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Preface

The University of Trieste (Università degli Studi di Trieste) and the Ostwestfalen-Lippe University of Applied Sciences introduced the International Double Degree Master Program ‘Production Engineering and Management’ in 2011. Its aim is to give students in Germany and Italy, along with other countries, the chance to learn the necessary abilities from lecturers and each other. This Master Program has been accompanied by the International Conference ‘Production Engineering and Management’ from the very beginning, in 2011.
The annual International Conference on Production Engineering and Management took place for the fourth time this year, and can therefore be considered a well-established event originating from the partnership between the Ostwestfalen-Lippe University of Applied Sciences (Germany) and the University of Trieste (Italy). The main aim of the four conferences has been to bridge the gap between production engineering and management theory and practice, by offering a platform where academia and industry could discuss practical and pressing questions. In this respect, the fourth conference (PEM 2014) continues along the same path as the first three successful conferences, which were held in Pordenone (2011), Lemgo (2012) and Trieste (2013). PEM 2014 benefited further from research and industry projects, particularly those of successful graduates. The title ‘An active interaction between university and industry’ introduced last year to emphasize lively cooperation proved to be more than appropriate to the conference’s main orientation:

- To present current research projects and their results at a highly sophisticated scientific level
- To discuss recent developments in industry and society
- To bring professionals, specialists and students together
- To enable professionals, lecturers and professors to exchange experiences
- To familiarize young professionals and students with scientific conference procedures
- To give postdoctoral and Ph.D. students the chance to present a paper
- To show the two partner regions’ uniqueness and performance
- To attract students for an international career in the industry
- To encourage students to be open-minded about different cultures, mentalities and manners

PEM 2014 took place between September 25 and 26, 2014 at the Ostwestfalen-Lippe University of Applied Sciences in Lemgo (Germany) and was supported by the German Academic Exchange Service with funds of the Foreign Office of the Federal Republic of Germany. The program was defined by the Organizing and Scientific Committees and clustered into seven scientific sessions.

Both universities and their partner organizations debated these topics, reporting their research, experiences and success stories. The scientific sessions dealt with technical and engineering issues, as well as management topics, and included contributions by researchers from academia and industry. The extended abstracts and full papers of the contributions underwent a double-blind review process.
The 24 accepted presentations were assigned, according to their subject, to one of the following sessions: ‘Pathways to the 4th Industrial Revolution’, ‘Industrial Engineering and Lean Management’, ‘Quality Management’, ‘Surface Treatment of Wood Products’, ‘Product Innovation and Design’, ‘Management Techniques and Methodologies’ and ‘Master’s Projects’.
These sessions have been carefully selected by the Organizing and Scientific Committees and are aimed at highlighting some of the current production industry’s most discussed topics. Therefore, the articles address sustainability and revolutionary developments in modern industry and cover not only production in the narrower sense, but also new aspects of: innovation and product development, supply chains and quality improvement.
The proceedings have been drawn together to form 24 full papers of the scientific contributions. The articles were reviewed by the Scientific Committee before being accepted.
As the editors of the proceedings, we would like to thank all contributors, the referees who accepted the burden of reviewing the full papers and the members of the Organizing Committee and Scientific Committee for planning such an effective conference.

Franz-Josef Villmer *Elio Padoano*

CONTENT

KEYNOTE – IMPORTANT SUCCESS FACTORS IN THE EAST-WESTPHALIA-LIPPE REGION AND ITS INDUSTRY

E.-M. Hasse
President of the Chamber of Commerce and Industry (CCI) Lippe, Detmold

Dear ladies and gentlemen,

I wish to extend my warmest greetings to you on the occasion of this exciting conference. Your conference is symbolic of a crucial theme applicable to the future of industry and Europe as a whole as a manufacturing base. In both science and industry we have to set the course for the future. In both short and long term we will only survive if we can provide highly flexible, unique and competitive systems.
You are meeting in East-Westphalia- Lippe, a region that has set its aims at becoming a leading industrial area in Europe over the next few years.
My presence here today is for three reasons:

- as president of the Lippe Chamber of Commerce in Detmold to let you know where exactly you are.
- as a member of the University Council I will explain why the transfer of knowledge is so important.
- as an entrepreneur to stress why it is well worthwhile to promote the area for the future.

On your journey to Lemgo you will have seen that we live, learn and work in a very green environment, without large cities.

We like that!

However, that is also a problem, at least as far as marketing is concerned. East-Westphalia-Lippe is an area not known by most people or at least not appreciated.

- As a German one may know the Teutoburg Forest, the Hermann Memorial or even the Extern Stones. Yes, East-Westphalia Lippe is a tourist region and leisure area (somewhere between Cologne and Berlin). East-Westphalia Lippe is an artificial name. Creative as we are we translated it into the English “OWL”.

We think that the abbreviation “OWL” is better to remember and to recognize.

- As an industrial region it is not so much known.
- However, many people are familiar with the brand names Miele, Melitta or Dr. Oetker, but few associate them with East-Westphalia-Lippe.
- Phoenix Contact, the company you visited today is probably only known by experts who work in industry.

What is especially missing in Lippe, that is, to portray us as an industrial area, is a selection of large well-known brand names. Lippe industry cannot boast well-known brands that you might find in supermarkets, electrical stores or at car dealers.
This results in hardly anyone regarding OWL as an important industrial location in North-Rhine- Westphalia. Would you believe that over 30% of the working population works in industry? That is about 10% more than the average for NRW. This is also way more than the cradle of German industry- the Ruhr Area.
The Ruhr Area is in a somewhat difficult position as the change in structure has not yet been successfully achieved.
This is different in OWL: the fabrics, textile, cigar, wood processing and furniture industries all dominated the industry in their boom days. However, they experienced surprising and aggressive competition from abroad which resulted in a downturn in business and structural crisis.
Reasons for this crisis were e.g. cheaper labor costs or faster or more efficient production processes abroad. A subject that you are discussing today.
How a structural change can be achieved may be seen in a small excursion into the history of my company.
S&H was founded in 1858 in Lügde. Along with many other companies in the region we manufactured cigars. We did so successfully! At the height of our activities in 1912, we employed no less than 600 persons. These were located in eight factories.
Not until the end of the Second World War did we start manufacturing magnet wire. We already know how to wind. We finally gave up manufacturing cigars in the 1980´s. Today we are the leading manufacturer

of enameled copper wire in Europe. We are independent and we employ 230 persons.
From the past we can learn that it is never good when a region is dominated by single companies or when the structure of industry is too one sided.
Our region is well equipped to withstand structural crisis. In the meantime there is a wide variety of industries here. The more significant ones are machine manufacturing, electrical, plastics and food industries.

- The result is that 75% of the world´s electrical connection technology originates in OWL.
- 70% of German kitchen furniture also originates from here.
- OWL plant engineering and machinery manufacturing belong to the leaders in Europe.

The fact that we are so well positioned in many areas has various reasons.

Success factor number 1 I will describe as being a "healthy selection" of private, family owned companies.

You will find it hard to find large corporations in OWL. That may be seen by some as a negative marketing feature. In actual fact, it is an advantage for the regional development, as most privately owned companies are family run.
Family owned companies view long term success as more important than short term gains. They show a sense of responsibility towards their employees and identify closely with their area. They are open for positive external influences.

This brings me to the second success factor." Networks and transfers."

Up until about 15 to 20 years ago one would have been correct in saying that many private companies in OWL

- supposedly knew everything better
- kept everything to themselves, or
- avoided working with institutes of higher education

That may be a reflection of the solitary nature of the "Lipper." Fortunately, we realized quickly that we would not be able to survive in a global environment with such an attitude. Today OWL is a prime example of networking and cooperation in Germany.
In more than ten own created branch networks companies exchange information which can help them in global competition. This extends beyond the individual branches of industry. At the same time competing universities work together on a variety of projects.

The result has been that the transfer of knowledge between industry and science has become commonplace in this region.

Success factor 3 is “successful research and innovation”.

In a world in which scientific findings in research are quickly transferred into common use, in which cycles of innovation are becoming increasingly shorter, and at the same time an increasing flood of information stops people from creative and productive working, privately owned companies need active and constructive support of applied science.
In many cases this works very well. Not least because a mutual understanding between the parties has been created. The “ivory tower” syndrome and the “linguistic” barriers have largely vanished.
The institutes of higher education in the region have in the last 20 years developed to a significant source of impulses for innovation in local companies.
Both sides benefit from this development i.e. an increase in external funding, excellent results in projects and trained graduates.

These three factors and the determined will to no longer be eclipsed by other significant industrial regions of Germany, has resulted in the fact that we are now one of 15 top cluster regions in Germany.

In 2012, 24 research companies, six institutes of higher education, 14 research institutions, 100 other companies and 30 industrial linked organizations applied to the Federal Ministry for Research to gain the status of “top cluster.” We won!
A € 40 million grant and € 60 million own resources will flow into the top cluster “Intelligent Technical systems OWL” by 2017. This in research and transfer projects but also further education and the promotion of acceptance of new technologies.
On a technological level the area bet on the right horse with its project “Industry 4.0”
With Industry 4.0 we combine the strengths of important branches in the region. Machine construction, electrical technology, information and communication technology together with the universities in OWL will create solutions for the future that will revolutionize production.
Self-optimizing systems, flexible and changeable manufacturing, intuitive operating, the direct cooperation between man and robot are just a few examples.
This research will not only benefit the associated companies from the three branches of industry. The new methods and technologies can already be applied in their early stages in plastics processing, vehicle production as well as food manufacturing. At the same time they can be tested developed further.

This will be an important contribution to enable complex but at the same time well manageable systems to be provided by Germany. This will achieve significant cost advantages, allow us to work in a highly flexible manner and thus remain competitive.
OWL did not only emerge as a “winner” as far as the financial development grant is concerned, but also through our success in becoming a high-tech region.
With the Top Cluster “Intelligent Systems OWL” has made its mark not only in the area of science but also in the economy and in politics.

Why is that so important?

Basically, we are all in competition with other companies, universities, regions and countries.
This for:

- Success in the market place
- Investment decisions and government grants
- And not least, qualified personnel!

As a region without corporations, without the supposedly attractive large cities and without being that well known, we have to fight that much more to get qualified employees. But we have to look to our own population to solve the problem. This is what we are doing with our campaign “Industry- a future in Lippe”. The campaign started two days ago.
Every company that supports our region should:

- Promote our area everywhere, be it exhibitions, customer visits or discussions with suppliers.
- Show the young generation, qualified personnel, and population at large, what industry is doing for them.
- Promote more acceptance of innovations and new technologies.
- Get involved in politics and local government to fight for good conditions in education, research and infrastructure.
- And in this way get involved in the successful future of our region.

I also invite you to get to know us better. Become inspired and convinced by OWL, through our small and large world leaders, our exciting jobs, the competitive cost of living, the high quality of life here and our special charm!
I wish you a successful conference, many new impressions and positive discussions.
I hope you will remember your stay in Lippe in a positive way.

INDUSTRY 4.0 – CHALLENGES FOR INTERLINKED PROCESS CHAINS

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Abstract
Information Technology (IT) has widely spread among the private and business life of humanity. In the so-called information age almost everyone is connected by means of IT and linked computers, smartphones etc.. The potentials of these technologies have been utilized since many years in the administrative sector of industry and shall now rationalize the production. The German term “Industry 4.0” comprises the integration of IT in all parts of the producing sector. Machines and production facilities will be upgraded to Cyber-Physical-System (CPS) with the capability of self-organization and self-optimization. Products will be able to operate their own manufacturing. Therefore, it is essential that the CPS and embedded computer systems are able to generate correct process data for manufacturing, respectively. This requires valid process models to create a virtual counterpart of the real production. As most products are not being finished with a single process, but with interlinked process chains also the virtual counterpart must consist of interlinked models for the process and product data. A combination of a product data model with connected process models for the production of profiled elements in the wood working industry has been developed in a research project at the University of Applied Sciences Ostwestfalen-Lippe. The results of the research work have shown that networking of process models by means of a product data model is a logical step to integrate IT into a complex process chain with high interaction between the individual processes and to benefit from simultaneous engineering and the potentials of “Industry 4.0”.

Keywords:
Industry 4.0, interlinked process chains, product data model, process models, CAD/CAM, process chain of profiling

1 INTRODUCTION

1.1 The vision of Industry 4.0

The German federal government has proclaimed the fourth industrial revolution (“Industry 4.0”) as part of its high-tech strategies combined with large research funding to accelerate the objective target to integrated information technology in production processes. The networking of the entire production with all components (machines, tools, products etc.) by means of information technology should increase the manufacturing flexibility as well as generate a higher production and resource efficiency. In the terms of "Industry 4.0", the future production plant ("Smart Factory") consists of decentralized units with the capability of self-organization and self-optimization. Machines and production equipment are upgraded by the integration of actuators, sensors and embedded intelligent computer systems to cyber physical systems (CPS). The CPS act together in the "Smart Factory" and are characterized by a high communication among themselves (Fig. 1). [1]

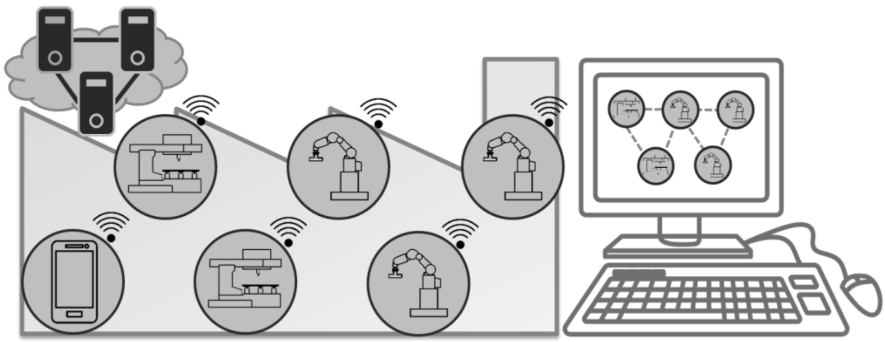

Figure 1: Industry 4.0 – networked production, acc. [2].

The elements of the "Smart Factory" stand out due to a high adaptability and flexibility. Machines are able to change their configuration in case of different requirements for the production of a new product or product variant. "Plug and Produce" allows to integrate new machines, components and tools without big effort in a production line like the example "Plug and Play" for hardware components for computers. Also the products are integrated into the communication and operate their own manufacturing. They are connected to a product data model, which includes all information for manufacturing as well as a production history. The information are linked by means of RFID-tags, Barcodes and databases respectively. [3]
The machine-to-machine (M2M) communication in the context of "Industry 4.0" creates the Internet of Things, which is not limited to elements of the tangible production. Also peripheral equipment will become "smart" and for example buildings allow the M2M communication to control the illumination, heating, etc. (Fig. 2).
The Internet of Services extents the communication to all kind of services linked to the production. Thus, diagnostic data for example can be analysed by a web-based service of the machine producer and organize maintenance

operations or places the order for spare parts automatically. Another example is the concept of “Smart Grids” where energy efficient processes or sub processes like the heating-up of a machine is done at the temporary lowest electricity rate. [2]

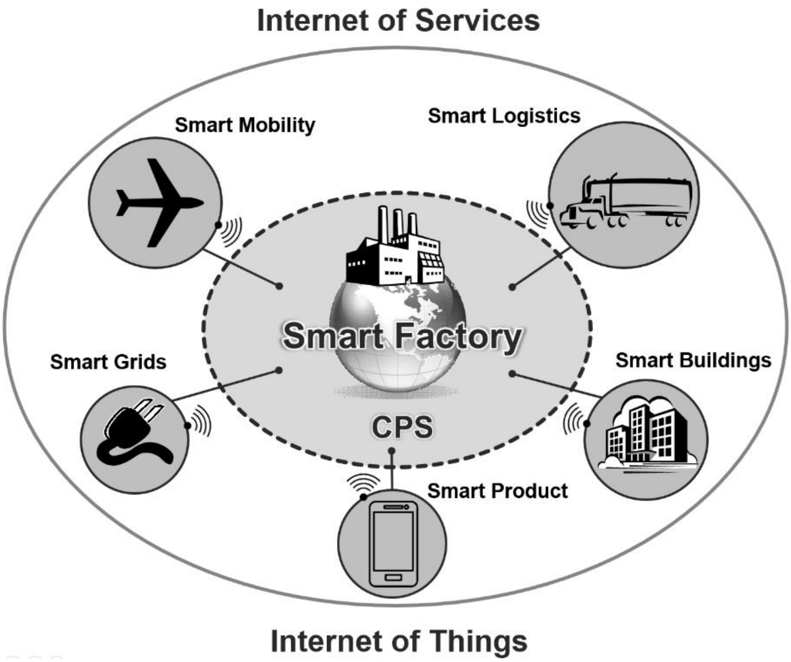

Figure 2: Elements of Industry 4.0, acc. [2].

This vision of “Industry 4.0” requires open interfaces and standards for the data exchanges between all individual elements of the Smart Factory. In addition, the embedded computer systems must have the capability to generate the necessary process data, control and monitor the represented individual (sub-) process. Therefore, a virtual counterpart of the real production must be created by means of process models, networked in a virtual reality. Also the required and collected data must be retained in a structured data model. These mentioned needs constitute the main crucial issues of this new attempt in production.

1.2 Interlinked process chains

The characteristics of these main problems increase with the complexity of the existing manufacturing processes and its interaction with other

processes in a production line. Such interlinked process chains can be found in all industrial sectors, including the woodworking industry.
The production for profiled elements for furniture, doors, kitchen etc. requires a production chain with processes that are strictly based on another and have a high degree of interactions. The process chain of profiling consists of main processes like sawing, moulding, sanding and coating as wells as sub-processes, for example the tool manufacturing and reconditioning (Fig. 3).

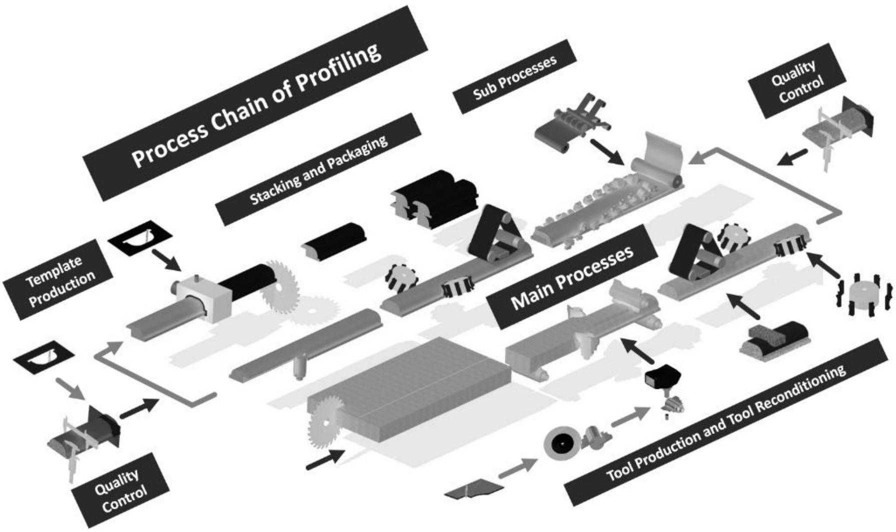

Figure 3: Complex setup of process chain of profiling.

The result of one process in the chain is the input for the subsequent one and this process has to be adapted to the characteristic of the product in this production stage with all occurred variations, due to systematic and stochastic (e.g. tolerance) errors. State of the art is manual process design and setup with real profile samples, based on the experience of the operator. CNC-technology is basically used as a (re)positioning aid. [4]
To upgrade the process chain in the context of “Industry 4.0” a programming system must be able to simulate and calculate the output of an individual process, which is probability related and useable for the next process calculation. The process data generation is thereby done with interlinked process models.

2 PROCESS MODELS

2.1 Individual process models

The analytical and empirical investigation of individual processes with the target to build a model to describe the real behaviour has been carried out for many years. In the wood working sector, in correlation with the process chain of profiling, different process models can be found in literature. Kivimaa [5] established in the early 1950 a model to estimate the cutting force to calculate the resulting surface, especially for moulding operations. In general for cutting operations Licher [6] introduced a knowledge database for cutting parameters together with a model to estimate the tool wear. Riegel [7] investigate sanding operations and found inter alia a model to calculate the stock removal. These models created a groundwork for the research work along the process chain of profiling at the University of Applied Sciences Ostwestfalen-Lippe.

The research work started with the process of profile wrapping, due to its complexity and the necessary expert knowledge to set up and run the process. In the first step, a process model was developed to calculate the temperature profile and in addition to estimate the adhesion strength of coating. In the next step a geometrical model was created to calculate the pressure of rollers. This was enhanced by means of an expert system to a programming system to generate the setup data (Fig. 4). [8]

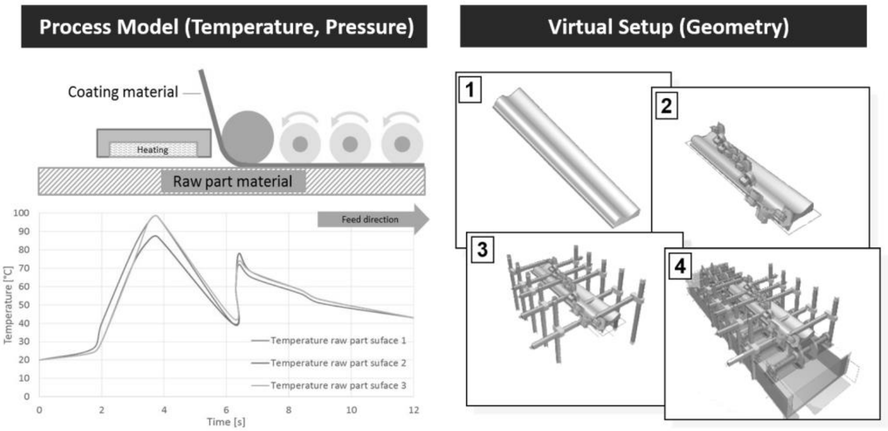

Figure 4: Process model for profile wrapping.

However, the position of the profile wrapping process in the chain requires the linkage of its process model with the models of the previous process, as the real input for the process is otherwise uncertain and will lead to wrong process data.

2.2 Networking of process models

In the process chain of profiling usually a moulding process is the first shaping step where systematic and stochastic errors have an impact on all subsequent processes. This process was modelled for the simulation in a virtual reality using the mentioned existing models for cutting parameters, cutting performance, tool wear and the geometrical description of the resulting surface of the general peripheral moulding operation. In the further research work an expert system was develop to generate all necessary data for the setup including the alignment of the work piece, the number of cutting passes and a full geometrical setup. The model was implemented in programming system to create the virtual counterpart. Fig. 5 shows the process design for a profile with the resulting parameters for the separate spindles in the moulding machine.

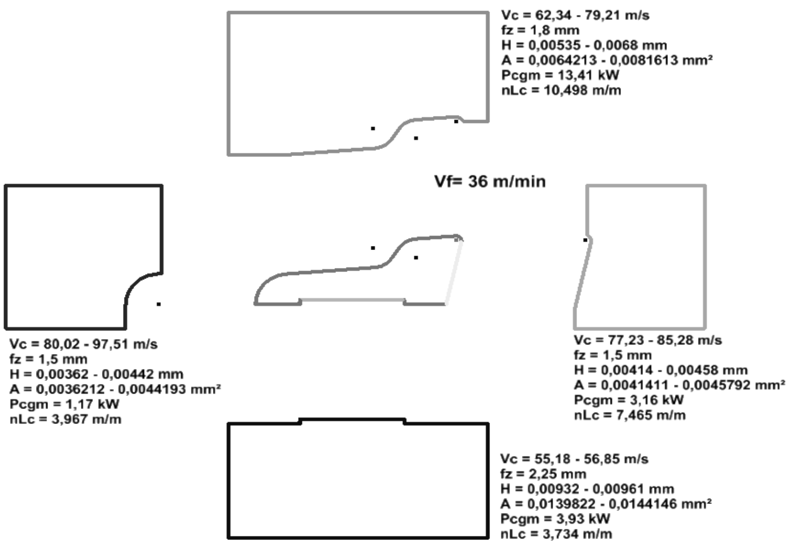

Figure 5: Process set up and parameters for a moulding process.

The developed model also implies the influences on the profile geometry of the moulding and the preceding tool manufacturing process. Thus, the result of the calculation is the estimated profile geometry after the moulding process with a geometrical description of the surface, with the typical pitch. This data is linked to the subsequent process to generate its process data

for the manufacturing. In case of subsequent sanding process, the linked information about the profile geometry is used for the alignment and the number of cutting passes, similar to the functionality of the moulding model. As the geometry is linked with the data of the pitch on the surface (pitch – fz, pitch height H and the area A) it is possible to generate the optimal process parameters. Riegel and Schneider [9] developed a model to calculate the necessary volume of material to be removed from the moulded surface to get a smooth one. The calculated volume is equalized with a process model to estimate the stock removal of sanding operation and provides the optimal sanding parameters.
This systemic functionality is used for all process models and provides the correct input and output data of any step in the process chain.

3 TOLERANCE MODEL

All calculations of the models are carried out before the real production to benefit from simultaneous engineering and to increase the efficiency. Therefore, it is essential that the model considers the influences and corruption of the process step on the profile geometry (Chapter 2.2). The influences must be divided into systematic errors, that occur every time and can be described with parametric rules and stochastic errors, which are caused by different effects and can be summarized as the fabrication tolerances of a process step. In the developed tolerance model, the different stochastic influences are considered by means of a statistical approach. Each influence, e.g. the positioning accuracy of a milling spindle, is characterised by a typical statistical behaviour and describable with a density function. Merging the influences of a single step or the whole process chain requires the convolution of the correlating density functions (Fig. 6).

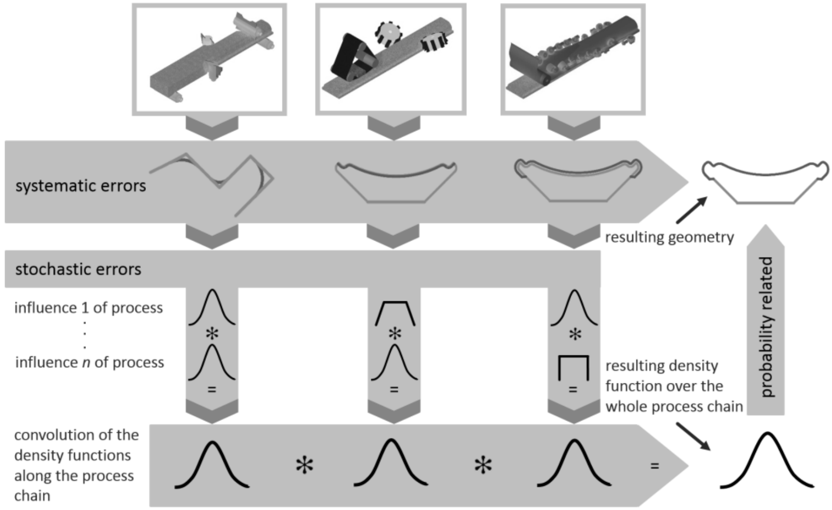

Figure 6: Systematic of the tolerance consideration along the process chain.

Thus, the consideration of the systematic and stochastic errors results in the probability related, corrupted output geometry of an individual process step. The uncertainty of the calculated output geometry is described with the resulting density function. This allows an estimation of the achievable quality and process capability before the real production.

4 DATA MODEL

The networking of the process and tolerance models with the described functionality is only possible, if the data exchange between the models is structured and standardized. It is also necessary to connect the process data with the product data to obtain all information for the different calculations. In the presented research work, a product data model was developed and used to interlink the data exchange. The product data model was realized by using the XML format with an integrated part for pure geometrical data in the DXF-format. In the first step, the data model contains the target profile definition with the geometry, materials, qualities and tolerances. This information is the input data for the first calculation with the process models, which are integrated into CAM-modules for the process steps. The output data representing the output of the process step is transferred back into the product data model and again the input for the next step (Fig. 7).

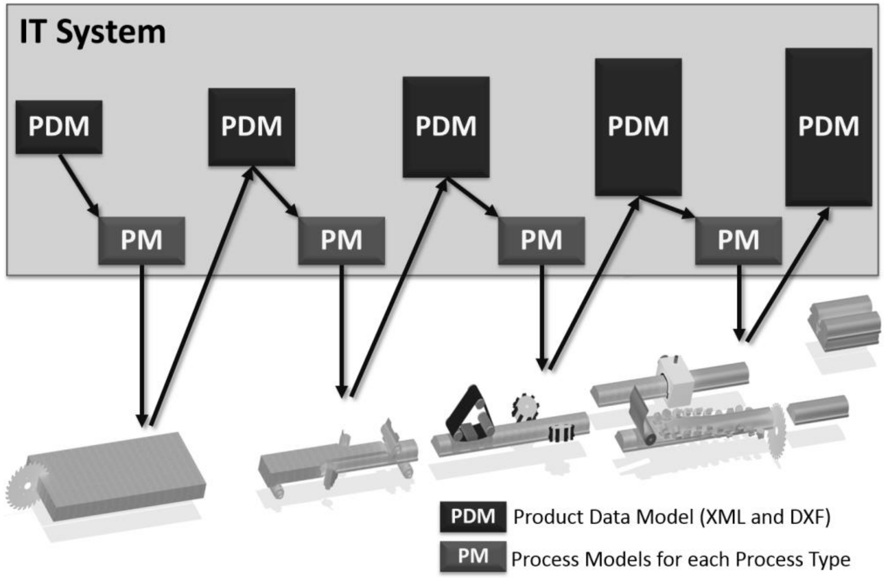

Figure 7: Networking of the process chain with a product data model.

This structured methodology ensures that at any point of the process chain, the product data model contains a complete definition of the profile in this production stage including the process information for the manufacturing.

5 CONCLUSION

The interdependencies in the process chain of profiling show representative, for other interlinked process chains, the challenges for the integration of information technology to automatize the process design, setup and to achieve the objective targets of “Industry 4.0”. The development of valid process models to create a virtual counterpart is a necessary first step. Furthermore, the networking of the process models by means of a product data model provides a proper way to make the required information available and structures the data exchange between the different models. The generation of the process data before the real production requires the consideration of systematic and stochastic errors of the individual process steps. The statistical approach for the stochastic influences has shown that only a probability related allowance of the profile geometry enhanced the virtual counterpart of the production to handle and generate realistic data.

The presented methodology of the research results compose a foundation to upgrade the elements of a process chain to CPS and get valid process data for the manufacturing.

6 EPILOGUE

The term "Industry 4.0" can lead to some misconceptions regarding the technical history of humanity and statement of the fourth industrial revolution. Historically it is already difficult to say that the first industrial revolution took place at the end of the 18^{th} century. The mechanization of work at an industrial level was already established back in the Roman Empire. The milling plant of Barbegal (3^{rd} to 5^{th} century A.D.) for example was built from two, ever consisting of eight single mills, mill chains arranged in a cascade and were able to produce around 4.5 tons of flour a day [10]. Furthermore, all considerably developments, of the first industrial revolution under the concept of "Industry 4.0", were done in the 12^{th} Century with the development of the crank drive by al-Dschazari [11]. The Chinese history of technology is not even considered. This shows that the in the term "Industry 4.0", the chosen numeration is arbitrary.
However, it is a question what forces an industrial revolution or an invention and introduces a new technology. Therefore, looking at the history of technology let one assume that for an implementation of a new technology, the need ("pull") is more important than the development ("push") of that technology. Nikolai Kondratieff had the theory (also called Kondratieff cycles) that after a basis innovation (mostly out of distress) was born, it has a boost for the next 50 to 60 years. When no production improvements can be made out of this innovation, it comes to regression or crash (Fig. 8). [12]

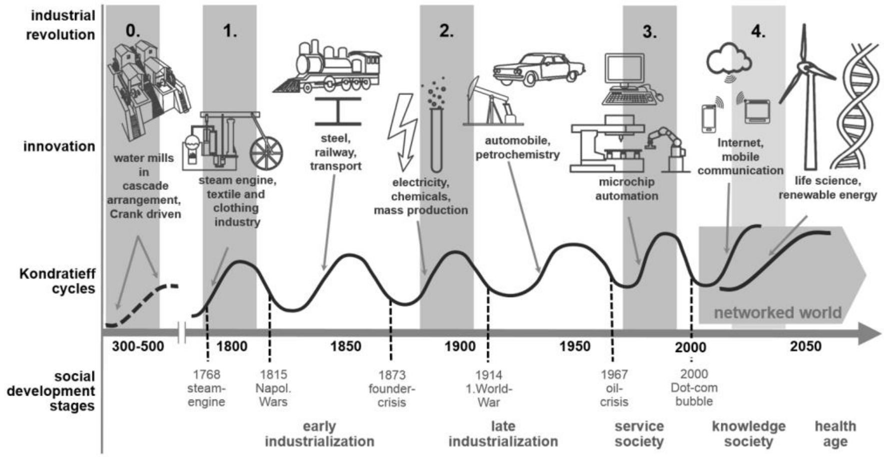

Figure 8: Industry 4.0 vs. Kondratieff cycles.

In addition, some aspects of "Industry 4.0" seem to be not revolutionary. Penzias under the term "Holon" and Warnecke under the term "Fraktale Fabrik" already introduced the decentralized structure of the "Smart Factory" with the ability of self-control and self-optimization [13].
All in all, "Industry 4.0" may also be considered as an evolution in production using the basic innovation "computer".

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FEATURE-BASED CAD/CAM SYSTEMS FOR THE FURNITURE INDUSTRY SECTOR – USAGE OF A UNIFORM DATA MODEL ALONG THE PROCESS CHAIN

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Abstract
The requirement for a uniform data model along process chains in the furniture industry has increased significantly over the last years. Beside the production itself, web-based product configurators, order and delivery management and the communication with suppliers require valid process and product data. The installed software applications must be interlinked by means of a sophisticated and powerful integrated product data model. It will support all steps in the process chain from the entire sales and order process to manufacturing and delivery. Thus, the product data model will finally lead to Product Information Management (PIM) and a product life-cycle system.

Keywords:
CAD/CAM, Furniture Industry, Data Model, Process Chain, Feature-based System

1 INTRODUCTION

Feature modelers are vital tools for realizing “agile manufacturing” where design & manufacturing activities are closely integrated to respond quickly to customer needs and market changes, while still controlling costs and quality.
The development of manufacturing support technology has been an enabling factor of agile manufacturer. This technology allows the marketers, the designers and the production personnel to share a common database of parts and products as well as data on production capacities and production problems; particularly where minor initial problems may have larger downstream effects. It is a general proposition of manufacturing that the cost of correcting quality issues increases as the problem moves downstream, so that it is cheaper to correct quality problems at the earliest possible stage in the process.

2 FEATURE-BASED SYSTEMS

In particular features can enhance the product model by clustering of geometric entities and their attributes which can be aligned with engineering knowledge used in various applications. This has the potential for improving the design environment and enabling automation of various tasks along the product design and manufacturing process - in the furniture industry even including sales and order management. The main target is to reduce product development time and to eliminate mistakes in the processes of market communication and order management.

3 REQUIREMENTS FOR DIGITAL PRODUCT INFORMATION

Computer controlled machine tools were introduced in furniture industry nearly 40 years ago and this technology was accepted in 90s even by small and medium sized manufacturers. This created the need for a digital representation of the underlying product design and manufacturing information [1]. The introduction of more advanced technology such as DNC, flexible manufacturing systems, robots, automated storage systems and part transporting systems each increased the need for complete and accurate product information [2].

At the same time social, economic and communicational changes in our society have significantly changed the way in which production technologies are being used. Previously functionally organized factories have operated nearly isolated of the market situation and customer requirements. Today manufacturing systems have become more product oriented and focused on decreased lead times as well as reduced work-in-progress, just-in-time material flow and higher flexibility (e.g. lot size 1 production). Other effects are coming from the threads of the emerging markets especially China, where products can be offered at completive prices in large quantities all around the world due to less manufacturing restrictions and cheap labor costs.

For many companies in the furniture industry also the order and delivery process and all related functions need to be integrated more closely. The logistical chain including mapping of customer and market requirements, product specification, engineering and manufacturing solutions is vital to achieve these goals (Fig. 1).

Figure 1: Product data model supports the entire business process.

The need for integration goes beyond the boundaries of a single organization. There is a remarkable increase in companies which are working in cooperation and partnership with suppliers and vendors. This is commonly known as virtual enterprise. Smooth operation between members of virtual enterprise requires an exchange of comprehensive, relevant and accurate product and process information.

4 INTEGRATED PRODUCT DATA MODEL

A sophisticated and powerful integrated product data model must be installed in order to support all relevant steps and software applications in the entire sales, order and manufacturing process. This process starts already at the consumer site. Consequently it will finally lead to PIM and a product life-cycle system (Fig 2).

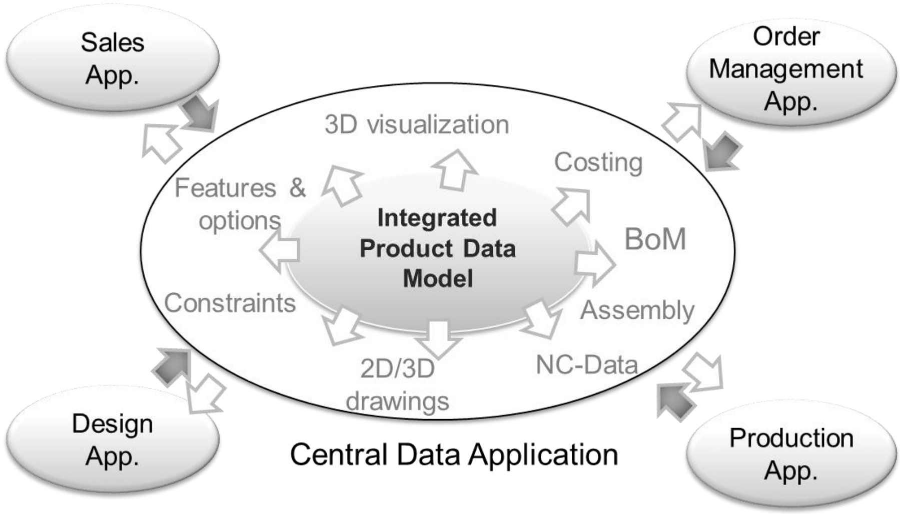

Figure 2: Integrated product data model.

The furniture industry and especially this particular sector is mainly processing panels in various sizes and shapes in a highly automated, way. This reduces the complexity of the task significantly. Due to the limitation of design options, feasible and easy modifications of the material or deployed, and the product design process resembles more a product assembly. The different parts like side, top, and back panels nowadays are connected by means of standardized components like dowels, hinges, cams, etc., which are normally supplied from industry partners. Most of these suppliers are already providing intelligent data sets of their products, which can be processed in industry specific feature-based CAD/CAM systems which can be directly processed. These CAD/CAM systems are enabled to assign furniture specific features (e.g. material) and classes (e.g. door), to 3D geometry clusters in a manner that at fully virtual representation of the furniture is developed and concurrently saved in a SQL database. This semantic description of a furniture product can be reused in various applications along the order fulfillment process.

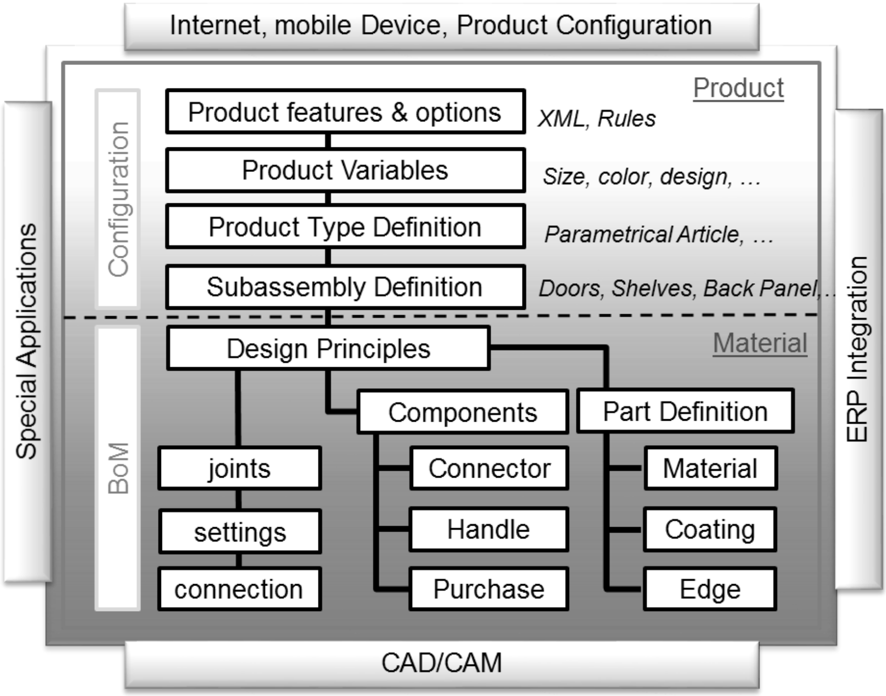

Figure 3: Feature-based CAD/CAM data model for the furniture industry.

Furthermore the furniture industry allows, unlike most other industry sectors, more and more modifications of the product during the sales and order fulfilment. Make-to-order and even engineer-to-order is an obvious trend in Central Europe to meet customer requirements and to achieve market acceptance in a highly competitive market environment. Small batch sizes, short delivery times and high price pressure leads to a procedure where the order entry is performed directly by the sales channels or even consumers by means of easy-to-use and highly functional product configurators. These product configurators, mainly applicable via web browser or apps on notebook computers, tablet PCs or even smartphones, interprets the product data model, offers the features and options of the product, visualizes the final selection in 3D and provides price information. It is a technical challenge to feed the product configurator with data which are directly derived from the integrated product model in order to keep the sales and manufacturing system always synchronized (Fig. 3). [3]

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AUTOMATED GUIDED VEHICLE SYSTEMS TOWARDS INDUSTRY 4.0

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Abstract
Automated guided vehicle (AGV) is a highly automated material handling technology especially for intra logistics. It has exhibited significant advantages regarding to cost effectiveness, flexibility, reliability and quality etc.
AGV started just at the beginning of the third industrial revolution. From the present till now, AGV, as an intelligent vehicle, has experienced a lot of development. Different navigation systems have been invented and applied in different applications. Safety mechanism has been enhanced from simple mechanical bumper to safety laser.
Simultaneously, automated guided vehicle system (AGVS), as a complex integrated system, has also been received much attention and research. There are plenty of published papers dealing with AGV fleet route design, system size decision, and scheduling of AGVs. The continuous increase of AGV applications has proven the value of AGVs for material transportation during the time of the third industrial revolution.
Industry 4.0 has been firstly proposed in Germany two years before. It is considered as the signal of the fourth industrial revolution. Based on Cyber-Physical Systems and Internet of Things, it is expected that the production system will become smart factory with even higher intelligence and flexibility.
Good interesting questions are: What can and what will AGVs contribute to this industrial revolution? In which direction should AGVs be developed with regard to specific technologies and the whole system? This paper aims at answering these questions. Hence, it is required to have an overall knowledge of AGV development as the basis. The statistics of AGVs produced by European AGV producers since almost 30 years will act as this basis for the analysis. As a result, the development, research and application of AGVs towards Industry 4.0 should be identified and exhibited.

Keywords:
Automated Guided Vehicle, Automated Guided Vehicle System, Cyber-Physical Systems, Internet of Things, Industry 4.0

1 INTRODUCTION

Handling of material flows in industrial environments has been always one of the most important aspects of logistics systems. Although the steady material handling technologies such as roller and chain conveyors exhibit high throughput, the majority of industrial applications rely on industrial trucks for material transportation. The reason is the high flexibility regarding integration of the material transport systems in an existing or changing environment.

Industrial trucks become automated guided vehicles (AGVs) after being automated. Automated guided vehicles are unmanned, computer controlled vehicles which safely transport raw materials, work-in-progress, and finished goods in industrial facilities such as manufacturing plants and warehouses. They are typically used to provide routine and repetitive movement. Although AGVs can operate individually, in more industrial environment, more than one AGVs run together as a system, i.e. automated guided vehicle system (AGVS).

After automation, the advantages of industrial trucks are extended. The reliability will be increased and the operating costs will be reduced, because AGVs are capable of performing transportation tasks fully automated at low expenses and high transport quality. Being equipped with safety and protection objectives, AGVs have also the advantages of protecting person from accidents, avoiding damage of equipment and goods, minimizing downtimes and consequently reducing maintenance costs [1]. Comparing to continuous conveyors, AGVs are able to fit into tight areas, to share aisles with people and fork lift traffic, and to easily adapt to future change. AGVs are an efficient, dependable, and versatile material handling solution.

Till now, AGVS have been known for more than fifty years. In this time, automated guided vehicles have proven their value in the area of material movement. They have been successfully installed in many different industries and applications. The trend of using more and more AGVs for material movement is shown in Fig. 1. The companies, which look for ways to improve productivity and increase efficiency, turn to AGVs to help them achieve their goal. As a result, the transport of goods in industrial environments is increasingly becoming automated.

The credit of AGV popularity goes to various technical advances, ranging from improved actuators and energy supplies to entirely new sensor concepts, from the enormous progress of computer systems to enhanced control strategies, from the modular design of the vehicles to the more flexible and accurate navigation and so on. Industrial and academic researchers have contributed a lot to the development of AGVS, which are summarized in the comprehensive review paper [2]. As a complex and complicated system and especially because of different application requirements, AGVs are normally very project oriented and customized just according to the material handling requirements.

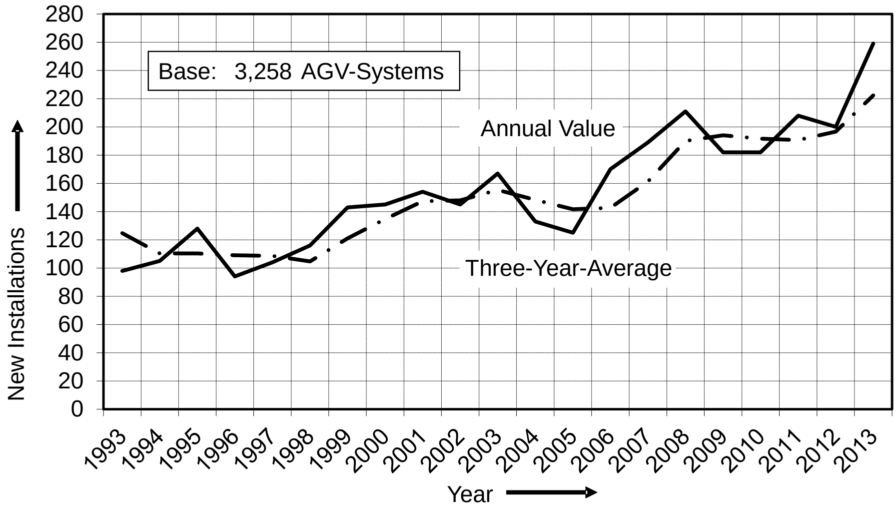

Figure 1: Application Trend of AGV/AGVS from European Manufacturers [3].

Automated guided vehicles started almost at the same time as the third industrial revolution. Together with other automation technologies, they have significantly enhanced the automation of production and logistics. The whole supply chains become more and more flexible to realize individual requirements for certain products. But for real mass customization, the flexibility, the adaptability, the ergonomy etc. of the production and logistics systems still need to be increased. Mass customization means that the individual required products can be produced in the same production line one after the other with less intervals, high efficiency, high quality and high flexibility. Towards this goal, Industry 4.0 was firstly proposed in Germany.
The appearance of the term Industry 4.0 is considered as the signal of the fourth industrial revolution. Based on the new technologies of especially Internet of Things, it is expected that the production system will have higher intelligence and flexibility. AGVs are in fact already such kind of very intelligent and flexible products. But towards the fourth industrial revolution, i.e., under the surroundings of Internet of Things, will AGVs play the same role as before or more and in which way they should play their roll in material handling? These are the questions which motivate the authors to explore.
The rest of the paper is organized as follows. Section 2 presents the basis of industrial implemented automated guided vehicles from the viewpoints of development, main applications and technological development. The technologies for Industry 4.0 are examined in the third section. Section 4 identifies the research potentials regarding single vehicle and integrated system from vehicles in smart factory when all the things there are smart.

2 AUTOMATED GUIDE VEHICLE SYSTEM

An automated guided vehicle system is essentially composed of vehicles, peripheral and on-site components as well as the stationary control system, as shown in Fig. 2. Only the faultless interaction of all these components ensures efficiently working plants.
The stationary control system covers all super ordinated control components. Its task is the administration of transportation orders, the optimization of schedules, the communication with other control systems via predefined interfaces etc. This system is also in charge of the customer interaction and often provides auxiliary functions such as graphical visualizations and statistical analyses. Aspects of the site's structural design that affect the AGVS as for example the ground, gates, lifts and so on belong to the category of on-site system components. Peripheral system components represent the counterparts to various on-board equipment of the vehicles. Examples are battery loading stations and load transfer mechanisms.
Vehicles are the central elements of an AGV-System as they perform the actual transportation tasks. The vehicles have to be designed individually according to the specific conditions of the environment in which they are used. This concerns load handling equipment, the navigation system, the drive configuration and other aspects.

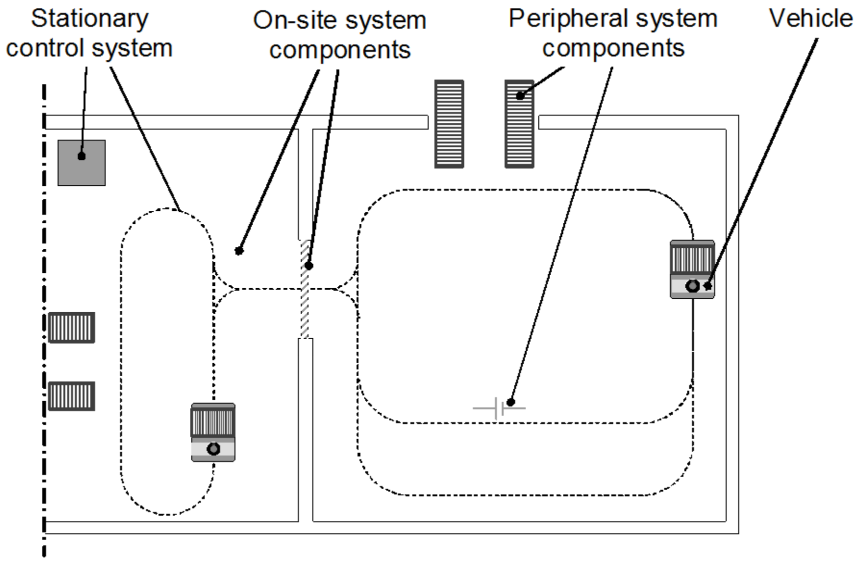

Figure 2: Components of an Automated Guided Vehicle System.

2.1 Vehicle technology development

The past years are characterized by significant technological advancements in navigation systems, energy concepts, sensor and safety systems, and automation of series vehicles and trucks.

Navigation and guidance

Navigation and guidance technology is essential for the automation of AGVs. Table 1 summarizes different navigation technologies being developed. Most of them are also being used more or less in different industries.

Table 1: Navigation technologies for AGVs.

Technology	*Characteristics*
Optical Guidance	Colored lines, Optical markers on the ground Cameras and image processing Lower investment and relatively high flexibility Lower reliability and positioning accuracy
Inductive Guidance	Embedded wires in the floor Sensor and radiofrequency emanating High costs and lower flexibility High dependability and accuracy
Magnetic Tape Guidance	Magnetic tapes on the floor Sensor and radiofrequency emanating Lower costs and relatively high flexibility Sensible to environment
Laser Navigation	Fixed reflectors above the floor Rotating laser on the vehicle High investment High positioning accuracy, reliability and flexibility
Inertial / Gyro Navigation	Transponders in the floor or markers on the ground Gyro sensor Easy to implementation and high accuracy High investment and relative lower dependability
Contour scanning [4]	No ground infrastructure Camera to recognize the environment Lower hardware investment and high intelligence Dependability and accuracy not reliable
GPS navigation	No ground infrastructure GPS High flexibility High costs and lower accuracy

Which navigation technology to be used depends a lot on the applications and environmental conditions. For example, the inductive guidance can only be implemented when the floor can be cut and the travelling distance is short. When flexible paths are required, then laser navigation is the recommended solution. Laser Navigation systems are ideal for facilities in which the floor may not be damaged mechanically and where reflectors can be installed without obstacle interference. Routing may be changed via software. Vehicles can leave their assigned path to perform evasive movements in order to solve deadlocks or avoid collisions. Flexibility, reliability and accuracy are the three words, which can be used to precisely describe the performance of laser navigation. Because of the advantages offered by laser navigation technology, it has proven to be premier choice for the majority of applications, as shown in Fig. 3.

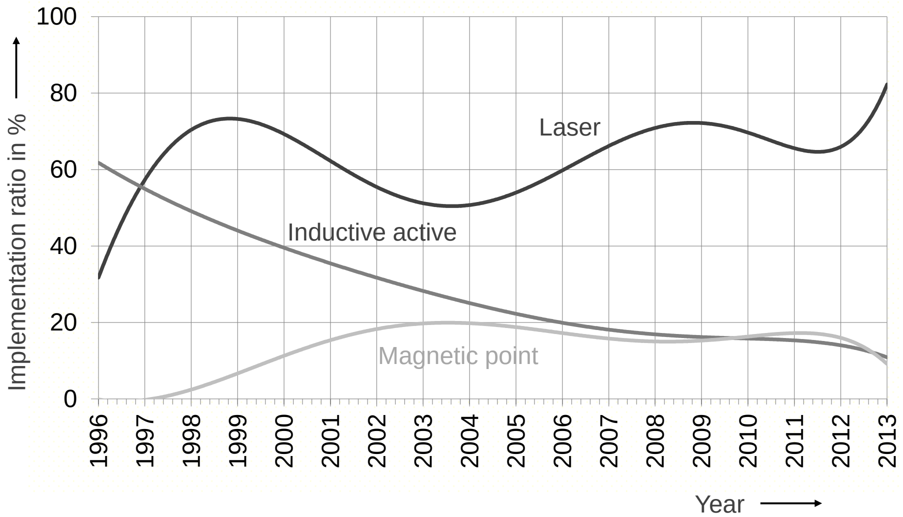

Figure 3: Frequency of Navigation Technologies in Systems [3].

Different navigation methods result in different investment requirements. If the companies do not want to invest too much money for AGVs, then the optical or magnetic tape guidance should be the right choice. For outside applications with lower requirement of the positioning accuracy, navigation based on GPS is to be considered. To avoid laying wires for long distance, but to have high accuracy, the interval or gyro guidance can be used. Transponders such as magnet points can be installed in the floor.

Inductive power transfer

A technical innovation increasingly used in the field of AGVS is inductive power transfer also known as inductive coupling. This technology transfers electrical power between two circuits through a shared magnetic field. The primary circuit is a conductor embedded in the ground whereas the secondary circuit is a pickup attached to the vehicle's lower surface. By energizing the conductor, a magnetic field is generated inducing a current in an inductor inside of the vehicle's pickup.

Two basic principles of inductive power transfer are to be distinguished. The first supplies the vehicle continuously at all times with energy. This requires the primary conductor to be installed on the entire driving course. The advantage is that the vehicles do not need on-board batteries. In the second case the vehicle is equipped with an on-board battery and can thus compensate an interruption of the inductive power supply. The battery of the vehicle could be charged inductively at one point, at multiple points or at a defined section of the course.

Inductive power transfer broke ground for new operational areas of AGVS, which were predominated by other conveyor technologies so far. However, on complex or strongly branched out driving courses and on grounds that cannot be mill cut or contain a high amount of metal, the battery will remain the preferred energy concept.

Standardization and modularity

Although AGVS manufacturers have to focus on adjusting the ordered system to the customers' needs, standardization is a common method to reduce costs. Therefore many modern companies have developed a small number of basic vehicle chassis, one type for each specific application that can be targeted in an economic way. Along with the chassis there are exchangeable sets of modules to choose from. Modularity is a common strategic production method to reduce both production costs and delivery times. Standardization and modularity will drastically reduce the variety of special parts as similar modules will become interchangeable between different vehicle types. At the same time the availability of parts is increased while the logistics for replacements is simplified.

Sensor and safety systems

Laser range scanners have proven an indisputable potential as a security equipment and as a laser navigation technology as well. It is only a question of time when the currently well-established two dimensional planar safety scanners will be extended by the third dimension to provide the necessary data for enhanced performance.

An important step by using laser safety scanners for navigation is to achieve independence of reflection markers and increased flexibility. Besides reduced installation costs, this allows overcoming the limitations of the laser triangulation method developed many years ago.

2.2 Applications and industries

AGVS can be found in virtually any area of industrial production, trade and service [5]. The main application areas are production, assembly, connection of different work areas, order picking and warehousing. Fig. 4 shows the main applications of the AGVs which are produced and installed by the European AGV producers in 2013.

The area with a high application rate of AGVS is production and assembly lines. In this sector the load is inhomogeneous and changing. Therefore the loading devices must be fitted to the specific application. The vehicle sometimes not only transports the load from one assembly station to the next, but represents an assembly station itself. In this case the vehicle can be considered as a mobile workbench. Another assembly application is the pick-up AGV which has the work piece mounted on it and virtually represents a conveyor for both the worker and the work piece.

The realization of the material flow processes in the warehousing and order picking sector is characterized by high volume of traffic from designated sources to designated destinations. This is a standard application area of AGVS which usually demands high loading capacities. The load units are usually standardized pallets, therefore the vehicles are equipped with standard loading devices. Due to the requested performance, these systems often consist of more than 50 vehicles. This AGV system demands a sophisticated central controlling unit and optimizing approaches for routing and path-finding.

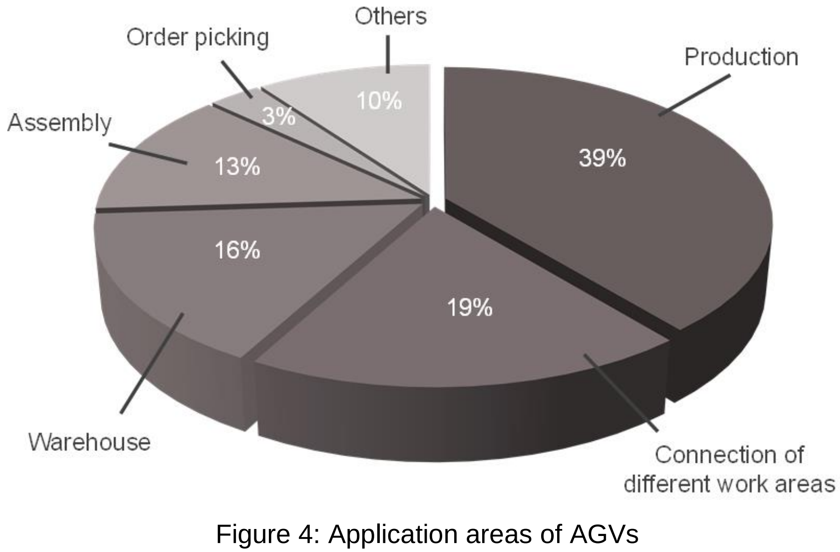

Figure 4: Application areas of AGVs
by European manufacturers in 2013 [2].

AGV applications can be found almost in nearly any industry. However, there are several industries where the use of AGVs is more common. The automotive industry utilizes more AGVs than any other industry. The automotive companies use AGVs mainly to minimize downtime and maximize production. The applications of AGVs in automotive industry include the movement of metal stamping, engine and transmission manufacturing and automobile assembly. Therefore, different vehicle types have been applied in automotive plants such as forked, unit load, tugger and even customized vehicles. The food and beverage segment is also particularly active. Many companies are using AGVs mainly between different stations, such product processing areas and packaging areas. In printing industry, AGV applications include paper roll storage, retrieval and delivery to the press, movement of printed materials to the area where they are bound, movement of finished products, and movement of waste material and paper roll cores. In paper industry, it is common to see AGVs for transporting large jumbo rolls, converted rolls, sheeted product or palletized finished goods. The use of AGVs in hospital continues to grow because hospitals look to reduce costs and improve operational efficiency.

3 INDUSTRY 4.0

3.1 Smart factory

In automotive assembly process, the vehicle doors and bodies are first joined in a body shop. Once it is ensured that the gap between the two parts is exactly right, they are then separated. The doors are sent to a paint shop for a coating to match the color of their body. Later on during the painting and door interior finishing steps, bodies and doors recognize each other with the help of radio frequency identification chips. The components know with which components to be together through the communication of these electronic chips. The data on the chips would be read and transferred to the robots that would join the components. This is a vision of factory of the future from Siemens [6]. This vision is referred to as Industry 4.0 in Germany.
Industry 4.0 is a long term project proposed by German research government. It is also a term, which represents the fourth industrial revolution. The main aim of Industry 4.0 is to improve the intelligence of the factory. The resulted smart factory should be characterized by adaptability, efficiency in using resources, ergonomic and integration of the actors in the value chain. It is expected, that in the era of Industry 4.0, information, communication, automation and production technologies will be more closely connected. The production operations are expected to be as flexible as possible with even lower cost. Internet of Things (IoT) and related technologies such as Cyber-Physical Systems, mobile Computer und Cloud Computing are considered as the technology drivers for smart factory with high flexibility, adaptability, productivity, transparency and etc.

3.2 Internet of Things

The term “Internet of Things” is mainly associated with applications involving Radio Frequency Identification (RFID) [7]. These make use of so called tags, tiny chips with antennae that start to transmit data when they come into contact with an electromagnetic field. Independent of any specific technologies, theoretically the reason that the things become into internet of things is that they are facilitated with embedded smart objects. These small objects enable the physical things intelligent and being connected through internet. From the purely technical viewpoint, a smart object is defined as an item equipped with a form of sensor or actuator, a tiny microprocessor, a communication device, and a power source [7]. The sensor or actuator gives the smart object the ability to interact with the physical world. The microprocessor enables the smart object to transform the data captured from the sensors, albeit at a limited speed and at limited complexity. The communication device enables the smart object to communicate its sensor readings to the outside world and receive input from other smart objects. This kind of communication is also so called Machine to Machine (M2M) communication. The power source provides the electrical energy for the smart object to do its work.

It can be assumed that the smart object can carry any information relating to the thing which is required, and they are able to communicate with each other when it is necessary with an acceptable speed. Based on the assumptions, it makes sense to examine the possibilities with AGVs regarding research and applications. In the next section, the research focus of AGVs in smart factory and potential applications will be presented.

4 AGVS IN SMART FACTORY

Under the lead of Prof. Jasperneite and Prof. Hinrichsen, the University of Applied Science OWL is a pioneer in exploring the technological possibilities for Industry 4.0. A factory is to be built based on the concept of smart factory. There, different technologies and industrial solutions are to be exhibited and applied. As the premier choice for flexible material movement inside factory, AGVs should also be the composing parts of the smart factory. But in which way should they be presented in order to fulfill the challenges of the smart factory? Independent of the smart factory at our university, the questions of further AGV research problems and new applications are also very interesting.

4.1 Decentralized controlling

In the world of Internet of Things, i.e., inside the smart factory, everything should be Internet of Things. That means the individual AGV is at least also such kind of things. In fact, the AGVs now can be already considered as Internet of Things, because they are equipped with computers and normally are connected with internet through WLAN. But the communication through

WLAN is the transfer the information of individual AGV with the centralized controlling system. The coordination and management of the AGVs in one system if the system has more than one AGVs are always done through the controlling system on the host computer which has a very high performance. If each AGV becomes now into an internet of thing with smart object and the smart object has high enough performance for data transfer, communication and even complex calculation and scheduling etc then controlling of all of the AGVs should be done autonomously and dynamically with each other, instead of through centralized controlling system. The material transport orders will not be given by the system any more, but will be inspired by the packaging unit of the material. It is because the packing unit, either carton, boxes, or pallets are also Internet of Things. They carry also the smart object, which can be much simpler than the smart objects of the AGVs. When one knows by itself that it needs to be moved from one location to another location, it will talk with the available AGVs and finds out one AGV to move it. What are the communication rules between the AGVs and other things? Is it necessary to develop some specific web services relating to the tasks of AGVs or should the communication just base on standardized protocols and services?

4.2 Smart AGV components

It can be undoubtedly said that an individual AGV is at least one intelligent thing in the internet. But that does not mean that the AGV has only one smart object on it. The idea is that the composed components of one AGV have also their corresponding smart objects and are consequently the Internet of Things. For a certain component, there are some information carried by the smart object, maybe a RFID tag. These information are used for the assembly of the AGV, for the error examination of the component, for the traceability of the component, etc. These can be considered as the basic information relating to production of AGV itself. But what kind of other information may be required relating to the operations of AGVs? If the operation of an AGV is based on the communication of the components of it, how to manage all of the smart components and let the AGV run according to the requirement? It is not necessary that all components are involved in the process. Which components should cooperate together to ensure the movement of AGV?

4.3 Navigation based on smart object

Suppose the things inside the smart factory where the AGVs are implemented carry the contour and the AGVs can obtain the contour information when they are with the things connected through internet and communicated. Then the navigation and guidance of AGVs can be calculated through the contour. It is not necessary to have complicated image identification equipment on the AGVs. It is also not necessary to have additional components for the infrastructure and the AGVs as well. The system is the most flexible with also high accuracy and reliability.

5 SUMMARY

Significant technological advancements contributed to increase the attractiveness of automated guided vehicles for the users. They essentially concern the modularity, the standardization, the navigation system, the energy concept, the automation of series vehicles and the safety system even in the era of internet of things. That is why it is meaning in this paper to have an overview of the related technologies.

Based on the basic but essential understanding of Industry 4.0, the paper has identified the potential development, challenges and applications to manufacturers and even users of AGVs. It is expected that this paper is a front line which impulses especially the further research of the team at the Science University of OWL in the newly constructed smart factory. The further research will focus on the two main identified potentials: routing based on decentralized communication and navigation based on smart objects.

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VERSATILE ASSEMBLY SYSTEMS - REQUIREMENTS, DESIGN PRINCIPLES AND EXAMPLES

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Abstract
The requirements of assembly systems are changing, due to trends such as shorter innovation and product lifecycles as well as an increase in the number of product variants and product customization. Certain markets are characterized by demand volatility and short delivery schedules. As a result of shortened product and innovation lifecycles and demand volatility, the assembly system design should be versatile. The aim of this paper is to demonstrate a versatile assembly system which was jointly developed by the Fraunhofer IOSB-INA and the Ostwestfalen-Lippe University of Applied Sciences.

Keywords:
Assembly System, Versatility, Modularity

1 VERSATILITY – CHARACTERISTICS, COSTS AND BENEFITS

1.1 Characteristics of Versatile Systems

Trends, such as shorter innovation and product lifecycles, an increase in product variants, combined with decreasing lot sizes and the demand volatility of certain markets, lead to changing manufacturing and assembly system requirements. Shorter product lifecycles result in an increase in new design or reconfiguration of such systems; due to global production strategies this applies not only to local plants, but also overseas. The trend towards a variety of products and product variants make it necessary to plan for machines to be able to produce a wide product spectrum, or to be quickly adapted to a new product or product variant. In short, many sectors require versatile manufacturing and assembly systems. Versatility or reconfiguration means structural modification of a system in a prearranged way to adapt the system functions to changed or new requirements.
Versatility is thereby to be distinguished from flexibility [1]: Whilst versatility is used in connection with structural changes to a system, flexibility means the reversible ability of a system to adapt to changed requirements without reconfiguration or dismantling. Both characteristics are applied not only to technical, but also to sociotechnical systems [2].

Versatility of technical systems means changes within a product lifecycle, particularly where the level of automation can be adapted to the production quantities as simply as possible and, in this way, a highly economic system configuration can be achieved. Versatility also means that at least parts of the system can be reused at the end of the product lifecycle in order to achieve a high return on investment (ROI).

Versatility gains in importance when referring to the supply of spare parts after a product has been discontinued. Important consideration is to be given to the fact that the spare part production timescale is usually much longer than the product lifecycle, but that the volume of components or units is generally much smaller after discontinuation and that the same, or similar quality measurements apply [3]. In order to guarantee economic efficiency, the versatility of manufacturing and assembly systems must be considered at the planning stage.

The modular design of assembly systems - in conjunction with the compatibility of single subsystems, units or components amongst one another - are an essential element of versatile structures. Thereby, a module is a subsystem of an assembly system, characterized by largely independent functionality, with standardized interfaces and can be comprised of sub modules [4]. Compatibility means that the modules can easily be mechanically and electrically connected to one another, using standardized interfaces, including the sharing of information and power supply.

According to Wiendahl et al. [1], aside from modularity and compatibility, universality, mobility and scalability also count as versatility enablers of a factory. Universality takes increased product variants and customization into account as, without adaptation, various products or variations up to customized products, as far as possible in “one piece flow”, can be produced by one system. According to the above definition, universality is synonymous with flexibility. Mobility refers to the maneuverability of individual modules, for example the modules can be stored on wheels. Technical scalability is used to describe flexibility, adapting the capacity offered to customer demand by making system changes, taking the trend towards volatile markets into account. Ergonomics is a further versatility enabler, as the changeover process efficiency is highly dependent upon the configuration of the human machine interface [5]. Efficiency can be guaranteed by, for instance, the use of quick-change systems, where the machine operator can simply connect or disconnect modules with each other, where possible whilst standing. Ergonomic operating concepts also help to reduce the employee training effort required during new system configuration.

If sociotechnical systems are considered, system scalability can thus also be achieved by using flexible working time systems; adjusting the deployment of staff according to the size of current orders as much as possible. Universality can be used to mean that employees are in the position to perform different functions within a department, for example programming, setting up, assembly of multiple product types.

"Plug and produce" functionality can be considered to be a particular characteristic of the compatibility of a manufacturing system; this means that, similar to "plug and play" functions of computer and its peripheral devices, the modules can be recognized by the system and configured automatically. Whilst the phrase compatibility can be applied to various levels of the entire system (subsystems, modules or components), "plug and produce" is primarily used to refer to mechatronic or IT (sub) systems and can, therefore be seen as a particular form of compatibility.

1.2 Cost and benefit

The degree of system adaptability should be integrated into the system development phase. The economic benefit of adaptable manufacturing and assembly systems is that it is possible to re-use the individual modules after the end of the product lifecycle. As a result of this, the useful life of assets is lengthened, which leads to an increased investment efficiency. Furthermore, within the product life cycle a versatile system enables to change the automation level according to the current demand volume of customers. In the consequence highly economic system configurations can be realized during the product life cycle. Investment in individual modules, for example assembly robots, is made only when demand has reached a certain level, which will achieve the required return on investment (ROI). If the demand forecast does not materialize, or is lower than expected, then the investment, for example in an assembly robot, would not be made and the operation in question would continue to be executed manually. Further, versatile systems are, with low effort, adaptable to changed customer needs and thus contribute substantially to customer satisfaction.

The economic benefit of versatility can be summarized as follows:

- The useful lifetime of assets is lengthened and thus investment cost effectiveness can be improved.
- Uneconomic investment can be avoided and efficient system configurations can be implemented.
- Customer satisfaction can be improved.

However, use of versatile systems is accompanied by extra costs, which are reflected in an increase in investment volume. Above all, modularization of systems leads to extra interfaces, extra units (for example, drive units in a modular work piece transfer system) and extra controls. As a consequence, versatility can lead to much higher personnel and material costs at the planning and implementation stage. However, these extra costs can be reduced by standardization of hardware and software on a company internal and external level (for example using a "plug and produce" feature).

The effects of versatility on investment decisions will be shown below, using the net present value method (NPV) as a dynamic investment calculation method. With the help of this method, the advantages of an investment to the sum of I_0 can be determined by calculating the NPV C_0. The NPV takes the preference for fast ROI into account, using interest rate i, as part of a multi period observation. NPV is the difference between an investment made in period 0 and the sum of the discounted cash flow (DCF) over n periods:

$$C_0 = -I_0 + \sum_{t=1}^{n}(E_t - A_t) \cdot \frac{1}{(1+i)^t}$$

E_t means incoming payment of the period t, and A_t means outpayment. If there is a decision to be made between various investments, the investment with the highest NPV should be chosen [6]. The costs of versatility are shown in a higher investment volume, I_0. The benefits of versatility are shown in that an investment object can be used over additional periods, so “n” increases, thus cash flow is generated in additional periods. Furthermore, versatile structures create the conditions for continually efficient system configuration, through which single periods can also achieve greater cash flow.
The challenge with versatile systems economic assessment in the system planning stage is that the single effects are difficult to predict.

2 ASSEMBLY SYSTEM

The assembly system developed by the Fraunhofer IOSB-INA and the Ostwestfalen-Lippe University of Applied Sciences consists of a mobile terminal for order entry, a manufacturing execution system (MES), a robot cell, a manual assembly station (including an “augmented reality” system), a laser engraving cell and a workpiece transfer system including an RFID read / write module (c.f. Figure 1).
The first step is for the customer to decide between different products, consisting of Lego® bricks, and to enter their personalized text by using a mobile device. In the second step, the order data is transmitted to the MES for order planning and management. The third step the customer order data (a product with personalized text) are transferred to a workpiece carrier, using an RFID read/write module and RFID chip of the carrier (digital memory). Fourthly, the workpiece carrier is transported to the robot cell by the transfer module. There the RFID chip is read and the order data is transmitted to the robot system. After the robot has performed the assembly operations, the sixth step is to inform the workpiece carrier, using the RFID chip, which operations the robot has completed. The robot also places the workpiece back onto the workpiece carrier.

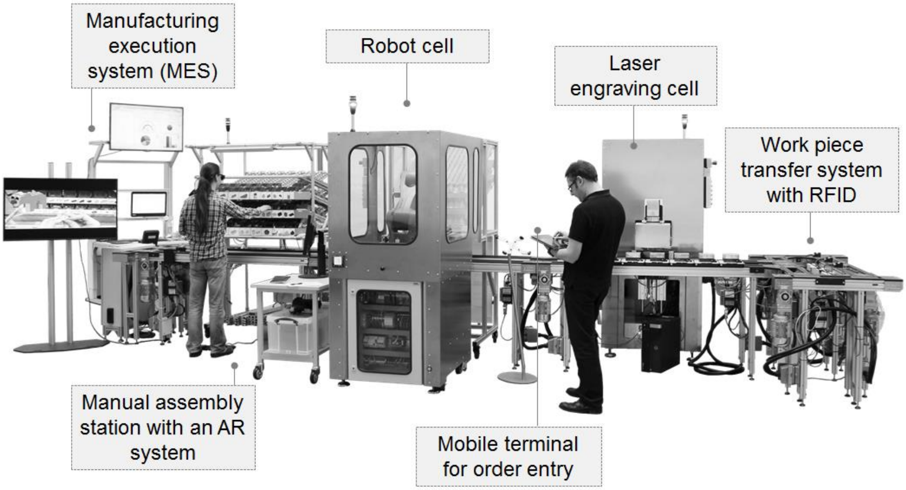

Figure 1: Structure of the developed assembly system.

The workpiece transfer module then, in a seventh step, moves the workpiece to the second processing station, the manual assembly station. There, the RFID chip is read again and the data transmitted to an augmented reality (AR) system, this is step eight and only the processes that the robot did not complete are shown in AR. After an employee completes the operations shown by the AR system, the current order status is saved again on the RFID chip. Figure 2 shows the AR operations from the employee viewpoint. The tenth step is the transfer module moving the workpiece to the laser cell, the third processing station. As in the two previous steps, the order data is read, the personalized text is engraved onto the workpiece using the laser, and the order data on the RFID chip is updated. Finally, the assembled and inscribed Lego® brick is transported to the goods collection area, where it can be collected by the customer.

Figure 2: Employee view using AR.

3 ASSEMBLY SYSTEM VERSATILITY

3.1 Overview of versatility enablers

The versatility of the assembly system is accomplished primarily through use of a modular system construction, with largely autonomous and mobile operations cells, as well as decentralized motor-controlled transfer modules. Compatibility of the modules with each other is achieved in that all of the modules are equipped with uniform hybrid industrial connectors (compressed-air, power, Ethernet) and are connected to one another using bus topology. Furthermore, the mechanics of the assembly system is designed in such a way as to allow the modules to be disconnected within minutes, without requiring a reengineering of the system. Figure 3 shows an overview of versatile system characteristics, these are assigned to the six versatility enablers listed earlier.

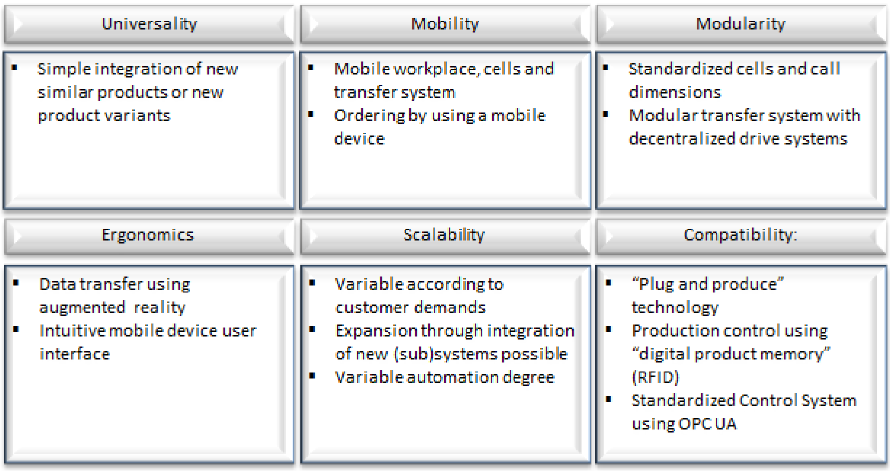

Figure 3: Assembly System Versatility Enablers.

3.2 Universality

The universality of an assembly system is primarily expressed in that using the system, different products are assembled in a one-piece flow and can be individualized by text (laser engraving). In addition, structurally similar products can be integrated into the system with low effort. However, in order to do this, adaptations to workpiece carriers and workpiece receivers in the robot cell are necessary. Integration of further product changes into the control program is also required.

3.3 Mobility

In order to guarantee fast assembly system reconfiguration, cells and material supply systems are stored on rollers. The laser and robot cell rollers are retractable, so that the cells then stand on height adjustable feet. In this way the positioning accuracy and vibration resistance requirements can be complied with.

3.4 Modularity

Assembly system modularity is basically achieved by the three processing modules (robot cell, assembly workplace with AR and laser cell) and the modular workpiece transfer system. The processing cells are equipped with independent control systems and software, as well as RFID read / write equipment to enable communication with the digital memory of the workpiece carrier (RFID). The dimensions of the robot and laser cells are 90 cm x 140 cm x 200 cm (width x length x height).

The workpiece transfer system, a belt conveyor system, is comprised of 12 individual modules. Each belt conveyor module is equipped with an individual drive system with a frequency inverter that is connected to a power distribution system, an Ethernet network and a programmable logic controller. The decentralized system construction means that each processing module and belt conveyor module is capable of functioning autonomously.

3.5 Ergonomics

The worker is provided with information through an AR system, which comprises of a head mounted display that projects virtual information directly into the worker’s field of vision. Information provision using AR particularly benefits customized products, or products with a high number of variations because the need for lengthy examination of a screen or order cards is eliminated. This form of information provision also facilitates shorter training times for new employees [7].

A further example of the implementation of ergonomic aspects in assembly systems is the mobile device multi-touch user interface. The products are shown as pictograms. The menu navigation conforms to user expectations and is self-descriptive, allowing intuitive operations.

3.6 Scalability

Modular assembly system construction particularly that of the belt conveyor system, enables the reconfiguration of widely varying layouts. The only restriction is that the transfer system must be a closed loop.

Due to decentralized drive technology, frequency convertors can be individually controlled, meaning that the belt conveyor module speed can be independently managed. If necessary, extra equipment can be integrated into the assembly system, for example to increase the automation or output levels according to customer demands.

3.7 Compatibility

The belt conveyor system and all other operation modules are equipped with industrial connectors, which supply the individual modules with power, compressed air and Ethernet connectivity. Standardized connectors ensure that each element can easily be connected to the others.

Each operation is recorded using digital object memory, which is integrated into each workpiece carrier by means of a RFID chip. The object memory includes all necessary assembly operation information, which is created initially by the MES at order entry and written directly to the chip. Assembly tasks are read at each processing module and each finished operation is confirmed on the RFID chip.

Communication between the MES, the operating cells and enterprise resource planning system (ERP) uses OPC-UA standard as well as PROFINET Real-time Ethernet standard.

4 OUTLOOK

The aim of further inter-disciplinary research is to develop mechanical, electrical, information and power standards for assembly system design. This will enable customers to configure their assembly systems according to their needs, put them into operation swiftly and easily adapt to requirements within a product lifecycle, using various differing base modules. The issue of how assembly systems universality can be optimized will also be examined; the vision is to enable the assembly system to assemble all parts of a similar size, but varying dimensions and shapes automatically according to a given working plan.

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DESIGN PROCEDURE OF A SPECIAL TOOL FOR MULTIPLE WORKINGS

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Abstract
The mass production of large lots of mechanical parts that actually evolves in materials and geometry, requests, at the same time, a reliable answer for complex tools solution and efficiency with economic operation.
Aim of the present work is the design and the carrying out of a chip removal tool that can work different surfaces in only one cut. A procedure is here described that, at the same time, would be efficient and coherent.
An actual tool has taken into consideration for having the cutting-edges position and the dynamic balancing constraints. In fact, such a tool has assigned to a transfer line where a part family, geometric similarity, was working. A proposal of a procedure definition, not only limited to the specific problem solution, will give an approach methodology for the study of non-common tools, which makes sure an economic advantage both in their manufacture and in their operation management.

Keywords:
Multiple cutting tool, design procedure, transfer line

1 INTRODUCTION

The design of chip removal tools has ever been very important in metal working production. Actually, in particular, the working costs are ever increasing and, on the other side, it is not the same for the products selling prices (fig.1).

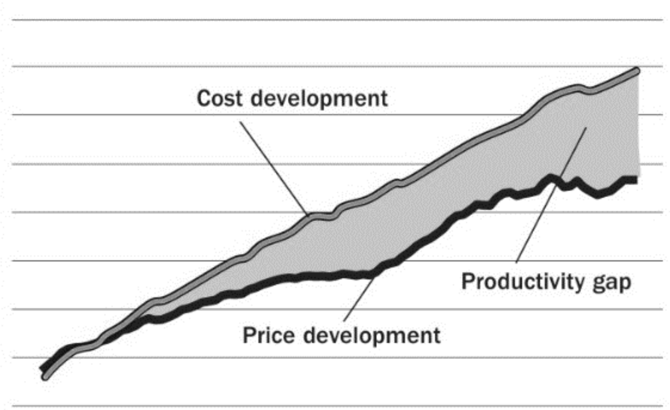

Figure 1: The cost growing trend and the product price development in mechanical industry [1].

The productivity gap increasing requests to be as possible limited, finding innovative solutions to remain competitive in the world market. As well known, the utilisation of a tool machine is not continuous, but, on the contrary, the processing time takes about 20% of machine occupancy and about 12% of the available working time (fig.2). In fact, apart from those due to staff management, the main losses (40% of machine occupancy) are the tool change, set and gauge, breakdown and part change setting up. Providing a careful design of the tooling used, it is possible to reduce the time loss due to the tooling setup-change and measures that are connected to the parts being processed [2]. Time spent in part processing can increase as percentage of machine occupancy and this is very noticeable if we operate with mass production systems.

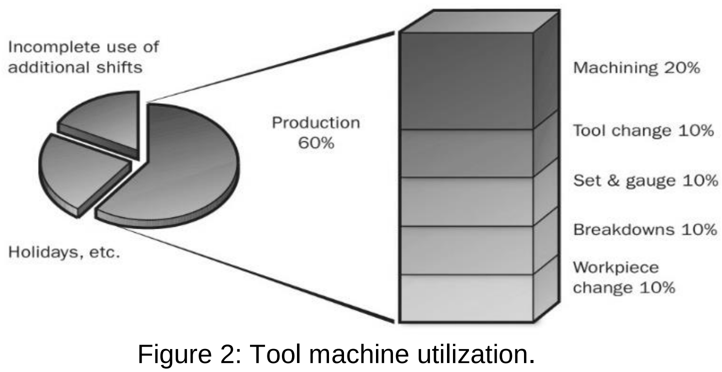

Figure 2: Tool machine utilization.

If the economic advantage is recognised for a careful design of the tool, the literature gives poor information and the knowledge is not very widespread. Production staffs try to solve their own problems on the field and often forget them. Tool producers keep their knowledge for their market surviving, but in the same way suggesting some guidelines for tool design approach.

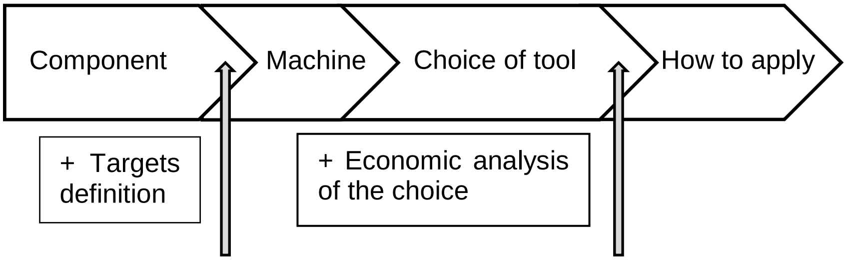

Figure 3: The Procedure approach.

In the case, the suggested procedure has integrated with two more steps as in fig. 3 [3], [4]. The contest here discussed is a mass production system and in particular a station of a transfer line that works a set of parts with geometrical similarity or closed part family. Once the part geometry has described, the target for the tool are stated; in general, a simple and fast setting up when changing working part, economy in working, inserts cost and dynamic balancing (vibrations).
The analysis of tool machine station informs on the space availability for the rotating tool dimension (encumbrance constraint). Inserts and insert holders: it is here used as the same procedure approach where the insert is the “Component” and the tool holder is the “Machine”. The development of the approach brings itself the economic analysis of the choices. FEM analysis verifies load distribution in the whole structure as estimated during chip removal. Finally, an evaluation of the dynamic equilibrium is carried out with tool mass redistribution at the tool maximum rotating speed. Once the new product is on hands, certainly new possible improvements could arise, but they should not be particularly difficult because the procedure is well defined and robust.

2 PROBLEM DEFINITION

The definition of the problem starts from the analysis of the geometric characteristics of the parts family. Part family is a set of pinion shafts to connect an electric motor to i.e. engines starting. The transfer line station roughing works the flange (fig.4), which belong to a part family with different geometries (fig. 5): the part is clamped in a fixture and the tool rotates. The pinion shaft flange has several versions that has introduced in the years, but still under production. The new flanges, that will replace old ones, don't have the deep central hole, but only a wide and shallow hole. For this reason, the decision has been taken to rough a plane flange for old pinion shafts and the central wide and shallow hole for the new ones.

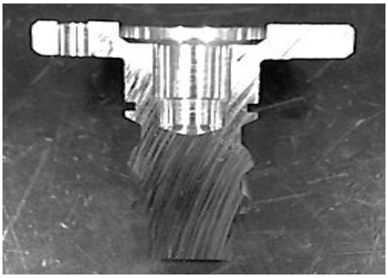

Figure 4: A flange example.

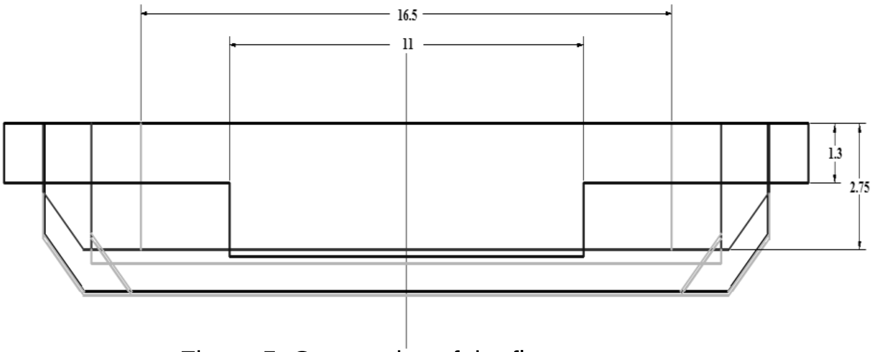

Figure 5: Geometries of the flange.

From the analysis of the geometries that are common for the whole family, three of them are found to be worked in this station.
The first surface is the cylinder identified by the diameter of the flange that has six values ranging from 39.05mm to 47.00 mm in the part family. The second surface is the chamfer between the cylinder and the front flat surface. The third is the front flat surface with or without the central wide and shallow hole. A last surface that is common for all parts is a centre drill.
The machine constraint is the encumbrance of the tool: maximum diameter allowed is 80 mm. The tool-body is worked from a 16MnCr5 cylindrical bar [5].

3 TOOL INSERTS SETTING UP

To work the first surface, the cylinder of the flange, a turning like operation, the relative motions are the same, is provided that should be finished before other workings start. With reference the maximum width in the flange family, the cutting edge (***t***) can keep a fixed axial position plus about 1 mm taking care of a possible contact with the machine part holder. The radial adjustment is requested due to work different diameters.
For cutting edge (***c***) that works the 45° chamfer, its position is axially fixed on the level of the front flat surface and only radial adjustment for different diameters has requested.
The processing of the front plane surface is spread over two cutting edges which operate to produce two co-planar rings: an external and an internal one. The external cutting edge position (***ep***) is the common reference for all geometries, the front plane surface. If it ensures the processes of all diameters, such a choice would implies a long cutting edge that would be a non-economic use of the insert. In fact, smaller inserts could be used for smaller diameters using different insert holders in the same holder position.

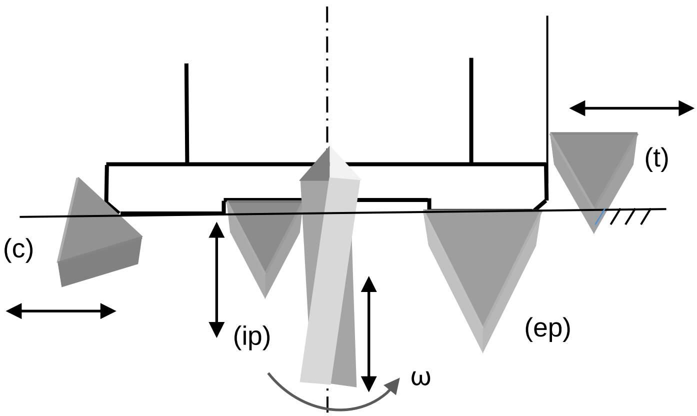

Figure 6: Positioning and setting of cutting edges.

The external cutting edge *(**ep***) axial setting becomes the reference position for all other cutting edges due to the fact that the front plane surface is the same for the part family.
The internal cutting edge (***ip***) has two tasks: processing the internal ring, if flat surface is requested, and working the central wide and shallow hole. The requested adjustment is only axial, because the radial position is that to produce the central hole that has only one diameter size. The two rings are concentric, but at the end they lay not in the same plane. This is not strictly requested from design specifications and, for technological reasons of

transportation handling to the next station, the internal ring does not exceed the external one.
The centre drill uses a Φ4 mm helical drilling tool that is useful to hold the part-tool connection during processing and for handling the part in the following stations.
Once the cutting edges positions are defined, some targets for the tool solution are listed [6]:

1. Insert easy to change;
2. Insert-holder easy to change and repositioned;
3. Efficient chip and lubricating-cooling fluid exhaust;
4. Adequate seat for the sliding of the insert-holder;
5. Good stress resistance;
6. Adequate overall structural strength of the tool body.

The position of the cutting-edges will be ensured by their insert-holders or insert-cartridge. So, the design and the structure of these devices are fundamental. The approach is the analysis for coupling the “component” to the “machine” where the component is the cutting edge (the insert) and the machine is the tool body. Starting from a probable hard-metal insert that respects the cutting-edge requested length, searching an insert-holder in the producer’s catalogue will follow. There is a good probability of finding a correct solution that could be installed in the tool-body. The main problem that can arise is its encumbrance in the available space. The insert-holder is composed of two parts: the insert fixture and the leg. The size of the insert fixture could exceed the dimension constraint of the tool and/or the available space. It is easy to find that the squared insert requests a greater holder size than the triangular one with the same cutting-edge length. Such a consideration brings to a triangular shape choice for inserts, in particular for those that work the external cylinder of the flange and the chamfer (fig. 7).The two insert are identical and interchangeable because one (***t***) works with the tip and the other (***c***) works in the middle of the rectilinear cutting-edge length. Their replacement does not need any registration setting-up and each of them can be used six times. The leg of the insert-holder is connected to the tool body in an adequate seat where the right axial and radial position of the cutting-edge is controlled. The original leg is then worked for having the right measure once positioned in the seat. For these two cutting-edges only a radial setting-up is requested so, the legs need to slide radially in the tool body seat and the right position is reached by using metal shims spacers.

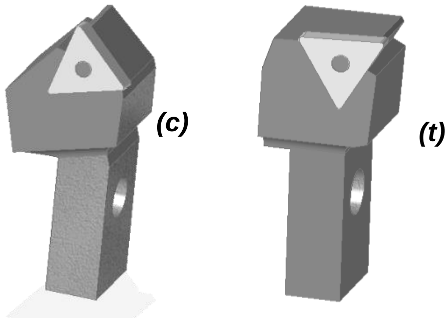

Figure 7: Insert-holders: Chamfering (c) and Turning (t).

The producer catalogues do not offer any solution for the other two insert-holders, for external (***ep***) and internal (***ip***) plane ring workings, despite the fact that they are very simple [7]. In this case a home preparing holders have proposed which also host a triangular insert (Fig.8). The internal one request an axial setting using again the metal shim spacers and the triangular shape choice is due to avoid the interference with the centre drill tool (Fig. 9). For the external one the solution is unique because its cutting-edge position is fixed and is taken as reference for all others. In this case the triangular shape insert offers a longer cutting edge for working the wider ring surface of the family.

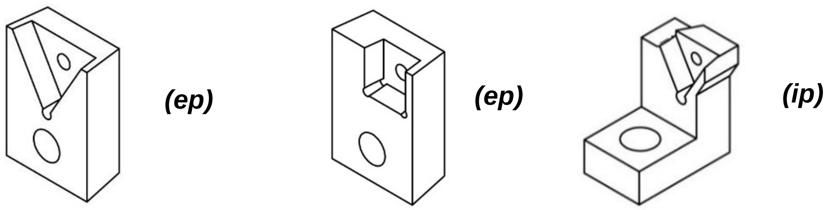

Figure 8: Insert-holders: external (ep) and internal (ip).

The smaller diameters for economic reasons could be worked with squared inserts that offer lower cost and one more cutting edge.

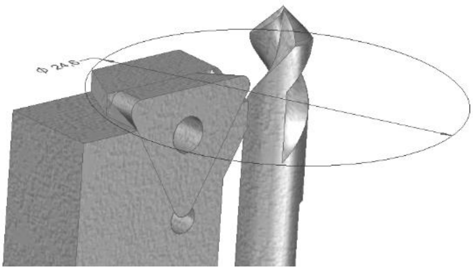

Figure 9: Internal cutting-edge positioning with respect to centre drill tool.

An appropriate design for insert-holder allows its quick replacement when changing flange diameter parts.

Table 1: Comparative actual costs per cutting-edge.

Insert types	n° of cutting edges	Cost/cutting-edge (€)
Actual tool for diameters from 47 to 42.15 mm		
3 □	12	7.485
Actual tool for diameters from 40.45 to 39.05 mm		
3 □	12	6.540
New tool for diameters from 47,00 to 45.65		
3 △	12	6.942
New tool for diameters from 44,35 to 40.45		
2 △ 1 □	13	6.500
New tool for diameters 39.05		
2 △ 1 □	13	5,555

The setting-up of the cutting-edges has been minimised and easy to do using appropriate insert-holders and metal shim spacers when changing part to produce. Process costs are also minimised using cheaper inserts for working smaller diameters. Such a cost reduction is very important and noticeable in particular for mass production [8].

4 DYNAMIC ANALYSIS

A first essay of the tool solution has now reached and a simplified 3D model can be drawn. This model hold the geometry that allows an easy and quick cutting- edge change: one screw for each insert-cartridge. The maximum requested dimension for the tool final assembly is 80 mm in this case and it is the exact measure of commercial finished bars. The stress condition during chip removal process has now estimated starting from cutting forces on cutting-edges. Forces that stress the tool body and the insert cartridges are decomposed into two orthogonal components: tangential forces or cutting forces and a compression force against the working material. With reference to the rotating tool *z* axis the entire tangential component for each cutting edge is taken into consideration. For turning insert, the flange diameter working, and for the chamfer working the compression force is again decomposed in axial and radial directions. In turning operation the radial component is negligible while in 45° chamfering both radial and axial components are identical [9]. For the purpose of estimating the global process loading stress, only axial and tangential forces are prudentially over-estimated. Radial forces are the main cause of periodic stress or vibrations, but noticeable if great [10]. All cutting forces are calculated by means the classic Kronenberg procedure once the cutting parameters are stated with a feed rate of *f*= 0.1 mm/round and spindle *s*=6000 rounds/min [11]. Cutting forces are tangentially oriented for chamfering and milling while for turning and drilling the axial direction is predominant. For sake of safety the calculated values has been raised of about 75% and from those, the axial components are taken as 60% of the tangential ones. Tab. 2 shows the rounded values.

Table 2: Estimated forces ad their orientation.

Operation	Cutting Ft [N]	$F_t \cdot 1{,}75$ [N]	F_T tang [N]	F_a axial [N]	F_r radial [N]
Turning	453	800	480	800	0
Chamfer	282	500	500	210	-210
Milling ext.	2917	5000	5000	3000	0
Milling int.	2584	4500	4500	2700	0

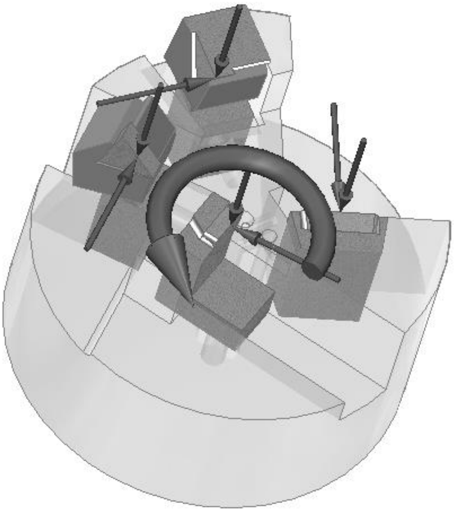

Figure 10: Cutting tools position solution and process loads.

From tab.2 the greater loads are for milling cutting edges, so they need of a robust cartridge and an adequate seat that is resistant to the stress. A FEM analysis of the stress distribution has been carried out for the insert-cartridge-tool body system to evaluate the solution validity. Mesh used was tetrahedral one and a convergence check showed that 1-1.5 mm the maximum mesh size to be used.

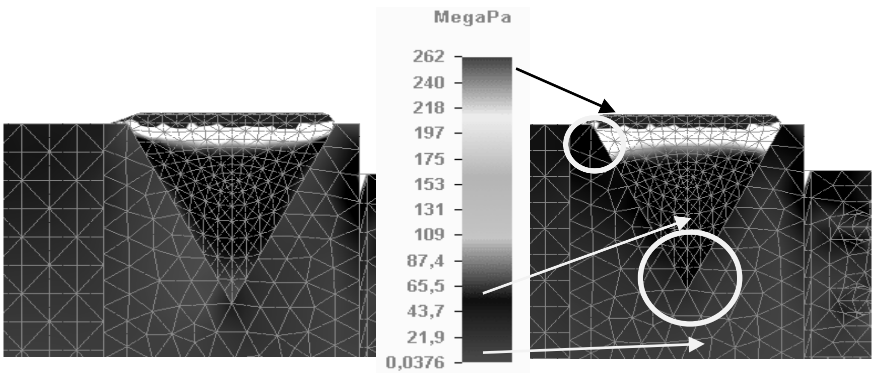

Figure 11: Overstressed contacts between insert and holder (right).

The FEM analysis helps to find overstressed conditions that can be avoided by an easy geometry modifications in the design (fig. 11). This is important in particular for the home built cartridge of milling working inserts and their tool body seats. Moreover these cutting edges are stressed by the highest cutting forces values (fig.12). In any case, the highest stress values in the cartridge and tool-body are very low and safety if compared with the yielding point of the steel: 262 MPa (scale of fig.11). Cutting-edges displacements give a maximum value of 0.01 mm that is considered enough low for a roughing working.

The cutting-edges position of fig.10 has been used for FEM analysis. The resulting tool geometry has given from common sense considerations. Two are the main constraints that drive the choice: the stiffness of the insert-holders seats and the screw drive approach for tool set-up (Fig.14).

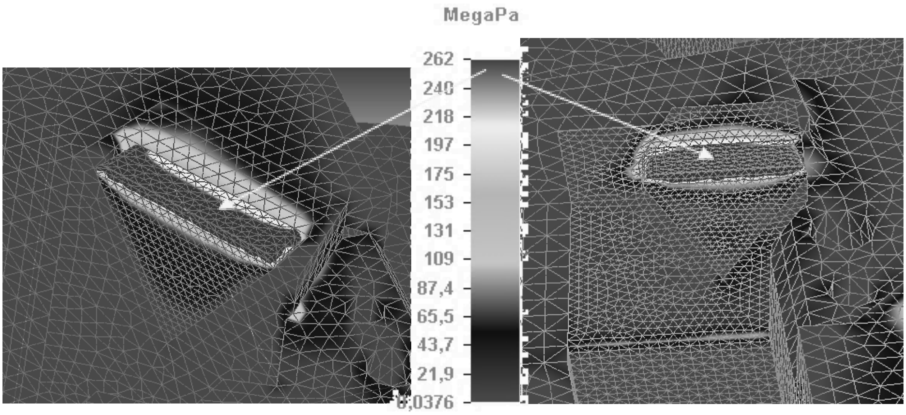

Figure 12: Stress distribution for external (left) and internal (right) milling insert.

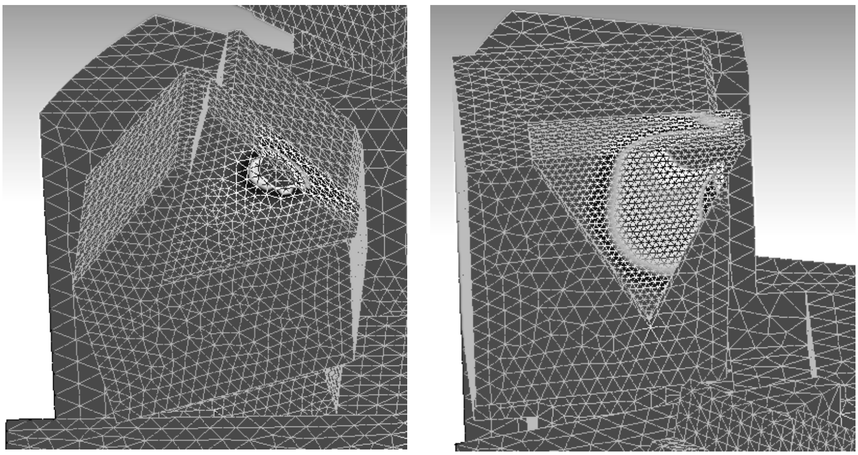

Figure13: Stress distribution for chamfering (left) and turning (right) inserts.

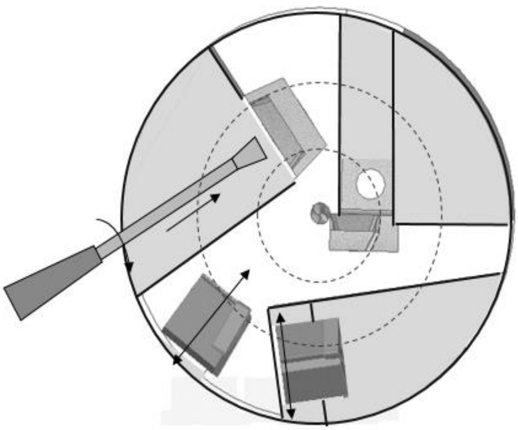

Figure14: Geometric solution for inserts. Grey zones are voids.

Once the tool structure has stated, FEM stress simulation of CAD software has used for the tool design. This FEM application is a fairly good solver and widespread.

5 DYNAMIC BALANCING

Given the overall geometry and the materials of the tool system, the same software easily founds the centre of gravity with the main direction of inertial axes: *1,2 and 3*. As well known, for static balancing, the centre of gravity must fall exactly on the rotation axis and, for dynamic balancing, the rotation axis *z* must overlap the inertial axis *3*.

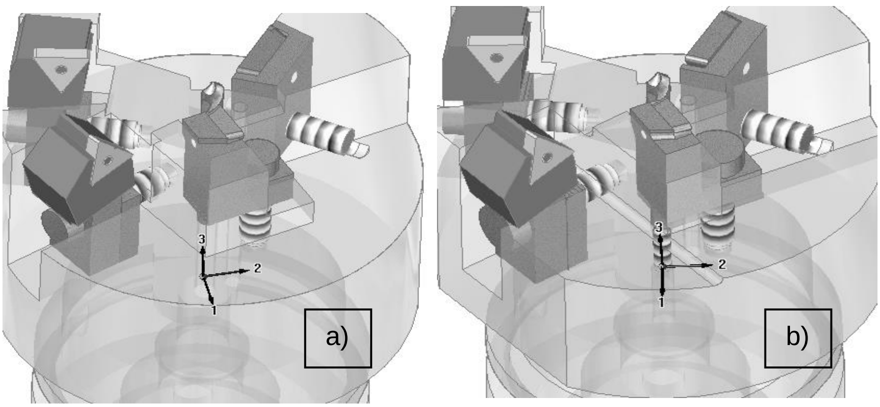

Figure15: Geometry of the tool-body before a) and after b) balancing.

The balancing has been reached by removing material from the body, fig.15 b), with the following values with respect to *z* axis: axis *3* cosine=0.999, axis *2* cosine=0.0386, *y*=0.009 and axis *1* cosine= 0.0064, *x*=0.0353.
The computational solution is satisfactory and the final fine dynamic balancing will be easily done by the tool maker with fast operation.
Enough free space, finally, is available before the inserts for chips evacuation in the final geometric solution.

6 CONCLUSIONS

A special tool for multiple chip removal working was analysed with the aim of introducing an efficient design procedure for complex tools. Literature searching didn’t give an approach methodology from a general point of view, but some fundamentals has been taken and adopted to the present work. The proposed procedure has then developed and followed through the design work using a widespread CAD software. First of all for fixing all constraints the geometry of part family, the existing tool and the machining centre was examined. The design starts with the selection of blank for the tool body, then position and adjustment of cutting-edges in the space has found with respect to the surfaces to work. This step requests an important work in selecting and adopting existing insert-holders in the producers catalogues. In this case, two cartridges were found, while other two has suitably designed to be home constructed. Easy fastening solutions are proposed for a quick and precise cutting edges setting-up. This minimises the resetting costs in working part changing time. After this, the dynamic analysis has been carried out to verify the stress distribution due to chip removal process and the overall geometry in rotation balancing, avoiding vibrations during process for a better quality assurance. The new designed tool can perform better, removing a greater amount of material using appropriate inserts with a reduced cost per cutting-edge. The proposed procedure is easy to use with actual common CAD software’s without encountering particular difficulties and getting a very satisfactory result in efficient way.
The new designed tool reduces the cost/cutting-edge by 8% when working the new flanges and also reduces the time required for tool change and set & gauge by 60%, from 15 minutes to 5 minutes. Considering a setup every 2000 pieces and a working time of 10 s/piece, the added 10 minutes, that are obtained with the faster tool change, increase productivity by 3%.

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ERGONOMIC DESIGN OF LASER SINTERING SYSTEMS - RESULTS OF AN EMPIRICAL STUDY

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Abstract
Additive manufacturing processes such as laser sintering are characterized by a high rate of innovation, are a standard procedure in rapid prototyping and are becoming increasingly important in small-series production.
Despite the growing importance of additive manufacturing processes, there are no comprehensive ergonomic studies about work using additive manufacturing systems. This study therefore investigates the working processes of laser sintering systems. The method is guided by the DIN EN ISO 9241-210:2011 standard and helps to record the context of use, to accomplish usability tests and to develop design recommendations.
The outcome of the study shows that the efficiency of the laser sintering operating process can be significantly increased by implementing ergonomic recommendations and consequently further improve the employees' working conditions.

Keywords:
Ergonomic design, additive manufacturing, laser sintering, usability

1 ERGONOMICS IN ADDITIVE MANUFACTURING

Additive manufacturing processes, such as laser sintering, are characterized by being highly innovative, are seen as the standard prototype production process and are increasingly important in small batch production [1]. As a result of this, the global market for industrial additive manufacturing systems achieved 19,3% growth in 2012 [2]. Despite the increasing importance of additive manufacturing in the industry, there are as yet no comprehensive ergonomic studies related to operating processes with these systems. Furthermore, discussions among experts in the field have shown that the subject of human-centered system design has not, as yet been a priority for this very new and dynamically growing industry.

2 OBJECTIVES AND PROCEDURES

The objectives of the study are to show where there is potential for improving ergonomics in additive manufacturing, as exemplified by EOS

FORMIGA P100 und P110 laser sintering systems, and to derive recommendations for action which lead to improved usability for the operators and raise productivity.
The chosen method is based on DIN EN ISO 9241-210:2011 requirements (Fig.1) and is comprised of three steps.

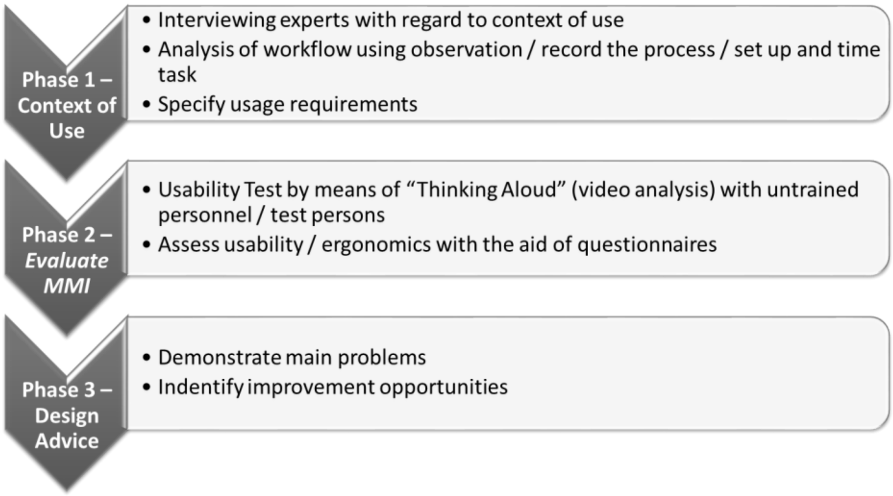


Figure 1: Project Method, Based on DIN EN ISO 9241:210:2011.

The first step is comprised of identifying and specifying the context of use. In order to establish the context of use, interviews were conducted with experienced users of laser sintering systems and processes were recorded at a large manufacturer of electrical connection technology. Furthermore, the operational processes using EOS FORMIGA P110 at this manufacturer were analyzed and the actual times for completion of an individual task were taken. The individual tasks were collated into a matrix, which shows the elements that the manufacturer can influence (controllability matrix), in order to assist the subsequent formulation of design recommendations (Fig. 2).

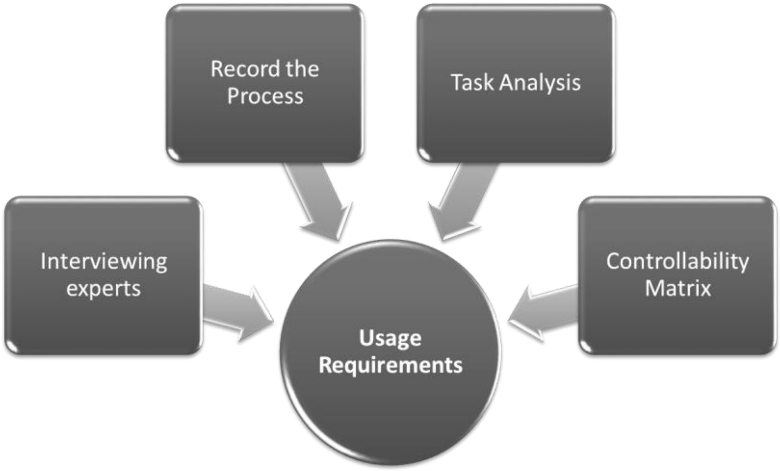


Figure 2: Methods to Establish Usage Requirements.

The second step involved conducting usability tests with EOS FORMIGA P100 in the design and development laboratory at the Ostwestfalen-Lippe University for Applied Sciences. In the third and final step, design recommendations are derived from the analytical results.

3 PROJECT PHASES AND RESULTS

3.1 Establishing the context of use

In order to establish the context of use, four semi-structured interviews were conducted, based upon an interview guide with 23 questions. This followed the content of DIN 9241-110:2008 context of use [4] and included information about user characteristics, aims and tasks as well as the system environment, amongst other things. The results showed that an employee’s tasks could be loosely subdivided into five subcategories:

1. Prepare customer quotes and accept orders.
2. Create works order.
3. Set up and complete order on the machine.
4. Clean machine and prepare for the next order.
5. Component finishing.

The first two sub processes are performed at a computer desk, only sub processes 3 and 4 are performed at the machine. It should also be noted that the first sub process is generally performed several times a day, since works orders for the machine usually comprise of a collection of customer orders.

Aside from the information about the user, tasks and system environment, the results of expert interviews also delivered the first indications of potential improvements. Employee statements indicated that the dust extraction from neighboring systems was insufficient; this resulted in the dust which results from unpacking components not being fully extracted, but distributed into the room. This dust generation can cause certain flooring to become slippery and can, therefore, pose a danger to employee safety. Furthermore, the space available was not large enough to allow placement of machines and materials for optimal workflow.
The objective of the Task Analysis was the analysis and evaluation of the completion of the five sub processes by one employee. The operational time of the person, not the usage time of the machine, was examined since the actual production process usually takes many hours without the supervision of an employee. The results of the study show that the first two sub processes, which are performed at the computer desk, take approximately two thirds of the total operational time examined (one hour and twenty four minutes) (Table 1).

Table 1: Task Analysis.

Sub Process	*Classification*	*Time Taken (Min.)*	Percentage of Total Time
(1)	Prepare customer quotes and accept orders	11:01	13%
(2)	Create works order	41:23	49%
(3)	Set up and complete order on the machine	04:49	6%
(4)	Clean machine and prepare for the next order	09:39	12%
(5)	Component finishing	16:58	20%

A lack of compliance with Dialogue Principles DIN 9241-110:2008, could be observed, as various software programs were used to prepare and convert CAD data. In “Magics” software, for example, when placing components, a wait time, which was not consciously noticed by the operator (Tacit Knowledge), could be observed and the software therefore did not conform to user expectations. It could also be shown that the software lacked intuitivism and learn-ability.
After collecting information and identification of improvement potential in the individual sub processes, these were represented in a Controllability Matrix showing factors that the company can control (Fig. 3). This figure shows that, in sub processes 1, 2 and 5, a medium to high controllability is possible,

whereas sub process 3 and 4 can only be marginally controlled, or are unable to be controlled by the manufacturing company, as it has no influence over the system design. The duration of the processes shows potential for ergonomic and efficiency improvement.

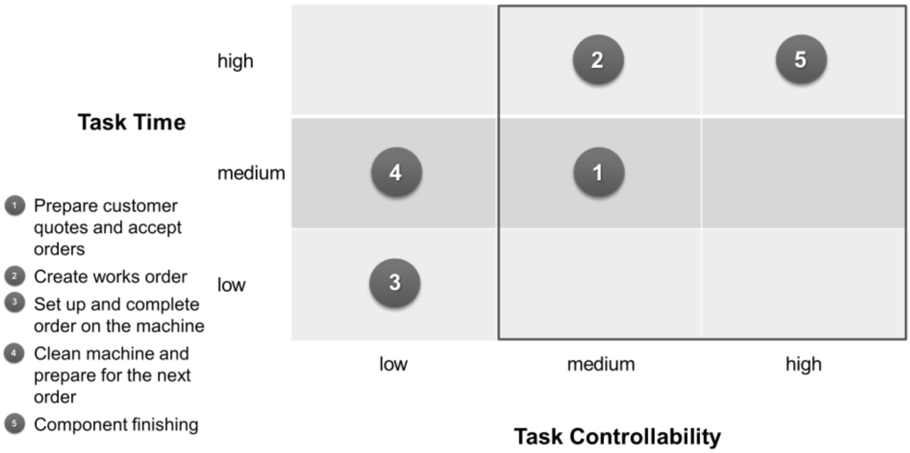


Figure 3: *Controllability Matrix (factors the company can control).*

3.2 Usability-tests and questionnaires

The usability test was performed on the EOS FORMIGA P100 laser-sintering system, with eleven participants, studying sub processes 3 and 4. The participants had no experience with the systems and, therefore, received an introduction to the manufacturing process before the tests began. The test took approximately 45 minutes and contained seven different tasks, which the participants performed on the system. The task execution was videoed and the participants were then required to assess each step of the task with the help of a questionnaire designed according to The Compendium of Ergonomics, by The Federal Institute for Occupational Safety and Health [5].
The single tasks "Raise Platform", "Pre-Heat", "Switch On / Off Nitrogen Supply" and "Begin Works Order" could all be completed by the participants within a short time period, as it appears that the system controls in this regard were self-explanatory and intuitive. Difficulties were incurred when switching the systems on (6 out of 11 participants), loading the works order (7 out of 11 participants) and shutting the system down (6 out of 11 participants). Above all, the works order loading symbol (7 out of 11 participants) and the shutting down symbols (6 out of 11 participants) were criticized as neither were considered to be self-explanatory in the context of this task (Fig. 4).

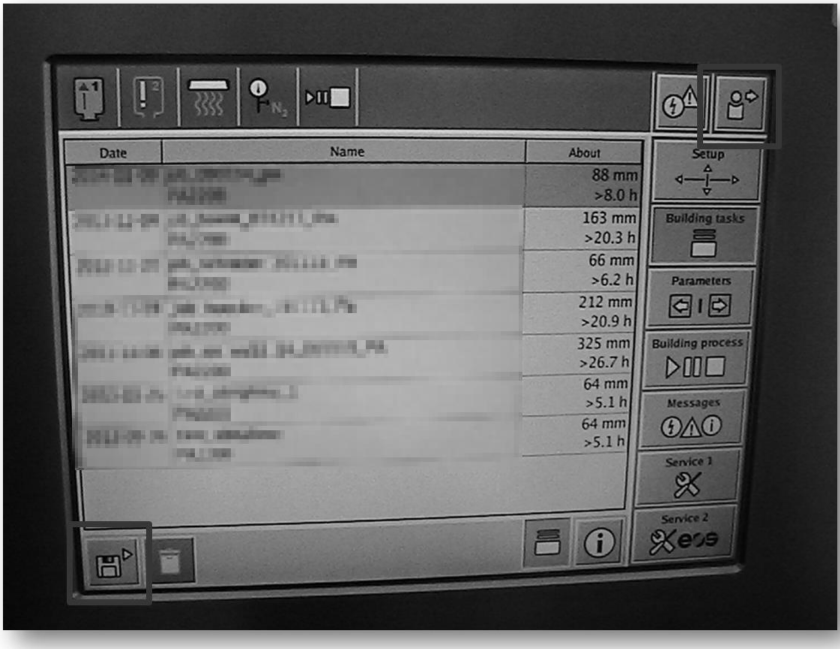
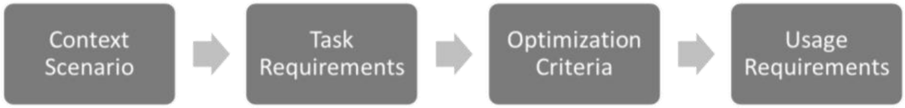


Figure 4: EOS FORMIGA P100 Laser Sintering System Control Panel.

Further ergonomic optimization potential could be identified in the ease of use of the powder container, during powder container changeover on the machine, as well as plugging in the heater plug, due to the participants often having to stoop or twist whilst performing these tasks. Furthermore, physical problems for the employees occurred during change over of the powder container, depending on the fill-up quantity, these can weigh up to 18 kilograms. It was noted that participants had problems with unscrewing the powder container lid because it was difficult to loosen and correct re-position when replacing was also problematic. Moreover, dust distribution was generally considered to be disturbing due to deposits on working clothes and the working environment, as well as the increased danger of slipping.

3.3 Design recommendations

Based on the context of use analysis and the usability study, design recommendations were formulated for each of the sub processes. A context scenario was described as the basis for the design recommendations, out of which task requirements, optimization criteria and, finally, usage requirements were derived and defined. Figure 5 shows an example of this process. A selection of design recommendations will be explained in each sub process.



Example:

Context Scenario	Task Requirements	Optimization Criteria	Usage Requirements
Employee places newly mixed powder on the mixing station. In doing so the employee has to stoop, as the mixing station is on the floor	The employee should have be able to place the powder container more easily	Work station ergonomics	Place the mixing station at an ergonomic height

Figure 5: Model and Example for the generation of Usage Requirements.

Sub Process 1: Prepare Customer Quotes and Accept Orders
It was noted that the quotation process involved enquiries from various sources, using differing file formats and containing differing information. Standardization of the quotation process, using a standard form as well as limiting the CAD formats accepted could dramatically reduce the operational time and therefore increase order processing efficiency.

Sub Process 2: Create Works Order
The manufacturer should adapt the software to conform with user expectations, improvements of intuitivism and learnability should also be made.
Due to the long component layout processing times, the use of an additional program “3D Nester” is to be recommended, this program produces an automatic layout, which dramatically reduces processing times. The yearly License costs of 3,150.00 € will pay for itself in a very short time.

Sub Process 3: Set Up and Complete Order on Machine
Due to the problems with unscrewing the lid and the lifting problems highlighted by the usability test, handling of the powder container can be greatly improved by the construction of an area / shelf to place the container on and a transport trolley. Single, non self-explanatory symbols in the control system should be replaced and learnability can be improved to conform to ISO DIN 9241-110:2008.

Sub Process 4: Clean Machine and Prepare for Next Order
Changing the location of the heating unit and simplifying the plug construction can improve heating unit handling. The heating unit plug is to be constructed in such a way that sharp parts are avoided and the risk of injury thus reduced.

Sub Process 5: Component Finishing
The finishing station, mixing station and blast cabinet should be height adjustable to accommodate the user's individual body size whilst finishing the components.

4 CRITICAL APPRAISAL

The results of the study show clear ergonomic improvements to be made to the additive manufacturing system appraised. Implementation of the design recommendations would provide improvement for both the employees working conditions and the efficiency of the operating systems. However, as yet only two systems have been examined. Further studies in this sector must be carried out before representative statements can be made regarding ergonomics in additive manufacturing. The development of industry standards with regards to regulations and guidelines could also help to establish ergonomic standards industry wide.

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OPERATIONS MANAGEMENT - A CASE STUDY OF VOLVO TRUCKS CORPORATION IN INDIA

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Abstract
AB Volvo is a Fortune 500 company based in Sweden. Its product portfolio consists of commercial vehicles like trucks, buses, construction equipment, marine and industrial engines and aero engines. When a transnational corporation is setting up a supply chain in the manufacturing industry in an emerging market, it is required in order to gain cost advantages and to shorten the development phase of components being purchased.
This study will examine the Globalization of Volvo Truck Corporation in India, focusing on the relationship towards its suppliers with international connections present in the Indian market using Operations Management tools. Presently, the company has a limited market share, although the company is benefiting from its global brand reputation. This case study discusses Volvo's strategy for the Indian market and how it became successful as a niche player. The analysis of the study was performed in steps which have a correlation with the history or timeline of Volvo and provides suggestions for the future progresses and company's business development.

Keywords:
Globalization, Volvo India Private Ltd, Emerging Markets, Operations Management

1 INTRODUCTION

1.1 Problem background

The topic is concerning the subject Operations Management and tools that have to be used in order to understand the perspective of Operations Management as well as the scope it has. The development of the study involved choosing a team with adequate knowledge on the subject and setting out goals for the team with given deadlines, the research was conducted to widen the knowledge of Operations Management by studying an organization's performance which also would help in good team management.

The base was to choose a company that had easy access for information and to incorporate the author's ideas in it. As one of the team members was an ex-employee of Volvo India Private Limited and with the knowledge acquired during the stint in VIPL, this led to us choosing Volvo India Private Limited as a base.

1.2 Introduction to the company- Volvo

Volvo was incorporated in 1915 as a subsidiary of AB SKF, the Swedish ball bearing manufacturer.
The 1920s was the decade when cars made a real breakthrough, both in the USA and Europe. In Sweden, people's interest in cars was seriously aroused in 1923 as the result of a jubilee exhibition in Gothenburg attended by 97 car exhibitors [2].
Volvo Trucks group operations include Volvo Trucks, Mack Trucks, Renault Trucks, UD Trucks, VE Commercial Vehicles Ltd (VECV).

Volvo's vision and values
Vision-To become the world leader in sustainable transport solutions.
Values- Quality, Safety and Environment

Volvo Trucks
Volvo Trucks (Swedish: Volvo Lastvagnar) is a global truck manufacturer based in Gothenburg, Sweden, owned by AB Volvo. It is the world's second largest heavy-duty truck brand

Volvo Trucks in India
Volvo Trucks in India came about as Volvo India Pvt Ltd (VIPL), it was established in India in year 1998 and had recent experience of how the liberalization process had affected an MNC's government strategy. Thus, the company had a lot of valid information on the subject of our study [2].

1.3 Limitations

There were several limitations that had been imposed, limitations like the scope of the study was too large and it was very difficult to conclude with one solution as each solution lead to risks. The study was purely on theoretical basis so many analogies were made from brainstorming and literature review.

2 METHODOLOGY

2.1 Objectives

- To study the globalisation process of Volvo by using Operations Management tools. To substantiate the reason for which Volvo chose India as a place of work during the year 2001. Political, Economic, Social and Technological analysis (PEST analysis) was carried out in order to prove that India was a country guaranteed to do business in and with

- To provide a solution for Volvo India to optimize Purchasing in India on the Asia market.
  The scope of this objective is large as Volvo is a multinational company - achieving the objective might be tentative and hence the scope of the objective was minimized to 'providing a better solution for Volvo India in order to improve Purchasing in India'. Strength, Weakness, Opportunity and Threat analysis (SWOT analysis) was carried out to understand the present status of work performance.
- From the SWOT analysis, the idea of risk analysis on the solution would provide as test corrective results for our solution.

2.3 Approach

Framing the objectives was a target or goal that was to be achieved but there was a need of an approach in order to achieve the goals, the method of reflecting the objectives from the company's point of view, by doing this a better and clear picture was grasped and helped the team to achieve the goals.

Targets to be achieved by Volvo:

- Workplace on a foreign land (PEST)
- Incorporating the company's way of working (Purchasing Department)
- Keeping up to the company's vision

The above is a theoretical frame developed by the research team filtering only the points that are forming the backbone of the research paper [2].

3 ANALYSIS

3.1 PEST analysis

The analysis examines the impact of each of the factors like Political, Economic, Social and Environmental on the business. The use of P.E.S.T. analysis can be seen effective for business and strategic planning, marketing planning, business and product development and research reports. P.E.S.T. also ensures that company's performance is aligned positively with the powerful forces of change that are affecting business environment [3].

Political

- India is a Federal, Parliamentary, Democratic, Republic country- Such republics usually possess a bicameral legislature at the federal level out of necessity, so as to allow for a set, and often equal number of representatives of the sub national entities [4].
- Allow tax deduction for R&D activities [5].
- Politically stable and effective judicial system hence easy to work with [5].

Economic environment

- The Indian economy has grown at 8.5% per annum. Monitoring, budget and external accounting tensions should not be under-estimated but remains under control [6].
- The level of Employment per capita is right - The consumption of goods and services is one way to measure an individual's economic well-being, it is easy to calculate the Gross Domestic Product (GDP) per capita (i.e., per person) to indicate the average well-being of individuals in a country [7].

Social Environment

- Changed lifestyle of people, leads to increased purchase of automobiles- Since India is a developing country there is a change in lifestyle and due to international advertisements and marketing techniques the people are more open and on experiment bases [8].
- They are price sensitive and put a lot of emphasis on value for money- Indian customers are highly discerning, educated and well informed. They are price sensitive and put a lot of emphasis on value for money [9].
- Indian citizens support globalization- the society welcomes foreign countries to enter India for business as English is one of the national languages there is no communication barrier it helps both India and foreign companies [9].

Technology Environment

- With the entry of global companies there is advancement in technology for product and production processes- there are foreign automobile countries stationed at India for the purpose of business this has provided a base for R&D programs at an institutional level [9].
- Weighted tax deduction of up to 150% for in-house research and R & D activities- the government and institutes help in tax reduction for the development of the country which serves as an advantage for Volvo [9].
- The PEST analysis gave concrete reasons to why Volvo chose India as a place of work while going global.

3.2 SWOT analysis

The second part of the study is about providing a better purchasing solution for Volvo Trucks India Purchasing Department; the initial step is to understand the work frame of Volvo purchasing.

SWOT stands for Strengths, Weaknesses, Opportunities and Threats. It is an operation management tool used in summarizing the current state of a company with respect to its external and internal factors and helps to develop a plan for the future.

Firstly to understand the SWOT analysis there is a need to understand the process that takes place in the purchasing department and these points on

SWOT where reviewed on bases of the process in order to make the study more streamline.

Volvo India Purchasing

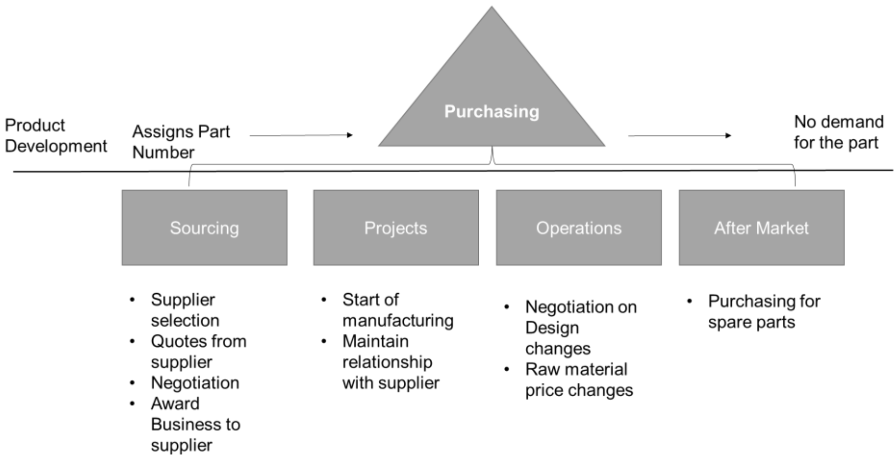

Figure 1: Volvo purchasing workflow.

Volvo Purchasing department's activity is divided into three phases Sourcing, Projects and Operations. There is also the purchasing for spare parts for the trucks that are on road, this section is called After Market. Figure1 shows the flow of purchasing or the activities of purchasing from parts (the products that have to be purchased in order to manufacture trucks) point of view, initially a part like for example screws, tires, nut etc., are developed in the form of drawings by the Product Development team they ensure these drawings have the exact specifications required for that kind of truck which is going to be manufactured the part gets a part number as an identity.

These part numbers are given to the purchasing department along with the drawings and specifications, a Buyer who is the designated employee from purchasing finds out suppliers from where he can buy these parts. In order to do that there is a supplier selection procedure were the buyer shortlists few potential suppliers with Volvo's supplier standards (these suppliers are from Volvo supplier database there is a separate team involved in hand picking these suppliers with desired standards). Quotes are sent to these potential suppliers and the best supplier with the best price is chosen and negotiation is done on the same, as well as the order quantity before awarding business to him, this process is called Sourcing and this is the first step in Volvo purchasing.

Once the start of production begins there is a need to maintain good relationship with suppliers and other activities like sample checks need to be done. These come under the Projects phase. Once the part is under manufacturing for a while it moves to Operations phase - here the activity of design changes take place (these are changes done by the Product Development on the parts for improvement) so these activities would once again relate to price negotiations and raw material price changes that happen every quarter in a year and is referred to as Intro-Bloc Parts when it is made to re-enter the Production Cycle for the project.
After the demand for parts are zero which is directly related to the demand of the truck they move to the After Market phase where the parts are purchased and kept in storage to serve as spare parts, later there is absolutely no demand for the parts the buyer from the purchasing department hands the part back to the Production Development department. Every Volvo purchasing department is stationed at locations to cover a certain market region, in India it is to cover the Asian Market.

Strengths

- Closeness to the market – India being in Asia
- Acquired Eicher Trucks, India- by having a joint venture Volvo need not only work from India but also own a market share in India [1].
- Ranked 3 in the world for GDP- Purchasing Power Parity (PPP Index) allows one to estimate what the exchange rate between two currencies could be [10].

Weakness

- Long working procedure- The Volvo way of working is a standardized long process which takes time to accomplish these long procedures like explained earlier about the purchasing procedure. It can be a disadvantage when it comes to competition (in India, TATA trucks are Volvo's main competitors and the Volvo truck projects must reach deadlines without delaying order to compete). The recent Volvo project for truck 'Quester' was not a successful one because of competition from TATA due to failure in completion within project deadline.
- Own ERP system- Volvo has its own ERP system that is a disadvantage with linking with supplier data bases [1].
- Communication time with suppliers- for MNC's doing business in India and getting parts delivered from a foreign land can be tedious in terms of time difference this was a key point given by the team member who was an ex- Volvo employee

Opportunities

- Existence of Volvo group- Volvo group which can be of advantage, the truck department can use networks of other department and use internal supplier data base for sourcing operations [1].

- Increase in small scale industries due to other foreign automobile company (Potential suppliers) - due to other foreign companies there is an increase in small scale industry which might give good potential customers in order to do business with [8].
- Increase the distribution network- Volvo has acquired Eicher Trucks which is a truck brand in India, the use of joint venture can help in having great distribution network for sales or even communication networks [1].
- Skilled Manpower- Abundant qualified engineers with low labour cost, this skilled manpower come in real cheap for foreign companies [11].

Threats

- Too much competition in Indian truck market- existence of truck firms is an increase in competition and huge burden to beat competition [1].
- Tax and Inflation - Many taxes that are imposed are threats in order to perform business successfully. Inflation is another key factor which is a big threat [11].

INTERNAL / EXTERNAL	STRENGTH	WEAKNESS
	1. PPP index is high 2. Acquired Eicher trucks India	1. Own ERP System 2. Long working procedure 3. Communication time with suppliers
OPPORTUNITIES a) Increase in small scale industry b) Existence of Volvo group c) Skilled manpower	(1+axc) Localization of purchasing (2+b) Increase distribution network	(1+a) Use a more flexible ERP system(SAP)
THREATS a) Competition in Indian truck market b) Increase in Tax and inflation	(2+a) Joint venture growth	(2x3+a) Reduce working process to fasten the project (2x3+b) Localization of purchasing

Figure 2: SWOT Analysis.

Figure 2 shows the result of the SWOT analysis, the matrix shows the grouping of internal factors i.e., Strength and Weakness with External factors and Opportunities and Threats. The center of the matrix consists of possible suggestions which were derived by discussions from the team and due to limitations only the repeated suggestion was picked and analyzed. In this case it is Localization of Purchasing.

4 PREDICTIONS FOR FUTURE DEVELOPMENT

The prediction from the SWOT analysis was the Localization Strategy which is the process of adapting a product or service to a particular language, culture or region.

4.1 The need for localization

The need for localization nowadays is immense from every aspect, as it brings benefits to industries, customers and government.

For example Michelin tires are bought from France to India and then they are assembled but if they are bought in India itself as in find a local supplier who can deliver the product Volvo can be beneficiary in many ways like cost (PPP index), communication time from India and France, also logistics cost.

The basic need of localization is to fulfil the companies need immediately, so a decision to localize.

Localization strategy have pros and cons. Few pros are Parts can be bought and trucks can be manufactured locally, also they are-Cheaper in price and logistics. Easy to perform business with and also few points as mentioned earlier, but the interest in the study thickens with the disadvantages and the best way to analyze this to opt for a risk analysis with these cons which would give a clearer picture on how promising is the suggestion made by the team to Volvo India Private Ltd [12].

4.2 Risk analysis

Risk analysis should be performed as part of the risk management process for each project. The data of which would be based on risk discussion workshops to identify potential issues and risks ahead of time before these were to pose cost and schedule negative impacts.

For this risk analysis done during the study, the risks were categorized into four according to the seriousness of the risks, as shown in figure 3. These risks were categorized accordingly by a brainstorming session conducted by the team.

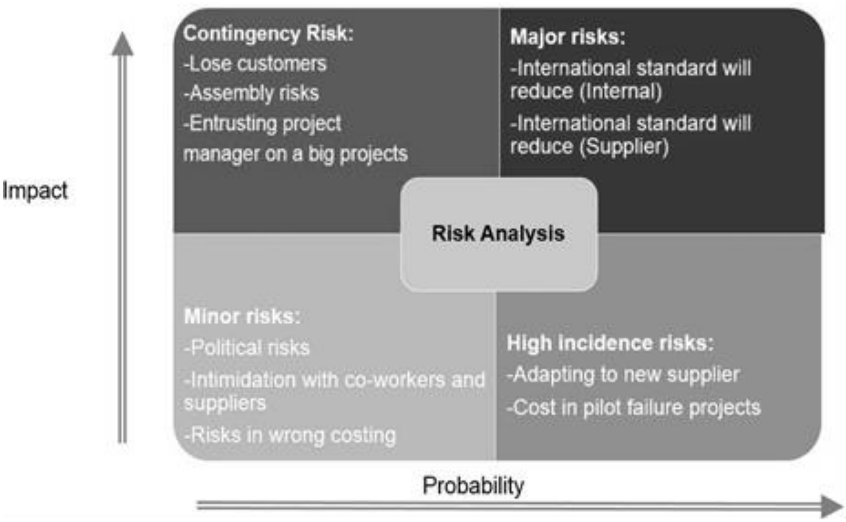

Figure 3: Risk Analysis.

5 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The study comprised of understanding how a multinational company like Volvo works, it provided knowledge in terms of how certain big decisions were made by Volvo during the time it went global. Operations management is a concept that can be implemented at all stages of organization or even any basic activity, it can show many business barriers as well as help solve them. The use of operations management tools in this study substantiated the author’s thoughts and drove the path towards roadblocks solutions till a line had been drawn.

PEST analysis gave a picture on why Volvo chose India during the time it decided to go global. Further studies were on the performance of Volvo India Pvt Ltd - The main factors of influence were drawn by conducting a SWOT analysis. To carry on the study and to streamline it, one suggestion was taking into consideration in the study and that is the suggestion for business was localization of purchasing in India, on review a need of risk analysis struck, and the third analysis in this study gave more results where the line had to be drawn.

Recommendations are of no harm as it is just a proposal given irrespective of acceptance or rejection.

5.2 Recommendations

One of the major risks in localizations was ‘International standard will reduce (Internal)’ - This is a risk which is difficult to pin point and is equally expensive; the cause of localization would make a psychological impact with the employees. When employees in Volvo India work with local suppliers their exposure to international behavior and quality would depreciate because both purchasing and manufacturing is done locally. This can drop the internal working culture and this would risk the brand of the company in the near future, by tedious brain storming, the team had concluded for an internal problem a business strategy has to be the solution.

Corporate governance using Divide and Conquer Strategy

Corporate governance refers to the system of structures, rights, duties, and obligations by which corporations are directed and controlled. "Divide and conquer" is a possible strategy that can be used in several settings the combination of both was a great business strategy to retain the internal working quality that had a probability to drop if Localization was adapted.

What the concept is to ensure the Volvo’s Vision and Values has to be incorporated in every internal activity that the employee performs, in order to incorporate this, the activity first company must be divided its main activity into smaller activities e.g. Volvo’s main activity is selling trucks. This activity is divided into further sub activities like purchasing, sales, logistics, product development etc.., these are further sub divided, like e.g. purchasing as explained earlier is divided into sourcing, projects and operations so once these sub activities are performed with the Volvo’s vision and values like sourcing the supplier, this activity can be done with sourcing the supplier with quality, safety and environmental values(the Volvo values) then the Volvo standards are up to mark with this activity. Likewise if every activity is done with the same intention or motivation then the sub activity fulfils the vales and the quality of job is retained. By adding up all the performed sub activities the main activity i.e. purchasing would be performed with Volvo’s values since the main activity is a summation of sub activities which would lead to selling trucks with the same values and vision. By doing this the entire organization has retained its standards and it keeps up to its brand image without compromising any of it.

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DEFINITION OF THE PRODUCTION PROCESS FOR A NEW COMPONENT IN AUTOMOTIVE INDUSTRY

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Abstract
Lean Manufacturing is a working philosophy designed to produce better products using fewer resources to obtain benefits. It has been applied to a wide variety of sectors different from the original automotive industry, in which it was developed.
An important part of this work, in addition to explain Lean theory, is a testimony of team activities and had the aim to introduce the Lean philosophy in an Italian industry, operating in automotive sector. This work analyses the applicability of lean production in an Italian die casting toolmaker, and the results that may be obtained from its application, using value stream mapping as main tool to identify opportunities for improvements. Starting with collecting process information, a current value-stream map was created that reflected the current process status. A future state map was then proposed to serve as a guide for future lean activity. Later were identified obstacles that kept the company from moving the future state were identified. The “5 whys” technique was used to find the root cause for each waste, followed by *Kaizen* events proposed as solutions. In this case study, five *Kaizen* events and one *Kaikaku* event was proposed.

Keywords:
Lean Manufacturing, Automotive, Value Stream Mapping, Performance Indicator

1 LEAN MANUFACTURING: PRINCIPLES AND OBJECTIVES

A system can be considered Lean when, inside, all the materials move according with a continuous flow as much as possible, passing through processes that increase the value. The application of this new line of thought, prior to the production system, then to the entire company led surprising improvements in business performance. The surprising results of Lean production implementation in Toyota contributed to its spread that goes beyond a simple rethinking of the production lines, but consider all company aspects.
Lean thinking is based on five fundamental pillars, through the pursuit of these five principles, the company decides to adopt the Lean logic like its

objective to eliminate progressively waste (*Muda*) related to the production process and to all business processes.
The fundamental topics to work in a full of lean thinking, according with Womack and Jones (1990) can be summarized as follows [1]:

- Value: identify what has value for the customer
- Stream: identify the flow of value
- Flow: slide the flow
- Pull: ensure that the flow is "pulled" by customer
- Perfection: search perfection

To increase the value chain is necessary to act on waste reduction. The wastes can be cataloged, according to seven major categories [2]:

- Defects
- Overproduction
- Transport
- Waiting
- Stocks
- Movement
- Unnecessary processes

2 VALUE STREAM MAPPING

The best technique to track and understand the flow of value (value stream) is the map of added value VSM (Value Stream Map). “Value Stream” is composed by all the actions (both value added and non-value added) currently required to bring a product through the main flow: the production flow from the raw material up to the final product, into the arms of the customers, and the design flow from concept to lunch.
The VSM is a qualitative tool that involves many benefits:

- Helps to visualize more than just the single process level, (i.e. assembly, welding), in production, integrates individual processes as part of a macro flow.
- Helps to highlight the source of waste in the value stream, computing the total lead time and the flow index.
- Integrates and makes consistent application of techniques and Lean tools compared with a future stream (future state) to reach, starting from the current materials and information flow (current state).
- Shows the linkage between the information flow and material flow.
- It is much more useful than quantitative tools and layout diagrams that produce a tally of non-value-added steps, lead time, distance travelled the amount of inventory and so on. Value stream mapping is a qualitative tool by which you describe in detail how facility should operate in order to create flow. Numbers are good for creating a sense of urgency or as

before/after measures. Value mapping is good for describing what is actually going to do to affect those numbers. [3]

The VSM is an effective tool that helps to see three fundamental sequences to map and optimize:

- Flow of materials
- Flow of information
- Flow of people and activities

One point to understand before starting is the need to focus on one product family. Customers care about their specific product, not all the products, so it will be not necessary to map everything that goes through the shop floor. Value stream mapping means walking and drawing (paper and pencil) the processing steps material and information for one product family from door to door in your plant. Identify your product families from the customer end of the value stream. A family is a group of products that pass through similar processing steps and over common equipment in the process.

Developing a Future State begins with an analysis of the current production situation. The Current State is essential both to understand what needs to change, to find out where wastes lurk and opportunities for improvement. In this way will be easier to see the flow. After that, follow physically the flow from the end, i.e. the shipment, then go up to upstream until incoming material department, not according to the physical layout of the plant: so start from the processes closer to the customer that should define the pace of all other processes more upstream avoiding overproduction. After this step, the boundaries related to the flow of the product along the factory become evident on the map, and it is possible to trace the production processes. The next mapping step is to draw the basic production process. To indicate processes are used the process box, which represents a process in which the material is flowing. The process box stops wherever processes are disconnected and the material flow stops. For example, a process with several connected workstation, even if there is some WIP inventory between stations, would be drawn as one process box. But if one assembly process is disconnected from the next process downstream with inventory stagnating, then two process boxes can be used. Another fundamental element of the map, drawn below the process box is the data box, used to record the information gathered on the process. The data process most important are listed below:

- CYCLE TIME C/T: Time that elapses between the input and the output of the product in a single phase, usually measured in seconds or in pieces/second (or mutual seconds/piece to be able to compare with the takt time).
- CHANGEOVER TIME: it is the time to switch from producing one product type to another, usually is measured in minutes.

- UP TIME: time in which the machine is engaged in production (expressed as a percentage of the total available time).
- EPE (Every Part Every): the average size of the production that can be expressed both in terms of time (For example, if there is a change every three production days, the EPE is worth three days) in terms of quantity, as, for example: number of variants produced size of the packaging or percentage of waste.
- NUMBER OF OPERATORS: number of operators necessary, for each machine or process, to carry out the operation.
- WORKING TIME without considering breaks, meetings and cleaning
- Percentage Of Defects

Once defined all process box, proceed tracking another flow: the flow of information. It is the way in which from the raw material to the finished product, come to know for each process how and when to produce. Once tracking the information flow it is necessary to show the areas where, along the flow of materials, there is accumulation of stocks. It is important to note its position and the amount in pieces or time in the map, because at these points the flow is interrupted. It is indicated in the map by means of a triangle to indicate the need to break down the waste in the future map (Future State).
At this point of the map processes are connected indicating the logic of production scheduling that binds them: push, the material flow is driven, based on the forecast, from the upstream process (represented by a stripped arrow) or pull, he stream is pulled by the customer process that determines how, what and when to produce.
At this point the structure of the map will present both the flow of the materials that will cross from suppliers to customers and information that instead will follow the reverse path. To complete the VSM is necessary to add the timeline, indicated below the processes box and the triangles of stocks, which highlight the total lead time of the process, i.e. the time between the initiation of a process and its completion until the shipment to the customer. Only a part of the lead time, is a value for the customer. The shorter the lead time, the better the cash flow. [4]

3 DEFINITION OF THE COMPANY'S PROBLEM

The company in which was this methodology was applied is active with its product in the international market. One of its market areas concerns the automotive. This is a demanding market that drives the search for higher and higher quality, both from the point of view of the machining accuracy and aesthetic appearance of the finished product, until the smallest detail. This request has generated the need for automotive articles with higher quality that, consequently, require different technologies and attentions. For

this reason the automotive product is managed and produced within the company, with own dynamics, driven by a customers that takes advantage of working with methods typical of the TPS and that serves as a tow to suppliers in order that they think in terms of "pull" rather than "push", and implement all possible strategies to reach the target of 0ppm defective rate. For these reasons it was necessary to create a project, with a dual goal of increasing customer satisfaction (therefore reduce complaints) and optimize the production process.
VSM allows to identify and eliminate waste, to increase the value added and improve the flow organization. Its application is, naturally, continue, in the sense that every state reached can be put in discussion again according with Deming's cycle (PDCA).

4 CURRENT STATE MAP

In the development of a project it is important to identify the level of performance owned by the company in the initial phase, which later will be used as comparison to obtain improvements at the end of the process. The first step is to map the production flow that will be carried out through the VSM (*Value Steam Mapping*).
To draw a map of added value has been selected a particular article. This is a critical article, newly obtained, because it is required by a demanding customer that provides machining with a reduced margin of error besides a long cycle. In fact its production flow passes through a number of workstations higher than the average, from which every error in the production has a high risk of generating delays in delivery. The criticality of the product will be a stimulus and incentive action, every improvement can bring results in the short period, carry new energy to research other aspects on which is possible to act. Because of the complex work cycle required, difficult production and high volumes demanded, it was necessary to map the cycle in order to catch the optimization opportunities. To be able to create the current state, in full Lean thinking, it is necessary to equip with a pencil and paper and go up the flow of the product from the customer up to suppliers of raw material. The Lean team performed two walkthroughs, tracing the path that the material and information flow through the production facility. For the first walkthroughs, the team walked from the raw material receiving area to the finished products shipping area. This made the team familiar with the current flow and the sequence of processes in the facility. Next, the team walked from the shipping area upstream towards the raw material area. This gives the team a better sense of the customer pace that the facility should operate on. Walking through the company allowed collecting the detailed process information that represents the current status of manufacturing system. Concerning the automotive, the last contact before the customer is identifiable with the department of control that makes a 100% aesthetic inspection. On the top of the board, it was drawn the flow of

information; on the bottom, in correspondence of each process, was placed the "data box" where are all information relating to the process that will be used in a second moment for optimization. The right bottom end box shows that only 281 seconds of the throughput time is dedicated to work with value.

Other yellow cards, glued on the board, highlight the most critical activity that must be taken in consideration and addressed during the future state map definition. As visible in the VSM of Figure 1, the backward path of the flow starts from visual control 100%.

5 KAIZEN EVENTS

The team brainstormed and identified a list of wastes present in the facility using the seven wastes. The main largest wastes are: defects, waiting time and inventory.
In Lean terms, there are two kinds of improvements:

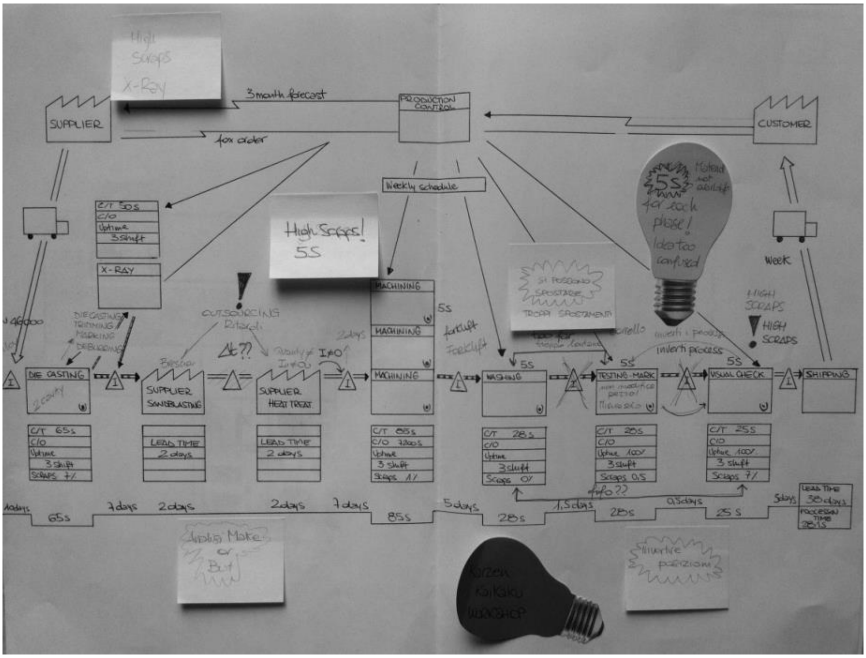


Figure 1: Current state map with possible improvements.

- *Kaizen* is evolutionary, focused on incremental improvements
- *Kaikaku* is revolutionary, focused on radical improvements

The transition from current state and future state may involve many kaizen projects planned in advance. However, due to the constraints in time, money, and resources, only some of them can be completed within the limitations of a company. Based on three key wastes as presented, team discussed and defined six immediate kaizen events for eliminate or reduce these wastes, as indicated with Kaizen light bursting shown in Figure 1. These kaizen events are hoped to bring company's production area closer to the future state. In order to assist carryout the Kaizen events, the "5 whys" method was utilized to identify the root cause for each of the wastes that existed in the current manufacturing system. Kaizen projects began with a daylong kickoff meeting, starting with a presentation about the focus and scope of the project, a review of lean concepts and analysis methodology and a tour of the physical facility of the process. The members collected data from direct observation. In the following days, the team found and suggested improvements.

5.1 *Kaikaku* event 1

Target
Reduce waiting time in part produced in external sandblasting.

Root cause identification
Waiting time was one of the largest constraints in the company from moving towards the future state. Waiting time occurs in the system because this is an external activity done by an external supplier with often delayed deliveries. Analyzing a period of 6 month it is possible to highlight a 10 % of delay in deliveries and most of them exceeded 3 days.

Goal
Bring the process inside the factory in order to have product control.

Proposal
Analyzing the spaghetti chart and according with movements and path followed by pieces, it is therefore convenient to place it close to the foundry area. Obviously, the team made economic considerations about it. But other aspects influence the decision and are crucial: logistics (availability of spaces for machines), and management /process (it is a process to monitor, to integrate and implement within the line).Once compared the costs for internal production and outsourcing, was necessary to know how many years are necessary to have a complete return of the investments. Actually for an accurate investment analysis it should compare all the end costs with

the new one. A direct comparison between these two categories of costs will underline the convenience of one choice rather than the other.

Implementation
Another fact to consider is the movement of the pieces. Once pieces exit the die casting, the robot places them in an appropriate thermoformed bin. To go to the outside supplier, parts must, instead, be place in a different bin. Once they return inside the company they, are place again in the thermoformed bins to be picked up by the robot of machining phase. Bringing sandblasting inside all these changes can be avoided. From here, follows a time saving besides the relative cost.

5.2 *Kaizen* event 2

Target
Reduce waiting time for delivery in part produced in external heat treatment.

Root cause identification
Like sandblasting, it is an external activity, and not always the supplier is in time with deliveries. This means that the process downstream has not the material to work.

Goal
Avoid the process outside in order to have better control on the product.

Proposal
Try to avoid this type of activity.

Implementation
Using different kinds of alloys, with different percentages of components provide greater mechanical and hardness properties. The pieces with this kind of alloys have successfully passed the tensile and hardness tests of customer.

5.3 *Kaizen* event 3

Target
Reduce inventory.

Root cause identification
Inventory is another key *Muda* observed in the manufacturing process. The existence of inventory increases production costs because it ties up money that could be used in other areas of the facility. Upstream of visual inspection, at the beginning of the project the observed inventory was of 0,5 days between testing and visual check. This was the buffer to cover any unexpected problems; before testing there was another inventory of 1,5 days

between washing and testing to eliminate. Additionally bringing internally the sandblasting, eliminating heat treatment makes it possible to eliminate that inventory.

Goal
Eliminate inventory between washing and testing phase.

Implementation
Analyzing the Spaghetti chart on both this phase, it was noted that they are too far from each other, despite one feeds the next, so a continuous flow was necessary. Therefore testing and marking machines was moved close to the washing machine and connected. Another point to consider is the visual check phase. The operator, instead to check pieces once marks are made, with the risk to mark a scrap piece, was interjected between washer and testing machines. In this way it is a unique cell working on FIFO logic.

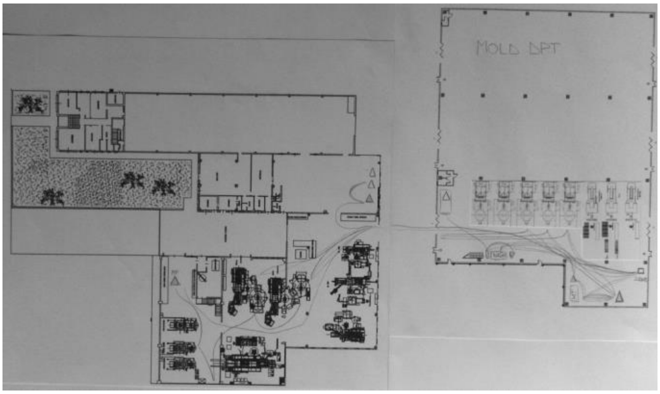


Figure 2: Spaghetti chart.

5.4 ***Kaizen*** event 4

Target:
Reduce scraps.

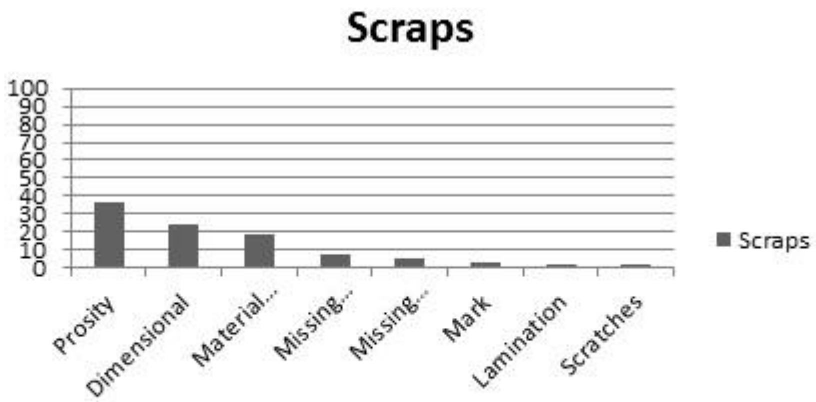
Root cause identification
The automotive product has a best finish of workmanship and high quality of the raw material. From this, it is easy to know the high economic value of each piece and the cost related to its non-compliance at the end of the production cycle. In order to realize the importance of the aesthetic problem, the project was taken into account for the final step of visual inspection. This phase was carried out within the department's manual processes, each piece is examined by a qualified operator who, in the face of internal

standards, decides whether the piece can be shipped to the customer or, instead, it becomes a scrap. The choice made by the operator is not as simple as it may seem, because it is not made on metrics basis, such as, for example, comparison between two measurements, but on aesthetic aspects that are affected by the arbitrariness of a single person. For this reason, analysis of the product was defined as scraps by the department to try to intercept the path to be followed to arrive at the decision of the correctness of the piece. In other words, it is important to understand when a product, for the department, is defined as waste.

Goal
Reduce scraps generation in order to reach zero defects.

Implementation
Once catalog defects are identified, with the help of the responsible person of quality control, a catalog was created with visual representation of product non compliant for the company. This catalog gives to the operator a correct indication about limits of scrap.

Table 1: Pareto' graph.



Analyzing data collected during a period of nine weeks of production, the obtained representation (Table 1) highlights the most numerous defects on which it is necessary act, in fact the non-compliance for porosity, dimensional and material excess are the 80% of the total defects.
The main types of scraps to eliminate or reduce as much as possible are:

Porosity

Root cause identification

Scraps are a type of Muda to avoid. During the mapping of the current state was highlighted a significant presence of pieces rejects for porosity. Porosity can be generated by gas that remains trapped during injection phase or due to the material shrinkage during the cooling phase. The team analyzed the causes for which this kind of problem was occurred in production, and listed a series of possible improvements activities.

Goal

50 % reduction of porosity scraps.

Proposal

The team created a check list of improvements for the injection phase. Starting with a better alloy control the following improvements were:

- Add chill block valves with current vacuum equipment
- In gate modification
- Shot sleeve length modification
- Piston modification
- Implementation of a die casting system using a vacuum system.

Implementation

By means of the first improvements this type of defect in the initial state was present in an amount of 19%, the current state is present instead of an 8%. If in the following months the scraps for porosity will increase, the company has to invest in the Vacuum system as previously explained.

5.5 *Kaizen* event 5

Root cause identification

From VSM and PBM analysis, appeared phases that didn’t lead any value added such as operators spin freely to reach materials and facility, or understand who contact in case of difficulty or presence of non-compliance. The operator was forced to leave his workplace to go to the responsible and asking for clarification. In this way the production was stopped.

Goal

Increase the order and cleanliness for each station of the process according with the “5S” methods. Standardize the corrective action and procedures in case of problems.

Process description

Visual Check.

Implementation
Creation of procedure. The same procedure was created for each phases of the process. In this way every operator has to check his workplace before start and leave it in proper conditions for the following operator. Furthermore they know in advance who contact in case of problems. Thus, concluding, these procedures avoid unnecessary movements.

5.6 *Kaizen* event 6

Root cause identification
Presence of mark/damage on machined surface. The team utilized the "5 whys" to identify the root cause of the mark.

Goal
Reduce to zero defects.

Process description
The "5 whys" analysis revealed that the root cause of why machining phase was producing defects was because there was a chip on the parts.

Implementation
First of all, operator's training is necessary in relation to the cleaning before positioning of parts on the fixture. In additions it is necessary the installation of a new lighting system above the machines to improve the light

6 CONCLUSIONS

Analyzing the future state map it is clear, compared with the current one, the achievement of the main goals we had set at the beginning of the project thanks to Kaizen workshops. Bringing the sandblasting inside means reducing the inventory of 7 days after the heat treatments phase. Considering the cycle time of this machine a buffer of 2 day was created. In fact the table of the Lead time brings the total lead time from 38 days to 27 days, decreasing of 11 day, equal to 29 % less.

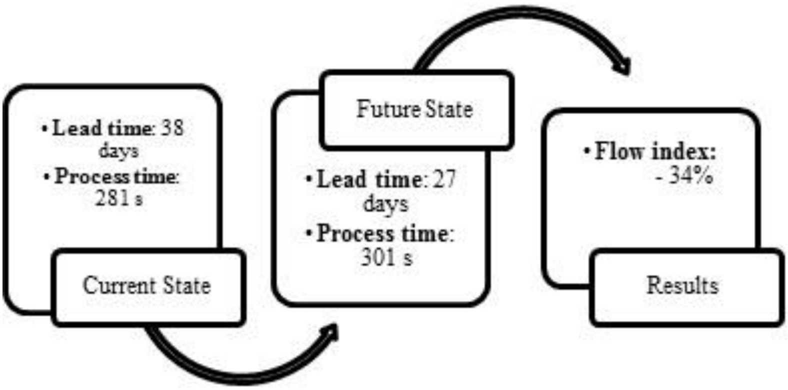


Figure 3: Results.

Also the process time was affected, with a 7% of increase, switch to 301 s instead of the initial 281 s because it is considered the sandblasting.

The company reduced their lead time while at the same time improve the quality of their products after lean implementation. Regarding scraps it is decreased. Starting from a 7% of scraps in visual check now it arrives up to 5%, from 7% in die casting to 4% from 5% during X-Ray inspection to 2%, with the aim to reduce them further in the following months. Regarding dimensional scraps it fell in machining stage from 1% to 0,5 %.

In addition, quality problems become more easily traceable since a catalog was created; communications was greatly simplified when a procedure was created. At this time the operators only need to inform the tester when a problem occurs, rather than having all other operators to be told, shift supervisor and department supervisor.

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OPTIMIZATION PROCESS OF A WEB-RELATED KEY PERFORMANCE INDICATOR IN AN INSURANCE COMPANY

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Abstract

If twenty years ago a managing marketing director had suggested to his company to aim towards greater visibility on the Internet's search engines, at the expense of TV or radio campaigns, he would have probably been taken for mad.

Nowadays, on the contrary, this has become, at the same time, a common practice for any company with a developing business on the online market, and a limitation for those corporations which do not aspire doing so and which do not essentially care.

The goal of this article will consist exactly in focusing on the impact that the greatest worldwide search engine, "Google", in 2014 is able to have on a company which bases most of its business on the World Wide Web, such as "Genertel".

Furthermore, the ultimate aim will be proposing the analysis and the refinement of a key performance index regarding the relationship between Genertel and the search engine, in order to monitor its behavior and quantify its effects. The intention is obtaining an overview of this perspective, based on a pragmatic methodology and approach in the management of huge amounts of data, giving them a precise meaning and extracting useful trends, which may also be supportive in company's business choices.

The issue regarding big data and their analysis results to be more and more important for every modern company, being immersed dealing with a double face theme. On one side the chance to obtain enormous quantities of information and figures about each kind of flow, from money to customers, from working times to those regarding ERP systems and logistics, allows to reach a level of consciousness and knowledge about them never seen before. On the other side, however, such a huge amount of data must be treated with an equally great care, attention and cleverness, so as to avoid a wrong interpretation that can be potentially also counter-productive and misleading.

A good process to delete the risk of a bad management of big data can't be created without the presence of the following two elements, that represents the starting point that are absolutely necessary in whatever best practice of this field. The primary element of great importance consists of the tools that are used in data acquisition, saving, monitoring and extracting. Any valuable analysis is able to obtain useful and decisive results thanks to reliable tools for data management that allow him to be confident about the credibility of

the information he deals with. Moreover, a second key aspect is represented by the methodologies that are used for the management of data in order to outline final trends, indexes or consideration; each calculation method, being judged in a positive way, must demonstrate its specific, engineered and reasonable milestones basis.
Two of the most important subjects that will be treated by this article will be exactly those of tools and methodologies used to analyze the impact above described, and they will be also the key elements on which the final evaluation of the work could be done.
The covered themes are certainly topical, and they are related to an industry, the Internet one, which is characterized by an incredible dynamism in a continuous evolution; furthermore, it is a field that, as already said, was born and developed only in recent times. The natural consequence of this scenario results to be an almost complete lack of traditional scripts on the matter and a low reference bibliography that, even when existing, appears to be in most cases not sufficiently updated or characterized by content of little value.
A huge repository of information on these issues, on the contrary, it is precisely the same Internet; through the new digital channels such as websites, blogs, articles and many other tools typical of the online market, nowadays it is possible to find a huge amount of information on these topics. The problem, however, is related to the quality of all these contents: today anyone can appear as a writer or a journalist with a few clicks, without any filter or censorship on the content of his material: after all this is one of the many example of positive but also negative aspects related to the new age of web-based communication.
It’s also true that, with the experience of those who work every day on this sector, it is possible to recognize the sources of value than those of low quality, thus being able to create a set of reliable sources to take as reference to stay updated and obtain interesting information.
This work aims to adopt exactly this kind of approach, which leads to the composition of a bibliography which, although almost entirely made up of material available on the web, is completely based on great and worth content within the considered business.

Keywords:
Search Engine, Big Data, Share of Search, KPI

1 GOOGLE’S IMPORTANCE IN THE BUSINESS OF GENERTEL

The main theme of this article is developed on Google’s search engine and more in particular on the analysis of the impact it has on a company that aims to develop the majority of its business on the online channel. This article will focus particularly on the case of the company Genertel SpA, but it’s important to take into consideration that the majority of the themes and the models developed in the following pages are completely applicable to each reality that activates a web channel and which wants to systematize some analysis methods or study some important aspects on the theme of search engines and their potential.

Genertel SpA is a company of direct insurance of Assicurazioni Generali SpA, and is that section of the group founded in 1994 in Trieste to enter the insurance telephonic market, and progressively, also in the online one, overcoming the traditional figure of the mediator between the company and the final customer.

Genertel has always pointed towards the telephonic path, identifying itself as the first company to create only one call center able to manage all the clients of the company which from always represents one of the principal core competences of the society. Despite this, with the passing years the web channel has gained always more importance, and from today represents a firm key point in the company: this, in fact, not only represents the window of the products of the company and the channel for making a quote and monitoring of the contracts by the customers, but even more developed is also the channel for full self-service through which the users can bypass the contact-center and complete autonomously all the phases of quoting, stipulation, management and renewal of their insurances.

When people talk about direct insurance companies they are referring, like stated before, to all of those companies which allow bypassing the level which interposes between the final customer and the insurance provider, represented by the traditional figure of the mediator, or insurance agent.

In the first years in history in this type of companies the telephonic channel was the one which represented the great key point and innovation, that is the cause for which they were often identified as "telephonic insurances"; up to the current days, despite the telephonic component is always present and maintains an absolutely important and necessary position, it’s exactly the web channel that has been strongly developed and innovated.

Today, the starting point in each direct company is precisely the websites, through which the users are able to bring to an end all possible activity: from the quotation to the signature on the contract, from the managing of the insurances to the possible complaints, from the view of the marketing campaigns to the evaluation of the insurance products offered. This is the reason for which, with the passing of the years, more than "telephonic insurances" the market is leading towards the definition of direct companies as "online insurances".

Treating the theme of the online market and the development of the “Internet Era”, it’s impossible not to face with the growing reality of search engines. Since the beginning of 90s some scientists have bet on the creation of those evolved forms of directories, supported by an intelligent algorithm; they were able to give back to the users’ questions, defined queries, a series of results that were ranked according to a certain logic, importance or priority. It was the birth of the first search engines, then developed year by year so becoming always more powerful, smart and precise, and identified by a

continuous growth that have transformed them in a solid and fundamental reality within the Internet market. The search engine became the natural mean used by users for reaching the final websites during the browsing, both when they are searching for a specific brand and site and when the intention of navigation is more generic and not specific.
In a scenario of such importance and solidity, it was born in Mountain View (California) a company that today represents the undiscussed leader of the search engines market: Google. The market share it reaches at a global level stays around the 70%, even if in some countries this share rises also to a higher level. It is the case of Italy, where Google covers about the 95% of the total search engine market, and also the background where the business of Genertel takes place.
Now it's the time to combine the two themes related to the extraordinary growth of the search engines and to the digitalization era of the insurance market, remembering also what can be defined as the monopoly of Google within the Italian online search market. It's not difficult to image the results of such a situation that brings to the fast rising importance that the company of Mountain View (Google) can represent today in the business of the direct insurances, included Genertel.
In order to quantify the term "importance" on the impact between direct insurance companies and search engines, it is possible to use a tool offered by Google that allows to know the average number of researches in the search engine: Google AdWords.
Taking into account the 20 queries related to the direct insurance market with the highest monthly search volume, their sum results to be greater than 400k. These are really scary numbers, which if added to the search volumes of the infinity of other less frequently used queries, lead to monthly volumes that are close to a million searches, excluding those related to the brands of various insurance companies. Focusing on the contrary on the part related to the brand, also in this case the figures are impressive: taking as an example the case of Genertel, the only KW (keyword) "Genertel" has raised about 200k monthly average researches in the last year.
In the same direction of the just discussed theme, another important data must be found in the trend of visits that the company Genertel received from the users coming from sources linked to Google (Figure 1).
Thanks to the trend line reported here it's not difficult to notice how the volumes of the visits in Genertel's website deriving from Google have clearly grown in the past five years, with the total that has even tripled from 2009 to 2014, reaching peaks also superior to 500k monthly visits: these numbers are very interesting, in particular if one thinks that they only come from the Google search engine.
Focusing on the visits linked to Google, it's necessary to do certain segmentations in order to have a complete and more detailed view of the internal phenomena of the same search engine. The users that access a site through a search engine must be divided in two distinct categories that are

for definition very different from each other and reflect different behaviors, as it will be seen in the continuation of the article.

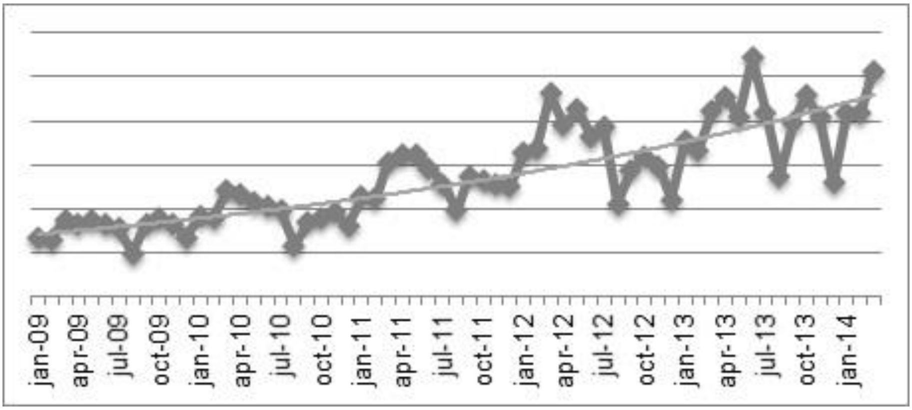

Figure 1: Visits to the website "*www.genertel.it*" from Google sources.

Google's Organic Visits: with "organic" one intends all that is not by payment; in this case, it is referred, therefore, to the clicks deriving from the search results not sponsored, so related to the queries of the users that Google classifies in a natural way according to its powerful search algorithm.
Google's PPC Visits: this second item includes, instead, all those visits originated by the clicks relative to the sponsored results, the ones that get therefore defined as PPC (pay-per-click). SERP (search engine result page), which present a CPC (cost-per-click), whose share varies according to different factors, and in first place the competition for each specific keyword, creating like this an auction to determine the positioning inside the paid part.

2 HOW TO MEASURE PERFORMANCES?

The traffic generated by the search engine to a certain website is not constant over time, but rather it is a matter highly variable and influenced by many factors including:

- Searches volume;
- Searches seasonal trend;
- Seasonal trend of companies' products;
- Amount of investment on AdWords campaigns;
- Organic positioning on SERPs;
- Type and quality of the users;
- Internal changes of the search engine or of the target website;

- Changing of the search habits and behavior on website.

All of these variables make quite complex and elaborate the quantification and assessment of traffic flows that are created between the two parties.
The aim of the next sections of the article will propose improvements, and in some cases even the creation, of models for measuring an important Key Performance Indicator (KPI) that reflects the impact of Google on a company that bases part of its own business on the search engine.
In particular the aim would be to give the idea of a good procedure and approach for the management of big amounts of data using specific tools and methodologies that allow to a company to monitor important indicators of its own business trends and performances. In this sense a key factor bases itself on the measurement of the proposed KPI's quality and behavior, so being able to evaluate them knowing how affordable they are in the management of a such high amount and importance data.

3 THE SHARE OF SEARCH INDEX

The key performance indicator that will be analyzed and taken as an example in this article is the Share of Search (SOS) one.
This index expresses, for a given reference period, the ratio between the visits to a website by a search engine, more specifically from a given set of queries, and the total number of researches of those same queries, without they necessarily brought to a visit to the analyzed website.

$$\text{Share of Search (SOS)} = \frac{\text{Visits}}{\text{Researches}} = \frac{\text{Organic visits + PPC visits}}{\text{Researches}} \qquad (1)$$

The SOS thus indicates the proportion of a target search market that a company has been able to carry on its website; it is therefore an index of performance that is very important for several reasons:

- Allows to compare the traffic volumes resulting from Google with those that are the trends of global market research, giving the ability to evaluate more objectively the performance of a company in comparison with the external market;
- Allows to compare the performance of different KW/set of KW, even when they are very different in traffic volumes;
- Being the index a percentage between two values that are subjected to the same seasonality and interest, it turns out to be an indicator free from seasonality that allows an objective and continuous evaluation of performances independently from typical fluctuations in traffic.

It's important to note, as underlined with the formula reported above, that the Share of Search index is essentially composed by three main fields values for the calculation of the final KPI:
1. Organic visits;
2. PPC visits;
3. Researches volume.

Moreover, another important aspect about the index is that Genertel pretends, about once or twice per month, to calculate the value of SOS for each line of business (LOB) of the company, so distinguishing its performance on keywords and queries related to the car sector, from those linked to the motorcycle one, from the home insurance ones, the branded ones, and so on.

3.1 Procedures

The index of Share of Search has historically been calculated within Genertel using a specific procedure, based on the analysis, one after the other, of the three main fields before listed. The process for getting the final SOS index was developed in a totally manual way that was also the cause for its slowness and frequent lack of accuracy of the final results and on the overall data management.

Another key aspect, dealing with the original method used for the SOS calculation, is related to the habit of starting from scratch for each new data elaboration session, without a solid and repetitive structure for data management that could allow to make the whole process faster and more reliable.

The method proposed in this paper wants to revolutionize the methodology used for the obtainment of the Share of Search Index, essentially basing its innovative approach on the individuation of two different and well distinguished phases:
1. Setting phase: it is dedicated to the creation of a model with which the main steps and procedures are pre-set and, where possible and convenient, also made automatic. Thanks to the introduction of this phase it is easier to create a model that is totally checked and reviewed in all its steps, developed with the aim of avoiding all the negative elements and bugs put in evidence by the original method. This phase needs for a certain amount of time for its generation, but this effort must be allocated just once, and can be maintained unchanged during each following calculation session of the KPI.
2. Calculation phase: it focuses on the real calculation of the final SOS index, using all the available and necessary tools for the data extraction and their processing. It must be referred to the analysis of the considered time interval and its related data, so bringing different results and figures each time it has completed. Differently from the setting phase, this one must be processed all the times the company wants to obtain the value of the index.

As just underlined, there is a shift from the unique phase typical of the original method, to a two-phase approach within the proposed alternative method.
The main goals of such a change consist of the improvement of many aspects along the overall procedure, and that can be resumed in the goal of creating a faster, more reliable and semi-automatic process for the SOS calculation, together with the reduction of some limitations founded in the original method.

3.2 Tools

The decision to divide the overall process in two different phases represents a positive intervention for the achievement of some targets, in particular those that are time-related, but for sure it is not enough for the realization of all these ambitious goals. Another aspect of great importance is linked to the theme of the tools used for extracting the data, in particular regarding the Google search volumes, whose precision is fundamental for the affordability of the final SOS index. The sources for the extraction of search volumes are two, with specific characteristic, pros and cons; both are tools that Google offers to its users for the analysis and the command of some trends of researches, advertising campaigns and other important indicators.
Google Trends represents the first option for conducting analyzes regarding user’s researches on the search engine, and it’s also the tool traditionally used within Genertel for the calculation of the Share of Search. This tools was created specifically for this kind of operations, such as the analysis of specific keywords research trend or the individuation of particular KW niches that are characterized by evident improvements or decrease of interest by search engine users. It must be said that Google Trends is also characterized by some important limitations that can represent an obstacle in the achievement of a complete and satisfactory research analysis, and in particular two are the obstacles. On the one hand there is a very low number of queries that can be inserted at the same time, of just 5 different ones; on the other, the given search volumes are expressed in percentage and not with exact figures, so giving just an idea of the whole trend without focusing on real data.
These two aspect represented a significant problem in the original method for the calculation of SOS: in fact, to obtain the final overall search volume of each line of business, and considering the time effort employed, Genertel operators had to choose just the most 5 significant queries for each category, and then weighting the percentage trend figures with real data given by another Google tool, AdWords.
The proposed method for the calculation of SOS index suggests a change also within this step, focusing on an alternative tool, and in particular the second tool given by Google for these kind of analysis previously cited: Google AdWords. This tool was born for the monitoring and control of another field related to the search engine, and more precisely on advertising campaign and paid traffic, those that are linked with PPC visits. In addition to

many adv-related functionalities, AdWords provides a tool related exactly to research volumes, called “Keyword Planner”: even if it was created for analysis looking for adv opportunities, it represents a valid alternative to Trends for obtaining information and data on search volumes. Moreover, both the limitations presented by its competitor Trends are in this case solved, because of the much higher limit of insert-able queries (up to 800 at a time) and the exact figures resulted. The choice in the original method not to use the “Keyword Planner” was based on the impossibility to select a time interval superior to 12 months, so making difficult the analysis of a long-term trend of researches. Recently this constraint has been bypassed, extending to a 3-year interval the maximum time interval that can be selected. This way, instead of using it just for the weighing of percentage data like in the original method, the proposed one bases the overall process for search volume data extraction on Google AdWords, making the process much faster and coherent (use of a unique tool).
Later in the article it will be underlined also the comparison between the forecast error that resulted in some experiments using the two different methods and tools.

3.3 Data processing

The last important field of intervention between the original and proposed methods for the calculation of the SOS index regards some aspects along the data processing flow that characterizes the final obtainment of the indicator. In particular, one of the most difficult parts along the process consists on the subdivision of the keywords that have brought at least one visit (indifferently if organic or PPC ones), in the different “categories” of analysis, corresponding to the lines of business of the company itself. Starting form a unique list of queries for the analyzed month, is then important to separate the brand ones to the car-related ones, to the motorcycle ones and so on. This phase presents a double importance: in fact, besides the correct calculation of the SOS for each LOB, this step represents also the starting point for the achievement of search volumes, obtaining those filtered queries for each category that must be after inserted in Google AdWords (or Trends) as explained before.
The original method provided to make this filtering phase directly from scratch for each calculation session, and in particular doing it in a totally manual way, so setting instant filters on Google Analytics (PPC queries) or on Excel (Organic ones) for dividing and assigning them to the correct LOB of membership.
With the proposed method, both the filtering of PPC and Organic queries are brought off-page to an Excel (or Access) spreadsheet. The main news is that, thanks to the setting phase previously treated, all the filters are pre-studied, optimized and set, shifting from a “each-time” approach to a more effective “just once” one, thanks to which it is possible to re-use, eventually making just minor edits in the direction of a continuous improvement, the same filters initially created for each calculation session of the SOS.

This change permits, once again, to make the process really faster, but also to have a continuity and constant reference in this phase of data processing, achieving more precise and coherent results. The process becomes in this way semi-automatic, because all the manual steps of filtering are avoided, leaving manual just the easy duty of downloading such data from the right Google tools (Analytics and Webmaster Tools), bringing them to the automated work spreadsheets.
Another important key aspect in the direction of an optimization and improvement approach consists on the creation, with the proposed model for the SOS calculation, of a final resume dashboard in which all the final data about the indicator are reported, together with other important “control indexes” that give important information about this indicator and its trends. In this way it can be much easier to communicate the results to the management who must use those data for decision supporting and high-level analysis. When high data volumes are treated, one of the most important aspect, in fact, is exactly that of being able to transmit their meaning and importance to those who guide the company: such data and information, so difficult to be treated and analyzed, can be so made equally useful and significant as they deserve to be.

3.4 Evaluation

In the previous sections the main aspects of difference between the two different methodologies used for the calculation of the Share of Search indicator have been underlined, focusing on pros and cons of each model and on peculiarities and approaches that characterize them. It’s clear that for being able to choose the best model, and for judging the general goodness of the models it’s necessary to structure an evaluation method.
In this case the evaluation develops around two main subjects: time and reliability.
Regarding the time aspect, it will be measured the time for data extraction, processing, elaboration and calculation of the final index, comparing the results of the two different methods. The measurements (a couple of proofs for each model) have been done referring to an operator without specific knowledge of the SOS index nor of the construction of the calculation models. The results have been those of Table 1.
It is evident how strong is the difference between the two methods, with a reduction of 80 minutes (-76.2%) of the time effort using the proposed method and its model; the result is for sure positive, and permits to be really satisfied about it.

Table 1: Time-related evaluation results.

	Average time (minutes)			
	Original meth	Proposed meth	Delta	Delta %
Organic click	25	7	-18	-72.00%
Search volumes	50	14	-36	-72.00%
PPC clicks	30	4	-26	-86.70%
Total	105	25	-80	-76.20%

To be correct, it's important to say that such reduction can be possible thanks to the different approach of the two models, and in particular thanks to the setting phase of the proposed one that permits to the calculation phase to save a lot of time.
The setting time, however, is not for free, and it's always time to employ for making possible the final optimization: therefore, it has been calculated also the time for preparing and setting the proposed model, with the same logic of the previous measurements and following a specific steps' guide for creating it. Thanks to the result of the setting effort (240 minutes), it is then possible also to calculate the Break Even Point (BEP) of such time investment.

$$\frac{\text{240 min (setting time)}}{\text{80 min (saved time)}} = \text{3 Sessions (Time Effort BEP)} \quad (2)$$

Table 2: Data accuracy-related evaluation results.

Modification	Original method	Proposed method
Webmaster Tools Gap	Organic clicks = -19.0% vs. correct data	
Exact search volume	Monthly researches = Δ 8.08% vs. correct volumes	
Introduction of the new model for seasonal trend calculation		Reduction of the average error of estimates = -57.31%
Introduction of two new segments		Reduction of "Generiche" organic queries = -35.3%
Deletion "(content targeting)"		Reduction of PPC queries = -9.6%

The second aspect of evaluation focuses on data accuracy, trying to quantify the main intervention brought by the proposed method in comparison to the original one. The final results are reported in Table 2.
Even in this case, the results of the evaluation seems to be really positive for the proposed method, that is able to reduce a lot of limitation of the old model achieving a relevant advantage in the reliability of the final SOS index.

4 CONCLUSION

The case of the indicator of Share of Search in the company Genertel is very representative not just for its specific performances and characteristics, but in particular because it presents an optimum example of a good procedure and methodology. The message this article intends to transmit is that related to the great importance of creating a pragmatic, engineered and well-structured approach for managing all the web-related KPI's and in general the theme of data analysis, especially when big data are treated.
As it has been seen in the case of the SOS, within the apparently simple theme of the indicator, they are included macro-areas such as methodologies, tools, procedures and evaluation methods; a good process for manage each of them can't rescind from the research of the optimization of each phase like also of the overall process.

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DEVELOPMENT AND APPLICATION OF GREEN MANAGEMENT IN A PUBLIC AUTHORITY

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Abstract
The objective of this work is to present the criteria of "Green Management" applicable to service companies and public authorities, in order to help them take the path of sustainability, highlighting the new types of waste on which they should focus in order to be considered by the whole community, "green activities".
This article presents the criteria applicable to each green waste applying to a case study in a Municipality of Veneto.

Keywords:
Green management, Sustainability, Public Authority

1 CRITERIA OF GREEN MANAGEMENT

To achieve sustainability, the tool of greater importance to create a useful model is the Green Value Stream Mapping, which has the goal of eliminating the seven green wastes (energy, water, materials, garbage, transports, emissions and biodiversity) and is accomplished through [1]:

- The broad definition of the study area.
- The preparation of a work team.
- The segmentation and clustering of the output's characteristics.
- The identification of the impact associated with the activities concerned.
- The collection of critical information.
- The representation of the current state.
- The proposal of improvement opportunities, both for physical activities of transformation and administrative ones, systematically eliminating the negative impacts.
- The representation of the future state.
- The preparation of the implementation plan.
- The review and update.

The criteria for each of the green wastes are [2] [3]:

a) Energy
From the perspective of environmental waste it refers to the consumption of electricity and gaseous and liquid fuels used to power the different present utilities (facilities, machines, etc.), and which is one of the factors that contribute to the negative impact on the environment. Therefore, the objective will be to use only clean energy, but also provide to self-produce it. The steps for the elimination of energy waste are:

- Identify the use and the sources of energy in every activity of Value Stream Map.
- Measure or capture the data consumption of the energy used in each activity.
- Minimize the use of energy for each activity.
- Offset the remaining energy use.
- Transition to the use of renewable self-produced energy.
- Identification of cost savings and/or environmental ones achieved with the adoption of the proposed solutions bringing them back in the Green Value Stream Map.

b) Water
The waste of water lies not only in its use, but also in the fact that companies are paying ever increasing costs to use it and to offload the contaminated or non-reusable water resulting from the activities. The ultimate goal, that should be achieved, is to minimize and eliminate the costs of the provision of water and those arising from the collection to purify it, trying to aim, if possible, to take advantage of direct rainwater harvesting and the reuse of water multiple times. This aim cannot be achieved immediately, but it is possible to get there by:

- Identifying the activities in which the water is used.
- Measuring or detecting the amount of the consumed water.
- Measuring the toxicity of the wasted water.
- Minimizing the amount of the used water.
- Minimizing the toxicity of the wasted water.
- Self-implementing rainwater harvesting.
- Aiming at the continuous water reuse.

c) Materials
Eliminating the waste of materials within the activity reduces and eliminates the need to use new raw materials to realize the services and reduces the negative impact on both the environment and the economic aspect. The goal is to get all the outputs back into circulation in the activities to create other services or put them back in nature as nutrients and create a continuous cycle, obtained by:

- Identifying the inputs and outputs of materials for each activity.

- Measuring the amount of the recyclable and compostable materials.
- Classifying each input and output as a biological nutrient, technical nutrient or otherwise.
- Evaluating materials according to their impact on the environment and society.
- Phasing out materials with a negative impact on the environment.
- Minimizing the used materials.
- Moving toward the use of 100% recyclable, reusable or compostable materials.

d) Garbage

People thinks of this waste when it has already been created. An enterprise must therefore try to reuse the wastes created in the activity. The goal is to use all the waste products such as biological or technical or energy nutrients or completely eliminate them. In this way a company would be able to avoid depositing them all in landfills and thereby protect the environment.
This can be achieved by:

- Identifying the creation of waste in the various activities.
- Analyzing the composition of such waste.
- Measuring the amount of harmful substances.
- Minimizing the creation of waste.
- Moving towards the creation of a 100% reusable or biodegradable waste, and the total elimination of waste.

e) Transports

The transport of people and material is one of the major negative impacts on the environment. It is more complicated to see the economic benefits produced by the elimination of wastes in transports, but there are both incentives that can be used for vehicles that are environmental-friendly and having benefits due to lower costs for route optimization. The goal will be to eliminate the negative environmental impact caused by transports which can be achieved by:

- Identifying activities that require transportation.
- Identifying the mode of travel and the distances traveled.
- Minimizing the traveled distance.
- Moving towards the use of completely ecological means of transport.

f) Emissions

To find this type of issue it will be necessary to look for the direct sources. The emissions contribute to air pollution and their reduction will give a positive contribution to environmental protection. The goal is to eliminate completely the harmful emissions, and it can be achieved by:

- Identifying the sources of emissions.
- Measuring the type and amount of such emissions.
- Minimizing emissions using devices that prevent pollution.

- Moving towards the total elimination of harmful emissions.

g) Biodiversity
Biodiversity (variety of living beings that inhabit the planet) comes from the fact that businesses pays a certain price when they takes away a part of the biodiversity of a particular area and when creates serious and immediate environmental impacts. The fact of trying to minimize previously analyzed wastes contributes to help reducing the damages to biodiversity. The objective is to eliminate the destruction of biodiversity and to promote the regeneration of what has already been taken from it, which can be achieved by:

- Identifying the existence of damages to biodiversity.
- By measuring the amount of damages.
- Minimizing the loss of the biodiversity.
- Moving towards the regeneration of the biodiversity.

2 CASE STUDY

Considering the guidelines given by the model presented above, it was possible to analyze the buildings under the control of the Municipality of Meduna di Livenza by applying the criteria of Green Management in order to verify the presence of the seven green wastes, even if not all the types of wastes and analysis could be taken into consideration, due to the particular reality that was examined.

2.1 Energy
Regarding the electric energy, all the data considered were taken from the bills that the Municipality receives every month from the energy distributor.
Thanks to this analysis as it was possible to detect the presence of some issues, like the anomalous consumption of reactive energy in some facilities, fact that caused the payment of surcharges added to the monthly bill.
The principal issues were found in the gym, that presented in 2013 a consumption of reactive energy above the limits nearly every month (except in October), with values that vary according to the monthly consumption of electric energy as shown in Table 1.
The amount was higher in autumn/winter (the maximum consumption was detected in December and in January) than in summer. This is due to the fact that in summer most of the activities those were done in the gym are suspended, then the amount of energy consumed decrease and with it also the reactive energy consumption.
Anyway, the amount of surcharges paid (48,10 € in 2013, Table 1) was not sufficient to justify power factor correction actions, like the installation of batteries of capacitors to remove this problem, because the payback times would have been too long, making this actions impractical and uneconomic.

The actions suggested for these situations are: the continuous control of the amount of reactive energy consumed per month, the detection of the source/sources of the reactive energy consumption and the analysis and evaluation of possible interventions in order to reduce or remove this problem.

Table 2: Data from the bills of Enel Energia.

Gym 2013			
	Cos φ (-)	**Surcharges (€)**	**Reactive energy (kVARh)**
January	0.805	14.79	458
February	0.835	5.78	179
March	0.893	0.13	4
April	0.836	2.45	76
May	0.821	2.75	85
June	0.786	0.81	24
July	0.822	0.10	3
August	0.832	0.10	3
September	0.859	1.26	39
October	0.896	0.00	0
November	0.862	3.33	103
December	0.786	16.60	499
Total	-	48.10	1473

Regarding the minimization, the only suggestion is to inform people about a rational use of energy, because the consumption is related to the amount necessary to run the different activities that are already trying to avoid every waste.

The energy consumed is offset by the presence of 3 photovoltaic systems mounted in 2011 with a power installed of 86 kWp that partially covers the energy consumption. Moreover the Municipality is trying to achieve the goal of offsetting the 20% of the energy consumed by self-producing it using renewable sources as prescribed by the European Union in the 20 20 20 strategy.

As regards the thermal energy consumption related to fuels, the heating system is implemented with methane, but the management of this facility was outsourced to an external company that administrates also the maintenance of the system; for this reason there are no data available about fuel consumption.

2.2 Water

For what concern water, the consumption is related to the utilization of sinks, toilets and fire systems for every building taken into consideration and for the fountains present in the area. An analysis according to the data reported in bills has been performed and the results does not present any issue that need to be taken into consideration.

Every leak is reported to the responsible employee who immediately calls the plumber to promptly solve the issue, avoiding the presence of wastes. Then, also for this green waste, the only suggestion is to inform people about a rational use of water, a resource that must be managed correctly, because, according to scientific studies and previsions, it will be interested by a worldwide crisis in a near future this is why it is already called “the blue gold”.

2.3 Materials

Concerning materials, the reality presents only goods necessary for office management, this include paper for printers and copiers and stationery. The procurement of office supplies is managed according to requirements. Furthermore the paper used in the Municipality is 100% recycled paper, this practice was introduced six/seven years ago, this stress again the attention that is given to environmental respect.

2.4 Garbage

As regards garbage, in this reality there is a boosted waste collection, every family has its own bins for wastes and the collection is administrated door-to-door, allowing a value of 75.1% in 2013 (data from ARPAV [4]) for the differentiated waste collection, much higher than national average 42,3 % in 2013 [5].

In fact, Meduna di Livenza receives every year since 2010 a recognition for being a high recycling Municipality and it is in position 147 over 929 in the ranking for town in north Italy with less than 10.000 inhabitants having an index of 70, 13, the 81.6% of differentiated waste collection and a total pro capital production of municipal waste of 0.57 [6].

In Table 2 is presented the position in the raking of Meduna di Livenza from 2010 to 2014 with the respective parameters included in the analysis.

Every family has a bin for organic waste, a bin for dry waste, a bin for glass, a plastic bag for plastics and aluminum and a recycled paper bag for paper and cardboard; all the bins can contain 120 dm^3 of waste, except for the bin for organic waste that allow a collection of 21 dm^3 of materials, the plastic bag can contain 100 dm^3, while the recycled paper bag can contain 25 dm^3 (data from Savno).

Non-domestic users, instead, can choose between bins with a capacity of 120/240/1100 dm^3, according to their needs (data from Savno).

In 2013 the amount of garbage produced was 6 926 468 kN subdivided in:

- 1 727 541 kN of organic waste.

- 965 990.8 kN of dry waste.
- 865 143.2 kN of paper.
- 253 882.8 kN of cardboard.
- 117 916.2 kN of plastics.
- 740 556.9 kN of glass/aluminum.
- 965 107.8 kN of glass.
- 1 290 329 kN of other types of wastes.

Table 2: [7]

Year	Category	Position	Inhabitants	Index	% RD	PC RU
2014	Absolute	98	2.926	72.20	80.92	0.67
	Municipalities under 10.000 inhabitant VENETO	45				
2013	Absolute	179	2.952	70.13	81.61	0.57
	Municipalities under 10.000 inhabitant VENETO	146				
2012	Absolute	313	2.972	64.09	72.71	0.69
	Municipalities under 10.000 inhabitant VENETO	246				
2011	Absolute	1143	2.968	52.71	66.00	0.59
	Municipalities under 10.000 inhabitant VENETO	827				
2010	Absolute	167	2.957	77.27	71.63	0.69
	Municipalities under 10.000 inhabitant VENETO	130				

Aiming to discourage the production of dry waste that is not recyclable every family has a certain number of collections of the dry waste bin included in the fee paid each year (the number is calculated according to the number of members of the family); each additional collection is paid over the annual fee.

Moreover, in every year some meetings were organized in primary and secondary school with the goal to educate and inform children about ecological life style and eco-behavior and also informative campaigns to update every citizen about the actions promoted by the Municipality to reduce the ecological footprint and to give advices regarding eco-friendly actions that can be applied to everyday life.
Furthermore, the Municipality encourages the use of reusable diapers, initiative that permits to reduce the amount of garbage produced by family with children, each family that presents the receipts that certify the purchase of reusable diapers receives from the Municipality a certain amount of money.

2.5 Transports

Regarding transports, the public transports that serve the town are managed by external service companies, no data is thus available. The Municipality, instead, administrate the transports of kids to kindergarten, primary and secondary school. This service is accomplished by the owned minibus and partially outsourced to a private renting company; this is due to the fact that the timetables of schools are different, making impossible to dispatch the service only by using the owned minibus.
A different analysis has been executed about transports related to waste collection, with the aim of identifying the best path to collect the garbage, allowing time and cost savings and the reduction of emissions related to transports.
The transportation of waste has a significant impact on urban transports. The aim here is not to consider the transport from the town to the treatment center, but to consider the collection within the urban area.
The collection of various wastes produced is carried out in specific days [8]:

- Twice a week for organic waste, every Tuesday and Friday.
- Every two weeks for dry waste, on Wednesday.
- Every two weeks for paper and cardboard, on Tuesday (alternate to plastic and aluminum collection).
- Every two weeks for plastics and aluminum, on Tuesday (alternate to paper and cardboard collection).
- Once per month for glass on the third Wednesday of every month.

There is no production of harmful or toxic substances and thus there is no generation of hazardous waste.
Knowing the urban area, it is important to determine the best path for the collection and transport of the various types of waste, which satisfies the condition of optimality of cost, time, length and service provided to users [9]. The first three conditions have to be imposed in the calculation code, while the last condition is difficult to express in numerical values.

The problem has been addressed through the simulation of the route itself. It requires a detailed analysis of all the components of the service and it is complex to implement and treat, but provides much information.
It allows to simulate the collection service for the various configurations without making any direct and practical experimentation.
The method used is the complete random one, which simulates the path by choosing the route randomly. The road urban network is outlined by a graph (Figure 1) [10]. The route is regarded as a set of nodes forming a connected set of branches. As shown in Figure 1 it has been decided to apply the model to a hamlet of Meduna di Livenza called Mure.
Set the starting node, the next node is chosen randomly, based on the adjacency matrix, thereby selecting one of the possible nodes reachable from the starting node connected to it with a branch (the first branch of the path). For the second and subsequent branches the same procedure will be used.

Figure 1

Set the starting node, the next node is chosen randomly, based on the adjacency matrix, thereby selecting one of the possible nodes reachable from the starting node connected to it with a branch (the first branch of the path). For the second and subsequent branches the same procedure will be used.
The program ends when it reaches one of the following conditions:

- The maximum allowable volume transportable by the vehicle has been exceeded.
- It has completed the removal of all wastes in the district.
- It has reached the maximum total number of branches forming the path exceeding a predetermined number.

A mathematical model was created to solve the problem, powered by data characterizing the streets present in the area (width, direction of travel, slope, and traffic level), the nodes that make up the intersections and the branches that make the road network and the containers assigned to the individual branches.
The road network of the portion of the town examined has been outlined according to the graph of Figure 2.

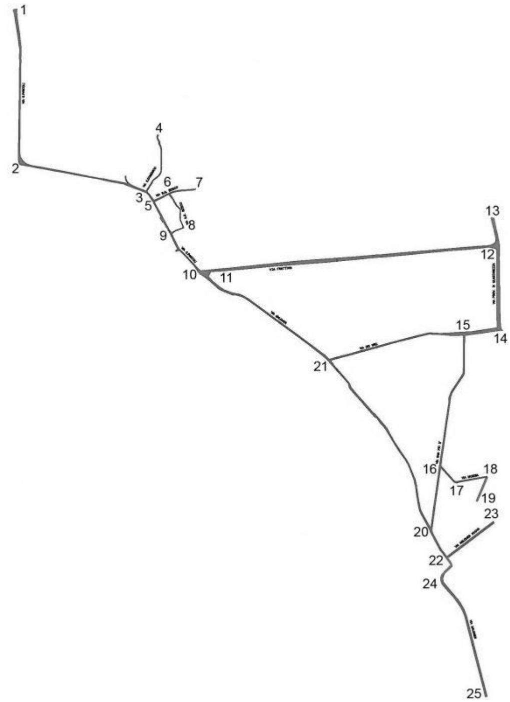

Figure 2

As the costs of collection are also variable depending on the type of waste in question (from a minimum of 110 €/t for glass up to 375 €/t for the plastic to which must be subtracted the contribution CONAI (National Packaging) of 229 €/t, data from [11] and updated with [12]), the times and lengths were determined for each of the twelve different paths obtainable by processing the problem (Table 3).
Therefore, the calculation processing has allowed to detect two optimal solutions between the different paths obtainable, which are those relating to the distance of the following branches:
1-2-3-3-4-9-8-7-6-6-5-9-10-22-23-20-17-18-19-19-18-17-16
and alternatively:
-15-14-13-13-12-11-22-21-16-20-24-25-25-26-27
-21-22-11-12-13-13-14-15-16-20-24-25-25-26-27
For the choice regarding which of the two paths will be implemented, the route must be examined and the verification about the correctness of the values of the average speed of the vehicle used for the collection, the time to perform there the inversion in dead-end streets, etc. should be performed.

Table 3

PATH	LENGTH (m)	ACTIVITY TIME (s)	OPTIMAL PATH
1	11.818,63	13.659	
2	12.906,81	13.659	
3	12.468,73	13.659	
4	13.622,28	14.013	
5	11.818,63	13.659	
6	11.818,63	13.659	
7	12.452,28	14.013	
8	11.818,63	13.659	
9	11.818,63	13.659	
10	11.818,63	13.659	
11	**11.778,63**	**13.659**	**X**
12	**11.778,63**	**13.659**	**X**

2.6 Emissions

For what concern the emissions, the only emitting facility is the heating system that is fed by methane, so the emissions are limited to this facility.
As explained above the management of this facility is outsourced to an external company, thus there are no data available.
Regarding the emissions of the vehicles used for transports it has been decided to start a test period to collect the data necessary to identify, analyze, minimize and possibly eliminate their emissions.

2.7 Biodiversity

Finally, regarding the biodiversity, any analysis was possible because the reality examined is a Municipality that does not discharge toxic substances that can threaten the flora and fauna present in the area; on the contrary, a big attention is dedicated to environmental respect and the conservation of the ecosystem.

3 CONCLUSIONS

The aim of this work was to propose the criteria of Green manufacturing that could be used both by service companies and by public authorities in order to identify the presence of the seven green wastes and to try to minimize, or better, to remove them, allowing to avoid environmental impacts and making the reality studied a "green activity". The criteria of Green Management has been successfully applied to a Municipality allowing to exemplify how to use these guidelines and what are the results of this analysis.
Obviously this work will be subjected to continuous improvements according to technological enhancements that will allow to further reduce the impact of every activity on the environment.

ACKNOWLEDGMENTS

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IDENTIFYING WOOD SPECIES FOR WOODEN PRODUCTS WITH MULTIVARIATE DATA ANALYSIS

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Abstract
In many cases only few wood species are used or even considered for any given wooden product, even though there are hundreds of wood species available. The objective of this project was the development of a time efficient and structured method to identify the most suitable wood species for wooden products based on a set of required material properties. This goal was achieved by applying multivariate-data-analysis. The method was based on a dataset consisting of commercially available wood species represented by many different properties. The scores and loadings of the Multivariate-Data-Analysis method Principal Component Analysis were used to identify the wood species with the most fitting property combinations for the product in question. Applying the method to an example case (electric guitar) resulted in several plausible alternatives to the commonly used wood species. It is possible to apply the method to any wooden product by determining the set of required properties.

Keywords:
material properties, product development, wood choice, wooden products

1 INTRODUCTION

Despite or maybe even due to its long history as a construction material wood is still very popular and probably becoming even more so in the future. Among others, one of the main reasons for this is the possibility to use the material in a sustainable way, unlike metal or various types of plastics.
However, in many cases wood is harvested and used irresponsibly. Relentless deforestation without subsequent reforestation is the standard in numerous countries around the world [1]. This is partially caused by the high demand for certain species with limited availability. An example is the guitar industry. Species like mahogany, rosewood or ebony were and are still widely used for guitar bodies, necks and fretboards, even though they are vulnerable or critically endangered. Even if endangered species are not used, the wood choice is often not justifiable from an objective point of view. In many cases only a few species are considered for application. Alder for example, is a very popular wood specie for electric guitar bodies. If people are asked why, some say because Leo Fender, who was the founder of

Fender Musical Instruments Cooperation, used it already decades ago. As a consequence, it must be good. Allegedly, he started using alder just because it was cheap and available [2]. Similar behaviour most likely prevails regarding many other wooden products. This is contrasted by the fact that hundreds of wood species from all around the world are commercially available, many of them not endangered in any way [3].
The question is: How to provide people with a method to identify the most suitable wood species for any wooden product in a quantifiable and comprehensive way that is also easy and fast to use. The objective of this research project was the development of a tool which is able to achieve this. The tool was based on the application of the multivariate data analysis (MVDA) method principal components analysis (PCA). In general PCA is utilized to extract and visualize useful information from large datasets, in particular those with many observations and variables [4].
Giving people the means to make profound material choices in an easy and quick way has the potential to enhance the quality and variety of wooden products while supporting responsible utilization of timber at the same time.

2 MATERIALS AND METHOD

The development of the wood identification tool was based on a large dataset, consisting of almost 200 commercially available wood species which were represented by various wood properties. Hence, the wood species were the observations and the wood properties were the variables of the dataset. Anatomical, chemical, economical, environmental, mechanical, and physical properties were included in the dataset. The data was collected from different sources, the Holzatlas, Wood Database, Inside Wood Database and the IAWA List of Hardwood Features [5-8].
PCA is a maximum variance projection method. The observations are seen as data points in a K-dimensional space where K is the number of variables. In other words, the variables represent the coordinates of the observations. As any space with more than three dimensions is practically impossible to visualize in a comprehensible way, the data points are projected onto lower dimensional lines, the so-called principal components (PCs). The PCs are calculated to comprise the maximum variance of the data. Two PCs form a plane. The PCs contain the data in a compressed form, thereby facilitating visualization and extraction of significant information. The first PC covers the highest amount of variation. Therefore it is the most important one. The other PCs are orthogonal to the previous ones. In many cases the vast majority of useful information is contained in the first two PCs.
The wood identification tool relied on the principles and capabilities of PCA. The so-called loadings and in particular the scores formed the base of the actual tool. The data contained in the scores and loadings was visualized by two-dimensional scatter plots. A score scatter plot is a plane consisting of two PCs which contain the projected data points. A loading plot is fairly

similar. It shows how the data points are projected on the PCs. They can be seen as a connecting link between the original data and the scores [9]. In the figures 1 and 2 a score and a loading plot is shown. Every point in the score plot resembles an observation, or wood specie in this case. Every point in the loading plot resembles a variable. Both plots were used in combination. For example, wood species which were located in the low left of the score plot had relatively high values regarding the variables located in the same area of the loading plot. Inversely, they had low values regarding the variables which were located on the opposite side of loading plot. Wood species which lay close to each other in the score plot exhibited similar property patterns.
The quality of PCA models was assessed by different validation algorithms [4]. The software package Umetrics Simca 13 was used to generate the PCA model. Many other programs like Matlab or SPSS also support PCA.

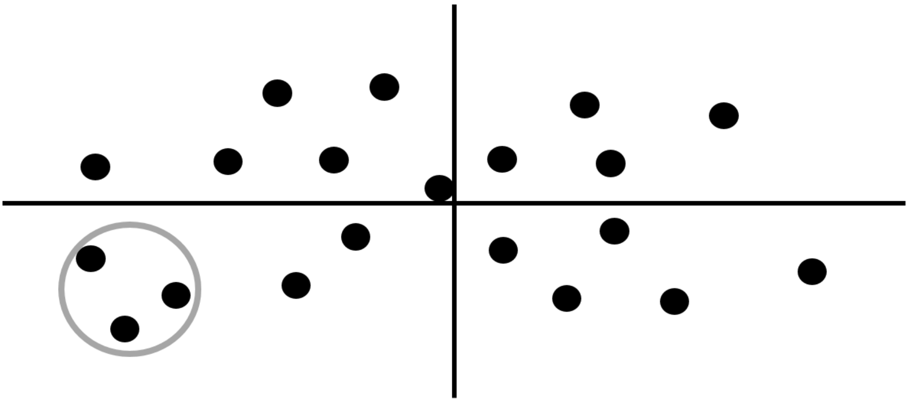

Figure 1: Score Plot Example.

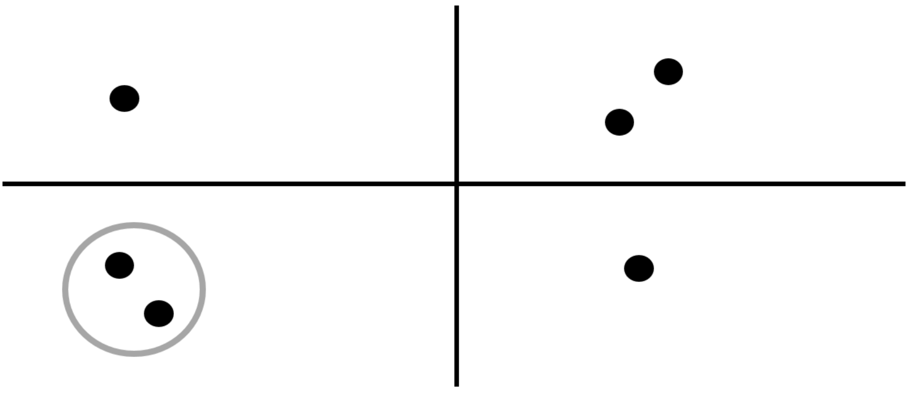

Figure 2: Loading Plot Example.

To actually extract important information from the dataset – in this case suitable wood species for wooden products – it was necessary to know the desired characteristic of this information. A set of material properties which are important for the product in question was needed. This can be done in various ways, for example by the product development team or through surveys. Many methods are explained in the literature, but it is not the topic of this research. If the desired wood properties are known, the score plot can be used as a map to quickly identify those species which fulfil the properties in the best way.
For this research the product electric guitar was used to exemplify the functionality and capability of the wood identification tool. An example for such a guitar is seen in figure 3. In this particular case the determination of the set of material properties was based on experience and the findings from a web-survey. The set of material properties is listed below and sorted after importance from top to bottom:

1. low movement;
2. low to medium density;
3. at least moderate hardness;
4. at least moderate modulus of elasticity parallel to the grain (MOE);

Figure 3: Electric Guitar [10].

3 RESULTS AND DISCUSSION

The PCA model which was generated based on the wood species dataset could be considered to be fairly strong due to the results from the validation algorithms.
Figure 4 shows an excerpt of the loading plot of the PCA model. It can be seen that the movement related variables (Movement R, Movement T,

Movement V) are in the bottom while density, hardness, as well as MOE are located on the far right. Because low movement was desired, it was necessary to look for wood species with an inverse correlation to the movement variables. From just looking at the loading plot for a few seconds it could be determined that suitable wood species most likely lie in the upper half of the score plot. Unfortunately there was a strong positive correlation between the density, hardness and MOE. For this reason, some sort of compromise was unavoidable. Eventually it was decided that a fairly low density is more important than a high hardness and MOE. Hence, potentially suitable wood species were located in the upper left quadrant of the score plot, however not too far away from the plot center. The area is displayed in the score plot in image 5. Wood species which are represented by dark dots are endangered and were not considered as a valid choice. All other species in the marked area were potentially suitable for the product in question. Examples are Limba, European Walnut, Hubaballi, or Camphor.
Picking out some of the wood species and verifying the choices with the actual dataset confirmed the capability of the tool. Limba, for example exhibited a rather low density of 550 kg/m³ and a volumetric shrinkage of less than 11%. Also hardness and MOE were acceptable. According to several instrument builders and guitar users, this specie could be considered an insider's tip. Comparing the findings regarding other species with the dataset led to similar results.

Figure 4: Loading Plot Excerpt.

Figure 5: Score Plot Excerpt.

4 CONCLUSIONS

The wood identification tool was based on the compression and visualization of a large dataset by using the MVDA method PCA. Applying the tool on the product electric guitar as an example provided promising results. Numerous potentially suitable wood species could be identified and verified. Some of the advantages of the tool were the ease of use, quickness, and profoundness of the results. It has to be noted, that an equal quality of the results can be obtained by using a calculation algorithm in programs like Microsoft Excel. Nevertheless, this tool provides results literally in seconds. It is very flexible and responsive due to the visualization of correlation patterns between the properties and the wood species. This aspect is of great advantage when compromises have to be taken due to contradictory desires like a high MOE and a low density at the same time. Another advantage was the ability to use the tool as a print-out on one or two sheets of paper. This might me particularly useful for made-to-order products with close customer contact and for small companies in general. This aspect gains importance in a world where focus on customer needs becomes more and more important.

There were two limitations to the tool. First of all, the results were not precise enough to make a final wood species selection. It was more aimed at narrowing down the choice to pool of suitable species. The second drawback was the origin of the data. In several cases it was not possible to

trace back how the wood properties were tested. However, the correlation patterns found in the model, suggested that the input data was plausible.
It also has to be kept in mind that the tool will only provide usable results if the set of desired wood properties was determined thoroughly. True to the motto: Rubbish in - rubbish out.
By expanding the existing dataset even further in the future the tool will become more powerful for two reasons. First of all, more species result in more choices. In addition, MVDA models generally become stronger with increasing amounts of correlated data.

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OPTIMIZING THE CROSS CUTTING OPERATION USING RESEARCH DESIGN METHOD

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Abstract
A cost efficient process is the goal of every part of the wood processing chain. It is directly related to a yield that is gained out of a raw material. On the other hand these processes have to deliver a certain product quality in order to satisfy customer needs. Very often a tradeoff has to be made between the yield and the product quality through optimization processes. The main objective of this work was to study if the research design can be used for the purpose of predicting scanning operation parameters, in order to maximize the yield and keep the mean length of the accepted pieces of center boards at a desired value. The obtained partial least squares (PLS) regression models quite accurately predicted optimum operating settings for the given material. This method can be used to achieve the goal of optimizing the cross cutting operation. Nevertheless the knowledge about the origin of processed boards in terms of the log type they were sawn from is significant, since developed models differed from each other accordingly.

Keywords:
Cross cutting, DOE, PLS regression, yield, mean length

1 INTRODUCTION

A solid wood processing chain can be roughly divided into primary, secondary and final wood processing. The goal of every part of the chain is a cost efficient process that achieves a highest possible yield from the raw material [1]. On the other hand these processes have to deliver a certain product quality in order to satisfy customer needs. Material is optimized along the processing chain to fit a certain product quality specification. Vourilehto [2] defines the quality of sawn wood as *its usefulness for the intended purpose*.
Along with the nature of its properties, the visual appearance of sawn wood varies a lot. The value of sawn wood depends on the quality which is defined by the features that are present in timber. Usually in practice, according to Vourilehto [2] the most important factors that influence quality are knots. Knottiness of the raw material directly affects the knottiness of the final product. Grönlund et al. [3] have shown how the waste, related to cut away

defects in cross cutting of wood, increases significantly when there are demands for small knot sizes and long wood lengths.

The data intended for this study was collected at the cross cutting operation within the finger-joint component factory (Fig. 1). The process of automated cross cutting is fully described by Rönnqvist et al. [4]. The process of finger joining is described by Grönlund et al. [3]. The material was followed through a) primary processing at the sawmill and b) secondary processing at the finger-joint component factory, both owned by Martinsons company. The finger-joint component factory is a supplier of an c) IKEA furniture factory (Fig. 1).

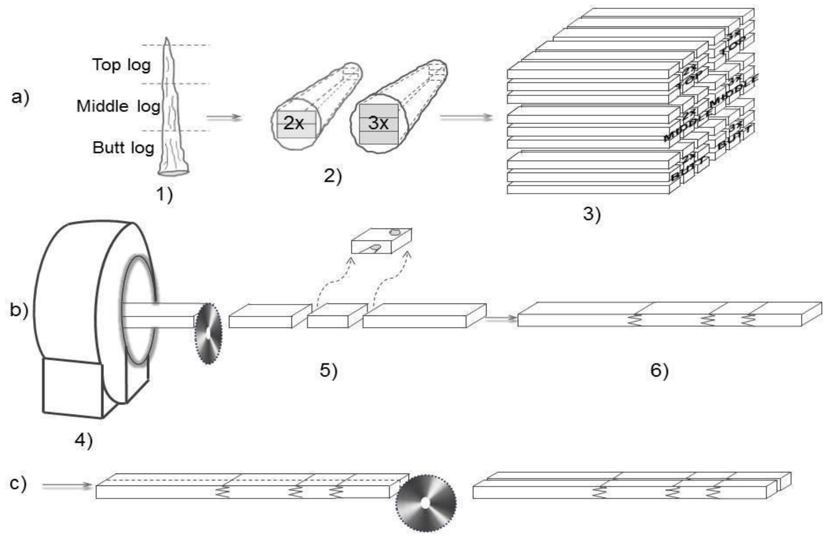


Figure 1: Project material collecting steps; a) the saw logs were classified according to the log type (1) and the sawing pattern (2) at the sawmill. After sawing and drying there were six groups of center boards (3) which were further processed in the b) finger-joint component factory: WoodEye scanner (4), cross cutting (5) and finger-jointing (6). Finger-joint components were ripped in half c) and profiled into cabinet legs at the IKEA furniture factory.

WoodEye One [5] is the scanning system that is installed in the finger-joint component factory and used for decision making in the cross cutting operation. For this particular product, cross cut decisions were made according to the specifications of both IKEA and Martinsons.

The finger-jointed components have to fulfill requirements of the surface quality such as the occurrence and sizes of different features, for instance:

black and fresh knots, pitch pockets, bark and cracks, thus the customer (IKEA) defines the limitations and acceptability of these various features.
As discovered by both IKEA and Martinsons, an important result of the finger-jointing process is the mean length of the accepted pieces after cross cutting. These components are later processed into products; cabinet legs of the IKEA´s Hemnes series (see Fig. 1). Shape rectangularity and dimensional stability are the quality requirements of the legs and are directly influenced by aforementioned mean length. If the mean length value is too high, the quality of the cabinet legs might be compromised since boards often, according to Cassens [6], *become crooked after ripping due to relieving of longitudinal stresses that remained after drying*. On the other hand if the obtained mean length is too short, the finger-joint component factory loses its productivity rate. Thereafter keeping the mean length of the accepted pieces for this particular product at a desired value is important along with keeping the yield at the highest possible value. As Martinsons has empirically discovered the desired value for the mean length is 400 mm. This value was used in the analysis even though being irrelevant for the presented method itself. Research design investigation i.e. design of experiments can be employed for the purpose of finding setting values that provide an optimum point for the both responses of the cross cutting operation. Research design approach hasn´t been used so far in order to reach this particular goal.
Design of experiments (DOE) is a powerful tool that can be used in a variety of experimental situations. DOE allows for multiple input factors to be manipulated determining their effect on desired outputs (responses). Research design methodology is comprehensibly described by Eriksson et al. [7].
The main objective of this work was to study if the research design can be used for the purpose of predicting scanning operation parameters, in order to maximize the yield and keep the mean length of the accepted pieces of center boards at a desired value.

2 MATERIAL AND METHOD

2.1 Material

The material that was used for the purpose of this study consists of 252 sets of center board images that were saved and exported from the scanner´s control unit after scanning and processing had been done. One set consists of four images that depict longitudinal faces of the center boards. The center boards were sawn from Scots Pine (*Pinus Silvestris*) logs and were classified into six groups (Tab. 1) according to two criteria: the sawing pattern and the log type they were sawn from. There were two kinds of sawing patterns, 2X and 3X, depending if there were two or three center boards, respectively, sawn from a single log. Center boards were also classified as if they were sawn from a bottom, middle or a top log. See Fig. 1, a.

Table 1: The overview of material classification.

GROUP	*SAWING PATTERN*	*LOG TYPE*
1	3X	Top
2	3X	Middle
3	3X	Butt
4	2X	Butt
5	2X	Middle
6	2X	Top

2.2 Methods

Two types of software packages were used in the analysis. The selection of the research design, partial least squares regression analysis (PLS) and the prediction of the optimum points for responses were done using the Modde 9.1.software package [8]. All the experiments together with the validation of the predictions were performed with the WoodEye simulation software [5]. See Fig. 2.

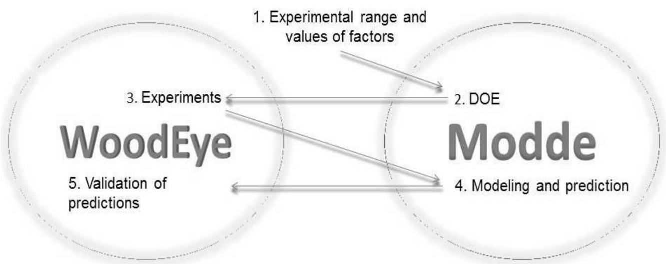


Figure 2: The Method. 1. As a first step experimental range and values of factors were defined; 2. Research design was selected based on the experimental ranges and values of four factors; 3. Experiments were performed according to the design; 4. Results of the experiments were inputs for PLS modeling and prediction; 5. Predictions were validated in order to assess their accuracy.

Research design

The settings that follow quality specification of a product were referred to as factors while the resulting variables of the cross cutting operation, i.e. yield and the mean length, were referred to as responses. Of the four factors that were investigated the first two were related to wood features and other two were related to length limits of the accepted pieces. The experimental range and values of factors are presented in Tab. 2.

Table 2: Four factors and their experimental range; Distances from the middle level to both low and high levels are equal. Middle levels of factors were standard settings of the Wood Eye One scanner for this product and the design of experiments was built around it.

FACTORS	**LEVELS**		
	LOW	**MIDDLE**	**HIGH**
Fresh knot [mm]	21	28.1	35.2
Black knot [mm]	29.1	34.55	40
Minimum length [mm]	170	180	190
Maximum length [mm]	470	480	490

The experimental range of defect related factors, for this study, was defined by Martinsons. The values, as seen in Tab. 2, represent a limit square. For example the limit square at the low level for fresh knot is 21x21 mm^2. A knot is classified as a defect only if a circumscribed square around it is bigger in both dimensions than the limit square.
The experimental range and values of length related factors were determined according to three length modules of accepted pieces from standard WoodEye One settings for this product. A lower limit of the first length module can be varied without changing the other limits, so it was taken as the middle level for the minimum length factor – 180 mm. The same stands for the upper limit of the third length module which was taken as the middle level for the maximum length factor – 480 mm. It must be noted that three length modules had different pricing, where short pieces had the lowest and long pieces the highest price. Algorithms which were employed by the simulation software, weight the importance of three length modules according to the pricing. Therefore to a certain extent it has affected the yield and the lengths of the accepted pieces during experiments.
A full CCF design requires $n^2 + 2n + 3$ experiments, where n is the number of factors (Fig. 3). In the case of four factors, proposed CCF design requires 27 experiments of which 16 are corner (factorial), 8 are axial and 3 replicated center point experiment. It is recommended to convey replicated experiments of a center point at least three times in order to discover the size of experimental variation [7].

Within this study there were in total 25 experiments with only one center point experiment. There was no experimental variation since the simulation software provides the exact same results when running the simulation with the same settings. The center point represents the standard WoodEye settings which were used during cross cutting.

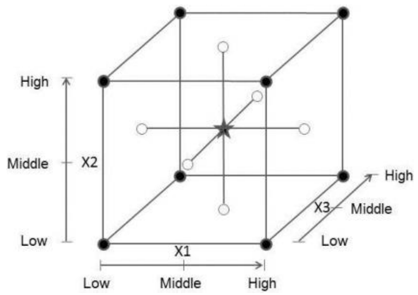


Figure 3: CCF design with three factors. Full circles represent corner (factorial) experiments. White circles represent axial experiments. The star represents a center point experiment.

There were 24 setting parameters that had to be defined in the WoodEye simulation software during experiments. The setting parameters related to four aforementioned factors were varied on three levels, see Tab. 2, and according to the CCF design, while other 20 setting parameters were kept constant throughout experiments.

PLS regression modeling and prediction

The research design that was chosen for the purpose of this study was a central composite face-centered (CCF) design. This design gives the in-depth information about the relation between few dominating factors and responses. Semi-empirical mathematical models of a second order are developed to estimate the true relation [7].

As there were two responses and six groups of center boards, twelve models were developed and fitted using partial least squares regression analysis (PLS).

Basic principles of PLS regression are described by Esbensen [9]. The CCF design enabled development of quadratic models. Non-linear quadratic relationships between responses and factors were approximated by a polynomial function of a second order. A general formula of such function is shown below (1).

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_{11} x_1^2 + \beta_{22} x_2{}^2 + \beta_{12} x_1 x_2 + ... + \varepsilon \tag{1}$$

where : Y – response; X_i´s – factors; $\boldsymbol{\beta_0}$ – the constant term; $\boldsymbol{\beta_i}$´s – the main regression coefficients; $\boldsymbol{\beta_{ij}}$´s – the interaction regression coefficients; $\boldsymbol{\beta_{ii}}$´s – squared regression coefficients; $\boldsymbol{\varepsilon}$ – residual response variation not explained by the model.
The obtained mathematical models were used for defining the factor values that maximize the yield and keep the mean length of the accepted pieces at the desired value of 400 mm. Optimizer is a software function [10] that was used for prediction of this optimum point.

Validating PLS regression predictions using "WoodEye" simulation software
The predicted values of factors that provide the optimum point for the responses were used for validation step in the simulation software to get the actual response values. Input data for these experiments were factor values calculated using the optimizer function. A single experiment per group of center boards was done with the simulation software with the aim to compare actual and predicted values of responses.
In order to assess the accuracy of predictions that the PLS regression models provided, the actual response values were compared with the predicted response for all of the six groups of center boards.
Another comparison between three types of experiments was made in order to compare response values between the optimum point, center point and maximum yield experiments. The results of the center point and maximum yield experiments were taken from the design matrix. Maximum yield experiment was chosen for this comparison since it was expected that, due to the optimization, the yield for the optimum point experiment can be slightly lower than that of the maximum yield experiment. It was also expected that the yield response values from the optimum point experiments would be higher than those from the center point experiments since the upper levels of defect related factors increase the acceptability of the material i.e. give higher yields. The same comparison was made for mean length response in order to observe the variation of mean length values around the desired value of 400 mm.

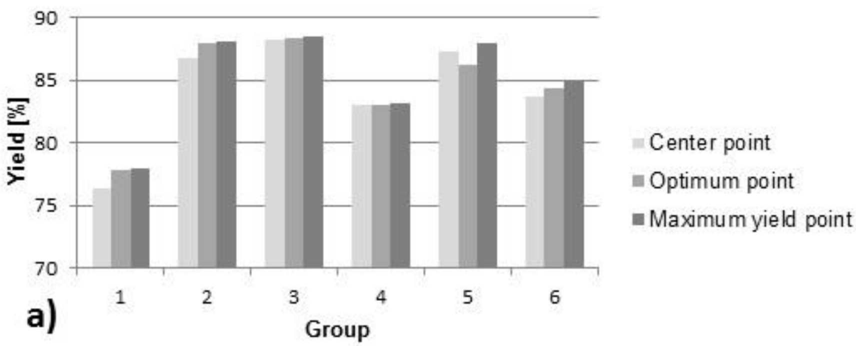
3 RESULTS

Predicted and actual values of responses are shown side by side in Tab. 3. Predicted responses are the results of corresponding predicted values of factors, obtained using optimizer function in Modde. These factor values when used as inputs for WoodEye simulations provided actual response values. Prediction ability of the PLS models can be assessed by comparing predicted and actual values of responses.

Table 3: Parallel overview of the predicted and actual response values in the optimum point for each of the six groups of center boards.

GROUP	RESPONSES - PREDICTION		RESPONSES – ACTUAL VALUES	
	Yield [%]	*Mean Length [mm]*	*Yield [%]*	*Mean Length [mm]*
1	78,29	400	77,85	401
2	88,49	400	87,95	395,5
3	88,56	400	88,36	399,8
4	83,12	400	83,03	398,9
5	86,37	400	86,23	398,9
6	84,83	400	84,41	397,2

The results of two responses from three different experiments are plotted next to each other for all of the six groups of center boards in Fig. 4.



a)

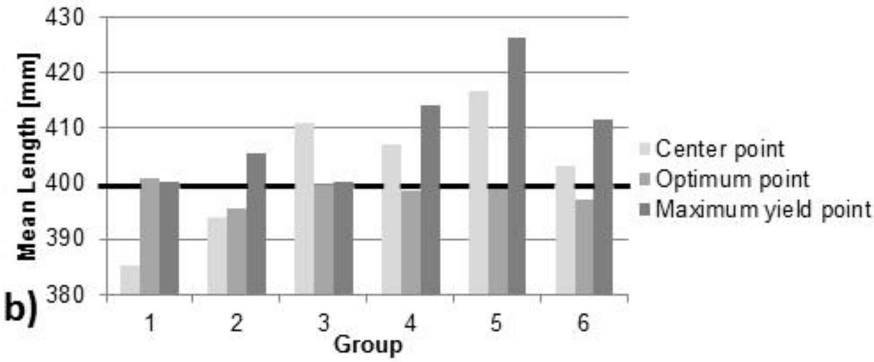


Figure 4: a) Overview of yield response compared between the center point experiment (standard WoodEye settings), optimum point experiment and the experiment with the maximum obtained yield; b) The overview of mean length results compared between the center point experiment (standard WoodEye settings), optimum point experiment and the experiment with the maximum obtained yield. Black line at the value of 400 mm denotes a desired value for mean length.

4 DISCUSSION

The CCF design has shown to be a good choice for the purpose of this investigation. As there were non-linear relationships between responses and some factors, a CCF design led to the development of quadratic polynomial models which in this case, unlike factorial designs, can closely approximate the true relation between responses and factors. Furthermore it requires fewer experiments than a central composite circumscribed design (CCC) that inspects each factor on five levels, which is found to be redundant for this analysis.

As it can be observed from Tab. 3, the prediction of PLS models appear to be accurate for all of the six groups of center boards. That can be attributed to rather strong developed models. Such strong models in wood science are not so common but it should be stressed that this multivariate analysis was done using the data from controlled experiments.

Except for group 5, yield response values from the optimum point experiment were, as expected, higher than those from the center point experiments and slightly lower than those from the maximum yield experiments. On the other hand the mean length response values from the optimum point experiments were found to be closest to the desired value of 400 mm.

Since the investigation included fresh and black knots as factors, the customer that orders finger-joint components has to approve changes in limits for these two quality requirements. An optimum point that is proposed by model most likely has these values different from standard ones. This finding can truly challenge the existence of strict specifications for wooden features that are often put by customers. From an aesthetical point of view the features of wood can only subjectively be experienced as defects.

The developed models could be used only for exactly same kind of product and quality requirements as presented in the study and also producing it from the boards that belong to the same type of log. Nevertheless, the method presented in this study can be useful and implemented in the finger-joint component factory for specific products where there are requirements regarding the mean length. Models together with predictions can be developed for different center board dimensions and materials. This is in the line with findings of Grönlund et al. [3] where it was shown that it would be possible to predict which wood quality is the most economical for a given application, if wood properties as well as quality and length requirements are known.

5 CONCLUSIONS

The main conclusion that answers the objectives of this study is that the experimental design approach can be used to achieve the goal of optimizing the cross cutting operation within the finger-joint component factory, through the presented method.

Furthermore additional conclusions arose during the analysis of the results. These conclusions are related to the limits of the method.

For the method to be applied in the industry, control over the input material in terms of the log type is necessary to exist in the sawmill. This shows to be important since the presence of fresh and black knots is different in different log types. Reducing the variation of the input material in this manner would lead to the development of PLS regression models that would give accurate predictions of the optimum points for the two responses.

Since the optimized settings for four factors differ from the standard operating settings both the customer and the supplier have to agree on these new settings. This implies that even closer communication between the supplier and the customer of the finger-joint components is needed in order to approve proposed optimum values of the four crucial scanning operation parameters.

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INVESTIGATING THE SURFACE QUALITY OF AFRICAN MAHOGANY FROM GHANA

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Abstract
Wood surface is influenced by wood properties and processing conditions. The evaluation of wood surface provides technical information on capabilities of gluing, impregnation, strength of joints, control of blade sharpness and decrease of waste. Several techniques for surface assessment have been applied to wood. These techniques operate by contact and non-contact imaging processes. Generally, the assessment of the surface quality of wood is mainly through visual observation. This can be improved by assessment that are more objective. There are limited studies and information on the assessment of surface quality of tropical African hardwood species. In this study, surface quality of naturally grown and plantation grown African Mahogany (*Khaya ivorensis*) harvested from Pra-Anum Forest Reserve, Ghana was evaluated. Preliminary results showed that roughness parameters, texture values and images for plantation samples have relatively lower values indicating smoother surfaces than natural samples. Further studies are needed to validate the differences between the samples.

Keywords:
Surface quality, hardwood, mahogany, plantation wood, machined surface

1 INTRODUCTION

Quality evaluation of wooden surface has been described as one of the most difficult issues in wood working research and its mode of assessment has been subject of great interest to researchers and consumers of wood products [1, 2]. The surfaces of machined wood are a complex heterogeneous polymer composed of cellulose, hemicellulose and lignin and is influenced by several intrinsic factors of the materials morphology of polymers, specific gravity, texture roughness and moisture content as well as processing conditions. In other words, surface roughness mainly depends on the factors linked between wood properties and wood working parameters. Properties inherent to wood, such as cell types and arrangement, porosity, density and color variations, make measurement of surface roughness a challenge [3].This could have been one of the reasons why there are no generally valid correlation to estimate surface roughness parameters as a function of influencing factors.

Over the years, various physical phenomena such as mechanical, optical, pneumatic, ultrasonic, electric, or temperature detection approaches have been used as principal components for the measurement of wood surfaces [4, 5, 6]. The appropriateness and applicability of these techniques for measurement vary significantly in industrial and laboratory conditions. The techniques most capable of determining surface smoothness of materials like metal, plastic and wood in an industrial environment are those that are non-contact, with reproduction of the profile such optical profilometers, microscopes, image analyzers, imaging spectrographs, interferometers, fiber-optic transducers, white light speckles, laser scatters, and optical light-sectioning systems. The contact process of measuring surface roughness like the stylus profilometer provides a more quantitative and hence more objective measure of the surface profile though there are some limitations in the filtering process especially in measuring tropical timber species with large vessel size (porous timber).

Generally, most natural tropical hardwood wood species are brown, cream (white), red or shades of these three colors and are predominately species of medium density though a few are of low or high density [7].These species like African mahogany are commercially used for decorative furniture, boats and boat components, vehicle bodies and decorative veneer for plywood making. Surface texture of machined surfaces of wood, as revealed by reaction to cutting tools which in turn is determined by size and proportional amounts of cells, especially the vessels, is an important wood quality when decorative and finishing process of tropical wood are concerned.

The world’s managed fast-growing forests have been increasing steadily. The managed resource is expected to dominate the world’s wood supply in some years to come. Worldwide, the transition from total dependence on depleting inherited stocks to reliance on a managed resource has been associated with a significant decline in wood quality [8, 9]. The managed resource is usually characterized by younger age, smaller stem diameter, larger taper, larger knots, higher juvenile wood content and different wood characteristics and processing properties. Therefore silvicultural manipulation, disease /insect infestation and the characteristics of the wood are important factors that could eventually influence the quality of the wood and finally the wood surface. However quality may also be influenced within limits by sawing especially when the head saw is a band saw or a circular saw.

The objective of this study was to evaluate the surface quality of the wood of African mahogany (*Khaya ivorensis*) from both natural and plantation forest using different techniques for more accurate and objective surface roughness assessment and make recommendations for the use of appropriate techniques in surface evaluation of commercial tropical hardwood species.

2 MATERIALS AND METHODS

2.1 Material

Khaya ivorensis A. *Chev* is a moderately durable, medium density wood used for boat and canoe construction, decorative veneers, high quality furniture and luxury cabinet works. It can be found in West and Central Africa, extending from Ivory Coast to Gabon. In Ghana, it is frequently found in the Wet and Moist Evergreen and Moist Semi-Deciduous Forest types. Macroscopically, the heartwood is red-brown, clearly demarcated from creamy white to yellow white sapwood. The texture is fine to medium with low luster and light pleasant odor [7]. Anatomically, the wood vessels or pores are medium in size (about 0.1-0.2 mm) with high proportion of solitary pores and low radial multiples of two with same size that are moderately distributed with the presence of inclusions. Axial parenchyma is indistinct, scanty paratracheal, vasicentric, occasionally aliform and confluent. Proportion of fiber tissue is medium to high. Ray parenchyma is variable, narrow and very narrow. This wood is diffuse porous, growth ring boundaries demarcated by dark ground fiber tissue, absence of pores and sometimes marginal parenchyma.

2.2 Harvesting primary processing and transportation of sample boards

Five matured trees of plantation grown mahogany and three matured naturally grown mahogany (NGM) were extracted from Amantia in the Pra-Anum Forest Reserve and Forestry Research Institute of Ghana (FORIG) plantation for the experiment during the dry season of February, 2012 using logging machinery from Log and Lumber Limited (LLL), Kumasi, Ghana. The logs were transported to LLL, Kumasi for the primary processing.
A vertical band mill at Logs and Lumber Limited, Kumasi with saw blade thickness of 8 inches and length of 33 feet 3inches with gauge of 17¨ without tipping was used. The saw blade was swage set for processing. In all about 600 lumber pieces of thickness 35mm and 70 mm were obtained from logs extracted from the five plantation (PGM) and three NGM trees.

2.3 Sample preparation

Ten (10) samples of plantation grown and natural wood of *Khaya ivorensis* with dimension 40mm x 40mm x 15mm were prepared and planed. The samples were then placed in the computer controlled climate chamber at 20º C and relative humidity of 65% for five days. According to [10] no significant difference existed between surface roughness characteristics of tangential and radial machined surfaces of Beech and Aspen wood samples at a 95% confidence level. Thus one surface, the tangential surface of board was sanded using sanding machine with grit sizes of P220, P320, P600 and P1200. An oscillatory sanding machine model ATM System labor WP 0285 (Figure1) with speed of 300µ/min was used to undertake the sanding (Silicon Carbid, waterproof) with. Ethanol was used for wetting the surface of the

wood samples during the sanding process. The sanded samples were later placed in the climate chamber before the measurement for surface profile analysis.
This special sample preparation is necessary to analyze the real wood structure with different measuring systems and also to familiar with the differences in plantation and natural grown wood of *Khaya ivorensis*. It is also to ensure that machined surfaces can be measured and separated from roughness due to the anatomical structure of the samples.


Figure 1: Sanding of samples.

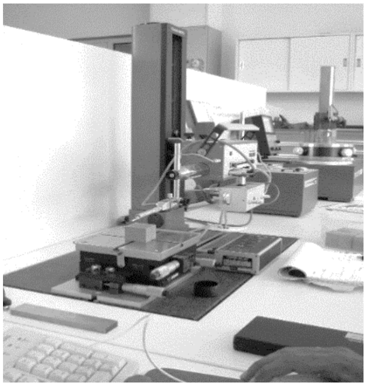


Figure 2: Stylus profiler.

2.4 Measurement

The stylus techniques

The stylus technique is the standard for roughness assessment of materials including metal, plastics and wood surfaces. There are various modifications of this method, such as with or without a skid, or varying stylus tips (geometry, materials). The stylus method has some important limitations such as possible damage of the surface; non-zero tip radius: missing fine irregularities; cone angle of the tip: sliding on the steep fragments of the profile; and relatively slow.
In this study, the stylus instrument that was used is from Hommelwerke with a tip type of TK300 (figure 2). The roughness parameters were taken with a 15 mm scan length and a cut-off length of 2.5 mm with a Gaussian regression filter - DIN ISO 11562.Each sample of the mahogany was measured 10 times on the tangential surface.

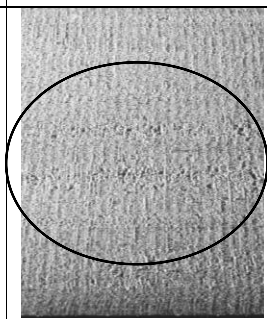
Deflectometry

In general, deflectometry is used for glossy surfaces like mirrors and glasses. The optical measurement projects a pattern on the surface of the material. The camera picks the images and analyzes the angle of reflection,

estimates the surface slope and the relative height values. With derivation local curvatures can be detected [11]. In this study, *Rhopoint´s Optimap PSD TM* was used with the stepwise phase deflectometry and an area of measuring of 95 mm to 70 mm and a lateral resolution of 75 µm. The model “extra dull”, which is suitable for very low gloss finish and with a gloss unit below 10, was used.
The advantage of the non-contact measurements include the fact that fibers cannot be destroyed or pulled down. Also, measurements are not restricted by the depth or size of vessels. But different reflection properties on the surfaces of the samples can lead to modified results.

Sensory quality assessment
The sensory quality assessment of wooden surfaces can be done by haptic or visual perception. For assessing the quality assessors need to be trained in using the right vocabulary for different attributes, using the right utilities like special illuminating conditions and become familiar with methods of assessing [12].Training material for assessors must include any special wood properties as represented in table 1. According to the method of sensory quality assessment in VDI 3414-2 [13] the assessors are trained.

Table 1: Example of training material for assessors to become familiar with attributes

Description of attribute and the use of utilities	Picture of attribute
Fiberness: The fibers are woolen and short. Because of alternating spiral growth fibers are changing the rising direction. Utilities: - dark field illumination - illumination cross and parallel - haptic exploration in all directions	
Interlocked fibers: Milling and planning the wood is difficult because of alternating spiral growth. Arise with fibers can splitting and lead to interlocked fibers. Utilities: - dark field illumination - illumination cross and parallel - haptic exploration in all directions	

3 RESULTS AND DISCUSSION

The stylus instrument

A typical profile for test samples of *Khaya ivorensis*, which was prepared as mentioned before, from the stylus method is shown in figure 3. The filtered profile indicates that nearly all fibers were removed and just a slight waviness existed. Moreover, it shows deep sinks/valleys along the surface profile of the Mahogany samples are the valley peaks. These valleys or sinks are usually related to large and wide vessels in wood samples. It is an indicator of oil retention and quantitatively represented by some amplitude parameters such as Rt (Maximum peak to valley height), Rz (Average peak to valley height) and Rv (the deepest valley below the center line)

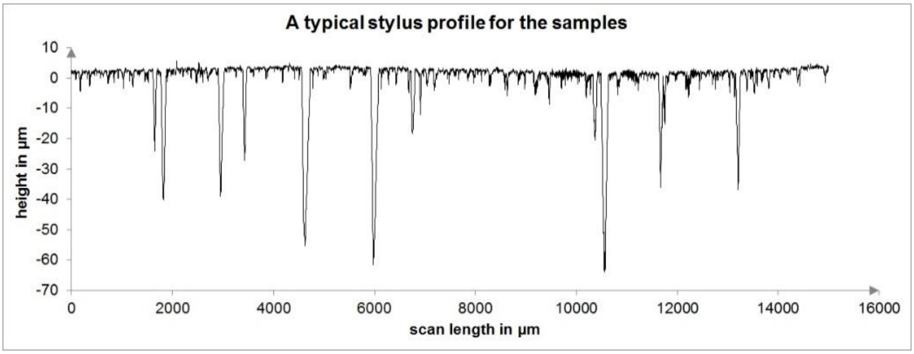
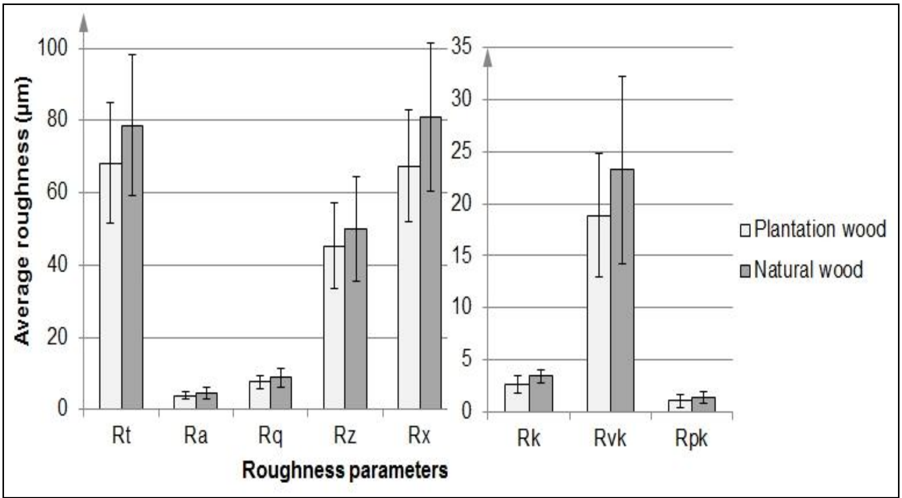


Figure 3: A typical stylus profile for the samples.

Results of the surface roughness of the samples are further presented in figure 4. Analysis of results revealed that for all the roughness parameters measured samples from the plantation samples recorded relatively lower values than the natural ones in term of arithmetic average roughness (Ra), mean peak to valley height (Rz), core roughness depth (Rk), reduced peak height (Rpk), reduced valley depth (Rvk), total height of roughness (Rt), maximum surface roughness (Rmax) and maximum depth of roughness motif (Rx). It is an indication that plantation samples are relatively smoother than the natural ones.

According to [14, 15] the roughness parameters Ra and Rz are the commonly used parameters in stylus profilometers but for very smooth surfaces like that in this study, the root-mean-square roughness Rq values are more appropriate for comparison. In addition to these parameters, Rk family parameters can give a more detailed information about the surfaces of the wooden samples.

Researchers over the years have proven that measurement of standard surface roughness parameters and characterization by a single, more or less simple, parameter, e.g., arithmetic average of the surface roughness (Ra) or the root-mean-square roughness (Rq) (ISO 4287 1998), may be erroneous, due to the introduction of artefacts by standard roughness filters at the edges of deep valleys, e.g., cut vessels. In recent years, several attempts have been made to overcome this limitation by introducing new filters [16, 17].
As shown in figure 4, the values of Rk and Rpk have a low standard deviation. However, any comparison of roughness separations may become more difficult, since Rvk indicates a high standard deviation with a range close to sanding roughness.



Rt Total height of roughness	Rx Maximum depth of roughness
Ra Average roughness	Rk Core roughness depth
Rq Root mean square roughness	Rvk Reduced valley depth
Rz Mean peak to valley height	Rpk Reduced peak height

Figure 4: Average roughness parameters for both natural and plantation grown Mahogany.

Deflectometry
Different textures of the wooden surface are displayed in the X, Y or X+Y directions at different bands (Ta, Tb, Tc, Td and Te) in increasing order of band wavelength (Table 2). Results of the analysis of the images revealed that the band levels especially in the X- direction give a good measure of

surface characters of the surface of the samples (figure 5). There was slight difference between natural and plantation grown samples.
The highest amount was found in Ta band with mean values of 340 and 319 for natural and plantation samples respectively. For Tb, Tc, Td, and Te bands the mean values of texture were relatively lower for plantation samples than the natural samples (Fig 5).
Relating to this idea the sizes of single characters, which are within the wavelength (Table 2), a classification was done. The preliminary tests shows that there are some differences between sanded surfaces of natural and plantation grown samples which was also revealed with the stylus profilometer.
A preliminary test of samples of natural grown Mahogany wood was made after sanding with a grit of P150 by hand. These samples were coated with different varnish. The application was done by hand with the aim to apply as less as possible or changing the character of the surface significantly rather lifting up and fixing the fibers for a better analysis.
Some processes like wetting, staining or lacquering cause the swelling of wood fibers and figure them out. For the other values Tb, Tc and Td only a low texture is detected with a small rising after sanding. Again, a coating with white lacquer hid surface textures within these wavelength. Td shows for this group the larges texture after sanding and coating with blue stain or clear, glossy lacquer.
For long wavelength, represented by the value Te, it indicates some rough texture rising especially after wetting with water and coating with stain and glossy lacquer. White lacquer hide the characters a lot, again. Sanding without any coating do not change the texture too much. Currently it is assumed that there are some kind of interaction between the coatings and bringing out color marks at the surface. Observation of the surfaces showed that the rays which appear as ripple marks and inclusions in the cut vessels, which are typical for *Khaya ivorensis*, are not affecting texture measurement by deflectometry.

Table 2: Deflectometry values relating to surface characters.

Value	**Wavelength**	**Examples for character**
Ta	0.1 – 0.3 mm	Raised ends of fibers, small fibers
Tb	0.3 – 1.0 mm	Fibers, small pores
Tc	1.0 – 3.0 mm	Interlocked grain, chatter marks, sanding roughness
Td	3.0 – 10 mm	Interlocked grain, chatter marks, sanding roughness
Te	10 – 30 mm	Interlocked grain, chatter marks, alternating spiral growth

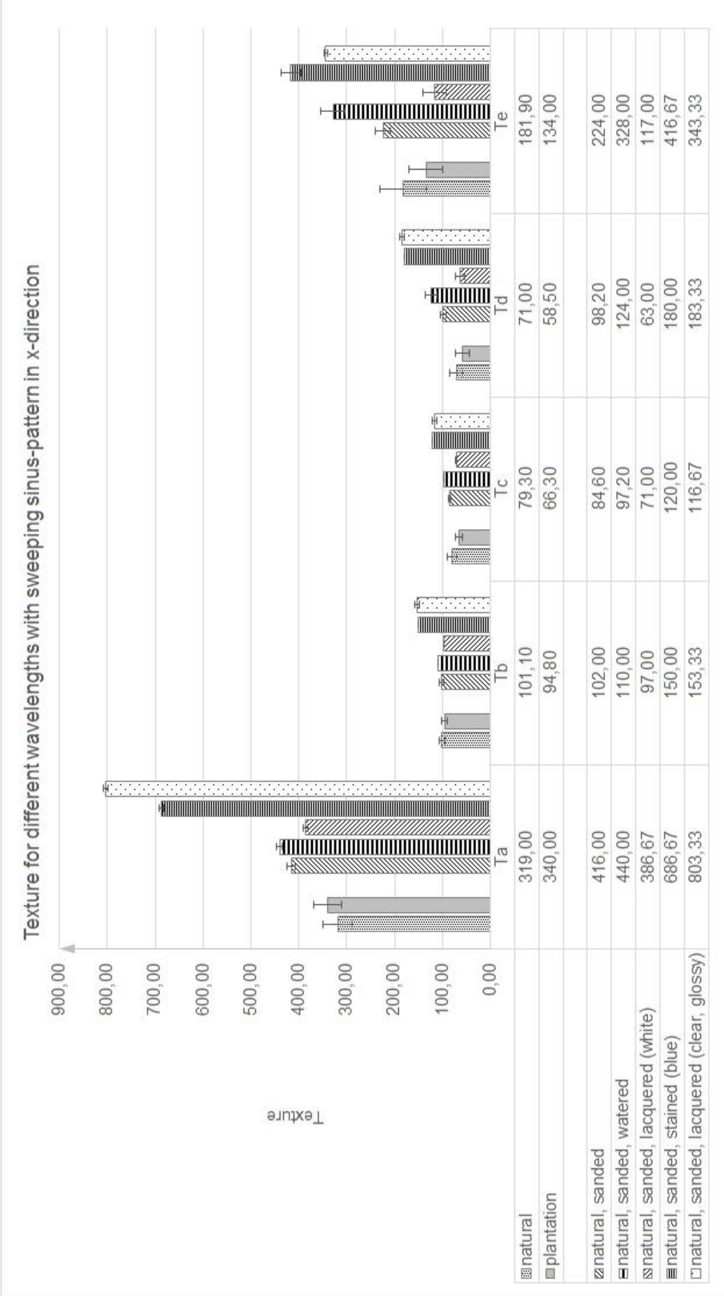


Figure 5: Texture of the image displayed for natural and plantation Mahogany.

Sensory assessment

No preliminary results of sensory tests could be presented. This is because the materials as shown in Table 1 for training the panel of assessors is still being prepared. Further, the assessors need to be properly trained to make any slight difference among the surface of the samples for the assessment and thus substantial results can be expected after their training.

Haptic evaluation of fibers on prepared surfaces of samples are particularly difficult. As shown in the first figure in table 1, the surface is very smooth and more woolen and the assessors need to have a high sensitive perception.

The visual evaluation seems to lead to better results especially with the dark field illumination both characters from above can be detected easily.

4 CONCLUSION

Tropical hardwood species like *Khaya ivorensis* species have characteristic that make them suitable for commercial uses. In this work, the evaluation of the machined wooden surface using the stylus profiler and deflectometry techniques was aimed at estimating differences between the samples of natural and plantation grown wood. Preliminary results of the study showed that average values of the selected roughness and texture parameters estimates the surface roughness of the machined surface. The haptic and visual techniques will be conducted to provide a full understanding and assessment of the surface quality of the wood samples. Further work on the filtering process such as the use of 'love filter' of the surface profiles obtained will be necessary to eliminate the effect of deep valleys obtained as a result of vessel openings on the surface of the material. Wetting and coating of the surfaces of samples are also being fully tested to understand their influence on surface quality assessment.

ACKNOWLEDGEMENTS

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LEARNING FROM GEOGRAPHY – TOPOGRAPHY AS A BASIS FOR QUALITY ASSESSMENT OF HIGH GLOSS SURFACES

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Abstract
Thinking of high gloss surfaces the most perfect one that comes to mind, is a mirror. This kind of surface is more or less without any surface texture and as even as possible. Due to this the perceived quality of surfaces rises with their smoothness. But for furniture surfaces a perfectly smooth surface is an almost unachievable aim as producing a surface always implies the risk of obtaining surface textures. The end customer's visual perception provides the facility to see these morphological deviations. To get results close to the human perception a topographical analysis is useful. This morphological appearance of surfaces is always three-dimensional, which makes a laminar topographic measurement necessary, like the deflectometry. Assessing the surface quality by projecting a pattern and analyzing the mirrored one is the essential function of deflectometry. With analysis of three-dimensional data, technical surfaces could be seen similar to geographic terrains, with their peaks, pits and passes. Like a landscape the surfaces can be divided in hills, basins or dales and every point on earth as well as on a technical surface. Based upon topological data, a method was developed which uses weighted surface networks for characterization of morphological elements. Those represent a powerful tool to analyze topographic surfaces.

Keywords:
High gloss, quality assessment, topography analysis, quality perception by haptic and visual inspection, morphology of surfaces, geology

1 INTRODUCTION

In fact, producing a high quality surface like a mirror starts with the choice of the raw material – the substrate as well as the lacquer – and the processing. In the process each production step builds up its own attributes [1]. For example waviness can be a result of the dysfunction of an electronic segmented pad of the sanding machine, large differences of grit sizes between two sanding steps will arise to a scratched top coat. Orange peel can be caused by the lacquer recipe, drying conditions or application parameters. Because of the multi-step-production especially regularly not avoidable quality attributes exists at the surface. As a consequence the aim should be to produce surfaces as smooth as possible at each production step.Within the research project “Development of a comprehensive quality concept for furniture high gloss surfaces” sponsored by the federal Ministry of Education and Research [2] showed, end customers can perceive and evaluate morphological deviation from a perfect surface topography by visual perception. Beside this, previous studies of the research project showed that the visual perception of surface topography and their morphology is correlating to Motif values according to DIN EN ISO 12085 [3] like mean length of the waviness Motif “Aw” and mean depth of the waviness Motif “W” [2]. But the stylus instrument just provides two-dimensional data. All morphological elements of surfaces are always three-dimensional, which makes a laminar topographic measurement necessary, like the deflectometry.

2 TOPOGRAPHY OF HIGH GLOSS SURFACES

The topography describes three-dimensional structures of landscapes or any other surface. Thereby single characters are expressed by morphological structures, which give an impression of the important topographic properties.

2.1 Topography of geological surfaces

As mentioned above, stylus instrument methods to obtain two-dimensional values need to be transferred into three-dimensional. Thereby single geometrical elements need to be differentiated from another. In this way selected elements occur. While changing from two-dimensional to three-dimensional analysis, technical surfaces could be seen similar to geographic terrains, with their peaks, pits and passes. For this reasons the description of these elements are based on morphologic definition following the geographical nomenclature, hence peaks and dales, sinks or slopes are used for structuring and describing surfaces. Table 1 gives an overview of generally applied elements, which are defined in DIN EN ISO 25178-2:2012 [4]. Major types of topographical elements are area, line and point, e.g. areas are scaled elements with the type of hills and valleys.

Table 1: Types of scaled/selected elements [4].

category of elements	types of scaled/selected elements
Area	hills
	valley, dale
Line	flow line, crest line, passes
	ridge line
Point	top, peaks
	hollow, sink
	saddle point

ISO 25178 includes several parts to measure and evaluate technical surfaces. Especially ISO 25178-2 describes the areal (three-dimensional) parameters, which are based upon simple extensions of two-dimensional parameters. Those definitions have a drawback, they are not exactly defined or mathematically described. Further the definitions could be incomplete or contradictory [5].
The first mathematical relation between hills and dales was given by Maxwell [6]. Within his work he carried out several definitions of topographic features. Furthermore the whole earth could be divided in hills, basins or dales and every point on earth has a line of slope. Areas where the slopes line come from the same peak could be called hills, whereas areas where lines lead into the same sink could be called dales.
Based upon topological data, Wolf [7] developed a method which uses weighted surface networks to analyze topographic surfaces. Surface elements like hills, passes and peaks include more information than any other element in this network [7].

2.2 Topography of furniture high gloss surfaces

In particular a furniture surface topography can be described analogously to geographical hills or dales. According to the definition of morphological elements used in geography, represented in table 1, the high gloss topography of furniture surfaces should be defined. On this occasion the character of hills and dales, the height of peaks or sinks as well as their kind of occurrence is the basis for defining single attributes for high gloss surfaces of furniture.
On the one hand the character of hills and dales is described by their shape of the top or sink. Tops or sinks can be pointed or shaped like a plateau. On the other hand the inclines e.g. flow lines and their spreading character describe how hills or dales look like. At least the kind of occurrence and expanse at the whole lacquered surface characterizes attributes. The kind of occurrence can be periodic and direction dependent or aperiodic and direction independent. Usually periodic and direction dependent attributes belong to regular surface processing like sanding. Aperiodic and direction independent attributes belong to substrate quality or lacquer properties. Common used terms like orange peel are described in table 2. It is indicated, that different attributes can be identified by different wavelengths.

Table 2: Description of topography attributes [8].

<table>
<tr><th>attributes</th><th>description of the attributes</th></tr>
<tr><td>waviness</td><td>Waviness occurs within different shaped frequencies. The waves can arise aperiodic and direction independent or periodic and direction dependent. Further the waves can be overlapped e.g. by different wave frequencies.
<table>
<tr><th></th><th>periodic & direction dependent</th><th>aperiodic & direction independent</th></tr>
<tr><td>long wave</td><td>sanding marks</td><td>spreading errors</td></tr>
<tr><td>middle wave</td><td>impact or chatter marks, roughness of the substrate sanding, levelling disturbance</td><td>substrate structure, lacquered fibers, levelling disturbance, orange peel</td></tr>
<tr><td>short wave</td><td>roughness, roughness of the lacquer sanding</td><td>orange peel, lacquer shrinking</td></tr>
</table>
The longer the waves are, the less the mirroring is disturbed. The perceived mirroring quality at the pictured edges depends on the observing distance.</td></tr>
<tr><td>chatter marks, impact marks</td><td>This attribute is periodic, equally shaped and marks are crossed as well as direction dependent. Due to the processing dales are thin and with tapering peaks. The incline is steep and concave.</td></tr>
<tr><td>sanding roughness</td><td>This attribute is largely periodic with direction dependent marks or roughness. They depend on the used processing directions. The roughness occurs as a spontaneous incline with a thin dale.</td></tr>
<tr><td>levelling disturbance</td><td>Due to the application type the levelling disturbances can be more or less periodic and direction dependent, e.g. roller coating. Or according to spraying this attribute is aperiodic and direction independent. Further the viscosity and solid body of the lacquer is responsible for the appearance or the character itself.</td></tr>
<tr><td>orange peel</td><td>Orange peel is always aperiodic and direction independent with a low incline. Dales appear more like a plateau, while peaks have no equally appearance and frequency.</td></tr>
<tr><td>lacquer sinking</td><td>This attribute is directly linked to the substrate properties and the layers. That is why the attribute is aperiodic and direction independent. According to the substrate, peaks are more shaped as a plateau and dales are thin, spontaneous and with a steep incline.</td></tr>
</table>

According to the VDI 3414 [9] attributes can be structured as shape deviations of second to fourth order. This order is based on their level dimensional shaping. The larger the attribute is, the smaller is the level of order. Topography attributes like levelling disturbances or orange-peel, which are characterized by a few millimeters, belong to the fourth order. Thereby these attributes lead to a deviation of ideal smooth surfaces. Accordingly these changes produce different reflecting properties of an ideal standard, which will lead to disturbances of mirroring. This is called the distinctness of image (DoI) [10], the main perceived appearance of high gloss surfaces. Characterizing a surface regarding the appearance needs to fulfil the description of geographical guidelines. Consequently the mean of relative height, expanse of dale or hill and the distribution on the surface and the level of slope or incline have to be taken into account. The ratio of the relative height and the expanse of hills relating to their number of occurs will give a first characterization. Combining this parameter/value with the level of slope will give a comprehensive knowledge of the surface.

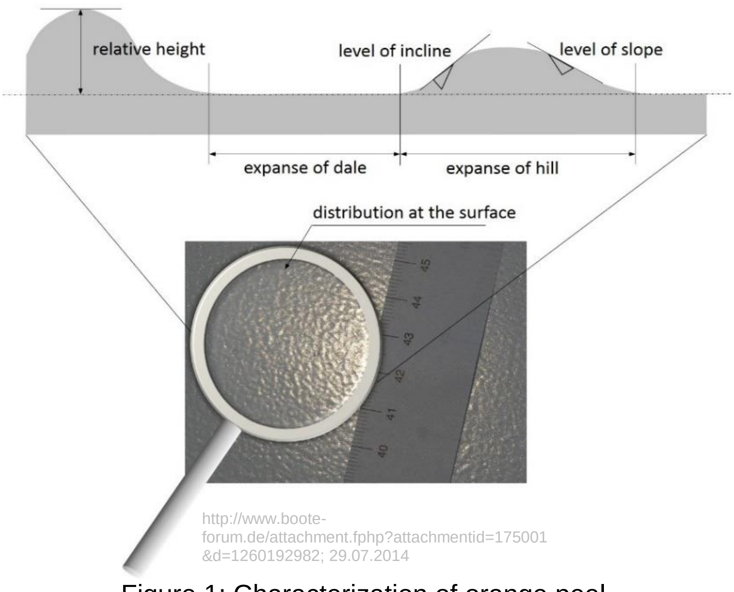


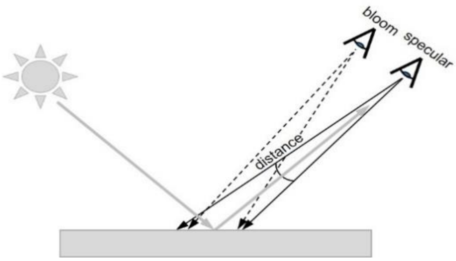
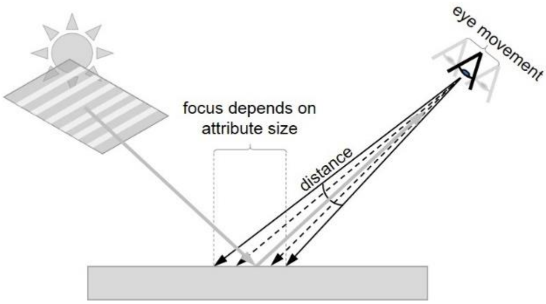
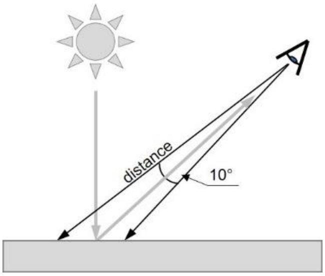
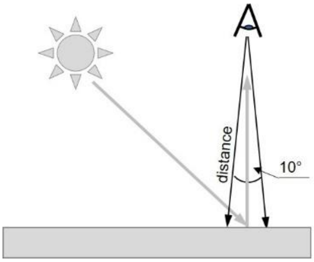
Figure 1: Characterization of orange peel.

3 ASSESSING THE QUALITY OF HIGH GLOSS FURNITURE SURFACES

3.1 Sensory assessment

Quality assessment of end customers by visual human perception never separates attributes. This is caused by the illumination in shop floors. Just with special light and observing settings single attributes can be separated for a more concrete respectively objective evaluation. These settings according to attributes are shown in table 3.

Table 3: Settings of sensory techniques on attributes of high gloss surfaces.

characteristic		settings
glossy	specular gloss bloom gloss, haze	 according to [11]
distinctness of image	long wave short wave roughness	 according to [11]
color	hue saturation	  according to [10]

For evaluating topography settings related to the distinctness of image have to be used. According to the guidelines RAL-GZ 430 [11] different observation distances are needed for details and general impressions. The recommendation by [12] implies a short observation distance of 0.5 m for small attributes and 2 to 3 m for a general impression respectively long waved attributes. For this purpose the level of filigree for projected pattern and their support for focus details depends on the observation distance. Further eye movements will give additional information about the wavelength and wave amplitude, which is related to the physic-anatomical interaction during visual observation, which is used in sensory quality assessment. The light beam reflection as well as scattering by surface structures are reflecting into the eyeball. This means that the reflecting light beam builds up the picture at macula lutea, also called the “yellow spot”, the spot of the sharpest vision. This is located on the back wall of the eyeball, the retina andit is shown in figure 2. This natural observation is generally used in sensory quality assessment and is supported by projected pattern with filigree-type is related to the observation distance (table 3).

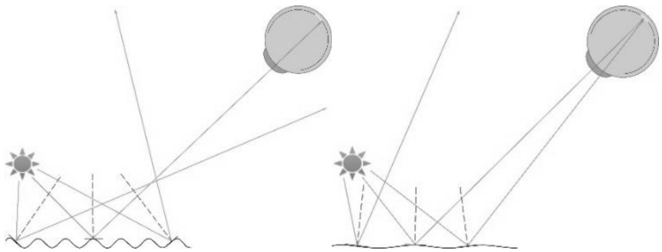


Figure 2: Reflection of light for visual observation according to the level waviness.

3.2. Measuring topography

As mentioned before classification and gauging of topographic elements on high gloss surfaces require three-dimensional data. While tactile measurements of the surface texture show quite good correlation to the visual perception (compare chapter 1), the two-dimensional data gained by these measurements is not sufficient to describe all the important characteristics, e.g. the distribution of elements like hills and dales on the surface or a directionality of these elements cannot be judged.

Though a large number of different measurement devices for three-dimensional assessment of technical surfaces are available, in tests only few of them proved to be applicable on high gloss surfaces as is shown in table 4. This is caused by the special optical properties of furniture high gloss surfaces, like high reflectivity or the use of transparent lacquer. Nevertheless certain measurement devices were identified, that are capable of capturing the topography of high gloss surfaces. One of these is *Rhopoint´s OptimapPSD*™, which is working with the technique of Phase Stepped Deflectometry. Figure 3 visualizes the principle of this technique.

Table 4: Applicability of measurement techniques on attributes of high gloss surfaces [according to 8].

	characteristic	gloss	bloom gloss, haze	long wave	short wave	roughness	hue	saturation
				distinctness of image			color	
measuring	image processing			●	●	◐		
measuring	confocal microscope			●	●	●		
measuring	„Wavescan“			◐ 1	◐ 1			
measuring	strip light projection			◕ 2	◕	◕		
measuring	shape from shading			◕ 2	◕	◕		
measuring	white light interferometry			●	●	●		
measuring	laser triangulation			◕ 2	◕	◕		
measuring	spectrometer						●	●
measuring	deflectometry („Optimap“)			●	●	●		
measuring	goniophotometer	◕	●			◐ 4		
measuring	reflectometry (20° and 60°)	◐ 3				◐ 4		
measuring	stylus with needle tip			●	◐ 5	●		
measuring	stylus with ball tip			●	◕ 5			
sensory	observation color						●	●
sensory	observation DOI			●	●	●		
sensory	observation gloss	●	●			◐ 4		

● well suited ◕ suited (with constraints) ◐ restrictedly suited

1) measuring the intensity distribution of the reflected light, not the surface itself
2) not applicable with all surfaces
3) low correlation to visual assessment
4) isotropic roughness influences the gloss, but linear structures, e.g. micro scratches have no influence
5) not distinguishable by single measurement, but by series of measurements

By use of a LCD display, a periodic grid is projected on the reflective surface. The observer, which usually is a camera sensor, captures the reflection of the pattern. Each source point is reflected in a certain point of the surface (M) and will appear at a certain pixel of the sensor. Each distortion of the ideal surface will lead to a variation of the ray path and result in a displacement of the point´s position on the sensor. Based on this position, the perpendicular to the real surface can be calculated in each point and thus the slope of the surface in this point is detected [13]. To get a complete image of the surface a phase of the pattern is shifted, which will move the reflection of the source point to a new point on the surface (N) and the calculation is repeated. This measurement will be repeated with a pattern in x- and y direction and results in a matrix containing the complete data of surface slope. By applying mathematic operation like differentiating and integrating on this data, also the curvature and the three-dimensional topography of the surface can be calculated. The data of the three dimensional topography can be used for further processing and by applying suitable algorithms, morphologic elements of the surface can be extracted.

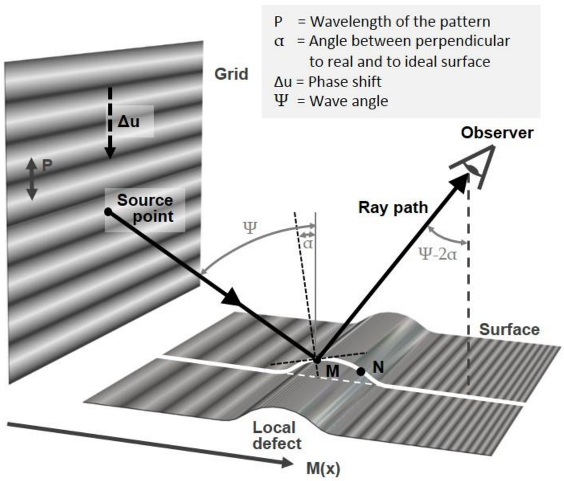


Figure 3: Principle of deflectometry. [14]

4 MORPHOLOGIC CHARACTERISTICS

As already mentioned in chapter 2.2 the morphologic elements can be described by special characteristics, like the mean of relative height, expanse of dale or hill, the distribution on the surface and the level of slope or incline. Due to the emergence of the different short wave disturbances the ratio of relative height to expanse of the hill can be expected to be an indicator for the perceived surface quality as well as for the kind of disturbance. Thus this value was chosen for first pretests to validate a correlation to the result of a ranking test. The results are presented in figure 4.

In the pretest the ratio of peak height to peak area showed a good correlation to the sensory ranking of a small panel, as long as samples with the same kind of disturbance are taken into account, like the samples containing lacquer sinking. Samples showing a different kind of short wave disturbance, like an uneven foil surface, cannot be compared to this, as the visual perception of the disturbances is very different. Here other characteristics of the attributes, like the formation of dales, need to be taken into account. While the algorithms applied on the surface data already are capable of reliably identifying morphologic elements like peaks or sinks, the values that are extracted from this data still need to undergo some further development to reach a satisfying level of correlation. Besides this for validation of the correlations the settings for sensory assessment strictly have to comply with those described above.

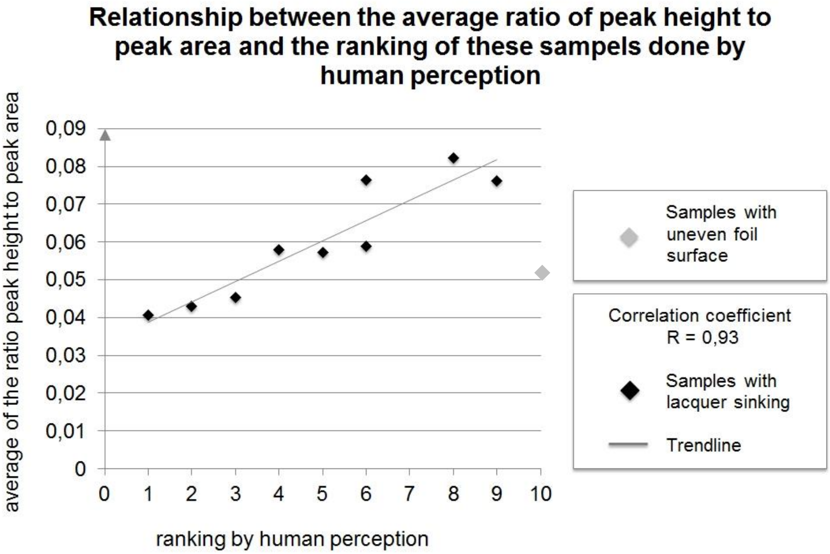


Figure 4: Relationship between the average ratio of peak height to the peak area relating to a ranking of sensory assessment**.**

5 CONCLUSION

Comparing sensory assessment and measuring especially in case of topographic characteristics of surfaces the discernibility of attributes e.g. orange peel or lacquer sinking is only feasible for trained assessors. But visual perception is limited and cannot be compared with the resolution capability of any measuring system. For a high reproducibility test settings carefully need to be complied. Further valid results still need a very high assessor qualification or a large group of assessing people. [15]

Measurements have a high resolution capability and good reproducibility, if the physical principals of attributes and measurement technique are compatible. On the one hand attributes interact with others, which will lead to a modified result. On the other hand the used illumination can be responsible for wrong or no results. To enable separating of morphological elements, the surface needs to be assessed three-dimensionally and in a large area. Moreover measuring results need to be developed to accordance with usual perceived attributes of sensory assessment. Concerning this attributes have to be defined carefully. [15, 16]

As mentioned above, currently morphologic elements of the surface can be identified and the deduced values are well suited to express the visual impression. But relating to all topographical attributes at high gloss surfaces their characteristics need to be further described and analyzed. Hereby it is especially challenging to take into account the different forming of the characteristics, as they prohibit the use of fixed thresholds. This is supported by the already detected correlation between the visual perception and the Motif values [2].

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ADDITIVE MANUFACTURING PROCESSES QUALITY MANAGEMENT

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Abstract
Over the last decades, a number of additive manufacturing (AM) technologies have been developed, some of them well capable of producing not only prototypes but also real parts. The AM processes can be classified according to the type of raw material used. Certain powder bed fusion processes, such as Selective Laser Melting, are capable of processing metals and alloys, which makes them suitable for producing dental structures, amongst other things.
Currently, AM technologies have shortcomings in certain aspects of product quality, as well as process stability. As AM processes hold special premises, such as a huge number of technology specific process parameters, the use of well-established Quality Management techniques is difficult. Nevertheless, the process stability can only be improved by increasing the empirical knowledge regarding the parameters and their influence on command variables of the process. Improving this can lead to an increased applicability of AM and thus result in these technologies achieving a higher market share.

Keywords:
Quality Management, Additive Manufacturing, Quality Parameters, Process Parameters, Process Capability

1 INTRODUCTION

In recent years, a large number of additive manufacturing (AM) technologies have been developed, beginning with the production of prototypes (Rapid Prototyping). The main characteristic of these technologies is the creation of parts directly from three-dimensional CAD data, by additive joining of layers or volume elements [1]. While the first so called Rapid Prototyping technologies were, due to choice of material and resulting mechanical properties, suitable almost solely for producing visual models or prototypes, a number of technologies are also currently eligible for the production of real parts. Because of this, a classification of Additive Manufacturing in Rapid Prototyping and Rapid or Direct (digital) Manufacturing according to the intended use of the product is quite common [2]. Within this paper, the term “Additive Manufacturing” is used to describe the whole field of technologies, as many of them can be used for producing real parts as well as prototypes.

As the production of parts by Additive Manufacturing makes the use of special tools or molds obsolete, AM technologies are appropriate for the production of small lots or unique parts.

2 ADDITIVE MANUFACTURING APPLICATION

2.1 Additive manufacturing processes

The AM process involves a number of steps to progress from a virtual model to a physical part. Although, dependant upon the product requirements, different efforts have to be taken in the single steps, eight generic stages can be identified within each AM process [3] as is shown in Figure 1.

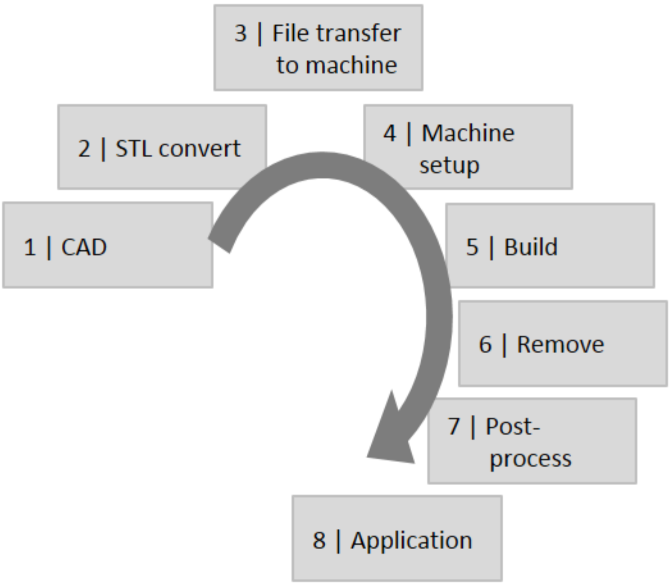

Figure 1: Eight stages of AM processes, according to [3].

AM process performance is always influenced by parameters in each one of these stages, starting from the virtual model over the build process itself to the final application.

While the stages of the AM process are more or less the same for all applications, the fundamental principles of the individual AM technologies differ greatly. Due to this, a classification of the different technologies is required, which most often follows the physical state of raw material used for the building process [2], which can be liquid, solid or gaseous. The solid materials based technologies can be subdivided into powder-based fusing, cutting and adding of laminate material, fusing of solid material or binding of powder. In technical application, the systems using gaseous raw material are currently more often used for coating than for Additive Manufacturing of entire three-dimensional parts. Table 1 provides a summary of the different principles and common examples of technologies.

Table 1: Classification of AM technologies, according to [2].

Classification	*Description*	*Example of AM technology*
Liquid based	Curing of liquid polymers by use of light or laser	Stereo lithography
Solid based	Fusing of powder by use of laser or electron beam	Selective Laser Sintering Selective Laser Melting …
	Cutting and adding of laminate material	Layer Laminate Manufacturing
	Fusing of solid material (Extrusion)	Fused Layer Modeling
	Binding of powder by use of liquid binder	3D Printing
Gaseous	Chemical or physical deposition from aerosol or gaseous phase	Aerosol printing Chemical Vapor Deposition

Within this paper, the focus will be on the powder bed fusion technologies, which create parts by fusion and solidification of powder and, amongst these, particularly on those capable of processing metal powder.

2.2 Selective laser melting

The first commercialized powder bed fusion process was Selective Laser Sintering, which is today suitable for processing thermoplastic polymers and composites of these together with metals or ceramics [3]. Based on this process, various technologies were developed that are able to also process metal powders. One of these technologies is Selective Laser Melting. The basic principle of this method is to spread a layer of powder on a build platform; this powder is selectively fused in the area where the part is to be generated. After that the platform is lowered, a new layer is spread and fused again. This procedure is repeated until the final height of the product is reached and thus the product is generated layer by layer, surrounded by the residual powder. The general construction of a Selective Laser Melting machine is shown in Figure 2.

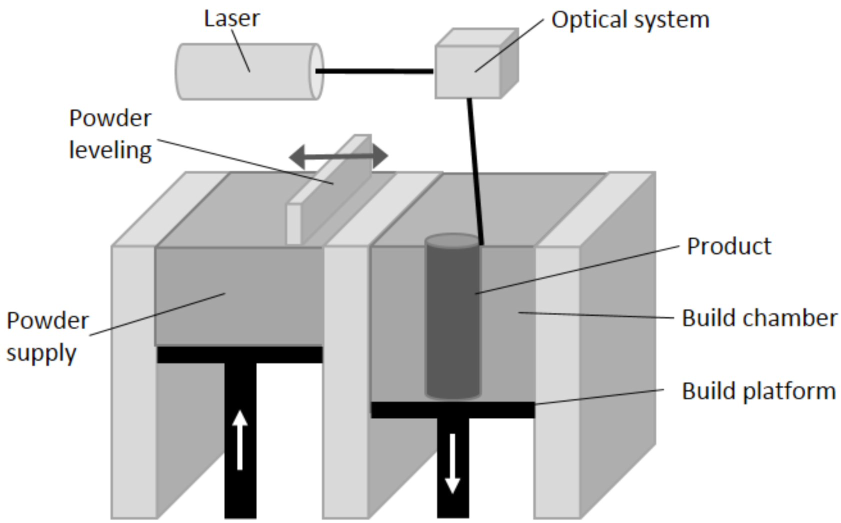

Figure 2: Principle of SLM process, according to [4].

An Yb-fiber laser, with a wavelength of 1030 nm, is usually used to fuse the metal powder. The optical system for positioning the laser beam on the powder bed contains, in addition to the laser itself, x- and y- scanning mirrors for positioning and a so called f-theta lens for correction of the focus length variation in different areas of the build envelope. With this laser beam the powder is completely melted, so that the fusion is based on a liquid phase sintering. In this way, almost completely dense products can be generated.
Contrary to the powder bed fusion of plastics, in metal processing support structures are required, which must be removed after the build process. One reason they are used is that they reduce distortion due to thermal gradients within the part, but the main function is to conduct heat from the part to the build platform, allowing the melt to cool and solidify. The build chamber in Selective Laser Melting is held at room temperature or higher (for further reduction of distortion), but far below the material melting point. For this reason a large amount of energy, up to 1 kW, has to be supplied by the laser source. In order to avoid oxidation of the melt, the process takes place under inert gas.

As “Selective Laser Melting” is a protected term, slight variations of metal processing systems are available under the names of “LaserCusing” or “Direct Metal Laser Sintering”. Another system, called “Electron Beam Melting” works with an electron beam instead of a laser source.
The metal parts produced by these technologies show good mechanical properties and are used in various industries, for example the automotive and aerospace industries and for medical applications. One example for medical application is the production of dental structures for which the suitability of Selective Laser Melting as a production technique is well proven [5].

2.3 State of AM technologies

Compared to traditional technologies such as milling, forging or casting, AM technologies provide a number of advantages [6]: as no molds or tools are needed, AM processes are suitable for the production of small lots even down to lot size one. This enables the use of Additive Manufacturing for the production of customized products in consumer-oriented industries as well as in medical applications. Furthermore, AM technologies allow structures to be produced that are impossible or very difficult to realize with traditional technologies. Products with internal cavities, strictly defined porosity or surface structures are opening up a wide area of application, like production of molds with cooling close to the surface, lightweight products with high mechanical properties or biocompatible structures for implants.
However, AM processes do not only provide advantages. There are also a number of shortcomings to be mentioned when compared to traditional technologies. One of the most commonly stated is a so-called staircase effect on the part surface, Figure 3.

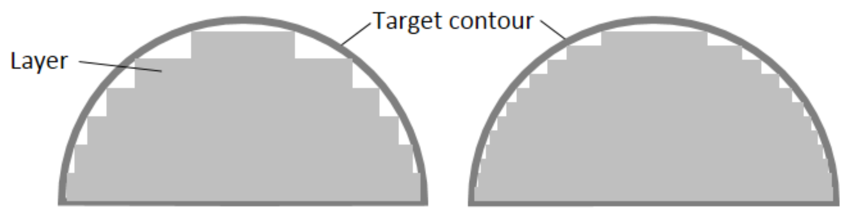

Figure 3: Staircase effect in AM parts.

The staircase effect results from the part being built from layers and depends mainly on the layer thickness. It leads to a deviation of the real surface from the target contour and can also cause insufficient surface quality [7]. Another shortcoming can be identified in the surface roughness,

which is quite high with most AM technologies and particularly derogates the usability of functional surfaces [8].
A look at the AM technology research landscape shows that a huge effort is currently being made to research the topics of material: new materials as well as material quality or material regeneration and recycling, mechanical properties and microstructure manipulation. Process tolerances and process automation are considered far less, although they have also been identified as important research fields [9].

3 QUALITY MANAGEMENT IN ADDITIVE MANUFACTURING

3.1 State of the industry

AM processes currently still have some quality disadvantages, when compared to traditional technologies: product quality, surface roughness and lower dimensional accuracy (which were described in chapter 2.3) are the most prominent of these. Additionally, AM technologies also suffer from a lower reproducibility than traditional technologies, resulting in a lack of process capability.
This, together with single part production, leads to the necessity of inspecting each part produced carefully. Nevertheless, quality control is often limited to dimensional measurement or technological testing methods that were transferred from existing material science methods. In Germany, the testing methods for metal-based powder bed fusion processes are described in the VDI guideline 3405, Part 2 [10], but a national or international standard does not jet exist.
Quality management systems available for AM technologies are limited to monitoring single parameters such as powder distribution, laser power or atmospheric properties inside the build chamber [11]. While these are, of course, capable of monitoring the general operability of the process, their informational value regarding process stability and product quality has not been verified. As the impact of different process parameters on the result is not as clear as it is with the traditional technologies, a lot of expertise is required to produce high quality parts using AM technologies.

3.2 Special requirements

Quality management (QM) activities regarding AM processes are more or less limited to quality control. This does enable fault finding, but not an improvement of the process itself, which requires the use of quality management techniques. For traditional technologies, a wide number of QM techniques are known and well established in industry [12] but, as AM technologies have different premises [13], not all of these techniques are applicable.
With AM technologies the intended use of the produced part has a major influence on the quality requirements, for example, a real part obviously needs different properties to that of a visual model. As AM technologies can

be used in different industries and, depending on the chosen technology, with a wide range of materials, the requirements must not only be considered in the technology choice, but also in part production.
Within every stage of an AM process, various influencing parameters exist. The parameters that directly influence the build process are mainly assigned to the “machine setup” and “build” stages (c.f. chapter 2.1), they are dependent on the technology chosen and will be described according to the example of Selective Laser Sintering and Selective Laser Melting.
The first parameter to mention is the conversion of the three-dimensional data coming from the CAD system, the quality of the data will influence properties such as dimensional accuracy or resolution [14]. Corresponding to this is also the positioning of the parts in the build chamber as, due to the production in layers, the parts usually show anisotropic mechanical properties. Thus, it may become necessary to ensure a particular part orientation to fulfill mechanical requirements.
For the build process itself, the chosen process parameters are paramount. They include the thickness of the single layers, the energy of the beam source, the scan speed, the beam diameter and the exposure strategies [15]. The layer thickness not only influences the shape and prominence of the staircase effect (Figure 3) but also has an important effect on the amount of energy required for melting the powder, the forming of the melt pool and the interconnection between the different layers. This is due to basic physical necessities, as melting a larger amount of material requires more energy and an unbalanced ratio of beam power, scan speed and amount of material may result in the lower layer melting poorly, leading to insufficient interconnection. The forming of the melt pool and its shape are crucial to the generation of AM parts, as the melt has to cover the current part surface precisely without forming droplets. The latter can be caused by a disadvantageous ratio of surface to volume of the melt, which will lead to the formation of droplets to reduce the surface energy.
The beam source intensity, together with the scan speed and the beam diameter, defines the application of energy at each point of the layer. A certain value is required to properly melt all of the powder, but too much energy may result in overflow at the edges of the part, or material evaporation. Additionally, the beam diameter influences the resolution and thus the smallest possible configuration. As other effects may influence the energy of the beam, it is important not only to have the correct setting for the electric energy of the source but also to supervise the influencing effects. The energy of a laser beam, for example, might be reduced by the laser source aging, or by contamination of the optical system, which can reduce the scanning mirrors reflecting capacity or the transparency level of the lenses.
The exposure strategy describes the principle of scanning. To generate a part in each layer, the laser has to scan the contour line of that layer as well as the area within the contour which is intended to become solid, as is shown in Figure 4. The scanning of the inner area usually follows parallel

lines linked with a curve, reminding of hatching in a sketch or drawing. Due to this, the pattern is often called “hatch”.

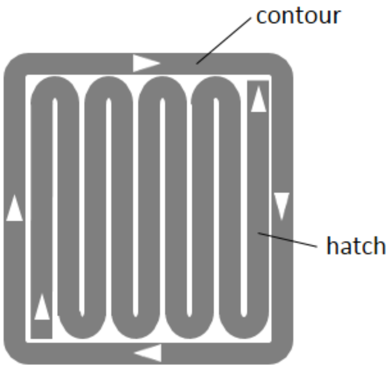

Figure 4: Exposure Strategy Principle.

On the one hand, the exposure strategy describes the sequence of the single elements, such as whether the contour is scanned first and then the hatch or other way round. On the other hand, exposure strategy defines the shape of the hatch; the distance between the single lines, how close the lines and the curves get to the contour and the direction of the lines, the angle of which might be altered with every layer. Not all systems work with a constant, complete scanning of the build area; some prefer more complex exposure strategies. With the definition of an exposure strategy, it is also possible to use different laser powers for the contour and the hatch or even different lasers, which some Selective Laser Sintering machines already have.

Besides the setting of the machine parameters, some environmental factors also have a strong impact on the result. One of these is the atmosphere inside the build chamber as an oxygen content that is too high will result in oxidation of the melt and thus influence the chemical and mechanical properties. Another factor to be mentioned is the average grain size and the grain size distribution of the powder. These will influence the bulk density of the layer and, with this, the porosity of the finished part.

Another very important difference between AM technologies and traditional ones is the material properties generation. In traditional manufacturing technologies, especially those that use cutting or erosive processes, the material properties are defined well before the manufacturing process, as they are a characteristic of the wrought material. In AM processes the physical condition of the material is changed during processing and

therefore material properties are generated with the building of the part. Due to this, the process parameters have a huge impact on the mechanical properties of the part produced [16]. The properties of a raw material are, as a result of this, not always available and because of the influence of the process parameters they are also difficult to determine.
These premises collectively affect the accuracy and the properties of parts produced with AM technologies; they are a result of the accuracy of the whole process and not only due to the accuracy of the machine, as they are with traditional technologies. Together with a lack of empirical knowledge and the use of AM technologies for single part production, which forbids a destructive sample inspection, this hinders the use of many standard QM techniques on AM processes.

3.3 Further development

An increase in empirical knowledge is essential to the further development of QM techniques for AM processes. The influence of different parameters on the command values of the process has to be evaluated in more detail. The most important command values in the use of AM technologies for the production of real parts are the part properties, such as;

- Mechanical properties such as tensile strength or hardness
- Dimensional accuracy
- Relative density and correspondingly, porosity
- Surface quality

Correlations and dependencies have to be identified for these values as well as for the process parameters as described in chapter 3.2. On the one hand, this is required to optimize the settings for each single production job. On the other hand, a proven correlation between different properties can enable the specification of indicators for a capability analysis and quality inspection.
Referring to the special requirements of AM technologies, the process capability has to be substantiated and consequently must be raised if it proves to be insufficient. This should result in more reliable production of high quality parts by use of AM technologies and enable the qualification of these technologies for branches with high standards regarding process capability.

4 CONCLUSION

Though certain AM technologies, for example Selective Laser Melting are, in principle, capable of producing real parts with appropriate physical and mechanical properties, the AM processes still have shortcomings regarding certain aspects of product quality and process stability. To improve this and transfer AM processes to a high level of capability, specific QM techniques have to be applied. As the premises of AM technologies differ from those of

traditional technologies, many of the established QM techniques are difficult to apply. Nevertheless, an increase in available empirical knowledge can enable the development of processes with substantiated and constantly high capability. Reliable high quality part production and a greater predictability of the results, based on more dependable empirical data, can open new markets for AM technologies as higher standards can be fulfilled and the need for the application of expert knowledge can be reduced. A good example is dental structures made by Selective Laser Melting: currently AM is used for the production of dental structures but most often the dental laboratories do not own AM machines, instead they order the parts from a provider who produces them according to their data. In Germany for example in 2011, more than 8.500 dental laboratories existed according to the professional association “Verband Deutscher Zahntechniker-Innungen” [17]. If a further development of AM processes enables the dental technicians to apply AM technologies themselves, a large number of these laboratories can be equipped with AM machines.
The development of specific QM techniques that are applicable to AM technologies, together with further improvement of the technologies themselves can thus result in an increased use of AM technologies.

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X-RAY BASED PROCESS AND QUALITY CONTROL IN WOOD-BASED COMPOSITES PRODUCTION – NEEDS AND BENEFITS

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Abstract
The inline measurement of area density is state of the art within modern production lines. However, a rethinking of the X-ray systems is necessary. Radiation physical requirements on quantitative measurements on inhomogeneous materials have to be met by device setup as well as calibration and data evaluation mode. This contribution shows the evaluation of an optimized measuring device regarding accuracy and resolution under statistical considerations. Furthermore, that implies needs for the mat forming regarding automation and machine engineering as well as process control. If these specifications are fulfilled and capable measuring devices and their data are properly implemented, enhanced panel homogeneity and savings in raw material and energy consumption are feasible.

Keywords:
Metrology, inline measuring device, accuracy, area density, homogeneity, statistical tolerance analysis

1 INTRODUCTION

After the “survival mode” [1] of the past years, the wood-based composites (WBC) industry seems to be in a rather optimistic condition nowadays. Nevertheless, the ongoing increasing shortage of wood as raw material due to the competitive situation with the renewable energy sector and increasing prices for urea and melamine based formaldehyde resins [2] represent the daily challenges. In Central and Western Europe the WBC industry is still minted by overcapacities [3], thus, plants were [4, 5] and will be shutdown henceforth. However, a slightly positive mood [6] is observed in the middle of 2014. A raise of retail prices was gained [7] and “the big 5” expand to Eastern Europe. Similar on supplier side, the German machinery and equipment constructors within the WBC sector have well-filled order books, not only new plants in Eastern Europe and abroad but also modernizations in Europe [8].

The current situation provides the motivation to rethink about proper application of measuring devices and their capability – not only with respect to raw material and energy consumption, but also to enhance quality, reduce property variations and optimize the production process. This contribution will focus on area density X-ray measuring systems utilized within the production process of panel shaped wood-based composites made of resin blended furnish. The homogeneity of the raw density distribution in the plane of such panels is an important quality criterion, i. e, this issue is indispensable to achieve uniform physical and mechanical properties all over the panel. Besides elasto-mechanical processes inside the furnish mat during the hot pressing process (e. g. lateral expansion) the mat forming prior to the press is responsible to meet these requirements. Furthermore, the mean raw density of the finished panel is an important target value for process control. A precise material dosing is necessary to reach the mean target density within narrow bounds and to achieve possible savings. Thus, controlling the area density as a process parameter is essential.

2 INLINE X-RAY MEASURING DEVICES

2.1 Application

Inline systems, which determine the area density or by known thickness the raw density of the material by means of ionizing radiation, such as X- and gamma ray, are industrially utilized for decades. First scientific investigations by [9] conclude an advisable industrial application for process control. Henceforth, practice oriented investigations point out the necessity of appropriate measuring devices to achieve cost savings, cf. [10, 11]. Today, the application of X-ray measuring devices is state of the art to measure the area density nondestructively and inline, particularly prior to the hot press, and common within the wood-based composites industry. Such systems can be installed behind the pre-press observing the whole furnish mat (Figure 2) or implemented between the respective forming machines to distinguish between surface and core layer area density, especially in particle board production. Further radiometric devices can be installed behind the hot press to observe the area density or raw density, respectively. Their setup is slightly different from the traversing systems in front of the hot press (Figure 2), e. g. several tracks of stationary detectors, but the radiation of physical considerations explained below are similar.
Inline X-ray measuring devices are available from the manufactures below:

- Electronic Wood Systems GmbH, Hameln, Germany (EWS),
- Fagus-GreCon Greten GmbH & Co. KG, Alfeld, Germany (GreCon),
- IMAL S. r. l., San Damaso (Modena), Italy (IMAL).

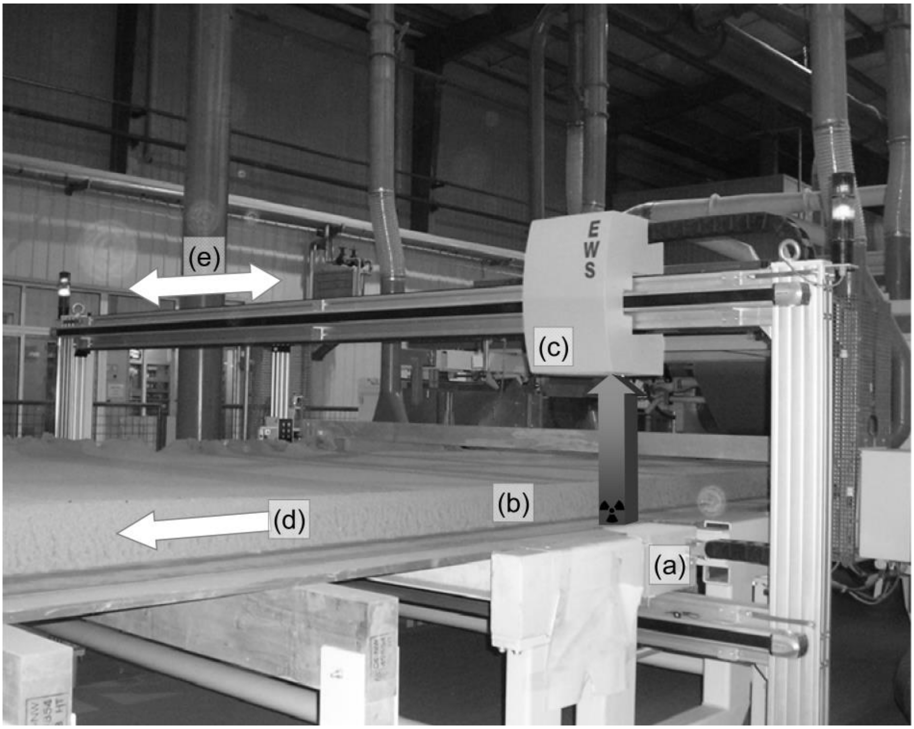

Figure 2: Area density gauge installed between pre-press and hot press, with (a) X-ray source, (b) furnish mat (MDF), (c) detector, (d) production direction, (e) traversing across the width (source & detector in sync), [12] with own captions.

All types of inline systems and their measuring results reveal a varying deep integration into the individual process control and quality assurance systems depending on WBC type and plant performance. However, the result validity of present radiometric devices is overestimated so far, how [13] already point out for X-ray raw density profile measurement in the lab. The displayed figures rather provide comparative than reliable absolute values and allow at best an estimation of relative tendencies within the production process.

2.2 Setup, parameters and properties

The commonly applied inline X-ray measuring systems for area density distribution show particular differences, of course. Their general setup, on the other hand, is similar regarding devices with a traversing pair of radiation source and detector. There, the source beneath the forming belt (see (a) in Figure 2) emits ionizing radiation, which penetrates the furnished mat (b). Passing through material, the radiation intensity is diminished. Afterwards, the attenuated beam hits the detector (c). The radiation attenuation follows an exponential function, commonly known as Beer's law

$$I = I_0 \cdot e^{-\frac{\mu}{\rho} \cdot t \cdot \rho} \quad (1)$$

With transmitted I [-] and initial intensity I_0 [-], mass attenuation coefficient μ/ρ [m²/kg], material thickness t [m] and the raw density ρ [kg/m³]. The mass attenuation coefficient μ/ρ is an energy- and density-depending as well as material-specific physical quantity corresponding to the diminution of the radiation intensity inside the material. With the context between density ρ, thickness t and area density ρ_A [kg/m²]

$$\rho_A = \rho \cdot t \quad (2)$$

The dependency of the transmitted radiation intensity from the area density becomes obvious in Beer's law

$$I = I_0 \cdot e^{-\frac{\mu}{\rho} \cdot \rho_A} \quad (3).$$

The measuring signal commonly appears as the ratio of transmitted to incident radiation intensity I/I_0 [-]. The consequential computation of the area density requires a calibration with a sample of known measures and weight under consideration of the forming belt. The familiar practical way, therefor, is the use of a ready pressed WBC panel to determine the mass attenuation coefficient μ/ρ, so far. Investigations of [14] show the invalidity of this procedure in case of area density measurement on just pre-densified furnished mats. According to [15] equation (1) and (3), respectively, cannot directly be applied in case of polychromatic radiation (such as X-ray) due to energy dependency of the mass attenuation coefficient. As a consequence of further radiation physical effects occurring in inhomogeneous material (e. g. Compton scattering, beam hardening), as well, deviations of the measuring results from the regular attenuation behavior have to be expected. These insufficiencies are considered by an optimized calibration mode in section 3.1.

As far as known, current inline devices are operated in an energy range <50 kV. The choice of an appropriate energy is suggested by [9] and [16], similarly, to minimize the device specific measuring failure in case of validity of equation (3). Due to the energy dependency of the mass attenuation coefficient μ/ρ, the energy has to be chosen considering the actually measured mean area density ρ_A to meet the condition

$$\left(\frac{\mu}{\rho}\right)^{-1} = 1...1.5 \cdot \rho_A \quad (4).$$

The respective mean energy of the X-ray spectrum can be assumed according experience, estimated (cf. [17]), and simulated (cf. [18] or measured (cf. [19]). Comprehensive tables of the mass attenuation coefficient are commonly known from [20]. Further X-ray spectra

considerations, like [21] do, are necessary as well. For the attenuation by aluminum they observe a linear slope of the relationship between $\ln(I_0/I)$ and ρ_A representing equivalent μ/ρ. Due to the inhomogeneity of WBC, this context is subsequently not directly applicable to area density measurement of furnished mats. However, it is unclear how these radiation considerations are individually implemented by the device manufacturers.
On detector side, two techniques are common for this measurement task, i. e. scintillators with digital cameras or photomultipliers as well as semi-conductive solid-state detectors (cf. [22]). They differ regarding sensitivity (esp. against low energies and intensities) and signal processing performance.
Non-radiometric parameters are rather fuzzy represented by the manufacturers. Resolution belongs in the data sheets mostly to geometrical considerations. High spatial resolution in the millimeter range is advertised but, critically reviewed, 50…100 mm segments in panel width are quite sufficient and no metrological challenge. The resolution of the measurement result, i. e. the distinguishability between area density values, and the accuracy are more important. Furthermore, actual gauge capability parameters (e. g. c_g, c_{gk}) are not provided by manufacturers so far.

3 EVALUATION OF AN OPTIMIZED AREA DENSITY GAUGE

3.1 Calibration and data evaluation

The first rethinking of area density gauges was done by [14]. He enhanced the measuring accuracy carrying out the device calibration by the fiber mat instead of the ready pressed panel, common so far. According [13] calibration and data evaluation mode has to meet the requirements given by material and radiation properties.
Considering these experiences and common approaches, cf. [21], for radiometric area density determination, an optimized X-ray measuring device was developed prior to the measurements of the following section. This multiple energy system allows the choice of X-ray energy range and spectrum (automatically) according to area density range. The respective calibration data and data evaluation algorithms are stored in the gauge controller. The calibration data were acquired by stacks of fixed thin furnishes mats with predefined area densities and raw densities.
For the investigations below, the following setup was applied:

- X-ray tube (up to 65 kV, 40 W) with tungsten target,
- radiation pre-filters on demand,
- one of the most common forming belts,
- Scintillator with photomultiplier as detector.

3.2 Measuring signal considerations

To determine the achievable accuracy and measurable resolution, i. e. the distinguishable area density, the confidence limits of the measurement have to be computed. Therefore, the spread of the measuring signals (count rates, i. e. counts per period cpp) was evaluated. The measurements were done over the whole range of the multiple energy system with an integration time of 3000 ms. Data from <25 kV tube power level is exemplary presented. With this energy preset and the described setup, a narrow X-ray spectrum with peak energy of 13 keV (measured) is obtained. Thus, area density measurements in the range $\rho_A = 3 \ldots 5$ kg/m² are feasible according equation (4).

After system warm-up, energy adjustment and an appropriate waiting time, measurements of the initial I_0 and transmitted I intensities were carried out. A specimen, cut out of a homogeneous lab panel (no raw density profile, fibers, UF resin), with $\rho_A = 4.5$ kg/m² and $\rho = 400$ kg/m³ was used for defined attenuation of the radiation. The count rates were read from the gauge controller in sequence ($n = 30$ each). Figure 3 shows the measured count rates and their expected Gaussian distribution of transmitted and initial signal. The summarized data are given in Table 3.

A χ^2-test under expectation of Gaussian distribution with the same parameters as the measured data showed that the condition is fulfilled in case of I. For I_0 the hypothesis has to be rejected. But the result is quite close to the critical value and with more measurement iterations the expectation might be proved. Thus, a Gaussian distribution with the observed parameters in Table 3 is assumed for all measuring signals.

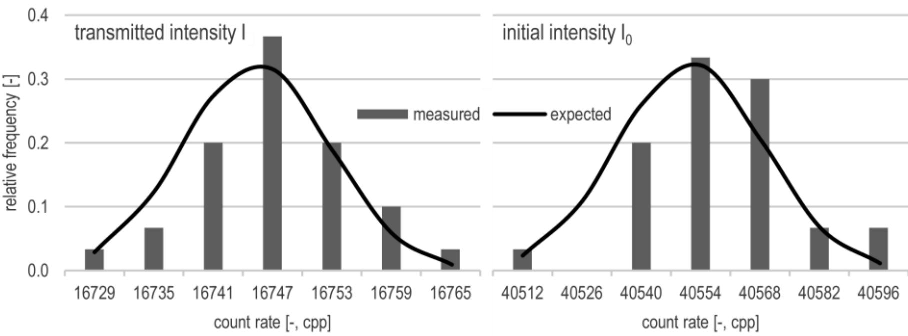

Figure 3: Histogram and expected Gaussian distribution of the count rates of transmitted and initial intensities ($n = 30$) on <25 kV level.

Table 3: Summarized measuring data of the count rates of transmitted and initial intensities on <25 kV level.

n = 30	min [-, cpp]	mean [-, cpp]	max [-, cpp]	range [-, cpp]	s [-, cpp]	CV [%]	±3s range [-, cpp]
I	16729	16745.3	16762	33	7.4	0.044	44.4
I_0	40512	40551.6	40589	77	17.3	0.043	103.8

3.3 Statistical approach

A Gaussian shaped distribution of the measured count rates within a certain range was observed, whereas the occurrence of limit values is highly unlikely. Thus, a worthy statistical approach, generally used for high sophisticated tolerance analysis, is applied as follows.

Basically, it is just a matter of mathematically precise superimposing the statistical distributions of the count rates of I_0 and I to compute the resulting spread of the measuring result and its statistical distribution. These are typical considerations of statistical tolerance analysis and the subsequent convolution of distribution functions. This method investigates according [23] interacting single tolerances regarding the resulting function of the considered assembly and can be applied to other measured variables, cf. [24]. The approach is adapted by [25] to take swelling and shrinkage explicitly into account of wood related tolerance calculations, as well. Therefore, not maximum and minimum values are added (no worst-case limit consideration) but the assumed distributions of observed data are taken into account. The comprehensive computation is carried out computer aided with input data as histogram or probability density function and the numerical solution of the convolution integral. Furthermore, a simplified calculation assuming Gaussian distributed results exists by means of the Gaussian failure propagation law

$$s_{tot}^2 = \sum_{i=1}^{k} s_i^2 \quad (5),$$

where, the empirical total variance s^2_{tot} equals the sum of the empirical single variances s^2_i. In case of a general functional context f, the total differential has to be adapted, to linearize equation (5) by the respective squared partial derivation

$$s_{tot}^2 = \sum_{i=1}^{k} \left(\left. \frac{\partial f}{\partial x_i} \right|_{\bar{x}_i} \right)^2 \cdot s_i^2 \quad (6).$$

Hereafter, this approach is adapted to combine the distributions of measured count rates and to compute the subsequent spread as range of area density.

However, it is also common within metrology (cf. [26]) to evaluate measuring failures occurring from several influence factors by failure propagation calculations.
The functional context f, i. e. the measuring signal, for the following statistical considerations is defined as the logarithmic ratio of the intensities

$$f = \ln\left(\frac{I_0}{I}\right) \tag{7}$$

in terms of equation (3) and furthermore evaluated according the very same by means of known μ/ρ. Hence, the partial derivations are

$$\frac{\partial f}{\partial I_0} = \frac{1}{I_0} \quad \text{and} \quad \frac{\partial f}{\partial I} = -\frac{1}{I}.$$

According equation (6) with the mean values and standard deviations from Table 3 the total standard deviation s_{tot} [-] of the measuring signal of the observed <25 kV energy level equals 0.00061 or the total coefficient of variation CV_{tot} [%] equals 0.069 %, respectively, with a mean [-] equals 0.88446. Under application of equation (3) and a pre-determined μ/ρ, the spread as range of area density considering a probability of 99.73 % (±3s of the estimated Gaussian result distribution) can be computed as ρ_A = (4.5 ± 0.0094) kg/m². More general, the fluctuations of the count rates on the observed energy level lead to variations of the measuring results in the ±3s range equals ±9.4 g/m² or ±0.208 %.
A worst-case computation considering the ±3s range of the measured intensities (Table 3) leads to a respective range of the measuring result equals ±13.3 g/m² or ±0.295 %. Thus, in comparison to the statistical results a reduction of the range of 29 % by the applied statistical tolerance analysis approach can be obtained.

3.4 Practice oriented implications

The above computed limits represent the uncertainty of the area density measurement on <25 kV energy level with the mentioned setup. Figure 4 shows a plot of the assumed Gaussian result distribution of the area density and makes the difference between statistical and worst-case results (ranges) more obvious. Hence, the occurrence of limit values is highly unlikely and a statistical consideration is the subsequent method. Furthermore, if the certainty is reduced to, e. g, a still acceptable value of 95.44 % (±2s), the range of the measurement uncertainty can be decreased to ±6.3 g/m² or ±0.139 %, which is less than half of the worst-case limits.

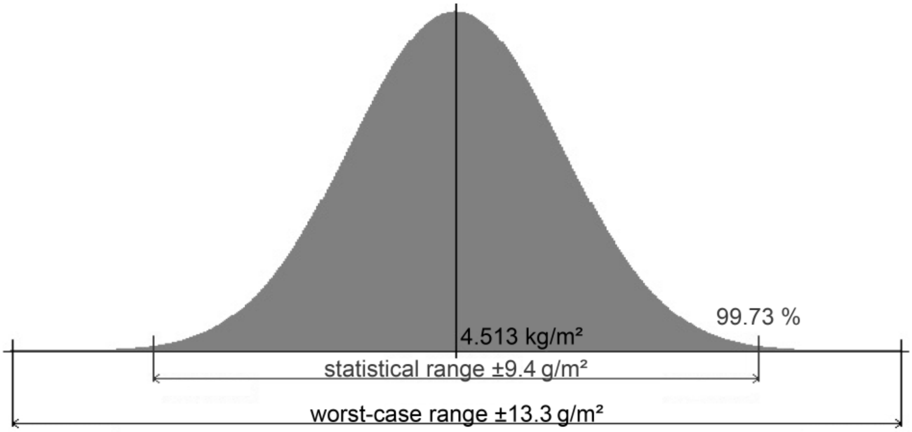

Figure 4: Plot of the assumed Gaussian result distribution of the area density, with mean and ranges (limit deviations), determined under statistical (99.73 % probability) and worst case considerations.

The resolution of the measurement result could theoretically be increased to infinity by extending the number of digits of the displayed area density, because the value is computed out of the measuring signal via the stored calibration function. Nevertheless, the reliable distinguishability between area density values lies above the determined measurement uncertainty. Thus, a feasible resolution is subsequently a multiple of the theoretically determined limit deviation. Below this value, a displayed change can only be due to chance.

The real measuring sensitivity should rather be determined via experiment, which is nontrivial in practical realization and includes undefined uncertainty due to the inhomogeneity of the measured furnish material. Hence, the sensitivity and the subsequent resolution of an X-ray area density measuring device have to be derived from the explained theoretical basis. However, the achievable measuring accuracy, which depends on appropriate device setup and energy selection, is rather of practice oriented interest. Furthermore, the above exemplary determined values can be enhanced by increasing integration time of the measurement, i. e. traversing frequency of the device. On the other hand, the measuring velocity can be accelerated accepting a slightly lower accuracy.

4 CONCLUSION

4.1 Needs

The forming machines and their preceding supplying devices are responsible for accurate metering and uniform spread of furnish on the forming belt. Further importance of mat forming is pointed out by [27]. Requirements on mat forming are given by [28], according to which a capable process should lead to a homogeneous material distribution with CV < 4 %, i. e. for a 4.5 kg/m² mat a range of ±0.36 kg/m² or ±8 % (±2s, 95.44 % certainty) and ±0.54 kg/m² or ±12 % (±3s, 99.73 % certainty). A CV > 6…7 % represents a forming process out of control. Similar values are given by [29]. At this time (1995), ±4 % deviations in transverse area density profile caused by mat forming were guaranteed. Additionally, deviations along production feed direction occur. He [29] further points out, that mat forming differences lead to effective loss in material. The context has not changed, but reliable values for achievable accuracy are lacking currently. Only unofficial information from machinery and equipment constructors for mat forming accuracy is known in the range from

$$\frac{10}{\sqrt{panel\ thickness}} \text{ to } \frac{14}{\sqrt{panel\ thickness}} \text{ [\% forming weight].}$$

Thus, for a 4.5 kg/m² panel with a possible thickness of 7 mm values between 3.8 %...5.3 % could be achieved (but unknown certainty range).
Requirements on process control metrology are already given by [30], where area density measuring devices for particle board production should be contactless and continuous with an accuracy of ±1 % (unknown certainty as well). Furthermore, there are still conventional electromechanical mat or panel weighing systems in use, occasionally of old manufacturing date. These devices apply huge scale platforms directly within the forming machines and behind the pre-press (both furnish mat) as well as behind the hot press (finished panel). Their considerable disadvantages are:

- high tare weight compared to weighed portion (especially thin panels),
- high feed rates cause increasing vibrations,
- only mean area density of the whole panel (no distribution).

The accuracy of such electromechanical scales is reported by [27] to be better than ±2.27 kg for the scale itself resulting in mat weights control of about ±6.82 kg. E. g, a 4.5 kg/m² panel with typical full size dimensions of 5.6 × 2.07 m² has a weight of 52.2 kg. Thus, the relative scale accuracy is in the range of ±13 % for such a light panel. In comparison, [27] quantifies also the accuracy and resolution of nuclear gauges at that time with ±54 g/m² (mean 2.44 kg/m²), i. e. ±2.2 %, which seems doubtful from the present point of knowledge.
As contributed, optimized measuring devices are able to provide process control with data of high accuracy and reliability, because their measuring uncertainty is more than a number of magnitudes lower than the achievable

forming accuracy. Now, the data has to be implemented into process control loop. Hence, the forming machines need enhanced automation and machine engineering. Therefore, appropriate technical conditions, especially for particle board mat forming, where most adjustments are handmade, have to be established. First suitable approaches exist already for fiber mat forming, e.g. with a segmented scalper introduced by [31].
Current gravimetric reference method for area density determination is to cut samples $100 \times 100\ mm^2$ across the panel width, weight and measure them in the lab. This is appropriate for the conditioned panel. A direct implication on the formed furnish mat is not possible because the effects of elasto-mechanical processes inside the furnish mat during hot pressing (e. g. lateral expansion) and the formation of moisture gradients can only relatively be considered. Sampling from the uncured total furnish mat is only possible in case of particle board production, but time-consuming and costly with a long segmented box over the mat width. Thus, if the customer needs a gravimetric reference for the actual area density distribution of the furnish mat, an appropriate procedure has to be developed.

4.2 Benefits

The well-designed multiple energy system for X-ray based area mass determination allows specific applications regarding the measured range with equivalent accuracy. Thus, appropriate control of each forming machine of a particle board production line is executable, for instance. Low measuring uncertainties are the basis for high resolution, i. e. fine distinguishability of the area density distribution, which is indispensable to achieve uniform physical and mechanical properties all over the panel. More reliable properties and panel performance are subsequent valuable benefits for the customers.
However, all these measuring data are only worthy if the process control loop is closed. Thus, the respective automation and machine components have to meet the requirements, mentioned above. Furthermore, a higher measuring velocity enables to shorten the response time. A more uniform and capable mat forming process would be the result. Increasing homogeneity across the panel plane facilitates to avoid oversizing in general. Henceforth, overall savings in raw material (furnish and resin) and energy consumption, thus in production costs, while keeping the required mechanical properties, or even enhance them, are feasible. Furthermore, reliable measuring data improves the basis for panel property simulation and statistical process modelling.

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LIFE-CYCLE ASSESSMENT OF A WOOD PRODUCT FOR OUTDOOR USE SUBJECT TO THREE DIFFERENT TREATMENTS

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Abstract
The paper reports the results of a life-cycle study of a pole made of pine wood for outdoor use which was exposed to three treatments aimed to counteract the bio-degradation of wood: impregnation, thermal treatment and acetylation (chemical modification). Impregnation is the most common treatment used to improve the durability of wood and the other two can be considered as “alternatives” not involving the use of biocides which can be potentially dangerous for the human beings. Nevertheless the overall environmental performance of such treatments has been hardly investigated, even if this aspect can be critical in order to select the most appropriate technology. In the specific case, a comparison of the three treatments was performed by means of the assessment of the impacts determined during the process to obtain finished products of comparable quality.

Keywords:
wood, life-cycle, environmental impact, timber treatment

1 INTRODUCTION

Wood is a natural material of organic composition. It is consequently sensitive to biological decay as some living organisms are able to use it as a source of nutrients or as refuge [1]. The natural composition of wood is then not compatible with the use of such material in outdoor environments as it is exposed to severe degradation agents normally starting their activity when the moisture content of wood is above the 20% (fungi), with a temperature between 10 and 40°C. Destructive fungi, blue stain fungi, insects and marine organisms can find a favorable substrate for their growth, while the ultraviolet rays, being part of sunlight, decompose the lignin by complex photochemical processes producing low molecular weight substances which are then easily leached being highly soluble in water [2]. As previously reported, one of the most important factors contributing to wood decay is represented by the moisture content of wood.
In order to protect wood products used in outdoor environments from the negative effects of such agents, wood shall be subjected to specific

treatments with the aim to directly counteract the biological aggression (use of preservatives) or to prevent the possible colonization of wood by such living organisms, by limiting the water sensitivity of this material (wood modification).

Accordingly, wood treatments can be considered as “passive” when they modify only the properties of this material without altering its chemical composition (impregnation). On the other side, the “active” treatments are all those which “modify” the chemical nature of wood. These treatments (thermal and chemical) produce a different material known as “modified wood”.

Modified wood can be defined as the result of a chemical, physical or enzymatic treatment, so that wood is improved in some of its properties such as biological resistance, dimensional stability and resistance to aging.

As previously reported, several treatments are commonly used to improve the durability of wood; however, their overall environmental performance has not received much attention in the existing scientific or technical literature. This fact is in contrast with the recent methodologies of process analysis and assessment, which underline that this aspect can be critical for the selection of the most appropriate technology. The paper reports the results of a life-cycle assessment (LCA) study of a pole made of pine wood for outdoor use which was exposed to three treatments aimed to counteract the bio-degradation of wood: impregnation, thermal treatment and acetylation (chemical modification). The study is a preliminary analysis aimed at assessing the environmental burden of the treatment process and not the final product. Therefore, the environmental impact discussed in this article is related to one impact category (Global Warming Potential – GWP). The next section will outline the three processes. Section 3 will describe the materials and methods that were employed for the LCA study. The results are presented and briefly discussed in Section 4, and some conclusions are proposed in Section 5.

2 THE INVESTIGATED TECHNOLOGIES

2.1 Wood impregnation process

Wood impregnation, unlike thermal and chemical treatments, does not involve a real modification of the substrate: it is a process designed to transport and fix preservative substances within the wood bulk, without altering its chemical nature. The impregnation processes are based on the principle of the penetration of various types of substances within the porosities of the substrate. The impregnation product, normally a water dispersion, contains one or more biocides, various types of resins and also pigments and additives [3].

The most common impregnation processes are those based on an autoclave treatment, allowing a very deep penetration of the preservatives into the wood structure, in such a way as to make it resistant to biological attacks. As already reported, the impregnating plant is made by an autoclave superimposed to a tank; the latter contains the impregnating liquid, while the autoclave is the place where wood is treated. During the cycle, the impregnating liquid passes from the tank to the autoclave, which already contains the timber, and, after having carried out the impregnation, the excess returns to the tank. The system operates using a maximum vacuum of -0.97 bar and a hydraulic overpressure of 12 bar. The process duration is variable and depends on the characteristics of the wood species used, the thickness of the material, the moisture content and the quantity and concentration of the employed preservative salts. Only the use of vacuum/pressure technology in the autoclave allows applying pigmented products with high solid content (12-30%), achieving a complete protection of the material. The main steps of the impregnation cycle are reported below:

1. Initial vacuum: a forklift truck loads the woodpile onto the automatic loading system of the autoclave. Then, after the closing and complete the sealing of the door the impregnation cycle starts, with the initial operation of the vacuum pump. The duration of this initial phase can vary from 30 to 90 minutes depending on the characteristics of the wood species.
2. Filling: the depression obtained is used to convey the treatment solution from the tank placed on the bottom to the autoclave.
3. Application of pressure: the aim of this step is to “force” the solution into the wood bulk. The operation of the pressure pump can vary from 30 to 180 minutes depending on the characteristics of the material.
4. Discharge of the solution through a drain valve on the bottom of the autoclave; the solution which has not been absorbed by wood comes back into the tank, allowing to reuse it for a new cycle, without any waste. Automated systems control the concentration of the preservative and adjust it to the optimum level for a new impregnating cycle.
5. Vacuum recovery: a further vacuum phase, lasting 20-40 minutes, fixes the active ingredients into the wood.
6. End of cycle: the autoclave is brought back to atmospheric pressure and the impregnated wood is then ready to be extracted and sent to the following shipment.

2.2 Thermo-treated wood

The process that produces thermo-treated wood is a heating treatment: timber is subjected to a heat treatment inside an oven, which modifies its chemical composition and consequently its physical and mechanical properties [2]. During the treatment, wood is subject to a high temperature cycle, varying between 180°C and 220°C, in a controlled atmosphere, poor of oxygen. The treatment conditions, temperature and duration of the process, can vary leading to final products with different characteristics [4].

During heating, lignin and hemicellulose undergo to degradation and polymerization; these processes involve the formation of low molecular weight chemical species and highly reactive phenolic radicals. Such modifications of wood composition reduce its water sensitivity, consequently improving its dimensional stability. On the other hand, wood becomes more fragile and less resistant to mechanical stresses. The increase or decrease in hardness depends on the wood species considered, the test direction, the temperature and duration of the treatment. The condensation reactions (esterification) of cellulose induced by high temperatures, explain the hygroscopicity reduction and consequently of the conditions for a possible molds attack, which occur with a moisture content exceeding 20%. The improved resistance to microbiological attack, compared with the natural durability, is one of the most significant benefits that the treatment causes [2]. However, the above mentioned decrease of mechanical properties excludes the possible use of thermal treated wood for structural applications. The heat treatment, the duration of which depends on the wood species considered, is normally carried out in the six steps reported below.

1. Heating: by a gradual increase, varying between 2÷8°C/h depending on the type of material and its thickness. The temperature is brought to 100°C in the presence of controlled humidity both in the oven and in the wood bulk.
2. Heating at high temperature: this step brings the material to a temperature of 180÷210°C, the latter being the value used in case of material intended for elements of high durability and resistance to biotic and abiotic stresses. The pressure inside the oven is kept constant for a period between 10-35 hours.
3. High temperature treatment in the oven: the material remains at the desired temperature for the time necessary to the treatment, which can vary between 1.5÷6 hours.
4. Cooling: the material is brought to 100°C inside the oven with a descent speed of 6÷10°C/h.
5. Conditioning: keeping the temperature constant at 100°C , the final moisture content of wood is increased in accordance with the final needs normally in the range 6÷9%; this phase may last 4-14 hours.
6. Cooling: wood temperature is decreased from 100°C down to ambient temperature.

2.3 Acetylated wood

The acetylation of wood is a chemical treatment that unlike impregnation does not involve the use of any harmful substance [2]. Wood contains a large amount of polar chemical groups (hydroxyl), which are responsible for the absorption and release of water according to the climatic conditions where wood is exposed.

Moreover the assimilation of wood by the enzymes, which are present in the microorganisms responsible for wood decay, takes place just at the level of hydroxyl groups. The acetylation is a chemical reaction directly involving the hydroxyl groups of the cellulose and forming new covalent bonds. The final result is the transformation of the free hydroxyls into acetyl groups, by the reaction of wood with acetic anhydride [5]. When the hydroxyl group is transformed into acetyl group, the ability of wood to absorb water significantly decreases, improving its dimensional stability and durability. In other words, acetylation can be considered a sort of “passivation” of water-sensitive chemical groups, by an esterification reaction [2]. It can be also mentioned that the acetyl groups, which are composed of oxygen, hydrogen and carbon, are already naturally present in all wood species (e.g. as free acetic acid). The final product does not release dangerous chemicals in the environment: it’s only by-product is represented by a small amount of acetic acid, which can be reused or recycled.

By altering the chemical structure of wood, rather than simply change the chemical content, it basically creates a "new wood species"; on the contrary, other common treatments are limited to introduce chemicals into the wood bulk.

The acetylated wood has been tested with all kinds of weather conditions, inside the soil, on its surface and even soaked in water, showing great resistance to weathering, great natural durability (excellent resistance to fungi and insects) and excellent compatibility with the environment (the product is 100% recyclable). The process is made up of the following four phases [6]:

1. the timber is initially dried, to avoid a greater consumption of acetic acid, and then sent to the reactor to start the acetylation treatment;
2. acetylating treatment, wherein the wooden material comes into contact with the reagent consisting of acetic anhydride with a concentration of 30-40% and the temperature is between 110-140°C. The contact time of the material with the reagent is about 15-30 minutes, which varies depending on the size of the material to be treated;
3. the reactor heats the wood up to a temperature of 120°C, promoting the acetylation reaction. The increase in weight, which can reach the 30% of the initial value of the product, is due to the bonds of acetyl groups with cellulose. The time required for this stage varies between 2-5 hours depending on the size of the cross section of wood;
4. removing the remaining mixture of acetic anhydride and acetic acid, formed during the chemical reaction . The reactor brings the temperature to 195°C for 1 minute and an extractor recovers the excess which will then be reported to the liquid state. The separation of acetic anhydride from acetic acid will occur at a later time by distillation. The acetic acid recovered is converted, through a chemical reaction, in acetic anhydride which will be pumped back into the reagent bath for a new acetylation cycle.

3 MATERIALS AND METHODS

3.1 General aspects

In order to compare the environmental burden of the three above mentioned treatments, three models of the life cycle of a finished product (a pine wood pole) were created. The models do not include the whole life cycle (i.e. ‘cradle to grave’ [7]), but only the stages from wood processing at the plant to the end-of-life of the product (‘gate to grave’ [8]). The aim of this study is a first assessment of the three processes; in this view, the final product is not analyzed in detail from an LCA viewpoint. The study is focused on one impact category, GWP, in order to evaluate the environmental performance of two energy demanding technologies (thermo-treatment and acetylation) compared with a traditional one. The results should not be considered exhaustive as other impact categories can be affected by the technologies. The normalization of impacts was performed through the CML 2001 method (GWP 100 year) and by means of the GaBi 5 package. It is worth remarking that the models included material flows, water consumption and energy consumption, but the diagrams here provided show only the main flows expressed in kilograms.

3.2 Preservative-treated wood model

The impregnation was carried out in an autoclave system. The oven was loaded with 2.2 tons of pine wood poles corresponding to 2.587 m^3 of wood material. The preservative is an aqueous solution (at 2% concentration) of Cu-amine salt (Impralit®-KDS). The total duration of the impregnation cycle was 4 hours with a consumption of 21kW of electric power. 260kg of the solution were retained by poles while the remaining part was recovered and stored in a container connected to the cylinder so as to be used for another cycle. It was assumed that the finished products have an operating life of 15 years. Two different life-cycle models were investigated. In the first model, it was assumed that the product was directly processed at a high temperature incineration plant at the end of its operating life (Figure 1). In the second model, the product, after 10 operating years, was submitted to a brush treatment and, after another 5-year period, sent to an incineration plant (Figure 2).

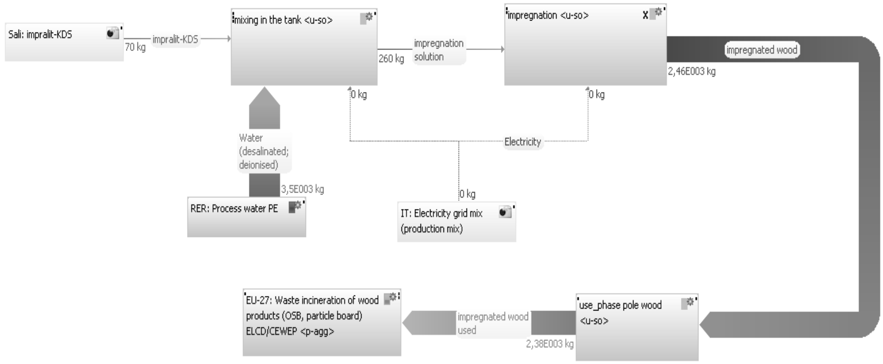

Figure 1: First model of preservative-treated wood.

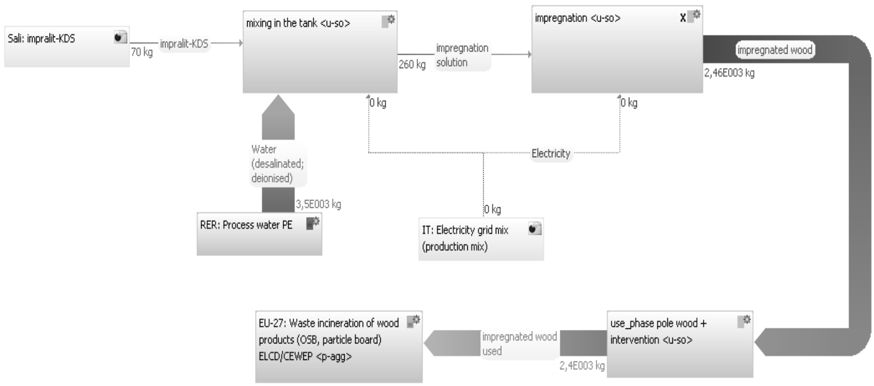

Figure 2: Second model of preservative-treated wood.

In this preservation treatment, the unit of product is subjected to a pressure and vacuum process, so no emissions are virtually released to the environment [9]. Furthermore, in the present study, leaching of the preservative during the product life-cycle was not consideration because the quantification of material released should have been highly accurate in order to assess reliably the environmental effects [10].
As for the CO_2 emission, the employed database provided the absolute values (kg of carbon dioxide equivalent - CO2e) related to the three relevant stages of the life-cycle (Figure 3): electricity grid mix, process water and waste incineration of wood products. Emissions are mainly produced by the incineration process: this method of disposal is necessary because, according the European Biocidal Products Directive of 1998, wood treated with copper-based preservatives cannot be recycled.

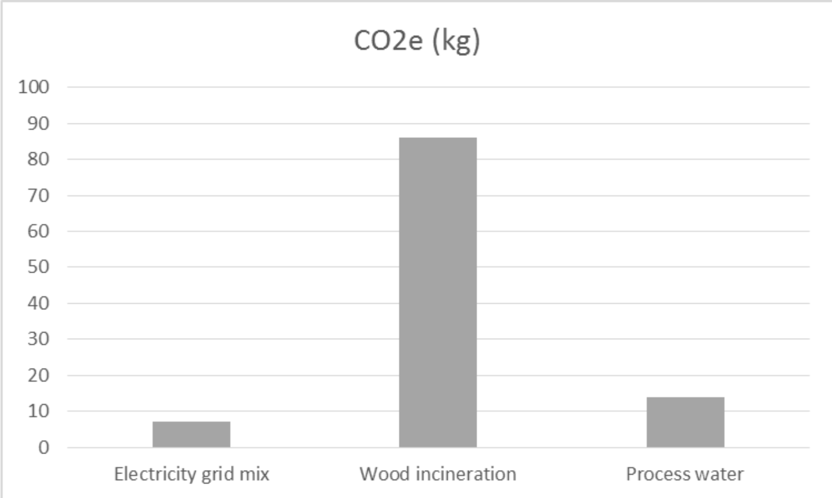

Figure 3: CO2e emissions for preservative-treated wood.

3.3 Thermo-treated wood model

This model is mainly based on process data included in the employed database. Therefore, even if the quantity of processed pine wood is the same as in the previous model (2200 kg), energy consumption and cycle time should be considered average figures which do not correspond to a specific process. Figure 4 illustrates the life-cycle model. In this case, recycling of wood material is possible (e.g. in order to produce particle board) because the treated wood does not contain toxic or noxious substances.

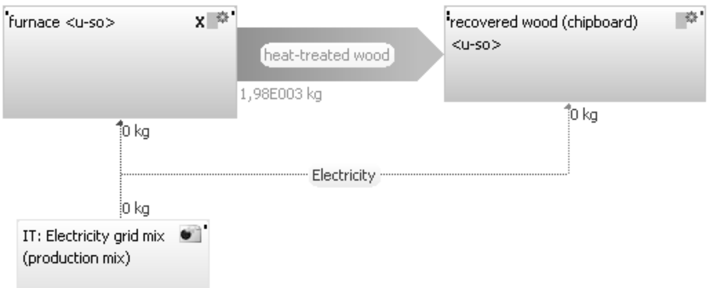

Figure 4: Model of thermo-treated wood.

3.4 Wood acetylation model

This model (Figure 5) is mainly based on process data included in the employed database and on literature data [6, 11]. The quantity of processed pine wood is the same as in the two previous models (2200 kg). It is worth noting that this technology is not presently diffuse because of its high cost which may justify its use only in case of very high production volumes. Also this treatment make the recycling of wood possible as the processed material does not contain toxic substances.

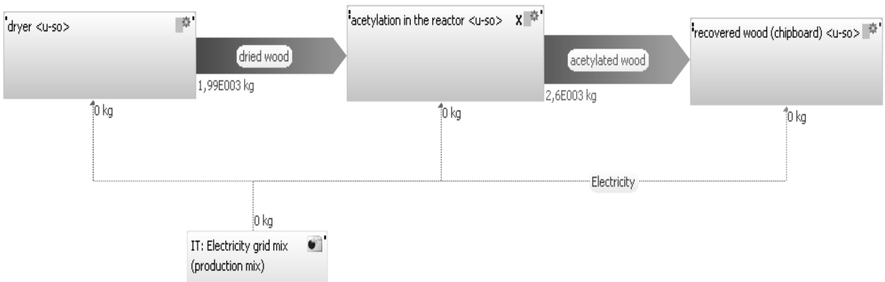

Figure 5: Model of the acetylated wood.

4 RESULTS AND DISCUSSION

The results obtained make it possible to identify some factors which should be taken into consideration in choosing the most effective technology. The chemicals absorbed by wood in the pressure-vacuum process are possibly released to the environment and, at any rate, hinder recycling; it is therefore necessary to treat the product at the end of its life-cycle by incineration. On the other hand, thermal-treatment and acetylation do not have those problems. Nevertheless, these technologies are economically viable only when high volumes of wood are processed. Chemical impregnation can be then a valid solution if the most recent preservatives, which have a reduced level of toxic substances, are employed [12].

Another significant factor to be considered is emission expressed as carbon dioxide equivalent (Figure 6). In this respect, the pressure-vacuum process has the lowest impact while the thermal-treatment process the highest, as a consequence of the heating stage. As for the acetylation process, it is worth noting that the overall emission is 385 kg CO_2e, but if the sole acetylation stage is considered, the emission is 56 kg CO_2e: in fact, the main contribute (83%) comes from the wood drying stage which precedes acetylation.

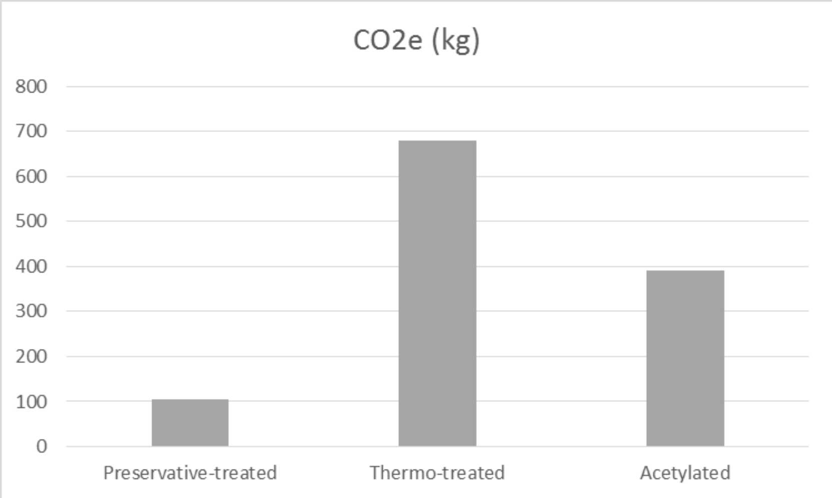

Figure 6: Comparison of emissions of the technologies.

Cycle time plays an important role in the assessment of the overall productivity of the three processes. The preservative-treatment cycle needs 4 hours while acetylation cycle time is between 4 and 6 hours, however this technique involves a drying stage of the wood that may require up to 48 hours. Thermal treatment is a time consuming process that may need 20 to 60 hours to be completed depending on the characteristics of the wood. These considerations point out how preservative-treatment can still be considered the most productive technology in terms of volume of output per unit of time at comparable plant sizes.

5 CONCLUSION

In order to choose the most effective technology for wood preservation, several dimensions of evaluation parameters should be taken into consideration: environmental effects, overall costs (investment and operating) and productivity. The present study especially investigated the environmental impact in terms of global warming potential and confirms what reported in other research: the fundamental role played by the opportunity of wood recycling and carbon dioxide emission. Cost and productivity were only marginally explored and the inklings that have been presented need a deeper analysis. At any rate, none of the technologies is dominant when the three evaluation parameters dimensions are taken into account. Further investigation is needed to assess the environmental impact when other impact categories are considered and before drawing exhaustive conclusions. The final choice should then be based on the levels of importance which a prospective decision maker would assign to such parameters dimensions; a multiple criteria model, in which the dimensions are further disaggregated into measurable criteria, could possibly support the evaluation.

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THE EMISSIONS EMITTED BY BEECH THERMOWOOD WITH AND WITHOUT SURFACE FINISHED

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Abstract
This paper investigates the problematic VOC emissions emitted by the massive beech wood and by heat treated wood at the temperature 180 °C and 200 °C. In this contribution, there is investigated the influence on the temperature of the beech wood heat treatment on the quality and quantity contains of volatile organic compounds, especially on the amount of emitted phenol and furfural. This contribution researches the correlation between the time after the modification of thermowood and amount and contains of VOC emitted by this heat treated beech wood. This study contains the results of influence of finishing beech thermowood by the waterborne lacquer on emissions VOC.

Keywords:
beech massive, TVOC, emissions VOC, finished surface of thermowood, finishing by waterborne lacquers**.**

1 INTRODUCTION

The volatile organic compounds emissions emitted by indoor equipment have significant influence on indoor and outdoor air and on the quality of indoor and outdoor environments. The emissions evaporated by wood based materials including native wood and modified wood such as thermowood become a part of the indoor sources of VOC emissions. In this contribution there is investigated the influence of the heat treatment conditions on the quality and quantity contains of the emitted emissions by thermowood. The next topic, which this article solves, is the influence of finished surfaces on the amount of VOC emissions evaporated from the finished surfaces by the waterborne lacquers on beech thermowood.
The heat treated wood is an increasingly popular decoration material. Heat treatment improves dimensional stability of the wood, but there is only little information about the VOC emissions of heat treated hard wood [1]. The information about evaporated VOC emissions is very important for using this popular heat treated wood in interior and for knowing the possible influences and the impact of the products made from heat treated wood on indoor air quality.

The heat treatment of wood was found to significantly decrease VOC emissions and change their composition [2]. Especially, emissions of terpenes decreased from softwood samples and aldehydes from European aspen samples after their heat treatment. In agreement with another recent study, the emissions of furfural were found to increase and those of hexanol to decrease from the entire investigated wood species [3]. In contrast to air dried wood samples, emissions of VOCs were almost in steady state from the heat treated wood samples even in the beginning of the test [1].
The influence of the temperature of heat treatment and the time of the emissions measuring after the modification of wood on the quality of indoor air are expressed in the connection to the term TVOC (total volatile organic compounds) which is used to describe the total amount of volatile organic compounds in the indoor atmosphere. The TVOC value indicates the level of indoor air pollution.

2 AIM OF THE RESEARCH

The aim of the research was to find diversity of VOCs amount emitted by thermowood samples which are heat treated at different temperatures (180 °C and 200 °C) and untreated wood without finished surface and with finished surface by the waterborne lacquers. Beech wood (*Fagus sylvatica), t*he chosen type of hard wood, has been tested for comparing under aspects of emitted chemical compounds and their amounts in the dependence of time from the wood treatment and finishing of wood surfaces. Quantitative difference of the entire emitted organic compounds was shown by the measured values of TVOC.

3 USED MATERIALS, EQUIPMENT AND METHODS

3.1 Tested materials:

- 10 pieces of lamellas made from native Beech wood, each of the tested lamellas has these dimensions: 0.74 x 0.04 x 0.001 m, size of tested sample: S=0.6 m^2
- 10 pieces of lamellas made from beech thermowood, heat treated beech wood at the temperature 200 °C, dimensions of one lamella: 0.74 x 0.04 x 0.001 m, size of tested sample: S=0.6 m^2
- 10 pieces of lamellas made from beech thermowood, heat treated beech wood at the temperature 180 °C, dimensions of one lamella: 0.74 x 0.04 x 0.001 m, size of tested sample: S=0.6 m^2
- 10 pieces of lamellas made from beech thermowood, heat treated beech wood at the temperature 200 °C, finished surfaces by waterborne lacquers, dimensions of one lamella: 0.74 x 0.04 x 0.001 m, size of tested sample: S=0.6 m^2

3.2 Used equipment for measuring emitted emissions

- Short path thermal desorption tube, Silco treated thermal desorption tube 786090-100, inner diameter 4 mm, fill in with 100 mg of Tenax TA (Scientific Instrument Services company) for collection of VOCs emissions emitted from tested samples in to the air in chamber.
- Air sampler Gilian–LFS 113 SENSIDINE with air flow 6 l. h^{-1} and 12 l. h^{-1}
- Gas chromatograph Agilent GC 6890 N with MS (mass spectrometer) detector 5973 with cryofocusation, thermal desorption and library of spectra NIS 05, column type HP – 5 (AGILENT USA).
- VOC equipment small-space chamber for VOCs testing with these.

Technical parameters during the collection of emissions VOC:

- Inner dimensions of space in chamber 1 m^3

Conditions in chamber during the collection of emissions

- Air temperature in chamber 23 °C
- Air humidity in chamber 50 %
- Air changing rate in chamber 1 m^3 per 1 h
- Air speed over the tested samples 0.1 to 0.3 m.s^{-1}

3.3 Methods of VOC testing were set via standards:

ISO 16000: 2004 Indoor air

ISO 16000-1: 2004 General aspects of sampling strategy

ISO 16000-5: 2005 Measurement strategy for (VOCs) volatile organic compounds

ISO 16000-11: 2004 Determination of the emission of volatile organic compounds – sampling, storage of samples and preparation of test specimens

ISO 16000-6: 2005 Determination of volatile organic compounds at indoor and test chamber air by active sampling on Tenax TA® sorbent, thermal desorption and chromatography using MS/FID

ISO 16000-9: 2004 Determination of the emission of volatile organic compounds—Emission test chamber method

4 RESULLTS OF MEASUREMENTS

The results of measurements of emissions emitted by native beech which depends on time after the preparation of sample are shown in the table 1.

Table 1: VOCs emitted by tested sample of untreated wood – beech.

Compound	After 3 hours[1]	After 24 hours	After 72 hours[1]	After 672 hours[1]
Unit	µg/m^3	µg/m^3	µg/m^3	µg/m^3
Ethyl acetate	(1.2±0.4)	(1.0 ± 0.3)	(0.2 ± 0.1)	< 0.1
Benzene	< 0.1	(0.2 ± 0.1)	< 0.1	(0.2 ± 0.1)
1-Methoxy-2-Propanol	(0.1±0.03)	(0.1 ± 0.03)	< 0.1	(0.9 ± 0.3)
Pentanoal	(2.5 ± 0.8)	(2.1 ± 0.6)	(0.8 ± 0.2)	(0.6 ± 0.2)
Trichlorethylene	< 0.1	< 0.1	< 0.1	< 0.1
Toluene	(1.3 ± 0.4)	(1.8 ± 0.5)	(0.3 ± 0.1)	(1.5 ± 0.5)
Hexanal	(10.9 ± 3.3)	(13.4 ± 4.0)	(3.3 ± 1.0)	(4.4±1.3)
Tetrachloretylene	< 0.1	(0.2 ± 0.1)	< 0.1	(0.3 ± 0.1)
n-Butyl acetate	(1.3 ± 0.4)	(1.4 ± 0.I4)	(0.3 ± 0.1)	(2.4 ± 0.7)
Furfural	**(2.2 ± 0.7)**	**(2.7 ± 0.8)**	**(0.8 ± 0.2)**	**(0.8 ± 0.2)**
Ethylbenzene	(0.7 ± 0.2)	(0.9 ± 0.3)	< 0.1	(1 ± 0.3)
m.p-Xylene	(2.2 ± 0.7)	(2.8 ± 0.8)	(0.3 ± 0.1)	(3.2 ± 1)
Styrene	< 0.1	< 0.1	(0.1±0.03)	< 0.1
o-Xylene	(0.4 ± 0.1)	(0.6 ± 0.2)	(0.1±0.03)	(0.8 ± 0.2)
Butoxy-Ethanol	< 0.1	< 0.1	< 0.1	< 0.1
α-Pinene	(0.1 ± 0.03)	(0.1 ± 0.03)	< 0.1	(0.5 ± 0.2)
Camphene	< 0.1	< 0.1	< 0.1	(0.2 ± 0.1)
3-Ethyl-Toluene	(0.3 ± 0.1)	(0.4 ± 0.1)	< 0.1	(0.3 ± 0.1)
4-Ethyl-Toluene	(0.3 ± 0.1)	(0.4 ± 0.1)	< 0.1	(0.4 ± 0.1)
Phenol	**(0.5 ± 0.2)**	**(0.7 ± 0.2)**	**(0.3 ± 0.1)**	**(0.3 ± 0.1)**
β-Pinene	(0.1 ± 0.03)	(0.1 ± 0.03)	(0.1±0.03)	(0.2 ± 0.1)
2-Ethyl Toluene	(0.1 ± 0.03)	(0.1 ± 0.03)	< 0.1	(0.1±0.03)
Myrcene	< 0.1	< 0.1	< 0.1	< 0.1
1,2,4-Trimethyl-Benzene	(0.2 ± 0.1)	(0.4 ± 0.1)	< 0.1	(0.2 ± 0.1)
α-Phellandrene	< 0.1	< 0.1	< 0.1	< 0.1
3-δ-Carene	(0.2 ± 0.1)	(0.2 ± 0.1)	(0.1±0.03)	(0.4 ± 0.1)
Limonene	(0.1 ± 0.03)	(0.1 ± 0.03)	(0.1±0.03)	(0.4 ± 0.1)
γ-Terpinene	< 0.1	< 0.1	< 0.1	< 0.1
$TVOC_{MS}$	**(22 ± 6)**	**(24 ± 7)**	**(7 ± 2)**	**(19 ± 6)**

NSLC - not specified limit concentration
[1] Average of result ± expanded measurement uncertainty

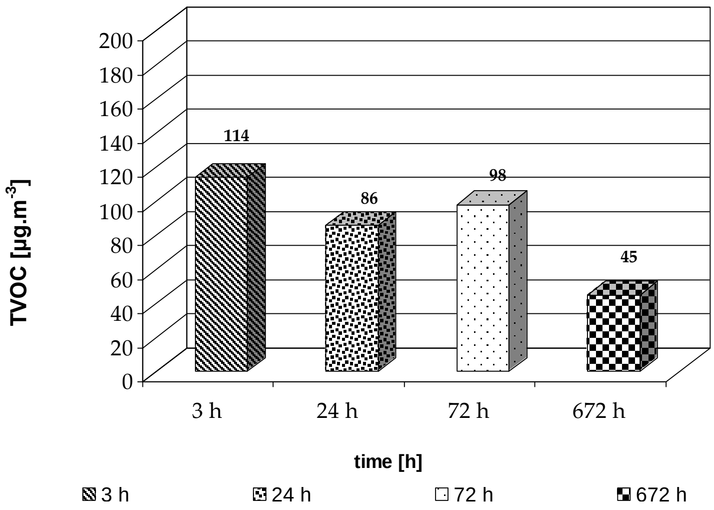

Figure 1: TVOC emissions emitted by heat treated beech (thermowood) at 180 °C.

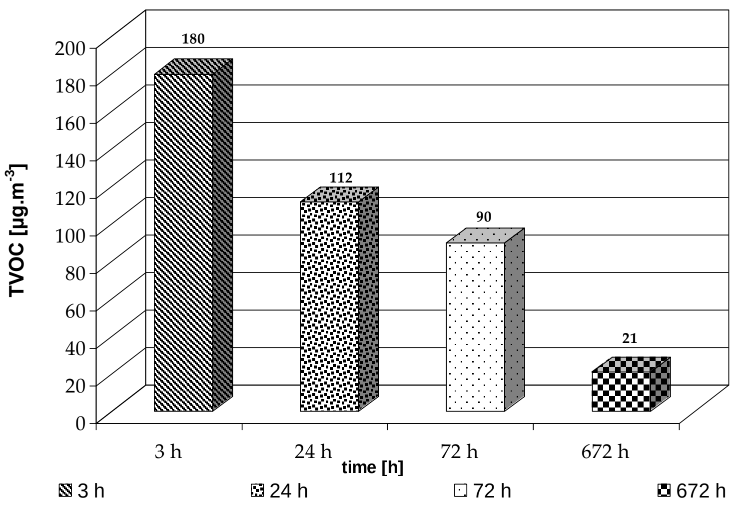

Figure 2: TVOC emissions emitted by heat treated beech (thermowood) at 200 °C.

Table 2: VOCs emitted by the tested sample of thermowood – beech, heat treated at the temperature 180 °C.

Compound	Beech wood heat treated at 180 °C, after modification				
	3 hours[1]	24 hours	48 hours[1]	72 hours[1]	28 days
Unit	µg/m³	µg/m³	µg/m³	µg/m³	µg/m³
Ethyl acetate	(0.2± 0.1)	(0.4± 0.1)	(0.2± 0.1)	(0.2 ±0.1)	< 0.1
Benzene	(0.2± 0.1)	(0.2± 0.1)	(0.2± 0.1)	< 0.1	< 0.1
1-Methoxy-2Propanol	(0.3± 0.1)	< 0.1	< 0.1	< 0.1	< 0.1
Pentanal	(0.5± 0.2)	(0.5± 0.2)	(0.5± 0.2)	(0.5± 0.2)	(0.1±0.03
Trichlorethylene	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Toluene	(0.8± 0.2)	(1.2± 0.4)	(0.7± 0.2)	(0.7± 0.2)	(0.2± 0.1)
Hexanale	(0.4± 0.1)	(0.6± 0.2)	(0.6± 0.2)	(0.6± 0.2)	(0.3± 0.1)
Tetrachlorethylene	(0.2± 0.1)	(0.2± 0.1)	(0.2± 0.1)	(0.2± 0.1)	< 0.1
n-Butyl acetate	0.1±0.03	(0.8± 0.2)	(0.3± 0.1)	(0.6± 0.2)	(0.4± 0.1)
Furfural	(278.5 ± 83.6)	**(194.7 ± 58.4)**	**(243.8 ± 73.1)**	**(239.8 ± 71.9)**	**(107.2 ± 32.2)**
Ethylbenzene	< 0.1	(0.7± 0.2)	(0.2± 0.1)	(0.5± 0.2)	(0.2± 0.1)
m,p-Xylene	(0.5± 0.2)	(2.2± 0.7)	(0.8± 0.2)	(1.3± 0.4)	(0.3± 0.1)
Styrene	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
o-Xylene	(0.1±0.03	(0.4± 0.1)	(0.3± 0.1)	(0.3± 0.1)	(0.1±0.03
Butoxy-Ethanol	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
α-Pinene	(0.3± 0.1)	(0.3± 0.1)	< 0.1	(0.1±0.03	< 0.1
Camphene	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
3-Ethyl-Toluene	(0.3± 0.1)	(0.4± 0.1)	(0.4± 0.1)	(0.4± 0.1)	0.1±0.03)
4-Ethyl-Toluene	(0.3 ±0.1)	(0.4± 0.1)	(0.4± 0.1)	(0.4± 0.1)	(0.1±0.03
Phenol	**(1.3± 0.4)**	**(1.3± 0.4)**	**(1.3± 0.4)**	**(1.3± 0.4)**	**(1 ± 0.3)**
β-Pinene	0.1±0.03	0.2 ± 0.1	0.1±0.03	0.1±0.03	0.1±0.03
2-Ethyl Toluene	0.1±0.03	(0.1±0.03	(0.1±0.03	(0.1±0.03	< 0.1
Myrcene	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
1,2,4-Trimethyl-Benzene	(0.2± 0.1)	(0.2± 0.1)	(0.4± 0.1)	(0.4± 0.1)	< 0.1
α-Phellandrene	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
3-δ-Carene	(0.2± 0.1)	(0.2± 0.1)	0.1±0.03	0.1±0.03	0.1±0.03
Limonene	0.1±0.03	(0.2± 0.1)	0.1±0.03	0.1±0.03	0.1±0.03
γ-Terpinene	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
$TVOC_{MS}$	(88 ± 26)	(66 ± 20)	(74 ± 22)	(75 ± 23)	(35± 10)

[1] Average of result ± expanded measurement uncertainty

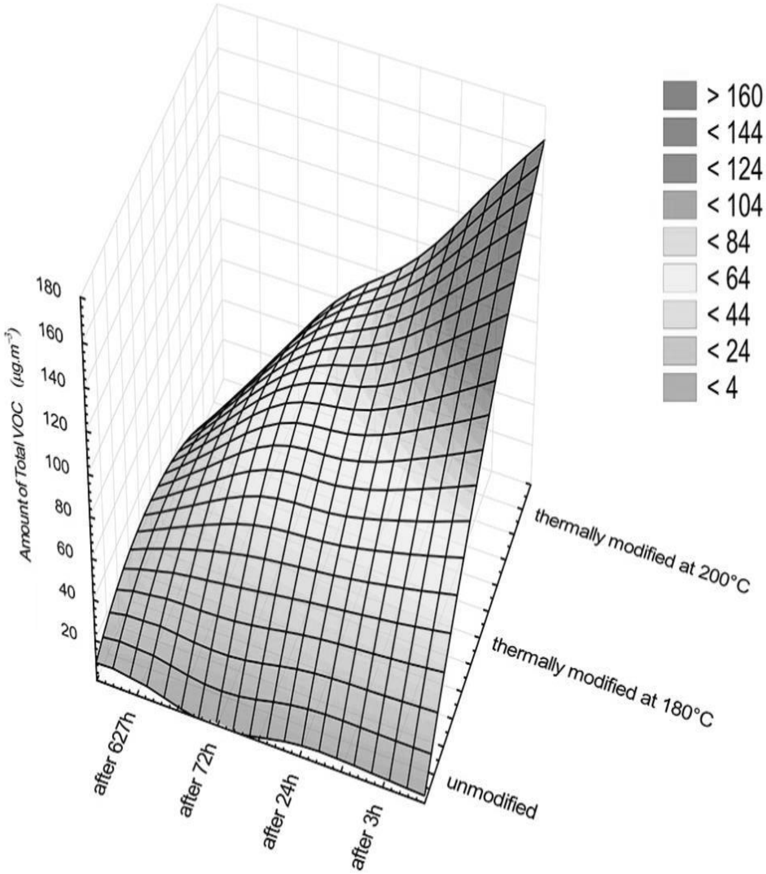

Figure 3: Amount of TVOC emitted by beech wood after 3, 24, 72 and 672 hours.

The quality and quantity contains of VOC emissions emitted by heat treated beech wood in dependence of time after heat treatment at the temperature 180 °C are given in table 2 and after heat treatment at the temperature 200°C are shown in table 3. The influence of finished surface on the heat treated beech thermowood at 200 °C is issued in table 4.

Table 3: VOCs emitted by the tested sample of thermowood – beech, heat treated at the temperature 200 °C.

Compound	Beech wood heat treated at 200 °C, after modification			
	3 hours[2]	24 hours	72 hours	672 hours
Unit	µg/m^3	µg/m^3	µg/m^3	µg/m^3
Ethyl acetate	< 0.1	< 0.1	0.1 ± 0.03)	< 0.1
Benzene	(0.1 ± 0.03)	0.1 ± 0.03)	< 0.1	< 0.1
1-Methoxy-2-Propanol	(0.1 ± 0.03)	(0.3 ± 0.1)	0.1 ± 0.03)	< 0.1
Pentanale	(0.2 ± 0.1)	(0.2 ± 0.1))	(0.2 ± 0.1)	< 0.1
Trichlorethylene	< 0.1	< 0.1	< 0.1	< 0.1
Toluene	(0.3 ± 0.1)	(0.5 ± 0.2)	(0.2 ± 0.1)	(0.2 ± 0.1)
Hexanale	(0.2 ± 0.1)	(0.3 ± 0.1)	0.1 ± 0.03)	< 0.1
Tetrachlorethylene	(0.1 ± 0.03)	0.1 ± 0.03)	0.1 ± 0.03)	< 0.1
n-Butyl acetate	(0.3 ± 0.1)	(0.2 ± 0.1)	< 0.1	< 0.1
Furfural	**(460.5±138.2)**	**(303 ± 90.9)**	**(223.3 ± 67)**	**(60.8± 18.2)**
Ethylbenzene	(0.1 ± 0.03)	(0.2 ± 0.1)	(0.6 ± 0.2)	< 0.1
m,p-Xylene	(0.2 ± 0.1)	(0.3 ± 0.1)	(1.6 ± 0.5)	< 0.1
Styrene	< 0.1	< 0.1	< 0.1	< 0.1
o-Xylene	(0.1 ± 0.03)	0.1 ± 0.03)	(0.2 ± 0.1)	< 0.1
Butoxy-Ethanol	(0.4 ± 0.1)	(0.2 ± 0.1)	0.1 ± 0.03)	< 0.1
α-Pinene	< 0.1	< 0.1	< 0.1	< 0.1
Camphene	< 0.1	< 0.1	< 0.1	< 0.1
3-Ethyl-Toluene	(0.3 ± 0.1)	(0.3 ± 0.1)	(0.2 ± 0.1)	0.1 ± 0.03)
4-Ethyl-Toluene	(0.4 ± 0.1)	(0.4 ± 0.1)	(0.2 ± 0.1)	0.1 ± 0.03)
Phenol	**(0.8 ± 0.2)**	**(1.5 ± 0.5)**	**(1.3 ± 0.4)**	**(1.5 ± 0.5)**
β-Pinene	(0.1 ± 0.03)	0.1 ± 0.03)	0.1 ± 0.03)	0.1 ± 0.03)
2-Ethyl Toluene	< 0.1	< 0.1	< 0.1	< 0.1
Myrcene	< 0.1	< 0.1	< 0.1	< 0.1
1,2,4-Trimethyl-Benzene	(0.1 ± 0.03)	(0.1 ± 0.03)	(0.2 ± 0.1)	< 0.1
α-Phellandrene	< 0.1	< 0.1	< 0.1	< 0.1
3-δ-Carene	< 0.1	< 0.1	< 0.1	< 0.1
Limonene	< 0.1	< 0.1	< 0.1	< 0.1
γ-Terpinene	< 0.1	< 0.1	< 0.1	< 0.1
TVOC$_{MS}$	**(138 ± 42)**	**(86 ± 26)**	**(69 ± 21)**	**(16 ± 5)**

NSLC - not specified limit concentration

[2]Average of result ± expanded measurement uncertainty

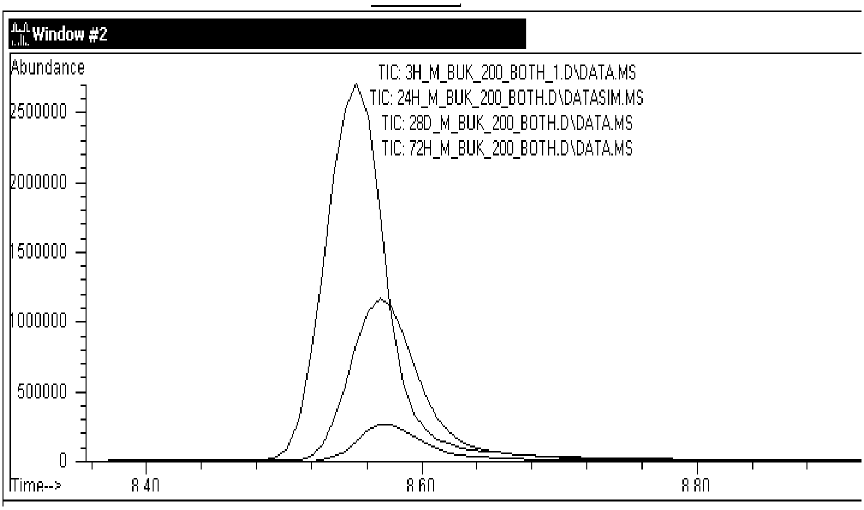

Figure 4: The dependence of the furfural peak size on the time of its measurement after the modification.

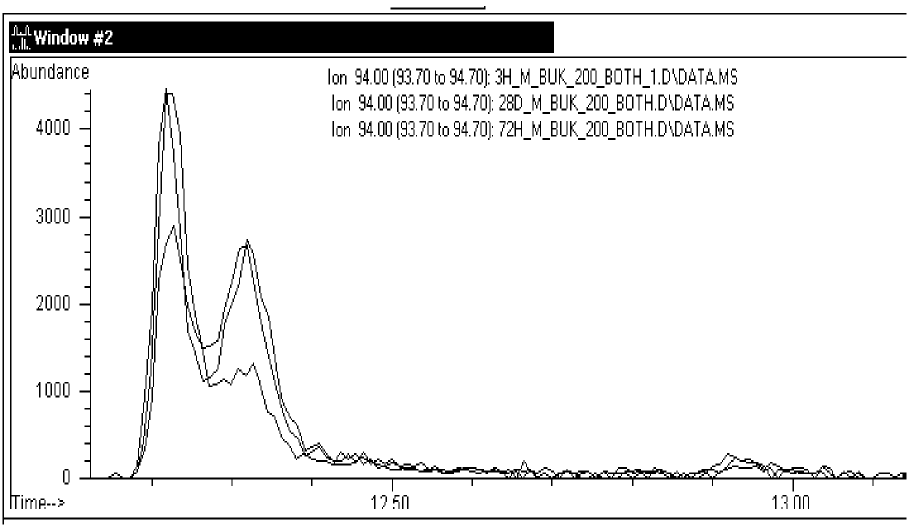

Figure 5: The dependence of the phenol peak size on the time of its measurement after the modification.

Table 4: VOCs emitted by the tested sample of thermowood – beech, heat treated at the temperature 200 °C with the finished surface by the waterborne lacquer.

Compound	without finishing[3]	After finishing[3]			
		3 hours[4]	24 hours	72 hours	672 hours
Unit	μg/m^3	μg/m^3	μg/m^3	μg/m^3	μg/m^3
Ethyl acetate	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Benzene	(0.1 ± 0.03)	< 0.1	(0.3 ± 0.1)	(0.1± 0.03))	< 0.1
1-Methoxy-2-Propanol	(0.6 ± 0.2)	< 0.1	(0.1 ± 0.03)	< 0.1	< 0.1
Pentanal	(0.1 ± 0.03)	< 0.1	< 0.1	< 0.1	(0.1 ± 0.03)
Trichlorethylene	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Toluene	< 0.1	(1.4 ± 0.4)	< 0.1	(0.7 ± 0.2)	< 0.1
Hexanale	(0.4 ± 0.1)	(0.3 ± 0.1)	(0.1 ± 0.03)	(0.4 ± 0.1)	(0.5 ± 0.2)
Tetrachlorethy-lene	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
n-Butyl acetate	< 0.1	(0.8 ± 0.2)	< 0.1	< 0.1	< 0.1
Furfural	**(29.9 ± 9)**	**(104±31.2)**	**(47.7±14.3)**	**(29.8 ± 8.9)**	**(10.5 ± 3.2)**
Ethylbenzene	< 0.1	(2.8 ± 0.8)	< 0.1	< 0.1	< 0.1
m,p-Xylene	< 0.1	(9.1 ± 2.7)	< 0.1	< 0.1	< 0.1
Styrene	< 0.1	(1.5 ± 0.5)	(0.3 ± 0.1)	(0.2 ± 0.1)	< 0.1
o-Xylene	< 0.1	(1.4 ± 0.4)	< 0.1	< 0.1	< 0.1
Butoxy-Ethanol	< 0.1	(931±279)	(591 ± 177)	(239.3±72)	(177 ± 53)
α-Pinene	(0.1 ± 0.03))	< 0.1	(0.1 ± 0.03)	(0.1 ± 0.03)	(0.1 ± 0.03)
Camphene	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
3-Ethyl-Toluene	< 0.1	(0.6 ± 0.2)	< 0.1	< 0.1	< 0.1
4-Ethyl-Toluene	(0.4 ± 0.1)	(1.2 ± 0.4)	< 0.1	(0.1 ± 0.03)	(0.1 ± 0.03)
Phenol	**(1.9 ± 0.6)**	**(3.8 ± 1.1)**	**(3 ± 0.9)**	**(1.7 ± 0.5)**	**(2.8 ± 0.8)**
β-Pinene	(0.1 ± 0.03)	(0.2 ± 0.1)	(0.2 ± 0.1)	< 0.1	< 0.1
2-Ethyl Toluene	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Myrcene	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
1,2,4-Trimethyl-Benzene	(0.1 ± 0.03)	(0.6 ± 0.2)	< 0.1	(0.3 ± 0.1)	< 0.1
α-Phellandrene	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
3-δ-Carene	< 0.1	0.1 ± 0.03	(2.6 ± 0.8)	(0.1 ± 0.03)	< 0.1
Limonene	(0.2 ± 0.1)	(3.8 ± 1.1)	(1.3 ± 0.4)	(0.5 ± 0.2)	< 0.1
γ-Terpinene	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
$TVOC_{MS}$	(10 ± 3)	2813 ± 844	1510 ± 453	(551 ± 165)	(259 ± 78)

NSLC - not specified limit concentration

[3] Without 220 days after modification
[4] Average of result ± expanded measurement uncertainty

5 CONCLUSIONS

Based on the obtained results (tables 1, 2, 3, figure 3) it is possible to conclude that the heat-treatment modification increases the quantity and quality contain of VOC emissions.

Main difference consists in the amount of emitted furfural and phenol in the blend of gaseous elements evaporated by heat- treatment beech in normal conditions. The temperature of heat-treatment has great influence on the emitted Furfural amount. The higher temperature during the beech treatment means the higher amount of furfural emissions. It is possible to state that TVOC, the indicator of indoor air quality, depends on the temperature of the modification. Furfural and phenol are typical chemicals which are resulting in degradation of wood components. The finished surface by the waterborne lacquer does not decrease the emissions escaping from heat treated beech wood. It does not even increase the quantity of evaporated VOS emissions from these samples.

It is very important in the next step of this research to focus on studying the influence of heat treatment on VOC emissions emitted by different kinds of wood and to study the influence of thermowood finished surfaces, especially to find the correlation between the kind of the surface finishing and VOC emissions; the relation between the quality and quantity of emitted emissions VOC by thermowood and the way of finishing of the heat treated wood.

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DESIGN MANAGEMENT – A NEW APPROACH IN CONSUMER-FOCUSED INDUSTRIES

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ABSTRACT
The text gives an explanation of the value of design and Design Management. It discusses crucial design and innovation management tools and is further an encouragement to benchmark industries for their human-centered innovation practice.

Keywords
Design Management, Innovation Management, technology centered Design Management, human centered Design Management

1 INTRODUCTION

Even though a well-known discipline for consumer and capital industries, design is still far from being commonly used in its full potential. Design is not "adding shape, color and the logo" in the end of product development but a cross-linked discipline that serves as a driver for innovation and value creation for products and services. Design Management is a discipline that combines the knowledge of the design process and practice, the methods of marketing, product and innovation management as well as the deep understanding of engineering and technology. The text describes design and Design Management and their role within these business functions.

2 DESIGN

2.1 Solving a defined problem

Design comprises all levels of activities where problems are identified, neatly described and turned into a project brief. Design work is problem solving with the user, the brand and the company and other stakeholders in mind. It contains also the aesthetic factor, which is, perceived with all senses, the main interface between company, brand and the user's experience. Design disciplines today reach from business design, process design, design thinking through communication, interaction and product design as far as service design or social design. Design has come beyond the sheer "appearance" factor that probably most of the readers would associate with "design". Design is about problem-solving, about turning ideas into reality and describing the desired experience in all physical and psychological aspects. That is why the biggest conceptual bracket that one could give to the design discipline is “experience design”. If done right in a company, it uses most of the current design disciplines today: product design, graphic design, interaction design, fashion design, photographic design, interior design, social design. As does the car industry. Brigitte Borja de Mozota, a Paris-based, internationally acclaimed researcher on Design Management, describes design is a differentiator to competition, it has a co-ordinating function and serves as a transformator within organisations.

2.2 Design – Art or science?

Design Methods combine a rational, scientific approach with creative and intuitive endeavor. Design in practice works best today in this “ambiguity”, following possible solutions for complex problems in combining the rational and the intuitive. Projects are well planned and executed, but should encourage iterative “expeditions” to reach new relevant solutions beyond known horizons (competitors).

3 DESIGN MANAGEMENT

3.1 Design Management – The business side of design

Tom Peters, the author of the business-bestseller “In search of excellence” is quoted in Borja de Mozota’s book on Design Management [1] for a business-focused understanding of Design: “„Design is only secondarily about pretty lumpy objects and primarily about a whole approach to doing business, serving customers, and providing value“.
The Design Management Institute from Boston (USA) [2], highly acknowledged among Design Management practitioners and researchers, defines Design Management as a creative business activity that considers processes, business decisions, innovation strategies, products, services, communication, space and brand.

3.2 Tools of Design Management

Brand Design Strategy, Brand Design Innovation Roadmap, Product Roadmap, Process Design, Design Research, Documentation (text and visual), Creativity tools, Visualizations, Simulations, Prototyping, Testing and Implementation support.
The success of good Design Management is based on the personality of the design manager, his or her experience in the discipline and his or her capacity to connect with the other functions in the innovation and product development channel. Some of the tools of Design Management are typical to the design profession, some have their roots in marketing or in product development. Unique to the design profession are tools around idea creation, visualization, quick visual prototypes, and the fast intuitive approach to solving problems, that is characteristic for the creative professions. Sketching and visualization are effective tools to develop and share innovation, make others sympathetic to new concepts and to get an emotional connection to the new project or service.

3.3 Design Management Tools – technology-centered vs. human-centered

As stated and defined above, Design Management is the activity to plan, organize and deliver design service to internal or external clients. The ways to practice Design Management vary from industry to industry, from company to company and from design manager to design manager.

3.3.1 Technology-centered

Design Management which is technology-centered is usually defined by a strong focus on internal strengths of companies or design consultancies. Traditionally very close to research and product development processes to product innovation, Design Management with a technology-driven process practice starts from existing products, product lines or manufacturing possibilities. Based on the experience and mastery of producing certain goods, a design team, close to product development management develops its design road map strongly tied to this. Product innovation is then a result of new technologies applied in a new product, being it a proper development by the company or in co-operation with an external supplier that provides a certain technology or skill.

Typical industries that follow a technology-centered Design Management are the automotive industry, the household appliance industry or the mechanical engineering industry. Some examples show the context:

Design Management in the car industry focuses on giving a new face to a new car or car family. Technology innovation features are rarely “visible” and need a “translation” into a formal feature or a new function that makes it part of the new car design. An example of that technology-driven design are the controls of the BMW 7 series called BMWConnectedDrive. A new interaction technology is available and needs to be adopted to the typical high-class fit feel finish and design of the 7 series. [3]

Technology-driven design is also what the author experienced and actively managed within the household appliance manufacturer Electrolux. Innovations like frost-free functions in freezers were developed and tested long before the design team started to find ways to formally and semantically integrate it into the interior of a freezer cabinet or, with its air vents to give even air circulation, also for the fridge compartment. Technology had to “find form” following pre-defined brand design guidelines. [4]

The Ostwestfalen-Lippe region (Kirchlengern)-based company DewertOkin produces electromotive drive systems for healthcare and furniture. The products are developed “inside-out”. Formal options that also improve aspects like handling, cleaning or repair are only added at a later development stage. Though the products are well-performing, the semantic aspects give no clear indication of how this component would work, be operated or be repaired. [5]

3.3.2. Benefits of technology-driven Design Management

This Design Management approach gives good results as it is executed with sound knowledge and close co-operation with the R&D-department. Primary goals of each product development supported by design activities are met, such as cost-efficiency, materials-efficiency and suitability for manufacturing. The examples of BMW and Electrolux clearly indicate that technology-driven Design Management can result in ergonomic and yet aesthetically pleasing product features that contribute to the overall brand design experience. Nonetheless, developing a new technology first, having the component pre-defined and leaves only little “room for improvement” for the design activity with its innovation and brand design focus. The innovation risk of Design Management dominated by a technological focus usually results in incremental innovation but not major leaps ahead. Under an economic aspect, technology-driven Design Management does usually not deliver truely innovative solutions that are substantially new to the market. They will probably not justify a price premium for being “incomparable”, unless the basic innovation is a true “game changer” as the LED flat TV screens that made bulky (even elegant) TV sets obsolete.

3.3.3. Human-centered tools of design and innovation management

Of the various Design Management tools, those who deal with the so called human factors have still enormous potential. Even if many now have heard about design thinking, design research or service design, for most design and product development processes, rigid, “mono-rail” processes and a “prepotent figures and facts”-based approach is still That is due to the belief in business and engineering, that everything can objectively measured by figures. The weirdest innovation theories get a formula added, even if the equation is nothing more than “business esoteric”. Other disciplines, such as psychology, sociology or business ethnography help to get structure, method and insight into people’s motivation for certain preferences or behaviors. The consumer goods industry, and of these especially companies like Procter & Gamble, Unilever or Nestlé, have applied so called “human factors”-consumer research for many years, with the success stories such as “dust magnet” duster Swiffer (P&G) designed by the American design consultancy IDEO, Dove beauty care products (Unilever) or the “generation” Nespresso (Nestlé). Nestlé with its brand Nespresso has more or less invented the instant espresso at home. [6] [7] [8]

Integrating an approach that combines the rational (facts and figures from the market research, in-depth technology research, impeccable product development, excellence in production and logistics) and the irrational (how consumers think and behave, creating brands people love, visions of marketing opportunity or creating the unexpected), leads to comprehensive innovation. Expanding human factor-based innovation to the capital goods industry remains a mostly unknown strategy. Some companies from the mechanical engineering and chemical industry have discovered already, that human centered design and innovation management methods could also give an innovation boost for them. Every industry is based on human interaction from workers, employees and managers that communicate between each other and with clients. Critical success factors are mostly based on excellence performed by individuals or by groups. Design Thinking has started to enter the mechanical engineering industry. The author is optimistic about how the holistic approach to innovation will make its path through the industry of the many “hidden champions”. Even if industries have different markets, clients and ways of doing business, there is still a lot to learn from each other, for those trained to lateral thinking. Benchmarking the enormous experience of consumer-centered product and service innovation of the fast moving consumer goods industry with one’s own industry can create substantial insights. That could be turned into competitive advantages, based on excellence in classical disciplines as customer relationship management (CRM) or process design and execution.

3.4 Comparing technology-centered Design Management and human-centered Design Management

Technology-driven Design Management is a well-established aspect in most companies, actively using design as a tool for product innovation and brand recognition. As it is close to R&D-concerns, products resulting from this approach are apt for the markets and their needs. Product innovation is mostly initiated by new technologies developed by its R&D-team or together with a supplier. The limit of technology-driven Design Management is that it is “good but not good enough” in markets that become more and more competitive and technologies become less and less a differentiator for the products of a company. As innovation has also become a main concern of suppliers, the use of a new technology alone is not enough to succeed on the market. Innovations in the furniture industry like the full-extension drawer runner is now provided by most suppliers and available to the kitchen buyers by almost all known kitchen furniture companies. In the car industry, innovations become quickly “inflationary” and hard to attribute to a specific brand. The ABS-technology today can not be associated with a specific car brand. In telecommunication, the touch screen of a smart phone is not a privilege of Apple or Samsung, but of basically all smart phone producers. That is because the supplier of the technology is mostly the same.
As technology-based innovation is less and less frequently monopolized by a single company or brand (see above), other effective differentiators need to be identified. The best is a strong brand with a distinguished brand image.
The brand does not necessarily need to be the innovation leader in its industry, but it needs to have a strong “DNA” to be recognized in a tough market environment. Brand history helps (e.g. Nivea, Bosch), a unique design language too (e.g. past Braun, now Apple) or a unique way to focus its customers (as the examples DOVE and Nespresso mentioned above). Design and user focus are assets that successful brands use to become recognized. Human-centered innovation practices help a brand to know more about their specific markets, customer groups and target clients. Using

methods of human-centered innovation, such as market research (qualitative and qualitative), ethnographics (observing and describing customers) or customer focus groups and bringing the results together into consumer insights, these become true “treasures” in the continuous work of a brand or company with its customers. Robert G. Cooper, the engineer, consultant and author that developed the “Stage Gate” innovation process calls these human-centered methods “Voice of Consumer / VoC”. Cooper and Dreher suggest eight VoC methods: Ethnographic methods, Customer-visit teams, Customer focus groups, Lead user analysis, the customer or user designs, Customer brainstorming, Customer advisory board, Community of enthusiasts. [10]. On “Lead user analysis” Cooper and Dreher describe how Hilti, the professional building industry tools manufacturer extensively uses lead-user analysis. The sales representatives serve as “ambassadors” to the customers and machine users, the innovation team holds workshops and other forms of focused group work to develop new solutions, based on insights gained by the frequent communication between sales force and the users. The author knows of the Design Management strategy at Hilti and received detailed information by the Head of Design, Stephan Niehaus [11], how these insights are turned into product briefings, product concepts and tools that are new to the market.

As customers are as unique as the brands they serve, consumer insights based on the perpetual research provide solid platforms for product innovation based on customer needs. Marketing also benefits as it then turns consumer insights into advertising campaigns that specifically address needs, wishes or worries of the targeted customer groups. The more experience gained, the more specific insights turn into innovations that can not be bluntly copied as they comprise more than just a feature of a product. Good human-centered innovation management defines the user experience at multiple levels (product, service, communication, corporate culture, etc). Human-centered Design Management is the very center of these activities, as it has the power to turn insights into concepts and products, in close co-operation with the business functions it interacts.

3.5 Integrating technology-centered Design Management and human-centered Design Management

As neither of the described focuses of Design Management guarantee unique products with the required technical, ergonomic, economic and aesthetic specifications, an integration of both directions seems to be appropriate. Robert G. Cooper’s “state of the art” Stage Gate-process, though a very technical and engineering-minded process, emphasizes the importance and leverage of the so-called Voice-of-Consumer methods. There is growing understanding in the industry that product solutions for complex technical and user-centered problems can not be solved by one approach or discipline only. Using technology-driven Design Management as a base, integrating it with the solid work in brand and brand design definition, with a sound knowledge about the markets, the users and their needs,

Design Management becomes a comprehensive discipline with a strong impact on product innovation.
Consumer insights of a brand are unique and can not “be copied” as a brand asset needs years or even decade to establish and can not easily be copied (example: Apple’s iPhone). The role of Design Management is serving as the “voice of the consumer” and turning insights and technologies into products that shape a specific brand products experience. Leading brands in the car industry deliver these experiences, such as BMW, Mercedes, or Citroen. In consumer electronics, Apple delivers these too, Samsung with growing public recognition. In capital goods, brands like Würth or Festo deliver brand product experiences, backed by exceptional services which go along with the brand image they communicate for their products. Design Management within or for a company helps to strengthen these synergies across product families, across communication platforms (Customer Relationship Management, print, online, social media). The various disciplines of design (as stated in chapter 2.1) represent the integrating function for a brand or company.

4 SYNTHESIS

The following aspects are key to the integrating function of Design Management for product innovation:

1. **Brand and brand design strategy**
   This is the base of all activities and gives a long-term vision of the company’s products for a well-known and well-defined market.

2. **Pool of market and customer/consumer knowledge**
   Along with the Brand and Brand design strategy, the knowledge base needs continuous “harvest”, documentation and analysis. A company defines the most appropriate tools that are in line with the market, budget and personnel.

3. **Key customer needs identified/Consumer Insights**
   The documentation stated above serves as a base for the generation of consumer insights. They need frequent check, validation or update and serve all functions of a company to be knowledgeable about the markets’ needs.

4. **Technology roadmap for the brand, by product and customer segments**
   A plan for the development, purchasing or introduction of new technologies, along a time line for continuous technical innovation.

5. **Product and Design Management roadmap addressing customer needs and technology opportunities**

Based on the consumer insights mentioned above, validated by the technology roadmap, this step brings the necessary aspects together to create a comprehensive product brief for all business functions. This combines customer needs know-how (leading to uniqueness and incomparableness) with newest technologies and production process available.

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PARAMETRIC COST MODEL FOR EARLY PREDICTION OF PRODUCT REALIZATION PROJECTS

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Abstract
The cost of product realization projects includes all efforts and expenses which occur in connection with the development of new products and the development of appropriate production systems. Due to the growing proportion of product development efforts, an early and reliable product realization cost prediction is becoming more and more important.
Within the scope of this paper, a cost prediction method will be introduced that combines a multivariate parametric approach with a stochastic result output based on the Monte Carlo method. Most of the cost determination methods that have been published in relevant literature, do not consider uncertainty and the lack of information that often exist in early phases of product realization projects. With the aid of the Monte Carlo method, the effects of insufficient information and uncertainty can be simulated as part of the cost determination process. The result output is based on a cost distribution function that shows the probability of occurrence for each cost value and also the result limits (min. / max.) for a specific project. The knowledge of these factors helps to interpret the result of cost determination while using the method and provides the opportunity to take appropriate measures.

Keywords:
Cost prediction for product realization projects, parametric cost model, cost planning, cost uncertainty

1 COST PREDICTION FOR PRODUCT REALIZATION PROJECTS

The product realization costs include all expenses that occur in connection with the development of a new product and the development of the related production system. Apart from labor costs, the product realization costs may also contain material costs, capital costs and costs for external provision [1].
For the cost determination process, various input and output parameters can be taken into consideration. Company specific input comprises the cost information of completed product realization projects (retrograde cost information) and / or the knowledge of experienced experts. Furthermore, cost prediction may rely on industry specific input, such as ratios and

empirical values. In each case information is needed regarding the project for which the cost prediction is implemented (anterograde cost information) [2]. Depending on the particular field of anterograde data a distinction can be made between product, production and project specific information. The potential input and output parameters for cost prediction approaches are illustrated in Figure 1.

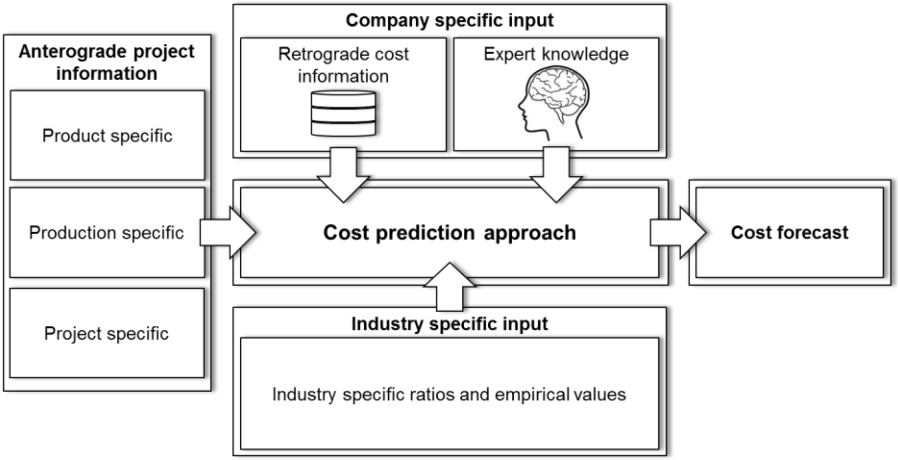


Figure 1: Cost prediction approaches: input and output parameters.

The cost of development is influenced by many internal and external requirements and conditions including, amongst other elements, the development subject matter, the duration of the project and the preconditions and specifications [3]. The planning of development costs normally takes place at an early stage of the project, before the start of product and production system development. At this time the knowledge and the level of information with regard to the development scope is rather low. For cost determination, such uncertainties should be taken into consideration [4]. Interpretation of the results may otherwise lead to misjudgment and faulty decisions.

2 FUNDAMENTALS OF PARAMETRIC COST DETERMINATION

Parametric cost determination procedures are based on the assumption that a functional relationship between the costs and one or more project-specific cost factors exists [5]. Such a relationship must be determined empirically [6] on the basis of retrograde information from completed projects. The significant project sizes and their influence on cost can be determined by using the retrograde data with the help of probing statistical methods. Figure 2 illustrates a linear dependence between the cost of the project and a project-specific factor using a correlation chart.

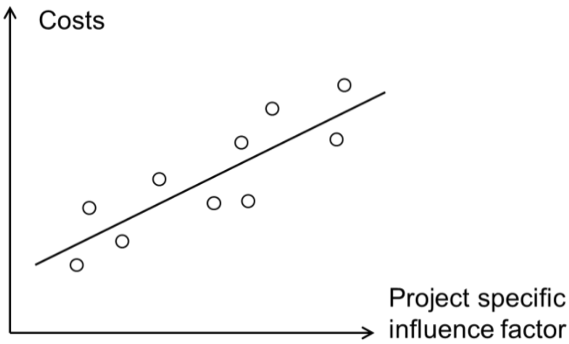


Figure 2: Linear interdependence between project costs and a project-specific influence factor.

To formally describe the correlation shown in figure 2, structure probing statistical methods, such as regression analysis, can be used. When the functional correlation is known, the potential cost of a project can be calculated on the basis of that factor. When using cost equations, it is assumed that the costs of two projects are equal when the significant input variables are also equally pronounced.
An important prerequisite is that the expression of the influencing values at the time of the calculation of costs is already known, or is easier to determine than the cost of the project itself. Moreover, the influence value for a large number of projects should be representative and documented in the retrograde cost records of completed projects [7].
In cost determination using parametric techniques, previous projects are usually structured into sub components. For each sub component, an individual cost equation can be defined. The total cost is determined by the aggregation of different cost equations. If there are several cost equations, which have to be summarized to enable a full costing for the project, they are called cost models [8].
Depending on the causality related to the development of costs, one or several project-specific values may have an impact on the costs. The inclusion of several factors allows a more accurate assessment of the project-specific terms and conditions. Due to the complexity of product realization projects, it can be assumed that more than one influencing factor has an effect on the costs of a specific project. For that reason

implementation of cost determination on the basis of multiple influencing factors is recommended. With regard to the statistical calculation of the cost equation, equations with a single effecting value can be created using **univariate** analysis methods. If more than one influencing factor should be considered for the cost equation, **multivariate** techniques must be used for the statistical analysis. Figure 3 gives an overview of the major structure probing statistical methods that are suitable for multiple relationships analysis.

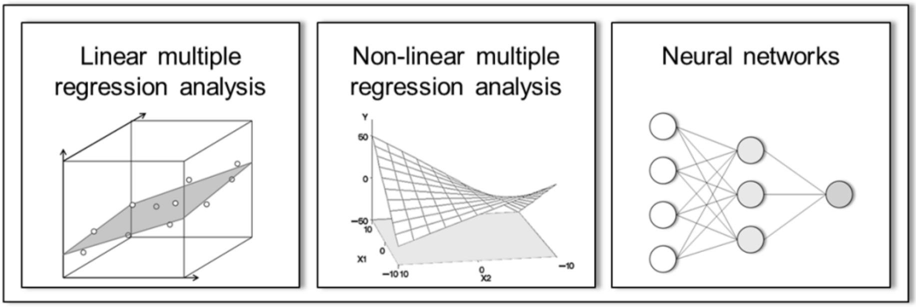


Figure 3: Multivariate analytical method categories.

3 METHOD FOR MULTIVARIATE PARAMETRIC COST DETERMINATION UNDER CONSIDERATION OF UNCERTAINTY

In the following, a method for the product realization cost determination shall be introduced that is based on a multivariate parametric cost model. The application of the method will be introduced by means of a 4 stage process flow (c.f. figure 4). In the first phase the specific project is **structured** into several project segments. The result of this segmentation leads to the whole project cost structure. In the second phase a **hypothesis** about the relevant input and output variables and their interactions is created for each individual project segment. The third phase involves the creation of the **explanation model**. Based on retrograde project data, the hypothesis created shall be proved statistically. Usually the results of the explanation model are cost equations that formally describe the relationship between input and output variables. The quality of the statistical relationship can be described with the aid of quality criteria, such as standard deviation and level of significance. If the results are unsatisfactory this indicates that the hypothesis model is based on misjudgments, which must then be eliminated by revising the model. The first three phases serve to create the fundamental cost model and need to be implemented only once. The fourth phase implies the creation of the **prediction model**. This phase should always be applied when a cost prediction for a future project needs to be implemented. Based on the characteristic anterograde influence factors and with the aid of the cost equations from the explanation model, the cost for future projects can be calculated. The uncertainty that exists in early phases of development projects should be simulated with the aid of the Monte Carlo Method. The result output is attained by means of a cost distribution function.

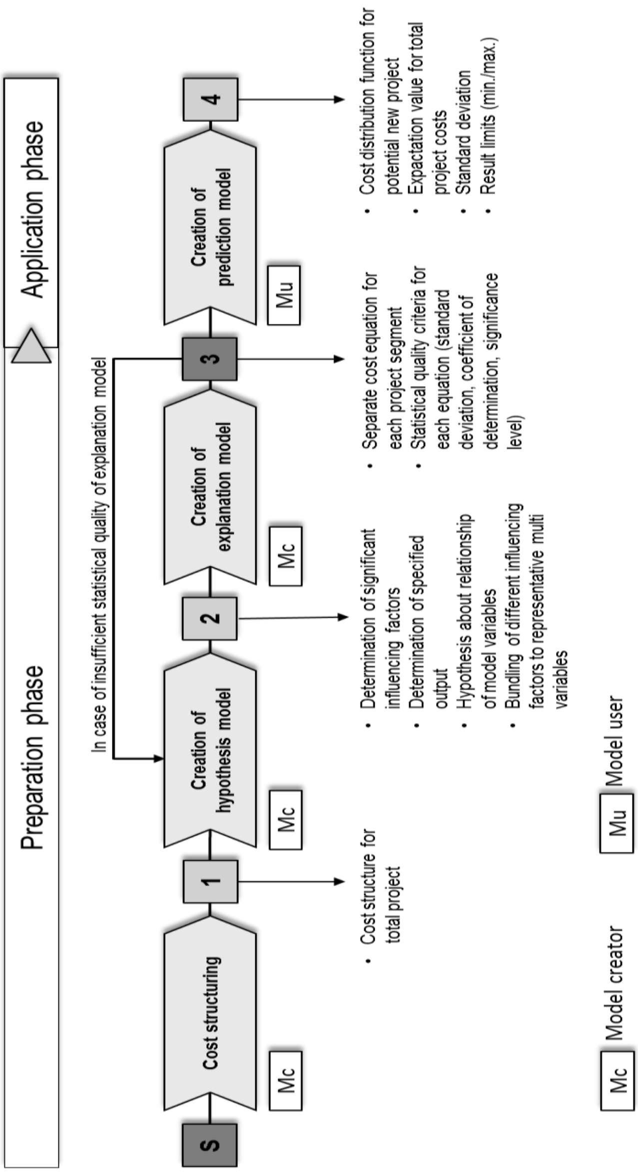


Figure 4: Procedure model of cost model preparation and application. [9]

3.1 Phase 1: cost structuring

Cost model creation begins with structuring the whole project into several project segments. Project segments can be characterized by individual work packages, project subcomponents or the workload of particular persons or departments.
Beginning with the assumption that the total costs of a project will correspond to the sum of the costs of each project segment, costs for each project segment are initially determined separately [5]. It should then be possible to determine the value of the total project costs by aggregation of the individual cost values [10] (c.f. figure 5).

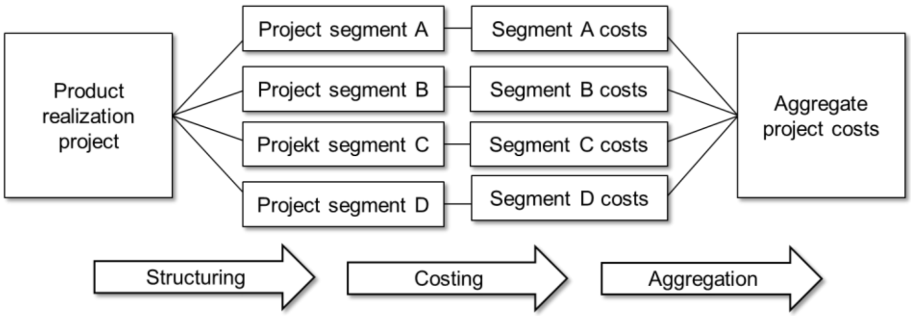


Figure 5: Cost structuring, costing and cost aggregation based on the \`bottom-up\` approach.

In comparison to a lump sum cost determination for the whole project (\`top-down\` approach), the cost determination based on structured segments (\`bottom-up\` approach) offers many advantages. Among an improved clarity and a cause-based cost assignment for each project segment, the \`bottom-up\` approach has a higher result accuracy than the lump-sum calculation. This is due to the fact that errors, which have been made within the cost calculation for the separate segments can cancel each other out when the project costs are aggregated. Equation 1 shows the error compensation in the event that the cost determination is based on several cost segments [11].

$$f_{ges} = \pm \frac{f_i}{\sqrt{N}} \tag{1}$$

f_{ges}: relative total model error
f_i: relative error by cost determination for each segment
N: number of project segments

3.2 Phase 2: creation of hypothesis model

After cost structuring, the hypothesis model creation follows. Within the framework of the hypothesis, the significant influencing factors and output variables are defined. Furthermore the hypothesis describes the connection and interaction of all model variables (figure 6).
The hypothesis is created for every project segment separately. Depending on the individual segment, different influencing factors can be selected. By contrast, the output variable should be equal for all segments to ensure that the results of the segment costs can be aggregated to the total project costs.

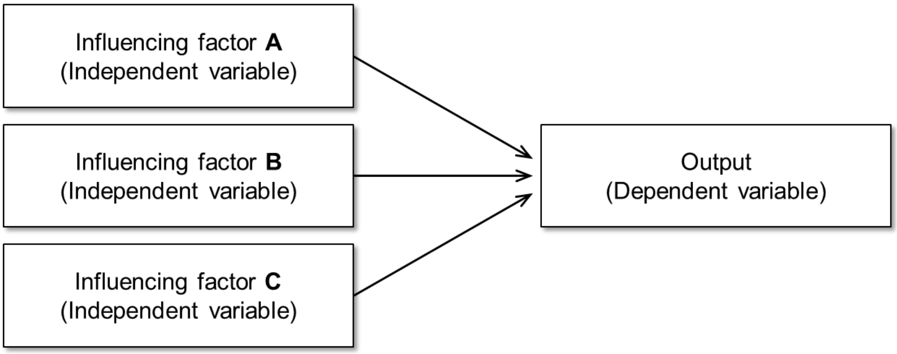


Figure 6: Hypothetic model consisting of three influencing factors and one output variable.

For the hypothesis it is necessary to first determine the output variable. Since the model should be applied to the prediction of development costs, costs, or values that are convertible into costs, must be used as output values.
The direct determination of cost values has the disadvantage that the model needs to be revised continuously, due to wage increases and inflation.
For that reason and due to the fact that the average share of personnel costs can be as high as 80% of the total costs, or sometimes even higher [12], the running of an indirect cost determination on the basis of man hours is recommended. When the number of man hours has been determined for a specific project segment, the cost can be calculated by multiplication with the current hourly rates. Thus the cost base of the model remains up-to-date and revisions can be reduced to a minimum.
Subsequent to the output variable determination, the relevant influencing factors for each specific project segment must be defined. All significant and meaningful factors that have a causally justifiable effect on the product realization cost should be used as influencing factors. Cost-specific factors

may result from the product requirements, the production system requirements, or from the internal project organization. Figure 7 shows some examples of independent variables and their causal classification.

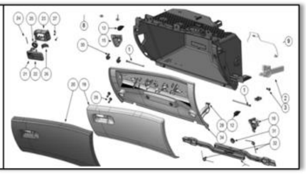
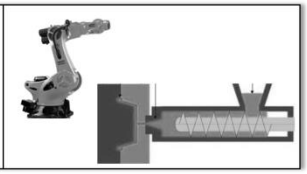
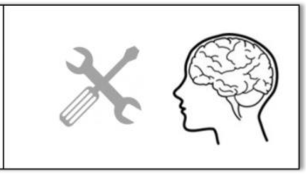
Product specific influence factors	– Number of components – Number of interfaces – Functional requirements – Operating principles …	
Production specific influence factors	– Number and method of production processes – Degree of automation – Interlinking of processes …	
Project specific influence factors	– Use of resources and tools – Experience and motivation of team members – Interfaces to development partners …	

Figure 7: Categories of project specific influencing factors.

3.3 Phase 3: explanation model creation

Within the hypothesis model framework, the assumption previously created concerning the interdependencies of the cost model should be proved empirically [13]. For this purpose, the retrograde project data of the respective company are evaluated with structure probing statistical procedures. The result of the specification model is generally a system of equations that formally represents the mathematical dependencies between the cost model input and output values [14].

As described in chapter 2, the following structure probing statistical methods can be used for the retrograde project data analysis:

- Linear regression analysis
- Non-linear regression analysis
- Neural networks

In addition to the creation of cost equations it should be examined whether the statistical relationship meets the typical quality criteria. The quality of a statistical evaluation can be described with the help of, among other things,

standard deviation (σ), coefficient of determination (R^2) and level of significance (F-test and t-test). If these results are inadequate it indicates that the hypothesis model is based on misjudgments. In this case, an examination and adjustment of the influencing factors and their relationship is necessary.
If the results are satisfactory, the cost equations can be used for the calculation of future projects.

3.4 Phase 4: prediction model creation

The prediction model serves as the cost forecast for future development projects. The independent model variables anterograde expression values are used in the explanation model of the formal system of equations. The potential costs for the new development project can be calculated by solving the system of equations (explanation model).
When applying the prediction model, two aspects should be considered. Due to the lack of information existent in early project phases, it may be difficult to do a precise determination for the anterograde expression value. For instance it is not yet clear whether the “number of interfaces” is 3 or 4. The uncertainty that persists in connection with the determination of the anterograde expression value shall be named **anterograde uncertainty**.
Furthermore the model equation never fully reflects reality, in each case minor deviations can be expected. These deviations (scattering) are represented by the standard deviation (σ) of the model equations and should be named **model uncertainty**. As shown in figure 9 both uncertainties can overlap and lead to quite substantial deviations (**result uncertainty**).
For that reason it is necessary for the method to provide information regarding which uncertainty exists and how big the risk of deviation is. This can be achieved by using a stochastic result output based on a cost distribution function (c.f. figure 8). A deterministic result output would only provide a fixed result value. In contrast to which, the stochastic distribution function gives information about the result limits (min. / max.) and the standard deviation of the result.

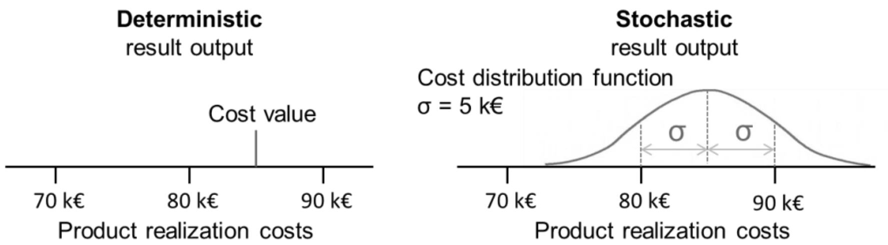


Figure 8: Comparison between deterministic and stochastic result output.

One possible solution to represent the effect of the different uncertainties and their interferences is the application of the Monte Carlo simulation. The Monte Carlo simulation is a method that originates in stochastic process and uses random number generators to solve problems. The method is appropriate for the calculation of stochastic values and for the simulation of complex random processes [15]. The result determination is based on a large quantity of random experiments and their statistical evaluation. By repeated calculation of the model with various value combinations, the method produces results that cannot, or can only with difficulty, be calculated analytically [16]. The result of the Monte Carlo simulation is a distribution function, which gives an overview of the possible result realizations and their probability of occurrence [17] (c.f. figure 9).

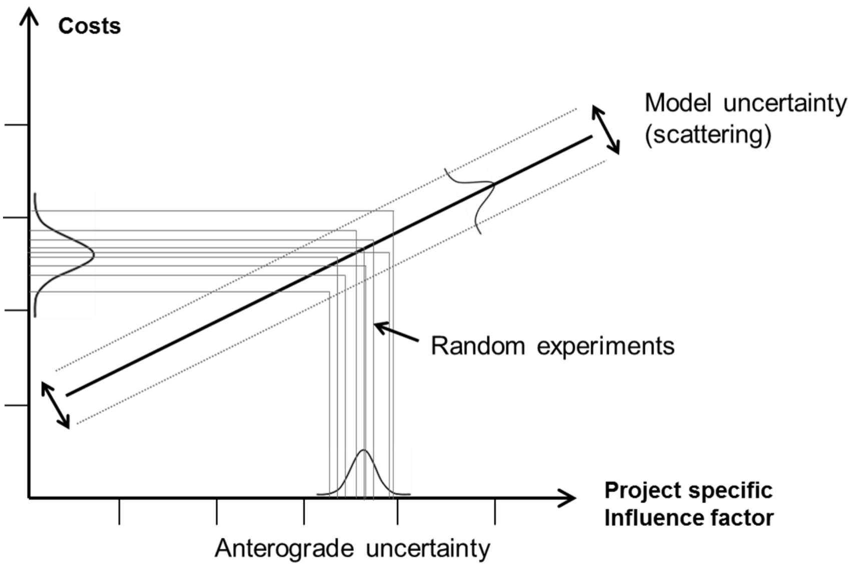


Figure 9: Principle of the Monte Carlo simulation with model uncertainty and anterograde uncertainty considered.

4 SUMMARY AND CONCLUSIONS

Accurate and reliable prediction of development costs has become increasingly important. Parametric cost modeling is an appropriate method for cost determination. With the aid of project specific cost factors the costs for future development projects can be calculated. The cost modeling

process is based on a systematic approach, which is marked by four process steps: cost structuring, hypothesis, explanation, and prediction.
Particularly in the very early phases of development projects, there are many uncertainties and risks to be considered within the cost determination process. The Monte Carlo simulation serves to aggregate and to describe the uncertainty with the help of a result distribution function. The knowledge about the deviation risks helps users of this method to evaluate quality and significance of the cost prediction results and provides the opportunity to consider reasonable risk surcharges.

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RETURN-ON-INNOVATION – A STUDY IN THE CHEMICAL INDUSTRY

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Abstract
Innovation has long been considered a cornerstone of growth and profitability for the chemical industry. In terms of the life cycle however, many fields in the chemical industry have already entered the maturity phase. A significant proportion of key products, such as plastics, have been produced in large-scale industrial environments for more than 30 years and real breakthrough innovations seem to be quite rare today. This commoditization trend of parts of the industry has weakened some companies' and investors' faith in innovation. In this paper a study is summarized which investigated how chemical companies cope with the measurement of their Return-on-Innovation at a business unit or company level. At first the study approach is explained, based on interviews by means of a structured questionnaire addressing 35 managers in the chemical industry. In the second part, the results of the study are discussed: More than half of the participants do not have an innovation output measurement in place at all. About 30% apply the KPI 'sales of new products'. Less than 20% of the interviewed businesses have established more sophisticated KPIs. In fact businesses in the chemical industry do not actually know whether their innovation activities pay off or not. Another take-away from the study is a strong focus on the 'classical' innovation fields: products, applications and technologies. Many companies show increasing awareness of innovation beyond products and technologies and aim to benefit from innovations in services, business processes and business models. In the third part, some best practices have been taken from the interviews, then further discussed and eventually consolidated into an approach to measure Return-on-Innovation.

Keywords:
Return-on-Innovation, chemical industry, best practice, R&D performance

1 GENERAL DEFINITION AND AIM OF THE STUDY

In a recent paper, the authors discussed the importance of benchmarking for analyzing and optimizing efficiency and effectiveness of R&D [1]. An insufficient focus on the output measurement of innovation management was identified as a key improvement potential – according to the old management wisdom stating that “you can't manage what you don't measure”. Effective product innovation is recognized as the single most deciding success factor for enterprises (as shown in [2] and [3]). Another finding was that innovation output measurement has many facets [1], and many attempts to measure the innovation output have failed due to complexity. Differences between industries regarding innovation management are one driver of complexity. Therefore this paper concentrates on the investigation of one industry and the chemical industry has been chosen as focus industry. A study from [4] builds the empirical fundament for this paper.

The chemical industry is one of the most important industries world wide, with global sales of € 3,127 billion in 2012 [5]. In terms of the life cycle, many fields in the chemical industry have already entered the maturity phase. The transparency on global R&D spending in the chemical industry is limited and the published figures do not give a clear picture. According to [5] the top 6 world regions, EU, USA, China, Japan, South Korea and India, spent € 33.8 billion in 2012. In [6] it is reported that only 26 out of the top 50 chemical companies report R&D spending, accounting for $12.7 billion (2012), which equals 2.6 % of sales. Studies in the chemical industry, based on the investigation of selected product launches, show that innovation is still an attractive business model despite the life cycle stage. According to the authors’ investigations, innovation activities pay off with an average internal rate of return (IRR) in the range of 16%, which is far above the cost of capital for nearly all chemical corporations [7]. However, this is an average value. The comparison of single product launches also shows that there are significant variances between product types, industry segments and other factors. Furthermore, the IRR was calculated based on selected project examples, even lighthouse projects, without considering the whole innovation environment. The return of single product launches is an important Key Performance Indicator (KPI) from a project perspective. However, the focus on the outcome of single launches might draw a false picture. Typically, it takes a high number of ideas for one successful product launch. The effort that has been put into all of the ideas that did not make it to product stage needs to be considered. Therefore, from an innovation controlling perspective, the overall return of all innovation activities should be the KPI used to measure innovation performance. The financial return of innovation is not the only positive outcome of innovation activities. Innovation can be used for marketing purposes, to improve a company’s reputation, to motivate employees by working on something really new and exciting or for the employee’s personal development. Nevertheless, solid financial returns are still the most important reason for most investors and companies to invest resources in innovation. In order to achieve transparency on the return, all investments and benefits, including their timing, must be considered. In terms of investment, the innovation or R&D

effort is typically tracked in most companies. Though the existing figures in companies have several shortcomings, the real challenge for measuring Return-on-Innovation is the benefit offered. Measurement of innovation output faces two industry-specific characteristics in the chemical industry: long time-to-market ranges and demanding definition and specification of new products. Investigations show that time to market for product line extensions is between two to seven years, however, new products on average have a time to market exceeding ten years. These huge time scales impede measurement. Additionally, the differentiation between new and existing products is not trivial in the chemical industry. Often products are customized for single customers regarding ratio of components, additives, colors or packaging sizes. The transition from existing products to new ones is fluid.

2 INNOVATION ACTIVITIES IN THE CHEMICAL INDUSTRY

Another important distinction for strategic innovation project portfolio considerations is whether the innovation has to be characterized as sustaining innovation, as efficiency innovation, or even as disruptive innovation [4]. However, for the Return-on-Innovation measurement in the chemical industry a more differentiated segmentation according to [1] is proposed (c.f. figure 1).

Figure 1: Segmentation of innovation types in the chemical industry.

2.1 Research, advanced development and technology development

Output of this innovation type is normally know-how and intellectual property rather than new products, applications or services. The output typically serves as a precondition or enabler and an input for new product development. This innovation type does not directly lead to financial impact, with the exception of selling intellectual property or technologies. Research, technology and advanced development departments therefore need a different steering logic compared to new product development and cost is treated as a type of ‘overhead’ for product, application and service innovations.

2.2 New products

There is no standard definition for ‘new products’ however, in the chemical industry, this term is often used when a product has a new chemical composition. However, this cannot be generalized. Due to regulatory requirements like REACH and quality specifications in the customers’ industries (e.g. automotive, aviation, pharmaceutical) a long time to market is typical for new product innovations.

Within the last years one exception emerged for ‘new products’: when products are produced with bio based raw materials instead of the conventional oil base, the term ‘new products’ is also used without a difference in the product’s chemical composition.

2.3 New applications

Existing products, or minimally altered or adapted ones, are used for new applications and purposes. For example the same ‘molecules’ are used for CD’s and automotive interior parts. The key challenge in application development is to make an existing chemical material that fit the needs of the respective application.

The development of new applications has no clear border between the customization of products, for example colorants, which is well established in many areas of the industry. In areas with intensive customization there is a risk that the business appears much more innovative than it really is. A generic definition between application development and customizing is hard to achieve it therefore needs to be defined according to each specific case.

2.4 New services

Physical products dominate the chemical industry. Service offerings, such as formulation, only cover a small share of the overall business. Services can be sold as a separate ‘service product’ with stand-alone value proposition and pricing. However, in many cases services are part of a ‘bundle offer’ with products and services or used as a customer loyalty tool.

2.5 Innovation in production processes

Raw materials and energy are major cost factors for many chemicals, particularly in the commodity area. Innovation activities are used to improve the production processes and efficiency, for example by reducing energy consumption, by improved catalysts or by increased yields through optimized process parameters. ‘Pure’ production innovations do not have an effect on the product itself so that the improvement effect can be measured easily. But there are also process innovations that effect the product. A change in production process, for example, can result in a higher grade product so that it can be sold for a higher price. On the other hand, certification requirements of automotive or pharmaceutical customers might create additional cost after changing the production process of a chemical.

2.6 Other innovation types

In addition to the innovation options described above, further innovation types need to be mentioned:

- New business models: e.g. applying forward integration and selling directly to end-customers, combining price formulas with customers and tolling agreements with suppliers to lower raw material risks
- Innovative organizational models: e.g. improve customer interaction with customer focused sales organization
- New business processes: e.g. use electronic channels for the order-to-cash process

These innovation types are mainly driven by non-technology topics.

3 INVESTIGATION PROCEDURE

The scope of the innovation activities needs to be clarified before evaluating the return. Innovation is often reduced to product innovations but the bandwidth can be significantly broader, as explained in chapter 2.

3.1 How to evaluate Return-on-Innovation

The basic principle of Return-on-Innovation measurement is to treat innovation spending in comparison to other investments, which are often rated by the internal rate of return (IRR). The IRR is defined as the discount rate at which the present value of all future cash flow is equal to the initial investment or, in other words, the rate at which an investment breaks even. Therefore all cost and commercial benefits of an innovation including their timing need to be taken into account.

Some further considerations are required for the different innovation types. For the first type - Research, advanced development and technology development – direct sales will typically not be generated, since the know-how and intellectual property generated are invested into new products, services and applications. With product, service and application innovations, cannibalization effects need to be considered in the IRR calculation. When new products replace existing ones, only the difference in price, cost and other issues can be counted as benefit of innovation.

The IRR is mainly used in the project initiation phase to challenge the business case of a project. In theory the IRR could also be applied to measure the actual Return-on-Innovation. This, however, requires a very

detailed allocation of cost as well as high transparency and clear definitions of the innovative products and services.
A less complex KPI to find an indication of the Return-on-Innovation is the KPI 'profit of new products'. Preconditions for the use of this KPI are; to have a clear definition of 'new products' and an accounting standard that allows calculating profits at product level. A further simplification of this KPI leads to 'sales of new products'. This KPI does not contain any profitability information, but it provides at least a quantitative indication of the turnover coming out of the innovation pipeline.

3.2 Description of the study approach and data gathering procedure

As described in chapter 1 many chemical corporations do not even publish their R&D budget. In addition many definitions are not standardized, for instance whether the cost for technical services belongs to the R&D budget or not. Therefore, desk research activities or surveys are not appropriate to investigate the Return-on-Innovation topic in the chemical industry. Interviews with senior R&D and business managers are the best way to gather data on Return-on-Innovation.
In order to gain interview access to the senior managers of major chemical companies, the duration of the interview was limited to 15 minutes. The interviews were based on a short questionnaire with 6 questions. Using this approach, 35 interviews could be held after inviting 55 managers to participate. The following six key questions were asked:

- How intensely are the different innovation types covered by your innovation management?
- How do you measure the Return-on-Innovation?
- What is your Return-on-Innovation?
- Why do you or don't you measure the Return-on-Innovation?
- Which components do you consider as most important to improve the Return-on-Innovation for your company?
- Which phases (stage-gate) do you consider as most important for your company to improve Return-on-Innovation?

The questions were partially supported with structured and categorized answering options. Discussions raised by the questions resulted, particularly, in many interesting insights.

4 DISCUSSION OF THE RESULTS

The discussion of the results is structured according to the survey questions. It contains not only the answers to the questions but also information gained during the discussions.

4.1 Importance of innovation types

One expected study outcome is the chemical companies focus on product, application and technology innovation. This reflects the technology-minded culture in most chemical corporations. Production process optimizations are considered to be more important than service innovation. Other innovation types, such as new business models, are almost never considered (fig. 2). However, many managers admitted that they would like to reduce the particular product focus towards services and business model innovation but have so far been unsuccessful.

Furthermore, most companies do not properly differentiate their innovation budget into the subdivisions described. This means that there is already a weak cost basis for solid a Return-on-Innovation measurement.

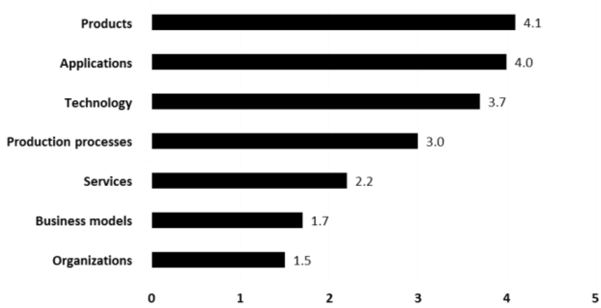

Figure 2: Importance of innovation types in the chemical industry.

4.2 KPIs for Return-on-Innovation

The key outcome of the study is that more than half of the participants do not measure their Return-on-Innovation at all. About 30% of the participants apply the KPI ‘sales of new products’. The importance of the KPI differs significantly between the companies. For some it is just a KPI to foster an innovative image, others use it as a steering KPI relevant to incentives for managers and employees. Less than 20% of the companies and business units interviewed have established more sophisticated KPIs (figure 3). In fact most companies and business units in the chemical industry do not actually know whether their innovation activities pay off or not at all.

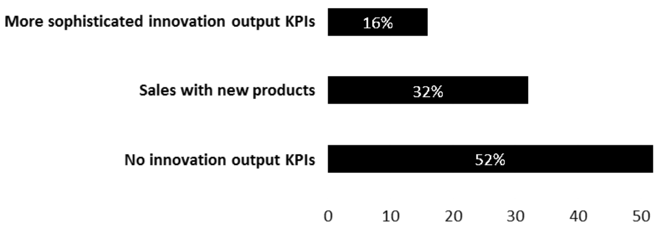

Figure 3: Use of Innovation Output KPIs in the chemical industry.

Therefore a study conducted about 20 years ago by A. H. Schainblatt [8] still appears up to date for the chemical industry: the study revealed that only 20 percent of the R&D managers in major companies even measure the productivity of their R&D operations. Of the 20 percent that do measure productivity, only a few measure any kind of return on investment or amortization in R&D. Besides, it is important not to confuse the Return-on-Innovation measurement on company level with the measurement of single projects. Most companies use business plans for their projects and control the project progress in a stage-gate-process.

4.3 Innovation activities Pay-off

As stated in chapter 4.2, most companies do not know whether their overall innovation activities pay off in terms of IRR. However, a quantitative indication was given by some of the companies using the KPI ‘sales of new products’. The typical range for this KPI was between 12% and 20% - one exceptional business unit came to 30%. For a more detailed analysis and for statistical significance, the sample size was too small.

4.4 Reasons for the current situation

The interview partners primarily stated three reasons for not measuring the Return-on-Innovation. First, the great effort involved in measuring the KPI prevents many companies from doing it. Second, many companies struggle in finding a clear definition of new products and third, the long time scale between investment and benefit were given as reasons for not measuring Return-on-Innovation. On the other hand companies that measure Return-on-Innovation use the KPI to set targets, to manage the innovation process and to steer employees by setting incentives based on Return-on-Innovation.

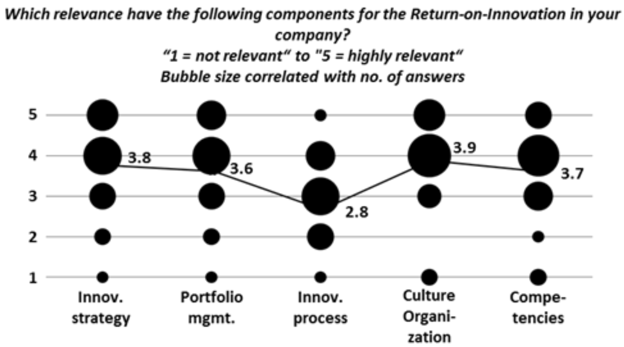

Figure 4: Relevance of elements for Return-on-Innovation.

4.5 Relevance of components

The assessment of the importance of key components for the Return-on-Innovation showed a very heterogeneous picture between the participants of the study. The answers given varied widely. On average innovation culture and organization scored the highest with a score of 3.9. Innovation strategy, competencies and portfolio management followed closely with scores of 3.8, 3.7 and 3.6. Surprisingly innovation processes ranked last with a distinctly lower score of 2.8. Many of the participants ran larger projects to improve their innovation stage-gate process in the last years and therefore currently see limited optimization potentials in the process topics (figure 4).

4.6 Importance of phases in stage-gate process

Similar to the components, the phases also led to a heterogeneous picture between the participants. The difference in the average values, however, is small. The most important phase with an average score of 3.9 is the launch phase followed by realization (score 3.7) and idea generation and selection (score 3.6). The proof of concept is the phase with the lowest importance and a score of 3.4 (figure 5).

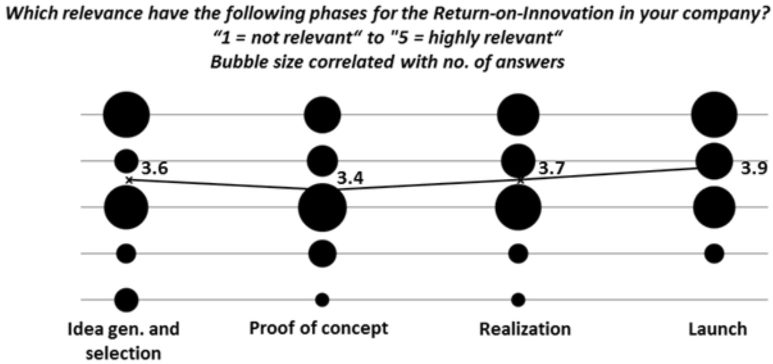

Figure 5: Relevance of phases (stage-gate) for the Return-on-Innovation.

Looking forward towards approaches for optimizing the Return-on-Innovation in chemical corporations, the heterogeneous picture for components and phases indicate that a 'one-size-fits-all' approach is highly unlikely.

5 BEST PRACTICES IN MEASURING RETURN-ON-INNOVATION IN THE CHEMICAL INDUSTRY

The study was not designed to focus on the generation of best practices for Return-on-Innovation measurement; however, the discussions produced some interesting insights. Five key pillars have been identified to establish a successful Return-on-Innovation measurement.

5.1 Going beyond product innovation

Many participants strive to expand systematic innovation activities beyond the classical product innovation. Three best practices have been consolidated to increase the share of these innovations

- Increase transparency: The first step is to achieve transparency on the current share of non-classical innovation projects, e.g. by their Net Present Value. This, typically, creates awareness of a potentially unbalanced project portfolio.
- Consider innovation types in portfolio management: The second step is to actively consider service and business model innovations in the project portfolio planning in setting target ranges for all innovation types
- Anchor in stage-gate process: The third step is to anchor challenging questions on relevant milestones of the stage-gate process to make sure ideas are not only developed towards new products.

5.2 Clear definition of 'new'

The foundation of an efficient Return-on-Innovation measurement, particularly for new products and applications, is a clear definition of what will count as an innovation. An important tool to structure the definition is the innovation type description in chapter 2. Based on that subdivision, the definition needs to cover the following topics:

- Time: A key parameter for the definition of a new product is the time a new product is considered as 'new'. With different product life cycles it becomes obvious that this parameter needs to be adapted accordingly. In the chemical industry typically 3 or 5 years are used as the time scale.
- Starting point: In the chemical industry the starting point for the 3 or 5 years period can be a very important definition parameter: in many businesses small samples are sold to customers, e.g. for tests from customers R&D or certification purposes. Years can pass from these first samples to the market launch of the customer's product. In order to consider this, sales with samples should be excluded.
- Innovation level: Particularly for new products and applications, some business specific definitions need to be taken to differentiate between 'new' and 'customized existing product'. A generic recommendation is impossible to define; this needs to be defined based on the particulars of each business.

One of the participants also used a financial parameter to classify innovations in level 1 and level 2 innovations. Level 2 innovations need to have a significantly higher profit. Therefore, the rationale is that, from a customer perspective, customers are willing to pay a premium for a 'real' innovation.

5.3 Automated measurement of Return-on-Innovation

Since effort has been one of the major reasons not to measure Return-on-Innovation, the integration of this measurement in the ERP system is a key success factor. Ideally, when a new article code is entered into the ERP system, a flag is set if the article is innovative, based on the definitions from chapter 5.1. Based on the flag the ERP can, depending on the ERP functionalities, measure Innovation output KPIs such as sales and profit of new products, services or applications.
In practice the ERP system can be a serious bottleneck for Return-on-Innovation measurement. In specific cases it might be best to specify the requirements for a Return-on-Innovation measurement and make sure that they are implemented in the context of the next overall system update.

5.4 Independent review

The translation of a 'new products' definition into an ERP flag is not always a black-or-white decision. Particularly when the flag decision impacts the incentives person setting the flag, there is a risk that the hurdle flag setting becomes too low. Therefore a survey of the flags by a non-biased person is very helpful to achieve an objective classification. Such a person could, for example, be the product manager who knows the overall product portfolio but has no specific focus on new products. In addition the top five or top ten new products should also be transparent for the management team.

5.5 Usage

The easiest way to weaken a KPI is to make no use of it. In contrast to technical instruments that measure their parameters independently from the importance of the results, the quality of KPIs typically correlates with the impact of their usage. A strong sign of a company's commitment to innovation is the use of innovation output KPIs for employees' incentives. Some of the participants already use the Return-on-Innovation KPI for incentive schemes, others plan to use it and are still in a test and verification phase and use it for planning and steering purposes.

In many company cultures innovation output incentives are still difficult to implement. Particularly in R&D environments it is often argued that innovation output is influenced by other factors and therefore should not be used at all. Other functions and departments seem to be more flexible: in sales incentives typically depend on sales or margin, both are also influenced by many parameters outside the sales department: for instance quality of products, performance of competitors or economic business cycle. Therefore the acceptance of the Return-of-Innovation as a key innovation target and R&D activities is an important cultural element.

6 SUMMARY AND CONCLUSIONS

Since effective product innovation is recognized as the single most deciding success factor for growth and profitability, it seems to be extremely important to overcome low output focus of innovation management. For all R&D managers in the chemical industry and those who are responsible for product innovation, transparency of the innovation process output and outcome is a major success factor. Therefore, the use of KPIs that are able to monitor the output and outcome side is crucial. They must be adjusted to preconditions, circumstances, status of product realization, product lifecycles and sector of the industries. Based on a survey of 35 R&D and business managers, it is obvious that most companies and business units in the chemical industry actually do not in fact know whether their innovation activities pay off. Another finding is that a commodity oriented innovation approach tends to result in significantly less growth and profitability than an innovation driven approach with high spending in R&D combined with proper Return-on-Innovation measurement. Return-on-Innovation KPIs must, therefore, be implemented as steering items matched to the individual company's requirements to show a clear strategy towards innovation success. Most chemical companies are strongly focused on the 'classical' innovation fields: products, applications and technologies, but some show increasing awareness on innovation beyond products and technologies and aim to benefit from other innovation fields such as services, business processes and business models. The identification of several best practices is possible, despite a wide range of products and development approaches. A clear understanding of what is ‘new’, automated measurement and an independent review of Return-on-Innovation are among those best practices.

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WHY BOTHER WITH OUTSOURCING? - SUCCESS FACTORS AND CORE COMPETENCIES

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Abstract
Outsourcing of logistics services is common practice for many manufacturers and retail companies. The main reasons given by decision makers are improving 'value for money' and flexibility. Often, this is justified with the company's need to focus on so-called 'core competencies'. Correspondingly, most outsourcing projects are triggered by the objective to reduce costs, while only a smaller proportion is driven by the objective to improve quality and overall performance. In reality, however, the expected benefits are often not (fully) achieved.

Keywords:
Outsourcing, logistics service provider, contract logistics, core competency, Total Lifecycle Cost of Outsourcing Projects (TLCOP)

1 SCOPE OF THE PAPER & METHODOLOGY

Based on literature research, this paper analyses the characteristics of the market for logistics outsourcing and tries to identify success factors and potential pit-falls in contract logistics outsourcing processes.

First, the motives for outsourcing and the different types of logistics service providers in the market are described. Next, the characteristics of logistics outsourcing-decisions are explained, before a detailed phase model (SCISSORs-framework) is introduced. This relates to the concept of Total Lifecycle Cost of Outsourcing Projects, describing all costs that need to be taken into account for a well-founded outsourcing decision.

Finally, the empiric findings of several studies are discussed, identifying several pit-falls and, thus, areas of improvement for future outsourcing management.

2 OUTSOURCING LOGISTICS PROCESSES

2.1 Motives for logistics outsourcing and characteristics of the outsourcing market

In a narrow sense, logistics refers to the physical and/or administrative execution of the basic COST-tasks in real-time (cf. [1], [2] and figure 1). In a broader sense, logistics also includes the related planning and control activities to best set-up and organize the flow of values, information and physical goods. Some authors define logistics as only related to the physical goods flow, whereas supply chain management also includes information and value aspects (cf. for instance [3] and [4]). In this paper, however, logistics (in the broader sense) and supply chain management are used as synonyms.

In the short-term the general conditions and the requirements to be fulfilled are fairly well-known. However, due to time pressure, there is only a low level of freedom of action in the logistics system. As opposed to that, in a long-term strategic design context logistics managers have a very high level of freedom but, at the same time, very little knowledge about the future requirements. They, therefore, have a stronger need to rely on theories and concepts to design and optimize their supply chains.

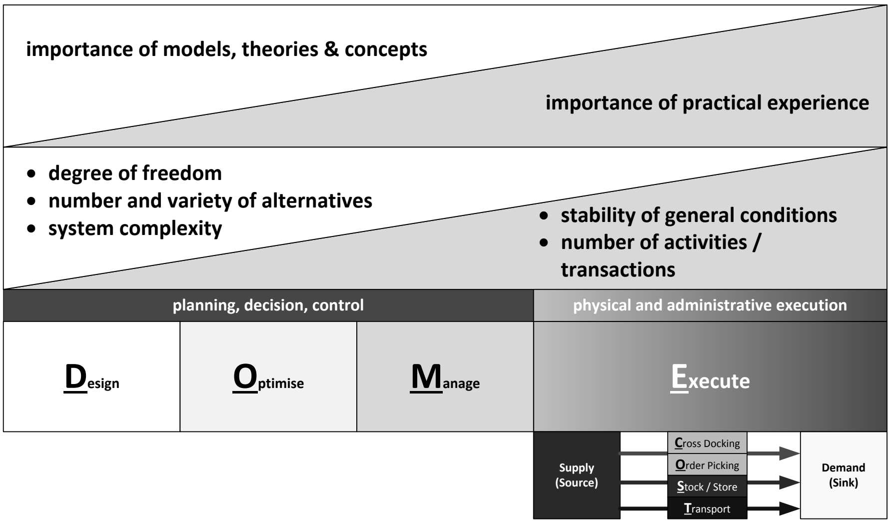

Figure 1: Logistics tasks and their general setting.

Nowadays, an increasing number of decision makers are under pressure to reduce supply chain cost. One approach is often justified with the company's need to focus on so-called 'core competencies' (logistics often not being considered as one of them). Therefore, outsourcing (from outside resource using) of logistics activities is common practice for many manufacturers and retail companies (cf. e.g. [5], [6], [7], [8] and [9]).
In this case, logistics service providers take over the execution of basic logistics tasks for their clients. This is especially the case for classical transport and warehousing activities (cf. [7] and [9]). Services related to strategic design, tactical optimization or even to everyday management activities are not as widespread due to the complexity and strategic importance of logistics planning and control activities (cf. [6] and [7]).
As shown in figure 2, the main reasons given by decision makers are improving 'value for money' (lower cost and/or higher quality) and flexibility (cf. for instance [6] and [7]). Short-term flexibility refers to balancing capacity / volume fluctuations, whereas long-term flexibility stands for both avoiding fixed costs and adapting to fundamental market developments. Most outsourcing projects are originally triggered by the objective to reduce costs, while only a smaller proportion is driven by the objective to improve quality and overall performance.

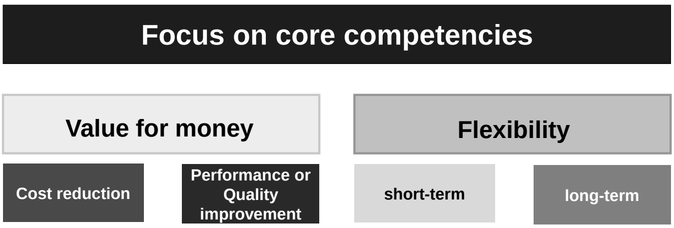

Figure 2: Key reasons for outsourcing.

Outsourcing companies vary strongly with regard to their requested scope of services, ranging e.g. from one-off transports purchased via the spot-market to long-term and comprehensive contract logistics business relationships.
Traditionally, many logistics service providers are asset-based with own trucks, warehouses, containers or other handling equipment. They mainly focus on executing physical and administrative logistics tasks for their customers. Sometimes, at least short-term planning and control activities are also included. These service providers are often referred to as so-called 3PLs (third party logistics service providers, cf. figure 3).
Others without physical assets focus on managing 3PLs for their customers, sometimes also offering support for strategic design and optimization challenges (so-called 4PL companies, cf. e.g. [6]). Increasingly, successful

3PLs are expanding their scope of services, both with regard to executional value added services (e.g. packaging, labelling, sorting, assembly or repair activities) and to design and optimization tasks. These companies are then often referred to as LLPs (Lead Logistics service Providers).

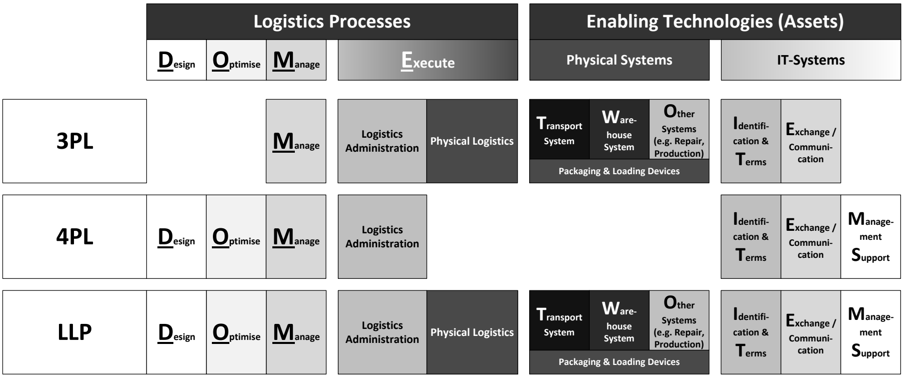

Figure 3: 3PL, 4PL and LLP logistics service provider models.

As the market for logistics services outsourcing is very diverse, an outsourcing company should carefully consider the logistics service provider's specific competencies, track record as well as their market positioning.

2.2 Why 'outsourcing' is not the same as a 'make or buy'-decision

This paper considers the case of contract logistics outsourcing projects, where several logistics services are outsourced as a bundle (e.g. warehousing, transport with complementary value added services) for a contract period of at least two years (cf. for instance [10]).

Sometimes, 'outsourcing' and 'make or buy' are used as synonyms. While the terms themselves are interchangeable, there are fundamental differences concerning the logistics management requirements of the concepts hereafter discussed (cf. figure 4):

- 'Make or buy'-decisions for physical goods
- 'Buy or lease'-decisions for durable enabling technology for logistics
- 'In- or outsourcing'-decisions for logistics processes

'Make or buy' in the sense of this paper applies to the decision to either produce physical goods yourself or to procure them from an external supplier. As long as the supplier fulfils the quality specifications and delivers on time, the buying company does not have to care about the supplier's logistics setup or supply strategy (e.g. network, equipment, asset or stock policy). Often, these decisions are primarily focussed on 'value for money' aspects.

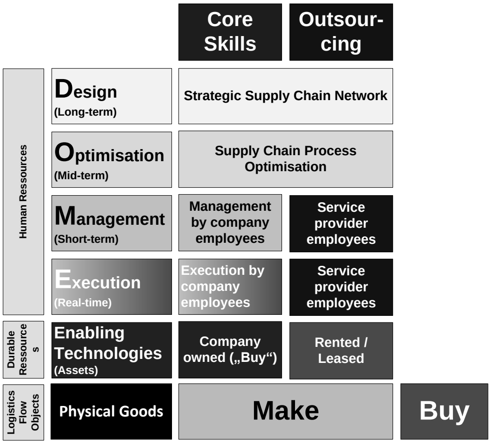

Figure 4: 'outsourcing'- vs. 'make or buy'- and vs. 'buy or lease'-decisions.

The question of who owns the enabling technology elements (e.g. picking equipment, conveyor belts or IT systems) leads to 'buy or lease'-decisions. These are often primarily related to flexibility, investment calculation and financial strategy issues rather than to supply chain management aspects.

In the case of logistics outsourcing, processes of a company's supply chain are operated by an external company with own goals, strategies and specific competencies. This requires a high level of competency regarding strategic logistics design, process optimization and management by the outsourcing party in order to best define the processes to be executed by the service provider.

2.3 Decision phases in contract logistics outsourcing

On an aggregated level, the phases within outsourcing may seem fairly straightforward and can be described as OSM (cf. figure 5).

Figure 5: OSM outsourcing phases.

- **O**utsource: First, a decision whether or not to outsource needs to be taken.
- **S**elect: Next, a suitable logistics service provider needs to be identified and contracted.
- **M**anage: Finally, the outsourcing party needs to continuously and professionally manage the service provider.

This paper claims that outsourcing long-term and comprehensive contract logistics is a complex process with a major impact on future business success. As the circumstances (e.g. customer requirements, supplier setup, service provider performance or legal restrictions) may change over time, the basic decision to outsource or not and, thus, the OSM phases need to be reapplied from time to time.

3 TOTAL LIFECYCLE COST OF THE OUTSOURCING PROJECT

3.1 Logistics outsourcing cost related to regular operations

Up front, outsourcing companies are, typically, mostly interested in the expected performance and cost of the (ongoing) regular operations phase throughout the planned contract duration. This is problematic for several reasons: First, calculating logistics cost is generally not easy (see below). Second, logistics service providers tend to have very different calculation and pricing models, making the comparison and cost prediction difficult, especially in the case of process based price models (cf. e.g. [11] or [12]).

Often, people disagree on what logistics or supply chain cost actually includes (see table 1 and cf. e.g. [13], [14], [15] and [16]). Obviously, bills paid to transportation or warehousing service providers form a straightforward part of a company's logistics costs. If, however, a manufacturer or retail company currently runs its own logistics operations using own assets, the related costs may not always be that transparent. And even if they are, they may be inappropriately assigned to decisions, ignoring the costs' actual origin and reason.

Similar difficulties apply even more to possible consequential costs of (bad) logistics performance quality. Furthermore, the decision, whether or not the cost for non-logistics activities somehow linked to logistics processes are to be considered as part of logistics cost is controversially discussed. In accordance with this, empiric studies typically strongly disagree both on the (average) cost of logistics and the proportion of outsourced logistics (cf. e.g. [5], [7] and [9]).

Table 1: Potential elements of logistics cost for the regular operations phase.

Type of costs	Direct costs	Indirect costs	Consequential costs	
Cause	logistics systems and/or performance		logistics performance	Non-logistics activities
Determination	Easy	Potentially difficult	Highly difficult	
Consensus	Non-controversial	Highly controversial		

3.2 Logistics outsourcing cost related to the contract logistics project before and after regular operations

Comprehensive contract logistics business relationships run through typical life-cycles, that all have a significant influence on the project's success or failure. In order to ensure a successful outsourcing process, there is a need to invest the adequate time and effort into the pre-operations and post-operations phases, also (cf. figure 6).

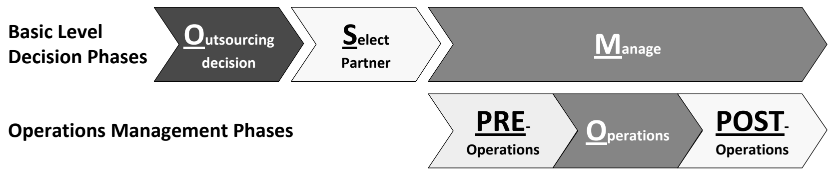

Figure 6: Relevant phases over the entire contract duration.

The pre-operations phase consists of defining the objectives and the scope of the outsourcing project, identifying and narrowing down the potential candidates in the concept phase. After the final choice, detailed planning and implementation, the set-up of assets and interfaces need to be accomplished. A systematic start-up phase is often neglected, but very important for the overall success of an outsourcing project.

In the post-operations phase, both customer and service provider need to establish a culture of continuous improvement in order to ensure long-term market success for both parties. Otherwise, managing the switchover from the current to a new, better service provider becomes an important step for the outsourcer.

3.3 SCISSORs-framework to manage the outsourcing project and the Total Lifecycle Cost of the Logistics Outsourcing Project

Based on critical milestones, the detailed steps required by the outsourcing party to professionally manage the contract logistics project can be described by SCISSORs (cf. figure 7):

- **S**earch: consists of defining the objectives and the scope of the outsourcing project, identifying and narrowing down the potential candidates in the concept phase
- **C**oncept: specification of processes, detailed volume and service planning
- **I**mplement: hiring and training of employees, set-up of assets and interfaces (e.g. building or renting warehouses, installing enabling technology), signing lease agreements, IT programming, EDI integration tests, signing the final contract, etc.
- **S**tartup: hand-over of operations from the previous logistics organization (either the customer or the former service provider) and so-called 'ramp-up'
- **S**teer: ongoing planning and control of logistics service provider's performance
- **O**ptimize: continuous improvement of structures and processes during contract period
- **R**eplace/**R**eturn: At end of contract period, revision of results, possibly renewing contract, setting up a bidding process or even switching to another service provider.

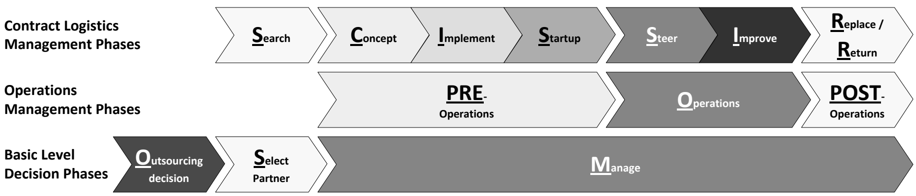

Figure 7: SCISSORs-framework for outsourcing project management.

If done correctly, the costs that are directly or indirectly caused by the project management itself (man-days, bills by consultants, etc.) are typically substantial. If done incorrectly, there are typically significant consequential costs of project management mistakes (e.g. due to incomplete process alignment, missed timelines, wrong volume estimates). All these project-related costs together can sometimes outweigh the predicted benefits during the regular operations period.

In an analogy to the Total Cost of Ownership-concept for physical goods or enabling technology, this paper advocates a comprehensive view of logistics outsourcing cost over the entire SCISSORs-phases: Well-founded outsourcing decisions, thus, require taking into account not only the cost for regular operations but also the significant cost and effort for professionally managing the outsourcing project and/or switching costs. This will be referred to as the Total Lifecycle Cost of the Outsourcing Project (TLCOP).

4 EMPIRIC FINDINGS AND AREAS OF IMPROVEMENT

Various empiric studies show that, in many cases, outsourcing does result in lower cost, higher quality and/or a higher level of short-term and long-term flexibility (cf. table 2 and e.g. [6], [7] and [9]).

Table 2: Empiric results of the global 2013 Third-Party Logistics Study [9].

Results		All Regions
Logistics Cost Reduction (%)		15%
Inventory Cost Reduction (%)		8%
Logistics Fixed Asset Reduction (%)		26%
Order Fill Rate	Changed **From**	58%
	Changed **To**	65%
Order Accuracy	Changed **From**	67%
	Changed **To**	72%

There are, however, cases in which outsourcing projects actually went wrong and reduced the quality and/or resulted in higher costs than before. That is alarming if – as assumed for many companies – logistics performance has a high impact (cost and quality) on the company’s overall success. Furthermore, improvements were often lower than expected beforehand.

This paper argues that some of the reasons for not achieving the overall project goals and, thus, areas of improvement are related to the following:

- Original project focus
- Core competency definition
- Logistics service provider selection
- expectations and/or project management
- TLCOP

An empiric study showed that, on average, both cost cutting- and quality improvement-driven outsourcing projects deliver a positive benefit to improving a companies' financial performance (cf. figure 8 and [17] and [18]). However, those projects that focused mainly on improving quality had an even higher positive impact than cost cutting-projects. This is assumed to be due to a more holistic, process oriented approach that questions the necessity and the execution quality of all process steps, including non-logistics activities as opposed to simply trying to lower cost on the largest, most obvious cost accounts.

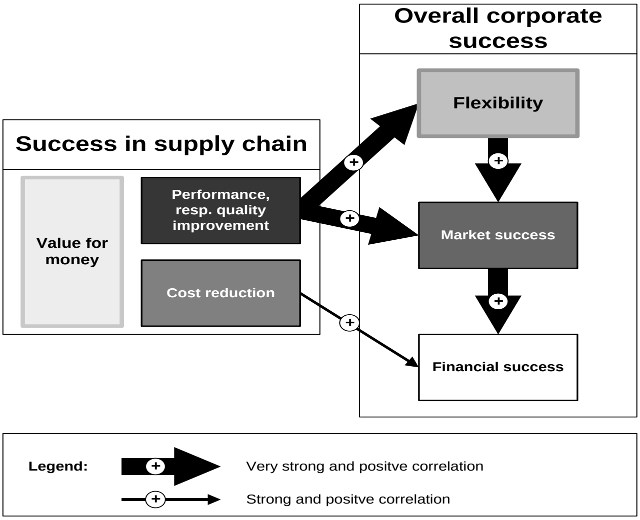

Figure 8: Outsourcing success related to original project scope [18].

What is to be considered as a company's 'core competencies' are not always easily defined and often based on past performance rather than on its strategic value for future market success. However, in many markets supply chain performance has a substantial influence on the perceived market performance and on the financial performance of a company (cf. table 3).

As a result, simply ignoring the importance of logistics as a 'non-core competency' and putting little emphasis on the related outsourcing processes is potentially dangerous from a strategic point of view.

Table 3: Core competencies vs. Outsourcing.

	High impact on achieving company objectives **in the future**	**Low impact** on achieving company objectives **in the future**
We are **'better'** than others	**Core Competencies**	**Depends** on available capacities
Others are **'better'**	**Critical**: Either build core competencies or strong integration, close monitoring	Ideal for **outsourcing**

When selecting a specific provider, the main reasons given include improving ‘value for money’ and flexibility, the service providers presence in the market (e.g. existing network and facilities) and the perceived skills and competency (cf. figure 9 and cf. for instance [6], [7] and [9]).

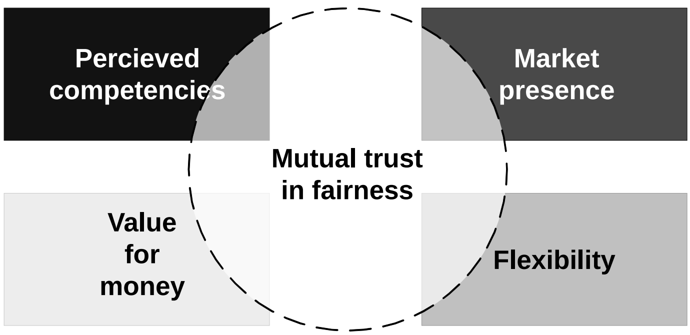

Figure 9: Reasons for selecting specific service providers.

Even when using service level agreements (SLA) and regularly controlling the operations based on key performance indicators (KPI), both the actual cost and the performance are difficult to predict before execution. And often, they are also difficult to assess in retrospect due to the lack of appropriate comparison possibilities (cf. e.g. [19]). Therefore, and due to the potential strategic impact of the business relationship, the level of trust towards the service provider should always also be taken into account (cf. [10]).

In some companies, logistics outsourcing is treated by purchasing specialists with the same procedures and tools as ‘make or buy’-decisions for standardised physical goods or simple ‘buy or lease’-decisions related to physical assets, ignoring the service characteristics of contract logistics.

Industrial and retail companies differ strongly with regard to their level of logistics expertise: It makes a huge difference whether a company is contemplating outsourcing logistics processes that have up to now been performed by own employees (first-time outsourcers) or if the question is whether or not to replace the current service provider. Therefore, some companies employ experienced internal specialists to manage the outsourcing process and/or integrate external consultants, whereas others don’t see the necessity to do so.

As mentioned, the decision phase-related project costs can be substantial. Often, the TLCOP is not taken into account sufficiently. This in addition to sometimes unrealistic expectations leads to a systematic underperformance of implemented outsourcing projects in comparison to the original project objectives.

In total, one can conclude that – done right – outsourcing within contract logistics is worth the effort it requires to do it properly. But done wrong, outsourcing can ruin a company’s future business.

An interesting future research area could be integrating the approach in this paper to a strategic logistic service provider marketing point of view (cf. e.g. [20] – [25]).

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INFORMAL STRUCTURES IN CHANGE PROJECTS – A HANDS-ON EXAMPLE

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Abstract
Change management projects often involve a large amount of effort and only partial aim achievement. The main reason for this is that the personal character, motivation and behavior of the participants and their inter-personal relationships are often inadequately considered. Classic project management seldom includes these factors, due the current lack of published practical informal structural analysis methods. This paper will show how a checklist of "Success Factors in Change Management Projects", as well as how selected informal structure analysis methods can be retrospectively applied to an Enterprise Resource Planning (ERP) project and what conclusions can be drawn for management success.

Keywords:
Project management, change projects, informal structures, management success

1 PROBLEM STATEMENT AND OBJECTIVES

The authors have often had the experience that change projects were difficult to carry out, even though a very good project management process, with accountability, defined activities, milestones and standards had been created, they did not fully achieve their objectives. The reason for this failure lay mostly with inter-personal relationships, the project participants' individual characteristics, motivation and attitudes, were inadequately considered in project management. Besides the formal structure within an organization, an informal structure also exists. Generally, when confronted with resistance, project leaders and management attempt to apply and correct the visible formal structures. The crucial issues, however lie in an invisible, barely accessible gray zone, in the informal structures [1].
In order to ensure sustainable change project success it is, therefore, necessary to treat formal and informal structures as equally important. These informal phenomena have been researched, but the results have not been included in practical project methods. It therefore comes as no surprise that this subject, according to the author's research, is hardly taken into consideration in classic project management.

This paper takes this as the starting point. The authors advance the theory that management success, in projects as well as in day-to-day operations, can be significantly increased if informal structures are taken into account. The focus here is not on actively changing these structures, but to understand them and, with this understanding, to gain the participants' commitment to the project.
The following will first show the basic parameters of a completed ERP project, in a SME where the author from the company was formerly employed as project leader, prior to his present position.
Initially, this project will be retrospectively assessed, according to general factors for success obtained from change project publications. Subsequently, practical, publicized methods for analyzing inter-personal relations will be presented and retrospectively applied to the ERP project.
In conclusion, it will be shown that the initial theory can be proved and where further research is required.

2 ERP PROJECT

During 2011 and 2012, a new ERP system was introduced in the subject company. The manufacturing company belongs to a corporate group, which employs approximately 75 people and has a yearly turnover of approximately € 10 million.
From a corporate point of view, the implementation of a new ERP system was necessary due to the use of different software solutions in each company.
In a preliminary project, the most suitable software was chosen and was then to be rolled out in a pilot project at the subject company. During this process serious problems recurred, such as:

- Key user conflict of interests.
- Background propaganda and rumors in the company.
- Mood swings in the project team.
- Individual project team members' excessive workload
- Repeated deviation from project plan, above all deadline postponement.

The ERP project could ultimately be implemented only with considerable effort.

3 SUCCESS FACTORS IN CHANGE PROJECTS

First of all, the typical change project success factors were identified and collected from relevant sources [2-12]. The ERP project was then evaluated according to these factors (Fig. 1).

Success Factor / Appraisal: Consideration...	Full	Predominantly	Partly	To some degree	None
Project Organization			x		
Rate of Change		x			
Resources				x	
Consultancy			x		
Target-Oriented Management				x	
Vision					x
Personal Development					x
Feedback and Monitoring				x	
Integration					x
Communication				x	
Participation			x		
Leadership				x	
Key Users			x		
Emotions					x
Resistance					x

Figure 1: Evaluation of the ERP project with the Checklist "Success Factors in Change Projects".

A detailed description of the success factors in Fig. 1 is not possible in this paper; instead the main reasons for the rating given to some chosen factors will be discussed.
The *project organization* schedule produced was only assessed at irregular intervals; only rough milestones were in place, this resulted in late recognition of project delays.
In order to save on *consultancy* services, many of the system preference changes were undertaken in-house; in retrospect this led to a greater need for correction.
Insufficient regard was given to the internal *resources* required, Key Users were not relieved of their every day duties, which often led to delayed and superficial project work.
Employees were not assessed as to whether they, as a result of a lack of experience, may require especially intensive training *(personal development)* before the system rollout.

Emotions were not examined or discussed in the project execution, which resulted in emotional outbursts due to changes of entrenched roles and responsibilities and new internal networks being formed.
Furthermore, which employee would offer *resistance* (oppositionists) was not considered.
The retrospective project assessment shows that the “soft” factors were predominantly responsible for the problems encountered.
The “success factors” illustrated do not take project members motives and their inter-personal relationships into account. This aspect of the ERP project should now be examined in more detail. The informal structures will therefore be analyzed, selected and applied to the ERP project.

4 COMPARISON AND SELECTION OF INFORMAL STRUCTURE ANALYSIS METHODS

Organizational achievement can almost exclusively be achieved by the group organizational form; individual performance is becoming less important. Therefore, knowledge of behavior within groups is gaining importance [13]. In order to select informal structure analysis methods, the authors have, based on their project experience, defined the following assessment criteria:

- Independence (the method is able to be applied without external consultancy/moderation).
- Effort (completion time is relatively short).
- Knowledge (important conclusions for change project optimization can be derived).
- Involvement (affected employees need not be involved in analysis)
- Knowledge/target situation (important conclusions for optimization/ target situation can be derived).
- Visualization (the constellations can be visually represented).

Twelve methods were found in publications, which could be analyzed according to the stated assessment criteria. The following five methods best fulfilled the criteria and were used for the ERP project:

- Force-field analysis.
- Sociomatrix.
- Sociogram.
- Clique analysis.
- Group as a Force.

5 APPLICATION OF SELECTED INFORMAL STRUCTURE ANALYSIS METHODS

Before the analysis results are presented, the ERP project structure must be explained briefly (see Fig. 2).
Two newly appointed project leaders were available to the company (PL1-K and PL2-K) who, together with the group project leader (PL-U), were to coordinate the pilot project. It would later be their job to lead the implementation projects in all the other companies within the group. Additionally, there were 10 Key Users (KU) from all relevant areas of the company and a steering committee for project control was formed.

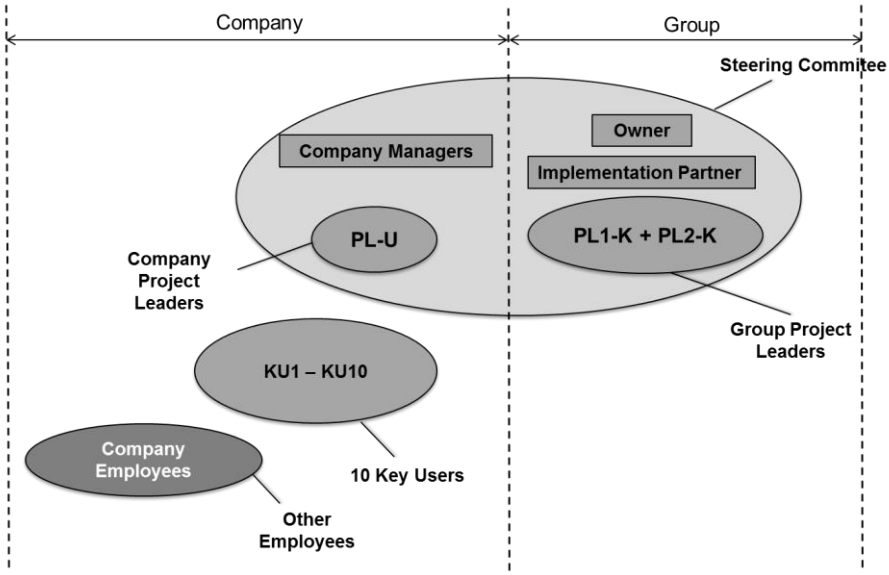

Figure 2: ERP Project Organization.

5.1 Force-Field Analysis

Initially a force-field analysis was applied [cf. 14]. This serves to identify the driving and restraining forces, or the *motivation* behind the project, the arrow thickness represents the strength of influence.
Producing a force-field analysis diagram is particularly helpful during the start phase of a project. The force-field analysis of the ERP project examined (Fig. 3) clearly shows that personnel can simultaneously be both driving (green arrows) and restraining (red arrows) forces.
The following conclusions can be made for the ERP project, for example:

- The owner exerts considerable pressure on the project behind the scenes.
- PL1-K possesses great technical knowledge, but cannot always get the other Key Users on board.
- PL2-K is not well liked and generates mistrust amongst the Key Users.

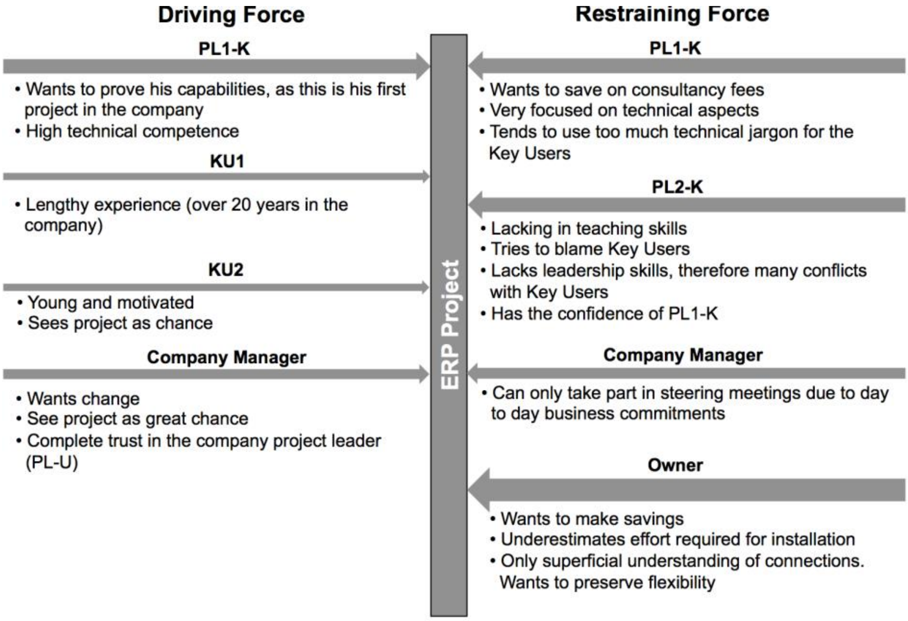

Figure 3: ERP Project Force-Field Analysis (detail).

5.2 Sociomatrix

A sociomatrix was also produced. In a sociomatrix the participants appraise each other, generally according to the criteria “positive” (acceptance / respect) and “negative” (rejection / disrespect). Alternatively, the matrix can be created without involving the participants [15] as was done in the ERP project examined here (Fig. 4).

+ = positive / Acceptance
- = negative / Rejection
0 = neutral

Chosing participant \ Chosen participant	PL-U	PL1-K	PL2-K	KU1	KU2	KU3	KU4	KU5	KU6	KU7	KU8	KU9	KU10	Positive Range	Negative Range
PL-U		+	0	+	0	+	0	+	0	0	0	0	0	4	0
PL1-K	+		+	-	0	+	-	-	0	0	0	-	0	3	4
PL2-K	0	+		-	0	+	-	-	0	0	0	-	0	2	4
KU1	+	0	-		0	0	0	0	0	0	0	0	0	1	1
KU2	0	0	0	0		0	0	0	0	0	0	0	0	0	0
KU3	+	+	+	0	0		0	0	0	0	0	0	0	3	0
KU4	0	-	-	-	0	0		0	0	0	0	+	0	1	3
KU5	+	0	-	0	0	0	0		+	+	+	0	0	4	1
KU6	0	0	-	0	0	0	0	+		+	+	0	0	3	1
KU7	0	0	-	-	0	-	0	+	+		+	0	0	3	3
KU8	0	0	-	0	0	-	0	+	+	+		0	0	3	2
KU9	0	-	-	0	0	0	+	0	0	0	0		0	1	2
KU10	0	0	0	0	0	0	0	0	0	0	0	0		0	0
Positive Votes Received	4	3	2	1	0	3	1	4	3	3	3	1	0		
Negative Votes Received	0	2	7	4	0	2	2	2	0	0	0	2	0		
Positive Agreement	4	3	2	1	0	3	1	4	3	3	3	1	0		
Negative Agreement	0	2	4	1	0	0	2	1	0	0	0	2	0		

Figure 4: ERP Project Sociomatrix (complete).

A project leader or manager can, for example, once the project has reached a certain point, produce the matrix independently, as the participants have been observed over a long period of time. Sociomatrices can identify sociometric stars (a large number of positive votes), sociometric rejects (large number of negative votes), ghosts (vote, but receive hardly any positive votes) and isolates (don't vote for other people and receive hardly any positive votes) [cf. 16].

5.3 Sociogram

The sociomatrix provides the basis of a sociogram, which serves to illustrate the relationship network as a diagram [cf. 17].
Before producing a sociogram, it is useful to assess the participants according to defined characteristics (Fig. 5). The characteristics chosen were considered to be relevant to the project situation.
In order to produce the ERP sociogram, every possible constellation between the project participants was assessed (see Fig. 6). A basic differentiation was made between like and dislike. The criteria character, purpose or incident indicate the possible motivation behind the given assessment.

Individual	Characteristics									Comments
	Identification with the company	Willingness to Change	Capacity for Team-Work	Extrovert	Honesty	Respect with the Company	Leadership Qualities	Power / Influence	Professional Expertise	
KU1	+	-	+	+	0	-	-	0	0	Would prefer to leave things as they are; tasks remain unfinished, therefore little respect within the company
KU2	+	+	+	-	+	+	-	-	+	Always friendly and cooperative; but introverted during team meetings; has familiarized themselves with ERP subject matter
KU 4	-	-	0	0	-	-	-	-	-	Ponderous; motivation almost impossible; only does the neccessary; is often untruthful; has some intensive relationships with other company employees

Key

+	Applies / Mostly Applies / Good
0	Sometimes Applies / Moderate
-	Does not Apply / Bad

Figure 5: ERP Project Participant Characteristics (detail).

Using Figure 6 as a basis, a sociogram could be produced (Fig. 7).
The following conclusions could, for example, be drawn from the sociogram:

- Due to numerous conflicts, the respect for PL2-K sank within a very short period of time. Seven out of ten Key Users rejected this person due to their lack of leadership skills.
- KU-3 was the only Key User to be relieved of other duties, as a result of which, they had more intensive contact to PL1-K and PL2-K and were able to establish a personal relationship with them, but, at the same time, lost the respect of other colleagues.
- KU-4 and KU-9 were lacking in technical competence, which led to an increase in antipathy during the course of the project.

Relationship Number	Individual	Like: Character	Like: Purpose	Like: Incident	Dislike: Character	Dislike: Purpose	Dislike: Incident	Explanaition of Relationship
2	PL1-K KU3	XO	X					Similar characteristics; PL1-K uses KU3 to achieve rapid project progress
3	PL1-K PL2-K		XO					PL2-K often takes over crtitical tasks for PLK-1
4	PL2-K KU3		XO	XO				They get along with each other well; have various points of contact within the project; KU3 is very tolerant and does not allow PL2K to disrupt his composure
15	PL2-K KU9				XO		XO	The situation between PL2-K and KU9 has escalated often; have both shouted at each other on more than one occasion

Key

X	Person Named First
O	Person Named Last
Character	Like / Dislike Based on Personal Characteristics
Purpose	*Positive:* Relationship as a means to an end (e.g. strengthen own position by support of other, or maintain a positive relationship to capitalize on the benefits) *Negative:* out of solidarity to other individuals, inevitably contrary to company interests
Incident	*Positive:* aceptance due to key private or business events (e.g. X got Y the job in the company) *Negative:* Rejection due to key private or business events (e.g. X prevented Y from being promoted)

Figure 6: Assessment of Relations between ERP Project Participants (detail).

5.4 Clique Analysis

Using the sociogram as a starting point, a clique analysis can be produced through the use of observation and meetings (Fig. 8). The aim of this method is to identify sub-groups (cliques). Cliques can be defined as a group of at least three people who have a high degree of connection to one another. Cliques within a network can overlap, meaning a single person can belong to multiple cliques [cf. 18]. Fig. 8 shows the ERP clique analysis.

The results of the clique analysis can be interpreted as follows, for example:

- The constellation shown in the sociogram between PL1-K, PL2-K and KU-3 is identified as clique 1.
- KU-3 senses this, wants to maintain a good relationship to PL-U and makes a great effort to do so (clique 2).
- KU-5, KU-6, KU-7 and KU-8 have joined forces due to the generally problematic situation (Clique 3).
- Finally, KU-4, who has had serious conflict with PL1-K und PL2-K, is the source of a great deal of negative propaganda about the ERP project outside of the project group (Clique 4).

Due to space limitations, the results of the Group as a Force method shall be omitted.

6 CONCLUSION

This paper has described the retrospective application of the Checklist “Success Factors in Change Projects” as well as the use of selected informal structure analysis methods. In the meantime, the authors have applied these “tools” to current projects. These projects have shown that, comparable to the ERP project illustrated, visual representations can quickly be produced and compared and that important conclusions can be drawn from these. In particular, the use of the checklist has greatly helped to reduce the personnel related problems in the course of current projects.

It is clear to the authors that the use of these methods by experts outside social science may present problems and that subjective influences can affect the results enormously.
It must be noted, however, after multiple applications of these methods that awareness of the importance of informal structures has greatly increased.
The main advantage of these methods can be seen in the structured way in which “instinct” can be visualized and that the extreme complexity of such social networks can be quickly ascertained. Therefore, principle fault lines and possible intervention approaches are quickly identifiable. Moreover, the use of various methods, such as force-field diagrams or sociomatrices, offers a broader view of the system as a whole.

The requirement of the scientific sector is that the available informal structure analysis methods be revised for day-to-day leadership practice and project management to enable technical engineers to apply them, since the authors experience has shown that this has led to a great improvement in management success.

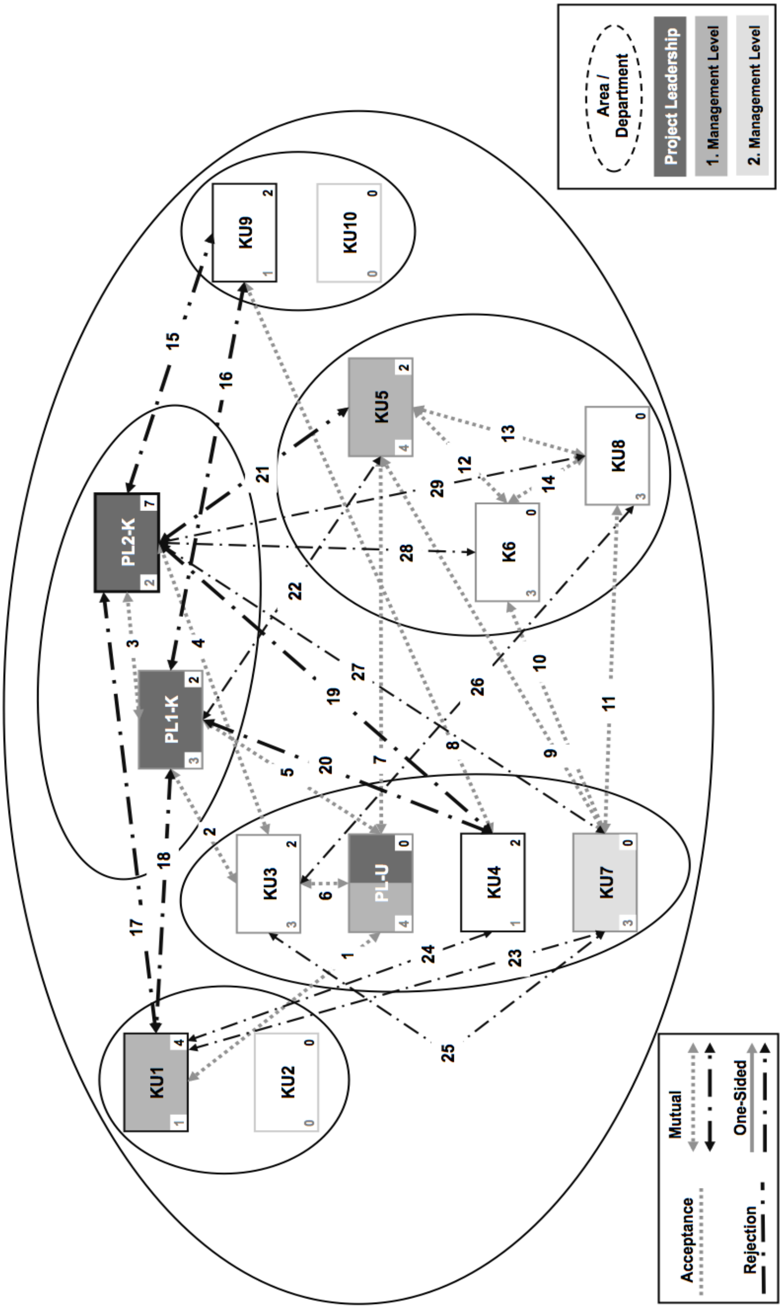

Figure 7: ERP Project Sociogram (complete).

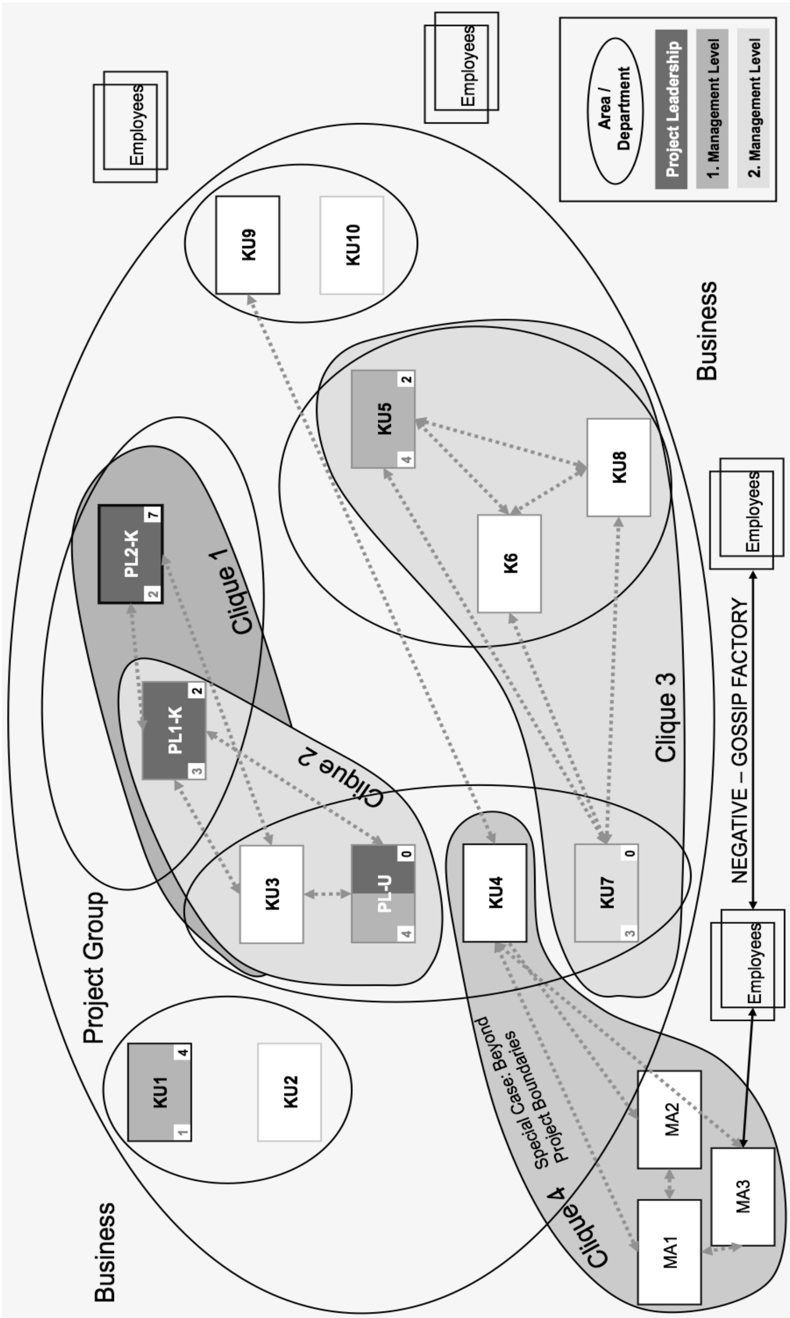

Figure 8: ERP Project Clique Analysis (complete).

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A GUIDELINE FOR ENTRAPRENEURS OF SME TO SUSTAIN THEIR PEOPLE´S MOTIVATION

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Abstract
This paper takes into consideration and study the employees' motivation at work as one of the main factors of sustainability of Lean Transformation in an industrial organization. It also states that employees' motivation is the consequence of a huge number of factors that have to be completely satisfied at the same time. Based on these considerations, the present work aims to provide a sort of guidelines for SME entrepreneurs drawing their attention on the psychological aspects of the human relations in an industrial organization that are much more delicate and intangible than every other aspect. These psychological aspects emerge as critical to the long-term success of the lean transformation.

Keywords:
Lean Manufacturing, Motivation, Involvement, Communication

1 INTRODUCTION

These recent years crisis has hit really hard the system of small and medium-sized Italian enterprises. For their part, there is a certain expectation that problems will be solved for themselves, and many companies are resisting, waiting that the wave will flow out. It is difficult to believe that this is the right strategy, even because many scholars are assuming that these are the new conditions in which our industrial system will operate in the coming years. If this is true, it makes the imperative to improve everything in the company even more categorical, using the most established production philosophies (such as Lean Manufacturing) and implementing a profound inner transformation.

The fact is that in the past a growing number of companies have adopted (or claims to have adopted) the Lean philosophy. Nevertheless, studies done by the best global consulting firm, show that less than a quarter of them gets the sustainable results in the long term, while the majority of these companies fail after a certain time and give the initiative up or they are satisfied with the meager results achieved. Beyond all the other causes, this happens due to limited corporate **culture change and lack of personnel's motivation**.

It is the same concept expressed by R. Dilts [1], in his scale of factors (Environment, Behavior, Capability, Values and Identity). In fact, he pointed out that changes required by a Lean Transformation have not to be applied only to the lower level factors such as Environment and Behavior (e.g. tools and yellow stripes on the floor), but to the highest ones, by working on people's involvement and belief side.

2 THE MOTIVATION PYRAMID

People's motivation can be seen as an inner tension that determines the will and the behaviors to achieve their goals.
An industrial organization can pursue its employees' full motivation on the job along the years as the result of a virtuous and, in many aspects, standardized, process shown in Figure 1. The pyramid is characterized by the fact that each level can be reached only if the activities of the previous level are fully carried out. This is exactly the same logic of the "A. Maslow's pyramid".

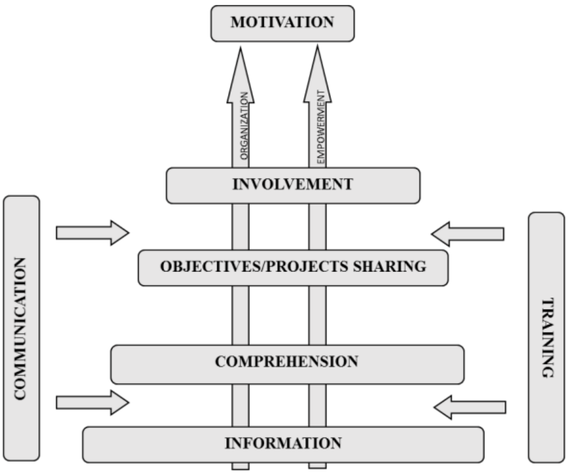

Figure 1: Motivation pyramid.

(Figure 1) shows that people are motivated if they are deeply involved in the project to achieve the agreed targets. The involvement follows the sharing of projects and objectives that is possible only after comprehension of the company's needs and the current problems. Understanding is therefore the consequence of the level and content of information that are the basis of the proper relationship with the employees. The information covers both general issues on the company business and specific subjects on the new managerial philosophy.

It is intuitive that the information is understood if the level and method of communication are suitable to the recipients. The understanding will be effective if people have been properly trained on the information contents. The interesting thing is that the virtuous path shown in Figure 1 can be standardized as far as contents and steps to be implemented are concerned [1].

Of course, the process is not so simple and actually starts from the entrepreneur’s awareness about the necessity to change. This is a strong pre-condition and is based on his/her leadership and his/her capability to inspire his/her people. In this paper, it is given for granted that the entrepreneur already did this self-examination and he/she is perfectly conscious of all these aspects. With this paper, the attention on the big part of the remaining organizational structure has been drawn, where actually things are done and value (or waste) is generated.

2.1 The motivating factors

With these assumptions, the concepts expressed in the pyramid example are correct if a number of other factors are satisfied. In fact, the SME entrepreneurs and their Top Managers should be fully aware that motivation is the result of a complex psychological mechanism, influenced by a number of factors that act in the same time. Like the many pebbles of a mosaic, they are not equal each other and belong, according to the author, to three different families, easily represented in the pyramid foundation (figure 2). The **basic factors** form the lowest part of the foundations, include the ethical values declared by the company and have a universal validity in all the organizations. Very frequently, they are **Respect, Fairness**, **Transparence, Coherent example, Trust.**

The next higher level includes the so-called **hygienic factors** [3], which have the characteristic that, if present, they do not generate necessarily motivation at work but, if absent, they generate a strong dissatisfaction of the employees. They are the:

- Corporate climate
- Company policies related to compensation and incentives, career development, pride of belonging development, unions relations
- Company’s vision, mission and values.
- Working conditions
- Work safety.
- Job security
- Group work.
- Personal acquaintance and relationships
- Compensation

Despite to the common perception, the compensation is not a motivating factor, it is a hygienic one. The effect of a salary or wage increase is very limited: it creates a positive feeling for a few days but, after them, this effect fades and loses its motivating power. Therefore, the right level of compensation is certainly very important, but it is wrong to charge it with too many expectations from the motivation point of view.

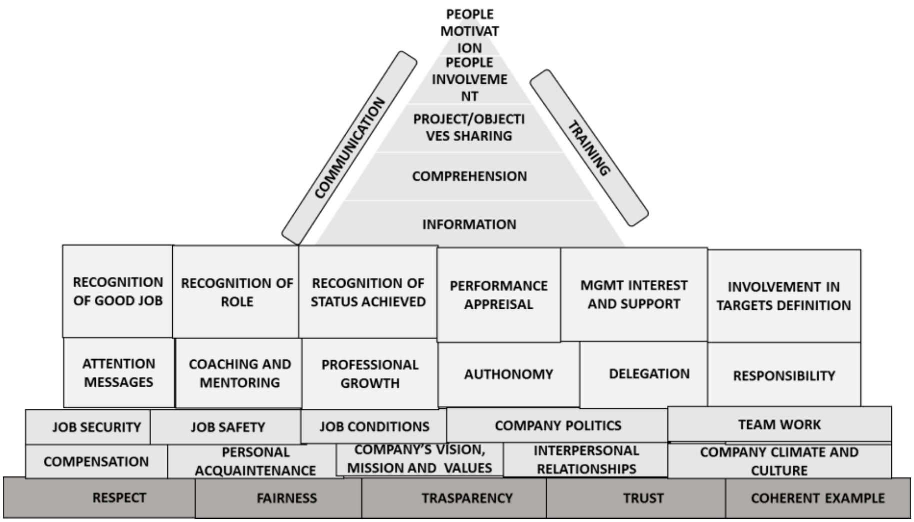

Figure 2: The foundations of the motivation pyramid.

- **Motivating factors**. The foundation top level includes the so-called motivating factors [3] that, if present, do generate a high level of motivation at work. They are:
- Professional growth.
- Level of job autonomy
- Level of Delegation.
- Recognition of the job done.
- Recognition of person’s role in the company and his/her status:
- Increase in responsibility.
- Performance Appraisal (feedback).
- Coaching, Mentoring and managerial support.
- Job itself
- Target definition

This last point deserves a closer look because it is of some importance in the generation of motivation and has been much studied in the immediate post-war period. Several factors was highlighted such as the difficulty of the task, the amount of the incentive and the success rate because full of motivational effect. Very easy tasks are linked to low incentives and high success rate; the motivation level is therefore very low. Equally low is the motivation when the task is very difficult, even in front of high incentives. Because there is a very low probability of success. The maximum value of motivation is achieved when the task has a medium-high degree of difficulty with a good balance between the percentage of success and incentive to complete the task.

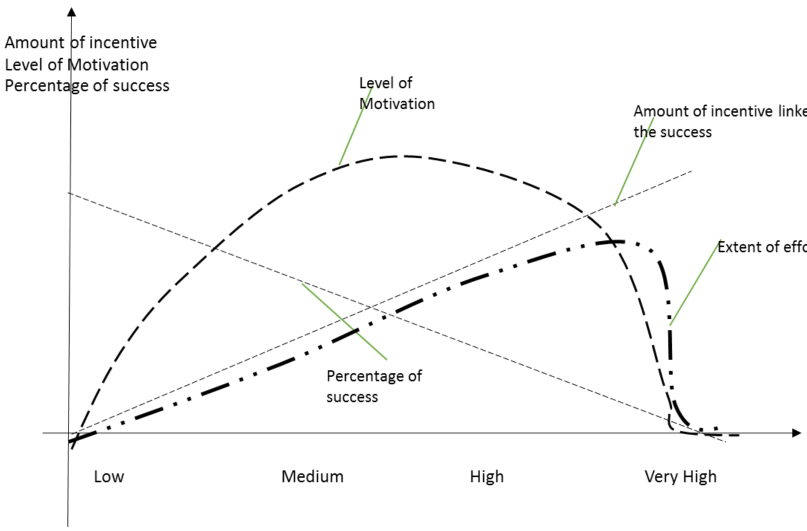

Figure 3: Curve of Extent of effort.

Some researches on the field led to a change of the symmetry of the curve of motivation, depicting a new shape (figure 3) that is due to the action of another factor called “effort extent“that is practically inversely proportional to the percentage of success. This factor at a certain point, it collapses when the person is aware of the inability to successfully complete the task.
Other motivational models have focused on the consequences of individual behavior in the workplace, which can be condensed into the prosaic question "what is the benefit for me”? They have highlighted two different point of view in two different period. The first is the long-term view that considers more motivational factors related to the final purpose, as the professional growth and career development. The second is the short-term rewards factors that highlight the pleasure of doing jobs for what they are [4]. In the later case, it is worth mentioning the "flow experience" [4], that is the

condition of an individual who is absorbed in a complete and totalizing activity that flows without obstacles. The flow experience is characterized by the fact that, at any time and without thinking, the person knows what is right to do, feels well occupied and, despite the complexity of the task, he is sure to be always in full control.
The actions done on the basic and hygienic factors are a sort of preparatory homework to settle the best conditions to work on the motivation factors that build the pyramid and its base (figure 2). As far as the pyramid is concerned, this paper will be focused on information, training and communication.

3 INFORMATION

3.1 Information Types

Experience shows that the following information types have to be provided (see Figure 4) in order to sustain the lean transformation for a long time:

- **First level**: These are general information on long-term goals of the company **(a-type)** and on the business situation and the future main initiatives **(b-type)**.given by the entrepreneur or the Managing Director to the entire organization.
- **Second level:** These are top-down information as well, like the lean techniques according with a program that involves progressively all the employees starting from the entrepreneur or CEO level who take on the role of sponsor and support of their people and sustain the lean transformation. Then the information is spread throughout the remaining organization (middle management and employees) **(c-type).** Together with the techniques, are included in this section the technical and/or managerial information moved constantly by the management to their people **(d-type)**.
- **Third level:** These are the typical bottom-up technical and managerial information **(e-type)**, which normally come up from the workshop people and are necessary to manage the actual operative problems.

3.2 Time and methods for the information flow

The first level Information **(a-type and b-type)**: is provided once or twice a year, normally at major events. These are plenary meetings with all employees, which last about an hour. In particular, the type b information should be updated in monthly meetings with the top management and key functions managers, when discussing the results of the activities of the previous month. As far the second level Information is concerned, **the c-type** (lean tools and techniques) is delivered through formal meetings planned according to the needs of individual departments. The meetings are then accompanied with the activity "on the field" which is the specific training (see Training).

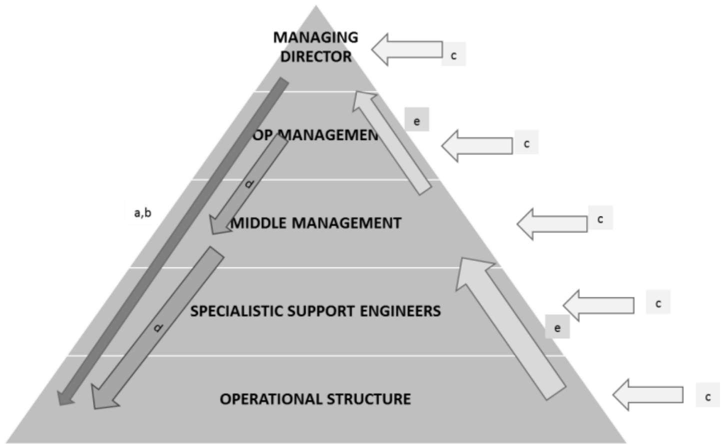

Figure 4: The information flows.

The d-type information (technical and managerial) can be exchanged any time in the field. The lean techniques emphasize the importance of so-called "flash meetings", that are daily meetings at the beginning of shifts, lasting a few minutes, where the various working groups and different hierarchical levels are informed about the current situation and the main problems that have still to be solved. In this way, in a little more than 60 minutes, a three-level hierarchical structure of the company knows what is happening and what kind of solutions are intended to take. At first glance, the number and the size of the subjects seem to exceed the few minutes available. But experience shows that the progressive training of the participants, getting more and more used to these meetings, and especially the team leader's effectiveness leads to a concentration on the issues that really matter, while those that can be solved within the working group are not even mentioned.

In spite of possible risks of endless discussions, the benefits achieved with this type of organization are obvious because there is a full sharing of information without wasting time and a quick information flow throughout the company. Finally, it has to be mentioned the third level **e-type** Information (technical and managerial) which can use the same procedures and the same time already seen for the type 2 information.

3.3 Information quantity

As far as the amount of information is concerned, the quantity is as important as the quality because an excess of information creates very frequently a state of confusion and difficult understanding.

3.4 Information Standard

Even if every business is different from the others, there is the possibility for each company to standardize the type of information packages to be delivered to employees, the quantity, the information issues and time.

4 TRAINING

Training means all the actions to let people acquire the skills, the appropriate knowledge, know-how and behaviors, necessary to perform the tasks for their professional growth and the consolidation and development of an organization. Since it is addressed to the single person, sends a positive message like: "The Company has found in you a person who has the potential to get more knowledge and skills and, therefore, has decided to invest on you". All these factors increase job satisfaction and, ultimately, the motivation of employees.

4.1 Training Time

Normally, from the time point of view, the first idea comes up by the entrepreneur or by the top management- They are trained by external consultants (i.e. Lean Manufacturing), appointing very soon an internal (usually high-level) manager that will act as a trainer and support on site. He/she will be the first unit of what is usually called Lean Promotion Office, or Kaizen Promotion Office, or Production System Dept. He/she will act later on as a driver of Lean in the company, as an element of stimulus for the rest of the structure and as a reference point in case of difficult understanding.
The longest and most difficult step is the training and the persuasion of the middle management, which in practice turns out to be the most resistant to change. It will be necessary a deep study of the people involved, of their mood, expectations, and career history to calibrate the best method to change their behaviors [9]. After the training of the steering structure, the first step will be the choice of a selected number of operators and an appropriate and limited production area where to make the first experiment of change that will be prepared in such a way to leave no room for doubt or failures. Everything should work as expected so that it can represent the positive example for all the other initiatives that will follow.

4.2 Training Methods

In order to allow operators understanding, learning and remembering easily the new concepts, experience shows that the best way to introduce these issues is to use the interactive and highly instructive experiments. They will be calibrated to the different topics and standardized in order to ensure cultural homogeneity within the production departments and offices of the company. The purpose of the experiments or games is to break the traditional roles and to show things from different points of view. Mostly used for this purpose is, for example, experiments [9] such as, for example, the identification of particular aspects in videos or pictures, in order to understand the power of the paradigms. The use of Lego bricks is also very common to demonstrate the effectiveness of techniques such as 5S and standardization. The simulation of a mini-production workshop where one is building simple products consisting of a limited number of parts or operations (such as ballpoint pens or paper airplanes) is useful to show the power of pull systems vs. the push ones.

4.3 Control of Training Results

Being aware of the importance of training and of the fact that the costs associated with it are the only significant ones in the starting phase of Lean Transformation, the outcomes of the training program and the achievement of the pertinent goals should be assessed. The most classic models of evaluation was due to the American scholar Donald Kirkpatrick [4] around 1975. It is based on the levels of **Reaction,** measuring the satisfaction of the participants, their feelings, their emotional impressions and their willingness to apply the new methods, and **Learning**, measuring the level of retention and the capacity of implementation. Furthermore is based on **Behavio**r that is the willingness of participants to transfer what they have learned in the daily working actions, and finally **Results** (follow-up) defining, after a certain time, if and to what extent the training activity has been moved into reality, changing in a stable way the individual actions and determining a lasting impact on the organization.

4.4 Training Standardization

What was discussed in the previous paragraphs can be standardized, in order to allow each company choosing the most suitable way to its organization, its culture, its arguments, without having to reinvent them each time.

5 COMMUNICATION

The communication experts point out that the process of transmission of information is very delicate and dispersive and generally less efficient than expected. The awareness of this fact is important because it allows improving aspects related to communication skills. One of these aspects is **clarity**. In fact, how many times has it happened, talking with someone, to get lost in the maze of his/her speech and, in the end, not catching all or part of the message due to the large number of subordinate clauses embedded within each other? The other factor that characterizes the ability (it can be said "art") of communicating is related to the **synthesis skills** that information should have. In fact, it must be calibrated both from quality point of view (objective and subjective, formal and emotional contents etc...) and from quantitative point of view just to avoid the audience “saturation”.

Once the information is submitted, a conversation with questions and answers may start, in order to solve doubts and inconsistencies. It happens frequently that the other person does not grasp the full meaning or the message nuances, or simply does not agree, bringing arguments in support of his/her idea. Who sends the information must then possess a high capacity to speak and argue coming from an adequate **level of self-awareness,** because people immediately understand if the speaker is convinced of what is saying or he is simply reporting the thought of others. Then one more factor that determines the ability to convince the counterpart is the **level of knowledge** of the topic. That is why it is necessary to be well prepared on the matter, in order to sustain properly and fluently the discussion about the objections or alternative proposals.

5.1 The Listening Ability

Studies on communication in the company have revealed that the process of exchange of information takes place, with different weights, through listening (40%), speaking (35%), reading (16%) and writing (9%). Therefore, looking at the percentages, most of the time devoted to communication has to be concentrated on listening. The point is that only a minority of people are able to listen effectively, while the majority does not pay full attention to what is being said. Based on the above considerations, different types of listening can be distinguished, such as **active listening**, when the listener does not judge a priori the interlocutor‘s words, but understands and demonstrates to have understood the content asking questions and using in the meantime also non-verbal signals. There is also the **superficial listening** when the listener does not grasp the deep meaning of communication. The attention is rather reduced, the risk of some misunderstanding is relevant, and who talks may have the false sense of being heard and understood. Finally, there is the **random listening** when who listens does not pay any attention to the speaker because he is focused on his/her thoughts and his/her point of view.

5.2 Communication’s Types

Only recently, the **non-verbal communication** has seen properly recognized its importance, because the latest studies reveal that the exchange of information is borne for the big majority, by the non-verbal methods (gestures, looks, posture ...) and para-verbal ones (tone of voice, intensity, volume, frequency). These are the main ways to express and communicate emotions and support, congratulate and interpret the meaning of verbal expressions. Besides to the **formal communication** that takes place during the official meetings, it is much more important, for the motivational effects, the **informal communication** occurring mainly during casual encounters in the workshop or in the office or during a break at the coffee machine. In these cases, the chances to transmit and receive messages about individuals and company climate are much more frequent and should be used whenever there is the opportunity.

6 INDICATORS OF MOTIVATION OR LEAN TRANSFORMATION SUSTAINABILITY

At the end, it could be interesting to find some ways to measure the motivation of people, taking into account their behavior and the organization's results. Some of these ways are subjective and come from the managers' feeling when they get in touch with their people. Has some worker ever stopped a manager during a visit to the production departments, and proudly informs him about the last idea he/she or his/her group is developing? More tangible indicators are, for example, represented by the **cumulative number of improvements**: generated by the kaizen groups, although it does not distinguish the extent of the improvements and treats them all in the same way. In fact, a curve that tends towards a horizontal asymptote is a bad sign, because it means that the ideas generated are less and less.

A rampant curve with constant derivative is instead a sign of great activity. The previous index could usefully be completed by comparison with the curve of **cumulative implemented improvements**. In fact, if the two curves are parallel, it means that the company organization can realize a number of ideas about equal to the generated ones. If the lines are divergent, the organization is not able to realize all ideas for improvement. This fact will lead, in the end, deep dissatisfaction in people who do see a company's inconsistent behavior (figure 5).

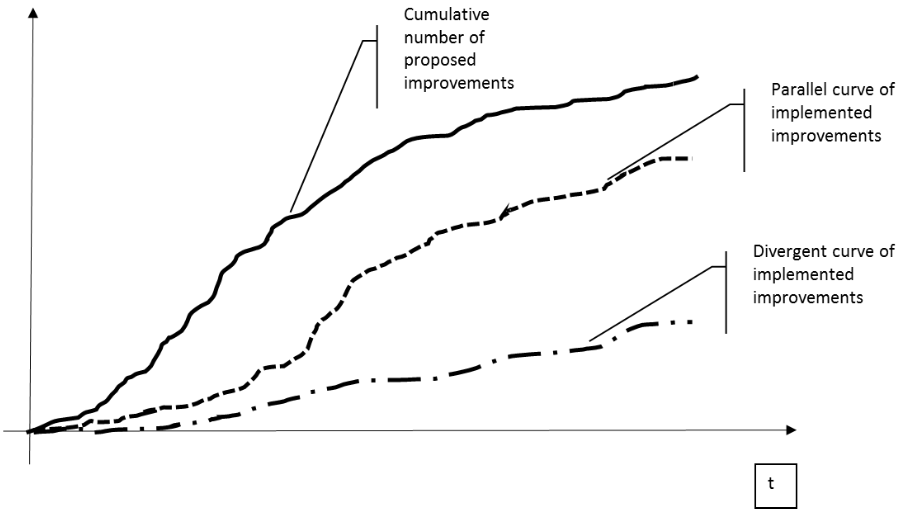

Figure 5: Cumulative improvement curves.

7 SUMMARY

Although the matter is wide, the aim of this paper is to draw the attention of the SME entrepreneurs and their top-managers on these issues, providing the evidence of the majority of the involved factors, in order to have clear ideas of what to do. The possible conclusions of the author's research show that:

- Motivation is the result of a complex psychological mechanism that is influenced by a number of factors that act in the same time.
- The managers, generally speaking, do not have a complete awareness of them and they are not skilled enough to treat correctly these factors.
- As every other important performance, motivation and satisfaction degree should be measured by pertinent KPIs.
- The prevention of people's dissatisfaction is just as important as the fulfilling of the motivators factors. This means that SME entrepreneurs and their managers have to settle a plan to cover all the aspects that create dissatisfaction.
- Many aspects, methods and procedures can be standardized, in order to ensure homogeneity of treatment and results.
- People motivation at work is surely positive for the company because allows it to sustain in the long term the deep change required by the Lean Transformation and to achieve significant results. It is also very positive for the employees because there are the conditions to "empower" them, meaning to strengthen the individual culture, capacity, skills, personal style, attitudes, empathy, feelings and behaviors. Finally, it can be said that motivated and satisfied people at work means to have better relationships among them outside the company and in their family and corresponds to an improvement of the social ambient. This is a little known contribution that the industrial world can provide the society.
- Whenever entrepreneurs and top managers decide to implement a Lean Transformation should prepare a plan that takes into consideration all the issues that form the foundation of the pyramid and the pyramid itself. Many of these issues seem obvious but, in the everyday life, they are rather neglected. This paper helps to remind them, easing the necessary actions to implement them.

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