Barriers to Implementation of Laser Welding Technology
– A Study of 11 Companies in Scandinavia

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Abstract In the manufacturing industry, one essential contribution to sustain high competitiveness is successful regular implementation of advanced manufacturing technology. Barriers of different sorts could interfere with this implementation. The purpose of this study is to investigate whether there are barriers to implementation of laser welding technology and how they affect the implementation process. Eleven small manufacturing companies, mainly in northern Sweden and Finland, are interviewed regarding their experiences with implementation of laser welding technology. What is clear is that this is a more complex question than just lack of money. The study shows other underlying barriers to have more influence on the lack of implementation. Many of the barriers are connected with organization and management. Identifying these barriers and when they occur in the implementation process may improve implementation efficiency.

Keywords Technology Implementation, Barriers, Organization

1. Introduction

In the manufacturing industry, one essential contribution to sustain high competitiveness is successful regular implementation of advanced manufacturing technology. Since such technology change often does not take place, in the here presented study various barriers for such implementation are identified and analyzed.

State funded programs are created every year to support increased growth and improved industrial efficiency, e.g. the European Regional Development Fund from the European Commission [1]. Innovation is considered as one key factor to achieve this increased growth and improved industrial efficiency as well as sustainability and increased living standards around the world. In order to gain and sustain a competitive advantage, firms need to have the capability to innovate in both products and production technology and processes [2]. Changes in technology and production processes both create and require new working conditions and place new demands on behavior, attitudes, skills and even new forms of organizational cultures that follow the new developments in technology [3]. Innovation can be stimulated in many ways but one way that has been identified as an important contributing factor for effective innovation is successful technology implementation [4,5]. The major contributor to increased employment and productivity is not, surprisingly enough, the big multinational companies but instead the small local companies [6-9]. Therefore it is essential to understand the technology implementation process within the smaller companies to make sure that the support programs are designed to assist the small companies in the best possible way. It is argued that organizational aspects have implications for processes of implementation of new technology [10,11]. New technology, in itself, is not guaranteed to change efficiency or production conditions, either positively or negatively. In order to ensure positive development, a sociotechnical approach is needed [12,13]. Such an approach also includes the human, the work environment, and the organization of work, both formal and informal. Looking at implementation today, one can find indications on the rate of implementation within certain fields not being as extensive and successful as could be expected. Studies have shown that technology implementations in industry could fail due to other causes than purely technological, such as not fully understanding the new technology, organizational immaturity, incompatible systems, etc. [14-16]. This indicates that there are underlying causes that need to be addressed and investigated in order to further improve efficiency of implementation.

The underlying causes, or barriers, can be categorized by properties, [17], whether they are due to finance, competence, government support, market, etc. Some of these barriers can be considered as firm internal barriers while others exist outside the firm. One problem is that organizational cultures
are a double-edged sword. They are platforms for both change and resistance. They create productivity, stability, professional identity, organizational boundaries, learning environments, and motivation, but they are also conservative and involve social control that can limit autonomy, flexibility, innovation, and opportunities for change for both individuals and organizations [18,19]. Companies’ organizational cultures can serve to restore the old order – such as diffuse backlash and disobedience that result from resistance and entrenched professional culture – and make it difficult to achieve the desired outcome [19-21]. Therefore companies try to control and change their cultures. However, it is not clear who has power over the cultures. They are socially created and owned by groups and are not directly accessible for control by the organization’s management. It may be that the organizational culture in the form of ambiguities, paradoxes, informal conflict, power and condition differences, subgroups, and evasive and contradictory objectives are more significant for what happens (or what does not happen) in the organization than the official company culture [18,21-23].

Lewis et al. [24] describes a company maturity model in five stages for small business. The stages are described as Inception, Survival, Growth, Expansion and Maturity with different issues in each stage. Implementation of new production technology is most likely to occur during the three latter stages; Growth, Expansion and Maturity where Lewis et al. defines cash generation as positive and company organization structure as functional and centralized. In the present study, most companies have reached the Growth-level or higher and therefore implementation should be feasible.

Studies have shown that the majority of failed technology implementations come from non-technological causes [14]. User understanding it is therefore of great importance and including users as early as possible in the implementation process increases the probability of successful implementation [25]. Since most change processes within a company includes uncertainty and surprises, one can minimize the negative effects of by managing these uncertainties in a conscious way [26,27]. Therefore, firms need strategic thinking on how to develop a particular organizational capability to implement new technology. One important part of this is workplace learning, a concept that is used to describe the collective, constant and simultaneous creation and sharing of knowledge in the organization. This situated and informal learning can be likened to the ‘everyday learning’ that takes place as part of work and as part of what Wenger [28] describe as communities of practice and Säljö [29] as contextual learning. Organizational cultures are important platforms for learning. Ellström & Kock [30] show that workplace structures, activities and different forms of development-oriented learning embedded in the work tasks are important parts of both individual learning and organizational learning. It is important to strategically organize for both the learning processes and the production processes [31]. El Sawy et al. [32] argue that having an organizational environment that encourages knowledge creation and sharing will lead to more successful process innovation projects.

In the present study, welding as a specific manufacturing technology was chosen because there is a high development potential within the welding field. Also, welding is a core business for many manufacturing companies. The change from established electric arc welding (Gas Metal Arc Welding, GMAW) to laser beam welding is a high potential – high risk change. Specific for welding is that its complexity makes it difficult to economically calculate [33]. A change in technology can lead to changes in product design and to changes in manufacturing steps prior to welding (e.g. joint preparation by cutting) and after welding (machining against distortion, cleaning, inspection). Moreover, a weld in general bears a high but often not easily detectable risk for product failure. Depending on the product, this can cause fatal technical and economic or even accident consequences. Therefore, welding faces the paradox that on one hand it plays a key role in manufacturing, accompanied by allocating many resources, and on the other hand it is treated very conservatively due to the personal risks for decision-makers at all organizational levels.

Laser beam welding offers high-tech advantages like smart product design, high welding speed and high quality that can often only be achieved if accepting efforts like high investment costs, [34] high skill demands and a high level of edge preparation. Therefore, despite its advantages, laser welding so far remains a niche technology [35,36]. For example about 10% of the welding applications at Volvo CC are carried out with lasers while for the vast amount of welds resistance spot welding or electric arc welding is preferred. An example is the A-pillar of the Volvo XC60, [37] where a change from resistance spot welding to laser welding in 2008 has led to use of higher strength steel, smaller flanges, less weight, lower air resistance (more inclined windscreen) and higher safety (more narrow A-pillar). In company studies in Sweden and in Germany [38], results show that introduction of new technologies in manufacturing depends less on the technical aspects but on human factors like attitude, knowledge, communication, responsibility, short term thinking, priorities or confidence. However, the traditional patterns of thinking as integral part of the established company cultures (particularly in production) hardly address human factors, despite an increasing introduction of the LEAN-philosophy – the culture remains technically oriented and rigid.

Using laser welding as an example for the possible implementation of an advanced manufacturing technology in industry, the study presents and discusses different barriers against implementation of such new technology, based on interviews of 11 companies and corresponding categorizations.

2. Methodology

The findings and the discussions of this article draw on
results from a qualitative interview study that is part of an on-going project, *Forum for the Industrial Future*, which is a multidisciplinary and applied research project at Luleå University of Technology (LTU) aiming at giving support for SMEs in the manufacturing industry in the north of Sweden and Finland to develop a leading environment for manufacturing technology. The project is running 2011-2014 and includes 20 small and medium manufacturing companies, as well as researchers from the universities of Luleå and Oulu. The main themes for the project are production technology and ICT solutions and their implementation in a social context. Laser welding is used as an example.

The here presented study is based on semi-structured and reflexive interviews at 11 companies with respect to their strategy and profile in general and when implementing new technology. Based on the interview information, an analysis is carried out to identify trends that can be categorized and essential conclusions on barriers against implementation of new manufacturing technology.

### 2.1. Field Study

The present investigation was carried out as case studies with the participating companies. Each company was contacted and physical meetings were held at each company with different members of the staff; CEO, production manager, welding manager, operator, mechanical designer, etc. The initial purpose was to establish a history and approach from each company by personal interviews regarding company history, previous investments and implementations, strategy, etc. To make the process comprehensible, the investigation was limited to welding and welding-related applications. Parallel to the initial interviews, the data was analyzed and formed a basis for developing more targeted interviews at an additional meeting at each company. These interviews were used for finding individual causes that prevented or disturbed these investments and implementations, both from a company perspective and from a research perspective. These causes were then grouped into nine clusters in order to see relations and trends.

### 2.2. Theoretical Approach

We base our understanding of the technology implementation on sociotechnical perspectives. The sociotechnical theory grew out of an analysis of the introduction of new technology (the semi-automated long-wall method) in English coal mines [39-41]. The conclusion drawn by Bamforth, Emery, Trist and Thorsrud and their colleagues was that the technological interdependence between the different working shifts was not supported by a social system requiring integration and a holistic approach. Instead, the work organization and wage and status disparities between different work tasks had the opposite effect and contributed to a further fragmentation of the production system which affected the function and use of the technology. In a later phase of their work, the researchers came into contact with a mine where the long-wall technology worked very well. Productivity was higher than that of other comparable mines. The difference was that, at this mine, the workers themselves had created a work organization based on broader roles and that included work rotation both within and between work shifts. They had also succeeded in creating a social system that harmonized with the technical system, and the new system incorporated a high autonomy for the workers at group level.

The sociotechnical theory has of course been criticized and developed during the years and needs still more updating [13]. One such modern way of using the theory is Grane et al [42] that see the operator who works closest to the value adding processes as a key to enhanced innovation and competitiveness for manufacturing companies. Grane et al mean that the new production technology must include tools for the operator, for example be developed with a modern IT-interface and well integrated in the production system and adapted to a modern organization. In other words: tools that are intuitive and situation adapted and with aim to "strengthen senses and powers of the operators", support teamwork, communication and learning and make the jobs more interesting, stimulating, and developing for the operators.

### 3. Results and Discussion

During interviews, negative workplace culture, lack of personnel and lack of competence, training and learning was mentioned as barriers (see figure 1).

A selection of illustrative quotes from the interviews is presented here and these quotes are part of the data that was used to identify the barriers.

- “We simply need this to move on” (production manager about a current investment)
- “Buying machines is my strength” (CEO about his involvement in technology investments)
- “There is room for ‘good-to-have’ investments” (welding manager about financial strength)
- “The customers own the products. We need design expertise to be able to influence existing products” (CEO)
- “I don’t buy machines. I buy companies” (company owner about business strategy)
- “We do not have an outspoken strategy for technology benchmarking” (CEO)
- “We need to know that the investment will generate profit” (CEO about technology investments)
- “We need to know that technology is reliable, consistent and the best choice” (technical manager about technology implementation)
- “We need to automate more production. It is very hard to find qualified welders” (production manager about supply and demand for welders)
“New technology comes with the product. If it is needed and can generate profit, technology will come” (CEO about what initiates new technology investments)

“An objective, neutral demonstrator would be useful” (production manager about how to evaluate and test new technology)

Designers need to know pros and cons of laser welding in order to design more efficient” (CEO about necessity of technology knowledge among designers)

“We have no engineers, only operators. We need engineers to evolve” (production manager about evolution of the company)

“We don’t shoot from the hip when making the decisions” (production manager about implementation strategy)

“There is always a rush when implementing” (CEO about implementing new technology alongside normal production)

In addition to the interviews, questionnaires were used. They covered overall business strategy, position on the market, competition, specialties, welding strategy, etc. Together they gave a base for analysis to identify and formulate the most significant barriers.

The implementation process can be broken down into a number of sub-processes [43,44]. In Table 1, the sub-processes identified in the present study are presented.

| Process Index | Sub-process                           |
|---------------|---------------------------------------|
| P1            | Identify needs                        |
| P2            | Pre-study and develop implementation  |
|               | scenario                              |
| P3            | Decide application                    |
| P4            | Install and prepare the change        |
| P5            | Ramp up the change                    |
| P6            | Change fully implemented              |

This can be described as a rough implementation strategy that can be used for developing a more detailed and company-specific strategy to be used in upcoming implementation situations. The participating companies vary both in size and level of development regarding production technology. In Table 2 below key features for each company is listed, e.g. size, key activity, laser experience and location details. It is obvious that the companies differ in many aspects including implementation capability. This means that the will to venture an investment in new, unproven technology also differs between the companies and must be taken into account. This fact also became apparent during the interviews with the companies. There is also the possibility that the laser welding application is not suitable for a company at this specific time and the company is better off not to implement this technology. This also needs to be taken into account when investigating the companies and defining their needs.

| Company Index | Employees | Business | Laser Use | Location, City population |
|---------------|-----------|----------|-----------|---------------------------|
| C1            | 500+ (part of a larger group) | PEM | Laser welding, laser cutting | Northern Sweden, 75 000 |
| C2            | 50        | PEM, job-shop manufacturing for many customers, no own products | Laser cutting | Central England, 290 000 |
| C3            | 160       | OEM, vehicle component manufacturer, four complementary factories worldwide, design and development in-house | Laser cutting | Northern Sweden, 2500 |
| C4            | 300+      | PEM      | None      | Northern Sweden, 120 000 |
| C5            | 70        | PEM, one own product, otherwise several customers | Laser cutting | Northern Sweden, 1800 |
| C6            | 100       | PEM      | None      | Northern Sweden, 2000 |
| C7            | 50        | PEM, one main customer | Laser welding | Northern Sweden, 8000 |
| C8            | 72        | PEM      | None      | Northern Sweden, 18 000 |
| C9            | 55        | O/PEM    | None      | Northern Finland, 195 000 |
| C10           | 1000+     | OEM      | Laser cutting | Southern Sweden, 60 000 |
| C11           | 35        | PEM      | None      | Northern Sweden, 18 000 |
3.2. Analysis

As the companies were interviewed and studied, 7 major barriers could be identified in the first round of interviews (See Table 3.)

Table 3. Identified major barriers to implementation of manufacturing technology

| Barrier Index | Barrier                                |
|---------------|----------------------------------------|
| B1            | Lack of financing                      |
| B2            | Lack of time and/or personnel          |
| B3            | Lack of competence and/or training      |
| B4            | Lack of knowledge of new technology     |
| B5            | Undefined needs                        |
| B6            | Lack of implementation strategy        |
| B7            | Negative attitude                      |

These barriers are entered in Figure 1 together with the participating companies. On the vertical axis the companies are listed and on the horizontal axis the barriers are listed. For each company it is listed whether they consider the identified barriers to be of great concern to them or not, “BARRIER” or “NO BARRIER”. During the interviews we often talked to more than one person from each company and from different levels within the company. In Figure 1 some fields are labeled “CONTRADICTORY” and in these cases the interviews gave contradictory results depending on which person in the company that were answering them. In the row with summed “no barrier/barrier”, it is shown whether the majority of the companies perceive each barrier as an actual barrier within their company or not.

With basis on the data in the here presented, interesting phenomena can be seen and combining the tables allows interesting analysis. By identifying and categorizing the barriers the underlying causes become more visible and one can prepare a chronological chart for when the different barriers occur.

In all of the sub-processes listed in Table 1 one can find different barriers that need to be addressed and overcome to succeed with the implementation.

![Figure 1](image-url)
P1, Identify needs: B4, B6

During the first phase when the needs are identified the two main barriers are if the needs are not clear and if an implementation strategy is missing. Unclear needs may result in implementing the wrong technology or not implementing at all.

P2, Pre-study and develop implementation scenario: B2, B4, B6

During the second phase where the current situation and selected application is analyzed is the barriers that are most present are lack of resources to perform the analysis and as in the previous phase, undefined needs and lack of implementation strategy. Insufficient resources regarding time and/or personnel together with vague strategy may result in poor or slow implementation and unclear needs may have the same effect here as in the previous phase.

P3, Decide application: B1, B3, B4, B5, B6

When deciding and acquire the optimal technology the most significant barriers are if you do not know enough about it. Lack of competence/training can delay the implementation if not handled correctly and lack of knowledge of the technology causes insecurity when selecting and adapting to it. These barriers may be dealt with if one has a well-defined implementation strategy. It is therefore of great importance and can be seen as a barrier if performed poorly.

P4, Install and prepare the change: B1, B2, B3, B4, B6, B7

Insufficient knowledge of the new technology (B3 & B4) makes it difficult to put the new technology into operation. Since most implementations imply changes also to the existing technology system, insufficient knowledge may lead to increased problems during implementation. Negative attitudes among the staff can also be an important factor and may cause problems and delays during this phase.

P5, Ramp up the change: B2, B3, B4, B6, B7

When the new technology is in place it needs to be calibrated and adapted to the existing technology system. Then it is of great importance to have a well-defined plan to do so. The staff operating the technology needs to be trained and the rest of the existing technology system needs to be adjusted to the new technology. Therefore, the barriers lack of competence/training and lack of knowledge of new technology has a great influence on this phase. Also staff issues, as not enough resources and negative attitudes, is of great importance here.

P6, Change fully implemented

From Figure 1 one may find interesting phenomena. First, by summarizing the number of identified barriers, one can see that the issues that are considered as barriers by most companies are “Lack of time/personnel”, “Lack of knowledge of new technology”, “Undefined needs” and “Lack of implementation strategy”.

Neither “Lack of financing” nor “Negative attitude” are considered as major barriers by the companies. At the same time “Lack of time/personnel” was considered a barrier. This may seem contradictory. In true, “Lack of time/personnel” is frankly just a question of finances, is it not?

Many of the barriers concern the human in the system. One does not see financing as a barrier but at the same time one considers lack of time and/or personnel as a barrier. Is time and personnel not just a question of money? Is it harder to “invest” in people than machines? Maybe it is easier to convince banks and other financiers to support an investment in hard technology than to find the means to employ more people.

Looking at the barriers alone, one can see that they also can be grouped depending on what company asset that is affected. B1, B2, B4, B5, and B6 are closely linked to company management and organization while B3 and B7 are more linked to personnel and staff. This indicates that the improvements that would affect implementation the most are within company management and organization.

In Figure 1, the companies have been ordered depending on the number of Barrier/No Barrier they have. The companies can be accordingly grouped; looking at C1 and C2, they are already working with laser technology and are likely to keep investing in this technology. C6 has laser welding technology but it is not used much and is probably on its way out. C7, C8, C9, C10 and C11 are not likely to invest in laser welding technology due to a large number of barriers to overcome. Companies C3, C4 and C5 are the ones most likely to invest in laser welding technology before long, having achieved a threshold level of conditions required for implementation of new technology. They see fewer barriers and the common barrier is B2, Lack of time and/or personnel.

4. Conclusions

In total the results in this paper show that it is not enough to just choose, purchase and introduce new tools and technology. The implementation of new manufacturing technology can be enhanced by using a wider approach, e.g. by including an organizational perspective in the sub-processes of the implementation.

- A key conclusion that can be drawn is that to increase the firm’s organizational capability, people must be given the opportunity to develop and create ideas together and the organization must facilitate the flow of ideas and information. Top management commitment together with empowerment of the operating personnel and their early involvement in technology implementation and development processes will lead to more engaged team members, better learning, greater satisfaction and lower resistance to change and, in essence, more efficient technology implementation.
- Looking at B4, B5 and B6, they all refer to management issues and are harder to assess since they deal with “softer”
values even though they have large influence on implementation ability. This means that companies should put greater effort in self-assessment and development of internal strategies for efficient technology implementation.

- From the study one can see that the size of the company is not a major factor for implementation ability. The two largest companies are located in the top and bottom of Figure 1, indicating one to be very able (in this case they are actually already using laser welding) and the other not ready at all for implementation. There is no clear pattern of the table position for the other companies regarding company size.

- In welding, the different experts’ worries or fears to avoid failure fatalities are so critical that large resources are spent to minimize risks for the actual welding technology; despite resources, these fears are a barrier that usually hinders productivity opportunities through a change in welding technology, owing to a new unconfident situation with less experience.

- The companies in Figure 1 are ordered according to the number of barriers where the ones in the top of the table experience fewer barriers than the ones lower down in the table. Looking at the companies and what barriers they experience one conclusion is that the companies in the lower part of the table are in their actual situation not able to implement laser welding in the short-term, while the companies in the upper part have a quite promising company culture (“threshold companies”) to implement it. Especially companies 3-5 seem very likely to implement this in a near future. Companies 1 & 2 already are working with laser technology owing to their good basic organizational conditions.

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