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REDUCING LEAD TIME IN CUTTING TOOL DEVELOPMENT BY IMPLEMENTING BLITZ QFD®

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ABSTRACT
A cutting tool producer aims to reduce the lead time from finding customer needs to achieving peak sales. There are many approaches to improving a company's new product development process in bits and pieces, but a more thorough impact is accomplished with a chain of well integrated methods in an educational package including certified skill levels. A modified version of the well known but sometimes misunderstood process, Quality Function Deployment (QFD), can fulfill the above aim. QFD is used by companies to better understand the spoken and unspoken customer needs their priority and translate them into product requirements, assuring quality throughout the design, manufacturing, and after-sales phases. Its traditional tool set focused on time consuming matrices, called houses. In today's lean businesses, the resources available to do this depth of analysis are reduced, and so more efficient methods have been introduced by the QFD Institute under the guidance of Dr. Yoji Akao, the founder of QFD. This paper will introduce some of the modern Blitz QFD® methods and discuss their impact as they have been applied to improve the product development at Sandvik Coromant.

Keywords: User orientation, Usage and integration of supportive technologies, QFD, Product development models and strategies, cutting tools, AHP

1 INTRODUCTION
Sandvik Coromant is a leading manufacturer of metal cutting solutions with worldwide presence. The main products are drills, turning and milling tools with interchangeable coated tungsten carbide inserts. Also tool holding equipment including dampened variants is offered to satisfy demanding customers in a variety of machining applications in different industries. The company has put forward a goal to reduce by half the time from identifying customer need to achieving peak sales. The company has had a long history of innovative products which has been the key to firm's success. Shortening the above mentioned lead time while still offering innovative products is seen as the way of increase earnings even more [1]. Blitz QFD® from the QFD institute has been used in two development projects to see if there is evidence that the method can be a part of the solution to making Sandvik Coromant achieve this goal. This paper aims to describe why Blitz QFD® was chosen, the implementation of it, the results achieved to date, and further elaborate on future influences. The authors believe that the experiences made at Sandvik Coromant together with the QFD Institute when pursuing the goal of reducing overall lead time are valuable both to academia working with design processes, methods, and tools for industry as well as for the industrial practitioners directly.
For many years, there has been an interest in making product development practices more foreseeable and plan able [2]. Sandvik Coromant has used a Stage-Gate® [3] product development process for several years. The process consists of predefined milestones and decision points which state what deliverables need to be available at different critical points in time. The process has not been well supported by methods and tools in a structured way. Activities such as definition of project goals, internal stakeholder analysis, establishment of a time plan, risk and consequence analysis among others and at what milestones they should be accomplished are stipulated by the process. Most of these activities are introspective and about project management with respect to time and cost and do not primarily drive innovation and focus on the customer. Furthermore the methods to be used to make the above activities and how they are actually being used depend on the individual project leader.
In order to improve the product development practice with respect to innovation, customer focus and lead time a common baseline and focus outward is needed. An improvement is an improvement relative to something; having a common baseline makes it possible to improve the above mentioned

stepwise (in a Kaizen manner). The vision is commonly understood baseline containing a process with methods supporting each process step and tools which support each method, everything in a seamless manner from seizing a market opportunity to a satisfied customer. This paper describes some experiences on the way to achieving this baseline.

1.1 Selection of Design process, methods and corresponding tools

Different product development processes have been suggested such as the classic process by Pahl and Beitz [4] or the development strategy framework of Wheelwright and Clark [5] to mention a few. Pahl and Beitz's process starts with the clarification of tasks which is about finding what customers need. We believe that the transition between what the customers really need and what can be expressed in a document containing tasks to fulfill is not at all straightforward and there is easily a loss of information about what the customer needs. Pahl and Beitz do not explicitly describe how this step is to be made or suggests any method. Wheelwright and Clark shows a development funnel where both technology assessment and market assessment and forecasts for these are put forward. The technology assessment is basically what can be done and what can be done in the future, the market assessment has to do what customers need today and what they will need in the future. Although also stressing the need for market insight, Wheelwright and Clark do not present any structured approach of how to find the needs, to actually make the market assessment, or how to transfer that information into the development organization. Both these approaches have their merits and would have the potential to help Sandvik Coromant in achieving part of the goal of significantly reducing lead time. However the successful implementation of a process, supporting methods and tools in a large company leading to a common baseline regarding the product development practice does not only depend on the merit of the a particular process or an individual method or tool but on a complete, solid and adapted educational package integrating process and methods [6].

1.1.1 The need of an educational package and its implications on selection of a process, methods and tools

An educational package can be developed in-house from scratch by fitting product development methods and tools from industry and or academia to the company's product development process if there is one at hand [7]. Furthermore, trainers have to be trained and educational material developed. This is like making part of an engineering curriculum in-house and a rough estimation has been made by the authors to conclude that making a draft of such package would need at least six man months by someone already proficient in engineering design methods. To validate the package by using it in different product development situations and refine it would add to that time especially since industrial size product development projects normally run for years. Furthermore in times of more and more focus on certification and documentation of knowledge a certification system coupled to the educational package is valuable. That is, what level of knowledge does a certain course give the participants, how is that assured – for example, are there mandatory exercises to be completed? It is to the discretion of each company to decide whether it has the necessary personnel, stamina and time to develop and validate its own educational package from scratch, or to hire external consultants. Sandvik Coromant found out that the QFD Institute has developed an educational package that they adapt to circumstances and a corresponding certification system, and they then decided to hire a trainer from this institute. As the name suggests, the QFD Institute works with QFD i.e. Quality Functional Deployment.

1.2 Why QFD and why in particular Blitz QFD®

Sandvik Coromant first attempted QFD in its product development process several years ago, and this effort yielded huge matrices which albeit giving valuable insight, were judged as to cumbersome to use. The QFD institute, put forward that true QFD, either Blitz QFD® or traditional QFD, does not require the use of matrices - it is about driving quality throughout the whole process; with quality defined as providing usefulness to the customer. It is also about aligning the effort of every part of the organization to contribute to satisfying the customer needs. In fact, the Japanese translation of QFD means that quality (as defined by the customer) must be deployed across all relevant business functions. Thus, there can be no QFD without a customer focus. What Blitz QFD® does is to channel efforts to focus on a small number of the most important customer needs and see that they are applied throughout the entire development process until the customer is satisfied with a delivered product and

after sales service. The philosophy is that by boosting the focus on the most critical customer needs and letting the others be taken care of "as usual," customer value and satisfaction will raise leading to a greater willingness to purchase the product. Traditional QFD is about keeping track of all customer needs throughout all the processes, and because it is comprehensive, it requires a greater effort. Traditional QFD has the potential to boost customer satisfaction even more than Blitz QFD® but not every organization has the resources to pursue such an effort. Starting with Blitz QFD® is a sensible way for today's companies to learn what it means to align their efforts around customer focus.

2 RESEARCH METHODOLOGY

The research methodology adopted to perform the study and the change in product development practice was Participatory Action Research (PAR), see [8]. Two of the authors participated as product developers during the implementation of Blitz QFD® in the pilot projects (alpha and beta), while at the same time reflecting on the impact of this implementation and keeping a continuous dialogue both with the trainer and the other team members regarding the content and adaption of Blitz QFD®. The trainer from the QFD Institute (the third authors of this paper) trained two development teams while the two other authors acted as facilitators dedicating time and effort to helping the teams during the days between the two training weeks. Participatory action research is cyclic and this paper describes going into the first cycle. It follows Shewhart and Deming's quality improvement model of PDSA (Plan Do Study Act) [9]. The need to improve the development practice had already been identified at the company when the QFD Institute was asked to make a first adaption of the QFD process to the management style and products of Sandvik Coromant. The adapted process has now been tried at the company and this paper describes the impact so far, i.e. the *Do* and *Study* phases. A core principle of Blitz QFD® is that there is no one-size-fits-all technique and that the methodology's tools and flow should be adapted to the needs of each company, much like proposed by Meissner and Blessing [7]. It is typical for an outside trainer to facilitate the first project and simultaneously train dedicated internal people who will continue to apply Blitz QFD® on additional projects. In this way, the company learns the method and how it should be adopted to specific situations. Successfully implementing and adapting Blitz QFD® is hence in line with performing PAR.

2.1 Success criteria and measurable criteria

The ultimate goal or success criteria of the change in product development practice is to reduce the lead time from finding customer needs to peak sales and satisfied customers. Furthermore, to stay competitive in the long run the solutions satisfying the customers should be innovative and patentable. To actually measure the impact of a process like Blitz QFD® on the above ultimate goal is difficult; first, the time span that should be reduced is long, several years, and second, other factors like business climate and competitor's moves also have a great influence. The concept of measurable criteria from the Design Research Methodology (DRM) proposed by Blessing and Chakrabarti [10] is used here. The idea behind the DRM is to establish a plausible link between success criteria and measurable criteria. The effect of a change on measurable (sensible and proportional to the actual change) criteria can then be seen and conclusions regarding the success criteria drawn at an earlier stage. The measurable criteria in this twin case study [11] consisting of two full size pilot cases are based upon experience from earlier product development projects at the company. The following measurable criteria have had a beneficial effect on lead time and innovative solutions:

1. A shared knowledge of the aim of the project aligns and motivate the people involved in the project
2. Shared knowledge throughout the organization of what the customer need and understanding of the conditions of use aligns the development as well as introduction and sales efforts
3. A shared vision of the relation between needs and technical characteristics, i.e. what characteristics are most critical in the product to develop eliminate contradictory development
4. A multitude of solution alternatives at an early stage followed by rigorous selection reduces the risk of running of with the first idea and pushing into a dead end
5. An early recognition of possible difficult challenges regarding manufacturing reduces the risk of bad surprises late in the process.

3 PILOT PROJECTS

Blitz QFD® was tested in two full size product development projects at Sandvik Coromant which is needed to see if a new process has the potential to improve practice in a large company [12]. The core project teams for each of these two pilots consisted of totally eight persons from the product development organization, two from production, one person representing marketing, and one project leader for each project. Two of the authors acted as apprentice facilitators under guidance from a trainer from the QFD Institute one in each team for the implementation of Blitz QFD®. It is hard to find the perfect timing in an industrial setting, budget for education, available projects, and availability of the facilitators and the trainer all need to coincide. The company decided to run the pilots at a specific moment when these factors seemed to coincide at least to a for the company acceptable level. The Alfa project dealt with a hole making solution based on tungsten carbide drills. The project was in it early stages and hence it lent itself very good for being a Blitz QFD® pilot. The main focus of Alfa was to find the customer needs and their priority hence the first stages of the QFD process were most appropriate. The Beta project was about the design of a threading turning system based on interchangeable coated tungsten carbide inserts. This project was to adapt an existing system to a smaller insert so the solution was very much decided by the existing system design. Because the status of the project it was late to expect big changes by implementing Blitz QFD® or any new process. However the team was eager to learn the process for making smaller changes and also for indicating future upgrade possibilities of the system. Because of the timing of the pilots the focus was on the early parts of the process, exploratory and selection methods were however tried to some extent, see 4.9 and 4.10.

4 IMPLEMENTING THE CUSTOM TAILORED BLITZ QFD® PROCESS

As earlier mentioned Sandvik Coromant has put forward a goal to reduce by half the time from identifying customer need to achieving peak sales. A representative from the QFD Institute first made a diagnosis and a tentative adaption to the Blitz QFD® process to custom tailor a subset of methods to comprise Sandvik Cormorant's minimum QFD effort, see Figure 1. One quick reference guide and two extensive course binders with examples from other industries but also with realistic examples from the area of metal cutting was a provided by the institute and used as material in the Blitz QFD® training. The training at the company consisted of an orientation QFD Gold Belt® briefing for top management, a primer i.e. the QFD Green Belt® course using the quick reference guide and the complete QFD Black Belt® course using the comprehensive body of knowledge binders. All this constitutes the aforementioned educational package and training that the authors believe to be a necessary but not sufficient condition to make an impact on the product development practice in a large company.

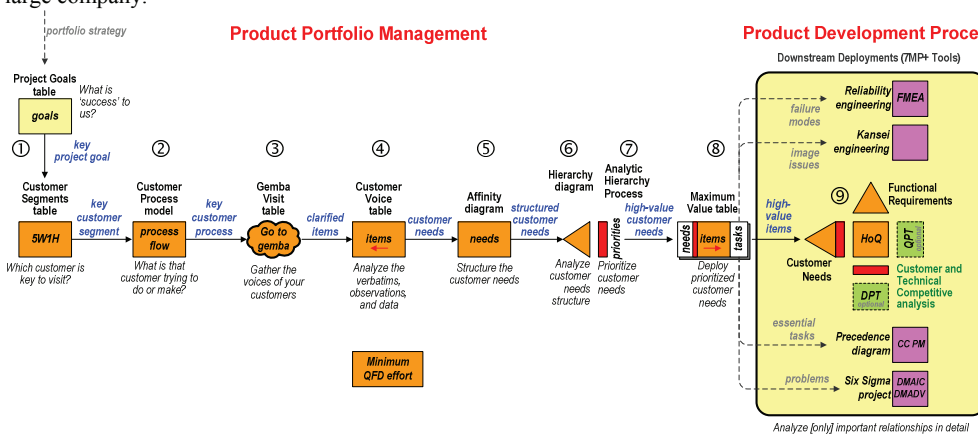

Figure 1. SANDVIK COROMANT'S CUSTOM TAILORED BLITZ QFD® PROCESS

In the following sections, a brief description of each method in the process in Figure 1, and their use in the pilots is made. One of the principal strengths of the QFD process and the educational package is that the output of one method is consistent with the input to the next, if properly executed the

information is flowing and gets refined throughout the process thus enabling alignment of effort, meaning that everyone works in the same direction enhancing the fulfillment of criteria #1 to #3 in section 2.1. This way information is preserved and refined instead of corrupted and reinvented.

4.1 Project Goals Table

The purpose with the project goals table (PGT) is to make clear by which criteria the project will be judged. The PGT deals with: what is the product, what are the business goals, what is their order of priority especially if they are conflicting or numerous, how can they be measured and who will do it? By making this early in the in the project and put it on paper it is will be easier to answer if "this" or "that" solution is the best, it will be about which one is the most likely to fulfill the goal?

4.1.1 Pilot project experiences

This table proved very valuable to the Alfa project because it pointed out information gaps about our management's expectations for business results, which were then forced to be pined down. Our experience was that the time invested in the project goals table was short and it helps to make the subsequent analysis of customer segment easier. To do the project goals table correctly, the right people must offer input i.e. "owners" of the project, like the sales manager. He pointed out that for the Alfa project to be successful in the eyes of Sandvik Coromant, it should help us increase our market share for this product family to xx%. (Confidential numbers). The team agreed that the measurement of market share will be the number of unit's sold/total market of units sold. This measurement clarified for all the development team members what must be accomplished. The Beta project was an extension in size range to an existing successful system; it is plausible that the commitment of the team members when seeing the importance of the extension project clearly stated increased. The experiences from the pilots indicate that filling in the PGT (table 2.) is little work and that the data should normally be available to the project owner; and that there is a positive effect on criteria #1 in section 2.1.

Goal statement	How measured ?	Current level	Target level	By when?	Who judges success?
Increase market share	units sold/total market	x%	y%	2012	Sales manager
Increase invoice sales	$	x.000	y.000	2012	Sales manager
Seen as no 1supplier	% of target	80	100	2015	Marketing manager

Table 2. Example of Project Goals Table, from the alpha pilot..

4.2 Customer Segments Table

We must ask, are all customers equally important? Are there similarities between different types of customers? Market data or estimations made by business intelligence need to be gathered and used to judge what customer segments are the most likely to fulfill the project goals. The customer segment table (CST) is a guide to get an overview over the different segments and their particularities with respect to how they use the product. The cells in the different columns can be tied together with symbols to visualize different segments and create a greater understanding in the development team on how the product will be used in a segment, see Table 3.

4.2.1 Pilot project experiences

In the Alfa project it took too long time to analyze the segments, about 50 man-hours of work. The reason for that is that the customer characteristics that are important for project success were unknown. The way to deal with it in Blitz QFD® is to fill data into many columns and then sort them out. Any missing segment characteristics will show up later in the process because if customer needs differs between customers first supposed to be in the same segment some characteristics must be added and a segment added. It would help to have a tool that more directly helps us to identify customer characteristics that are important for project success. The data is reusable because it can be a starting point for future projects. The part of the CST where the customer segments are assembled

went satisfactory (one segment marked with doted line one with plain line), Table 3. It just took 2 hours and the invited sales persons liked the approach. The Beta project aimed to provide a general purpose threadening system. Experience tells that threadening is a general operation needed to an often little amount on a wide array of machined products hence made in all kind of industries in most kind of working materials. The CST reflected the fact there are virtually no key segments but many segments contribute a little bit to the sales of the product.

Machine size?	What materials?	Hole dia	Hole depth	Size of drill sales?
ISO 30	Unalloyed steel and Low carbon steel	3-10 mm	2-5xD	<xK$/Y
ISO 40	High carbon steel	10-20 mm	5-10xD	xK$ to zK$/Y
ISO 50	Low alloy steel	Other	Other	x$K to yK$/Y
7-10% of the market, will they help us fulfill the project goals?			<1% of the market, will they help us fulfill the project goals?	

Table 3. Example of Customer Segment Table from the alpha pilot with segments indicated.

4.3 Customer Process Model and the first steps when going to Gemba

Having representative customers from key segments willing to accept a visit from the product development team is crucial to performing meaningful QFD. With the right guidance, an enormous amount of data can be retrieved from a customer visit. The method advocated in Blitz QFD® is called GEMBA or visit to the "crime scene" (one of its meanings in Japanese). Before going to Gemba it is valuable to try to diagram the customers' process. This has several purposes, most customers get impressed that instead of making a traditional sales call, the visitors have actually tried to think about what the customer does in his everyday work [13]. The Customer Process Model (CPM) proposed does not need to perfectly reflect the customers process in the beginning as most customers will, after having said they are impressed by the effort, immediately start to correct the process. In that way a lot of valuable information is gathered which might not have been found just by asking straight questions? Furthermore, by defining a process to guide this part of the visit, the risk of getting stuck on one matter during the whole visit is mitigated. After going through and revising the customer process model (CPM) together with the customer, failure modes (FM) and failure effects (FE) should be annoted they give valuable information about what to investigate more in detail during the workshop visit.

4.3.1 Pilot project experiences

According to marketing people, for any kind of customer visit, it is mandatory that the responsible salesman make contact with the customer and also participate during the visit, this since he or she is the one that is supposed to have a long term relation with the customer. The projects had slightly different approaches in preparing and going to Gemba. In the Alfa project, the marketing member of the team needed up to 8 weeks to find salesmen to contact representative customers from the different segments and markets and get them to agree upon a visit. The Alfa team prepared the salesmen that should be involved with a 2-day introduction to Blitz QFD® which included a "test Gemba". The experience of that is that a 2-day introduction is too short. There should either be just an explanation of how much time is needed at the customer's site (no language barrier), or a QFD Green Belt® education (when language barrier between team and customer) possibly with an extra day of training on Affinity diagrams and Hierarchy diagrams (described later). The CPM was considered easy to do, and it was a good instrument to get the customer to talk. There were exceptions where some sales people had not understood the purpose of getting the customers to talk and instead talked themselves, and it was hard to intervene because it was in a language not understood by the Alfa team members. The Beta team decided not to invite the salesmen in beforehand but instead made a gemba brochure, to increase the understanding of the visit and its content. Made in manga style reflecting the Japanese origin of the method and translated into, English, French, German, Italian, Portuguese and Swedish, the brochure was sent by email together with further written instructions. A clear advantage for the Beta team was that their facilitator was multilingual and could speak directly to the customer in the visited markets without any bias from translation. By going step by step through the process, unexpected findings were made which might not have been found if the focus had been immediately put on the cutting tool, e.g. the uneven quality of raw material, see Figure 4.

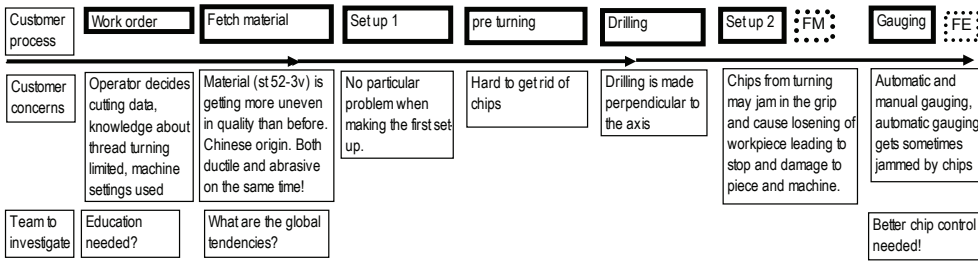

Figure 4. Example of Customer Process Model from the beta pilot.

4.4 Gemba Visit Table

When the Customer Process Model has been gone through, it is time to visit the actual workplace of the customer where the most critical job gets done. All sources of data are to be used, smell, sound, discrete utterances by the customer, strange workarounds. To capture this wide array of data the Gemba Visit Table (GVT) is helpful. Its purpose is to annotate observations, refer to relevant documents or manuals used at the workplace, write down verbatim i.e. comments from the customers visited. All this data is then to be translated into measurable, clarified items. The clarified items are single-issue statements complex data gathered during the visit. It is beneficial if the customer is able to give a measurement and target value to these items since that would make the evaluation of design solution easier. If the customer allows filming or recording at the customer's workplace is a good complement to the GVT.

4.4.1 Pilot project experiences

The GVT was printed out on A3 sheets, with 2-3 copies, so the team had something to scratch notes down on during the workshop visit. It was an effective way to collect verbatim and observations when voice recording was forbidden. The GVT worked as a guide during the visit, was found to be really an easy tool to use, see Table 5 for an excerpt showing just one row of notes under the headlines.

Gemba Visit Table

Interviewee:	Operators and technicians			**Interviewer(s):**	Mr X and Dr Y
Place:	XXXXX, Sao Paulo, Brasil			**Date and Time:**	May 14, 2008 , 12pm-16pm
Contact info:	through Mr Z at Sandvik do Brasil				
Interviewee Characteristics (*memorable):	Very dynamic and outspoken (this is used to make it easier to remember the interviewee)				
Environment:	threaded tube production plant				
Process Step	**Observations**	**Verbatims**	**Documents**	**Notes**	**Clarified items**
Threadening	**Uses uncoated inserts.**	**Fast delivery of special important!**	**Drawings on site**	**Value of tube very high in comparison to insert.**	**Fast delivery of sp ecia essential (weeks)**

Table 5. Example of Customer Process Model from the beta pilot.

4.5 Customer Voice Table

What customers tell during the visit is called a verbatim in the GVT and is often a mix of benefits and product features. As pointed out by Ulwick in [13], what customers really need is "a job" to get done understanding what job is to be done is the basis for understanding what the customer need from a product or and service. Blindly accepting that a feature or solution a customer mentions is the one that get the job done best, is depriving the development engineers the possibility of finding innovative new solutions that could possibly outperform earlier ones known by the customer. The Customer Voice Table (CVT) see Table 6, is used to translate any form of data from the Customer Process Model and the Gemba Visit Table into customer needs. This step is best performed at the customer's site; it is beneficial if the customer can offer an office for one to two hours for the visiting team.

4.5.1 Pilot project experiences

Extracting customer needs with the help of the CVT started out a little slow; most Alfa team members found the Customer Voice Table (CVT) tricky to use at first. It is not intuitive how all the data gathered from the Gemba recorded in the Customer Process Model (CPM) and the Gemba Visit Table (GVT) should be deployed in the CVT to yield the customer needs. The Beta team used reasoning and

a fishbone or Ishikawa diagram approach [14] to discuss the cause and effect relationship between clarified items from the Gemba visit and the customer needs.

Customer Benefits					
Customer (product independent)					
segment	segment characteristics	machining conditions	clarified items from Gemba or Inquiry Form	needs	customer measures
Maintenance shop in Sweden	Repair of machine parts	SS2172,SS2541 and stainless steel	Insert should not move (mm/N)	High quality of the thread	Threads cecked by stop and gauge
	Manufacturing of spare parts	Numerical controlled machine	Easy to chose correct insert and shim (seconds)	availability	Are there the neccesary inser in stock (yes / no)
		manual lathes	No need for tightening hard *(Nm)* / (Female operators)	productivity	Short time to reapir compone critical to main plant (hours
			Easy to put correct in place (indexing) *(mm)*	Good ergonomy	Easy to fasten insert for fema operator
			Right cutting data		Fast programming of machir (minutes)

Table 6. Example of Customer Voice Table from the beta pilot.

4.6 Affinity Diagram and Hierarchy diagram

Customer needs relate to each other and it is thus possible for customers to make a structure out of their needs listed in the Customer Voice Table. This is the purpose of the Affinity Diagram and subsequent Hierarchy Diagram, shown in Figure 7. The diagrams are done by putting the customer needs from the customer voice table on Post-It® notes and letting the customers, under team guidance, group the notes together according to their affinity. Then customers make a hierarchy of the needs which will truly reflects the customer's picture of how needs are related and will be the basis for the prioritization of the needs.

4.6.1 Pilot project experiences

The Alfa team found out that affinity grouping, was fun and easy, and the creation of a hierarchy, either "worked by itself" or not at all. It seemed like that some customers were able to think in abstractions, and they put up groups, subgroups, and built a hierarchy almost with no help at all from the team members. And the customers who were not used to thinking in abstractions made some basic groups, and then started to ask "How should I think now?" Here it was important that the team members supported the customer with questions whose answers created subgroups and then a hierarchy. That is the major reason why it is an advantage to send the sales persons to a QFD Green Belt® class to cover Gembas made in a country where none of the team members speaks the language. The QFD Black Belt® course could also benefit from more training on how to create a hierarchy by asking the right questions of the customer. The QFD Institute recommends that the hierarchy is better done left to right than top down, but during the Gemba visits, the Beta team found that many customers found it natural to do it top down. Furthermore, first grouping needs into affinity groups was seen as cumbersome by customers who would immediately put the needs into hierarchy. It should be stressed that when the team members met again and shared and discussed hierarchies from different customer they had met in smaller groups, they were able to create a shared understanding and hence this process step strongly contributed to criteria #2 and also somewhat to criteria #3, in section 2.1.

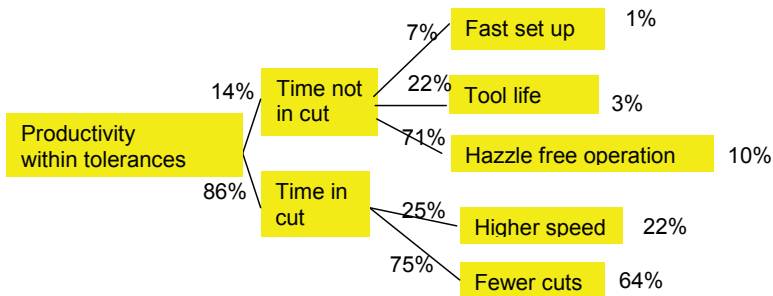

Figure 7. Example of hierarchy from the beta pilot.

4.7 Analytical Hierarchy Process

The Analytical Hierarchy Process is a method developed by Dr. Thomas Saaty to prioritize and select alternatives [15]. The AHP produces ratio scale numbers from paired comparisons (here, between needs but can also be applied to technical concepts and other data). The advantage of ratio scale numbers is that these can be multiplied and summed and hence used as weights. This is not possible with ordinal numbers which are sometimes erroneously used in selection and ranking methods. This weighting math problem is why early QFD methods using e.g. 1,3 and 9 as weights often gives contra intuitive results! The limitation of ordinal scales is that the numbers only imply order not the actual distance between the items. For example, being second in a game does not say how much slower or worse than the winner the second is, only that it is worse than the winner but better than number three. For an explanation about the scalar properties of numbers, the authors recommend the seminal paper by Stevens on the theory of scales [16]. In Blitz QFD®, we use AHP to let the customer compare the importance of his needs with each other, pair by pair, using a verbal ordinal scale, such as equal (1), moderate (3), strong (5), very strong (7) and extreme (9), and even intermediate judgments are allowed, such as a response between moderate and strong (4). AHP is applied top down to the customer needs hierarchy with local priorities of a single branch able to be multiplied by "parent" weights to give global priorities. In the example in Figure 7, "time in cut" got ranked higher than "time not in cut" by the customer. At the next level, "fewer cuts" got ranked higher than "the speed of cut." The global weight of "fewer cuts" is the weight of "time in cut" multiplied by the weight of "fewer cuts." If there are several people at customers and they have different opinions, it is desirable to average their votes by taking the geometrical mean of their opinions. Furthermore, AHP can identify any inconsistency in the decisions. A logical inconsistency would exist, for example, if need A is more important than need B, and B is more important than C, but the customer votes that C is more important than A. When multiple inconsistencies occur, AHP can even identify the most inconsistent pair. Several studies have shown that informed users can make a very precise ranking of a range of different phenomena such as size or volume of objects, light intensity, GNP of different countries, etc. by judging with pair wise comparisons using AHP [15]. Pair wise comparisons yields a better result than directly trying to rank the entire list of items at the same time. This makes AHP a good candidate prioritizing the importance of customer needs. The following website has a free AHP calculator [17].

4.7.1 Pilot project experiences

During the AHP activity at the gemba visit, a system was developed so the customer just had 2 notes in front of him with the two needs to compare. This reduced the time it took to do AHP by approximately 50% compared to looking at the whole matrix at the same time. In the cases where a hierarchy had been reached, the AHP was easy and fast. It was not possible to do an AHP if no hierarchy was reached, hence making the hierarchy is essential. The experience from the pilots was that customers agree with the numbers coming out of the AHP and they do not want to go back to "fix" decisions to alter the result. Table 8 shows the AHP made for part of the hierarchy in Figure 7. Here, for example, the customer has judged "hassle free operation" to be extremely more important than a "fast set up".

	Fast set up	Tool life	Hassle free				sum	row avg
Fast set up	1	**1/4**	**1/9**	0,071	0,048	0,082	0,201	**0,067**
Tool life	4	1	**1/4**	0,286	0,190	0,184	0,660	**0,220**
Hassle free	9	4	1	0,643	0,762	0,735	2,139	**0,713**
	14,000	5,250	1,361	1,000	1,000	1,000	3,000	1,000
						Inconsistency		**0,03**

Table 8. Example of AHP from the beta pilot.

4.8 Maximum Value Table

The Maximum Value Table (table 9) is used for going from customer needs via technical requirements to solution alternatives and their relation to manufacturing. The MVT is a tool that helps to develop and compare different solutions. It is basically a tool that documents thoughts and knowledge, while in the same time it structures thinking in an efficient way. The first step is to create technology independent functionality that fulfill the by AHP prioritized customer needs. Technology independent means it states what the product & service should do, i.e. which function the product should have.

4.8.1 Pilot project experiences

In the Alfa project, examples of functions that the drill should have to fulfill the customer needs are: remove metal, communicate its remaining edge life to mention a few. Next step is to start to look at the technology that can provide that functionality and find many alternative solutions. For every solution we "go to the right" in the MVT and investigate and collect information about the manufacturability, maintainability, and eventual sales organization issues. In this way we get the information we need in order to choose the most appropriate design. The MVT is important and should be focused more upon in the training. The MVT contributes to criteria #3 to #5 in section 2.1.

		Functionality (technology independent)			Solutions (technology selected)		Build and Delivery
needs	customer measures	technical requirements	design criteria	functions (hardware)	technology	reliability /durability	manufacturing steps
Tool lasts for entire shift	*(# Workpieces before replacing insert set)*	cutting edge sharpness	Edge roughness i	remove metal	eliptical edge	long tool life	PVD Coating
	(insert replacements/ shift)	cutting edge hardness	28 Rockwell	indicate edge life	positive geometry		
		coating durability	C-T = 510 µm	evacuate chips	High axial and radial rakes		
No scrap or rework of parts	*(% workpieces in spec)*	corner radii	Corner radius of 0.115"	dissapate heat	integrated wiper facet		

Table 9. Example of Maximum Value Table from the beta pilot.

4.9 Explorative Methods

The Blitz QFD® process includes the option to use different methods for boosting creativity and find solutions that fulfills the customer needs. In the package the following methods are included:

- TRIZ [18]
- DeBono's methods of lateral thinking and six hats [19]
- Innovative system questionnaire, also a part of the TRIZ methodology. [18]

It is not the purpose of this paper to describe these methods widely used also outside QFD and Blitz QFD®, or their implementation, for the interested it is recommended to read the references.

4.9.1 Pilot project experiences

All the explorative methods above push the development teams to really agree on what functions will satisfy needs and what they mean even before going to the explorative solution phase in the MVT. Both teams found this to be one of the best and unforeseen features with the creativity methods.
The explorative methods proposed by Blitz QFD® contributed to criteria #3 and #4 in section 2.1.

4.10 Selection methods, Super Pugh with AHP

In Blitz QFD® using AHP there is the ability to combine measurable criteria, absolute judgment and relative judgment in the same decision matrix in a mathematically sound way [20]. The Pugh selection method is used here not to select but to hybridize by combining strengths from different concepts.

4.10.1 Pilot project experiences

These methods were only tried to some extent in the pilots because of the timing, see section 3. Using the method the Beta team felt that the selection result where right and did NOT want to go back and alter numbers [21] this indicates the methods usefulness and robustness, contributing to criteria #4.

4.11 Misconceptions about QFD or QFD does not equal house of quality

There is a common misconception that QFD in synonymous with the often cited "House of Quality" matrix. This problem arose from early applications of QFD in the 1980s by U.S. auto suppliers. Basic design was then done primarily by the original equipment manufacturers (OEM) such as GM, and Ford. Drawings and specs were given to suppliers and QFD was used to improve the components' quality and cost. Complex matrices were useful in finding which improvements would deliver the best "bang for the buck." Typically, four matrices were used to translate product requirements into part specs, manufacturing requirements, and finally production and operating standards. These matrices could contain hundreds of data juxtaposed against hundreds of other data resulting in thousands of correlations assessments. Many QFD teams would run out of time and abandon their analysis in the middle. As companies have come to embrace lean practices, the resources to perform this detailed analysis have evaporated, crudely put, Blitz-QFD is the lean equivalent of QFD.

4.12 Sandvik Coromant's understanding of Blitz QFD® or Gemba not equal Blitz QFD®

The training provided by the QFD Institute eliminated a lot of the earlier misunderstanding that QFD was just a house/matrix relating customer needs to technical requirements. However, new misunderstandings started to appear instead. Many in management positions assumed Blitz QFD® to be a "small" method that could be used now and then, mainly on bigger projects to find customer needs. Others thought Blitz QFD® was limited just to gemba visits. While using just one or two methods will give partial benefit, for an organization to fully reap the full benefits of Blitz QFD®, a clear understanding of both the overall process shown in Figure 1, and each of the individual methods and tools is needed. We now see the half day QFD Gold Belt® orientation for management is not enough to get the level of understanding necessary to sustain the QFD effort and we will work to improve their understanding.

4.13 Organizational issues in implementing Blitz QFD®

At Sandvik Coromant the product development department drove the challenge of improving the product development practice and identified Blitz QFD® as the means to do that. Since Blitz QFD® is most effective at delivering customer satisfaction when it spans several organizational units within the company, it can become a great challenge to successful implementation to include activities upstream of product development - marketing and sales. These organizations are critical because their input and consent is needed. It cannot be overstated that Blitz QFD® is a system-wide process and not an isolated method for use in a narrowly defined product development organization. Hence, the political implications regarding organizational silos need to be recognized so conflicts are mitigated. The existing approach at Sandvik Coromant has been very different; marketing and sales provide to the product development organization a written document stating what they derive are the customer needs, plus some additional requirements and a tentative technical solution. There was a fear that engineers might not be adept at meeting with customers and could embarrass the sales staff, the company, and themselves. At the same time, marketing and sales are sometimes frustrated that their document cannot convince the product development organization of what the customer needs. Conversely, some people in the product development organization feels that the requests they get from marketing and sales, are too solution-focused and do not include the actual needs of the customer. We believe that Blitz QFD® is a way to overcome exactly those problems. To implement the Blitz QFD® process fully, the marketing and sales staff should also use this process in their upstream work, such as in defining customer segments and how to get into new markets.

5 WRAP UP AND CONCLUSION

The Study part in the *Plan Do Study Act* research cycle tells us that the pilot studies both indicate that the Blitz QFD® process with its set of methods has increased the common understanding regarding project goals, the needs of the customers and their interrelation and priority according to the customers. Furthermore the coupling between needs and the necessary technical characteristics has been better reviled aligning the development efforts freeing resources to develop alternative solutions thereby increasing the likelihood of finding the best solution avoiding dead ends. Possible challenges regarding manufacturing has been identified earlier reducing the risk of delays and costly changes. These positive influences indicate that Blitz QFD® has the potential to fulfill the goal of reducing lead time significantly if fully implemented companywide, see section 2.1. What needs to be *Act* upon in the near future is to increase the understanding at all levels that to benefit fully, the whole Blitz QFD® process with its method set needs to be implemented across departments at Sandvik Coromant and not only in product development. This would give a common baseline to further improve upon, see section 1. An improved way of always providing a balanced picture of Blitz QFD® should also be found, to mitigate the tendency people have on focusing on specific methods in the process. Without balance, the sought after deployment of quality from customers needs all the way to a solution satisfying the customer will not occur. For example the Maximum Value Table section 4.8 is a very powerful tool and should hence be more in focus in the educational package to balance up the gemba focus. Furthermore the explorative methods and the selection methods need to be tried in dept in projects being in stages apt for it.

The way of driving the implementation with an outside trainer adapting the process to the particular business context, and to keep up the teams' speed between the two course weeks by having facilitators that later will be trained to continue the implementation was successful. The authors believe and hope

that the reported findings are helpful to others wanting to enhance development of innovative and useful products. Blitz QFD® is a process which with appropriate adaption to context has the potential to improve product development practice in all kinds of industries, since both the process and its methods are generic and adaptable. From a research perspective it should be noted that successful implementation of supportive engineering design methods needs time, stamina, and adaption to circumstances as well as an understanding of a company's political matters.

Last but not least the participants in the pilot projects appreciated the common understanding of the projects enhanced by Blitz QFD® which boosted team-spirit and made the teamwork more fun.

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