Chapter 13
Optimizing Care Processes with Operational Excellence & Process Mining

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13.1 Introduction

Providing high-quality and accessible health care is very important due to growing awareness and public pressure to do so [1]. However, this is becoming increasingly difficult as the demand for care continues to rise. Due to an aging population and increased patient demand for new services, technologies, and drugs, it is expected that healthcare expenditures will only continue to increase in the future [2]. Considering the burden of costs, healthcare has to be transformed in order to keep it available and accessible. To cope with this challenge, healthcare managers and professionals have been looking for new methods of resource utilization and optimization to potentially apply to health care. However, health care is not a standard manufactured product and a patient is not a simple widget in a manufacturing process line. Each patient has needs unique to his or her physiology, genetics, social circumstances, and other characteristics, for which different management options may be appropriate. This uncertainty in both demand for care and the provision of care is visible at all levels of the healthcare system, from an individual consultation with a general practitioner to a complex care process in a very large hospital [3]. Because of this, a care process and the coordination of the process often becomes very complex and not efficient [4]. Using data, either measured manually or extracted from data systems, about these care processes is therefore very important in order to understand and, subsequently, improve and control the process. In this

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chapter we will explore how Operational Excellence can optimize care processes and transform healthcare using these data. Among other, we will discuss how process mining can be used in this regard.

13.2 Care Process

A basic care process consists of different steps but frequently follows a similar pattern (Fig. 13.1). First, a patient seeks physician consultation regarding symptoms. Typically, further diagnostic or therapeutic decision-making is then needed to decide on next steps in care. This could involve another consultation, a procedure, or other additional steps added to the process. Follow-up consultation usually follows to close the loop on diagnosis, treatment, and management of the initial symptoms for which a patient sought care; this may be recurrent in complex or chronic conditions, and numerous variations in this basic process are possible.

Of course, not every care process is the same. For any given process, an analysis of the type of process and organization where the process takes place is essential to be able to optimize it. Johnston and Clark (2008) use two criteria to distinguish between different process types: [1] volume and [2] process variation and process complexity (Fig. 13.2) [5].

There can be variation in healthcare demand (what and how many of a given service is asked for, at which time and place?), healthcare supply (what service, at what quality can be offered, at which time and place?) and the service itself (is it delivered according to the specifications?). Complexity can be related both to the case (medical complexity) and to the coordination of processes. Patients with multimorbidity, or multiple chronic conditions, and super-utilizers, or frequent users of high-cost services, are examples of complex cases. Such cases inherently involve many persons and/or activities in care of the patient. This often results in a higher burden of care coordination, making it difficult to streamline processes in an efficient and standardized way. In the next chapter, the concepts of multimorbidity, or patients with multiple chronic conditions, and super-utilizers of healthcare services will be explored further.

Due to the complexity and variation, it is difficult to predict what the demand will be and how much capacity is available to meet the demand. For example, waiting time for a patient is a symptom of a process where demand and supply are mismatched. Managing waiting times is surprisingly complex, unless one accepts high overcapacity. Moreover, even in simple waiting systems there is a non-linear relationship between utilization rate of appointment capacity and waiting time. The relationship between utilization rate and waiting becomes more linear when there are more workstations and customers have no preference for one of them. For example, a patient seeking an appointment at a practice with one general practitioner

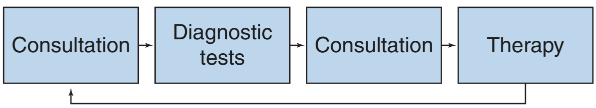

Fig. 13.1 The typical steps of a care process

could have a high waiting time due to more limited appointment capacity; in a practice with two general practitioners, the patient may choose the first appointment available, resulting in a reduced waiting time (see Fig. 13.3). For the same utilization of capacity this reduces waiting significantly.

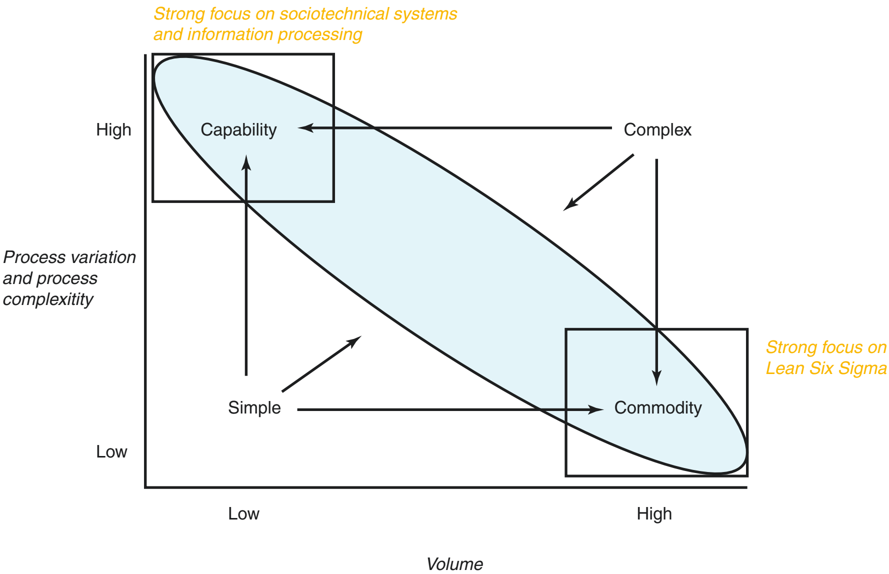

Fig. 13.2 Volume-variety matrix adapted from Johnston et al. [5]

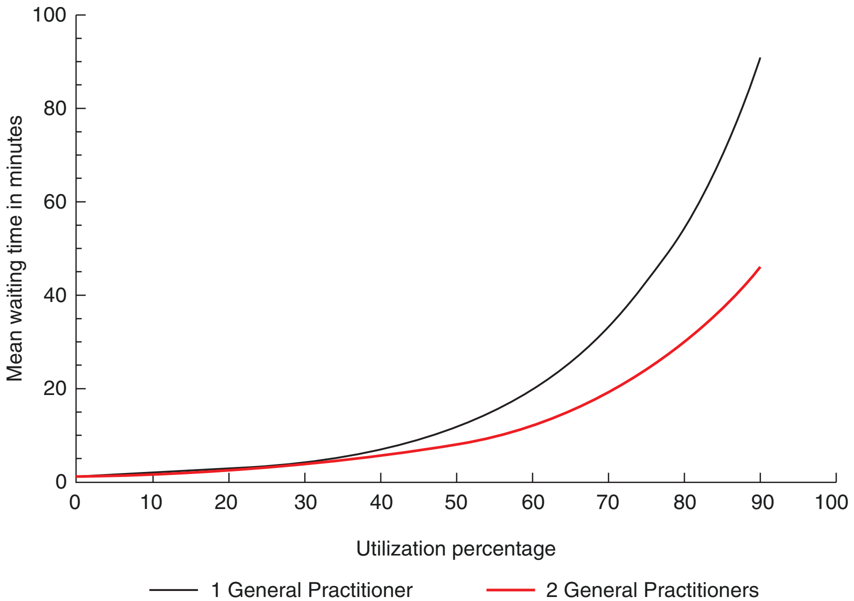

Fig. 13.3 Relationship between waiting time and utilization

By optimizing the processes, the waiting time can be reduced, but to be able to cope with the uncertainty of demand, which will always exist due to the nature of healthcare, flexibility of the resources is required. A low degree of flexibility can lead to a mismatch between supply and demand. Inflexibility determines the adaptability of the production system to changes in the chain of activities. There are three types of inflexibility [3]:

– *Technical inflexibility*: equipment can only be used in one way;
– *Economic inflexibility*: extra costs are incurred when capacity is used in a different way to that originally intended; for example, an operating room designed for certain operations can also be used for other operations, but then the equipment must be changed, which leads to switching costs;
– *Staff inflexibility*: occurs due to limited knowledge, specialization, legal reasons, working times and motivation.

13.3 Operational Excellence

The main goal of Operational Excellence (OE) is to enable any organization to excel at the service it provides or product it produces. Within healthcare, OE is strongly focused on optimizing the care process and creating (more) value for thepatient. Operational Excellence uses the data from these processes to continuously analyze, improve and control them. A process is defined as a specific ordering of work activities across time and space, with a beginning and an end, and clearly defined inputs and outputs: a structure for action [6]. Processes are the structure by which an organization does what is necessary to produce value for its customers. The methods and theories of OE are applicable in any health care setting by any type of healthcare provider, including small general practitioners' offices or large multispecialty hospitals with different departments, emergency rooms and operating rooms.

Operational Excellence works through the Define, Measure, Analyze, Improve and Control or DMAIC- Cycle as its continuous improvement framework to optimize the care processes [7]. Data plays a very important in this cycle. At every step of the cycle, process data is needed to perform actions. The phases within the DMAIC are defined as [8]:

– **D**efine by identifying, prioritizing and selecting the right project;
– **M**easure key process characteristics the scope of parameters and their performances;
– **A**nalyze by identifying key causes and process determinants;
– **I**mprove by changing the process and optimizing performance;
– **C**ontrol by sustaining the gain.

Operational Excellence has a wide range of optimization methods that can be used to improve the care process. OE is best known for its popular methods of Lean (Thinking), Six Sigma or the combination Lean Six Sigma (LSS). However, OE also relies on sociotechnical systems (STS) and leadership to transform care processes, which we will briefly discuss at the end of this chapter. First, we will discuss the basis methodologies of Lean, Six Sigma and Lean Six Sigma.

13.3.1 Lean Thinking

Lean (Thinking) is derived from the term 'lean,' introduced by Womack *et al.* who published their book 'The machine that changed world' [9]. Focusing on car manufacturing, the report described how Japanese production methods were superior to Western because they were able to produce cars efficiently without losing quality. This was in contrast to the mass production of cars then common in the West, which was very effective in producing large volumes, but had a lot of rework needed. Toyota, the first company that successfully implemented 'Lean Manufacturing' and to car production, was successful because of a deep business philosophy based on its understanding of people and human motivation. They implemented quality improvement methods and as a result created Operational Excellence. Toyota had successfully enriched leadership, teams, and culture to create strategy, built supplier relationships and maintained a learning organization [4].

The main purpose of using Lean is to eliminate waste in order to create more value. The approach describes seven types of waste: overproduction; waiting; unnecessary transport or conveyance; over processing or incorrect processing; excess inventory and unnecessary movement and defects [10] (Table 13.1). Later publications added an eighth type of waste: unused human potential [4].

Table 13.1 Overview of all types of waste according to Lean Thinking and a short description [3, 4]

Type of waste	Brief description	Healthcare examples
Overproduction	Doing more than what is needed by the patient or doing it sooner than needed	Blood tests being done weeks before a consultation, so they are not recent when needed
Waiting	Waiting for the next event to occur or next work activity	Patient waiting for an appointment or doctors waiting for a lab result
Transportation	Unnecessary movement of the product in a system (patients, specimens, materials)	Cardiac catheterization lab being located far from the emergency department
Overprocessing or incorrect processing	Doing work that is not valued by the patient; or the result of care quality being defined in a way that is not aligned with patient needs	Buying the newest surgery robots to perform simple procedures with no benefit for the patient in terms of quality or outcome
Inventory	Excess inventory cost, for example, due to added financial costs, storage and movement costs, spoilage, or wastage	Buying all surgical equipment in the same order of magnitude while not all equipment is being used as extensively
Motion	Unnecessary movement by employees in the system	Lab employees walking between lab and their desk
Defects	Time spent doing something incorrectly, inspecting for errors, or fixing errors	Surgical cart missing an item
Human potential	Waste and loss due to not engaging employees, listening to their ideas, or supporting their careers	Employees being overworked and developing burnout

13.3.2 Six Sigma

In this same period as Lean Thinking was gaining popularity, Six Sigma was introduced. This approach was created at Motorola in the late 1980s [11]. Today, Six Sigma is a technique used to improve processes not only for manufacturing, but also for other sectors including healthcare. Six Sigma strategies seek to improve the quality of the output of a process by identifying and removing the causes of defects and minimizing variability in processes. It uses a set of quality management methods, mainly empirical, statistical methods; hypothesis testing is applied to empirical data, in order to find evidence for or against supposed causes of process problems. It also creates a special infrastructure of people within the organization who are experts in these methods. The term ‘six sigma’ comes from ultimate goal of this method: having only 3.4 defective features per million opportunities. This means that in a process 99.99966% of all opportunities to produce some feature of a part are statistically expected to be free of defects.

13.3.3 Lean Six Sigma

Lean Six Sigma describes the integration of Lean and Six Sigma philosophies [12]. A combination of Lean and Six Sigma can provide an effective framework as both are systematic approaches to facilitating process optimizations. Where Lean focuses more on standardization and production flow leveling, Six sigma has an approach where reduction of process variability is central. Because of this, Lean often has not consistent (changing) performance metrics. By combining the two methodologies, the more quantifiable methodology of Six Sigma, such as statistical process control, and the more cultural approach of Lean, such as Value stream mapping, a more complete analysis of an organization can be made. Six Sigma’s focus on statistical rigor and control of variation and Lean’s focus on reduction of non–value-added activities both require data collection and analysis to improve performance. [13].

DMAIC cycles can be performed by anyone in the organization, if trained and supported by leadership. Equipped with the skills to do so, healthcare professionals can improve their own process and, consequently, have a sense of ownership of the care process and its continuous improvement. This gives them an in-depth look on their process, which helps them to Analyze and Improve the process. Because it is a continuous improvement tool, the purpose is to keep measuring, also when the improvement is completed. A dashboard is an effective method to continuously visualize the process in real-time or close-to-real-time data.

One important process output is the access time, which is the number of days a patient has to wait to get an appointment (Fig. 13.4). When the access exceeds a certain limit, action is taken. Visualization, even in this primitive form, thus keeps health professionals attentive to indicators that are critical to a smooth care process.

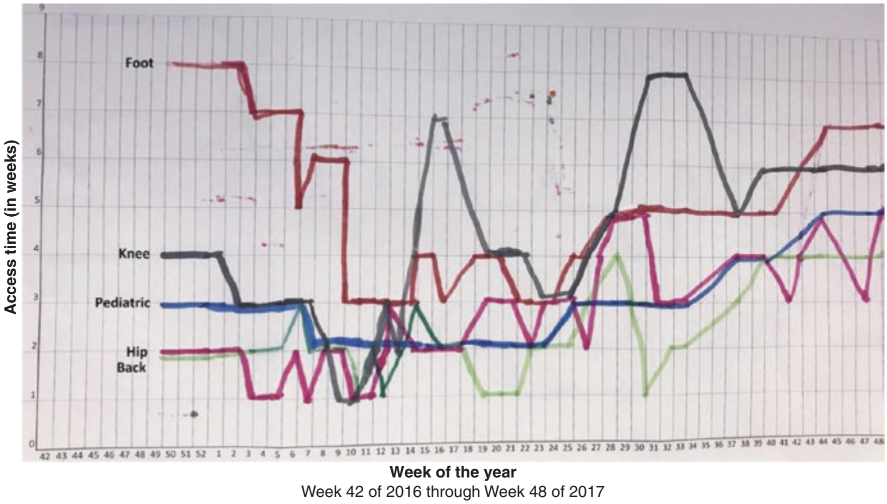

Fig. 13.4 Visualization of access lead time to Orthopedics subspecialty outpatient clinics at the Maastricht UMC+

Because these optimizations are done in a cyclic, continuous way, processes are constantly changing and adapting. These changes are generally incremental and not seen as transformative in themselves. However, by continuously changing elements of the organization, Operational Excellence can transform entire organizations.

13.4 Process Mining

A more advanced technique that can be used in the context of DMAIC cycles is process mining. Process mining extracts process knowledge from so-called event logs which may originate from all kinds of software systems (Fig. 13.5) [14].

The example event log shown in Fig. 13.6 contains the typical information needed to perform process mining. Each event belongs to a single process case. Events are related to activities. The “case id” and “activity” columns are essential information for process mining. The “event id” can be used for ordering events within a care process. This is needed in order to see causal dependencies between events. An event log may also contain additional information, which can be used for calculating performance properties of the process. For instance, the “resource” (performer of the event) and the “cost” attribute (cost of the activity) can be used for discovering additional process knowledge. The table shown in Fig. 13.2 contains 12 events for 2 cases. For case id “1”, subsequently the activities “First Visit”, “Surgery”, “Second Visit”, “Radiotherapy”, “Chemotherapy” and “Evaluate” have been performed. Here, the “First Visit” event has id “589,585”, is performed by “John” at “05/04/2017”, and has cost “150”.

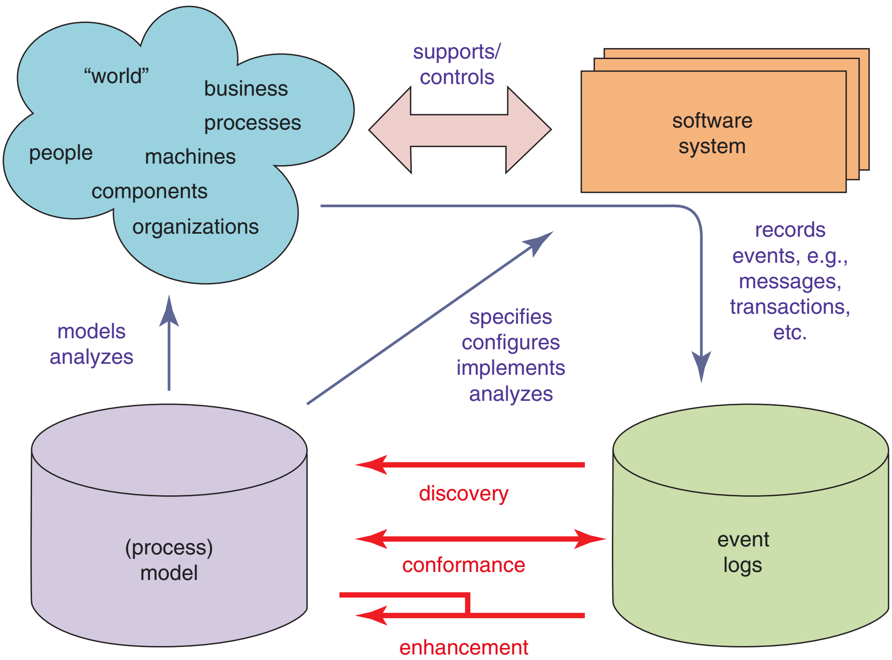

Fig. 13.5 Basic objectives and types of process mining [14]

Caseid	Eventid	Properties			
		Timestamp	Activity	Resource	Cost
1	589585	05/04/2017	FirstVisit	John	150
	589586	08/04/2017	Surgery	Henri	55
	589590	10/04/2017	SecondVisit	John	150
	589593	16/04/2017	Radiotherapy	Peter	200
	589595	21/04/2017	Chemotherapy	Suzan	300
	589601	28/04/2017	Evaluation	John	175
2	748384	01/02/2018	FirstVisit	Tom	150
	748385	03/02/2018	Surgery	Olivia	55
	748386	10/02/2018	SecondVisit	Tom	150
	748400	16/02/2018	Radiotherapy	Peter	200
	748408	19/02/2018	Immunotherapy	David	300
	748412	22/02/2018	Evaluation	Jack	175

Fig. 13.6 Example of an event log

Process mining applies specialized mining algorithms to gain insights into how process are actually executed based on stored event logs. So, where traditional modeling techniques try to model a processor create a value stream map based on interviews with people working in the process, process mining makes use of stored data to model and analyze these processes automatically and overcomes human limitations in reconstructing complex processes. There are three main types of process mining that can be distinguished: Discovery, Enhancement and Conformance [14].

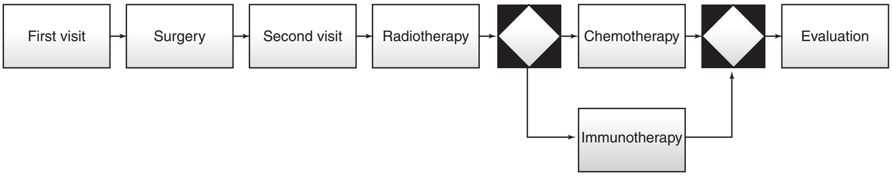

Fig. 13.7 Care process discovered from example event log

Discovery Here, event logs are used to model the different steps that are taken within a care process. From the example event log in Fig. 13.6, the following process model will be discovered by making use of process mining (Fig. 13.7).

The discovered process model in Fig. 13.7 represents the behavior of all (in this case just two) cases. The model shows that cases have a first visit, a surgery, a second visit and then receive radiotherapy successively. Subsequently, a case receives either chemotherapy or immunotherapy, before an evaluation is performed.

Discovering a process model by means of process mining can be very helpful in the Measure phase of the DMAIC cycle to gain insights into how the care process actually looks like. For care processes that are more complex than the one shown in Fig. 13.7, discovering a process model by means of process mining is less time-consuming than modeling a care process "by hand" based on interviews. Moreover, process mining will also shed light on less frequently executed process paths, which are easily overlooked by practitioners modeling processes "by hand".

Conformance Conformance checking is used to check whether the observed steps in the event log conform to a desired care process (see Fig. 13.6). In case there are deviations between the desired situation and the event log, these are identified such that they can be further analyzed. In the Analyze phase of the DMAIC cycle, one might check to what extent processes comply with internal and external guidelines. For example, for certain patient groups, standards may exist in the form of clinical practice guidelines or protocols that can be translated to process models to be adhered to. By making use of process mining, deviations from guidelines and protocols can subsequently be identified and quantified, after which the desirability of deviations can be discussed. As part of the Improvement phase of the DMAIC cycle, process improvements are generated implemented based on the results of the Analyze phase leading to a new care process (model) to be adhered to [15]. Subsequently, process mining can be used once again during the Control phase. Then, healthcare professionals or managers can check adherence to this new care process (model) and identify deviations.

Enhancement This type of process mining extracts additional information from the log and enriches a process model with additional perspectives (times, costs,, resource usage, etc.). These enhancements facilitate a more in-depth measurement/monitoring of the process (e.g. monitoring throughput times) during the Measure and Control phase in the DMAIC cycle. For example, average throughput times between the different steps might be automatically projected on the process model, as illustrated in Fig. 13.8.

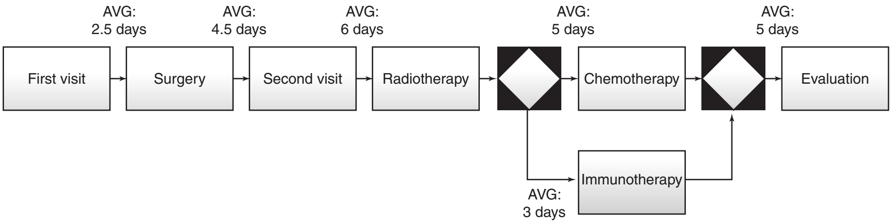

Fig. 13.8 Care process enriched with throughput times based on time-related logs in Fig. 13.6

13.5 Sociotechnical Systems & Leadership

As mentioned earlier, Operational Excellence also entails, besides process optimization, a sociotechnical systems approach (STS). The before-mentioned methods of improving processes are very powerful, but with more complex care processes that are very unpredictable or that need a higher level of coordination because several different professionals are involved, Operational Excellence relies on STS. Below, we will also briefly discuss the role of leadership in optimizing care processes with Operational Excellence.

13.5.1 Sociotechnical Systems

Sociotechnical systems, also called socio-technique, offers tools for analyzing which tasks within a care process should be performed by which people. Where processes are unpredictable, the capabilities and flexibility of people are needed, socio-technique can help in defining these decisions and functions. Karasek's Job Demand Control Model (Fig. 13.9) is one of these tools that can help to define jobs and tasks in a care process [16].

The higher the variability of a care process, the more flexible and autonomous the employee should be. Low flexibility means reduced decision-making autonomy. Passive jobs, where there not much variability can be performed by employees without a lot of flexibility and therefore more standardization and efficiency (Lean Six Sigma optimized processes). Active jobs, in the upper right quadrant, have high demands but also high levels of control. These challenging jobs lead to active learning and motivation to develop new behavior patterns. High strain jobs, in the lower right quadrant, have high demands and low control. These jobs have a high risk of psychological strain and physical illness. Low Strain jobs can lead to waste of human resources. Defining which tasks in care processes should be performed by which people is therefore essential to be ensure that the process is able to cope with the uncertainty of demand.

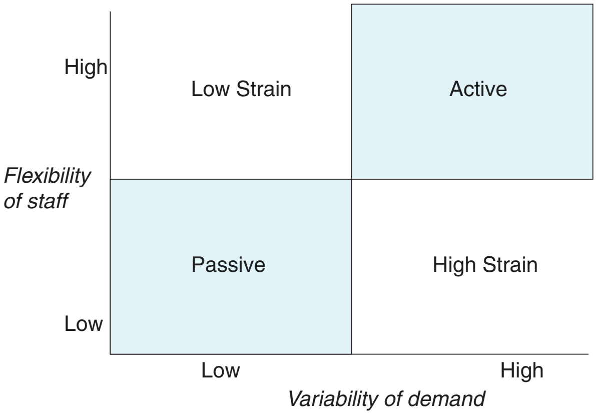

Fig. 13.9 Job Demand Control Model adapted from Karasek [16]

13.5.2 Leadership

Lastly, Operational Excellence requires a specific type of environment where people want to experiment and try to improve the processes. To create such an environment, leadership is needed. In times of change, such as in healthcare system transformations or even in small-scale process improvements, this is especially important. Research found that leaders use six styles: commanding, visionary, affiliative, democratic, pacesetting and coaching [17]. The one that fits best for Operational Excellence is the *coaching style¸* which is defined by a leader who develops people for the future and most importantly motivates employees to experiment. By encouraging employees to experiment, more DMAIC projects will be started and employees are not afraid to fail. The leader should be constantly stimulating their employees, helping them improve performance, and develop long-term strengths.

13.6 Conclusion

In conclusion, Operational Excellence can help healthcare professionals and managers in transforming healthcare organizations towards processes that create more value for patients. Besides process optimization methods, Operational Excellence also involves sociotechnical systems and is most successful with a leader who has a coaching leadership style. Understanding the type of care process and organization where Operational Excellence is implemented is important in order to choose the right approach. Data is an essential part in the DMAIC cycle, which is central in Operational Excellence. Process mining can help in this improvement cycle by gaining insights into how care processes are actually performing and controlling processes after an improvement has been implemented.

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