INCREASING PRODUCTIVITY AND FLEXIBILITY IN MANUFACTURING

REDUCTION OF LEAD TIME AND WASTE, IN OWN FACTORY AND IN SUPPLY CHAIN. SMART PRODUCT DESIGN AND FLEXIBILITY IN ORGANIZATION AND DEPLOYMENT OF EMPLOYEES
THE INNOVATION OF MANUFACTURING PROCESSES, WHETHER OR NOT AUTOMATED, PRIMARY DEPENDS ON THE KNOWLEDGE, MOTIVATION, CREATIVENESS AND INVOLVEMENT OF EMPLOYEES, ALSO DURING IMPLEMENTATION
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INCREASING PRODUCTIVITY AND FLEXIBILITY IN MANUFACTURING
TNO WAS FOUNDED IN 1932 IN ORDER TO STRENGTHEN THE NETHERLANDS’ COMPETITIVENESS. THIS IS STILL VERY RELEVANT TODAY AND FORMS AN IMPORTANT PART OF OUR MISSION.

TNO assists industry by enabling it to use our broad-based knowledge for its products. This includes a wide range of disciplines, such as materials research, mechanical engineering, optics, mechatronics, human factors, and many more. However, the process of converting a technological invention into a product that can be manufactured efficiently and effectively is far from straightforward. It is not without good reason that TNO also focuses on the implementation and optimization aspects of new products. An invention only becomes an innovation if it is actually used. This is why translating an invention into an efficient production process is a challenge in itself. In many cases, an additional complication is the speed and flexibility required by the value chain. This means working with different suppliers and maintaining short lines with the end-users. Chain and group innovations are new phenomena.

The Dutch manufacturing industry is facing major challenges. Continuous innovation and a structural increase in productivity and flexibility are needed in order to compete with the world’s best – and that applies not just to new products, but to existing ones as well. In addition, businesses have to be able to find and retain enough qualified employees. In that context, it is not sufficient to improve productivity and process flexibility – of greater importance is the need to make the best possible use of employee input.

Through this book, TNO seeks to show that businesses can achieve all of this. Together with TNO, a large number of companies in the manufacturing industry have successfully created innovations in the field of productivity and flexibility with the help of input from their employees.

Be inspired – we are here to help you!

Arnold Stokking
Managing Director, Industrial Innovation, TNO
INTRODUCTION

THE NATURE OF PRODUCTION IN THE MANUFACTURING INDUSTRY IS CHANGING. MARKET DEMAND IS LESS PREDICTABLE. THE TIME-TO-MARKET IS SHORTER, AND PRODUCTS HAVE AN EVER-SHORTER LIFE CYCLE. THIS MEANS THAT THE MANUFACTURING CHAIN HAS TO INCREASINGLY ADAPT TO CHANGING PRODUCTION VOLUMES, SHORTER DELIVERY TIMES, SMALLER SERIES, AND THE PRODUCTION OF CUSTOMER-SPECIFIC VARIANTS. AT THE SAME TIME, THE PROPORTION OF OLDER EMPLOYEES IS RISING DUE TO THE AGEING POPULATION AND THE TRENDS FOR WORKING LONGER INTO OLD AGE. ANOTHER FACTOR IS THE EXPECTATION THAT THE SIZE OF THE WORKING POPULATION WILL SHRINK.

How can the manufacturing industry respond to these developments? The answer lies in being quick and flexible, raising productivity, and continually innovating. Improved coordination in the manufacturing chain is another way, including working together with customers and suppliers to identify potential risks at an earlier stage in relation to design, production, service, and maintenance. And, last but not least, by using and developing the competencies of employees.

Production innovation
Every day, the manufacturing industry uses production innovation knowledge and tools that have been devised by TNO in order to meet these challenges. This is an interactive process that involves the relevant parties in the company in question. In addition to this knowledge and tools, the most important factor for success is involvement. The involvement of various company disciplines is essential for gaining support and momentum for pushing ahead with innovation. Involvement is also essential because the minds of employees contain a great deal of knowledge and experience about the production process and the problems that occur on a day-to-day basis. And that knowledge and experience can only be tapped into by working together. TNO has been providing practical support in this area for 25 years.

Greater involvement of personnel and entrepreneurial drive
The primary aim of the projects in this book is to improve the performance of companies so that they are better equipped to face the future. For entrepreneurs, that of course is the most important thing. But there is more …
Some of the companies were asked what contribution the projects made to the appeal of the work among new and existing employees. Here is a brief selection of the answers:

- The employees who were critical slowly came round, and they ended up very positive! Give them plenty of information, and give them time;
- Involvement has been enhanced by allowing people to add their input. Their priority now is their internal customers. Training and rotating employees is now much easier;
- Because of the new building and better layout, we are better able to recruit and keep people;
- People have introduced and assessed improvements themselves. That certainly helps!
- We were forced to hold intensive discussions and to coordinate our activities. That led to much greater involvement and better teamwork, and more pleasure in our work!
- It is as if we were given a mirror to look at ourselves. The work is now much more logical and more clearly organized. The training for the whole production line now takes nine months instead of eighteen months!
- Colleagues were given a shared insight into future processes, and that has led to greater cooperation. There are fewer errors, and the process of training new employees is now faster. TNO really does bring about change!

What is particularly noticeable about all this? First, that the heart of the issue is that you should involve your employees with improvements – it really helps! Second, that it is difficult for companies to distinguish between improving performance and making the work more attractive, but this way the two actually go together. The innovation of production processes, whether they are automated or not, depends primarily on the knowledge, motivation, creativity, and involvement of people, and that includes the actual work itself!

These, then, are outstanding projects that have simultaneously made work in the manufacturing industry more productive and attractive. There is much to learn in this area, and that also applies to those who are rightly concerned about the shortage of skilled personnel and engineers in our manufacturing companies.

Innovating and making continuous improvements together with employees makes the work more challenging, more appealing and creates involvement, which in turn leads to greater productivity and company performance.

Klaas ten Have,
TNO Business Line Manager
Innovation and Sustainable Productivity
LEAN & FLOW FACTORY: 40% MORE TURNOVER WITH THE SAME NUMBER OF PEOPLE

Supplying more products with the same number of people by making the primary process smarter and through a smarter product design. Add the improvements to the work instructions, and you are on your way to the Lean & Flow Factory, the result of a cooperative partnership stretching back years between Biddle Klimaatwerk and TNO.

Biddle is a company based in Kootstertille (Friesland) that develops and manufactures climate products. Every year, thousands of air curtains, ventilation convectors, and air heaters are supplied to supermarkets, shops, offices, industrial buildings, and elsewhere. Around 85 people are employed at the company in Kootstertille, which has modern machinery and an extensive R & D department. In the past three years, Biddle and TNO have together designed the process for manufacturing components, assembly and dispatch according to flow.

Working in parallel on process and product improvements

Since 2009, Biddle has worked using Lean in partnership with TNO in order to streamline its sheet metal manufacturing process. A large proportion of the factory was refitted in 2010 for the punching, bending, spot welding and coating parts of the process. The assembly process for a part of the overall product family was equipped according to the principles of demand flow. Assembly work had previously been done in batches at fixed work places, which meant a lot of walking back and forth and extra handling.

While the changes to the primary process were underway, it also proved necessary to make improvements to the product structure. The results of the Product Design for Flow Assembly project were directly incorporated into the new assembly plan. This led to, among other things, a smaller variety of casings, not so many different straps, and greater access to the assembly locations. “It is very important to harmonize the activities of engineering and production employees at an early stage. The experiences gained are now being carried forward to the process of developing new machines,” explains Sjouke Land enthusiastically. Sjouke is the Production Manager at Biddle and leader of the Lean team. “The change process that we went through with TNO and our employees also led to greater involvement and motivation,” continues Peter Bethlehem, one of the key players in the team.
Improvements to work instructions
In 2012, Biddle worked in a cluster of nine companies in order to improve work instructions for assembly. Patrick Janssen, an industrial designer at Biddle, talks eagerly of the experiences that Biddle gained during the work instructions project. “We used to pass things on by word of mouth, but it was limited to bills of materials, while the content of the manuals dealt mostly with safety. The manuals were not easy to access. With the transition from batch-based assembly to one-piece-flow assembly, the total workload was divided into zones. The old manuals no longer corresponded to the actual process. Moreover, there was a greater need to deploy employees more flexibly.”

“WE ARE VERY KEEN ON THIS! WE PRODUCE 40% MORE, BUT WITHOUT EXTRA PEOPLE AND WITHOUT NEEDING ANY EXTRA SPACE! IN ADDITION, THERE IS NO LONGER ANY NEED FOR OVERTIME DURING THE BUSY PERIODS. THE GUYS IN PRODUCTION ARE FULLY BEHIND IT TOO, AND THEY CONTRIBUTE TOWARDS IMPROVING THE LAYOUT OF THEIR WORK PLACES.”

“AS WELL AS THE INCREASE IN PRODUCTION, IT ALSO OFFERS MANY OTHER BENEFITS: THE PEOPLE ACQUIRE MORE KNOWLEDGE AND THEREFORE BECOME MORE INVOLVED, AND NEW EMPLOYEES, WHETHER TEMPORARY OR NOT, CAN PICK UP THE WORK MORE RAPIDLY BECAUSE THEY DO JUST A SMALL PART OF THE ASSEMBLY AND CAN QUICKLY LEARN IT”.

Sjouke Land, Manager Production at Biddle
Biddle came to realize that work instructions actually come about during the design process, so responsibility lies with R&D. Engineers set down draft instructions, and production checks whether or not they are correct. The production foremen ensure that the work instructions are altered in the event of any changes to the product. “Working out the details of the work instructions takes half a day a week, on average,” estimates Patrick. It is very important that they are implemented and safeguarded consistently, and that they are communicated effectively and convincingly. “The systematic incorporation and evaluation of work instructions leads to better coordination of engineering and production.”
“THE DEMAND FLOW PROJECT HAS CHANGED THE ORGANIZATION OF OUR PRODUCTION ENORMOUSLY, FROM A TRADITIONAL PRODUCTION COMPANY TO A DEMAND-DRIVEN PRODUCTION ENVIRONMENT. THIS HAS SIGNIFICANTLY INCREASED THE INVOLVEMENT OF THE PRODUCTION EMPLOYEES, BECAUSE THEY HAVE TO CONSIDER THEIR INTERNAL CUSTOMER DURING THE PROCESS – THAT IS, THE NEXT STAGE IN THE PROCESS. THE FIRST STEP IS TO OPTIMIZE SUPPLY FOR YOUR INTERNAL CUSTOMER, FOLLOWED BY OPTIMIZING YOUR OWN WORK ENVIRONMENT – THAT RAISES THE INTEREST OF EMPLOYEES IN THE WORK PROCESSES, AND THEREFORE THEIR MOTIVATION.”

Sjouke Land

More turnover without extra people, and less haste
What has the overall change process resulted in for Biddle so far?

- No more costly overtime when pre-processing orders. That saves around €15,000 per year.
- Two FTEs fewer are needed during pre-processing.
- 25% fewer assembly hours per machine.
- Reduction of WIP (Work in Process) of around €100,000.
- The investments repay themselves within one year. The production process is calmer, less hectic, and there are no longer any rushed jobs. Orders are entered on the input side of the assembly.

The material is delivered to the assembly on the basis of kanban, in other words, working backwards from assembly-based demand.

The work places have been redesigned to make sure that the work is carried out more efficiently and ergonomically. Examples include having the tools in the right places and lifting devices for dealing with heavy parts.

Lean not just for production

“Our working partnership with TNO has now been expanded, to include order preparations. They refer to that as Lean Order Processing at TNO,” says Sjouke Land. Lean is not just for production, but actually for the entire order preparation trajectory, including the supply chain.

The project involves looking at streamlining the preparation of orders for standard or special orders, as the case may be.
In its new premises, De Boer Machines Nederland used TNO’s knowledge in order to coordinate its workflow in relation to custom-made machines. Supplying small series and individual custom-made items in a short time requires not only optimum flow but also a reduction of waste and an efficiently organized method of change over the manufacturing process for one type of machine to another. Together with TNO, De Boer devised solutions aimed at maintaining its competitive position.

De Boer Machines Nederland supplies all aspects of machine building and is optimally equipped for the manufacture of medium-sized to heavy machines. The company enjoys a worldwide reputation on account of its pressing equipment for the brick industry. De Boer Machines employs around one hundred people, and in late 2010 it relocated from Nijmegen to brand new premises on the Bijsterhuizen business park in Wijchen.

“IN NIJMEGEN, WE OFTEN HAD TO WAIT AROUND FOR FORK-LIFT TRUCKS OR HOISTS, OR FOR ITEMS THAT HAD TO BE BROUGHT FROM FAR AWAY. THERE IS NONE OF THAT IN WIJCHEN, FORTUNATELY. FOR US, THE LAYOUT IS A BIG IMPROVEMENT.”

Herbert Aalbers, the deputy director of operations at De Boer Machines
Small series and individual items
Like other companies in recent years, De Boer Machines has seen an increase in the demand for small series and individual orders to be supplied custom-made in a short time. As a result, there was a growing need to make the method for changeover from one type of machine to another more flexible. TNO carried out several observations of how this method was performed during the overhaul of the ‘mould boxes’, before setting about the task with the staff. With the help of the ‘lean working’ idea, they jointly came up with solutions for better organizing the preparation of tools and for making the overall operation easier.

For the design and layout of the new premises in Wijchen, TNO and De Boer compared various production concepts with a view to obtaining optimum flow in every process. This also involved considering how to accommodate the machine-building activities from the company’s subsidiary in Boxmeer.

Maintaining competitive position
The recommendations made by TNO were put to good use during the construction and design of the new company premises. Much emphasis was also placed on providing facilities for simplifying the process of

“WE ARE CONVINCED THAT THE NEW PREMISES, INCLUDING THE IMPROVED LAYOUT AND APPEARANCE, MAKE IT EASIER FOR US TO RECRUIT NEW PEOPLE AND TO KEEP THEM HERE. THE EXCELLENT DESIGN OF THE WORK PLACE AND EQUIPMENT ALSO MEAN THAT OUR EMPLOYEES ARE NOW MUCH MORE MOTIVATED.”

Herbert Aalbers
handling heavy components. Examples of this include a transport frame and a lifting unit for handling mould boxes.

After the move to the new premises, the co-operation with TNO continued, with the focus now on the flow of orders, from the sale all the way to production – or lean-order processing. “Creating flow in our business process in combination with a reduction in waste is vital if we wish to retain our competitive position,” explains Herbert Aalbers.

**Time bank**

De Boer also took part in a project with TNO and five other companies on the flexible deployment of employees (see p. 52). “Because of the greater fluctuation in demand, we are forced to deploy staff even more flexibly. As well as increasing the range of tasks that employees can perform, we also examined the possibility with TNO of the options associated with a time bank. We have now introduced this.”
PROCESS OPTIMIZATION IN THE MANUFACTURING SUPPLY CHAIN OF HIGH-END EQUIPMENT

The key question during the TNO SME knowledge transfer project that was carried out in cooperation with the ACT was how each party in the manufacturing supply chain industry could be strengthened by the others. Six companies from the high-end equipment sector in the eastern Netherlands worked successfully in partnership with TNO on both optimizing their own processes and on interaction in the supply chain.

The Technology Transfer Centre - ACT supports the manufacturing industry in the Achterhoek region in relation to all types of technological and business questions. The project saw cooperation in two supply chains: instrument building and special machine building.

Smaller series at lower cost
The supply chains in the manufacturing industry are facing increasingly changeable market demand; at the same time, they are expected to meet shorter delivery times, to be more flexible, and to come up with customer-oriented solutions. In order to maintain their competitive position, or even to enhance it, they have to respond quickly, in terms of both volume and product mix. The chain has to be in a position to supply smaller series at lower cost. Cooperation between parties is needed to survive the squeeze on margins, and also to compete with the Far East.

IN ORDER TO BE COMPETITIVE, OEM COMPANIES (ORIGINAL EQUIPMENT MANUFACTURERS) WILL HAVE TO INNOVATE TOGETHER WITH THEIR PARTNERS IN THE SUPPLY CHAIN. ALSO IN THIS PROJECT WE OBTAINED RESULTS BY REDUCTION OF LEAD TIMES AND COSTS. IN OUR TECHNOLOGY TRANSFER NETWORK IN EASTERN NETHERLANDS WE WERE HAPPY TO EXCHANGE EXPERIENCES. IN OUR REGION WE REALISE THAT THE MAJOR COMPETITION WILL COME FROM CHINA. BY SHARING EXPERTISE, SMART COMMUNICATION AND ZERO DEFECTS WE WILL SURVIVE.

Martin Stor, director at ACT
Six companies from the high-end equipment sector in the eastern Netherlands worked jointly with TNO and ACT to improve the performance of their processes. They represent two supply chains in the sector: instrument building and special machine building. The businesses from the former were Bronkhorst High-Tech, a developer and producer of mass flow meters, and four specialist suppliers for machining, BMI-Thegon, Hartman Fijnsmechanische Industrie, Mevo Precision Technology, and Tielトjes Precision Parts. Those taking part from the special machine building chain were special machine builder Tumakon, and Machinefabriek Tuinte, who supply constructions and components.

Together with these companies, TNO developed ways of optimizing the individual processes and the interaction within the supply chain. Among other things, this involved reducing order lead times, making the method for change over production processes more flexible, creating a clearer overall picture regarding order planning, early-stage coordination between engineering and production on the manufacturability, and simplifying the control and supply of components based on the customer’s needs. The input by TNO was aimed primarily at activating change processes among the participants and transferring knowledge and tools. This was done in individual work sessions at the companies’ premises themselves, and during sessions involving the customer and the supplier. Joint sessions were also held in the interim for the purpose of exchanging experiences.

The companies participating presented their results during the final meeting at Bronkhorst High-Tech in Ruurlo.

**BRONKHORST HIGH-TECH AIDS TO HALVE ITS DELIVERY TIMES**

“The sessions gave us fresh insights into such aspects as reducing intermediate waiting time through the order process, making earlier evaluations with suppliers regarding the manufacturability of components, simplifying the logistical material flow for regular orders in accordance with ‘supermarket’, and eliminating waste during packaging,” explains Bas Strijker, who is responsible for engineering. “Together with our partners, our aim is to reduce delivery times from between six and eight to between three and four weeks.” Procurement manager Hans Bruins adds that Bronkhorst High-Tech regards the most significant benefit from the project as the stronger mutual trust in the manufacturing chain and the more structured approach to areas of improvement with the suppliers.
BMI-THEGON IS AIMING TO HALVE ITS AVERAGE LEAD TIME

Director Harold Groot Roessink is clear: “We need to reduce our lead times.” In the original process, looking for and handling tools and materials took up a lot of time. On top of that, the distances for transportation between successive machines in the production process were long. “Now, the storage locations for incoming material, equipment and interim storage are in a better-ordered sequence, while unnecessary aspects have been eliminated from the process. Some machines have been relocated so that orders can flow through in a more logical way. This led to an increase in productivity of around 6%. We have also been able to cut back on overtime. We now expect to halve our average lead time,” Groot Roessink continues, enthusiastically. With the assistance of TNO, the company, in partnership with Bronkhorst High-Tech, is moving towards the setting up of a supermarket from which orders that are easier to handle for the customer and the supplier can be delivered within a day in previously defined packaging units.

HARTMAN FIJNMECHANISCHE INDUSTRIE IS COUNTING ON A REDUCTION OF AT LEAST 25% IN PRODUCTION CHANGE OVER TIMES

Production manager Harry Langenberg says, “After analysing the order lead time and examining the TNO lean order processing checklist, we have put calculation, work preparation, planning, and issueing for production into one group. The result is easier coordination and a reduction in errors. The progress of orders and delivery reliability are now monitored and measured more effectively. We also carried out an analysis of our production change over process with TNO in order to achieve greater supply flexibility. That led to action being taken to make the preparation of tools and machining equipment more efficient. We expect the production change over times to be reduced by at least 25% as a result.” That will mean a direct increase in production capacity and enhance the ability of the company to meet customer demand for smaller batch sizes. Langenberg adds, “Bilateral discussions with Bronkhorst High-Tech have created greater insights for both parties into the options for making improvements to the engineering process and to logistics. In consequence, a team has been put together to work on optimizing existing products, on the feasibility of new products, on simplifying logistics, and on the packaging process.”
TIELTJES PRECISION PARTS LAYS THE FOCUS ON ORGANIZING ITS CONVERSION PROCESS MORE SMARTLY

“The spindles of our production machines have to turn,” is how director Erwin Tieltjes opened his presentation. During the supply chain project, the company had placed the emphasis on the smarter organization of its production change over process. A wide range of orders comes in every day, which have to be delivered in ever-smaller batch sizes. Making the company more flexible is therefore highly necessary. “We were fortunate that during the supply chain project with TNO, a new employee started working for us who also knew about lean, 5S, and reducing set-up times, so we were able to make progress quickly. TNO and the employees highlighted the production change over process at an experimental location on our premises, which we also filmed. Working with the employees, we generated ideas for improvements, such as preparing toolsets more thoroughly in advance, keeping tools and machining equipment in a more ordered way, and clear guidelines as to what should be where. We did all this in the experimental location and the initial readings suggest that we have already made an average saving of 40 to 50% per change over,” Tieltjes adds eagerly. The experiences gained in the experiment will shortly be applied elsewhere in the company, which is now eyeing up the opportunities for reducing order lead times by organizing things differently.
“THERE ARE THREE COMPANIES HERE, ALL OF US WITH MUCH IN COMMON, BUT WE WERE TOO PREOCCUPIED WITH OURSELVES AS INDIVIDUAL COMPANIES. TNO HAS HELPED UP TO HARMONIZE OUR PLANNING AND COMMUNICATIONS AND TO EXCHANGE THE KNOWLEDGE THAT EXISTS IN THE MANUFACTURING CHAIN MORE EFFECTIVELY. THAT MEANT, AMONG OTHER THINGS, LETTING GO OF OUR INDIVIDUAL PLANNING MODULES AND ALL WORKING ACCORDING TO THE SAME ONE, IN ORDER TO HARMONIZE OUR PLANNING. IT WAS VERY REWARDING TO INVOLVE SOMEONE FROM OUTSIDE THE PROCESS.”

Robert Pelgrim (left), operations manager at Tumakon

TUMAKON AND TUINTE WORKING TOGETHER ON MORE EFFICIENT ORDER FLOW

In joint sessions involving representatives from both companies from the machine building chain and TNO, an examination was made of how orders could flow through the process more efficiently. “The various disciplines of engineering, production and installation/maintenance each had their own planning schedules, but they were not adequately coordinated,” explains Robert Pelgrim, operations manager at Tumakon. “The result is that a lot of what we did when processing was ad hoc, and that we had to put in extra effort.” With a coordinated method for planning orders, both companies are now together better able to show the consequences of any problems or deviations and to better control individual processes based on the need to complete the order. There is also greater clarity regarding the number of employees needed and the lead time. “Rules have been drawn up, such as with regard to periodically evaluating the progress of orders. We also create a draft order flow schedule as early as the quotation stage in order to show how many employees we will need from the various disciplines, and also to check the feasibility of the delivery time. We believe that this approach will reduce the need to jump ad hoc from one project to another and that it will lead to a calmer process. That in turn will lead to reduced lead times and failure costs.”
With the help of TNO, Bronkhorst High-Tech has achieved significant innovations in three areas: 1) a new layout of the clean room for optimum flow, 2) improved work instructions for straightforward production with fewer failure costs, and 3) an improved product design, leading to a reduction in the time-to-market.

Bronkhorst High-Tech (BHT) in Ruurlo is specialised in developing, calibrating, and testing of flow instruments. These high-quality and custom-made products are delivered all over the world to the chemical, semi-conductor, and process industries.

With TNO, innovations leading to an improvement in the company’s operations have been realized in three areas.

**Upgrading the clean room**

Part of the production at BHT takes place in a clean room, which has a dust-free environment. An increase in the number and variety of products and more stringent requirements on the part of the market made it necessary for the clean room to be expanded and upgraded. Using a product-process matrix, the entire production flow was identified with the help of TNO, so that both the current capacity and the future capacity could be envisaged. This has enabled BHT to target its responses to market demand and to adapt its production capacity at any time. The first part of the method used for upgrading the clean room involved setting out the various production flows using a MAS (assembly process scheme) and by making a distinction between main and sub-
processes. The various operation times for each product type and for each type of operation were then entered into a product-process matrix, which eventually led to an up-to-date overview of the various work places; this can be used for forecasting future manpower needs. This was all used to determine the new layout for the clean room, thereby creating an optimum flow. Thanks to this new clean room, BHT will be able to respond quickly and flexibly to the wishes and needs of customers in the future.

Improving work instructions

"Why we need to focus on work instructions at Bronkhorst High-Tech?"

This is how production leader Eddo Hissink began his presentation at the final meeting of the TNO SME ‘Assembly Work Instruction’ project. Nine companies from the instrument, machinery and machine building sectors were involved in the project with TNO for the purpose of improving instructions for assembly work. Hissink continued, “Several years ago, we started to organize our primary process according to the Lean idea, and put it ‘in flow’. Before that, employees used to make the entire product, but there were all kinds of delays on the way concerning materials, semi-manufactured goods, and end-products. The work has now been split up into separate processes with a logical sequence of work places and tools. The original work instructions contained a lot of text and tables and it was very difficult to look anything up. Finding the right work instructions was laborious and there was also a great deal of unnecessary information.”

Together with TNO, work was started on improving the work instructions. The so-called ‘exploded view’ drawings that were already available through 3D CAD, were set out in a logical sequence, with text being added to them in the case of critical operations. Everything is presented in a consistent and clear manner, with as few references to specific article numbers as possible. That, after all, makes maintenance easier.

Work instructions have been drawn up for each stage in the process flow, to help new employees quickly learn (with additional supervision). Instructions have been divided into two categories – basic instructions for general and frequently occurring actions, and product-specific
instructions for the successive assembly stages with critical assembly and test operations. The management of work instructions is organized centrally, with the Q engineers. Because the production employees are continually adding texts on critical operations to the exploded view drawings, and to the instructions, they are improving all the time. Actual colleagues receive the information in smaller portions that are related to their task – this means that fewer errors are made. New colleagues, meanwhile, can be taught more quickly. “This takes us much closer to flow production. Work instructions make the work at BHT easier. It leads to less complicated production and fewer failure costs,” says Eddo Hissink.

Reducing the time-to-market
Higher quality and a reduction in the time-to-market are part of the continuous improvement process at BHT. Against that background, a design review has been carried out in conjunction with TNO to obtain assembly-based product design, involving as few risks, and as low integrated costs, as possible. The question of when Design For Assembly (DFA) should be included in the R&D stage has led to lively discussions between the departments concerned. The process for a new product, made up of 3D printing components, has been developed with the help of the working method MAS, and an estimate made of the time needed. Every operation has been tested using the TNO checklist for assembly-friendly design. Areas for improvement were agreed upon for the purpose of simplifying the construction of the product, for reducing certain handling such as tilting and rotating, and for ensuring fewer separated components, easier positioning and accessibility.

The conclusion after the design review that DFA should be included from the very beginning of a new development was unanimous. By highlighting from the very beginning the risks, service, assembly-friendliness, larger series, outsourcing to suppliers and the interchangeability involving multidisciplinary teams, the design can be optimized more quickly, thereby reducing the time-to-market.

“BECAUSE OF THE ANALYSIS OF THE MANUFACTURABILITY EMPLOYEES HAVE GAINED A CLEAR IDEA OF FUTURE PROCESSES. EVERYONE NOW HAS A BETTER UNDERSTANDING OF THE CONSEQUENCES OF DECISIONS THAT ARE OFTEN TAKEN AT AN EARLY STAGE OF THE DEVELOPMENT PROCESS, AND THAT LEADS TO GREATER COOPERATION.”

Bas Strijker, engineering manager at Bronkhorst High-Tech
What can be done to optimize the primary processes of new products and maintenance within companies supplying the aerospace industry? This was the key question of the project that TNO carried out together with the NAG at five companies. The focus lay on shortening lead times, lean manufacturing, and structuring production. Thanks to the TNO SME programme, the project has helped improve the competitive position of a number of aerospace SMEs in an inspiring way.

The Netherlands Aerospace Group (NAG) seeks to improve the competitive position of its members in the global aerospace market. It does so by means of the following three main activities: promotion, exchanging knowledge, and representing the members to stakeholders. The TNO SME Technology Cluster programme is used for creating momentum among the participants for carrying out innovations in the primary process with the expertise of TNO, and for exchange the results more broadly to the sector.

During the final meeting, TNO showed how the NAG members could reduce their lead times and waste, and how they could deploy their employees more efficiently. The three participating companies - Avio-Diepen, NDF Special Light Products, and KVE Composites Group – shared their experiences with the NAG-affiliated companies who were present.

AVIO-DIEPEN
Avio-Diepen in Alphen a/d Rijn is a stock-holding supplier of components for the aviation industry. Their reason for taking part in the project was the greater number of AOG (Aircraft On Ground) orders and their too low and fluctuating delivery performance. “Using an order process scheme,
MAINTENANCE COMPANIES AFFILIATED TO THE NETHERLANDS AEROSPACE GROUP (NAG)

TNO went through all our company disciplines and examined our complete process and established that our average order lead time was two days, for order processing, picking, all the way to delivery. From this analysis and the TNO lean checklist, what stood out most were the waiting times between successive process stages,” explains Anneloes de Koning, the Avio-Diepen Quality Assurance Manager in her presentation. “We defined the areas for improvement in the work sessions, some of which have now been acted upon. High delivery reliability is crucial for Avio-Diepen. Since the start of the project, the number of late deliveries has been reduced from 8 to 4%.”

At the same time, efforts have been made at Avio-Diepen at deploying its staff more flexibly. A competency matrix was drawn up, featuring employees versus competencies. The 3 x 3 rule was used to see where a broader base of employees is needed. The starting point is that every employee should be able to perform at least three tasks, and that at least three employees should be able to perform each task. Cross-training is now underway in order to broaden people’s knowledge.

NDF SPECIAL LIGHT PRODUCTS
NDF Special Light Products in Roosendaal specializes in special lighting technology for both the professional and decorative markets. Together with TNO, the company worked on three programmes:

1) Order flow of a new product, where various people from sales, engineering, purchasing, and production were shown when specific activities had to be ready in order for the delivery time not to be jeopardized. Problem areas were identified and courses of action to be taken set out.

2) Design and layout of a clean room for a new generation of LCD backlight products. The analysis of process stages and of the required work areas formed the basis for the design and the layout. Frank van der Schans, an engineer at NDF, says, “The clean room now operates satisfactorily and the employees are always helping to improve it. That involvement is really important.”

3) Development and design review of a new type of fluorescent lamp, with the aim of modifying the prototype to allow for easy and more robust assembly. With the help of the TNO MAS (assembly process scheme) method, each of the stages has been examined with the employees using the TNO Product Design for Flow Assembly checklist. Improvements were implemented for the pilot run. NDF

“WE NEVER REALLY ALLOWED OURSELVES THE TIME TO TAKE A CALM LOOK AT THE FLOW. WITH SOMEONE FROM OUTSIDE, YOU DO TAKE THE TIME, AND IT IS NO BAD THING TO HEAR NOW AND AGAIN HOW THINGS SHOULD BE DONE.”

Frank van der Schans, engineer at NDF
“DURING THE MEETINGS, THE COMPANIES TAKING PART HAD THE CHANCE TO DISCUSS PRACTICAL METHODS AND EXPERIENCES, AND TO IMMEDIATELY ADOPT THEM. THE NAG MEMBERS WERE GIVEN THE INSTRUMENTS BY THE TNO TEAM FOR GETTING STARTED IN THEIR ORGANIZATIONS. IT IS INSPIRING HOW THE COMPETITIVE POSITIONS OF SEVERAL AEROSPACE SME’S HAVE BEEN IMPROVED, THANKS TO THE TNO SME PROGRAMME.”

Diana Nikolova, business support manager NAG

engineer Frank van der Schans: “The development of the new lighting technique has led to an entirely new production process at NDF. The production employees and TNO together made a critical evaluation of the process, simplified the work method, and implemented a number of improvements.”

KVE COMPOSITES GROUP
KVE Composites Group concentrates on the development and production of composite products. Together with TNO, the company worked on optimizing the work place flow in its Ypenburg branch. “The original layout was not clear, and led to a lot of extra activity,” recalls Max Willekens, product engineer at KVE. With a KVE project group, TNO drew up a product-process matrix for determining the number and type of work places that would be needed. The employees then helped to calculate what was required in terms of equipment and spaces, and the result was a new company layout, including the addition of a new hall. “With the new layout, we expect the amount of time spent handling materials and tooling to be about 25% shorter. But we will also see an increase in productivity due to more efficient production.”
10-20% SHORTER LEAD TIME IN COACH-WORK MANUFACTURING

The restructuring and more detailed preparation of orders have made the production process more efficient, with shorter lead times and lower production costs as a result.

Brinks Carrosserieën is an enterprise based in the Dutch region Twente, which in eighty years has evolved from a small bodywork and trailer business into a renowned company with a wide range of products. It is a total supplier, with the production of trailers and specific loading platforms as part of its overall product package, and trailer and tail-lift service, damage repair, renovation, and modifications to all kinds of constructions among the range of products and services provided. In the new build sector, the company specializes in supplying custom-made truck-loading cranes, hook-lift and cable systems, tippers, and trailers, including refrigerated trailers.

5S (workplace arrangement) and reduction in waste
At Brinks Carrosserieën, orders required more time, the further they progressed along the primary process. Delivery times and margins came under pressure. How could we make the process of bodywork construction more efficient, with shorter lead times and fewer failure costs? TNO set to work at Brinks Carrosserieën in Hengelo with this question in mind.

“USING THE NEW APPROACH, WE RECENTLY CONCLUDED A PROJECT FOR A CUSTOMER IN EXACTLY THE NUMBER OF HOURS SCHEDULED AND AT A COST OF 10% BELOW BUDGET.”

Jan Gerrit Vink, Brinks director
In a number of successive projects, a team from Brinks worked together with TNO on 5S, on redesigning the work place, and on lean – in other words, on reducing waste. This was done to some extent as part of a cluster with the CarrosserieNL trade association.

The redesign and the reordering of work places and material storage in a logical sequence resulted in orders and materials being dealt with more efficiently. To that end, the CAS instrument – the bodywork process scheme – was used, with which the building process was dissected and prepared. This was done in close cooperation with sales, purchasing, the company management, and production staff.

“Large series of more than ten items, for example, often took many hours more than they should. Lead times and costs were therefore a heavy burden on the company, partly because of our small team of 25 people and the great diversity of our range. Overruns of 10% or more in terms of planned production time, lead time, and costs were no exception,” says Brinks director Jan Gerrit Vink.

**Shorter lead time**

Because of the more detailed preparation of larger-scale new building projects, it is easier to manage the process and to make tighter schedule agreements with customers. “We have seen the lead time reduced by 10 to 20% because of this approach. Ultimately, this will result in greater turnover per m2 of work space, which was one of our objectives. This, in combination with the improved structure of the process, has led to a noticeable decrease in production costs – and at the present time, that is an absolute necessity, given the sharp decline in market sale prices. It is important that we stick to the new work method, including with incidental orders.”
NEW PRODUCTION CELL WITH GREATER PRODUCTIVITY AND REDUCED PHYSICAL LOAD

Together with TNO, Merford Cabins has set up a new production cell for the assembly of a special seat for crane operators on container cranes. This occurred in the context of the TNO SME efficiency and healthy workplace design project, in which four other companies in the manufacturing industry, in addition to Merford Cabins, took part. The result is clear enough: greater productivity and less physical load on the production employees.

Merford Cabins develops, produces, and supplies cabins and seats for different types of crane, specific vehicles, machines, and plants all over the world. The company is based in Gorinchem.

New production cell
One of Merford Cabins’ top priorities is ergonomics. That applies to its products and to their actual production alike. Merford Cabins director Daan Potters emphasizes the importance of the right working conditions for manufacturing crane cabins. “Ships are getting larger and longer all the time, so container cranes have to be larger in order to keep up, which means the operators have to work much more quickly.” The company recently set about improving the Ergoseat production cell. The Ergoseat is a special seat for crane operators, which has been evaluated by TNO.

In the old production environment, work was carried out on pallets on the floor – the parts were welded, with the heavy welded parts regularly being lifted and the individual components of the seat being assembled in the cabin. This meant that the production employees had to manoeuvre

"WHENEVER YOU WANT TO IMPLEMENT CHANGES, YOU ALWAYS RUN UP AGAINST SOME SNAG OR OTHER. WHEN IT MANIFESTS ITSELF, THE EMPLOYEES ARE ALWAYS READY TO SAY, ‘TOLD YOU SO, WE KNEW IT WOULDN’T WORK’. TAKING THE STEP TO ACTUALLY DO THINGS DIFFERENTLY IS THEREFORE NOT EASY. WHAT HELPED IN THIS CASE WAS THAT THE GUYS ON THE FLOOR WERE IMPRESSED THAT AN ORGANIZATION LIKE TNO WAS INVOLVED. IT PROMPTED A LOT OF PEOPLE TO START THINKING DIFFERENTLY.”

Daan Potters, director Merford Cabins
themselves into very awkward positions. Together with TNO, a design was made for a new production line that meets today’s ergonomic standards.

Stillage
In the new production cell, welding work is carried out at a working level; the components are all located on a universal stillage that is used for internal and external transport. All the assembly work takes place outside the cabin. At the end of the assembly process, the whole seat is mounted into the cabin, before being tilted into place and fitted in accordance with the individual customer’s wishes. For the production employees, this means that there is hardly any lifting of heavy parts by hand, that the need to adopt awkward postures pre-assembly and post-assembly has been sharply reduced, and that unnecessary handling of materials has been eliminated.

Joint project
As part of the joint TNO SME project, TNO introduced ergonomic knowledge and provided concrete recommendations towards the creation of optimum work places. In individual sessions, the participating companies and TNO set about making the changes almost immediately, while during the joint meetings, the parties swapped experiences and looked critically at each other’s processes and work environments. For every company, the end-result was twofold – work places that were more productive and less in physical load. The project was concluded with a joint presentation of the results to companies in the manufacturing industry.
WORK INSTRUCTIONS FOR PERFORMING ASSEMBLY WORK EFFICIENTLY – GETTING IT FIRST TIME RIGHT

Innovating work instructions for performing assembly work was a key part of the SME Knowledge Transfer Programme that TNO carried out in partnership with Syntens Innovation Centre, involving nine companies from the equipment, instrument, and machine building sectors. It concerned both companies that assemble product mixes in flow and machine building companies with an engineering-to-order environment. Here, we highlight two of the companies, Fri-Jado and Hytrans Systems.

Fri-Jado in Etten-Leur is active in the markets of the food retail, food service and non-food retail sectors. An all-round installation and service company and system integrator, Fri-Jado operates primarily in the Dutch market. Its most important fields are refrigeration technology, electrical engineering, security, and automation in stores.

Hytrans Systems in Lemmer specializes in the development and assembly of systems for large-scale mobile water transport and of mobile traffic signal systems. The systems are delivered all over the world.

Assembly process scheme – MAS – as the basis
Work instructions are an increasingly important tool for securing the quality of the assembly process. Quality here refers to minimum failure costs, short lead times, ease of learning, and a high level of reproducibility of the process. In practice, work instructions are often too brief, bear too little relation to the task in hand, and are insufficiently systematically updated. These factors, as well as the unpredictable nature of market demand and the flexible deployment of employees, mean that innovation of work instructions is essential.

Innovating work instructions for performing assembly work was a key part of the SME Knowledge Transfer Programme that TNO carried out in partnership with Syntens, involving nine companies from the equipment, instrument, and machine building sectors. It concerned companies that assemble product mixes in flow and machine building companies with an engineering-to-order environment. The companies participating were Biddle, Eleq, Hytrans Systems, Bandall, Bronkhorst High-Tech, IthoDaalderop, Bronneberg, Fri-Jado, and Tobroco.

Using the MAS method – the assembly process scheme – the assembly processes (for sample products) used by the
participating companies were designed with the assistance of the employees, and work instructions created and/or made more relevant to the sub-processes. To ensure that information was transferred as effectively as possible, guidelines were used for text and images. Below are the case histories for Fri-Jado and Hytrans Systems. Elsewhere in this booklet, you can find out more about how the improvement in work instructions was experienced by Biddle, Bronkhorst High-Tech and Tobroco.

Greater focus on work instructions also leads to improvement in product design
At Fri-Jado, the instructions are presented digitally on a screen, for each zone on the line and for each product type. They are managed on a demand basis via a barcode on the pallets. The screen shows an image with text. However, the texts proved to be too long, and as part of the project, they were changed into key points, set out in chronological order. Some photographs were replaced by 3D images, which convey the message more effectively. In parallel with the improvements to the work instructions, an examination was made with the engineers and production employees of possible improvements to the product design of a food buffet unit. The result was a simpler assembly process and work instructions that were easier to follow.

Setting down and transferring critical process information
The first thing Hytrans did with TNO was to examine the building process of a machine, with the help of MAS. It was immediately clear that not every bill of materials corresponded to the assembly process. Different parts of a module were needed at different stages of the product building process. As a result, focusing on the aspects of the building process and their related work instructions led to an improvement in how the structure of the bills of materials was organized. “In our company, we do not have much to do with turnover in employees. With a drawing and a bill of materials, most assembly
operators can reproduce the process. For more complex actions, such as alignments using special tools, it has proved useful to have additional instructions. We are now making more detailed instructions for larger systems, with an emphasis on critical action, safety, and testing,” says Johan de Kuijper, the head of the process planning department. “As far as Hytrans is concerned, an instruction is acceptable when an experienced assembly operator is able to test the installation using a document.”

For the testing instructions, Hytrans is considering placing digital screens in the assembly areas on which drawings can be shown. The company can also see the benefits of early-stage kick-offs with engineers and assembly operators when new products are introduced and when major changes are taking place. This will make it easier to evaluate and share expertise on the intended building process.
As part of the TNO EZ co-financing R&D programme, TNO examined, with DAF Trucks, Weir Minerals, and Total Productivity, what the most effective way would be for these organizations to teach and train their employees about assembly work. At DAF Trucks, the result was electronic work instructions, and at Weir Minerals a format and a method for developing the instructions. Total Productivity discovered more about the effect of age on different concepts of learning instructions.

DAF Trucks – a subsidiary of the American PACCAR Inc, one of the largest producers of heavy trucks in the world – is a leading producer of light, medium-sized, and heavy trucks. DAF is also leading in the services behind the product: its MultiSupport repair and maintenance contracts, financial services by PACCAR Financial, and first-class provision of components. In addition, DAF develops and produces components like axles and engines for bus and coach manufacturers throughout the world. DAF Trucks has production facilities in Eindhoven (the Netherlands), Westerlo (Belgium), and Leyland (United Kingdom).
Weir Minerals Netherlands in Venlo is part of the Scottish company, Weir Group PLC. It designs and produces technically sophisticated industrial pumps. Weir is an international firm and ranks in the top six of the world’s largest pump manufacturers. The products are used in mining, the production of raw materials, pipeline transport, energy extraction, wastewater purification, and in other fields.

Total Productivity in Broek op Langedijk conceives and builds production resources for customers in the manufacturing industry, from limited alterations all the way to entire work places or production lines and related software platforms for instructions and quality assurance, whether it involves products in large or small series.

The effective way to learn
What is the most effective way for employees to learn when product varieties are changing all the time? How do you determine whether someone is sufficiently familiar with the relevant knowledge? And what form do the work instructions that support experienced and inexperienced employees alike in the assembly process take? Does age play a role? These were the key questions in the project that TNO carried out with DAF Trucks, Weir Minerals, and Total Productivity, as part of the TNO EZ co-financing R&D programme.

Electronic work instructions
Assembly line employees at DAF Trucks in Eindhoven have to be able to master a variety of work tasks. Before anyone can start using electronic work instructions, it is important to know whether they are sufficiently familiar with the work. A decision is then taken as to whether the employee in question needs extra supervision when working. For the assembly of slow movers, an instrument has been developed in partnership with TNO that the team leader can use to determine whether an employee is skilled enough for the line position where he works. In the next stage, various electronic work instruction options are compared and assessed with a group of production and work preparation employees. The new electronic instructions are first tested before being implemented.

Format and method
“In the current situation, the experienced assembly operators possess a great deal of knowledge in their heads. There are work instructions, but they are not used enough,” says Ad Kock, Innovation Engineer at Weir Minerals. Together with a Weir working group, TNO used the MAS – the
assembly process scheme – to explore the assembly process in stages. The employees then helped to categorize the various stages according to their complexity, after which the sequence of the most complex stages and the critical operations within them were identified. This formed the basis for working out the details of the work instructions, for both experienced and less experienced employees. In consultation with engineering, process planning and assembly, a format and method were devised for establishing the work instructions, and for keeping them up to date and amending them.

**Effects of age**

How effective are learning instructions and does age play a role here? This was the key question for Total Productivity. To find the answer, TNO carried out an investigation together with the University in Amsterdam into the effects of learning instructions for a simple assembly task among both older and younger people. The quality and speed with which the tasks were performed were measured after a period of instruction of around thirty minutes. The researchers also checked to see if the participants still remembered these aspects after two days, and whether the quality and speed of their work remained the same if they were carrying out an additional duty to the assembly task in question.

The results showed, among other things, that it all depends on the instruction method. Older people in particular perform better if they receive instructions with explicit explanations. Peter Jan Zwart of Total Productivity says, “We thoroughly supported this experiment and made our resources available for it because we would like to know about the effectiveness of automated work instructions and possible differences between people. This knowledge will help us with the continued development of our instruction and monitor platform.”
CONSIDERABLE REDUCTION IN TIME NEEDED TO ASSEMBLE WHEEL LOADERS

Tobroco Machines in Oisterwijk has started using a new flow assembly line with which it has successfully achieved a more efficient product mix of different versions of wheel loader. The transition to flow assembly led to a considerable reduction in the assembly process time. Improvements to the work instructions shortened the amount of time needed for training employees to work on the entire production line from eighteen to nine months.

Tobroco Machines manufactures wheel loaders, fertilizing machines, and low loader trailers for agriculture, horticulture, and earthmoving. The company’s main activity is the wheel loaders, which it designs and builds. Welded parts are supplied and the final assembly work takes place in the factory in Oisterwijk. With a team of 95 enthusiastic employees, the firm builds around 1,500 wheel loaders a year. The range of wheel loaders extends to 25 different models.

Frame on a carrier
Working together with TNO, a team from Tobroco set about the task of converting the original assembly process into one that fulfilled the principles of demand flow and lean. The original assembly method at the factory in Oisterwijk involved building the wheel loaders individually at a particular location. This meant a lot of extra handling in order for the materials to be collected for each order and to bring them to the location in question.

“THERE WERE THREE THINGS THAT HAPPENED AT THE SAME TIME. WE MOVED TO NEW PREMISES, WE IMPLEMENTED A NEW WAREHOUSE, AND WE STARTED PRODUCING A NUMBER OF NEW MODELS. WE HAD OFTEN THOUGHT ABOUT PRODUCING ON A LINE BASIS, AND THIS SEEMED LIKE THE RIGHT TIME TO START. WE BROUGHT IN TNO BECAUSE THEY HAVE EXPERIENCE IN SETTING UP FLOW ASSEMBLY LINES.”

Michel Vriens, quality and production innovation manager at Tobroco
With the assistance of TNO, the employees drew up an assembly process scheme (MAS) for the product mix. A product-process matrix was then used to identify the differences in the individual pre-assembly, final assembly, testing, and dispatch processes. Alternative concepts for flow assembly were subsequently worked out, with particular attention being paid to moving the wheel loaders down the line and to establishing where materials need to be kept. “The frame of the machines under production is now on a carrier which is moved in phases to more than 23 zones. Pre-assembly items, such as the engine and the hood, are constructed immediately alongside the line and incorporated onto the line in the relevant zone. Materials and resources are present at the zone on the line where they are needed. The assembly operators work wherever it is necessary. An extra major advantage is that the assembly work takes place in small stages, so that the learning process for new employees is much easier,” explains Michel Vriens.

Considerable reduction in assembly time
Tobroco started operating its new flow assembly line in Oisterwijk in early 2011. It has led to a considerable reduction in assembly time of each wheel loader, and can be used for a wide product mix. “The results
are so good that we are also going to set up a line for the pre-assembly of welded frames.”

Digital work instructions
In a TNO SME cluster project involving nine companies, Tobroco and TNO together looked at the options in relation to digital work instructions for each zone and product type on the basis of the available data on product details held by Tobroco. The aim was to show step-by-step work instructions for each zone, including photographs, images and various options, in both Dutch and English languages, for the benefit of non-Dutch employees. Tobroco has opted for paperless instructions:

“We calculated that we can save around sixty man hours a week – just in overheads – if we move to digital work instructions,” says Michel Vriens. “In the project, we have organized the work instructions into a relevant sequence and were prepared for the transition to digital.”

“THE TRANSITION TO FLOW ASSEMBLY HAS CONSIDERABLY REDUCED THE TIME SPENT ON ASSEMBLY WORK. THE STRUCTURE OF THE PROCESS ALSO LOOKS MORE PROFESSIONAL. IT IS CLEAR THAT THE EMPLOYEES ARE VERY ENTHUSIASTIC AND ARE KEEN TO LEARN MORE. THANKS IN PART TO THE IMPROVEMENTS TO THE WORK INSTRUCTIONS, THE TIME NEEDED FOR TRAINING EMPLOYEES TO WORK ANYWHERE ON THE PRODUCTION LINE HAS BEEN CUT FROM EIGHTEEN MONTHS TO NINE MONTHS. WE EXPECT THAT TIME CAN BE REDUCED EVEN FURTHER IN THE FUTURE.”
In a variety of projects, a number of companies in partnership with TNO started using Lean Order Processing. Improving the preparation of orders in the sales – engineering – process planning – purchasing – planning trajectory resulted in a reduction in lead times and failure costs. This led to highly promising results. Three companies - Kinkelder, Inmaco, and Boon Edam – tell their story.

*Kinkelder* in Zevenaar specializes in the production of circular saws for professional applications. Their raw materials are high-alloy sheet steel and cemented carbide. Round sections are cut from this sheet material which are then hardened and ground. The most important market is the automotive industry.

*Inmaco* in Hoogeveen develops machines for the production of paper packaging for the food industry and others. Inmaco supplies its machines all over the world, usually adapted to the wishes of the customer.

*Boon Edam* is the international market leader in the field of access technology and specializes in the development of revolving doors and access systems. It employs more than 1000 people worldwide, in production companies in the Netherlands, China, and the United States, and in service and sales organizations in twenty countries.

**Lean Order Processing**

It has been shown time and again that inadequate preparation of quotations and inefficient processing of orders across the engineering, process planning and purchase processes leads to hold-ups during production and assembly, and therefore to increasing failure costs. Two examples of how things can go wrong: 1) order specifications that have to be modified after the order has been confirmed, even though the delivery date has been agreed upon, and 2) lack of awareness at an early enough stage of when which parts have to be ordered so that the materials needed for assembly are available. With the pressures of fluctuating market demand and shorter delivery times, and the need to keep costs under control, these problems are becoming more and more acute.
Reducing lead times and waste – or lean order processing – starts by harmonizing successive stages of order processing early on, and through clear external and internal communication. Lean concerns not just the manufacturing process here, but also – and very much so – the process preceding it. Disruptions to the overall process can be reduced by assessing the risks associated with order specifications at an early stage, by making the intended order process visible at an early stage, and by evaluating the feasibility milestones for engineering and supplies and the level of available manpower at an early stage. It is also about ensuring that everyone involved understands the benefit and importance of organizing the process more smartly, with clear release moments and rules.

Three companies – Kinkeldey, Inmaco, and Boon Edam – were joined by TNO in order to make lean order processing part of their everyday operations.

**KINKELDER REDUCES LEAD TIMES BY ONE THIRD**

Kinkeldey and TNO looked at enabling orders to flow rather than sub-optimisation at local work places. Previously, orders were issued weekly to production, which resulted in sub-optimization at the various machines and work places. Now, the production orders are issued on a daily basis and optimized on the machine with the greatest capacity.

Cooperation between planning and production employees in this area is excellent. Production provides the planning department with the right information regarding the amount of time needed for which type and size of saw. This means that the previous ‘tsunami’ of orders has been replaced by a continuous steady stream. On the shop floor, the order input and output locations for the different days of the week are colour-
coded and shown in clearly delineated areas. Kinkelder Quality Manager Walter van Marwijk says of the result, “The lead time has been reduced from fifteen to ten days. The process runs more smoothly and less chaotically, and the people have a clearer idea of what is happening overall.”

INMACO ELECTS FOR COORDINATED ORDER PLANNING
Together with TNO, Inmaco examined the possibilities for preparing and fulfilling orders in a more efficient way. From an analysis performed by TNO and the employees, there appeared to be too little coordination between the successive phases involving sales, engineering, purchasing, and assembly. This led to the need for extra work on the part of the assembly and order preparation employees for the orders to be delivered according to plan. Information on when which drawings and which parts had to be ready by in order for the assembly process to run without any disruptions was clearly shown on order process schemes. Work was carried out on setting up a coordinated planning process for the purpose of better monitoring and making visible the required level of manpower.
“FOR US, IT IS STANDARD THAT NOTHING IS STANDARD. THAT MAKES LEAN MANUFACTURING COMPLICATED, DURING THE SESSIONS WITH TNO, IT BECAME CLEAR THAT WE NOT ONLY HAD TO PLAN MORE EFFECTIVELY, BUT MORE ESPECIALLY THAT WE HAD TO KEEP OUR COLLEAGUES THROUGHOUT THE COMPANY INFORMED ABOUT THE PLANNING. THAT INCREASED EVERYONE’S SENSE OF INVOLVEMENT AND THEREFORE THEIR SENSE OF URGENCY. AT THE SAME TIME, BY PREPARING BETTER YOU CAN CONCENTRATE BETTER ON ORDERS, DEPLOY MORE PEOPLE, SHORTEN THE LEAD TIME, AND NOT HAVE SO MANY ORDERS CLUTTERING UP THE PROCESS AT ONCE.”

Gerard Markhorst, director at Inmaco
**BOON EDAM IMPROVES ITS ORDER ENTRY PROCESS**

Following on from an earlier project with TNO for streamlining the layout of its production, the order flows at Boon Edam were identified. This revealed that disruptions arose because products initially designated as standard nevertheless required certain options or non-standard construction methods further along the process. This meant additional engineering work for which special components sometimes had to be ordered that were subject to long delivery times. To improve this, the checklist used by Boon Edam during the sales order configuration process was expanded and made more relevant, so that the product was clearly defined at the order entry stage. A distinction was then made between three types of order flow: 1) standard, 2) standard plus customer-specific alterations, and 3) specials, which require a specialized project team. Each flow has its own colour code, so there can be no doubt what type of flow is being worked on.

“WE HAVE STARTED ALLOCATING EMPLOYEES TO ORDER TYPE 3, THE GREEN PROCESS FLOW, AND THE RESULTS SO FAR ARE VERY PROMISING. BY PROGRESSING TO LEAN, WE HAVE NOTICED THAT WE ARE ABLE TO PROVIDE BETTER SERVICE FOR OUR CUSTOMERS, WHILE DERIVING BENEFITS OURSELVES IN THE PRODUCTION PROCESS.”

Mark Koning, Senior Operations Manager at Boon Edam
GREATER PRODUCTIVITY THROUGH 5S – ORDERING WORK PLACES

Working together with the employees at Goma in Hengelo, TNO applied the 5S method to the company’s production of sheet metal – the result was greater productivity through a reduction in waste. In practical terms, this means less searching, less material handling, and better organized storage of resources and tools.

Goma is an internationally-oriented supplier that specializes in high-quality sheet metal products, including both semi-manufactured and complete products. With co-engineering, the use of fully-automated sheet metal processing machines, welding and spot-welding robots, its own powder coating equipment and assembly facilities, Goma offers a range of options for the production of housings and casings for different markets in the Netherlands and abroad.

GOMA decided to further innovate its production process by applying the 5S method. In the context of the Syntens -TNO SME programme, it was implemented with the help of TNO under the auspices of the Achterhoeks Centrum voor Technologie (ACT).

Organizing work places
5S stands for sort, set in order, shine, standardize, and sustain. The 5S method focuses on organizing the materials, tools, resources, and information in a work place so that activities can be carried out more efficiently – with less searching around for items and less handling of the materials through a practical layout.
Together with the employees, TNO examined the various work places in every department in the company. The sessions were always preceded by an introduction to the 5S method, so that everyone was persuaded of the benefits. The non-relevant materials and resources were then identified and removed. Agreements were made on what action to take on better arranging the materials in each work place and on keeping records of equipment and tools. Suggestions were also made regarding improving incoming and outgoing routes and storage.

In order to maintain the momentum of the improvement process, a panel was placed in each department with an illustration of the original situation, the improvements that had been made, and a to-do list that is reviewed on a periodic basis.

“In any company process, there are always people who embrace new developments immediately and others who prefer a more wait-and-see approach,” says Goma production manager Jos Beun and process engineer Luc Peelen. “That’s why we put together a small team of foremen who will keep their eyes on each other and make periodical critical evaluations of departments and work places. We are highlighting the assembly department as an example to our other colleagues.”
In the context of the TNO SME knowledge transfer programme in cooperation with Syntens, several companies utilized the expertise of TNO in improving the design and layout of their work places. The physical organization of the work and the internal logistical process of material supply and removal to and from the work place were the focus of this improvement process. The experiences from the project were then shared with other stakeholders at industry meetings.

Aqualectra, based in Heerhugowaard and Emmen, is a producer of high-quality electrical switchboards and operating panels, and a supplier of knowledge, services, and total solutions for energy distribution, control technology, and industrial and building automation.

Brink Climate Systems in Staphorst is a manufacturer and supplier of indoor climate solutions for homes and utility buildings.

Contour in Winterswijk specializes in precision sheet metal and module construction, with a clear focus on machine frames, containers, packaging, machine housing, and electrical modules and equipment. As the supplier and partner to Original Equipment Manufacturers, the company is mostly active in western Europe.

Sensor suit
In order to maintain a competitive production environment in the Netherlands, a healthy and productive work place, together with a demand-driven flow process, are essential. A healthy and productive work place is determined by such factors as the product design, component delivery by suppliers, the logistics process, resources, and the behaviour of the employees. Influencing the behaviour factor, in order to reduce the physical work load of employees for instance, is the most difficult aspect. When designing or redesigning work places, the behaviour factor should therefore be minimized, and instead the focus should be on the physical layout, the organization of the work, and the logistics process with respect to materials delivery to the workplace.
When designing and evaluating work places, TNO uses the 3D Ergomix and APLE (Automatic Physical Load Evaluation) instruments. The 3D Ergomix allows employees to work in their future 3D work place with the help of 3D visualization software and a 3D sensor suit. This means that the most important problem areas can be established and resolved at an early stage. Using the same sensor suit and on the basis of the most important relevant guidelines, the APLE quickly and automatically evaluates the physical burden. Checks can therefore be made in the work place as to whether a situation is green (safe), or orange or red (unsafe and chance of being physically overburdened).

**Less physical load during assembly**
Aqualectra was already in the process of changing the layout and organization of its production process, and in the context of the project the ergonomic aspects were included as an integral part of that process. The most outstanding ergonomic problem areas involved employees lifting heavy panels during assembly and then mounting the panels in a forward bending position. Together with TNO, a project team redesigned the work place, and included a universal assembly vehicle and a flexible material carrier. A balancer is used for putting the panels directly into the units without the need for employees to lift them. The evaluation of the new work place design by the APLE software and the sensor suit showed that employees no longer needed to bend or twist their backs. Aqualectra has since discovered that the new work place design is making a significant contribution to reducing handling times and that it has a beneficial effect on the health of the production employees. Director Tom Stringer summarizes the results for his company:

“*The most positive results of the project are less physical load during*
assembly work and more focus on the employees. The steps that have been taken contribute to people’s enjoyment in their work, reduce failure costs, cut the time needed to learn and to do the work, and enhance quality.”

Flexible deployment

A team from Brink Climate Systems and TNO worked jointly on a new design of the line and of the work place for the production of ventilation equipment. A flexible production concept was developed in which employees can work in different locations. This enables the line to deal with a mix of multiple models and with differences in production numbers. There are also fixed locations for preassembled products so that they can be attached to the end-product without physically overburdening employees.

Flexible work place design

Contour was prompted to make changes by the condition of the long-existing assembly department, where large quantities of material littered the floor. In the old situation, employees spent a lot of their time carrying materials. A new design was made in conjunction with TNO for a flexible assembly cell with a logical organization and with fewer items on the floor, and where people could work quickly and efficiently at a proper working height. Jan van der Kolk, an engineer at Contour, says, “I was inspired by the layout of the work place at Brink Climate Systems, and will be making the same changes at Contour.”
AIM – Advanced Instruments Manufacturing – found that the original set-up of its production line led to insufficient flow and flexibility. With the help of TNO, AIM succeeded in changing the design and the layout of the flow assembly line, and achieved its objective of reducing its production lead time by 50%.

AIM – Advanced Instruments Manufacturing – specializes in the production and assembly of high-quality medical equipment and instruments for various customers. The added value that AIM brings is its ability to produce flexibly for a very competitive cost-price and to meet worldwide quality standards for the production of medical equipment. The company has fifty employees and is based in Brunssum.

On behalf of TSCI (The Surgical Company International), AIM produces and tests the Mistral Air (MA+), a device that is marketed in combination with a sterile blanket made of an innovative material. The Mistral Air actively heats patients during operations. Since the start, the number at AIM has grown from around one hundred devices a month to three hundred in 2012, and this is expected to rise to about one thousand every month.

Insufficient flow and flexibility
A problem with the original version of the production line was the insufficient flow and flexibility. Extra transport to separate test areas, interim storage during production, and the handling of parts hindered any reasonable flow of products. In addition, demand is highly variable,
ranging from fifty to three hundred items per week. AIM’s objective for this project was to reduce its production lead time (for assembly and testing) by 50%, and to increase its ‘scaling up time’ from fifty to three hundred items a week within five working days. With the help of TNO, AIM and its customer TSCI spent a number of sessions working on the set-up of a new assembly line, including work places for the MA+ equipment.

**Improved product design**

During the analysis of the existing assembly process, time-consuming and laborious aspects of dealing with the product design were also critically examined. It transpired, for example, that sealing the housing took up a lot of time. It was also necessary to store items during the production process to allow them to dry. After the purchase of the appropriate equipment, the drying can now take place in the line, immediately after testing. Also, it used to be the case that sensors were fitted first and then embedded after the assembly process. This then required time to dry out, which again led to the need for interim storage. By making changes to the housing (mould) and by using specific tools, it is now possible to completely embed the sensors at the start, and then fit them to the device. The improvements to the product design were incorporated directly into the set-up of the ‘flow line’ so that both assembly and testing have become easier.
“THANKS TO THE CHANGES TO THE DESIGN AND THE STRUCTURE OF THE FLOW LINE, WE HAVE ACHIEVED OUR OBJECTIVE IN RELATION TO REDUCING THE PRODUCTION LEAD TIME (THE TIME FOR ASSEMBLY AND TESTING). IT ALSO MEANS WE CAN MEET FLUCTUATING DEMAND, AND IT SHOULD NOT BE FORGOTTEN EITHER THAT QUALITY CONTROL HAS BECOME EASIER THROUGH ONE PIECE FLOW-BASED ASSEMBLY AND A MORE SYSTEMATIC WORK FLOW WHICH IN TURN HAS SIMPLIFIED THE PRODUCTION OF UL CERTIFIED DEVICES.”

Peter Rindt, director and owner of AIM

Innovations in the flow line
Changes in the test software allowed for a completely automated test. The dependence on environmental factors such as temperature was also reduced. This means that testing can be done on the new version of the line instead of on each individual batch in a separate conditioned room. That reduces the need for transport and the use of space, and saves time. It also means that any errors can immediately be fed back.

The assembly flow line has been set up in such a way that material, pre-assembled items and tools are immediately available. Other proposed improvements concerned the packaging, among other things. Smarter packaging now means that forty devices can be placed on a pallet, rather than eighteen, as before, which makes an enormous difference in transport costs to countries like America.

The desired flexibility in terms of manpower has been achieved by operating two production lines. One line operates continuously at the minimum level necessary, but the rate of production can be changed on a daily basis by bringing in extra manpower, and by adding the extra line output can be further increased within five days.
"THANKS TO THE IMPROVED PRODUCTION PROCESS, WE HAVE ACHIEVED AN INCREASE IN PRODUCTION OF OVER 25% PER WEEK WITH THE SAME NUMBER OF PEOPLE, COMPARED WITH THE ORIGINAL SITUATION," SAYS BIERMAN TECHNICIAN KEESE LELTZ. "CREATING SUPPORT AMONG THE EMPLOYEES WAS AN IMPORTANT PRECONDITION."
Practical exercises
The company management and employees worked alongside TNO on improving the production process. Process schemes were drawn up, the flow of materials in the company layout was analysed and the number of work places established, while also taking an increase in production capacity into account. TNO held practical exercises with the employees in order to familiarize them with the batch and flow production process principles. The possibilities for adapting the product design for the sake of simplifying the assembly process were also examined. The construction parts for attaching belts are now included before the laminating process, for example, whereas in the original situation the heavy product had to be tilted by two people to mount these parts.

More in flow
Now that most of the changes have been implemented, products are handled in flow, resulting in a clear overview of the production process. In addition, less space is needed, there is less handling, and the physical load on employees is reduced. Material storage locations have been set up for the supply of individual components. Measures have also been taken to speed up the hardening process, while others are underway to reduce the need for the processing of laminated constructions.
Together with TNO, five companies in the TNO SME Technology cluster on flexible working have agreed on an approach for increasing the flexibility of their employees. We report on three of the companies, all of which are affiliated to the ‘Federatie Metaalplaat’ (the sheet metal federation, or FDP). The results vary from autonomous teams to flexible working hours.

Thomas Regout in Maastricht is a leading international player in the market for slide rail systems for use in bank systems and office equipment.

De Cromvoirtse in Oisterwijk is a supplier to the metal processing industry in the Netherlands. Custom-made steel, stainless steel, and aluminium parts can be ordered seven days a week, 24 hours a day, via the internet.

De Boer Machines in Wijchen is involved with the development, production, assembly and overhaul of pressing equipment for the brick industry. The company also manufactures, assembles and installs customer-specific machinery (see also page 10).

Varying market demand
Increasing productivity, flexibility and innovation are key in the sheet metal industry. It is these elements that enable the industry to maintain

“For FDP member companies in the manufacturing industry, TNO’s pragmatic attitude is appealing. That ‘down-to-earth’ approach makes all the difference when it comes to working with industry: no complicated textbooks or models, just very accessible information explained with a motivational touch. Most firms are convinced of the importance of increasing productivity and flexibility in their organization. But too often, they do little or nothing about it.”

Frederik Lodeizen, director FDP
its position on the European market. In order to remain competitive, organizations and employees have to move with the times. That involves, among other things, dealing with varying market demand. The more a company is able to adapt its workforce, the structure of its processes and the skills of its employees, the easier it can deal with fluctuating market demand. Any measures taken, of course, should be related to the nature of that market demand. However, the availability of employees and the complexity of the product also play a part in determining what measures should be taken.

Flexible working in self-governing teams
The first autonomous team was set up at Thomas Regout in January 2012. Eighteen people now have responsibility ‘from metal conveyor belt to customer product’. Working in a team automatically means everyone is jointly responsible for the end product. The quality and the lead time are important to the customer, and therefore to the team. In order to succeed, the team members have to be prepared to take over each other’s duties, to move to wherever the need is most pressing, and to be flexible in terms of working hours. In practice, production has increased, while the number of errors has fallen. Of course, this does not happen simply by itself. For the employees, this method of working took a great deal of getting used to, but they were assisted in the process through various instructional sessions and guidance on the work floor. For example, a special session with TNO was organized in which lean production was practised in the chain of successive stages in the process. The line managers also receive special training; they have been given a different, more coaching, role. Other departments now view the freedom of the team with a certain degree of envy.

“WE HAD TO OVERCOME A LOT OF RESISTANCE, BUT NO-ONE WANTS TO GO BACK NOW.”

Ruud Keulen, director of operations at Thomas Regout
Training and developing

In this context, having flexible employees who can be deployed in a wide range of tasks means being able to flexibly adapt to market demand. Given that market demand at De Cromvoirtse is somewhat changeable, it is essential that employees are capable of operating in different areas. De Cromvoirtse has created an overview of all employees and their skills, using a matrix in which the machines are grouped according to their weight category. For each employee the degree to which they are able to operate the machine is stated, along with whether they possess sufficient knowledge and skills to do so, and whether they are able to plan other work duties or help solve problems. Effectively, the team leader generates an overview of the ‘weak’ points in his team. The overview also helps promote discussions on continued growth and developments; many skills can be developed further. De Cromvoirtse provides a lot of support in this area, in the form of learning tracks and coaching on the work floor.

“THE COMPETENCY MATRIX OPENS UP THE DISCUSSION ON CAREER PATHS.”

Anja Aerts, P&O Advisor at De Cromvoirtse
Flexible working hours
The most important purpose of a time bank is to make a business more flexible. Employees work extra hours during busier periods, and fewer hours when things are quieter. The level of work at De Boer Machines varies, with the peaks and troughs spread out over several months or even a year. Has De Boer Machines managed to introduce a time bank for this complex situation? “Yes,” says Herbert Aalbers, the deputy operations director, “in close consultations with the employee representative body, we have introduced a scheme that stretches out over several years. Leave hours that are accumulated in one year do not have to be taken in that same year, and vice versa. It means that De Boer Machines has created a flexible scheme that can spread out those peaks and troughs over a longer period of time. Calculations by TNO have shown that we can expect savings on wages of around 5%. This will help strengthen our competitive position, but equally important is the growing realization among employees and managers alike that in this day and age, flexibility is needed in order to survive. As a concession to the employees, it has been agreed to provide compensation in the form of extra leave hours; in addition, individual arrangements are available for each employee.”

“THE SITUATION WAS VERY URGENT. OUR SURVIVAL DEPENDS ON THE INTRODUCTION OF THE TIME BANK.”
Herbert Aalbers, deputy director of operations at De Boer Machines

ROADMAP FLEXIBILITY
1. Set objective
2. Look at the resources to meet objective
3. Evaluate the utilisation of resources
4. Communicate desired changes
5. Implement and monitor results

Objective: __________

FLEXIBILITY PROCESS
- Flow production
- Parallel
- Flexibility in supply chain
- Delivery time, lead time
- Lean manufacturing
- ________

FLEXIBILITY PRODUCTION CAPACITY
- Timebank
- Overtime regulation
- Employee lend out
- Work timetable
- Temporary hire
- ________

CURRENT SITUATION
- Well organised
- Poor organised
- Bad organised

Objective: __________

FLEXIBILITY EMPLOYEES
- Large Employable
- Self governing
- Flexible workhours
- ________
MANUFACTURING INNOVATION – THE TNO APPROACH

The activities undertaken by TNO in relation to production innovation for the manufacturing industry involve a wide range of instruments and tools that are deployed interactively with the relevant parties in the company in question. This is the only way to create acceptance and momentum within a company for actually putting TNO’s expertise into action, and to conceive innovations that will have an impact. TNO’s knowledge and tools, and the means by which they are used in the manufacturing industry, are described in greater detail in this chapter.

Optimization supply chain

Cooperation in chains is the basis for increasing competitive strength, in both product and process innovation. A crucial factor is the bringing together of added value in the area of technology, materials, and processes, and the optimization of the integrated costs of the pooled expertise. The degree to which a customer can operate flexibly is determined by how flexible his suppliers are. Being able to deliver quickly requires a capacity to adapt on the part of your suppliers. This means carefully seeking out the right balance between short lead times, stock levels, and flexibility when changing from one process to another.

From the order preparation stage all the way to the completion of the order, value is added to the components and the final product. This can be in the form of hours, materials, or parts purchased from a supplier. The lead time is directly proportional to capital resources and the ability to deliver to customers in a short time. It means that the lead time forms a very important factor that can enhance competitive strength as well as the capital position of the company.
Suppliers can best tailor their operations accordingly, primarily by coordinating their successive disciplines in order processing at an early stage. An additional challenge in this regard is to have the flexibility to be able to supply small batches or individual items based on the customer’s needs in a short time, and to incorporate expertise on manufacturing feasibility at an early stage of the customer’s product design phase.

Reducing order lead time and reducing waste

Being able to operate quickly and flexibly in the manufacturing industry requires a focus on the flow of orders and on reducing waste, in both your own company’s processes and the supply chain. This focus is crucial for being able to deliver components and final products to the customer in a short time, as well as for getting it right the first time.

Experience shows that many orders are, as it were, “left lying around” during the lead time, often because certain processes are not properly optimized. This occurs during both the order preparation and completion stages, and the amount of ‘waiting’ time can be as much as 75% of the total lead time.

In the projects it runs with organizations, TNO aims to make lead times visible and quantifiable. The involvement of every company discipline in this is essential in order to ensure that everyone is pulling in the same direction and to make the lead time transparent. For a number of typical sample orders, we jointly identify the moments at which successive processes in the chain are ready, and determine the length of time needed for each stage to be completed. Then, together with the company team, we devise ways of making orders run more smoothly. Examples include preparing specifications at an earlier stage, setting deadlines by which parts have to be ordered, a better overview of overall order planning, clearer distinctions between the processing of standard and special orders, orders being issued more evenly, structuring the production process more smartly to allow orders to proceed more smoothly between successive processing stages, smarter organization of the process by which critical production machines are converted from one product to another, and so on.

Making the order lead time and each stage of the processing time quantifiable

<table>
<thead>
<tr>
<th>Times at which each stage is completed</th>
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</thead>
<tbody>
<tr>
<td>Acceptance of order</td>
</tr>
<tr>
<td>5</td>
</tr>
</tbody>
</table>

Critical path in order lead time: D = 51 days

<table>
<thead>
<tr>
<th>Processing time for each stage</th>
</tr>
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<tr>
<td>2</td>
</tr>
</tbody>
</table>
Waste is everything that takes time and incurs costs but without adding any value. TNO carries out observations in the process and uses a checklist for identifying eight types of waste in the company: producing more than what the customer has asked for, waiting, too much transport, too much storage, too much processing, too much movement, errors and recovery work, insufficient use of employees’ knowledge.

We run through this checklist together with the employees in the company and give a score. The results are used as the basis for the task of devising solutions for reducing the waste that has been identified (Lean).

Reducing the time needed for change over from one manufacturing order to another
Customers are asking for ever-shorter product delivery times in increasingly smaller batch sizes. Meanwhile, final products are becoming more and more varied. New product generations are appearing in rapid succession - an effect of continual product innovations - and product life-cycles are steadily getting shorter. As far as the manufacture of components is concerned, this means a shift from producing in large batch sizes with large quantities of intermediate stocks to demand-driven manufacturing in smaller batch sizes. In other words, gone are the days of grouping large orders together and bringing orders forward in order to keep the number of times that machines had to be changed over as low as possible. The same applies to manufacturing components surplus to what has been ordered so that they are in stock – which will result in delay of other orders.

To restrict stock costs, production machines and the way in which production is organized should be highly flexible. Competition in the manufacturing industry requires top-level performance when it comes to machine conversions. The organization of tools for processing and measuring, and for configuring the machinery, as well as CNC programmes and the supply and removal of materials, should be carried out smartly and in parallel in order to deploy capital-intensive manufacturing resources for smaller batch sizes in an efficient manner. The first thing needed here is an understanding by the employees of the importance of order flow in the context of optimizing processes at individual work places.

Increasing flexibility and production capacity by smarter change over to next orders
In its joint projects with organizations, TNO and the employees from the organization in question focus on the need to make the set-up process of machines flexible. We establish the details of the current process at work places that are critical to capacity, and together with the employees, we devise proposals for improvement and estimate what their effect will be. This is followed by a plan of action by which the most feasible solutions can be achieved. In many cases, reductions in set-up times of around 50% have been shown to be possible. The result is immediate benefits in terms of greater production capacity, faster order flow, more efficient production, and lower stock levels.

Reducing disruptions to production and assembly
We use the diagram below to identify and reduce disruptions to production processes, such as in the case of the manufacturing of sheet metal, machining, welding and assembly. Each process is systematically analysed in terms of the availability and quality of material, information, resources, and people needed.

What kind of disruptions occur during manufacturing as a result of deficiencies in the order preparation stage?

Lean Order Processing
In practice, the inadequate preparation of quotes and inefficient processing of orders through the engineering, process planning, and purchasing trajectory lead to unexpected events during production and assembly and, consequently, to increased failure costs. Disruptions can

Lean starts as early as the quotation stage
be reduced by assessing the risks associated with the order specifications at an earlier stage, by making the intended order process from beginning to end more visible, by evaluating the feasibility of engineering and supply milestones at an earlier stage, and by checking on the availability of required manpower. TNO uses a checklist for identifying the most important bottlenecks in the order preparation process and their causes. This is used as a basis for defining options for improvement.

Design reviews, modular product structuring, assembly-friendly design
Greater flexibility and shorter lead times in the order preparation and realisation phases can be achieved by using modularity in the product and process structure. This means that different final products can be built using flexible methods through the smart configuration of the product range. Modularity results in opportunities for parallel structures. Parallel structures provides a means for considerably shortening the lead time of the total process, as long as there is sufficient manpower and space. Modularity also makes it possible to base entire sub-modules, such as sheet metal frames, power units, and control cabinets (as well as the purchase of materials needed for these aspects), at specialized suppliers, thereby enabling the manufacturer to concentrate fully on the remaining aspects. Modularity also requires a clear demarcation of drawings and bills of materials at the engineering stage and correspondingly complete units that can be assembled and possibly inspected. Modularity can also contribute towards a higher level of service and installation, as service-sensitive parts can be exchanged quickly.

Example
Modular product structuring
Coachwork
- chassis
- floor
- sides
- front
- rear portal
- roof
Shorter time-to-market through parallel product and process development

Earlier coordination of product design and process:
- more project-based in multidisciplinary teams
- with partners in the supply chain

Both in concept stage and detail design:
- design review of risks of the function
- but also review of modular product structure, assembly process (MAS) and simplicity in assembly.

For streamlining the product design, including the process, TNO uses the MAS work instrument (assembly process scheme, page 62). MAS is a graphic representation of successive and parallel process stages, including timing estimates. It can be used to weigh up alternatives to the product structure and the structure of the process in terms of their effects on lead times and productivity, at both concept level and during the detailed development stage.

When analysing a product design, or draft product design, TNO also uses the Product Design for (Flow) Assembly checklist, which contains a series items such as modular product structure, the exchangeability of modules and parts, reducing the number and variety of parts, simplicity of handling and positioning. It is important that every company discipline is involved in this from an early stage, and preferably also the supply partners on account of their specific knowledge of the feasibility of manufacturing technology. The result is that everyone pulls in the same direction from an early stage, which helps prevent costly modifications later on.

Product structure – work instructions WI

<table>
<thead>
<tr>
<th>Assembly oriented product structure</th>
<th>Work instruction for each assembly</th>
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<tbody>
<tr>
<td>e-module</td>
<td>WI</td>
</tr>
<tr>
<td>m-module</td>
<td>WI</td>
</tr>
<tr>
<td>m-sub</td>
<td>WI</td>
</tr>
<tr>
<td>Complete to assemble and to test unit</td>
<td>WI</td>
</tr>
<tr>
<td>In case of machine building: work- and test instructions for each assembly</td>
<td>WI</td>
</tr>
<tr>
<td>In case of flow assembly: work- and test instructions for each zone/workstation</td>
<td>WI</td>
</tr>
</tbody>
</table>

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MAS - Assembly Process Scheme

Tool for streamlining product structure and process

Work and test instructions

The aforementioned MAS work instrument is also used when structuring work instructions. Work and test instructions form an increasingly important link for teaching and safeguarding critical process information, and for making it transferable. We make a distinction between basic instructions for teaching, and order-specific instructions for supporting customer-specific situations. TNO also operates guidelines for transferring information using text or images, so that the information is more appropriately tailored to the task at hand.

The experience, ages, knowledge, skills, backgrounds and languages of employees can vary considerably. This requires flexibility when it comes to teaching and instructing, which is why work instructions are increasingly frequently set out in a modular manner, and applied in accordance with the degree of experience of the employees.

Example workinstruction
Source: IKEA
Optimum design of process flow and work places

Whether improving an existing production and assembly structure or setting up a new one, TNO always attaches particular importance to the combination of smooth order flow and the efficient and healthy task execution by the manufacturing employees.

In the case of part manufacturing, this may concern the transition from a functional structure (like turning department, milling department, welding department) to a manufacturing cell based around a product group, in which a team processes parts in a common sequence using a group of processing machinery.

With regard to assembly, the assignment may concern the transition from batch-based to flexible flow assembly for a variable mix of products, but it could also entail the layout of a new factory.

Demand Flow Assembly for a productmix

As the basis for the design of the new structure according to Demand Flow, TNO always uses a matrix of product types, intended quantities, required process stages, and the actual work at each stage. Then, for each product group, the MAS method is used for examining the successive process stages as value is added, both sequentially and in parallel. With the help of Demand Flow calculations, we establish how many and what types of work places are needed. We then look at material locations, resources, and the amount of space that will be taken up. Alternatives for process flow and transport are also compared.
and considered, and the solution with the greatest chance of success is then selected, after which we examine the most logical sequence of work places. We also look at the structure of the individual work places, so that the work can be carried out as efficiently as possible.

We use checklists for evaluating both the process layout and the ergonomic design of work places, and tools are available for analysing and improving the ergonomics of the work places. For example, we use Ergomix for positioning employees in virtual and 3D drawings of the work place, and for evaluating their actions (see the Work Place Design case elsewhere in this book).

Analysis and design workplaces using Ergomix

5S – order and neatness on the work floor
Applying the 5S method leads to order and neatness on the work floor, both in manufacturing areas and in offices. The five S’s stand for sort, set in order, shine, standardization and sustain; the method clarifies the need to organize the efficient use of work places, machines, resources, tools, material locations, and documents.

In any project, TNO takes a pragmatic approach, starting with a look at the work places, working together with the employees. Action labels are attached to objects in the work places, stating whether they should be removed or placed in order. Signs at the entrance highlight the progress being made, and the original situation and the improved situation are both depicted. Periodic internal audits are held to make sure that efforts at creating order and neatness are maintained.

Using employees more flexibly
More demand-driven production in short lead times, and with limited stocks, represents a tough challenge for an organization (in terms of its own processes and delivery) and requires dedication on the part of employees. TNO has the expertise that can enhance the flexibility of an organization and the flexible deployment of employees, and coordinate them according to changing market conditions. We run through a number of scenarios involving various flexibility measures, and make a cost-benefit calculation of each scenario. For example, this allows a
company to determine whether or not it should operate a time bank and to what degree, while perhaps taking on flexible employees at the same time. It also enables companies to decide the optimum ratio of permanent and flexible employees. We use a competency or deployability matrix to highlight multi-deployability – showing which employees can perform which tasks, and whether they can do so unsupervised or not. This serves as a starting point for training programmes (see the ‘Resilience in the sheet metal industry’ case elsewhere in this book).

**Further development of our expertise**

**7 drivers for success in the manufacturing industry.**

In de management journal MT – Management Team of March 2013, seven drivers for success are indicated:

- To be a specialist in a particular market, product or technology. That means innovation with a consistent strategic focus.
- High level of qualified management able to invoke employees to realise the company vision.
- Create trust within the company structure in order to enhance cooperation between internal and external disciplines.
- Management of the manufacturing supply chain, create partnership.
- Overtake care from the customer, like logistics for product modules, maintenance, etc.
- Do not only compete on price. Focus at more added value.
- Sustainability will become increasingly important. Develop a long term vision.

In the light of these market developments, TNO will continue to expand its expertise and tools in the next few years in collaboration with industry in the following areas:

- Optimization of manufacturing supply chain
- Product modularity and design for (dis)assembly, maintenance, (re)manufacturing in order to reduce time to market and failure costs and to expand product life time (Circular Economy)
- Flexible manufacturing and assembly factories and organizations
- Teaching and instruction, to ensure optimum knowledge transfer to employees
- Interaction between people and machines & robots in automated and hybrid production environments
TOWARDS INCREASING PRODUCTIVITY AND FLEXIBILITY IN MANUFACTURING

With:

- Higher added value and reduction of waste (Lean)
- More efficient flow of orders in shorter lead time (Flow)
- Optimization of co-operation in the supply chain
- Higher motivation and involvement of employees in multidisciplinary innovation processes
- Efficient preparation of orders through quotation, engineering, purchase and process planning (Lean Order Processing)
- Smart organization of set-up process at manufacturing equipment
- Modular, assembly oriented product design (DFM – product design for manufacturing)
- Ergonomic workplaces for efficient and healthy task performance
- Sustainable employability for young and aged people
- Flexibility in employability
- More effective training and application of work instructions to perform the task in zero defects

By: Continuously development and application of new expertise and tools for the manufacturing industry

Together with: The TNO team Sustainable Productivity & Employability for the Manufacturing Industry