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Production flow analysis: A tool for designing a lean hospital

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Abstract

Production flow analysis (PFA) was used in the planning process for a new acute care hospital. The PFA demonstrated that functional organisation – for example, with centralised medical imaging – generates a lot of back and forth patient transfers between functional units. This to-and-fro patient flow increases lead times of care processes and also exposes the patients to unnecessary complications. PFA produced an ideal patient flow model and layout model for the acute care hospital. Thus, PFA revealed information for use in proximity ranking of different units of the hospital; the planning team then decided which units should be placed next to each other.

Medical imaging should be essentially ubiquitous, to achieve simple, high-velocity patient flow. Thus, a modern decentralized layout model for medical imaging was planned. Furthermore, PFA enables optimizing transfer routes for patients and also, e.g., lift capacity in the hospital.

Experts agree on the need for a widespread system redesign in health care. An ageing population, among other things, will present hospitals with a new productivity challenge. System-engineering tools have demonstrated significant potential for health care development and modern research techniques are required for the planning of hospitals for the future.

Organisational barriers play an important role that restricts the implementation of new designs in hospitals. Within a hospital, individual departments are usually isolated and behave like functional “silos”. Because of this, hospitals are typically based on functional organisations. Process organisation and process-focused organisation are both actual synonyms for functional organisation. With such a set-up, units specialise in their own particular processes and facilities with similar functions are grouped together. Traditionally hospitals' functional layouts support this concept. Laboratories, medical imaging, operating theatre units, and intensive care units, as well as wards are examples of functional layout solutions. The disadvantages of functional organisation are long throughput times, poor overall process control, complex patient flows, and long transfer distances. Many UK hospitals transfer patients from one unit to another via lengthy and complex routes. Scheduling and the achievement of fluent patient flow is difficult in such hospitals.

In product organisation or cellular manufacturing, widely used in modern industry, production cells or lines complete products, as they have all the facilities they need to do so. The product of a hospital is a treated patient – not an

<table>
<thead>
<tr>
<th>Code</th>
<th>Process</th>
</tr>
</thead>
<tbody>
<tr>
<td>D</td>
<td>Stroke unit</td>
</tr>
<tr>
<td>E</td>
<td>Intensified monitoring</td>
</tr>
<tr>
<td>I</td>
<td>Invasive cardiology</td>
</tr>
<tr>
<td>K</td>
<td>Home</td>
</tr>
<tr>
<td>M</td>
<td>Intensive care unit</td>
</tr>
<tr>
<td>N</td>
<td>Cardiac care unit</td>
</tr>
<tr>
<td>P</td>
<td>Emergency</td>
</tr>
<tr>
<td>Q</td>
<td>Neurology ward</td>
</tr>
<tr>
<td>R</td>
<td>Radiology</td>
</tr>
<tr>
<td>T</td>
<td>Monitoring</td>
</tr>
<tr>
<td>U</td>
<td>Ultrasound examination</td>
</tr>
</tbody>
</table>

Table 1: The process codes for neurology
Number of patients

<table>
<thead>
<tr>
<th>PRN</th>
<th>Number of patients</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>KPRPDK</td>
</tr>
<tr>
<td>2</td>
<td>KPK</td>
</tr>
<tr>
<td>3</td>
<td>KPRPEQ</td>
</tr>
<tr>
<td>4</td>
<td>KPRPJDUDQK</td>
</tr>
<tr>
<td>5</td>
<td>KPRPK</td>
</tr>
<tr>
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<td>KPRPTDK</td>
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<tr>
<td>7</td>
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<tr>
<td>8</td>
<td>KPRPJDUDQK</td>
</tr>
<tr>
<td>9</td>
<td>KPTK</td>
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<tr>
<td>10</td>
<td>KPRPJDUDQK</td>
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<tr>
<td>11</td>
<td>KPRPMDQK</td>
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<td>14</td>
<td>KPRPJDUDQK</td>
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</tr>
<tr>
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<td>KPRPJDUDQK</td>
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<td>19</td>
<td>KPRPJDUDQK</td>
</tr>
<tr>
<td>20</td>
<td>KPRPJDUDQK</td>
</tr>
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</table>

Table 2: PRC frequency chart of neurology patient flow in 2011. Total number of neurology patients per year is 6,000. For instance, 1,200 patients per year go through the process route of home-emergency-radioology-emergency-neurology ward-front; therefore, the process route code is KPRPDK.

individual operation or examination. In hospitals, product organisation means that all staff and appliances used in the treatment of illness are grouped together as a multi-professional group that completes patient’s care. Therefore, product organisation supports patient- and treatment-focused health care. The well known benefits of product organisation include quicker throughput times, better quality, smaller inventories, and smaller inventory-carrying costs, in addition to better controllability of overall processes. In the UK, the National Health Service accentuates the elimination of unnecessary patient transfers and a reduced risk of delay while transferring the patient to another phase of care as benefits of the product-based layout in high volume patient care.

The objective of this paper is to demonstrate how production flow analysis can be applied to analyse and simplify patient flow systems to help in the planning of a new, acute hospital. PFA is a pragmatic technique that has been used to plan a change from functional organisation to product organisation in industry. Burbidge also defines PFA as a technique for planning the simplification of the material flow systems for factories. In this paper, we have used care-line organisation as a synonym for product organisation. The terms of product organisation are based on an industrial frame of reference. The terms of care-line organisation better illustrate this organisation model from a health care viewpoint.

Case study: Turku University Hospital (T-Hospital)

PFA was used in a study of the patient flows between different units of a new, acute care hospital; the T-Hospital in Turku, Finland. The hospital will be completed in 2011. Our target was to study and simplify patient flow in the hospital by PFA in order to achieve the advantages of care-line organisation. Currently, the hospital is functionally organised.

The patient flows were analysed together with the key personnel of the five main care-lines (cardiology, traumatology, neurology, surgery, and other medical (non-surgical) treatment). All patient flow data is based on the care-lines’ evaluations of increases in patient volumes between now and the year 2011. Following this, emergency, radiology, laboratory, intensive care, operating theatre units, and maintenance gave their comments on the route data. PFA’s subtechnique, factory flow analysis, was adapted into the steps of the project. The patient flow of each main care-line was analysed by the following steps:

A. Analysis:
1. Code processes in the care-line identified with a code letter (Table 1).
2. Finding process route codes (PRC) for all patients.
3. Printing out the PRC frequency chart (Table 2).
4. Calculating the numbers of patients’ transfers between processes and printing out the from/to chart (Table 3).
5. Drawing a patient flow network for 2011, based on functional organisation (Figure 1).
6. Drawing a primary patient flow network for 2011, based on functional organisation (Figure 1).
MANAGEMENT: PRODUCTION FLOW ANALYSIS

I. BACKGROUND

Production flow analysis (PFA) is a tool for acute hospital layout planning, where high velocity patient flow is a critical goal. This type of analysis supports such planning by indicating with good precision the location of patient care activities and the layout of hospital units.

II. METHODS

PFA is based on the Pareto principle, in which 20% of the processes cover 80% of the care line's patients. The primary flows are based on the neurology care line, which was selected as a case study. The patient care line (PCL) is divided into several primary care lines (PCLs), and each PCL is further divided into several process routes (PRs).

B. SYNTHESIS

7. Drawing a streamlined primary patient flow network in 2011, based on a care-line organisation (Figure 2b).

The Figures 1 and 2a represent neurology patient flows in functional organisation. The patient flow system network (Figure 1) covers all the neurology patients who use 20 different process routes (Table 2). However, patient flows are concentrated in a few process routes which compose a primary patient flow. Figure 2a represents neurology's primary patient flow in which 80% of the patients use the seven most important process routes (PRNs 1-7 in Table 2). Back-flows between radiology and emergency, radiology and the stroke unit, plus ultrasound examinations and the stroke unit reduce efficiency and risk patient safety. The targets are to eliminate the back-flows and place the primary flow's units next to each other or join some of the units together.

The streamlined patient flow model in care-line organisation is presented in Figure 2b. The streamlined patient flow model would reduce neurology's patient transfers between departments by nearly 70% (from 23,300 transfers to 7,300). The streamlined patient flow requires the elimination of the back-flows (Figure 2a) by the decentralisation of ultrasound examination and other medical imaging. Thus, the emergency unit has its own radiological functions (Rad1); the unnecessary boundary between emergency and radiology can be eliminated. Similarly, the stroke unit has its own ultrasound functions, and the CT imaging/MRI (Rad2) are placed immediately next to the stroke unit. Streamlined flow can be largely implemented. When the streamlined flow (Figure 2b) is compared with today's flow (Figure 2a), the streamlined flow provides the following benefits for acute neurological patients:

- Quality of care can be improved because patients' unnecessary and potentially risky transfers are reduced.
- Direct personnel cost savings because much fewer personnel are needed for patient transfers between the stroke unit and radiology (ultrasonic, CT or MRI).
- Development of team work, when most of resources needed in the patient care are located close to each other. Better team work supports continuous care process improvement.
- Indirect cost savings. The following factors contribute to indirect cost savings:
  i. The delays and errors caused by transfers are eliminated.
  ii. Nurses spend their working time in the stroke unit and not transporting patients, their productivity can be increased.
  iii. Elimination of referrals between units — referral is not a value-adding activity.
  iv. The transfer appliance costs and lift load are reduced.

The four other main care-lines were analysed in the same way as acute neurology. Then all main care-lines' PRCs were summed up and the entire hospital's from/to chart for primary patient flow was printed out. The primary and streamlined patient flows of the main care-lines and the hospital's primary flows were essential information for the layout planning.

CONCLUSION

PFA is a substantial tool for acute hospital layout planning, where high velocity patient flow is a critical goal. This type of analysis supports such planning by indicating with good precision the location of patient care activities and the layout of hospital units.
certainty which functions should be placed next to each other. PFA challenges the prevailing practices of functional organisation and offers a starting point for streamlining the patient flow system. PFA illustrates the complex patient flow pattern in functional organisation.

A notable finding is the dominant position of medical imaging within all five of the main care-lanes' primary flow. Medical imaging has a central role at both ends of the care process; at the beginning in the emergency unit and at the end in the wards (e.g., neurology case, Figures 1-2). Medical imaging should be ubiquitous in an acute care hospital. This can be achieved by well thought-out decentralisation, which tends to centralise imaging facilities under the radiology function. In care-line organisation, the imaging facilities are located in close proximity to care-lines' needs. This can half transfer distances can be reduced by more than 50%. In the transfer process; at the beginning in the emergency unit and at the end in the wards (e.g., neurology case, Figures 1-2). Medical imaging should be ubiquitous in an acute care hospital. This can be achieved by well thought-out decentralisation, which tends to centralise imaging facilities under the radiology function. In care-line organisation, the imaging facilities are located in close proximity to care-lines' needs. This can half transfer distances can be reduced by more than 50%. In the

Figure 2b: Streamlined primary patient flow neurology in 2011, based on care-line organisation.

demonstration unit, Hendrich has showed the value of not transferring patients from unit to unit. Every time a patient is transferred, the patient comes into contact with another 25 or so caregivers. The benefits of care-line organisation are additionally supported by two findings: the patient transfers from unit to unit are a potential cause of quality deviations and they generate significant indirect costs. Hospitals' labour productivity and patient flow velocity should be increased. Current functional organisations tend to increasingly reduce the productivity because nobody is responsible for the entire patient flow management and patient transfer distances are long. In the future, increasing numbers of patients will need more health care personnel to transfer them via complex process routes. Functional layout generates unnecessary waiting times between departments and hospitals' corridors will be more likely to get blocked during peak hours.

Functional organisation prevents the use of the theory of constraint (TOC), a modern production control principle. TOC aims to maximise a bottleneck's utilisation as the bottleneck determines the throughput of the entire system. On the other hand, maximising non-bottlenecks' utilisation is useless. In functional organisation, each function tries to maximise its own utilisation, whether or not the function is the bottleneck of the patient flow. Therefore, functional organisation sub-optimises and generates unnecessary costs continuously. On the contrary, in care-line organisation, a patient flow manager could focus on bottleneck utilisation because he/she manages whole patient flow including intermediate support activities.

One of the biggest challenges to modernising acute hospitals is to implement the organisational change from functional organisation to care-line organisation. As a result of this change, the value-adding units in care production, such as emergency, operating theatre, medical imaging, intensive care, and so on, no longer behave like functional silos but rather support care-line organisation and so achieve high velocity patient flow, in addition to high quality care. Modern layout planning plus PFA will support this target of high velocity patient flow.

References