methodological framework for further evaluation as S&T is implemented more broadly.

Although this study took a specific approach to the S&T process, the methodology could also be applied to other process management strategies within healthcare. Within a brick and mortar healthcare settings, process efficiency measures, patient volumes and patient pathways will always be present. Therefore, SPC and PM could be used in conjunction with each other for process-based evaluation in a broader context other than S&T.

The study can deliver potential value to public health from two perspectives. PCCs who have implemented or are looking to implement a S&T process will be the direct beneficiaries of this study. In providing a new way to evaluate process, this study provides the basis upon which PCCs can improve their existing operation management, and therefore productivity. The continuous improvement of primary care in Sweden is also of benefit to the public given that accessibility is low, in relation to the rest of Europe (31). Additionally, this study can serve as a reference point to the patients who would like to have an overview of what the S&T process is and how long it takes.

Recommendations and Future Research

Future studies could use observation data to explore the fidelity with which the S&T process is actually implemented. This can provide further information on the actual process.

Four recommendations can be made based from the findings of this study for further research. Firstly, it is recommended that an in depth observational study is carried out in PCC 4 and contrasted with another PCC where the TLoS has not sustained a reduced TLoS. Any differences (or similarities) which can be highlighted may serve to understand what specific parts of the S&T process can be further controlled to minimise variation of delivery.

Secondly, it would also be of use to focus observations across all PCCs on the part of the process where patients fill out the digital form. This study has identified patients who skip completion of the form as a potential bottleneck. Patients may need further education on how the process works in order to maximise process efficiency. Thirdly, it was found that TLoS decreases 2-7 months after implementation of a S&T process, yet there may be a number of other factors which affect this finding. It would be interesting to control for the demographic (e.g. gender, region and age) and clinical variables (e.g. symptom types and severity) in the study in order to isolate the effect of the S&T process. Methods by which this could be investigated could be linear regression whereby, for example, TLoS could be the dependent variable and independent variables could include the demographic and clinical examples listed above.

Fourthly, the addition of baseline data would provide an interesting development to the study presented here. This study shows variation between PCCs with the same S&T, but the question remains how much variation occurs before S&T is implemented. Collection of baseline data would be necessary to study this. It is recommended that in the future PCCs who are deciding whether to implement a S&T process first collect data on process efficiency measures so that they may properly evaluate how S&T has changed their process outcome measures. The same method outlined in this study could be used to conduct a pre- and post-implementation analysis.

Conclusion

In conclusion, this retrospective observational study has demonstrated that variation is present between PCCs who implement a S&T process in Sweden. The method in the study was innovative, combining multiple quantitative methods to analyse process efficiency, patient volumes, and patient pathways. Process efficiency was improved in 3 out of the 4 PCCs whilst this improvement was sustained for 2 of these (PCC 3 and PCC 4). Patient volumes were found to be relatively stable with a degree of seasonal variation. For patient pathways, the majority of patient visits followed the S&T process as expected, however, a potential bottleneck was identified during completion of the digital form. Patients were more commonly triaged to the doctor than to the nurse. Evidence for the theory was shown by the combined results of PCC 4 for process efficiency, patient volumes and patient pathways.

The findings of this study are limited given that only 4 PCCs were available which had data over 6 months. Additionally, the use of proxies for patient entry and discharge may have resulted in slight inaccuracies in estimates of time durations. The use of mean values in SPC may not have been the most optimum average as the data deviated from normality. Despite

these limitations, the study provides a new methodology which serves as a comprehensive way to evaluate process efficiency of operational management in primary care. Future studies can build on these findings through qualitative observations and interviews in PCCs implementing the S&T process.

References

1. Nicolay CR, Purkayastha S, Greenhalgh A, Benn J, Chaturvedi S, Phillips N, et al. Systematic review of the application of quality improvement methodologies from the manufacturing industry to surgical healthcare. Br J Surg. 2012 Mar 1;99(3):324–35.

2. Irwin R. Understanding variation in the clinical quality of primary care: a typology of general practice organisations [Internet] [d_ph]. University of Birmingham; 2017 [cited 2018 May 6]. Available from: http://etheses.bham.ac.uk/7573/

3. Addressing unwarranted variation: literature review on methods for influencing practice [Internet]. Health Quality & Safety Commission. [cited 2018 May 6]. Available from: https://www.hqsc.govt.nz/our-programmes/health-quality-evaluation/publications-and-resources/

4. Appleby J, Raleigh V, Frosini F, Bevan G, HaiYan G, Lyscom T. Variations in health care: the good, the bad and the inexplicable. Var Health Care Good Bad Inexplicable [Internet]. 2011 [cited 2018 May 7]; Available from: https://www.cabdirect.org/cabdirect/abstract/20113168634

5. Understanding the impact of variation in the delivery of healthcare services / Practitioner application - ProQuest [Internet]. [cited 2018 May 7]. Available from: https://search.proquest.com/openview/82331c4171a0db910a64ea342b2db9c1/1?pq-origsite=gscholar&cbl=7080

6. Wadmann S, Strandberg-Larsen M, Vrangbæk K. Coordination between primary and secondary healthcare in Denmark and Sweden. Int J Integr Care [Internet]. 2009 Mar 12 [cited 2018 May 7];9. Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2663705/

7. Mohammed MA. Using statistical process control to improve the quality of health care. BMJ Qual Saf. 2004 Aug 1;13(4):243–5.

8. Savage C, Bjessmo S, Borisenko O, Larsson H, Karlsson J, Mazzocato P. Translating "See and Treat" to Primary Care: Opening the gates does not floods the system swamp?

9. Maull R, Smart PA, Harris A, Karasneh A. An evaluation of "fast track" in A&E: A discrete event simulation approach. Serv Ind J. 2009 Jul 1;29.

10. Jarvis PRE. Improving emergency department patient flow. Clin Exp Emerg Med. 2016 Jun 30;3(2):63–8.

11. A Simpler NHS: A fresh look at management in the NHS (Simplicity Book 1) eBook: Patricia Cantley, Michaela Finegan, Angela Nisbet, David O'Regan, Sharryn Gardner, Trevor Gay, Sir John Oldham: Amazon.co.uk: Kindle Store [Internet]. [cited 2018 May 8]. Available from: https://www.amazon.co.uk/Simpler-NHS-fresh-management-Simplicity-ebook/dp/B00NMNGQ82

12. Cremonesi P, Bella E di, Montefiori M, Persico L. The Robustness and Effectiveness of the Triage System at Times of Overcrowding and the Extra Costs due to Inappropriate Use of Emergency Departments. Appl Health Econ Health Policy. 2015 Oct 1;13(5):507–14.

13. AlSamnan MS, Mousa A, Al-Kuwaileet S, AlSuhaibani AH. Triaging self-referred patients attending ophthalmic emergency room. Saudi Med J. 2015 Jun;36(6):678–84.

14. Coyle AL. Dealing with patient self-triage: Nursing (Lond). 2017 Dec;47(12):17–8.

15. Wyatt JC. Fifty million people use computerised self triage. BMJ. 2015 Jul 8;351:h3727.

16. Hurlimann T. EU: Tools and Methodologies for Assessing the Performance of Primary Care [Internet]. Quebec Population Health Research Network | QPHRN. 2018 [cited 2018 May 7]. Available from: https://www.santepop.qc.ca/en/node/2610

17. Lenz R, Reichert M. IT Support for Healthcare Processes - Premises, Challenges, Perspectives. Data Knowl Eng. 2007 May;61(1):39–58.

18. On theory in operations management | Ehsan Sabet - Academia.edu [Internet]. [cited 2018 May 7]. Available from:

http://www.academia.edu/6370789/On_theory_in_operations_management

19. Devaraj S, Ow TT, Kohli R. Examining the impact of information technology and patient flow on healthcare performance: A Theory of Swift and Even Flow (TSEF) perspective. J Oper Manag. 2013 May 1;31(4):181–92.

20. Donabedian A. The quality of care. How can it be assessed? JAMA. 1988 Sep 23;260(12):1743–8.

21. Santos MA. Variation in Healthcare Processes: Implications for Quality of Care [Internet]. [Göteborg, Sweden]: Chalmers University of Technology; 2013. Available from: http://publications.lib.chalmers.se/records/fulltext/183776/183776.pdf

22. Numnum TM, Kirby TO, Leath CA, Huh WK, Alvarez RD, Straughn JM. A prospective evaluation of "see and treat" in women with HSIL Pap smear results: is this an appropriate strategy? J Low Genit Tract Dis. 2005 Jan;9(1):2–6.

23. Sankaranarayanan R, Rajkumar R, Esmy PO, Fayette JM, Shanthakumary S, Frappart L, et al. Effectiveness, safety and acceptability of 'see and treat' with cryotherapy by nurses in a cervical screening study in India. Br J Cancer. 2007 Mar;96(5):738–43.

24. Mutyaba T, Mirembe F, Sandin S, Weiderpass E. Evaluation of "see-see and treat" strategy and role of HIV on cervical cancer prevention in Uganda. Reprod Health. 2010 May 10;7:4.

25. White HL, Mulambia C, Sinkala M, Mwanahamuntu MH, Parham GP, Kapambwe S, et al. Motivations and experiences of women who accessed "see and treat" cervical cancer prevention services in Zambia. J Psychosom Obstet Gynaecol. 2012 Jun;33(2):91–8.

26. Ramogola-Masire D, de Klerk R, Monare B, Ratshaa B, Friedman HM, Zetola NM. Cervical cancer prevention in HIV-infected women using the "see and treat" approach in Botswana. J Acquir Immune Defic Syndr 1999. 2012 Mar 1;59(3):308–13.

27. Pearson SD, Goulart-Fisher D, Lee TH. Critical pathways as a strategy for improving care: problems and potential. Ann Intern Med. 1995 Dec 15;123(12):941–8.

28. Hellström A, Lifvergren S, Quist J. Process management in healthcare: Investigating why it's easier said than done. J Manuf Technol Manag. 2010 May 4;21:499–511.

29. Press TM. The New Economics for Industry, Government, Education, Second Edition [Internet]. The MIT Press. [cited 2018 May 7]. Available from: https://mitpress.mit.edu/books/new-economics-industry-government-education-second-

edition

30. Institute of Medicine (US) Committee on Quality of Health Care in America. Crossing the Quality Chasm: A New Health System for the 21st Century [Internet]. Washington (DC): National Academies Press (US); 2001 [cited 2018 May 7]. Available from: http://www.ncbi.nlm.nih.gov/books/NBK222274/

31. EURO-HEALTH-CONSUMER-INDEX-2017 – Health Consumer Powerhouse [Internet]. [cited 2018 May 7]. Available from: https://healthpowerhouse.com/publications/euro-health-consumer-index-2017/

32. Hassan Rahmatullah S, Chamseddin R, N Farfour A, Alomar M, Eldali A, S. Butt T. Rapid assessment and treatment (RAT) of triage category 2 patients in the emergency department. Trauma Emerg Care. 2017 Jan 1;2.

33. Rogers T, Ross N, Spooner D. Evaluation of a 'see and treat' pilot study introduced to an emergency department. Accid Emerg Nurs. 2004 Jan 1;12(1):24–7.

34. Partington A, Wynn M, Suriadi S, Ouyang C, Karnon J. Process Mining for Clinical Processes: A Comparative Analysis of Four Australian Hospitals. ACM Trans Manag Inf Syst. 2015 Mar 21;5:1–18.

35. Collabodoc [Internet]. [cited 2017 Dec 22]. Available from: http://collabodoc.com/en/

36. Wang H-MS, Wang S-P, Lee W. A Case Study for Reducing Client Waiting Time in a Health Evaluation Center Using Design for Six Sigma. Eng Manag J. 2014 Jun 1;26(2):62–73.

37. Seasonality of primary care utilization for respiratory diseases in Ontario: A timeseries analysis | BMC Health Services Research | Full Text [Internet]. [cited 2018 May 7]. Available from: https://bmchealthservres.biomedcentral.com/articles/10.1186/1472-6963-8-160

38. Fernandez-Llatas C, Lizondo A, Monton E, Benedi J-M, Traver V. Process Mining Methodology for Health Process Tracking Using Real-Time Indoor Location Systems. Sensors. 2015 Nov 1;15(12):29821–40.

39. Thor J, Lundberg J, Ask J, Olsson J, Carli C, Härenstam KP, et al. Application of statistical process control in healthcare improvement: systematic review. Qual Saf Health Care. 2007 Oct;16(5):387–99.

40. Kim H-Y. Analysis of variance (ANOVA) comparing means of more than two groups. Restor Dent Endod. 2014 Feb;39(1):74–7.

41. Mazzocato P, Holden RJ, Brommels M, Aronsson H, Bäckman U, Elg M, et al. How does lean work in emergency care? A case study of a lean-inspired intervention at the Astrid Lindgren Children's hospital, Stockholm, Sweden. BMC Health Serv Res. 2012 Feb 1;12:28.

42. Benneyan JC, Lloyd RC, Plsek PE. Statistical process control as a tool for research and healthcare improvement. BMJ Qual Saf. 2003 Dec 1;12(6):458–64.

43. Statistical Process Control (SPC) | NHS Improvement [Internet]. [cited 2018 May 8]. Available from: https://improvement.nhs.uk/resources/statistical-process-control-spc/

44. Savage C, Mazzocato P, Muhammed R, Keel G, El-Farouki G, Brommels M. Evaluation of the See & Treat Unit at Stockholm South General Hospital [Internet]. Stockholm, Sweden: Karolinska Institutet; 2014 Mar p. 41. Available from: https://ki.se/en/lime/clinical-management

45. Aalst W van der, Adriansyah A, Medeiros AKA de, Arcieri F, Baier T, Blickle T, et al. Process Mining Manifesto. In: Business Process Management Workshops [Internet]. Springer, Berlin, Heidelberg; 2011 [cited 2018 May 7]. p. 169–94. (Lecture Notes in Business Information Processing). Available from: https://link.springer.com/chapter/10.1007/978-3-642-28108-2_19

46. Isaksson D, Blomqvist P, Winblad U. Free establishment of primary health care providers: effects on geographical equity. BMC Health Serv Res. 2016 Jan 23;16:28.

Appendix

Frequency and Performance Charts of each PCC



Figure 13. Frequency Charts of PCC 1 N=2024 (left) and PCC 2 N = 4145 (right)



Figure 14. Frequency Charts of PCC 3 N = 4342 (left) and PCC 4 N = 1449 (right)



Figure 15. Performance Charts of PCC 1 N = 2013 (left) and PCC 2 N = 4137 (right)



Figure 16. Performance Charts of PCC 3 N = 4329 (left) and PCC 4 N = 1448 (right)