Production preparation methodology in Swedish metal working industry - a State of the Art investigation

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ABSTRACT

This article presents a brief state of the art in the Swedish metal working industry regarding the production preparation process for the machine centre. The article is based on a relationship model from which a questionnaire was developed. The model incorporates the perceived preparation process efficiency, the amount of systematic preparation work, in relation to the companies' premises as possible causes. The investigation is based on a general hypothesis that a more systematic approach in the preparation process leads to higher preparation process efficiency. This hypothesis was supplemented by two more hypotheses and additional analyses to create an understanding of the situation. The main finding in this investigation is that there appear to be no relationship between increased systematic preparation work and perception of higher preparation efficiency. The investigation also indicates that many metal working companies have little knowledge about the performance of their preparation process and that there is an efficiency improvement potential of nearly 30%.

Keywords: Production preparation, methodologies, Metal working industry, Information management, PLM

1. INTRODUCTION

The main research effort in the area of 'lean' has been put into the physical production itself, whereas less attention has been paid to the leanness of the production preparation phase. The importance of also taking the production engineering work into account was shown by Murgau et al.[1], where the interaction between physical work and information handling was studied. In another work Murgau and Pejryd [2] studied productivity in engineering processes focusing on the managing of engineering work in a multi-task environment. Pejryd and Andersson [3] have studied effects of implementing PLM system in the preparation process. They found a productivity increase of at least 20% when new working procedures and IT tools were used.

The objective of this investigation was to study the effects of factors such as differences in company size, owner structure, machining processes and machined materials have on the preparation process. Also the extent of integration and computer support in the production and preparation process is studied. One main issue of the preparation efficiency is the information flow and information availability. The reason for paying great interest to information (and data) management is that it is the knowledge foundation and thus influence decision making and activities performed in the company. Information is important since the information often have long life and is reusable, but it has to be accessible, accurate, updated and current [4]. There can be many barriers between an efficient information exchange, such as non-compatible file formats and software applications on one side and juridical, physical and interpersonal barriers on the other.

This article aims at increasing the understanding of the present situation in the Swedish industry and thus to give both the academy input of the areas where research efforts should be concentrated, and to give the investigated industry an input regarding its overall performance. This article should be seen as a starting point for further studies and work to develop the understanding of the preparation process and for identifying the main strengths and weaknesses of the preparation process in the Swedish metal working industry in order to improve the efficiency of the Swedish metal working industry with respect to working methods.

1.1 Production preparation overview

This investigation has a general perspective of the preparation process, however the tender submission process is excluded from the preparation process; the focus is merely on the preproduction aspects such as process planning, technology preparation, geometry preparation (CAM) and cutting process verification.

The outcomes of the preparation process can be classified under two different efficiencies i.e. process efficiency and production efficiency (productivity), where the former is investigated in this article. The preparation process efficiency can be measured in different ways, e.g. manufacturing lead time, preparation lead time, product quality, production cost. There are numerous factors influencing the preparation lead time and amount of resources needed for performing an adequate production preparation. The type of materials machined can have a significant influence on the preparation lead time. Materials with good machinability such as aluminium or steel SS2172 are likely to cause little problems in the tool selection phase, thus leading to a shorter preparation process time, whereas difficult to machine materials such as nickel base super alloys and titanium alloys implies more constraints on the selection of cutting tools and thus longer lead time. The above stated materials are often used in the aerospace industry and e.g. titanium-aluminides are difficult to machine due to low thermal conductivity, its brittleness and high chemical affinity to cutting tool materials [5]. It is often for those materials necessary to make test runs where cutting data is tested, before the actual production starts, to verify that tool life, surface finish etc. are acceptable.

The geometrical complexity of the product has a significant influence of the preparation process complexity and lead time and is subjected to extensive research. A simple geometry (e.g. a cylinder or cubic workpiece), with only longitudinal turning, drilling or face milling operations, is less likely to cause problems in the geometry preparation phase. Whereas, on the other hand, free form surfaces and thin-walled products are more likely to extend the preparation process, since different tool path optimization strategies exists and verification of the machining may also be necessary, to ensure that no collision occurs between tool - machine tool, tool - fixtures or tool - workpiece. It is therefore of interest to study the effects that the above stated production parameters have on the investigated companies' preparation process.

The extent to which these parameters influence the level of systematic production preparation work and methodology usage was one of the main questions to answer with the performed investigation.

1.2 Research fundamentals

The analyses of this investigation was based on a relationship model (Fig 1), where cause and effect of an increased or decreased level of systematic work and preparation methodology in the preparation process were investigated, mainly by relating it to the companies perceived preparation efficiency.

The overall hypothesis that was to be tested for the investigation was; *a more systematic preparation process leads to higher preparation process efficiency*. However within the limited access to companies a complete efficiency study has not been possible to perform. This means that the process efficiency that is measured here is not the actual, objective efficiency, but the preparation process efficiency as perceived by the company itself.

The hypothetical statement above is based and supported by today's trend where many PLM (Product Lifecycle Management)/PDM (Product Data Management) software solutions have been applied in the manufacturing industry and have had a positive influence in the enterprises [6] but also by the PLM/PDM software industry. However, these software systems are often costly to purchase and maintain so their usage are often limited to larger companies where the aerospace and the automotive industry are driving the implementation of PLM systems. In the work by Pejryd and Andersson [3], they showed that the change of working methods and the change management of the

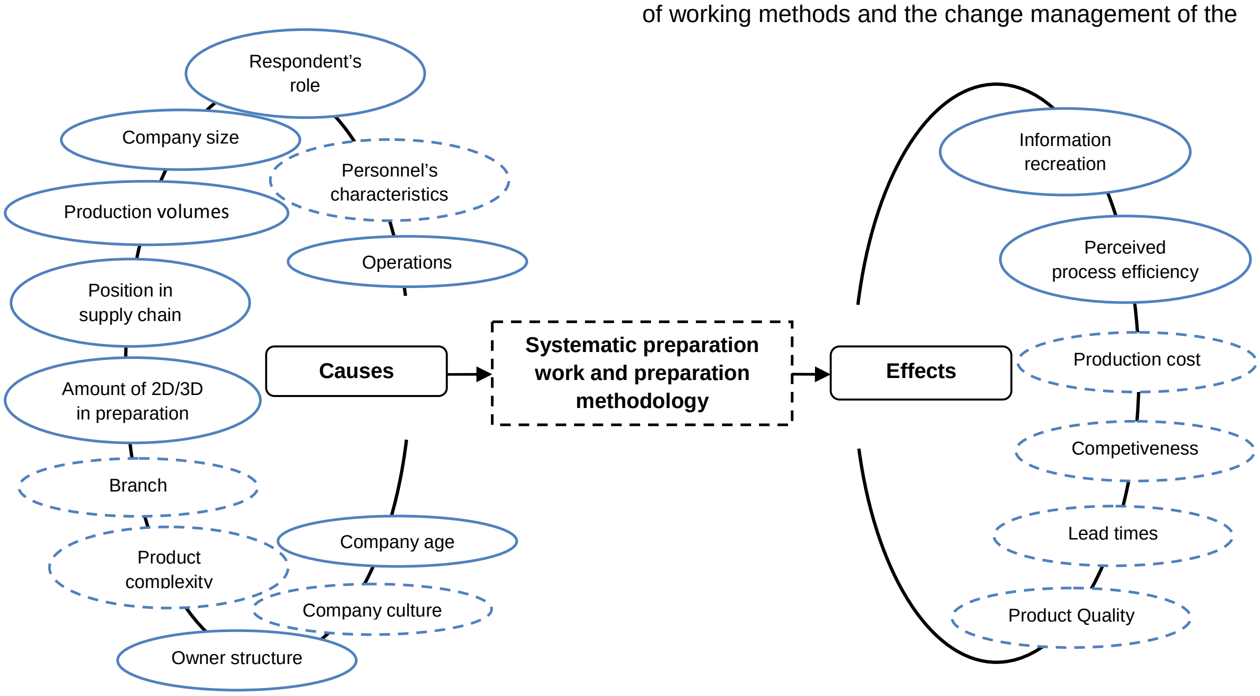

Fig 1: The figure describes the relationship model used in the investigation. The possible causes and effects that have been investigated here are marked by full line ellipses, whereas potential causes and effects that were not studied are marked by dotted line ellipses.

PLM system was at least equally important as the PLM system itself in order to explore the efficiency potential in the preparation process.

1.3 Scope of investigation

This investigation measures the perceived process efficiency and not the process output efficiency. There are numerous reasons for not doing so in this investigation; one is that information such as cassation rate, profit-sharing or production lead times for specific products can be sensitive for companies to reveal. However these figures only partly describe the preparation process efficiency since production is complex and diverse where companies of different branches and produced components not easily can be compared.

2. METHOD

This article is based on a quantitative survey that was performed from February through to May of the year 2008. The survey has been distributed to 104 companies, which were prior contacted to ensure that the survey was to be answered by the proper staff within the company organisation, having insight in the current preparation process. Due to the nature of the questions, where no absolute numbers are given and the results derived from it cannot be understood as the factual truth, the results must be interpreted qualitatively. The answers collected through the questionnaire are merely the individual company's or individual persons' perception of their company's performance. The survey was restricted to companies completely or partly connected to metal working production. Common for all the studied companies were that they had any kind of combination of turning, milling, drilling or grinding processes in their respective production.

As mentioned above, the investigation is based on the hypothesis that a more systematic preparation process has a positive relation to higher preparation process efficiency. This hypothesis is however paired with two additional hypotheses to better understand if there are any underlying reasons for the situation. The first one investigates whether there is a relationship between perceived preparation process efficiency and the complexity level of premises that the companies work according to and the second investigates if a relationship exists between systematic preparation work and complexity level of company premises. The hypotheses are tested in chapter 3. Beside these hypotheses, a number of individual parameters' relationships were tested to investigate whether certain 'cause' parameters exist that have greater impact on any of the 'effect' parameters. The hypotheses' testing is further discussed in chapter 3.

2.1 Questionnaire construction

The questionnaire was developed around a set of questions that maps the company's characteristics in order to be able to answer the posed hypotheses. The distributed questionnaire is divided into four parts, where the first part maps the manufacturing preparation process of the company, the second deals with company characteristics, the third product characteristics and the last part concerns the respondent. In total the questionnaire consists of 57 questions, distributed on the four parts according to 32/15/5/5. Most questions are closed ended by the type of yes/no and multiple choice, where the respondent must choose one or several alternatives or one interval set of numbers. A number of questions are open ended and completely unstructured, which lets the responded answer freely. A draft of the questionnaire was tested on three responding companies, which caused a few adjustments to be made to the final questionnaire.

2.2 Data treatment and analysis

The answers from the open ended questions have been categorized for the quantitative analysis. Due to various reasons (including interpretation problems, misunderstandings or inessentiality to investigation scope) some of the questions have been excluded in the quantitative analysis.

The various parameters have been classified depending on their nature under three indexes that in turn is weighted and plotted against each other. The different indexes and their respective parameters and weighting are listed in Table 1. One set of parameters are classified under potential causes and are labelled *complexity level of company premises* and is the first index describing the degree of difficulty of the conditions that the companies have in the preparation process. Index two is the *level of systematic preparation work and methodology* and is built up of the level of structured work in the preparation process and the existence of an outspoken or subtle preparation work methodology. Index 3 is the *preparation process efficiency* and is based on one parameter that describe the companies more subjective and one that describe the efficiency more objective.

The parameters that make up the three categories are individually weighted on a subjective basis, so that their importance relative to their category is realistic. Weighting is often problematic due to its subjective nature of ranking the importance of different parameters against each other and must be performed with carefulness and must be evaluated, to study the weighting's influence on the results extracted from it. For this investigation different weighting criteria have been tested, where all parameters have been given their extreme values (1 and 0) individually, which however did not have any significant influence on the results. The currently used weighting does not have any significant influence on the presented results and the conclusions drawn.

2.3 Survey size and response rate

The response rate of the survey was 40%, which means that the investigation is based on 42 companies from all over Sweden. The number of metal working companies that uses CNC machines is difficult to estimate, but a search on 'CNC' and 'bearbetning' on the website www.industritorget.se, a Swedish subcontractor web portal returns 769 hits. This is not all the companies in Sweden, but gives a hint of that industry's sector size. In the investigation companies with a wide size range have been included from SMEs to bigger enterprises.

Table 1: Classification of investigated parameters

Index 1: Complexity level of premises	Weighting
Ratio between contract works and in-house designed products	0,75
Machining operations	1
Existence of multi-task machining centres	0,75
Shortest manufacturing lead time	0,5
Longest manufacturing lead time	0,5
Product geometry complexity	1
Product material	1
Company size	0,75
Index 2: Level of systematic preparation work	
File format compatibility throughout preparation process	0,25
Existence of preparation methodology	1
Usage of preparation process support systems (e.g. PDM solutions)	1
Usage of preparation follow-ups	1
Documentation of preparation	1
Index 3: Preparation process efficiency	
Perceived preparation process efficiency	1
Level of preparation data recreation	0,5

3. RESULTS AND DISCUSSION

This chapter presents the results from the investigation where the foundation is the hypotheses testing, mentioned in chapter 2. The hypotheses are complemented with general information about the investigated companies in order to establish a contextual description of the companies' characteristics, so that the analysis of the hypotheses can be better understood.

A general result from the investigation is that there seem to be little focus on the preparation process in the industry, which is indicated by the fact that very few companies claim to have any performance measures or evaluation methods for the preparation process. However, 62% of the investigated companies perform evaluations of their preparation process.

The results show that 59% of the investigated companies have some form of defined preparation methodology, and that they continuously and repeatedly make exceptions to it. However, this does not necessarily have to be completely negative, since it increases the flexibility of the methodology. Only 19% of the investigated companies have a software based support system for the preparation process and the main reasons for having implemented it appears to be for enabling a holistic view of the process and for acknowledgement reasons. Fig 2 illustrates the distribution of the performed operations. 95% of the companies perform more than one operation, and 88% have at least one machining centre, meaning that most companies have experience of production preparation for more than one machining operation and have changing demands, products and preparation scenarios over time.

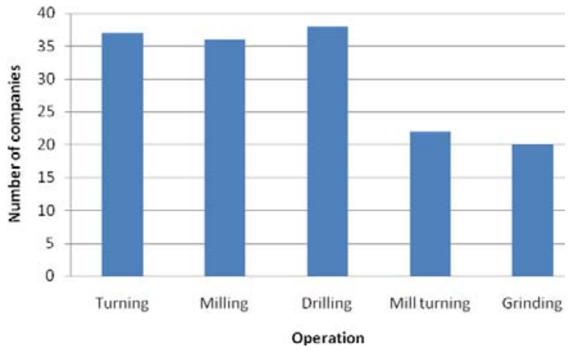

Fig 2: Operations performed by the investigated companies.

For the hypothesis testing, the machined materials were categorized under index 1 – *the complexity level of premises* and were individually categorized under certain material classes (see Fig 3) based on the material characteristics. A few of those (hardened steels, titanium alloys and stainless steel) were regarded as having lower machinability and were as such given more attention in the analysis. As already mentioned in chapter 1, these materials often cause more problems when machining, with respect to cutting data optimization and were thus analysed separately, in order to find whether they had any certain influence on the companies' usage of systematic work in the preparation process. This could however not be verified and did not appear to have any significant influence on increased usage of more systematic working methods.

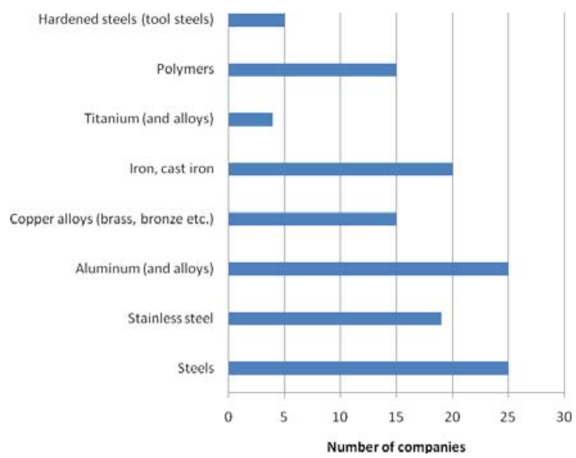

Fig 3: Distribution of machined materials among investigated companies.

3.1 Hypothesis testing

This section discusses the hypotheses that were tested in order to create an understanding of the situation in the Swedish metal working industry.

Hypothesis 1:

Companies with a more systematic preparation process, more often experience a higher efficiency than companies with less refined and systematic preparation process.

The industry's attempt to implement various quality management systems, which mainly are based on the philosophy of using more structured and systematic working methods in the production as means for improved productivity, can as well be transferred to the preparation process to improve its efficiency. As mentioned in chapter 1 this is already today being done to some extent. The usage of a systematic preparation process can thus be considered as an indication of the preparation process' efficiency potential. The result from this investigation presented in Fig 4 however, does not indicate such relationship between the two parameters. The Pearson product-moment correlation coefficient is 0,01, which means that no correlation exist between the two investigated variables. If such a relation would be supported, the data plotted would be distributed in a pattern around the hypothesis line.

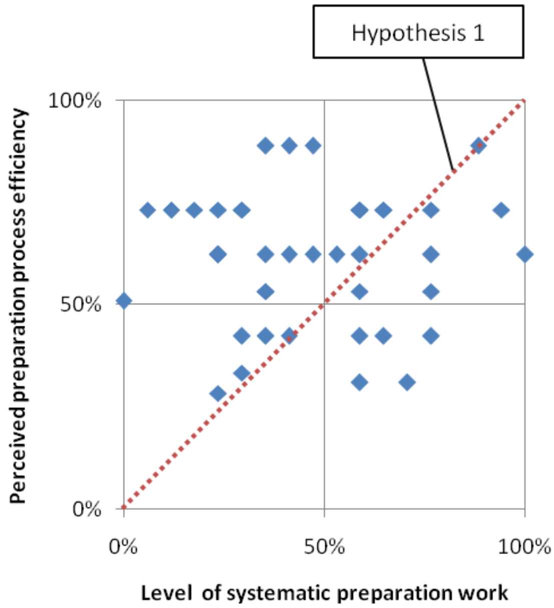

Fig 4: Plot over the perceived process efficiency as a function of the level of systematic preparation work. The dotted line illustrates the hypothesis.

Hypothesis 1 is generally supported, as mentioned in chapter 1, by academic theory, the PLM software Industry and the general tendency in the manufacturing industry to implement preparation methodologies and PLM solutions. The reason for it not being supported here must therefore be due to uncertainties and vaguely defined criteria for measurement of preparation process efficiency in the companies or that the IT systems in use are not fully utilized.

Hypothesis 2:

Companies with a higher complexity level of premises, more often have a more systematic preparation process than companies with a lower complexity level of premises.

Fig 5 shows the complexity level of premises in relation to the systematic preparation work, which is the level of systematic and organised preparation work according to a certain methodology within the company. The Pearson product-moment correlation coefficient is 0,2, which is a small positive correlation. Even though it is small, some validity to the hypothesis is given and an indication that companies with more complex production premises uses a more systematic approach in their preparation process in order to overcome some of the difficulties. Fig 2 shows the great dispersion of the plotted data, which implies difficulties in making any certain statements about the correlation in general.

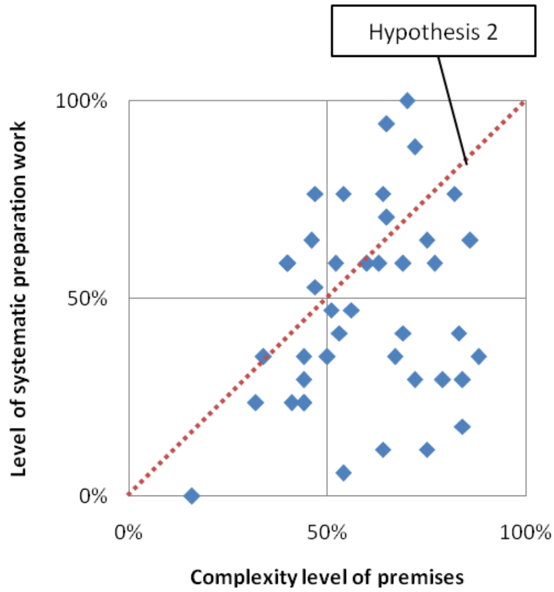

Fig 5: Plot over the investigated companies' complexity level of premises and the companies' level of systematic preparation work. The dotted line illustrates the hypothesis.

Hypothesis 3:

Companies with a higher complexity level of premises, more often experience higher preparation process efficiency than companies with a lower complexity level of premises.

Hypothesis 1 and 2 did not indicate any strong correlation between the studied parameters, and hence complemented with hypothesis 3 (see Fig 6) for testing if a relationship exists between the complexity level of premises and the companies perceived preparation process efficiency. The influence of the preparation situation for the companies' perception of the preparation efficiency is thus investigated. If an increased complexity level of premises correlates to higher level of systematic preparation work, and increased level of systematic preparation work is correlated to perceived higher preparation process efficiency, then hypothesis 3 should follow using logical argumentation.

The plot does not indicate that any clear relationship exists between the two parameters, since the data has high dispersion as seen in Fig 6. However the Pearson product-moment correlation coefficient in this case is 0,2, a small positive correlation, which gives some support to the hypothesis. The correlation coefficient is very small, so no definite conclusions can be drawn, but it is however interesting to notice that the companies that have a more complex production, tend to experience a higher perceived preparation process efficiency. To explain the potential reasons for this correlation is difficult, since it is not possible to refer the positive correlation back to hypothesis 2 and refer it to their increased tendency to have a more systematic preparation process, since this cannot be verified by hypothesis 1. The conclusion is thus that there must some other parameters to investigate than the ones presented here for a more comprehensive understanding.

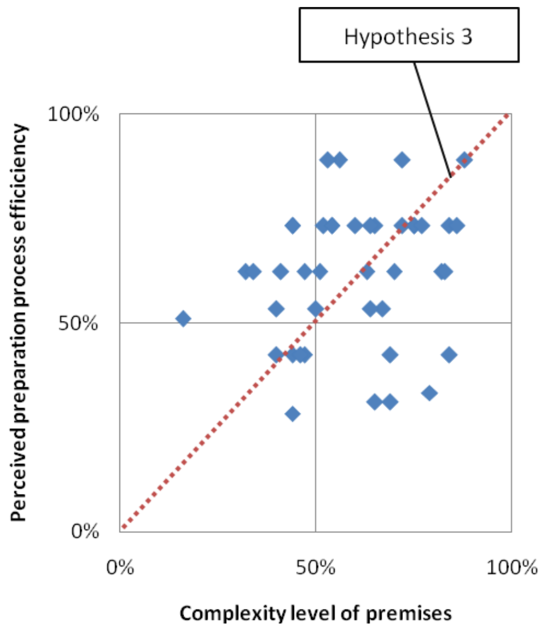

Fig 6: Plot over the investigated companies perceived preparation process efficiency as a function of the complexity level of premises. The dotted line illustrates the hypothesis.

3.2 Perception of efficiency as an efficiency measurement method.

Fig 7 shows that the majority of the companies regard their preparation process efficiency as good. However the response on the main reason for regarding the preparation process efficiency to be in a certain way, only one of the respondents, state that they have a preparation lead time focus and this company graded their company as less good in preparation process efficiency.

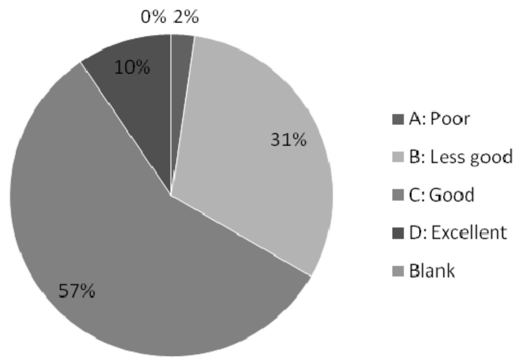

Fig 7: The preparation process efficiency as perceived by the company

A majority, 52% of the investigated companies as seen in Fig 8, state that between 26- and 50% of their production preparation time is consumed by information and data reconstruction. This is inefficiency in the preparation process with respect to information and data management. This implies that the majority of the investigated companies use a significant part of their resources without adding any value to its products, which leads to longer preparation lead times and higher costs.

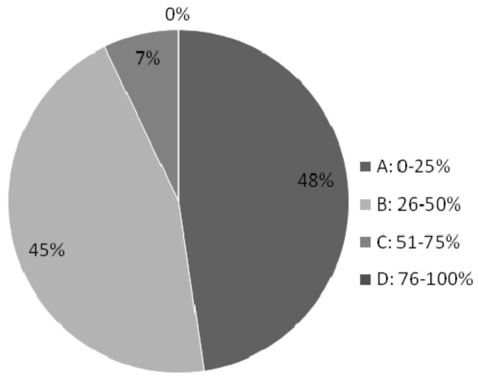

Fig 8: Percentage of preparation time dedicated to preparation information/data reconstruction.

As mentioned in chapter 1, Pejryd and Andersson [3] found when investigating the potential of implementing an engineering PLM system and ERP (Enterprise Resource Planning) system, a productivity increase of at least 20% when new working procedures and IT tools were used. This efficiency increase was only based on the production engineering work, finding data more easily, and eliminating data reconstruction etc. However, though not evaluated, productivity improvement potential was also seen in better operation instruction, which would lead to better product quality.

In analogy to the above, the efficiency improvement potential of the preparation process of the investigated companies, only counting the data reconstruction inefficiency, there is a potential of 27% for increased preparation process efficiency.

To understand the actual content of the perceived preparation process efficiency the answers are analysed using the response from the information and data reconstruction level in each company. Since this must be considered as a definite inefficiency and non-value adding activity, it can give an understanding of the companies' perception of their efficiency, when the two are related to each other. Fig 9 thus combines the results presented in Fig 7 and Fig 8. The figure indicates that 33% of the companies may overrate their efficiency, since there are 14 companies that claim to have good or excellent preparation process efficiency and at the same time state a data recreation percentage of 26- 50% or more. It appears in accordance to these figures that the companies have little knowledge about their own preparation work and their actual efficiency. None of the investigated companies state that they have any method to evaluate the preparation process itself. Some mention the communication and organizational platform as the reason for responding positively or negatively, while other uses the personnel's characteristics for performing better or worse with respect to perceived efficiency. This is a non-satisfying result that so many of the investigated companies have little knowledge about their preparation process performance, since it influences the possibilities for making improvements to the process.

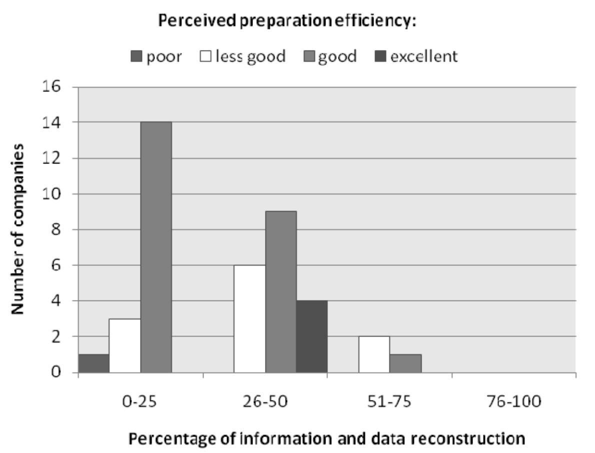

Fig 9: Combination of the diagrams displayed in Fig 7 and Fig 8.

3.3 Company size in relation to the perceived efficiency

Fig 10 indicates a strong tendency among the smaller companies (fewer than 100) employees) to be very positive to its preparation process efficiency, while bigger companies (more than 100 employees) to have a more critical stand towards their preparation process efficiency. This tendency can indicate that it is possibly in the medium size and bigger companies that the most benefit of PLM systems can be seen in a shorter perspective. This is true if their perception of low efficiency mainly is related to problems with coordinating and conducting the preparation process. Also, the results from the number of companies that claim to have some sort of PLM system, there appear to be none that run any of the more common ones, e.g. Siemens (Teamcenter), PTC (Product Development System), Dassault Systems (Enovia SmarTeam). However, among the sample of the investigated companies the ratio of the smaller companies that uses some IT support is merely the same as for the companies with more than 100 employees. The ratio is 18% for the companies with fewer than 100 employees and 22% for the companies with more than 100 employees. Interesting to note is that among the three companies that has more than 250 employees, none had any IT support system, which may explain why they claim to have less satisfying preparation process efficiency.

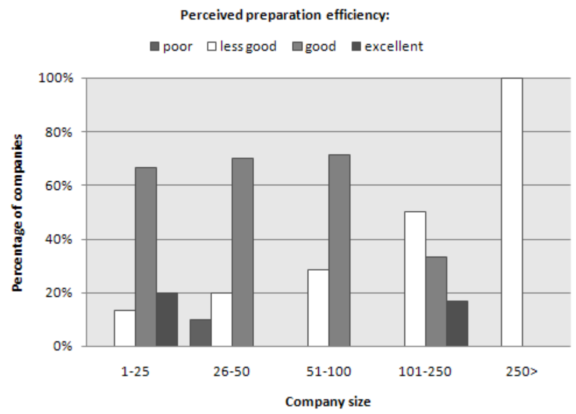

Fig 10: Percentage of companies categorized according to perceived preparation efficiency in relation to company size (i.e. no. of employees).

4. CONCLUSIONS

This investigation showed that 59% of the investigated companies use a defined production preparation methodology. However it is also apparent that none of the investigated companies have any objective measurements of quality or efficiency of the preparation process.

The company size, product complexity or production lead time flexibility have no unambiguous relationship to the level of systematic work in the preparation process, however the level of preparation premises (including the three parameters above) have a small positive correlation to the level of systematic preparation work. The survey also showed that there is a small positive correlation between the level of preparation premises and the perceived preparation process efficiency. There is no correlation observed between the level of systematic work in the preparation process and perceived preparation process efficiency, which implies that there must be other parameters that explain the investigated companies preparation process efficiency perception.

There is however a strong tendency for bigger companies to be more critical to their own preparation process efficiency than smaller companies. The perceived preparation process efficiency as used here, as the main measure of the preparation process efficiency, is not correlated with the preparation data reconstruction level. The data reconstruction level is a more objective measurement method of one of the components that influences the overall preparation process efficiency. Even though it is only a partial measurement of the preparation process, it has as shown here, a significant effect on the whole preparation process. This means that there is a high potential for efficiency improvements.

A majority of the investigated companies use a substantial part of their resources without adding direct value to the product, since the preparation process acts as a support activity and thus indirectly on the value chain [7]. This implicates longer preparation lead times and higher product cost. In the invested companies the overall potential for efficiency improvement was found to be 27%, using the companies own figures.

5. FUTURE WORK

As a validation of the questionnaire survey presented in this paper, a complementary investigation with a qualitative deep study of a limited number of companies should be performed. This to ensure that the results from the questionnaire correspond to the real situation, and if it does not reflect the actual situation, how can it thus be improved.

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