USABILITY OF A MANUFACTURING STRATEGY FRAMEWORK DEVELOPED FOR SMES

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Still, 45 years after Skinner's (1969) call for manufacturing strategies, explicit manufacturing strategies are scarse in manufacturing industry, especially in SMEs. Together with a number of SMEs, we have developed a manufacturing strategy tool, aimed at supporting manufacturing strategy formulation. In this paper, the focus is on requirements on a manufacturing strategy tool related to the usability in SMEs. Results from evaluation of the tool during development is presented. The resulting tool was considered to be useful to the participating companies, helping them to get over the initial treshold of working with manufacturing strategies.

Keywords: SME, manufacturing strategy formulation, usability.

1. INTRODUCTION

SMEs are the backbone of the European economy, being key driver for economic growth, innovation, employment, and social integration (European Commission, 2013). Of the 2 million enterprises, operating within the manufacturing sector in EU-27, 98 percent are SMEs, employing 20 million of the total 130 million people. European manufacturing industry is working under severe pressure, due to e.g. increased globalization and competition from low cost countries. It is essential that SMEs take full advantage of their capabilities and efficiently support the market needs (Hudson-Smith and Smith, 2007; Hudson *et al*., 2001). To obtain global competiveness, high manufacturing performance is required in the vast amount of manufacturing SMEs. The task for a manufacturing company today is to provide operations that support the factors that the company has chosen to compete with, which might be facilitated by means of a well-formulated and implemented manufacturing strategy (Hill, 2000).

Manufacturing strategy is usually divided into content and process. The content of manufacturing strategy is described in terms of competitive factors (order-winners and order-qualifiers) and decision categories (Skinner, 1969; Wheelwright and Hayes, 1985; Miltenburg, 1995; Hill, 2000). The manufacturing strategy process describes strategy formulation and implementation. Extensive work has been done to develop and refine the manufacturing strategy field (e.g. Hayes and Wheelwright, 1984, Hill, 2000; Hayes *et al*., 2004). Focus has been on the content of manufacturing strategies and less knowledge is available on the manufacturing strategy process (Dangayach and Deshmukh, 2001). Until now, mainly larger companies have been aware of the role of manufacturing for competitiveness and therefore formulated manufacturing strategies (Winroth, 2004). This situation is also reflected in academia and there is a lack of research on manufacturing strategies related to SMEs (Dangayach and Deshmukh, 2001; Barnes, 2002a and 2002b, Löfving, 2014). Knowledge on manufacturing strategies has to be made accessible and applicable also to SMEs and the approach taken here is related to the formulation of manufacturing strategies. Formulation of manufacturing strategy is often described in terms of a procedure (Hill, 2000), methodology (Platts, 1994) or framework (Miltenburg, 1995; Mills *et al*., 1995). Despite the vast amount of suggested frameworks, the usability of these is seldom considered. There are of course a few exceptions. Common characteristics of strategies have been identified and grouped into procedure, participation, project management, and point of entry (Platts, 1994). Many of these characteristics focused on organisational aspects and less focus was linked to the actual framework aimed at developing the strategies. With a starting

point in identified characteristics of successful formulation (Platts, 1994), Löfving *et al*. (2014) suggested a set of assessment criteria categorised into procedure (e.g. simple and easy to understand, specific steps, etc.), realisation (e.g. participation, resourcing, etc.), and contextual issues (e.g. company size). Apart from issues related to the procedure of using a framework and contextual issues, usability also includes aspects related to the achieved result (ISO 9241-11, 1998). Therefore we have further elaborated on previously presented assessment criteria. In this paper, focus is on requirements on a manufacturing strategy framework related to the usability for SMEs. A categorisation of requirements, including aspects related to the achieved result, is proposed and the possibility to fulfil these requirements during the development of a manufacturing strategy framework is discussed.

The rest of the paper is structured as follows. In the theoretical background we start with a short note on the unambiguous terminology used to denominate frameworks, tools, etc. Thereafter, theory from adjacent areas concerning usability is presented, followed by issues specifically related to usability of manufacturing strategy frameworks. The theory section is followed by a description of the research methods and techniques used for data collection, and the case descriptions. After that, the results are presented, in terms of a categorisation of usability requirements and some results from applying these requirements during the development of a manufacturing strategy framework. The paper ends with a brief discussion and some conclusions.

2. THEORETICAL BACKGROUND

2.1 A note on some of the terminology

In this paper focus is on formulation of manufacturing strategies and specifically on the usability of manufacturing strategy frameworks for SMEs. The terminology, describing the tools, methods, and frameworks, used to support manufacturing strategy formulation, is certainly not uniform. We define a tool as an implementation of a method (i.e. a systematic and prescribed way or practice of achieving certain ends with accuracy and efficiency) to be used for a specific purpose, an operationalisation in for example a software program, according to Johansson and Säfsten (2014). A framework is considered to be an overall concept, potentially including both tools and methods, and a description of a procedure of steps to follow. A framework is a structure that guides objects of a system to perform something useful for the user. A framework answers the question "how to" and provides an overall way forward (Yusof and Aspinwall, 2000).

Usability of a manufacturing strategy framework is one of the aspects that need to be considered if a framework should contribute to making manufacturing strategy accessible and applicable to SMEs. Usability, referred to as a measure of the success of a software, computer system or product, is commonly discussed within areas such as human-computer interaction, man-machine interaction, ergonomics, etc. (Nielsen, 1993). In this context usability is defined as "*the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use*" (ISO 9241-11, 1998). According to the same standard, effectiveness refers to the accuracy and completeness with which the users achieve specific goals, efficiency refers to the resources expended in relation to the accuracy and completeness of goal fulfilment, and satisfaction refers to freedom of discomfort, and positive attitude to use of the product. Other attributes of usability mentioned in usability engineering are learnability and memorability. Learnability means that the system should be easy to learn so that the user rapidly can start work with the system and memorability refers to the that the system should be easy to remember so the user easily can return to the system after some time not using it, without having to re-learn everything (Nielsen, 1993).

2.2 Usability of frameworks and tools in general

An area, frequently using various frameworks and tools, is product development (Johannesson *et al.*, 2004; Norell, 1992). Three main reasons are given to why methods are useful in the context of product development (Ulrich and Eppinger, 2008). First, it is pointed out that methods make the decision process explicit, which helps the team to understand the decision rationale and reducing the possibility of moving forward without supported decisions. Furthermore, a method serves as a "checklist" for activities the team has to do, and consequently reduces the risk that essential issues are forgotten. In addition, structured methods are to a great extent self-documenting. That is, when the method is used by the team, the decision-making process is documented and made available for future reference.

Only a few studies have addressed which features methods should possess to contribute to product development, despite the common use of various support methods. Norell (1992) studied required features on support methods such as Design for Assembly (DfA), Failure Mode and Effect Analysis (FMEA), and Quality Function Deployment (QFD) in product development, and concludes that methods should:

- Be easy to learn, understand, and use
- Incorporate accepted, non-trivial knowledge, within the area of interest

- Give support in finding weak spots
- Useful for several professions and thereby contribute to the establishment of common frames of reference
- Support cooperation and have a learning influence on the users
- Contribute to a systematic way of working
- Give a positive and preferably measurable effect on the project work within the product development process, within the area of interest

2.2 Manufacturing strategy frameworks suitable for SMEs

SMEs vary in their manufacturing strategy maturity, which to some extent could be the consequence of them acting in different industrial arenas with varying requirements, traditions, and values. Furthermore, the use of supporting tools or frameworks seems to be limited (Säfsten and Winroth, 2011a and 2011b). One problem may be that existing frameworks are too complicated to use in SMEs (Säfsten and Winroth, 2002). Most of the existing frameworks are developed for larger companies and research on manufacturing strategy formulation in SMEs is still limited (e.g. Barnes, 2002a; Löfving *et al*., 2014). Based on a thorough review of the advantages and disadvantages of the specific features of SMEs, certain characteristics of a framework that is applicable and suitable for small businesses were identified. A framework applicable to SMEs should: be systematic and easily understood; have a simple structure; have clear links between elements that are presented; be general enough to suit different contexts; represent a road map and a planning tool for implementation; answer `how to?' and not `what is?'; and finally it should be implementable (Yusof and Aspinwall, 2000). In addition, Hudson *et al*. (2001) conclude that a strategic development process in SMEs has to be resource effective, produce short-term and long-term benefits, and also be flexible and dynamic enough to accommodate changes that might occur due to e.g. emergent strategies. In Löfving *et al*. (2014), 15 manufacturing frameworks were assessed and it was concluded that no framework fully fulfilled the requirements raised by SMEs. The criteria used to assess the frameworks were grouped into procedure (e.g. simple and easy to understand, specific steps, etc.), realisation (e.g. participation, resourcing, etc.), and contextual issues (e.g. company size) (Löfving *et al*., 2014), partly following the criteria suggested by Platts (1994).

3. METHOD AND MATERIAL

The research presented in this paper follows a two-phase logic and in this paper focus is on the results from the latter. As a foundation for the research, a case study methodology was adopted (Yin, 2009). A deeper understanding was required concerning manufacturing strategy formulation and maturity in SME. It was also necessary to understand the current use of frameworks, and the requirements on frameworks to be considered as useful in SME. Four manufacturing companies were selected based on a replication logic (Eisenhardt, 1989). Two of the companies were SMEs (Company Casting, Company Aluminium) according to the definition by EC[1] and the other two were small and medium-sized plants within international groups (Company Automotive, Company Outdoor). Data were mainly gathered through interviews with key informants, complemented by documents and archival data (Yin, 2009). During the initial phase, interviews were carried out with 25 key respondents (5 at Company Automotive, 5 at Company Aluminium, 8 at Company Outdoor, and 7 at Company Casting). The respondents included managing director, production manager, sales responsible, production engineer, engineering designer, quality manager, etc. The interviews lasted between 1 and 2 hours. All interviews were transcribed before analysis. Analysis was made based on the initial areas of interested, articulated in an interview guide. The result was fed back to the companies, and confirmed among the participants, during a workshop. The companies identified and initiated a number of development activities as an outcome of the feedback workshops (for more details see e.g. Löfving, 2014).

The second phase included the development of an easy-to-use framework; an activity initiated by the research team and carried out in parallel with the development activities in the companies. The development of the framework and the result thereof is further described in e.g. Winroth *et al*. (2013) and Säfsten *et al*. (2014a and 2014b). During the development, the perceived usability of the framework was evaluated, following a normal procedure for usability tests (Nielsen, 1993). The main purpose with the evaluation was formative, i.e.to provide guidance on further improvements (Patton, 1990). The evaluation included the requirements raised by the companies during the initial interviews combined with more general requirements as well as specific usability requirements on frameworks for manufacturing strategy formulation. In total 13 questions (Q1-Q13) were asked, combining closed- and open-ended questions. The closed-end questions used a 7-graded Likert scale, ranging agreement from "not at all" to "to a high degree", and was treated as interval-level measurement in the analysis (Norman, 2010). Two of the questions (Q5 and Q6) included three sub-questions (a, b, and c) and one question

[1] Headcount <250, Turnover ≤ € 50 million or Balance sheet ≤ € 43 million, and not owned by another company to more than 25 % (European Commission, 2003 and 2005).

(Q7) had two sub-questions (a, b). The questionnaire had a formative purpose and all of the questions had space for comments. In total three different versions of the framework were formally evaluated by the companies and in total 16 evaluations (16 respondents) were carried out with the questionnaire. In addition, we had adjacent discussions and wrote down the raised suggestions for improvements and included them as far as possible in the development of the framework. Gradually a suitable framework evolved. The final version of the framework was implemented in Excel (called the STRATEGO-tool since we refer to the actual implementation in Excel). The entire STRATEGO-framework consists of the tool in Excel and a collection of guidelines to be used when formulating the manufacturing strategy (Säfsten *et al*., 2014a and 2014b).

4. CASE DESCRIPTIONS

Below the four companies are briefly presented, together with their requirements initially raised on a tool to be considered as useful.

Company Automotive. Company Automotive was a self-managing unit, making components to the automotive industry, within a major company group. The company acted as an independent small company. They did not have much in common with the company group, apart from some common sales resources. They did however have a demand from the company group to grow 10 per cent annually. Marketing and product development were perceived to be in focus, thus with a minor interest for production. They were quite dominant on the market and had almost all major car manufacturers as customers, based on three patented product groups. Very few tools were used. For tools to be useful it was required that they were simple, easy to use and to understand, easy to communicate, and not time-consuming. Paper was perceived as a better medium than computer software. They would also like to have support for various decisions concerning manufacturing strategic choices, such as level of automation, material handling, and cell layout.

Company Aluminium. Company Aluminium was one of two companies in a small group. Final customers were automotive industry, machining industry, furniture, telecom, and electronics. The company worked continuously with their business plan. Their core competencies were described as profile bending, CNC-machining, and welding, which also was described as part of their main strategy. Another competitive factor was the high degree of flexibility and the competence to perform all kinds of jobs on aluminium extrusions. The strategy was to not compete on very high volumes at low cost, but more on flexibility and a good mix which the larger competitors were not very interested in. The business plan was assessed once a year and revised if necessary. For a tool to be useful they required that it was simple, and easy to understand. It also had to be easy to visualise, both the actual work and the results. Tools were perceived as important to gather different employees. With support from a tool they perceived that they could synchronise people and make different things explicit.

Company Outdoor. Company Outdoor was part of larger group making outdoor equipment. The studied plant was quite independent and described themselves as a factory-within-a-factory with about 300 employees. The company had a tradition of being product oriented, with strong focus on the technology related to their products. Recently a change of focus was perceived, mainly due to the introduction of the new operating system. They had clearly formulated and implemented manufacturing targets, which were followed up on a regular basis. They worked actively towards these targets, although the strategy to reach the targets was unclear. A prerequisite for a tool to get impact was that it was requested either by management or by a customer. Tools had to be simple, easy to use, and easy for everyone to understand. For the actual work with a tool, paper was preferred before computers. Computers were however advocated for the dissemination of results. The result should be indicative, suggesting e.g. type of flexibility required. Furthermore, it was emphasised that the result had to be objective, unambiguous, and concrete.

Company Casting. Company Casting was an old foundry with two business areas. Their competitive priorities were mainly linked to delivery precision, quality, and customer relations. Manufacturing strategy was partly, and mostly implicitly, discussed in the management team. So far, the company only had a few competitors and a comfortable margin, and therefore the requirements on improvement had been limited. However, during the last three years, extensive investments had been made in production equipment and the possibilities to expand to new markets were discussed. When it came to tools, the use in general was quite sparse at Company Casting. According to the respondents, the company had no tradition of using various tools. To be useful, tools had to be simple, easy to use, and not time-consuming. The result had to be valuable, useful, and ready for implementation. Visualisation was important, and computer software was perceived as a suitable form. The use of the tool should generate some learning.

5. RESULTS

5.1 A comprehensive set of requirements for usability

Based on the case studies and the literature presented above we found a number of requirements on frameworks relating to their usability in SMEs. The identified requirements could be grouped in different ways, see e.g. Platts (1994). In this paper we have elaborated on the three groups of assessment criteria suggested in Löfving *et al*. (2014): procedure, realisation and contextual issues. The main reason was that we wanted to include requirements reflecting the outcome of using a framework. For example Norell (1992) points out that a method should support co-operation and have a learning influence on the users, requirements also mentioned by the case companies. Requirements mentioned on a framework were related to the actual result, i.e. the developed manufacturing strategy, and to effects from using the framework. The suggested categorisation of requirements includes Realisation/process, Tool characteristics, Results, and Effects, see Figure 1.

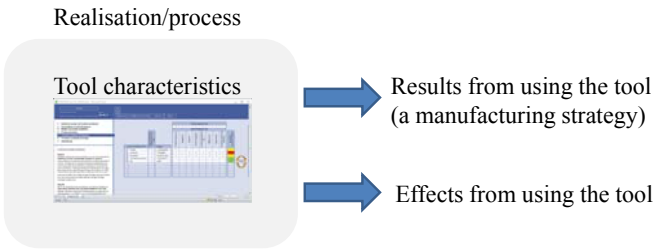

Fig. 1. Categorisation of usability requirements.

For an overview of the included requirements raised by the companies during the initial interviews, general tool requirements as well as specific usability requirements on frameworks for manufacturing strategy formulation, see table 1.

Table 1 Requirements on a manufacturing strategy framework suitable for SME.

Tool characteristics	**Realisation/process**	**Result**	**Effect**
simple to learn, understand and use[2,3,5]	participation from several functions[2,5]	results that can be applied in practice	explicit decision process
visual[5]	support a systematic way of working	unambiguous	act as a checklist – nothing is forgotten
include guidance[5]	agreed timeframe[4,5]	visual and easy to communicate[5]	self-documenting[4,5]
systematic[3]	agreement on required resources[4]	support decsions[5]	learning among participants[2]
focus on 'how to'[3]	quick[5]		make people work in the same direction[4]
implementable[3]	a decription of the process/steps to follow[4,5]		
suitable for different sectors and contexts[3,5]			
clear links between different parts[3]			

[1]Ulrich and Eppinger (2008), [2]Norell (1992), [3]Yusof and Aspinwall (2010), [4]Platts (1994), [5]Case studies

The perceived usability of the developed framework

During the development of the before mentioned STRATEGO-tool the perceived usability was regularly evaluated. The evaluation included questions related to all four of the identified categories, see Table 2, and two questions covered all areas (Q12: What could be done more to further improve the suggested version of the tool?, Q13: Other comments).

Table 2 Categorisation of questions asked when evaluating the manufacturing strategy tool during the development .

Tool characteristics	Q2: Do you consider the tool to be easy to understand? Q3: Do you consider the tool to be easy to use? Q4: Is the tool designed in a way making it possible to use without support from the research team?

	Q6a: Is the tool designed to contribute to formulation of manufacturing strategies? Q6b,c: What is the main advantage/disadvantage with the tool when formulating manufacturing strategies? Q11: In what format (paper, excel, other) would you prefer a final version of the tool?
Realisation/ process	Q8: Do you consider the time required to carry out analysis reasonable? Q9: Can the tool support cross-functional formulation of manufacturing strategies? Q10: Can guidelines support formulation of manufacturing strategies?
Result	Q5a: Does the tool provide a clear analysis of the curremt position? Q5b,c: What is the main advantage/disadvantage of the tool when analysing the current position? Q7a: Does the result format support further work with manufacturing strategies? Q7b: Can the result be communicated with employees in an easy way?
Effect	Q1: Did the tool contribute to your understanding of manufacturing strategies?

Focus was to provide input for further improvements during the development and therefore less effort was put into the effect category. However, several of the respondents mentioned issues related to effects that were perceived already during the test-sessions, see also table 3 where the results are presented. In table 3, the average value (on the scale from 1 to 7) is shown for each question with closed-end questions, open-ended answers and comments are also presented. Sometimes the same, or very similar, answers were received from more than one respondent, in table 3 we only present each unique answer.

Table 3 Results from the evaluations during development of a manufacturing strategy framework suitable for SME.

Category	**Closed-end questions**	**Open ended questions and comments**
Tool characteristics	Q2 (easy to understand): 4.41 Q3 (easy to use): 5.0 Q4 (independent use): 4.41 Q6a (contribute): 5.41	Q2 (comment): the instructions can be better, with better instructions 6 (*refers to the 1-7 scale*) Q3 (comment): logically designed, clear line of though in the instruction Q6b (advantages): gives a comprehensive picture which facilities decision, support discussion, support prioritization, creates engagement, forces us to find data and information Q6c (disadvantages): black/white – reality is more complex, other things a guiding, different perspectives Q11 (format): computer, Excel and paper was mentioned, with strong dominance for Excel and computer
Realisation/ process	Q8 (time): 6.00 Q9 (cross-functional): 5.82 Q10 (guidelines): 5.5	Q10 (comments): always good with suggestions and new ideas
Result	Q5a (current): 5.35 Q7a (further work): 5.25 Q7b (communicated): 4.88	Q5b (advantages, current position): the visualisation, focuses a management team, quantify in group, forces to discussion, weight importance/difficulty, cretaes discussions, creates a structure for discussions, you get a result quickly Q5c (disadvantages): sometimes difficult with the definitions, a lot of red cells is difficult to interpret, a lot of red cells gives a negative signal, has to be more self-instructive, dificult to uderstand the first time-easier second time and onwards, reality is a bit more complex
Effect	Q1 (understanding): 5.0	
Overall questions		Q12 (improvements): more details in the instruction (the far most common suggesteion for improvement), examples, suport for how to interpret the results, a more visual interface with guidance on how to fill in the cells Q13 (other comments): a manufacturing strategy has to be aligned with the company´s vision, goal, ambition, etc., the tool needs some improvements but can for sure be valuable for a company not used to working with strategies

6. DISCUSSION AND CONCLUSION

Among the requirements on manufacturing strategy frameworks mentioned by the companies, the most commonly mentioned where: simple, easy to use, understand and communicate, and visual. Another important requirement was time and the companies were explicitly worried about too high time-consumption. Another group of requirements was related to the outcome, i.e. the expected and preferred result from using a manufacturing strategy framework. Guidelines for making various choices were requested, as was useful results possible to implement. A framework was also expected to gather employees, and to create unity and a common goal. The final version of the STRATEGO-tool was perceived as useful. The empirically raised requirements were similar to the features found relevant for other support methods (e.g. Ulrich and Eppinger, 2008; Yosuf and Aspinwall, 2000). Several dimensions have to be considered when developing a manufacturing strategy framework. Raised requirements are concerned with dimensions such as the actual work procedure, the framework, and the outcome of the work both in terms of result and effect. Based on this we proposed a categorisation of various requirements: Tool characteristics, Realisation/Procedure, Result, and Effect, i.e. adding Result and Effect to the categories presented in Löfving *et al*. (2014). The suggested categories are related to the attributes of usability suggested by Nielsen (1993). Usability alone is not a guarantee for successful and broad use of use a manufacturing strategy framework, or of any other method or tool. According to Nielsen (1993), usefulness of a computer system, besides usability, involves whether the functionality of the system can do what it actually was intended to, i.e. utility. Other aspects also affecting practical acceptability includes cost, compatibility, reliability, etc. In the research presented here, we have not focused on the utility of the resulting manufacturing strategy. Previous research has for example evaluated manufacturing strategy in terms of the contribution from manufacturing to competitive advantage (Hayes and Wheelwright, 1984; Hayes *et al*., 2004). This is of course very relevant to consider, but at the same time associated with some difficulties.

A relevant concern is the relevance of the evaluations carried out. Three different versions of a tool was evaluated, involving a limited number of respondents. The first test (version 2.1) included 4 respondents, the second version (3.0) 9 respondents, and the third version (version 3.1) 4 respondents. However, previous research has shown that elaborate usability tests are a waste of resources. After 5 tests 85% of the usability issues are normally found. The best results come from testing no more than 5 users and running as many small tests as you can afford (Nielsen and Landauer, 1993).

At the end of the project, of which the development of the tool was one part, the participating companies had gained an increased maturity concerning manufacturing strategies. Two of the companies had implemented manufacturing strategies, developed with various versions of the tool (the STRATEGO-tool). In a comparison between the developed framework and other already existing frameworks, there are both similarities and differences. One difference is the relatively extensive description of competitive priorities and decision categories in the STRATEGO-tool. Another distinct contribution is the guidelines, providing ideas on *how* to proceed *when* with different activities. These additional features correspond to the need perceived by the participating SMEs. However, the final version of the STRATEGO-tool was not yet been systematically evaluated. The comments received so far are though very positive. One of the managers said, "*all of our comments seem to be taken care of*". It also seemed that we had been able to overcome most of the criticism related to Q4 (Is the tool designed in a way making it possible to use without support from the research team?). The final version implemented in Excel was perceived as straightforward and easy to use. The STRATEGO-tool will be used in master programmes and further evaluated and distributed to a number of companies outside the former research project.

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