Logistics in the area of Virus diagnostics
– A lead time study of virus analyses at the Department of Clinical Microbiology, UMAS.

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This article is an abstract of a Master Thesis written at the Department of Industrial Management and Logistics at the Faculty of Engineering in Lund. The case study was performed at the Department of Clinical Microbiology at Malmö University Hospital, UMAS. The purpose of this study was to identify all contributing factors that enhance the response times of virus analyses and to suggest concrete measures aiming to improve present routines.

Introduction
At Clinical Microbiology at UMAS about 1500 samples arrive from southern parts of Sweden every day in order to be analyzed. Clinical Microbiology is divided into different departments according to types of analyses performed, for example bacteria analyses or virus analyses. The Master Thesis focused on the processes at the Department of Virus Detection, which performs eight major virus analyses and a few other tests.

Most of the analyses are specific in term of which type of virus to detect and consequently, the analysis batches are rather small. The medical development in the area of virus diagnostics has greatly improved in the last years and the response times have extensively been reduced. This fact increases the requirements of an efficient supply chain in order to completely exploit the medical and the technical improvements. Inadequate synchronization between factors, such as transportation schedule, operation times, analysis schedule and working hours, sometimes leads to unreasonable long response times. The management at the Department of Virus Detection had insufficient knowledge in how these factors contribute to longer response times and how they interact to create synergy effects. This led to the issues raised in the Master Thesis:

• Which factors contribute to longer response times? How do these factors interact and what are the resulting synergy effects?
• What concrete measures in the present organization can reduce the response times?
We have limited our work to consider internal processes at the Department of Virus Detection, i.e. from sample arrivals until printing and posting of analysis results are performed. Thus we did not examine present transportation routines. The processes of four virus analyses, with different medical and operational conditions, were profoundly examined. The limitation included the analysis of Herpes simplex virus (HSV), Calici virus, Cytomegalo virus (CMV) and Entero virus.

**Confirmation of applying logistics tools**

At an early stage, it was essential to confirm that general logistics tools and concepts can be applied to this problem. In Figure 1, an overview of the supply chain of Clinical Microbiology is shown.

The most important difference to a manufacturer is that Clinical Microbiology’s customers are suppliers as well as buyers of the analyses. Otherwise there are close similarities in terms of operations and functions. The most vital part of the study was the production unit, called Virus Detection in Figure 1. This unit has essential similarities to a conventional production chain, for example samples are stored in between machine operations in sample storages. Moreover, the analysis schedule functions as a conventional production schedule, determining when specific analyses should be performed. After the samples are processed to analysis results, the Department of Virus Detection is, like most manufacturers, responsible for distributing the analysis results to its customers. From this discussion, we could conclude that logistics tools and concepts, which are successfully applied by manufacturers, could be useful to this problem.

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**Figure 1.** Overview of the supply chain of Clinical Microbiology.¹

**Theoretical framework**

To reduce lead times no specific suggestions can be given. There are however assorted *general measures* that can be utilized according to practise.² In Table 1, a selection of these measures is presented along with brief explanations.

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¹ Inspired by Aronsson, Ekdahl & Oskarsson, Modern logistik – för ökad lönsamhet, s.20
² Aronsson, Ekdahl & Oskarsson, Modern logistik – för ökad lönsamhet, s.166
### Table 1. General measures to reduce lead times.

<table>
<thead>
<tr>
<th>Measure</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eliminate</td>
<td>Remove activities which do not add value to customers nor to the organization</td>
</tr>
<tr>
<td>Simplify</td>
<td>Simplify current processes to make them less complex</td>
</tr>
<tr>
<td>Integrate</td>
<td>Consolidate activities that create no additional value if they are performed separately</td>
</tr>
<tr>
<td>Parallelize</td>
<td>Perform independent processes parallel instead of sequential</td>
</tr>
<tr>
<td>Synchronize</td>
<td>Perform activities so that the passive time between them is reduced</td>
</tr>
</tbody>
</table>

#### Methodology

The Master Thesis was based on a mapping of processes, which we analyzed from a general perspective. The main process is not the sum of the sub-processes, thus an analytical approach would not be properly applicable. Since we studied how synergy effects influenced on the main process, we identified that a system approach was the most suitable to this problem.

The Master Thesis was conducted as a case study where the Department of Virus Detection was the object of study. Accordingly, it limited our possibility to generalize the results to other virus laboratories.

We mainly used primary data from the internal business system, observations, interviews and questionnaires. In compliance with the formulated problems, most of the collected data was quantitative to enable measures in the processes.

#### Approach model

To facilitate development and improvements of the logistics in an organization it is important to use a structured approach.\(^4\) Figure 2 illustrates the model we used in this project. Due to lack of time we decided not to perform the final two stages in the model.

In the initial phase we clarified the conditions. This included raising the issues and stating the limitations and target groups for the Master Thesis.

In the following phase, *Describe current situation*, we collected data to enhance our understanding of the operations and the organization at the Department of Virus Detection. Collection of data included process mapping, machine performance, organizational structure, analysis schedule and studies of response times and analysis demand.

From the identified problems, we formulated alternative solutions with assistance of the general measures described in the section *Theoretical framework*. Most of the alternative solutions were evaluated in a simulation model and their results were compared with the current situation.

Finally, both short and long term recommendations were given to the Department of Virus Detection, intending to reduce the current response times.

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3 Aronsson, Ekdahl & Oskarsson, Modern logistik – för ökad lönsamhet, s.166

4 Aronsson, Ekdahl & Oskarsson, Modern logistik – för ökad lönsamhet, s.166
Empirical studies

To understand the operations at the Department of Virus Detection, we mapped the processes at four different levels. We called the main process Detect viruses, which we divided into sub-processes down to activity level. Figure 3 illustrates the main process and the second level sub-processes. The process begins with arrival of a sample to

the sample reception at Clinical Microbiology where an analysis demand occurs. The extraction is a prerequisite to the PCR-analysis since the sample material needs to be purified before it is further processed. The PCR-analysis, which amplifies the DNA/RNA-strings to enable detection of the virus, is performed according to a predetermined analysis schedule. This schedule declares when the analyses are started and completed. After the analysis is complete, a biomedical analyst approves the analysis as well as interpreting the result. In a second phase, a doctor interprets and signs the result of the analysis. At this time, the analysis result is accessible in the internal data system and printing of the result is made, which ends the main process Detect viruses.

As mentioned before, the Department of Virus Detection performs eight major virus analyses. In Figure 4 the percentage distribution between these analyses is seen. The analysis of Herpes simplex has the highest demand and represents almost 40% of all analyses.

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5 Aronsson, Ekdahl & Oskarsson, Modern logistik – för ökad lönsamhet, s.166
According to the collected data, the weekly demand is approximately 250 analyses.

![Distribution between different virus analyses](image)

**Figure 4.** The demand distribution of the analyses performed at the Department of Virus Detection.  

The arrival time of the samples to Clinical Microbiology mainly depends on the transportation schedule. About 50% of the samples arrive around lunch time, as seen in Figure 5. Moreover, about 20% of the samples arrive during the last working hour of the day.

![Arrival times during the day](image)

**Figure 5.** The distribution of arrival times between the working hours.  

In order to measure the processes, lead time analyses were performed for the analyses mentioned in the limitations. The lead time analyses were based on primary data from three consecutive weeks. Figure 6 shows the diagram of the lead time analysis for Calici virus, where the dark and the light areas correspond to active and passive time, respectively. In general, it is the passive time that should be reduced to effectively decrease the response time.

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6 Data from a period of 10 months (20060101 – 20061031)

7 Data from a period of 5 weeks (20060904 – 20060917 and 20061023 – 20061112)

8 20061023 – 20061112
Development and evaluation of measures

When comparing the different lead time analyses we could identify common problems as well as specific ones. From the discovered problems, potential measures were evolved with assistance of the general guidelines mentioned in the section Theoretical framework. Most of the measures were evaluated according to the result in the simulation models. We tested different measures in working hours, analysis schedule and machinery, which were compared with the present situation. We found that different measures affected virus analyses with same attributes, such as analysis demand, analysis frequency and operation times. Generally, analyses performed more often, benefited from increased extraction frequency and synchronization between arrival of samples and start of analyses. To efficiently reduce the response times for analyses performed less frequent, additional analyses should be scheduled according to the simulation results.

Recommendations

Finally, we want to summarize the recommendations we provided to the Department of Virus Detection. Some of the recommendations were evaluated in a simulation model. Formally, we could not select a solution, as a final stage in the approach model, since it is several other parameters to consider, for instance cost limitations, legal issues and medical priorities, before a decision can be settled. These issues should therefore be handled internally at Clinical Microbiology.

The Master Thesis partially resulted in a grouping of the virus analyses into four different categories. The categorization was based on the three factors: analysis demand, analysis frequency and machine operation times. For each category of analyses, we developed specific guidelines that effectively can reduce present response times.

1. HSV & VZV
Measures: Synchronization of analyses and sample arrivals, increased extraction frequency

2. Entero, Adeno & CMV qualitative
Measures: Increased analysis frequency
3. Influenza & Calici

Measures: Treated as category 1 in peak season and as category 2 off-season.

4. CMV quantitative

Measures: Synchronization of analyses and sample arrivals, increased analysis frequency

On a short term, we suggested that the Department of Virus Detection changes its routines for the quantitative CMV-analysis. At present, the analysis is performed on Tuesday and Thursday afternoon, however we advise it to be rescheduled to Monday and Thursday evening, due to the centralized analysis demand on Mondays. Moreover, we proposed that the biomedical analysts, to some extent, should obtain authority to confirm and sign sample results. In this way duplicate interpretations of the analysis results can be eliminated.

On longer term we recommended the Department of Virus Detection to acquire a universal machine, in which non-specific virus analyses can be executed. Before it can be ready for use, analysis methods need to be developed and quality checked. Therefore we suggested a priority order to integrate the virus analyses. Analyses from category 3 should be integrated at first, followed by category 2-analyses, due to the long response times and medical importance of the analyses in these categories. We also claimed that working hours and the analysis schedule should be synchronized to the transportation schedule. In practise, this implies that an evening shift needs to be established. Finally, a computer-based response system should replace the present postal service, which is currently one of the most crucial causes of the long response times.

Keywords

Virus detection, laboratory medicine, Clinical Microbiology, UMAS, response time, lead time analysis, process mapping, supply chain management, simulation

References

Interviews with personnel at the Department of Virus Detection