ABSTRACT
The contribution deals with total rationalization of several workplaces. There were the analysis of operation sequences, necessary fixtures, jigs, spatial arrangement, etc. performed. The rationalization methodology was the same for all workplaces – specifically for the upright mechanism, Magni and Meti assembly, Pit ladder assembly. Based on the analysis were determined main problems that provoked a need to standardize workplaces. Rationalization lies in optimizing the individual sections related to design suitable jigs for individual workplaces. Consequently it was necessary to create completely new operation standards as well as new workplace layout.

KEYWORDS
Rationalization, Layout, Ergonomics, 3D modelling, Jigs, Fixtures

INTRODUCTION
The contribution was made in a company produces mechanisms and elevator parts. The production can be described as serial production with month volumes up to several hundreds of pieces of each product. There were designed the methodology for workplace rationalization which has checked following aspects:

The main goal of whole rationalization was to design cheap and simply adjustment to achieve higher productivity by:

a. Workplace adjustments
b. Definition of different sequence of operation

PRODUCT ASSEMBLY
Products were assembled on a workbench mostly out of metal profiles. The assemblies are performed mostly by pressing nuts (M10 and M12) in to the metal profile. Pressing nuts in to the hole in the profiles are made by tightening screws. This operation is performed manually in four steps.

- Firstly - worker prepares nuts and screws – worker simply puts all nuts and screws on the table. This operation represents pure waste (no value added – should be eliminated)
- Secondly - worker put screws through profile and connects with nuts
- Third - worker grasp two spanners and starts tightening screw.
- Four - worker lose all screws and put them away
Third and four operations represent biggest issue by whole Upright assembly. This can be reduced by using electrical screwdriver

**RATIONALIZATION OUTCOMES - PROBLEMS**

There were identified several problems which extend overall assembly time. Most of those operations are caused by not-standardized operation sequence especially not necessary manual operations. Main problems are stated below:

**Workplace overall**
- Ergonomics - workspace, placement of tools and components
  - Slide plates - are placed in the shelf above the working level (longest and heaviest profiles)
  - Too narrow and low table
  - Placement of assembled tools and material too far and high
  - Wrong (not ergonomics) assembly positions
  - Placement of profiles – too low on the ground.
- Standardization - the location of tools, equipment and components
  - Screws, nuts and washers are scattered around the table
  - Not fixed positions (for material, jigs, tools, etc.) – worker looks for something all the time
- Packaging and protection - Packaging and protection of materials and components
  - Flat boxes – not optimal material picking
  - Rubber protection
    - worker usually goes to cut it to the different workplace
    - Must measure cut length (find, grasp and use scale and scissors)
    - placed below table

**Operation sequence**
- Standardization of way of assembling
  - Worker doesn’t know operation sequence
  - Biggest problem is the tightening screws – manual operation using two spanners tightening manually.
  - Screws which must ensure ladder move-ability – worker must estimate certain power ("method try and fail") – too time consuming.
  - Overall non-systematic way of assembling
  - Some of preparation operations (screws or nuts putting on the table) are pure waste
  - Too many manual operations performed by hand and tightening by spanner
  - Wrong performed taping – by flat rasper
  - Completely wrong operation sequence by marking profiles before sticking
  - Sticking by reversible tape – performed on another clamping (almost different worksite)
- Elimination of wasting (time of looking for, unnecessary movements)
  - Lots of kinds of material needed to assemble (worker search material)
  - Unnecessary handling (handling with small connecting material and profiles)
  - Long lead times (caused mainly because of searching)
  - Unnecessary movements (walking for oil, screw thread, tape)
REALIZED SOLITIONS

There were performed several solutions which have been previously discussed among responsible people within the company workers higher management included. After several meetings have been agreed several adjustments.

Alteration on assembly sequences

There were completely changed assembly sequences. All changes counts with certain degree of automation. Especially screwing, pressing or tightening parts in the metal profiles. Approximately it represents 40% saving on assembly time. Figure below shows the former op. sequence on the left side and new op. sequence on the right side. There have been at around 90 different operations on each assembly the figure shows just part of it. Waste operations are marked red.

<table>
<thead>
<tr>
<th>Op. no</th>
<th>Former sequence</th>
<th>sec</th>
<th>New sequence</th>
<th>sec</th>
</tr>
</thead>
<tbody>
<tr>
<td>...</td>
<td></td>
<td></td>
<td>...</td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>Grasp screws and nuts M12</td>
<td>10</td>
<td>Grasp 4 screws M12</td>
<td>6</td>
</tr>
<tr>
<td>31</td>
<td>Tight screws on the side of 300520H01</td>
<td>28</td>
<td>Tighten screws 4x M12 in 200901C01</td>
<td>20</td>
</tr>
<tr>
<td>32</td>
<td>Remove wooden blocks under 300520H01</td>
<td>8</td>
<td>Turn part 300520H01 on the side</td>
<td>15</td>
</tr>
<tr>
<td>33</td>
<td>Turn part 300520H01</td>
<td>4</td>
<td>Put the whole sub assembly out of the jig</td>
<td>5</td>
</tr>
<tr>
<td>34</td>
<td>...</td>
<td></td>
<td>...</td>
<td></td>
</tr>
</tbody>
</table>

Based on changing of op. sequences were spared in average 40% of assembly time.

Table adjustments

Table adjustments are based on several slight alterations on existing tables. Especially features for fixing or holding material in defined position as can be seen on figure 2 below.

To achieve suggested assembly sequence it was necessary to design completely new or at least modified assembly jigs. There were designed jigs for three different assemblies. Example of the jig for the Upright assembly is shown stated below see figure 3
Assembly jigs

Assembly jig for Upright comprise also clamping mechanism which had to allow positioning of the product and assembling on it at the same time. Clamping mechanism is stated below in the figure 4.

To achieve better positioning nuts (which were pressed in to the profile) has been manufactured nut holder see figure 5.

Part of upright assembly was also tape sticking on the metal profile surface. The stripes was necessary to stick in pre-defined distances. Therefore had been manufactured also separable scale see picture below.
Due to the fact that most of operation were in former state performed manually it was also necessary to purchase tool and assembly devices. There were necessary to purchase many more tools than is stated in figure below.

Figure 7: necessary tools for purchasing

ERGONOMICS STUDY – RULA ANALYSIS

An integral part of each rationalization work is also ergonomics study which must provide a proof of the solutions wholesomeness. As most suitable method which provides it is RULA analysis. RULA analysis was performed repeatedly and evaluates at least four most common assembly positions at each workplace see figure below.
The figure below shows an example of the examined position (picking from the upper shelf). The overall score was 3 see figure below.

Figure 9: Ergonomics study - results

Results interpretation

Overall score

1 – 2: Completely convenient
3 – 4: Convenient if not performed for long time – need further evaluation, consider corrective actions
5 – 6: Need for corrective actions shortly
7: Inconvenient: Immediate corrective actions

LAYOUT

The change of operation sequences entails the need for spatial different arrangement. There were also identified some gaps towards optimal state:

- Provided materials were not up to date – more than half of accessories are missing
- Machines are placed somewhere in space – not precisely placed
- Drawn machines sometimes not respect real dimensions
- Missing areas – expedition, material, etc.
- Just roughly drawn – missing pallets, workbenches
- Machine dimensions are wrong (probably just put out of the library)
- Wrong workplaces placement
• Example: stocks Layout – 2 pallet segments, Shop floor: 3 pallet floor

• There is only one thing which actually fits – perimeter & walls

Based on rationalization and identified gaps were drawn new layout see figures below

By the definition of the new layout were shifted several workplaces which created new assembly cell. In total it represents saving 42 square meters. Quantifying has been made by comparing former layout and new spatial arrangement.
CONCLUSION - EFFECTS ON RATIONALIZATION

There were performed total workplace rationalization which were focused on operation sequences jigs and layout. All workplaces are rationalized to achieve certain saving. The success rate is always measured by spared assembly time, material or square meters. All calculations are based on measuring current state, provided information and internal evaluation of tightening and loosening times. Lead time reduction based on using electric screwdriver (current state 14 sec, future state 7 sec) is stated in figure below.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Manual screwing 1 pc</th>
<th>Electric screw drive 1 pcs</th>
<th>Manual screwing 34pc</th>
<th>Electric screw driving 34 pcs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Screwing</td>
<td>0:14</td>
<td>0:07</td>
<td>7:56</td>
<td>3:58</td>
</tr>
<tr>
<td>Expected time savings by screwing</td>
<td>50%</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Overall lead time reduction based on change of operation sequence, material replacement and rearrangement of workplace is shown in figure below.

<table>
<thead>
<tr>
<th>Current assembly sequence (min)</th>
<th>Suggested assembly sequence (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>31:47</td>
<td>18:41</td>
</tr>
<tr>
<td>Expected time saving (%)</td>
<td>41%</td>
</tr>
</tbody>
</table>

There were also achieved saving based on different spatial arrangement of all examined workplaces. Definition of new layout represented saving of 42 square meters.
ACKNOWLEDGMENTS

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REFERENCES


