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DECISION PRINCIPLES FOR ASCENT SUPPORTS IN BUILDING CONSTRUCTION

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Ladders are the ascent system most commonly used to scale up a building, due to the low initial costs compared to other ascent equipment. The insufficiency of this approach is shown in an economic comparison of ladders, stair towers, and scaffoldings with integrated ascent support. Based on empirical studies, cost data and the current state of scientific knowledge, the ascent support with the highest economic value can be determined by considering safety, cost, time, stress, physical stress and strain, and frequency of use. A survey evaluated vertical transport routes, the ascent systems ladders, stair towers, and scaffoldings with integrated ladders. The findings indicate that from an economic point of view, ladders should be used only on construction sites where less than 54 ascents were performed each day. This leads to the assumption that for typical construction sites, with at least 6 ascents per person per day and a site usage for a period longer than one week, the operation of ladders is uneconomical.

Keywords: Ladders, Stair towers, Economic assessment.

1 INTRODUCTION

Ladders are one of the most-used equipment on construction sites. The decision to choose a ladder instead of another ascent support is often based on the foreman of the construction site, and generally based upon no criteria other than investment costs. Other common ascent supports include builder's hoist, staircases inside the building, and integrated ladders in frame-scaffold systems. Within the project, a comparison between the use of ladders, stair towers, and scaffolding-integrated ladders was performed since a ladder usually does not replace a hoist. Moreover, indoor staircases were excluded from this research because for the top levels they are usually not finished, and so another ascent support system has to be used. Taking Health & Safety into account, it can be seen in different statistics that ladders are one of the most frequent causes for injuries: more than 50% of the injuries in the Austrian construction industry on ascent support systems occurred on ladders (AUVA 2012). The increasing focus on this topic has brought about some change in the mind of construction site supervisors, but the economic and safety benefits are not known by most people in the construction industry. To quantify these benefits, this research project was undertaken, with the goal of developing a decision tool that integrates important factors into the decision process and gives supervisors the opportunity to document their decision.

2 METHOD

For the decision tool, the factors of “costs”, “time”, stress and strain”, “number of uses”, boundary influences of “construction site facilities”, and “transport possibilities” were included in the economic assessment. The factor of “safety” was not integrated into the calculation in the first step, but it seems possible that costs of injuries could be implemented into the decision tool.

These factors were divided into three groups, based on the kind of investigation to gain the required data: (1) Basics from literature: statistics (Labor Inspectorate 2000, AUVA 2012) and costs of the different equipment; (2) Data generated by a questionnaire: costs, number of uses, and material usually transported with each of the ascent supports; (3) Data recorded by on-site observations: Stress and strain for each ascent support, corresponding construction site facilities using modified REFA (1984) methods (as per Schlagbauer 2011), and the individual usability of each system.

The economic assessment based on the calculation of the total costs (TC) caused by initial costs (IC) to buy the system (or the rental costs (RC) to rent the system), establishment costs (EC) to install the ascent system on the individual site, and usage costs (UC) to use the ascent system. These costs are calculated by multiplying the time for an ascent and a descent by the average number of ascents and descents each day, and by the costs of a construction worker per hour, as per the following equations:

- In case the ascent support system is owned: TC = IC + EC + UC
- In case the ascent support system is rented: TC = RC + EC + UC

After the establishment of the equations, the individual costs had to be discovered.

3 QUESTIONNAIRE AND ONSITE INVESTIGATION

To gain sufficient empirical data, a questionnaire was sent to construction companies, then additional interviews were conducted with companies that sell or rent the ascent support systems. Finally, onsite observations were conducted to explore miscellaneous data regarding the usage of different ascent support systems.

3.1 Examining IC/RC and EC

To gain information for the IC, different construction companies were asked to provide their costs for each of the systems. Additional, companies that sold or rented one of these systems also provided us with their costs, and were compared to the information gained from the construction companies. This led to a mean RC or IC value that could be integrated into the total cost calculation. A questionnaire also measured the distribution costs between bought and rented equipment, the operating costs, the duration of use of each system, and the most important criteria for choosing one of the systems. This was supported by 50 supervisors.

3.2 Examining EC

The establishment costs are calculated by multiplying the time to establish the individual system and the mean cost of a construction worker per hour. As these worker costs were specific to each company, and can be very different in different countries, this factor had to be evaluated each time the decision tool was used. To get sufficient data for the establishment time, the 50 supervisors were asked to estimate a mean assembly and disassembly time for each system. In addition, the supporting company of this research project was asked to provide a usual duration for each system, based on their own investigations in previous years.

3.3 Examining UC

UC were based on the mean costs of a worker per hour, the number of ascents and descents each day, and the corresponding duration. The mean costs of a worker for this calculation were similar to the ones used to calculate the EC, and were usually easy to tabulate for each company.

To gain a number for ascents and descents, onsite observations were conducted at three different sites for a total of 26 days. Within the observations, the number of ascents and descents were counted every hour, and a mean number was generated. To assess ascent and descent duration, a simulation on a training ground for construction workers was executed. For the simulation, skilled workers, trainees, and volunteers of the Austrian Workers' Compensation Board (AUVA) performed exercises in 28 different scenarios at each of the ascent support systems. The scenarios were based on typical situations at construction sites. For example, scenarios included the ascent of a single worker with small equipment, the ascent of 2 or 4 workers at the same time (with or without equipment) heading in the same direction, and the movement of 2 or 4 workers in different directions at the same time (again with or without equipment). These exercises were recorded and evaluated to gain an average time of an ascent and a descent.

4 RESULTS

4.1 IC and RC

Based on the data above, the following sections indicate the costs for each of the most-used ascent support systems, with the limitation that only the cost for ladders can be displayed. For stair towers and frame scaffolding with integrated ladders, costs were obtained according to the regulations of the supporting company: only the amount of the depreciation, maintenance, and repair is shown, as a percentage of the IC:

- Ladders: 68 € for a 4m wooden ladder, 97 € for a 4m aluminum ladder and 120 € to 182 € for a 6m ladder, depending on the material. For comparison’s sake, the price for a 4m aluminum ladder was used because these ladders are more often found on construction sites in Austria. Based on the answers of the supervisors, the mean life expectancy of a ladder was calculated at about 14 months; then it had to be replaced for various reasons.

- Stair towers: The monthly depreciation for a stair tower in Austria was estimated at 3.2% of the initial value, with maintenance and RC estimated at 1.4%.

- Frame scaffolding with integrated ladders: The monthly depreciation was estimated at 2.3% of the initial value, maintenance and RC estimated 1.4%.

4.2 EC

Based on the observations and the questionnaire, the resulting duration of the establishment for each ascent support system is 1.25 hours for the stair tower, and 0.22 hours for the installation of the integrated ladder for the frame scaffolding. The duration of the ladder, including all safety issues, was recorded at below one minute and therefore not integrated into the calculation process.

4.3 UC

Based on onsite observations, an estimation of the daily movement on different ascent support systems was found to be six ascents and six corresponding descents.

Through the movement simulation on the training ground, the different speeds to ascend or descend one level could be derived. Compared to ladders: For the stair tower workers needed only 2/3 of the time to ascend one level, and only half the time to descend one level. For the platform level using the integrated ladders in the scaffolding, workers took about 1/5 longer than on the ladders to ascend one level, but only 5% longer to descend one level.

4.4 Comparison of TCs

Based on the above data, TC could be calculated and graphically displayed. Some additional influence factors had to be set:

- Worker wages were defined at 35 € per hour.
- The distribution between bought and rented equipment was set according to the results of the questionnaire:
    - All ladders were assumed to be bought by the company.
    - 40% of the stair towers were bought while 60% were rented.
    - 47% of the integrated ladders for the frame scaffolding system were bought while 53% were rented.
- The mean life expectancy was stated as
    - 14 months for ladders.
    - 70 months for the stair towers and the integrated ladders.
    - After these times a replacement of each system was needed and the initial cost had to be added again for the bought systems.
- The number of ascents and descents was defined as 6 per person; the number of workers was set as 6 for first calculations.

The following graph shows the result of the calculation for the three different ascent support systems:

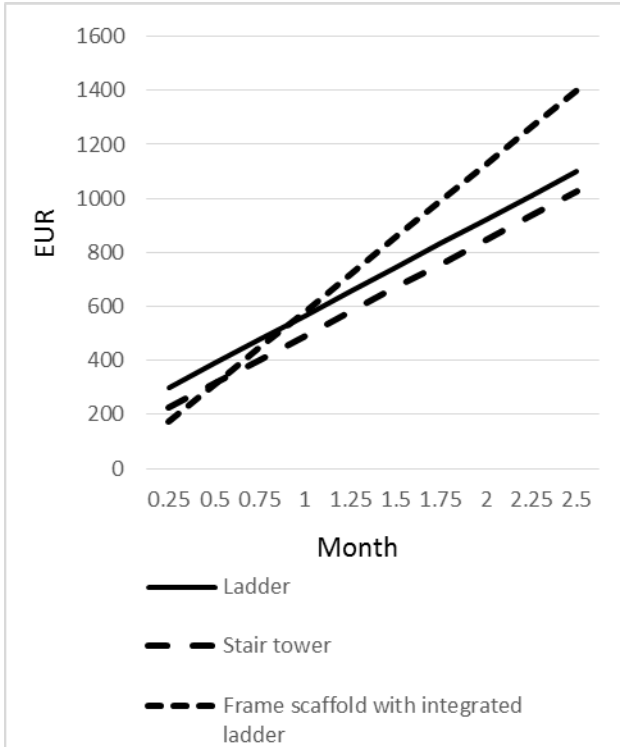

Figure 1. Comparison of the costs for the different systems.

It can be seen that projects less than 0.25 month (i.e., one week), frame scaffold integrated ladders are cheapest. The stair tower is the cheapest for the long period. The most expensive solution for under a month is a ladder, overtaken by frame scaffold integrated ladders after a month.

Using sensitivity analysis to test changes for different input parameters, the result shown in the graph above did not change significantly. Even assuming 10% lower costs of the construction workers, the number of daily ascents and descents needed (which resulted in the lowest costs for the stair tower) is only 54, meaning 9 construction workers would have to perform the average amount of six ascents and descents per day.

5 CONCLUSIONS

Comparing the different ascent support systems used for the top levels of a building, the results show that for the economic benefits of the stair tower are strong even for a short period of use. Based on the observation of a mean number of 6 ascents and descents per day for a construction site with more than 6 Austrian workers with average wages, a stair tower is the most economic system. This result is based on the higher velocity of movement on the stair tower compared to the ladders, especially with additional equipment to carry. Within the simulation of the movement on other ascent support systems, the findings showed that, compared to ladders, the workers needed 1/3 to 1/2 less time to move between the levels when they use a stair tower.

These results are only based on economic criteria, and do not take into account Health & Safety factors. Considering the high number of injuries caused by the use of ladders, this paper concludes that ladders should be reduced as much as possible. This is especially true since the cost of ladders, compared to the use of a stair tower, are not significantly different than what company owners or supervisors assume. Further, the results show the economic benefits of using a stair tower start at even very small numbers of ascents each day.

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