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## **Economy of Scale and Scope in Healthcare Operations: Lessons from Surgical Services**

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## **Abstract**

Literature concerning the economy of scale and scope in healthcare is often confusing. To assuage the issue of confusion, we present a theoretical framework regarding the concepts often covered in healthcare. We illustrate how proper understanding of healthcare topics can improve productivity over 30 percent. In conclusion, effects of the scale and scope depend on the definitions being used and production context.

## **1. Background**

Theories of the economies of scale and scope have been used to explain the outcome and efficiency in production systems. Specifically, economy of scale states that unit cost decreases as the volume of output increases (Gaynor et al. 2005). The connection has been explained by several mechanisms, including effects of volume on fixed costs, specialization of resources, and market positions toward suppliers (Given 1996). On the other hand, economy of scope is typically linked to the phenomenon in which unit cost decreases when the output increases (Given 1996; Preyra and Pink 2006). Cost complementary effect and scale effect are the explained mechanisms behind the scope effect (Preyra and Pink 2006). The cost complementary means that once the inputs have been used for producing one good they become available, at no additional cost, for use in the production of other goods (Nehring and Puppe 1999). The scale effect in that connection refers to the situation where it is profitable to produce different outputs in a one large unit instead of in several specialized production units.

As the scale and scope effects are more or less interwoven, the connection between the theories and the operationalization of the concepts becomes more complex when they are applied in the

context of healthcare. The scale effect is understood quite straightforwardly in healthcare, and study results support the existence of the phenomenon (e.g., Lavernia et al. 1995, Kreder et al. 1997, Katz et al. 2004), but when speaking about the scope effect the literature is more confusing. The first question arises about the different definitions for output. Studies that investigate the relationship between scope and performance operationalize different outputs based on services, mix of used resources (Preyra and Pink 2006), medical discipline or even based on payer (Given 1996). It is obvious that the mechanism of the effect depends on the definitions being used and therefore the existence of the scope effect cannot be generalized based on individual studies.

In this study we present a theoretical framework concerning the economy of scale and scope concepts in healthcare operations. Based on this framework we illustrate the use of the concepts in vascular surgical services.

## **2. Economy of scale in healthcare operations**

In the context of healthcare, economy of scale means that volume per given procedure is connected to better outcomes. However, there has been debate about the share of the impact of different mechanisms on the scale and also whether a better outcome might precede high volume, and therefore lead to selective referral. Current research supports the argument that volume still has remarkable impact and that it is the actual volume that matters more than the cumulative volume of previous years (Gaynor et al. 2005). The result means that the effect of volume on fixed costs dominates the effect of the learning curve, which is more a matter of history.

When the outcome of the operations is measured by clinical metrics, it is also possible that high outcome incurs first, which in turn leads to higher volume due to selected referrals. However, the latest studies have found that the direction of causation largely runs from volume to outcome (Gaynor et al., 2005; Gowrisankaran et al. 2004). When the direction of causation runs from clinical quality to volume, we are actually speaking about economy of quality, which means that high quality leads to high operative efficiency due to higher demand but also potentially due to lower direct costs of quality errors.

The third mechanism of the economy of scale refers to a market power position toward suppliers. This means that “larger firms may be able to negotiate lower prices with their suppliers, based on market power, the promise of a continued, long-term business relationship, and actual lower per-unit costs of inputs” (Given 1996). In the context of healthcare, this is especially relevant in services that use a lot of instruments and material or other resources that have to be purchased; surgical procedures are examples of such services. Conversely, it is also possible that small or medium-sized service units and companies use a separate combined purchasing organization that is large enough to purchase materials and resources at an affordable price.

A summary of the mechanisms of the scale effect, along with explanations and criticisms are presented in Table 1. The effect of the volume on fixed costs can be complex in situations where technical minimum quantity of purchased additional fixed resource is too large to be satisfied by available demand. For example, purchasing another X-ray machine or hiring a second specialist when actual demand is less than required for high utilization, is an example of such situations. The positive scale effect might still exist but the relation is wavy instead of an increasing function.

**Table 1 The mechanisms of the economy of scale: Explanations and criticism**

Mechanism	Explanation	Criticism
Volume on fixed costs	High volume decreases the fixed cost per produced service.	Technical minimum quantity of fixed resource might hinder the scale effect (e.g. purchasing another X-ray machine or hiring second specialist).
Specialization of resources	Higher volume enables specialization of resources, which leads to higher quality and lower use of resources.	Learning-by-doing effect is a personal phenomenon, and not necessarily connected to a volume at a production unit level.
Market power toward suppliers	Large organizations are able to negotiate lower prices with their suppliers.	Purchasing can be separated from production units to large organizations, meaning that small production units can benefit market power.

The specialization of resources can be criticized due to the confusion factor and unit level phenomena. This means that the somewhat high volume of healthcare operations is necessary for the specialization of resources but is not sufficient if the specialization does not happen at the employee level. In a highly professional unit, such as a multidisciplinary teamed surgery, the input of each member increases the learning curve as well. Similarly, high volume is a sufficient condition for market power but not necessary because purchasing can be separated from production. In summary, we argue that in order to utilize the scale effect in healthcare operations management, the mechanisms of a given phenomenon have to be understood profoundly and applied correctly in practical situations.

### **3. Economy of scope in healthcare operations**

Whereas the current debate around the economy of scale is mainly related to the mechanism of the effect, the discussion about the economy of scope relates more to definitions, approaches, and the role of theory in healthcare.

Economy of scope is typically linked to the phenomenon in which unit cost decreases when the number of different outputs increase (Given 1996; Preyra and Pink 2006). The first question arises about the definition of different output. In healthcare literature, definitions of output vary greatly. Given (1996) defines the output of health maintenance organizations (HMO) as different customer markets: commercial, Medicare, and Medicaid. This division is made based on the payer system and does not reflect the operative output or medical services provided to individual customers.

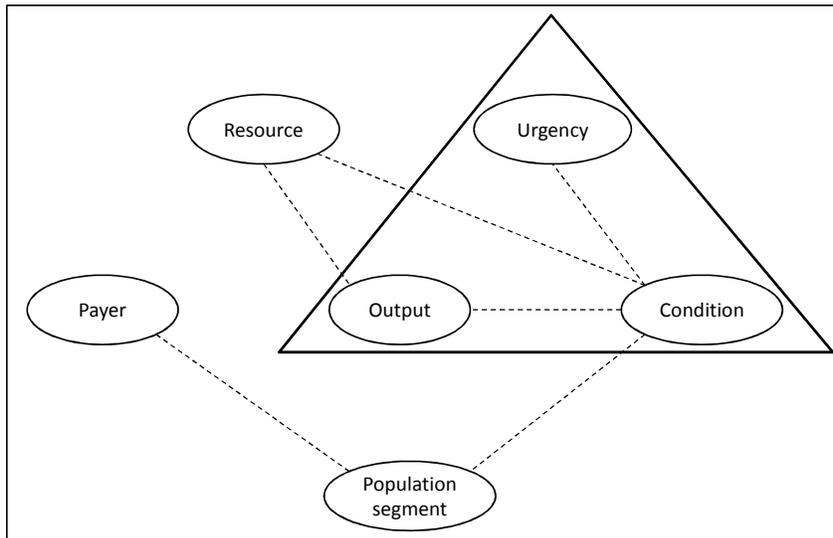
It has also been common practice to define the economy of scope based on a number of specialties working in the same unit of a hospital. Weil (2002) found diseconomies of scale in multi-specialty practices with more than 50 doctors for several reasons: 1) they deliver care on multi-sites, 2) experience a higher percentage of managed care patients, and 3) are less effective in controlling their peers' use of time and resources. Rosenman and Friesner (2004) compare the efficiency of single specialty and multispecialty group medical practices, and provide evidence that multispecialty practices are less efficient. They interpret scope efficiencies or inefficiencies from the use of divergent types of physicians as inputs into the production of health services, and test to see if practices that use a combination of specialist and family practice physicians are more or less efficient in producing a given amount of health care services than practices using

only one type of physician. However, their study has some problems in analyzing different case-mixes, which is an important factor when comparing different units.

Based on the work of Preyra and Pink (2006), it has become common in the multiproduct hospital cost literature to separate outputs by type of acute service, typically medical, surgical, obstetric and pediatric, and to sometimes append a case mix term to control for patient complexity and severity. The division of output is more often made based on the used inputs, using four output categories: primary/secondary inpatient care, tertiary inpatient care, ambulatory visits, and sub-acute days (chronic, long term or rehabilitation). This is a problematic simplification as groups are seldom truly comparable. Thus, the case mix has to be controlled. In a clinical series we may want to use statistical approaches like propensity score analysis to control the bias caused by case mix.

In summary, used definitions and approaches to scope in healthcare can be illustrated by several concepts that are related to each other (Figure 1). Service-related patient *condition*, *urgency* of the situation and *output* of the produced service form the basis for a core concept of the scope in healthcare. Other concepts, such as *payer*, *population segment* and *resource*, are market or organization-based restrictions that either reflect or predefine the scope of a given healthcare operation. Payer scope restricts operations to certain population segments, such as working-age people or retirees. Population segment, on the other hand, is connected to medical conditions, which is most obvious in children or women segments of the population. Condition, itself, is highly correlated to urgency and provided service, or output. Resources refer to different personnel groups, such as nurses, GPs and specialists, and they reflect or define what kind of outputs can be provided to certain conditions. From the strategic perspective, it is relevant how

the healthcare organization defines the scope of its operations. For example, what is the role of payer and population segments of the strategic focus of an operation?



**Figure 1 Approaches to the scope in healthcare operations**

Cost complementary effect and scale effect are the explained mechanisms behind the scope effect (Preyra and Pink 2006). The cost complementary effect means that once the inputs have been used for producing one good, they become available, free of cost, for use in the production of other goods (Nehring and Puppe 1999). Shared common inputs can be used to produce several outputs. The production line of cars is an example of an input that can be utilized in producing several different car models. Based on the scarce examples of the existence of the scope effect, the phenomenon is mostly joined to the shared use of overhead, R&D or other fixed costs instead of variable costs related to actual production. Strictly speaking, this bears a close approximation to scale effect, but on a more general level: Large fixed input is utilized in several outputs, regardless of whether those outputs are similar or different from each other.

When analyzing the scope effect of producing different outputs in the same production unit, the essential questions concern whether there are inputs that, when first used in the production of one type of output, are no longer able to be utilized in the production of that output, but are useful for some other outputs. That kind of utilization of used resources is typical in a processing industry, such as in the pulp and paper industry, where it is useful to produce energy from lye, which is the waste of the pulp process.

In healthcare operations the complementary effect is not so typical due to high personnel intensity and low use of materials. However, capacity utilization is an essential question in healthcare, and because we are speaking about service operations where fixed personnel costs are high and capacity is perishable, managing capacity utilization by diversifying the scope of operations might play an important role in increasing efficiency. Here we present three illustrations where diversifying the scope increases capacity utilization:

1. *Task type diversification:* Laboratory nurses can take samples only in the morning, because it is the only time when patients have not eaten in several hours. During afternoons, nurses have other tasks, such as sample testing, which increases their capacity utilization rate.
2. *Procedure length diversification:* Surgical operating room (OR) team is involved in heart surgery, which takes from five to six hours. The team cannot operate on another heart patient during the regular 8-hour day. Therefore, after one heart operation they conduct a shorter procedure, which increases their capacity utilization rate.
3. *Patient urgency diversification:* Doctor examines patients, by appointment, at an outpatient department. When there is patient no-show or the doctor is ahead of schedule, he or she is allowed to receive acute patients that are waiting for examination.

Although the cases presented above are more or less connected to the tight capacity management policy, they are still very common and practical ways to utilize the economy of scope in a real-life context. Diversification in task type, procedure length or patient urgency typically also means that the output and produced service range is diversified.

## 4. Illustrating the use of the concepts in surgical services

### 4.1 Case description

The study was conducted in the Department of Vascular Surgery at Helsinki and Uusimaa Central Hospital (HUCH) in Finland. The department is responsible for vascular surgery patients in the area of 1,532,000 inhabitants in Southern Finland. Surgical operations are performed in two hospitals (Jorvi and Meilahti) with an annual volume of 2,550 surgeries. Meilahti clinic is further divided into two units (wards) with dedicated surgeons and OR sessions; 35.6% of vascular surgeries are urgent, meaning that the patient has to be operated on in less than 48 hours after ED admission. In addition, 25.4% of the surgeries are ambulatory and performed in a separated ambulatory operating unit at Jorvi hospital. The rest, 39% of the cases, are non-acute surgeries for patients that need in-hospital care after operation.

**Table 2 Vascular surgery volumes of the case hospitals during Jan - Jul 2010**

	Meilahti	Jorvi	In total
Emergency 0-8 h	162	13	175
Urgent 8-24 h	142	24	166
Urgent 24-48 h	77	37	114
Elective in-hospital	256	233	489
Elective ambulatory	0	325	325
In total	637	632	1269

The aim of the department was to develop practical methods to improve efficiency of OR personnel (surgeons, anesthesiologists, and nurses) by utilizing the concepts of scale and scope without violating the standards of treatment. Optimizing surgery scale and scope both in terms of the individual surgeon and at the clinic level were used as practical methods to achieve higher efficiency.

## **4.2 Materials and method**

In the area of the economy of scale and scope, three managerial scenarios were modeled and analyzed at the case hospital. The scenarios were conducted based on the theoretical statements presented in the literature section. Finally, the results of the three scenarios were summarized and discussed in a wider context.

### *A. Utilizing scope effect by reallocating surgeons to surgery types:*

Since learning-by-doing is mainly a personal phenomenon and, in the case of vascular surgeries, the volume per surgery type is more essential than the total volume, our hypothesis was that efficiency can be improved by allocating surgeons to surgical operations based on their speed and medical quality per surgery type (Kantonen et al. 1998a; Kantonen et al. 1998b). In this context, we suppose that diseconomy of scope exists at the individual surgeon level. The analysis concerning the reallocation was conducted based on the data gathered from 4,134 operations that were performed at Meilahti hospital between January 2006 and July 2010.

Aortic aneurysm surgery, carotid surgery and infrainguinal bypass surgery were used as index procedures. Operative mortality rates of 5% and 50% after AAA (abdominal aortic

aneurysm, not ruptured) and RAAA (ruptured abdominal aortic aneurysm) surgery, combined mortality and morbidity rate of 6% and 3% after CEA (carotid endarterectomy) for symptomatic and asymptomatic carotid stenosis and morbidity of 5% after infrainguinal bypass surgery was considered acceptable operative standards. Operators with occasional activity were excluded. Reallocation of surgeons to operate index surgical operations was performed so that there were at least three surgeons performing each surgery type, and maximum time for one surgeon to work in OR is two days per week.

*B. Utilizing scale effect by combining OR sessions of two units:*

At the operating unit and OR level, it was suggested that the scale effect exists. The production volume of two ward units is useful to combine into one scheduling queue in order to level daily and weekly variations, and to confirm that suitable patients can be found to fulfill OR sessions.

Models to reschedule vascular surgeries of the two ward units were developed and tested using a six month retrospective simulation. The data consisted of 245 elective patients operated on at Meilahti hospital during the first half of 2010. In the first phase, vascular surgical operations were categorized to hourly-based classes based on their average OR time. The Nomesco classification system with five characters was used to specify different surgeries. In the second phase, allowed combinations of surgery categories were defined to fulfill 8 or 10-hours of OR block time. Three different scenarios were formulated based on the OR session length and whether the tight or loose case combinations were allowed.

In the testing process, surgical operations were first ordered based on their last valid operating day. The valid operating day depends on the acceptable waiting time for each of the indications for each surgical operation. After that, the OR sessions were fulfilled, taking the first surgery from the queue and scheduling it to the first open slot in the open ORs. The scenarios were evaluated based on the following three measures: 1) sufficiency of capacity, 2) OR utilization rate (mean and median), and 3) share of overtime days.

*C. Utilizing scale and scope effect by combining operations of two hospitals:*

At the hospital level, it was hypothesized that combining the production of two hospitals affects both scale and scope. The effect on scope was assumed to exist due to procedure length diversification, which has its origin in different case mixes between the hospitals. We investigated centralized and decentralized production models for vascular surgery in order to find the best models to improve efficiency, especially in the use of OR capacity, without violating the standards of treatment. Models used to reorganize vascular surgery production within the region were developed and tested by a six-month retrospective simulation. The data consisted of 954 vascular surgical operations performed in Meilahti and Jorvi hospitals during the first half of 2010.

## 5. Results

### 5.1 Utilizing scope effect by reallocating surgeons to surgery types

During the data period 990 infrainguinal, 363 aortic aneurysm and 744 carotid operations were performed by 21 surgeons (Table 3). Those surgical operations comprised about half of all vascular operations.

**Table 3 Vascular surgery volumes in Meilahti hospital during Jan 2006 - Jul 2010**

Surgery type	2006	2007	2008	2009	2010	In total
Infrainguinal bypass surgery	248	209	212	216	105	990
Aortic aneurysm surgery	63	87	91	90	32	363
Carotid surgery	134	135	168	215	92	744
Other vascular surgeries	477	457	450	530	303	2217
In total	922	888	921	1051	532	4314

Surgeons' relative speed in terms of the indexed surgeries are presented in Table 4. Four of the surgeons (S1, S5, S8, and S9) were accepted for further analysis so, in total, there were three surgeons performing each surgery type (as shown in gray background in Table 4). Index surgeries were allocated to those four surgeons, taking into account the demand of each type and maximum OR time per surgeon (Table 5). In summary, operating time used for the surgeries could be decreased from 1,341 hours to 1,090 h, per year. This means an 18.8% savings in the use of surgeon and other OR personnel resources. The reallocation also makes it possible to maintain diversity in case combinations of daily OR sessions.

**Table 4 Relative speed of the surgeons with the highest volume of vascular surgeries (elective and emergency)**

Surgeon	S1	S2	S3	S4	S5	S6	S7	S8	S9
N	171	160	137	136	134	118	115	94	90
Infrainguinal bypass surgery	-22,0 %	3,8 %	6,3 %	-3,9 %	8,2 %	0,3 %	20,6 %	-27,1 %	-19,5 %
Aortic aneurysm surgery	-4,0 %	7,3 %	12,8 %	1,6 %	-15,9 %	-3,2 %	-1,6 %	-22,1 %	1,9 %
Carotid surgery	-10,0 %	-4,6 %	2,6 %	19,0 %	-8,7 %	-3,2 %	22,7 %	-16,6 %	3,1 %

**Table 5 Results of the reallocation: number of surgeries allocated to selected surgeons and share of those surgery types of their total OR time capacity**

Surgeon	S1	S5	S8	S9
Infrainguinal bypass surgery	60		93	60
Aortic aneurysm surgery	10	55	20	
Carotid surgery	86	80	24	
Share of surgeon's OR capacity	100 %	89 %	100 %	51 %

The study shows that total productivity of surgical services can be radically improved by supporting more specialization among surgeons within specialties. Current management principles in surgical services are too democratic and not affected by natural variation of personnel capabilities and actual demand of services.

## 5.2 Utilizing scale effect by combining OR sessions of two units

Based on the duration-based classification, surgeries with average OR time between 2-3 hours (category 3) and 4-5 hours (category 5) had the highest volumes. The next three OR scheduling scenarios were tested by retrospective empirical simulation:

- 1. 6x8 h:** Weekly capacity of six, 8-hour OR sessions. Allowing daily schedules of combinations 3+3+3, 3+5, 4+4 and 6+ from the duration categories.

2. **4x10 h and 1x8 h: (tight)** Weekly capacity of four, 10-hour and one 8-hour OR session.  
Allowing daily schedules of combinations 6+4, 5+5, 4+3+3 (10 hour sessions), and 3+5, 4+4 (8 hour sessions) from the duration categories.
3. **4x10 h and 1x8 h: (loose)** Weekly capacity of four, 10-hour and one 8-hour OR sessions.  
Allowing daily schedules of combinations 6+3, 5+4, 3+3+3 (10 hour sessions), and 3+4 (8 hour sessions) from the duration categories.

The summary of the simulation results are presented in Table 6. The first two scenarios led evenly to slight overcapacity, but at the same time to unrealistically high utilization rates and high shares of overtime days. Loose scheduling with four 10-hour sessions showed some undercapacity, but also led to more realistic utilization rates and less overtime use.

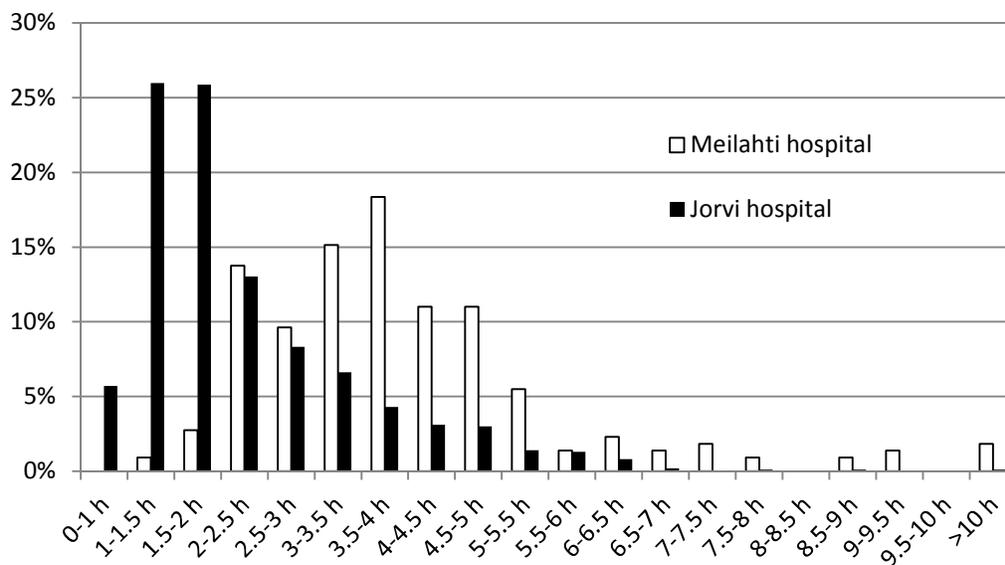
**Table 6 Results of the analyzed OR scheduling scenarios (n=123 days and 245 surgical operations)**

Weekly schedule	6x8 h	4x10 h + 1x8 h (tight)	4x10 h + 1x8 h (loose)
Over- (+) / Undercapacity (-)	+2,1%	+4,6%	-4,6%
OR raw utilization rate			
Mean	94 %	97 %	83 %
Median	92 %	94 %	81 %
Share of overtime days	27 %	41 %	12 %

All the three scenarios had total weekly OR capacity of 48 hours. By taking into account the slight undercapacity of the most realistic scenario, Scenario 3, 50 hours weekly capacity would be sufficient to fulfill the demand of vascular surgeries. This means a 10.7% resource savings when compared to the current 56 hours weekly capacity of two separated ward units (7 x 8 hours).

### 5.3 Utilizing scale and scope effect by combining operations of two hospital

The deeper analysis of the vascular surgeries at Meilahti and Jorvi hospitals showed that Jorvi focused more on short surgical operations, whereas longer and more complicated procedures were concentrated at Meilahti (Figure 2). Some of Jorvi's patients were re-operated on at Meilahti and vice versa, meaning that combining the operations of two hospitals would also simplify patient processes.



**Figure 2 Distribution of the OR times of two hospitals (n=954 surgical operations)**

In the combined operations, all elective non-ambulatory vascular surgery patients were rescheduled to 8- and 10-hour OR sessions in one OR unit. In the optimal model, based on the retrospective scheduling simulation, weekly capacity consisted of on average 7.5 8-hour OR sessions and 2.5 10-hour OR sessions. This policy led to 83.6 % OR utilization rate. In the current operations, the total OR capacity of the two hospitals was 96 hours (12 x 8 hours). The savings achieved by the combined operations was 10.8%.

In summary of the three analyzed scenarios, applying the economy of scale and scope in vascular surgery operations could lead to 35.3% total savings in personnel costs of OR sessions. Some practical issues have to be considered when estimating the real-life benefits. First, demanding vascular surgery is centralized into university hospitals. University hospitals have a teaching function, including that of vascular surgeons. The vascular surgical staff must be capable to take care of a 24-h vascular emergency call, which necessitates a certain professional standard for all. High specialization of personnel may threaten this standard. Secondly, in real life the case-mix is changing as a function of time and development of new technologies. Therefore, continuous systematic follow-up of the management decisions and reacting to them allows for the optimal use of operation units.

## **6. Discussion and conclusions**

This study developed the framework of the concepts of economy of scale and scope in healthcare operations and illustrated how understanding these concepts properly can improve productivity in surgical services.

In the area of economy of scale, the developed framework separates the mechanisms behind the concept and criticizes some explanations by posing issues that have to be understood when applying the concept in healthcare operations. Technical minimum quantity of fixed resources and the existence of learning-by-doing phenomenon at the personal level are examples of such criticisms. Based on the case study, economy of scale exists mainly due to more even demand, which eases case scheduling and queue management of acute and sub-acute services. However, when comparing the results to previous literature (e.g. Weil 2002), it seems that economy of

scale exists to certain volume, but after that the complexities of coordinating multi-sites and individuals hinder the benefit.

At the individual level, our case study showed that organizations and production units might be too democratic to allocate tasks and procedures based on individual strengths and weaknesses. It seems that performance of individuals differs a lot in healthcare, but that difference has not been fully utilized, especially in production units with salaried personnel. Specialization of surgeons and other personnel has increased during the last years, but this increase is due to education and training rather than performance. There is a lot of potential to using a selective approach to the economy of scale concept at the individual employee level.

From the scope perspective, specialization of individuals means that there exists diseconomies of scope in healthcare operations. However, from the capacity management point of view, it seems reasonable to maintain some variety in individuals' task repertoire in order to fulfill the reserved capacity by tasks with different length and urgency. This is the area where scale and scope are connected: Also in healthcare, large organizations with plenty of resources enables more specialized individuals.

The study shows that tight capacity management rules decrease performance in personnel intensive healthcare services. The operating room is an example of a production unit where 8-hour sessions are not optimal from a capacity management perspective. Similar problems can be found in outpatient clinics and other hospital units. Widening the scope of outputs might enable a higher capacity utilization rate and more productive operations. However, the policy has to be matched with individuals' repertoire. Therefore, there might also exist economy of scope only to

a certain magnitude, and after that the disadvantages of unspecialized operations dominate the marginal utility to widen the scope further.

This study highlights some problems that exist in current literature about economy of scale and scope in healthcare operations, and presents practical examples of the application of concepts in real-life contexts. Despite the methodological shortages and weak generalizability of the case findings, it can be emphasized that utilization of the concepts is an optimization problem where the contradictory effects of scale and scope have to be understood and analyzed carefully. In further research, it is recommended that the framework be developed more cohesively and that the scale and scope theories be tested with a large data set of different healthcare operations.

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