Leveraging Technology for a Sustainable World

David A. Dornfeld • Barbara S. Linke
Editors

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Preface

Welcome to the 19th CIRP Conference on Life Cycle Engineering hosted by the University of California, Berkeley! The Berkeley campus is both the University of California's flagship campus as well as a renowned research center that continues a legacy of innovation in engineering, science, society, culture, and politics. We hope that this environment will lead to a productive discussion within our Life Cycle Engineering (LCE) community.

The 19th CIRP LCE conference continues a strong tradition of scientific meetings in the areas of sustainability and engineering. The theme for this year's conference is Leveraging Technology for a Sustainable World. As resources have become increasingly scarce and the environmental impact of business and industry has grown, it has become vital for engineers to provide leadership in developing those innovations that will enable green businesses and industries that remain socially responsible and economically successful. It is our goal that this conference will serve as an international forum for researchers to review and discuss the current developments, technology improvements, and future research directions that will allow engineers to meet this societal need.

The conference includes over 100 technical papers that have been accepted after a rigorous peer review and revision process. The research covers Businesses and Organizations, Case Studies, End of Life Management, Life Cycle Design, Machine Tool Technologies for Sustainability, Manufacturing Processes, Manufacturing Systems, Methods and Tools for Sustainability, Social Sustainability, Supply Chain Management. Keynote talks will be given by Dr. Julian Allwood of the University of Cambridge, Dr. Michael Overcash of Wichita State University, Mr. Richard Helling of Dow Chemical, Ms. Karen Huber of Caterpillar, and Mr. Adam Hansel of DTL/Mori Seiki. We hope that these presentations and the proceedings will serve as a valuable source of information on the state of LCE.

We would like to thank all of the participants for their contributions to the conference program and proceedings, as well as the organizing team at the Laboratory for Manufacturing and Sustainability for their support. We would also like to extend our gratitude to the members of the Scientific Committees for their continued support in helping to make this a successful conference!

The conference program would not be possible without the generous financial support of our industry sponsors who, at the time of this writing, include: Samsung, Mori Seiki/DMG, Esprit by DP Technologies, and Dow Chemical. In addition our thanks go to the National Science Foundation NSF, who provided financial support for graduate students and postdoctoral researchers attending the conference.

Thank you again for your support of the 19th CIRP LCE conference and we look forward to a great meeting!

David A. Dornfeld
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Unit Process Life Cycle Inventory (UPLCI) – A Structured Framework to Complete Product Life Cycle Studies

Michael Overcash and Janet Twomey

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Abstract

Major life cycle studies of even moderately complex products have been limited to the life cycle of the product materials and possibly assembly of the final product. The intervening manufacturing transformation of materials/chemicals into products is thus a major segment not well represented by life cycle analysis tools. Yet these transformational manufacturing plants are a large and important industrial sector. In contrast the synthesis of chemicals or materials (often representing the supply chain) is well developed on the basis of connected unit processes (reactors, furnaces, heat exchangers, distillation, etc) to make chemical plant life cycle inventories. This paper addresses an international life cycle effort to develop a unit process approach for the manufacturing plant transformations of materials representing the majority of all product manufacturing plants. The UPLCI approach is thus an enabling technology in the life cycle field. This paper discusses the development of the UPLCI structure, recent successful efforts in verifying/improving UPLCI, the challenges of linking these in sequences to represent plants, and combining the manufacturing and the supply chain life cycle profiles. An important part of this effort is the CO2PE! Project which develops UPLCI data sets with a quality assurance system based on in-depth multi-plant field testing.

Keywords:
Unit process life cycle inventory; UPLCI; Screening approach; CO2PE!; Life cycle analysis

1 INTRODUCTION

Sustainability initiatives are being developed on an increasing scale within corporations [6], product groups [7], industry associations [2], and purchasing organizations [12]. These create a very large and currently under-populated information base needed to provide energy, emission, and other data commonly referred to as life cycle analyses. The total information demand is so large that an underlying, interchangeable, transparent, and non-complex approach is essential. The alternative of individual life cycle studies for hundreds of thousands of products and manufacturing plants is simply untenable.

A life cycle analysis strategy has been developed to efficiently and effectively meet the multi-stakeholder needs. The basic life cycle principle to develop the sustainability information is that all products and manufacturing processes emerge from individual manufacturing plants. These plants operate in a coupled fashion to take material and chemicals from nature and through a series of plants, create a finished product (industrial or consumer market places). The coupled system is first a supply chain and can then be divided into two general segments,

a) Molecular shape-building

b) Macro shape-building

As illustrated in Figure 1.

These manufacturing plants have a substantial similarity in that each consists of a series of individual unit processes. Further, the number of individual or different unit processes is relatively small (between 100 and 200) and generally interchangeable, even as these are used in tens of thousands of different manufacturing plants. That is, a drilling step is undertaken in many plants by a drilling unit process, even though there are hundreds of actual machines manufactured and sold to provide this material removal and create a hole in some material. Thus two logical communities have arisen that are interested in manufacturing sustainability and environmental improvement;

1) those focused on the product step where a hole is drilled in some workpiece as a part of a large number of steps or processes that produce a product

2) those focused on understanding how the drilling machine can be more efficient.

Both seek to develop unit processes life cycle inventory (UPLCI) data and engineering knowledge.

The first community is looking at a long sequence of multiple steps (often a series of manufacturing plants) in which drilling might be one step. For this group, a relatively rapid, product-related, and transparent estimate of energy use and mass losses are sufficiently and the 90:10 rule of information can be used.

For the second community, the emphasis must be on detailed field measurements, involving multiple versions of the same machine type or unit process (like drilling) and multiple manufacturing plants. They seek more fundamental sustainability improvements that can be incorporated in machine design, manufacturing, and operations. These results have an important cascading effect across many manufacturing plants. In a historical perspective, the first community began in the last 15 years, while the second community has been making contributions since before the Industrial Revolution.

The product-focused community and the machine improvement community utilize the same universe of unit processes. This is known as the taxonomy of manufacturing processes and is illustrated by several versions [10, 4, 3]. For the macro-shape building portions of the product life cycle, the taxonomy is about 120 individual unit processes. So, a life cycle quantitative understanding of these 120 (not a particularly large universe) processes estimation tools sets the stage for the environmental sustainability analysis of hundreds of thousands of products and thousands of actual machines (i. e., models of the 120 unit processes). These taxonomies have a first level classification of 5-6 groups and then these groups are populated by the actual different 120 unit processes.

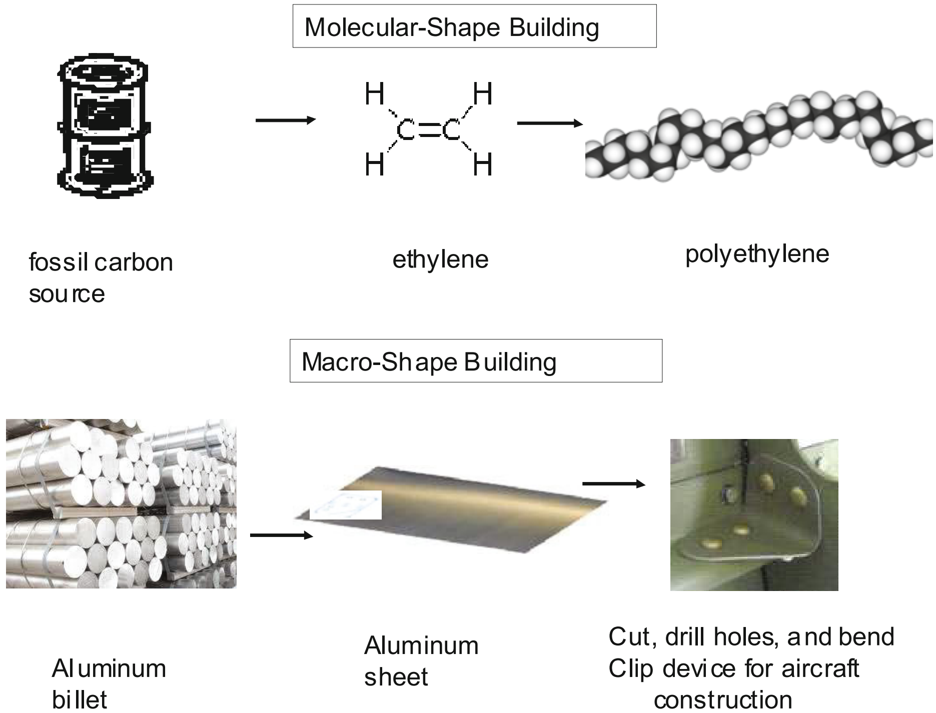

Figure 1: Building chemicals and materials into macroshapes of products.

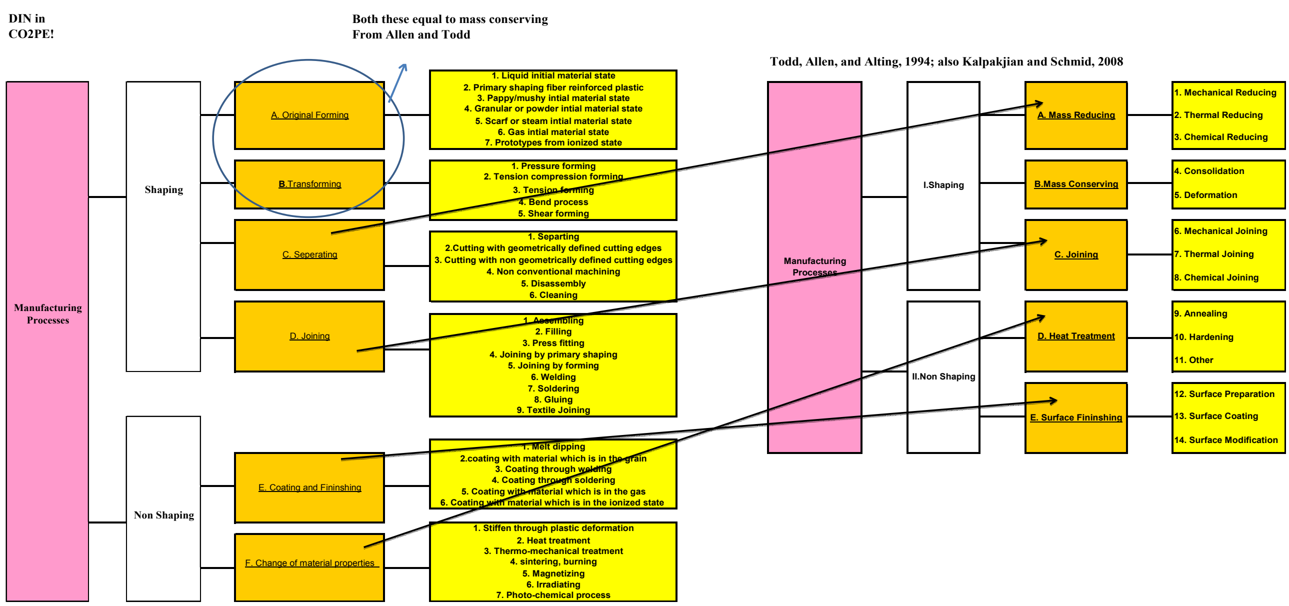

Figure 2: Comparison of 3 taxonomies for industrial manufacturing processes, showing macro categories and some subdivisions of the approximately 120 total unit processes in each taxonomy.

The concept of unit processes for macro-shape building manufacturing operations is not unique as a parallel system has been constructed and used for molecular-shape building manufacturing operations [5]. These were developed and used over the last 15 years and provide solid lessons learned. The sustainable manufacturing tools for chemicals and materials have been applied to over 1,000 products and have allowed industrial personnel to more easily and uniformly estimate sustainability improvements in energy and chemical efficiency. In these chemical plant cases there are about about 30 unit processes. Thus the basic principles of developing a unit process framework of individual blocks and applying this to the manufacturing of products (such as gears for wind turbines, parts for aviation, composites for vehicles, etc.) has a clear path forward.

2 DEVELOPMENT

An international effort has been developed to achieve greater efficiency and quality in producing the fundamental data needed for the UPLCI database. It is referred to as the Cooperative Effort on Process Emissions in Manufacturing (CO2PE!) and has grown steadily in the last 2-5 years. The two communities focused on manufacturing energy improvement are referred to as

a. Screening or preliminary approach (UPLCI - www.wichita.edu/sustainability)

b. In-depth approach (http://www.mech.kuleuven.be/co2pe!/taxonomy

This paper discusses the screening approach.

The UPLCI methodology was begun in 1995 [5], and has been described in a Society of Mechanical Engineers Technical Paper [9]. Currently the method to create a new UPLCI or to review an existing UPLCI involves four components,

i. Preparation of a process description detailing the nature of the unit operation and including appropriate Figures and pictures describing the value-added step performed. It is generally written for a wide variety of audiences. Batch process energy calculations are typically built around three power and time contributions:

   a) Stand-by or basic period (often loading and unloading or scheduling downtime)

   b) Partial mode or idle period (often involving machine motions)

   c) Full or peak energy period (this is most often the value-added step).

   These equations are supplemented with Tables that contain the necessary physical and energy properties to allow a user to analyze alternative workpiece materials. These equations are not intended to be sufficient to support design/construction details that are needed to implement a unit process.

ii. Process mass loss equations based on the use of ancillary inputs (like lubricants) and loss of material (such as machining chips) from workpieces. If necessary, Tables may be included to support calculations that are provided.

iii. An example of using the UPLCI that shows the reader how to obtain the overall energy and mass loss results for a specific workpiece and process/machine.

iv. References are cited to detail where specific equations and data have been extracted from the technical literature.

Eleven unit process life cycle inventory reports have been completed, Table 1.

UplcI Identification	
MR1	Drilling
MR3	Milling
MR4	Turning
MR2	Shearing
J2	Submerged arc welding
J1	Gas metal arc welding
MC1	Brakeforming
MR6	Reaming
MR5	Punching
MC2	Injection molding
HT1	Annealing
MR8	Boring

Table 1: Current list of completed UPLCI documents (www.wichita.edu/sustainability).

An additional five UPLCIs are anticipated to be completed in 2012. The UPLCI team beginning from 2003 is shown in Table 2.

- Bert Bras, Georgia Tech
- Andres Clarens, Virginia Tech
- Delcie Durham, University of South Florida
- Tim Gutowski, MIT
- Karl Haapala, Oregon State University
- Jackie Isaacs, Northeastern University
- Kevin Lyons, NIST
- Mahesh Mani, NIST
- Leon McGinnis, Georgia Tech
- Cynthia Murphy, University of Texas, Austin
- Michael Overcash, Wichita State University
- Frank Pfferkorn, University of Wisconsin
- Matthew Realff, Georgia Tech
- Steve Skerlos, University of Michigan
- John Sutherland, Purdue University
- Jan Twomey, Wichita State University
- Fu Zhao, Purdue University

Table 2: Listing in alphabetical order of unit process life cycle inventory development team, begun in 2003.

3 FUTURE CONCEPTS

The current suite of completed UPLCI reports for screening analysis, Table 1, is sufficient to now allow the development of broader research activities for manufacturing improvement. The first is creation and maintenance of a review network. We seek individuals with expertise in any of the unit processes since these are used across a variety of product applications. The CO2PE! community with respective field measurements is an excellent resource for this review network. In addition, the Society of Manufacturing Engineers has committed to the adoption of the UPLCI concept and a role for their members to serve in review and improvement. This network has been started in 2010 and some lessons learned are

- Review by a knowledgeable individual takes 2-5 hours
- A thought shift is essential because the UPLCI are not documents for detailed design or for one specific workpiece/product. These are representative life cycle inventories.

- The adage "do not let perfect get in the way of good enough" should be remembered during this review. Results of a screening analysis show major effects and only if it is economical to refine the results should that be pursued.
- The unit process application is for high production scenarios in which many aspects of low production systems are not significant (like set up of computer systems, etc.).

The review results are then incorporated as improvements in the UPLCI reports.

With the current UPLCI library, a further challenge is how to couple these together to form manufacturing sequences that estimate energy of manufacturing plants or subsections of such plants. The goal is to create testbeds of 3-10 unit processes linked together. Estimates using the screening UPLCI would require evaluation of process-to-process links. That is, the coupling of each unit process must account for the changed nature (mass, shape, strength, etc.) of the intermediate workpiece or product advancing along the manufacturing sequence. The functional unit basis of the UPLCI will first include product production over extended manufacturing time periods (such as 100 large gears per week, 100,000 aviation clips per week, 5.000 coated elbow pipe fittings per month). These functional unit flows allow sufficient time to capture

1) unit processes with different floor-to-floor times,
2) unit processes with different materials flow inputs, and
3) unit processes with potentially different energy inputs besides electricity

Also transport between unit processes should be included.

The UPLCI testbeds can then be compared to manufacturing plant data. An early example of this is Rahimifard [8]. At this size (3 – 10 unit processes) and with the significant transparency of energy estimates in the UPLCI tools, it will be possible to see clearly where improvements are of value. The Society of Manufacturing Engineers will serve as a portal to identify and allow researchers to explore this sequencing concept with industry. The National Institute of Standards and Technology (NIST) Sustainability Laboratory will proceed further and explore industrial standards for linking unit processes life cycle inventory database that build on the current industrial manufacturing tools. They will also begin to examine how optimization can build on the underlying UPLCI testbed.

4 INDUSTRIAL PARTICIPATON

Manufactuirng organizations participating in this UPLCI proejct are important and can assist in a number of areas:

a. Evaluating and review of the basic descriptions of unit processes (UPLCI)
b. Serving as sites for process data collection
c. Collecting data on representative process flow sequences (testbeds)
- Utilizing the screening approach to estimate manufacturing energy for products

5 CONCLUSIONS

The screening approach for unit process life cycle inventories in CO2PE! has begun to develop and demonstrate the information technology potential to meet the need of many industry and organizations interested in environmental sustainabiltiy. The in-depth life cycle inventory examination of unit process machines has also grown as the value of the information-intense studies have been appreciated. Screening UPLCI is approaching 20% of the necessry taxonomy of unit processes and continues to attract young faculty to particiapte. The propress report and workshop at the CIRP LCE 2012 help build the overall CO2PE! community and resoruces.

6 ACKNOWLEDGMENTS

Support was received by U.S. Department of Energy, DOE-EE0004167, Wind Energy and Sustainable Energy Solutions. An important review was done by Professor Joost Duflou (Katholieke Universiteit Leuven, Belgium) and continued input was received by the Society of manufacturing Engineers.

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Quality Information Management for Advanced Quality Planning in Small and Medium-Sized Companies

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Abstract

The paper presents the possibilities and advantages of collaboration platforms for the quality information management of the advanced quality planning. This is based on a quality information system that provides all information necessary for the specification and the control of product and process conformity. The goal of this quality information management is the reduction of changes after the development process as well as a back flow of information for a sustainable product development process to save money and resources.

Keywords:

Quality Information Management; Quality Information System; Collaboration Platform; Advanced Quality Planning

1 INTRODUCTION

Quality management has been established to organize the processes and information to create a product that fulfills all requirements of the customer as well as internal requirements. For sufficient and sustainable products an immense potential can be found within the advanced quality planning process by defining the requirements before the contract with the customer is signed. As a major aspect for sustainability the possibilities for changes during and after the design process will be reduced immensely and with that the waste of resources and money [1,2]. The development of a quality information management tool for the advanced quality planning to control the input, time and effort for the planning process became therefore a research topic at the Chemnitz University of Technology.

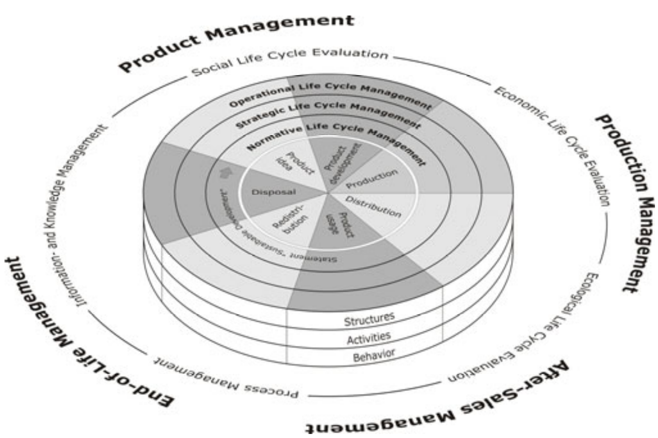

Figure 1: Life cycle management model [1].

The basis for this advanced quality planning tool is the management of quality information that is strongly connected to the management of processes and documents along the product life cycle [Krause]. Figure 1 shows the Life Cycle Management Model introduced by Herrmann [1]. The fact that the information exists beyond the lifetime of the product demonstrates the challenges for the information management [1].

Today the information management still deals with the problems that the quality information is often stored in different sources and places and with that, different versions of the same document as well as insufficient access to the information as a result of different systems to create and change the information exist. Searching for and in documents is a waste of time and there is no possibility to achieve a powerful information back flow. A multidirectional information flow along the product life cycle is an important source for life cycle oriented innovations [1,3].

Especially small and medium-sized companies are unable to buy expensive and complex systems to solve these problems. Therefore it is necessary to develop a system that is easily understandable, adoptable and compatible with existing software as well as easy to handle. A suitable organization of the teamwork based on an intelligent system for the knowledge management is the basis for a sustainable and structured system that is accepted in the companies.

The paper presents the definition of quality information and quality information systems and an overview of the advantages of collaboration platforms for the management of information and teamwork. First results of the development of the quality information management tool will prove the possibilities to support the advanced quality planning for a sustainable product development process.

2 QUALITY INFORMATION SYSTEMS

Quality information is defined as all data necessary for the specification of the product and the processes and the proof of conformity with this specification [4,5,6]. Requirements that affect the product quality are created in all departments of the company and have to be managed and documented in terms of quality management. Figure 2 describes the quality related product life cycle with the requirement and confirmation documents.

The quality information is comprised in the media and has to be organized, provided and archived.

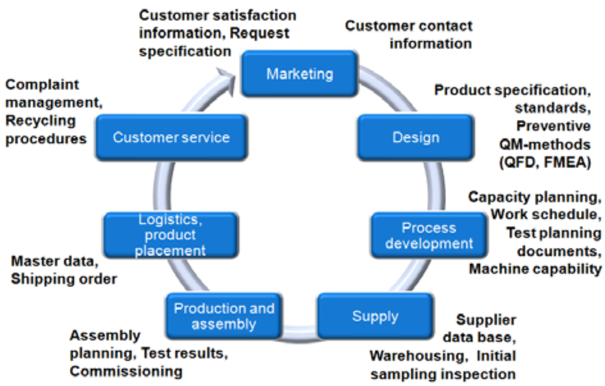

Figure 2: Media of quality information in the product life cycle.

Figure 3 visualizes the information life cycle that describes the processes that have to be specified for the information management. The created data has to be saved, managed, provided for others, changed, archived and regained. This approach is also necessary for the management of quality information. Therefore a quality information system is needed.

Figure 3: Information life cycle.

Quality information systems include information logistics (collection, saving, processing, packing and archiving) to achieve and evaluate product conformity in all processes and departments [4,5,6]. The implementation of such a quality information system requires the linking of all product life cycle phases and the control of the multidirectional information flow.

In all departments of the company and all phases of the product life cycle, quality related documents, information and knowledge are created as part of the everyday work routine. Today different systems and software tools are used to handle this quality information [7]. Well known are Office-software systems, Computer Aided Quality (CAQ) systems, Enterprise resource planning (ERP) tools, Computer Aided Design (CAD) systems or Product Data Management (PDM) systems. Most of them are developed to support the bigger companies or solve problems in isolated applications. Other systems concentrate on quality management methods (QM methods) like Failure Mode and Effects Analysis (FMEA) or Quality-Function-Deployment (QFD).

The information is saved in paper documents or file systems and transported via e-mail which often leads to information gaps. The search for information takes a long time without a good storage structure. Validity problems occur if there is more than one version of the same document due to not existing interfaces.

Team members working in different places usually are highly challenged with providing valid information to all members. Innovative web-based collaboration platforms can solve these problems because they provide tools like Wikis, workflows and team sites to organize a paperless teamwork with the benefits of a flexible basis.

3 WEB-BASED COLLABORATION PLATFORMS

3.1 Advantages

Web-based platforms provide a tool for the collaboration of co-workers in the company with the customers and suppliers. Information can be provided in a save and productive way for everybody with an internet compatible computer. Six features are especially helpful for the advanced quality planning:

- Collaboration and personalization: intern and comprehensive (e.g. calendar, task assignment);
- Document and knowledge management: structured storage, use, versioning, search and Wikis;
- Direct integration of documents;
- Process management: Implementation of controlled, automated and document-based work flows;
- Project management and
- Customization by the company without the help of the software provider.

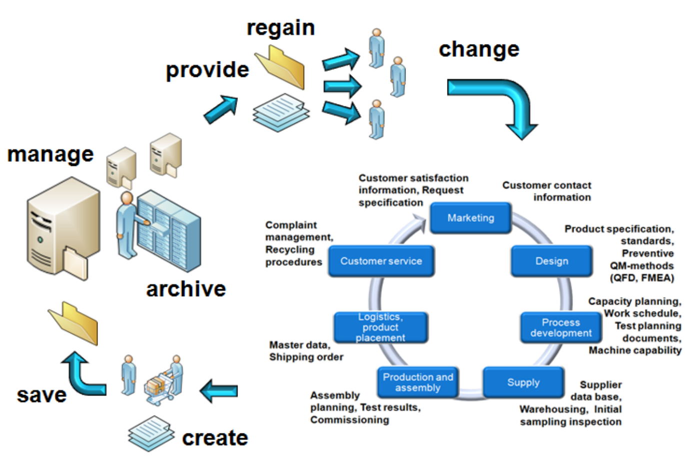

Figure 4: Information logistics.

Information transparency and communicative networking for all parts of the development process with a collaboration platform is the basis for the quality information management for advanced quality planning. Figure 4 shows the information logistic that has to be developed for the advanced quality planning. Quality information as defined in Figure 2 has to be collected, saved, processed, packed, archived and regained again to be used for the development process of a new product. Microsoft® SharePoint® is one web-based collaboration platform that fulfills all the requirements for this task.

3.2 Microsoft® SharePoint®

Microsoft® SharePoint® is a web-based collaboration platform that helps to share documents, manage projects and publish information internally and to customers [8]. It is easy to integrate Microsoft® Office® documents and therefore the platform is especially helpful for small and medium-sized enterprises.

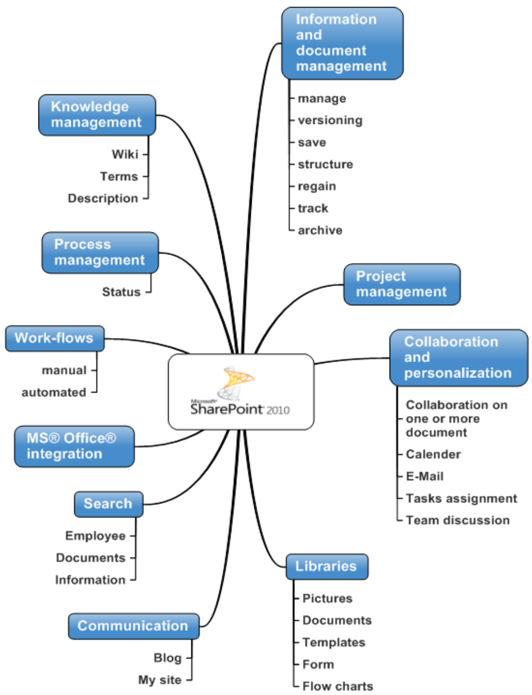

Figure 5: Capabilities of Microsoft® SharePoint®.

With SharePoint® it is possible to have:

- Reduced administration effort for projects (e.g. document exchange and administration, appointment control, …);
- Universal communication between team members;
- Consistent knowledge of quality information in the form of the quality plan;
- Advanced realization of possible quality problems;
- In time activity for correction and prevention action and
- Reduction of failure costs and increase of reliability and sustainability.

The capabilities organized in Figure 5 are conform to the requirements of a collaboration platform for the advanced quality planning.

4 QUALITY INFORMATION MANAGEMENT FOR THE ADVANCED QUALITY PLANNING

4.1 Advanced Quality Planning

Advanced product quality planning (APQP) [9] (Figure 6) has been introduced by the automotive industry in the QS 9000 standard. This standard no longer exists and the APQP is now part of ISO 16949 [10].

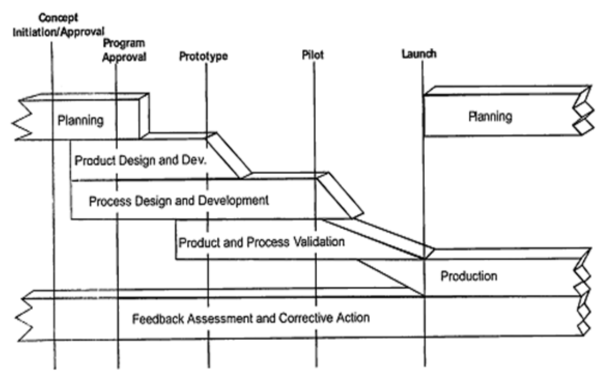

Figure 6: Advanced Product Quality Planning - APQP [9].

The APQP is described as the steps and activities prior the start of production of a product to gain a customer satisfying product. The APQP is a structured process that integrates QM methods like FMEA and QFD to secure that all processes are finished in time and the customer requirements are fulfilled. The result of the APQP process leads to a quality management plan.

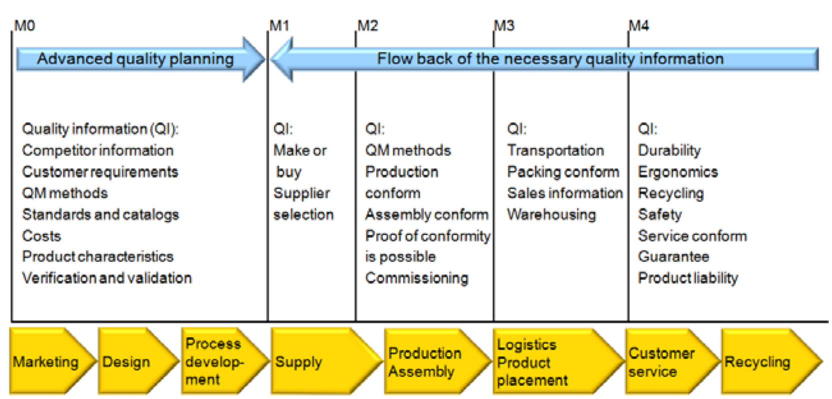

Figure 7: Advanced quality planning with quality information.