Designing logistics infrastructures
a conceptual approach

Findhammer, M.

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1998

...CARGO
...ss Unit Logistics

Master Thesis
Designing Logistics Infrastructures
A conceptual approach

"Logistics is magic for some.
For us it's our profession!"

Eindhoven University of Technology
Industrial Engineering and Management Science
Michel Findhammer
Februari 1998

KLM CARGO
Business Unit Logistics

Master Thesis
Designing Logistics Infrastructures
A conceptual approach

to receive the title of "Master of Science (Ir.)"
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Abstract

"Designing Logistics Infrastructures: A conceptual approach" is about the way in which logistics solutions at a high abstraction level can be designed. For this design process a certain structure is proposed: The Consultancy Design Process. This CDP is only the structural aspect of designing. Besides that, designing logistics infrastructures has a contentual aspect where the focus is on Logistics Engineering Guidelines.

Designing logistics infrastructures means having to take a number of logistics decisions. These decisions can be clustered in different design stages. Each design stage has a solution structure, being: design prescriptions, the Economic Trade Off to be made, the required input and the output. Furthermore, each design stage can be designated specific analysis techniques such as linear programming or simulation. In the future it is necessary to chose a software tool in which these techniques are incorporated. Such a tool should be able to deal with a number of logistics functionalities. Finally, a list of logistics requirements for the software tool makes a justified selection possible.

A summary of this thesis can be found, starting on one of the following pages.

Preface

The Graduation Project is the final part of the study "Industrial Engineering and Management Science" at the Eindhoven University of Technology.

What you have in your hands at this moment is the result of an eight-months-effort. Actually it is the result of a four-years-study (five and a half for me, but without any regrets). Then again it is the result of a twenty-one-year-school-attending-life. What I am getting at is that this thesis, the final result of my Graduation Project, makes an end to my educational life. A weird experience when I walk out of the building on the 12th of February 1997, my graduation day. Looking over my shoulder I will most certainly think: "Was this it? Is this what prepared me for a job? Yes, this wás it! This did prepare me. At last, I am done! Let's celebrate and let's use the planes which I have seen passing in front of my office, all these eight months!"

I would like to thank:

- All the people of Business Unit Logistics for the positive attitude towards a graduating person. Besides this I would like to thank them for the pleasant time and the good laughs.
- Anke: For putting a whole lot of effort in my project. Besides, it was the best to have a tutor like you, with whom I could work seriously as well as fool around with. Please do go to Chili this year. Leon: Also for investing a lot of time in my project. I wish you a lot of traveling pleasure, good jokes from colleagues and success on your squash.
  I am sure that with the effort and critical attitude of Anke and Leon my graduation project was lifted to a higher level. Thanks!
- My tutors from the university, for understanding that my graduation project was very conceptual and was hard to make concrete. I would also like to thank them for the time and support they put in my project.
- My parents who have always supported me and made it possible for me to study.

For my colleges I hope that this graduation project really contributed to the Engineering job, thus to the Business Unit. Hopefully I will hear or see you work with the developed concept.

I wish you lots of reading pleasure,

Michel Findhammer

Amsterdam, February 1998

Summary

This thesis deals with "Designing Logistics Infrastructures". Focus was on a high abstraction level, hence the sub-title "A conceptual approach".

Business Unit Logistics (BULog) developed a concept that asks for the unique combination of logistics consultancy, implementation, management and execution of critical logistics activities.
The Engineering Department is faced with the task to engineer logistics solutions for the clients of BULog. There are a number of problems that the department has to deal with:

1. There is a lack of guidelines for engineering logistics solutions which provides a situation in which engineering is unstructured;
2. Logistics knowledge and used engineering methodologies are implicit (part of the subconscious) and for that reason difficult to explain;
3. Use of quantitative tools has little foundation. Logistics solutions rather are tuned to available tools instead of tuning the tools to the situation;
4. There is a lack of experience in logistics projects related to the clients.

These problems lead to the following objective for the graduation project (note that a quantitative approach to designing is a main consideration):
Being able to engineer logistics infrastructures, based on quantitative reasoning and in a sound, coherent and explicit way.
To deal with this objective, focus in the graduation project was on the structure and on the contents of a design process for logistics infrastructures. Development of the structure is dealt with in the first part of the graduation project. Besides the structure, the aspects of creativity and use of tools in a design process were addressed. The contents of the design process is dealt with in the second part of the graduation project.

First part: Structure of the Design Process

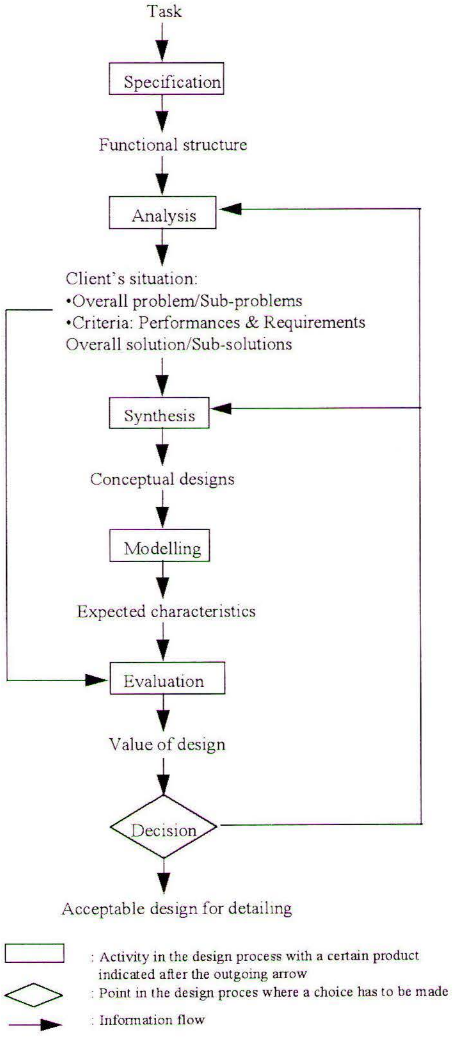
Structure of the Design Process:
The development of a structured design process is useful for the fact that quality will be improved by structuring the process in a consistent and justified work method. Such a design process is named the "Consultancy Design Process (CDP)". This CDP should contain a number of characteristics:

1. an iterative approach: The iterative approach means that backward steps are made in the design process, thus a certain part of the design process will be redone. Based on the "hard" facts of a quantification a choice can be made whether or not to make a new iteration. Iterations will be made due to non-satisfying performances of a conceptual design.
2. divergent and convergent thinking: By divergent thinking the number of alternatives is increased as by convergent thinking the number will be decreased. This means that the overall problem in designing will be divided in sub-problems. For the sub-problems, sub solutions should be found which are being coordinated to an overall solution.
3. solution focused thinking instead of problem focused thinking: Solution focused thinking is an efficient and effective work method. Besides, it provides much flexibility. Though, there is a risk of setting a wrong or less optimal solution, reaching a solution might be done at the expense of other areas and, to set the right solution this method asks for a lot of experience. The advantages of the solution based approach are substantial and the disadvantages can be overcome.

4. performance indicators: Performance indicators specify what has to be accomplished. A conceptual design can be evaluated on the basis of such performance indicators. Important indicators are cost levels and customer service levels.

A final structure of the Consultancy Design Process was created on the basis of the above mentioned characteristics and some design models from literature. The structure of the CDP can be seen in the figure below. The CDP consists of a number of products:

- Task: statement of the basic question in terms as objective as possible, not even in specific logistics terms;
- Functional structure: statement of the intended behavior (main logistics functions) of the design;
- Solution, problems and criteria: statement of the overall logistics problem with its sub-problems leading to sub-solutions and an overall solution. In the criteria, performances and requirements are stated which have to be accomplished;
- Conceptual designs: statements of designs that are reached by synthesis (creative thinking and thinking based on know how);
- Expected characteristics: statement of the behavior and characteristics of the conceptual design in quantitative performances like costs and customer service level;
- Value of design: evaluation of the conceptual design by comparing the expected characteristics it accomplishes against the criteria.



Creativity in the Design Process:
The importance of creative thinking is acknowledged though it is not made explicit in the design process of consultancy firms that were interviewed.
Reasons for this might be that:

- logistics is a discipline with a limited number of aspects;
- with an available database of previous projects a standard approach can be adopted;
- with an available benchmark database, a solution can be based on the best performances in the market.

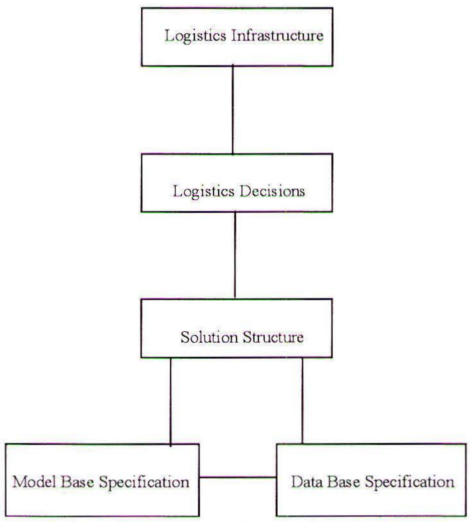
Creativity mainly is incorporated in the capacities of people. Multidisciplinary teamwork supports thinking in different directions, thus motivates creative thinking. Use of creative techniques is very individual driven and mostly is on an implicit basis. The most used technique is brainstorming.

Tools in the Design Process:
Again the importance of tools is acknowledged though it cannot be seen in the design process of consultancy firms. A database is an important tool according to consultancy firms. A database with raw data, data from previous projects and benchmark data supports designing. Other important tools are those that can support quantitative reasoning. Use of quantitative tools is important as it provides a basic understanding for designing. It might also be considered as a platform above which qualitative aspects play a significant role. Qualitative aspects though, appear to be dominant over quantitative aspects in designing logistics

solutions. Qualitative aspects can be dealt with by addressing them in the form of constraints. The quantitative approach towards designing hence is bounded by these constraints.

Second part: Contents of the Design Process

Development of Logistics Engineering Guidelines for the design process of logistics infrastructures, was the main recommendation as followed from the first part of the graduation project. The figure below gives the structure of the way in which is looked at a concept with engineering guidelines.



The vertical figure might be seen as hierarchical. To be able to design logistics infrastructures a number of logistics decisions have to be taken. These logistics decisions have a certain Solution Structure. The Model Base Specification indicates what quantitative techniques can be used to support decision making and it indicates the logistics functionalities that software tools have to live up to. The Data Base Specification is left out of the graduation project.

Logistics Decisions:

A number of logistics decisions have to be taken in designing logistics infrastructures. The logistics decisions had to be set in a specific logistics context. This was done by defining the logistics infrastructure and an overall objective for designing logistics infrastructures. Proposed definitions are:

- The logistics infrastructure focuses on the static and boundary providing aspects of logistics being both the aspects of logistics network and logistics control as defined below.
- The logistics network is the way in which the logistics aspects of location-allocations, transport and stock are divided or the way in which they are physically organized.
- Logistics control is the way in which decision rules are set to manage the goods flows through the elements of the infrastructure (location-allocations, transport, stock and order processing as an additional element) and the way in which decision rules are set to achieve set performances.

The overall objective provides for a long term focus in designing logistics infrastructures and is defined as: "Maximizing profits on the long term by balancing the customer service level in relation to the cost level".

A recommendation from the first part of the graduation project was to break down the overall problem in sub-problems for which sub-solutions should be found that can be coordinated in an overall solution. The overall problem is designing the logistics infrastructure. The sub-problems are the logistics decisions. The logistics decision can be classified in three ways:

1. to the elements: location-allocation, transport, stock and order processing;
2. to logistics network and logistics control;
3. to different stages in the overall design process for logistics infrastructures.

The figure on the next page presents all the logistics decisions that have to be taken in designing logistics infrastructures and are presented according to the first two classifications.

Logistics network		
Location-allocation decisions	Transport decisions	Stock decisions
1. Functionalities over the supply chain, being: production, assembly, cross-dock, consolidation, deconsolidation, stock, outlet; 2. Assignment of facilities to specific locations; 3. Long term capacity of facilities (ex stock); 4. Structural goods flow connections between suppliers, facilities and customers; 5. Number and regional location of functionalities (ex stock) and facilities; 6. Product assortment of facilities (ex stock) on the long term;	7. Transport modality or combinations in modalities on the long term;	8. Long term capacity of stock holding points; 9. Number and regional location of stock holding points; 10.Product assortment of the stock activity on the long term;

Logistics control			
Locations-allocation decisions	Transport decisions	Stock decisions	Order processing
11. Short term capacity adjustments of functionalities (ex stock); 12. Positioning of the CODP; 13. Product assortment of facilities on the short term;	14. Long term and short term capacity of transport connections; 15. Long term and short term product assortment of transport connections; 16. Transport modality or combinations in modalities on the short term;	17. Short term capacity adjustments of stock holding points; 18. Product assortment of stock holding points on the short term; 19. Stock control policy per stock holding point;	20. Order acceptance; 21. Delivery time release.

The third classification expresses that logistics decisions can be taken in a certain order hierarchy. Designing the logistics infrastructure will be done in 5 design stages. These design stages together form the whole design process for logistics infrastructures. In each design stage a number of logistics decisions will be taken. Next design stages with their decisions (numbers relate to those in the figure above) can be distinguished:
1. Geographical deployment of the infrastructure: 1, 5, 9, 12;
2. Infrastructural flow: 4, 6, 10, 15;
3. Infrastructural capacity: 3, 7, 8, 14, 19;
4. Detailed geographical deployment of the infrastructure: 2
5. Infrastructural control rules: 11, 13, 16, 17, 18, 20, 21.

The iterative way of designing also applies for the design stages. Each design stage itself will pass a number of iterations and iterations will also be made between design stages.

Solution Structure:
A quantitative approach towards designing logistics infrastructures is bounded by qualitative constraints. The constraints were classified in three groups: 1. Restricted possibilities of the client to develop their infrastructure; 2. Design freedom which the client allows; 3. External. These three groups together determine the solution space in which the design process with its five design stages has to take place.

Each design stage has a certain solution structure which consists of 5 elements:
1. Logistics decisions: those decision that will be taken in a design stage;
2. Design prescriptions: the way that Engineering has to deal with designing in succeeding design stages. Important considerations in this matter are the customer service aspects to take into consideration and the level of data aggregations;
3. Economic Trade Off's: the cost factors that should be included in the weighing of alternative conceptual designs;
4. Required input: the data needed to be able to make the logistics decisions and the Economic Trade Off's;
5. Output: the deliverables of each design stage.

An important consideration in the design prescriptions is the way that customer service should be taken care of. Customer service can be taken care of via the performance indicators of delivery time, reliability, flexibility and quality. Each performance indicator is influenced by certain logistics decisions, hence they can be dealt with in different design stages. As a result, the lead time and the fill rate aspect of reliability, will be dealt with from design stage 1 onwards. In design stage 2, mix-flexibility will be included. In design stage 3, the standard deviation aspect of reliability and volume flexibility will be included. And finally, in design stage 5 quality will be dealt with.
In the Economic Trade Off's an important choice is: what cost factors should be considered for the logistics decisions. In each design stage different cost factors are applied for the ETO's. Main distinctions are:
1. that the first design stage considers installation costs of logistics functionalities;
2. that the second design stage is focused on variable throughput costs as a result of combinations in product flows through the supply chain;
3. that the third design stage is related to the balance between throughput costs of capacity types, handling and inventory costs versus transport costs;
4. that the fourth design stage basically considers the location of facilities based on purchasing- and routing costs;
5. and that in the fifth design stage different control rules are weighed on the basis of additional throughput costs versus customer service costs.

Model Base Specification:
Three techniques are applicable for designing logistics infrastructures:
1. optimization (linear programming);
2. simulation:
3. calculation.

Each design stage has certain characteristics due to the logistics decisions to be taken. These characteristics can be linked to the characteristics, advantages and disadvantages of the quantitative techniques. The applicable techniques per design stage follow from this comparison.
The first two design stages typically represent a network flow problem. A cost optimum is sought for a great number of geographical alternatives. At this point in the design process the needed level of accuracy and detail is limited. Linear programming (and it's integer variant), thus, is the most applicable technique in this design stage. At the end of the second design stage, the logistics network is quite well developed. Continuous simulation provides the possibility to fine-tune the developed concept in a an easy and quick manner.
In the third design stage discrete simulation is the applicable technique. Infrastructural capacity namely can only be calculated when the dynamics of the real world are incorporated. Using discrete simulation the developed concept will be evaluated on it's cost and customer service performances.
In the fourth design stage, again a typical network problem appears, basically related to the routing problem. Thus, linear programming again is applicable here.
In the last design stage effects of decisions on control rules have to be evaluated. With discrete simulation, such effects can easily be evaluated by asking what-if questions.
Use of calculations is to be seen as ad-hoc support for mathematical functions or via spread-sheets.

A number of functional requirements can be related to software tools for linear programming and simulation, as these are the most applicable techniques. Result is a list of 9 requirements. What is especially important is that it should be possible to deal with specific definitions of products, product groups, product assortments, cost factors, operational customer service performance indicators. Besides, it should be possible to include additional mathematical functions.

Contents

Chapter 1: Organizational Description

In this chapter KLM will be presented. First the KLM, then KLM Cargo and at last Business Unit Logistics with its Engineering Department will be discussed briefly. Besides general descriptions, organizational structures will be put under the attention. This chapter also presents the organizational surroundings in which the graduation project was done. Each paragraph which follows the previous one presents a more detailed surrounding. In reverse order: the graduation project was done within the Engineering Department of Business Unit Logistics which is one of the Business Units of KLM Cargo, being a division of KLM.

1.1 KLM

KLM Royal Dutch Airlines was founded on October 7, 1919. It has continued to operate under the same name until this day, making it the oldest scheduled airline in the world with a continuous history. Nowadays KLM is an international airline operating worldwide with its home base Amsterdam Airport Schiphol. Over the years KLM has become a major player in both the passenger- and cargo markets. Annually KLM transports around twelve million passengers and around five hundred thousand tons of freight. In terms of international revenue ton kilometers, KLM ranks sixth among the more than 200 International Air Transport Association (IATA) member airlines. Over 26 thousand people are employed within KLM and net profits were NLG 236 million over the year 1996/97.

Core business of the KLM is to transport passengers and freight by air. Policy is to concentrate on business which supports these activities.
Mission statement of KLM is: "KLM is positioned as an airline operating worldwide from a European base, providing professional service for passengers and shippers demanding high-quality products at competitive prices with a reliable and punctual product and caring and friendly service".
To achieve this mission, KLM is committed to:

- generating customer preference by offering a continued high-quality product at a competitive price;
- strengthening its market presence through alliances with other carriers;
- maintaining competitive cost levels in relevant markets, and;
- enhancing financial strength in order to guarantee future access to capital markets by realizing a strong financial base.

This commitment is presented graphically in the "Cornerstones of KLM-policy", which can be seen in appendix 1.

In the fall of 1996 an ambitious transformation program, Focus 2000, was set in motion. This was done because it became apparent that all the actions taken within KLM would not result in the fundamental changes needed for sustainable success. This program is needed to prepare KLM for the next millennium. Targets of focus 2000 are:

- being an important player in the global airline system;
- being structural profitable by having competitive activities in the field of: network organizer, capacity supplier and service provider;
- a turnover of NLG 1,5 milliard in 1999/2000;
- cultural change.

The focus 2000 program has a high impact on the daily activities of KLM. Programs with focus 2000 targets are set in motion and certain activities have to be reconsidered towards focus 2000.

KLM is organized according to the structure presented in appendix 2. Main issue is that KLM has a separately organized Cargo Division which is responsible for transport of freight. In the next paragraph KLM Cargo will be presented.

1.2 KLM Cargo

KLM Cargo was put to live in 1991 as a separate division of KLM, responsible for the transport of freight over the world. Mission statement of KLM Cargo is: "To rank among the top-3 customer driven suppliers of high quality transport, distribution and information services". To accomplish this ranking, KLM Cargo has to strengthen its line-haul position, direct service at the high end of the market, position itself in all of the world's main markets, respect traditional and develop alternative distribution channels and market effectiveness and operational efficiency.

Core concept of KLM Cargo is divided in three parts:
- core Activity: Air transportation and related services;
- core Business: Contract distribution on behalf of 3rd parties;
- core Competence: Arranging and integrating logistics chains.

The air-freight industry is faced with a number of logistics force fields which are; increasing market demands, increasing technical possibilities and an increasing complexity of the goods flow. Because of these power fields KLM Cargo has to reposition itself in the market for logistics service providers. Second reason for repositioning is the so called "squeeze". This means that revenues on freight are decreasing as time goes on. It is the forwarding business which absorbs main part of the revenues. As efficiency in air freight is reaching it's maximum, a strategic move has the be made. More grip on the customers is a must. A third reason for repositioning is of course the focus 2000 program with its set targets.
As a reaction to the above mentioned situation the strategic development department of KLM Cargo [B. Grin] defined the "Strategic Migration". This Migration Ladder can be seen graphically in appendix 3: "Air Network" offers a distributed network with a central hub and "Air Logistics" offers added-value services on the basis of an air network. "Full Logistics" offers added-value services on the basis of air, sea and ground networks and "Supply Chain Management" offers management of the entire logistics chain.
Purpose of KLM Cargo is to move up this ladder. At this moment KLM Cargo is moving from "Air Network" to "Air Logistics".
Also because of the migration, the Cargo Division realized a radical reorganization which resulted in an improvement in flexibility and in customer-focus. In this reorganization Business Units for specific product/market combinations were put to live with the purpose of a more segmented market approach. This approach has led to the organization structure as it is now (see appendix 4). KLM Cargo consists of seven Business Units of which Business Unit Logistics is one. Generally speaking, Business Unit Logistics provides logistics services for high demanding customers concerning their logistics processes. This Business Unit will be discussed more specifically in the following paragraph.

1.3 Business Unit Logistics

Business Unit Logistics is one of the younger Business Units of KLM Cargo and was founded in September of 1995. Business Unit Logistics will contribute to the implementation of KLM Cargo's strategy to migrate from "Air Network" to "Full Logistics" by mapping, preparing, developing and proving-the-rightness of the migration process. Business Unit Logistics might be seen as front runner in the migration process.
For that reason this Business Unit positioned itself as a "Full Logistics Supplier" with the next deliverables to accomplish:

- capabilities, concepts, methods and tools which are necessary to act as a "Full Logistics" service provider;
- migration experience together with a dedicated group of clients from today's position towards "Full Logistics";
- a structured core-organization, competent and capable to serve clients interested in "Full Logistics" services;
- KLM Cargo Division's qualification in the domain of "Full Logistics".

Business Unit Logistics (BULog) has identified an attractive business opportunity through which KLM Cargo can capitalize on its current market strengths and relationships, by entering the business of organizing and managing logistics processes of customers. This new concept asks for the combination of logistics consultancy, implementation, management and execution of critical logistics activities. BULog's business consists of providing logistics services on a global scale. Customers are approached by giving them the opportunity to enable them in integrating and optimizing their business and logistics processes.
The service offered by BULog is primarily focused on the design and redesign of logistics infrastructures, process engineering, the management of logistics chains, direct involvement in executing the most critical logistics activities as well as the implementation required in achieving the predicted results.

BULog is organized according to the organization diagram as can be seen in appendix 5. It is organized in three departments being the Commercial-, Engineering- and Operations Department. Basic task of the Commercial Department is acquisition of customers for the service offered. Implementation of logistics solutions will be supported by the Operations Department. This graduation project is located within the Engineering Department. For that reason, this department will be discussed separately in the next paragraph.

1.4 Engineering Department

Main tasks and responsibilities of the Engineering Department reflect themselves best in the "key result areas" and "main tasks" according to the "Department Description" [internal document].

"Key result areas" for the Engineering Department are:

1. management and execution of Customized Logistics Projects according to the defined Customer Approach Methodology (see appendix 6);
2. management and execution of (innovative) competence development projects to secure a continuous uniqueness of the Business Unit's service offering in the market;
3. looking after and developing the Business Concept and logistics Methodology of the Business Unit.

Primary Process of the Engineering Department consists of managing and executing Customized Logistics Projects on behalf of the Commercial and Operational Department of Business Unit Logistics. Besides the Customized Logistics Projects, the Engineering Department is responsible for conducting (innovative) competence projects. These projects will be structured by the Engineering Department. The department has a complete list of "main tasks" to accomplish. Besides above mentioned key result areas and with respect to the graduation project, the most important tasks of this list are [internal document]:

- managing Customized Logistics Projects from Initial Assessment through to Implementation;
- performing logistics assessments;
- engineering logistics solutions;
- translating engineered solutions to requirements for suppliers of the client;
- preparing operational manuals per client for internal business unit use as well as for suppliers, partners and clients. This will be done in close cooperation with the Operational Section of the Business Unit.

The Customer Approach Methodology (CAM) [internal document] reflects the primary process of the Engineering Department. This Methodology consists of a number of steps. The steps that are relevant for the primary engineering job of the Engineering Department are:

- Desk Research: collection of detailed desired information in order to be able to perform a reasonably accurate initial assessment;
- Initial Logistics Assessment (ILA): examination of the client's logistics processes in order to engineer a solution for that logistics issue with the most improvement potential;
- Expanded Logistics Assessment (ELA): an extensive examination to gain in-depth understanding of the client's logistics processes in order to engineer a scala of logistics solutions, which are tailored exactly to the client's needs. End product of the ELA will be a conceptual design for a logistics infrastructure, for a chain management methodology and for logistics processes;
- Logistics Redesign & Logistics Engineering: In these two stages the developed concepts of the ELA will be engineered to a detailed and implementable product.

The organizational context in which this graduation project is situated has been clarified in this chapter. It is relevant to be aware of main issues like the Mission Statements, the Focus 2000 program and the Strategic Migration. These are important aspects, though the aspects of Business Unit Logistics and especially the Engineering department are of more concern for this graduation project. A complete insight was not given but most relevant organizational aspects of Business Unit Logistics and the Engineering Department were quoted. Other important organizational or situational aspects which are not discussed yet but which are of concern to the graduation project, will be discussed where necessary.

Chapter 2: Problem definition & Research methods

First stage of the graduation project is the orientation stage (see paragraph 2.4). Deliverables of the orientation are the situation description, the requirements & demarcation and the problem definition. The situation description presents the current situation of the Engineering Department with respect to the graduation project. A list of relevant problems for the Engineering section is part of this description. All of this will be stated in paragraph 2.1. The requirements and demarcation specify the play field for the problem definition and these make the situation for the graduation project more workable. The most important deliverable of the orientation is the problem definition, which is stated in paragraph 2.3. It specifies exactly "why" the graduation project was done and "what" was done to accomplish that. The used research methods served as a guidance for the project. Research techniques used and activities done, can be read here. To cope with the time limits, this project was extensively planned during all it's stages. In this planning all activities are placed in a time frame. Paragraph 2.4 discusses the research methods and paragraph 2.5 the planning.

2.1 Situation description

As can be seen in the previous chapter, the Engineering Department is primarily concerned with Customized Logistics Project and all related aspects. To manage and execute these projects a Customer Approach Methodology (see appendix 6) was developed. This methodology is a structured work approach which includes what to do with which objectives in what stage of the Customized Projects. It can be seen as a guidance through a Customized Project. Part of the engineering job in this matter is to develop logistics solutions. What is not taken account of in this methodology is the way in which logistics solutions should be engineered. In other words: there are no logistics engineering guidelines. Therefore, the Customer Approach Methodology (CAM) is more a management process description.

At this moment logistics solutions are engineered in an unstructured manner. Ideas are scattered and know-how as well as engineering methods for logistics solutions are part of the subconscious. To a certain level engineering is a creative process and for this reason difficult to explain. On the other hand engineering should be a structured process and easy to explain [N. Cross, 1989]. For the Engineering Department explaining their job to new engineers, to the Commercial Section and to other people involved is considered to be difficult. This is, for example, underlined by the fact that the Commercial Department finds it hard to understand the engineering activities.

Another aspect is that tools[1] which are being used for engineering, were selected properly only to a certain level. Little comparison has been made between tools available in the market. Mostly they are used because someone coincidentally ran into them. Result of this situation is that logistics solutions to a certain level are tuned to available tools instead of tuning the tools to the situation. From a scientific point of view tools should have been chosen based on functional specifications.

Furthermore, the Engineering Department knows what their logistics capabilities are. But only to a certain level has there been a practical reflection of these capabilities within a Customized Project. Until now Engineering only went through the first stage of the CAM, which is the Initial Assessment (see appendix 6), on a very creative basis. So an additional problem is a lack of experience in Customized Projects and a lack in going through the stages of the Customer Approach Methodology. This means

[1] The Engineering Department defined a tool as: "Any means with which the engineering of logistics solutions might be supported taking into concern that the tool in itself is situation independent and that out-coming results are explicit".

that a scientific foundation on the results of the graduation project cannot be drawn from practical applications. Therefore, the scientific foundation in this graduation project basically will have a theoretical base.

In summery the Engineering Department has to deal with the following problems:
1. Lack of guidelines for engineering logistics solutions which provides a situation in which engineering is unstructured;
2. Logistics knowledge and used engineering methodologies are implicit (part of the subconscious) and for that reason difficult to explain;
3. Use of certain types of tools has little foundation;
4. Lack of experience in Customized Projects and through the stages of the Customer Approach Methodology.

2.2 Requirements and demarcation

In chapter 1 the graduation project was put in its surroundings of the KLM organization. In this paragraph important requirements concerning the graduation project are described at a more detailed level. Furthermore, some demarcations were created to narrow down the scope of the graduation project to a manageable level considering the time limits of the project.

The requirements and demarcation for the graduation project were the following:
1. It should live up to the uniqueness of the service concept that BULog delivers. The main uniqueness is: "The scope of the logistics service offering, including consultancy, implementation, management and execution".
2. Besides the uniqueness of the service concept, Engineering considers a quantitative approach to designing logistics solutions as an additional uniqueness [internal document].
   According to Fleuren and den Hertog [1997] a profound quantitative analysis helps in supporting solidly a good strategic-tactical distribution structure. Van Doremalen [1997] argues that a quantitative analysis of different alternatives in logistics provides additional insight in what a good distribution structure should look like and how control should be done.
   In other words, quantification serves as a basic understanding for the design of logistics solutions. You might consider it as a platform above which other aspects play a significant role (think of politics, financial issues, etc.). But without the fundamental understanding of quantitative issues, a platform would be missing.
3. It should fit the Logistics Control Model (see appendix 7) in which logistics complexity is reduced by tackling different problems at different levels. These levels are those of infrastructure, chain control and operations management [internal document].
4. Focus has to be on designing logistics infrastructures (definition in paragraph 5.1). Note that the infrastructure is the first aspect to design in logistics systems for the fact that it has the longest time horizon [Goor, van et al., 1994], thus has the highest impact.
5. It should fit the Customer Approach Methodology (see appendix 6) until the stage where the logistics solutions will be detailed. The stages of importance for that matter are: Desk Research, Initial Assessment and Expanded Assessment [internal document]. In these first three stages a concept for a logistics system will be designed. Detailing the concept does not have to be considered.
6. Knowing that competition is fierce and costs are high, efficiency should be striven for in developing solutions to logistics problems. In this graduation project, purpose is to get a profound insight into designing logistics infrastructures. Efficiency in designing for that matter is of later concern.

7. The concept to be developed has to be about designing logistics infrastructures in general, thus not directed at a specific client.

2.3 Problem definition: Objective and first part of the Phrasing

The problem definition could be reached by taking into consideration the situation description of paragraph 2.1 with its problem statements. The problem definition should also meet the requirements and demarcation, which were stated in paragraph 2.2.
The problem definition consists of an objective and a phrasing [Verschuren, 1994]. The objective is meant to specify "why" the investigation will be done. The phrasing specifies "what" has to be figured out to reach the objective. The phrasing actually is the description of the assignment.

Objective:
Being able to engineer logistics infrastructures, based on quantitative reasoning and in a sound, coherent and explicit way.

The means with which the objective can be reached is by the development of a design process, which is named the Consultancy Design Process (CDP)[2] . In first it was not clear what aspects of the design process to focus on. Thus the graduation project was split in two parts.
The first part was named "Structure of the Design Process" and is meant to figure out what a CDP should look like in a structural sense. Besides this an insight in design processes with related aspects should be provided to be able to make a choice for the continuation of the graduation project. Below, the first part of the phrasing can be seen.
The second part, named "Contents of the Design Process" focuses on the logistics engineering guidelines of the design process. The phrasing for the second part was based on the outcomes of the first part and can be seen in chapter 4.

First part of the Phrasing:
What should a structured logistics Consultancy Design Process look like in the steps to be taken, which means:
- *What should the Consultancy Design Process look like from a theoretical point of view?*
- *What should the Consultancy Design Process look like from a practical point of view?*
- *What are other implications for the design process from a practical point of view, being: the way that creativity is organized and the tools[3] used to support the design process?*

2.4 Research methods

The research methods mean what research techniques were used and what activities were done to collect necessary information in the different stages of the graduation project. The research methods in this graduation project were built around the general guidelines from the Eindhoven University of Technology [1997] and the "Tien-Stappen-Plan (TSP) van het organisatieadviesproces" [Kempen et al.,

[2] Remember that the Engineering Department is mainly concerned with logistics consultancy and from this perspective the design of logistics solutions. For that reason the design process is being indicated as the "Consultancy Design Process (CDP)."
[3] Tools in this matter are defined as being able to support quantitative logistics decisions on an infrastructural level and having a software application. This definition was used for this graduation project.

1996]. The guidelines and the TSP provided input for determination of the Master Planning, which is the rough planning over the Graduation Project. The Master Planning consists of the following stages; orientation, analysis, design, implementation (when possible) and report writing. The research methods used in each stage will be discussed separately.

Orientation:
Purpose of the orientation is to provide insight in the actual situation and in the problems of the organizational surroundings in which the graduation project will be done.
Most important deliverable of this stage is the problem definition with it's objective and phrasing(s). Other deliverables are the situation description and the requirements & demarcation. All deliverables could already be read in this chapter.
The necessary insight to state the deliverables was gained by interviewing people from BULog related to the logistics engineering job. Furthermore, literature available about BULog and the Engineering Department was studied.

Analysis:
Objective of the analysis is to specify what to do in the following "design stage" of the Master Planning, to reach the objective of the graduation project. Related to this graduation project this meant that the first part of the phrasing had to be answered. Based on the outcomes the second part of the phrasing was developed. The second part of the phrasing is the specification of "what to do" in the design stage.

The investigation for the first part of the phrasing was partly theoretical and partly practical. Reason for a theoretical and a practical investigation was to gain a profound understanding in design processes. For the theoretical part a literature study was done, which provided a scientifical foundation.
Remember that part of BULog's job is to consult their clients concerning their logistics issues. For that reason the practical part of the investigation towards the Consultancy Design Process was setup within logistics branches of consultancy firms. By means of desk research a selection was made of the consultancy firms to approach. The investigation itself was done with the interviewing technique. The interview questionnaire can be found in appendix 14. Five consultancy firms were willing to participate. This number was considered to be sufficient for creating insight in practical implications. In an arbitrary order these firms were: Coopers & Lybrand; Halec (Deloitte Touche); Twijnstra Gudde; Private consultant; KPMG.
Via the investigation with consultancy firms insight was also provided in the use of creative techniques and in the use of tools to support designing logistics solutions. The interviewing technique was applicable again. Via desk research the market availability of applicable software for logistics was checked.

Design:
The research methods used in the design stage, are related to the second part of the phrasing (see chapter 4). The second part consists of three main sub-phrasings, being: Logistics Decisions, Solution Structure and Model Base Specification. For these three sub-phrasings the same research methods were used.
A number of questions to be answered in the phrasing depended on choices to be made by the Engineering Department. Besides this a lot of questions had to be answered using logistics knowledge of specialists. These were two reasons to create a "platform-group [4]". A third reason was the fact that

[4] A platform-group is a group of people that is used to create carrying power for the benefit of project continuation and to lean on with respect to specialistic knowledge. Most important sponsors of the project usually are included [Kempen et al., 1996].

the design stage of the graduation project was on a very conceptual level. This meant that a lot of discussion was needed which is only possible with such a group. The platform-group existed of the Engineering Department including the graduating person. In addition to the platform-group, the university tutors were used for evaluation of choices made. Thus, group discussion was a frequently used research method.
Because the design stage was on a very conceptual level a lot of ideas had to be obtained. Second used research methodology in this matter was a literature study which was done on a continuous basis.

Implementation:
The developed design of the graduation project should be implemented to evaluate its value, if time would be available. In this way it could be adjusted until an ideal one would be reached. First of all implementation would be very difficult for the fact that there is no client to reflect the design on. Secondly there was not sufficient time left in the graduation project. Conclusion is that, an implementation could not be done in this graduation project.

Report writing
By means of the technique of a written report (thesis) all the findings of the graduation project will be presented towards the KLM as well as towards the Eindhoven University of Technology.

2.5 Planning

In the previous paragraph the Master Planning was discussed with all it's stages and activities. Figure 2.1 presents the Master Planning over the duration of the graduation project. The marked areas indicate when a certain activity was performed.

Stage of Master Planning	**Activity**	June		July		Aug.		Sept.		Oct.		Nov.		Dec.		Jan.		Feb.	
Orientation	Interviewing BULog	■																	
	Literature Study BULog	■	■																
Analysis	CDP: theoretical					■	■	■	■										
	CDP: practical			■	■	■	■	■											
	Tools & Creativity: practical			■	■	■	■	■											
	Tools: desk research							■	■										
	In between Report writing						■	■	■										
Design	Logistics Decisions									■	■	■	■						
	Problem Structure												■	■	■				
	Model base specification														■	■			
Report writing	Concept- and final report writing												■	■	■	■	■		
	Presentation																	■	

Figure 2.1: Planning of the graduation project

Part 1: Structure of the Design Process

Chapter 3: Structure of the Consultancy Design Process

First part of the phrasing for the graduation project, as described in paragraph 2.2, is: "What should a structured logistics Consultancy Design Process (CDP) for BULog look like in the steps to be taken?" To gain full understanding of design processes for consultancy work an investigation was set up which was partly theoretical and partly practical (see research methods, paragraph 2.4). The theoretical part of the research was directed at design processes in general [Cross, 1989; Roozenburg & Eekels, 1991]. The practical investigation served partly as additional and partly as a parallel for the theoretical one. It can be seen as a parallel for the investigation in design processes. Creativity and tools to support the design process were investigated additionally in the practical investigation.
A number of important characteristics for the CDP appeared from the theoretical and practical investigation. The theoretical implications lead to a structure for the CDP but a final structure of the CDP was created based on the practical implications. Paragraph 3.1 presents the outcomes of the theoretical part whereas paragraph 3.2 presents the practical outcomes including the use of creativity and tools.
The investigation resulted in a number of conclusions and recommendations for the Consultancy Design Process. These will be presented throughout the paragraphs. In paragraph 3.4 a summary of the conclusions and recommendations will be given.

3.1 The Consultancy Design Process from a theoretical point of view

Many designers are suspicious of rational methods, fearing that they are a "straightjacket" or that they are stifling to creativity. This is a misunderstanding of the intentions of systematic design, which is meant to improve the quality of decision making and hence of the end product[5]. Thus, the development of a structured design process for the engineering process of the Engineering Department is *recommended*.
The design process should contain a number of characteristics such as an iterative approach and divergent versus convergent thinking.

Iterative approach:
Designing might be seen as a trial and error process, consisting of different empirical cycles. Within the empirical cycles knowledge of the problem and the design increase in a spiral movement. In other words, the spiral movement is also indicated as the iterative aspect of designing. This means that in the design process backward loops are made and phases will be redone. By means of numerous iterations the design process moves along.
When iterations should be made however, could not be found in literature. Design models according to the VDI [1986] and Pahl & Beitz [1984] do not say when exactly to make iterations. In these models, iterations should be made continuously (see appendix 8: the arrows going up and down).
It is *recommended* to make iterations only at critical moments in the design process. This is where the choice is made to make a new iteration or to detail a conceptual design. At these critical moments the conceptual design has to be quantified. Based on the "hard" facts of the quantification a choice can be

[5] Quality will be improved by structuring the thinking process in a consistent and justified work method, which is the design process. Experiences from the past proved this many times. When the design process is felt as a straightjacket it was not well developed or it is not used in the right way.

made whether or not to make a new iteration. Remember that designing should be done based on quantitative reasoning (see paragraph 2.2 and 2.3).

Divergent and convergent thinking:
Another characteristic of designing is divergence and convergence (see appendix 9) [VDI, 1986; Cross, 1989]. By divergence the number of alternatives is increased as by convergence the number will be decreased. This means that the overall problem will be divided in sub-problems. For the sub-problems, sub-solutions should be found which are being coordinated to an overall solution. Iterative thinking as well as convergent and divergent thinking were linked to the stages of the Customer Approach Methodology (see appendix 6). Figure 3.1 presents the results. Each little circles presents an iteration in designing. From now on such an iteration will be called a "design loop". Further explanation of figure 3.1 will follow in the text below it.

Logistics is a discipline with a lot of aspects (for example: think of all different aspects to consider from raw product until the final customer-product). Each aspect can be considered as a sub-problem for which sub-solutions have to be developed. Thus a *recommendation* is that thinking, related to the logistics discipline, should be done in overall problems/sub-problems and sub-solutions/overall solution. The aspects of the logistics discipline in this matter can be classified in different ways. A possible classification is in the financial, commercial and organizational aspects of logistics. Another classification might be in transport, stock and location-allocation aspects or a classification in quantifiable and qualifiable aspects. The chosen classification will be worked out in chapter 5.

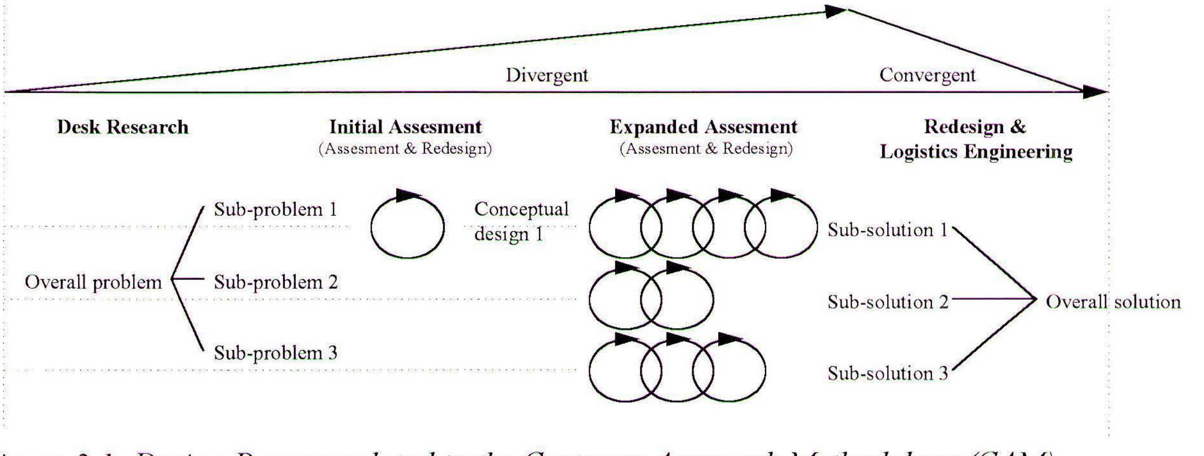


Figure 3.1: Design Process related to the Customer Approach Methodology (CAM)

Design characteristics related to the CAM (explanation of figure 3.1):
The design process may be considered divergent until the detail phase. Related to the Customer Approach Methodology (CAM), this is from Desk Research until Expanded Assessment. This means that a broader scope on the logistics problems of the customer will be gained (more sub-problems). Around different relevant problems a design process should originate. Each sub-problem leads to one or more alternative sub-solutions by going through a number of design loops. After having found all the designs (sub-solutions) the convergent phase starts by coordinating the sub-solutions to an overall solution (design to be realized). The overall solution will be build up by a number of sub-solutions, thus by making rational choices of alternative designs. Both the VDI model of development from problem to solution as well as Cross' six stage model are included here (see appendix 10). With respect to the CAM the convergent stage is "Redesign & Logistics Engineering". The convergent phase however falls outside the graduation project.

In the Desk Research and Initial Assessment the overall problem should be made clear. A sub-problem with enough improvement potential will then be chosen to deal with. The sub-problem has to be set in the context of the overall problem. For the first time a "design loop" will be passed through. End product of the Initial Assessment is a first conceptual design for the sub-problem. In the Expanded Assessment a next design loop will be entered. In the figure this is indicated by the dotted line. The going-through-design-loops will continue until a satisfied and feasible design is found which can be detailed.
In later phases of the CAM better insight in the logistics problems of the customer will be gained. Therefore, more problems to include in the design process, will appear. For each sub-problem a design process can be started. This clarifies the second and third row with design-loops (three is just an imaginary amount of sub-problems). Already from the beginning of the CAM one could be aware of the existence of more sub-problems. For that reason the dotted lines start in the Desk Research phase. The design process for the other sub-problems will also continue until satisfying and feasible designs for detailing are found.
In summery can be said that the Expanded Assessment primarily is concerned with deepening the sub-problem of the Initial Assessment until a sub-solution is reached. On the long term however optimizing one sub-problem may never be the objective. At the end, all the sub-problems together are of concern. Thus the Expanded Assessment has to deal with all of them.

Problem and solution focused designing:
As was discussed by Roozenburg & Eekels [1991] as well as by Cross [1989] a distinction can be made between design processes that take a descriptive approach and design processes that take a prescriptive approach; the first being solution focused and the second being problem focused. Design processes that start with a problem analysis are prescriptive. Design processes that start with a solution analysis are descriptive.
In the prescriptive models, solutions are developed, based on prescriptions which are derived from the problem analysis. But the design process goes around in loops meaning that problems and solutions are being adjusted to each other in an iterative manner. From a theoretical point of view can be concluded that in the end it does not matter whether a descriptive or prescriptive approach is chosen. By means of the iterative way of working both aspects will be dealt with. Thinking in problems and solutions also is useful for the sake of creativity. Creativity namely is captured in the design loops.
From a theoretical point of view it is concluded that thinking in designing should be done from a problem based focus in combination with thinking from a solution based focus.

Structure of the Consultancy Design Process:
Having made clear how the theoretical characteristics of design processes fit within the CAM it is time to create a structure for the Consultancy Design Process itself. Here the "design loop" is made clear as being a part of the structural design process.
In general design processes consist of a number phases. One design model defines more phases than another but the activities appear to be the same. The basic cycle (appendix 11) presents the following phases:
1. an analytical phase;
2. a conceptual (synthesis) phase;
3. a simulation phase, based on criteria (also performances) and
4. an evaluation phase.

These phases also can be seen within other design processes, though sometimes named differently. For the fact that the design loop (iteration) is very clearly explicated in the basic cycle, this design process is *recommended*. What is missing in the basic cycle is the input that defines the functions to be realized by the design. The VDI model and the model of Pahl & Beitz (see appendix 8) do this very well.

The *recommended* design process for the CDP (see figure 3.2) is a combination of the basic cycle [Roozenburg & Eekels, 1991] and starting points according to the models of the VDI [1986] and of Pahl & Beitz [1984]. Other aspects which were included in the CDP are:

- performance indicators. These are a pro in Archer's [1971] model and Jones' [1981] model and should be mentioned explicitly. Inclusion of performance indicators makes it possible to evaluate conceptual designs;
- iterative thinking, or the so-called design-loops;
- thinking in an overall problem and in sub-problems leading to sub-solutions and an overall solution.

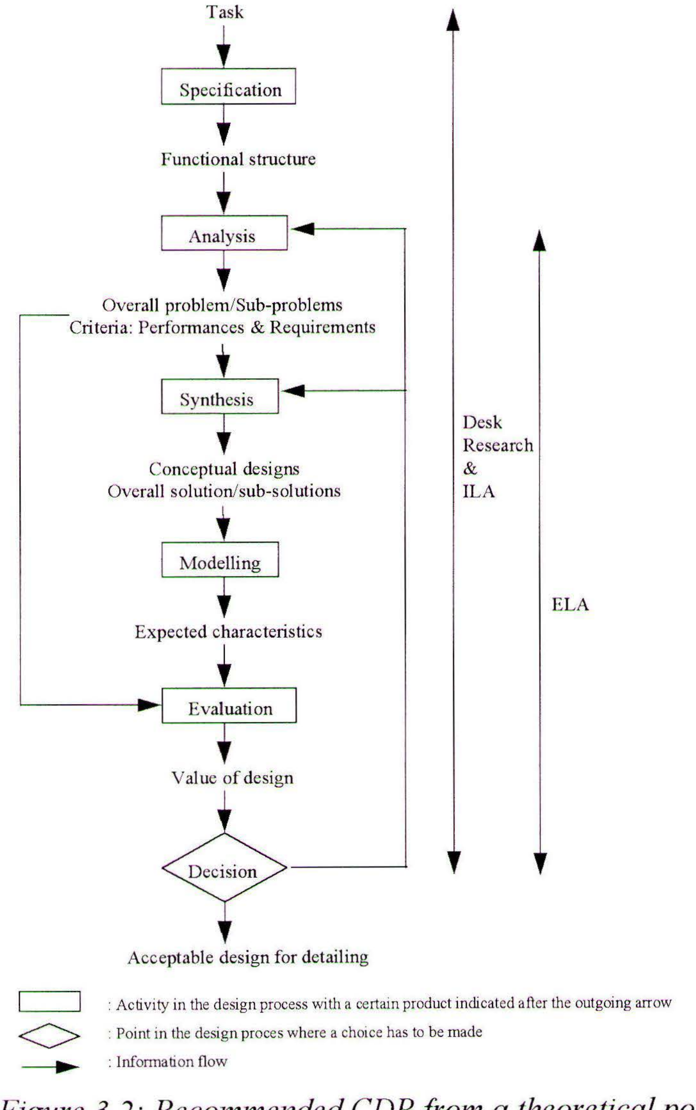


Figure 3.2: Recommended CDP from a theoretical point of view

In the CDP a number of separate products are realized by the activities to perform. The CDP consists of the following products:

- Task: The basic question is stated in terms as objective as possible and as broad as possible, not even in specific logistics terms. Other things to do here are: establishment of crucial issues, proposition of a course of action, collection-, classification-and storage of data.
- Functional structure: The intended behavior, or in other words the function, of the design should be stated here. The function does not have to be specified to the smallest detail but it should describe the main logistics function, that needs to be performed in the logistics infrastructure. The functional

structure is very customer dependent. A functional structure is more the beginning of a solution to a design problem than a definition of that problem.

- Problems and criteria: By analyzing, a vision of the overall problem and sub-problems can be gained. (Remember that sub-problems are related to the way that the aspects of the logistics discipline are classified.) Based on a profound understanding of the logistics aspects, performances and requirements (together criteria) can be set. To be able to check whether the solutions suggested really are solutions to the problem it is necessary to explicate the criteria in measurable parameters like costs, customer service level, etc.
- Conceptual designs and solutions: These are reached by synthesizing (creative thinking and thinking based on know-how). This might be done throughout the design process in total, but here the ideas should be explicated. A great number of techniques exist to support creative thinking [van Gundy, 1988; Jones, 1981].
  Thinking based on know-how can be supported with specified logistics engineering guidelines. Sub-solutions for the sub-problems should be found here. By combining sub-solutions, the overall solutions can be reached.
- Expected characteristics: By modeling, an opinion about the behavior and characteristics of the design is formed. Techniques used here depend very much on the discipline for which designing is used. In this investigation especially quantitative techniques for logistics (in the form of software tools) should be used. It is here where tools (see paragraph 2.3 for the definition) have their application.
- Value of design: The evaluation is used to compare the expected characteristics with the desired ones. Desired characteristics follow from the criteria. Based on the findings a new design loop can be started or the design can be proven ready for detailing. Starting a new loop means returning to the phase in the design process where adjustments should be made.

In figure 3.2 you can see that the design loop starts with the analysis and ends where the decision for acceptability of the design is taken. This means that the steps previous to the loop should be done beforehand. Linking the design process to the Customer Approach Methodology (appendix 6) means that the Desk Research in combination with the Initial Logistics Assessment should reach until one design loop has been made. In the Expanded Logistics Assessment only new loops will be made for the sub-problem of the Initial Assessment and for new sub-problems.

3.2 The Consultancy Design Process from a practical point of view

The results of the practical investigation within consultancy firms will be presented in this paragraph. Based in these results the final structure for the Consultancy Design Process will be presented.

Three issues were standing central in the practical investigation:
1. the structure of the design process: Is there a general work method in designing logistics solutions? Perhaps certain steps can be distinguished with a certain sequence dependency.
2. how creativity is organized regarding the development of logistics solutions: What different techniques can be used to support creative thinking?
3. how tools support the design of logistics solutions: What kind of tools are being used? These tools could be things like computer software. You might also think of data base systems that can support decision making.

The results will be presented in the same order as the three issues are presented here.

Structure of the design process:
As was discussed in the theoretical part, designing can be problem focused and solution focused. Without any exception, all the consultancy firms take a solution based focus at designing.
In general a solution based focus has the following advantages:
- it is an efficient work method because time will only be spent to accomplish the solution;
- it is an effective work method because focus always is directed at the final solution;
- it gives a lot of design flexibility because it does not matter how to get to the result only getting there in the end counts.

General disadvantages are:
- the risk of setting a wrong or less optimal solution or a solution which is too ambitious;
- accomplishing a solution might be done at the expense of other areas when prescriptions are not set very strictly;
- being able to set the right solution means needing a lot of experience in working with this technique and a lot of experience in the logistics practice.

Starting point in the design process of consultancy firms, also without any exception, is the client's situation. The client's situation means the specific logistics problems that it faces. This client's situation provides input for determination of the performances and requirements. Based on the performances and requirements, a solution/hypothesis for the design will be determined. Both the problem description and descriptions of the performances and requirements relate to the situation of the client. Thus, they are placed under the title of "client's situation" in the CDP.
A focus on key performances is considered to be important. This was mentioned specifically by the consultancy firms. This also appeared in the theoretical investigation.

A recommendation is to take a solution based focus in the CDP based on the client's situation. This recommendation is incorporated in the structure of the CDP (see figure 3.3). For example: "Lowering stock costs with 10% by means of a centralized stock holding point". This means that solutions are not an outcome of the design process but should be stated before starting the actual design. In the CDP can now be seen that solutions should be placed before the synthesis instead of afterwards.
A solution based focus is *recommendable* from a practical point of view because of the above mentioned advantages. Though a lot of experience from the market and experience in working with this method is necessary to cope with the mentioned disadvantages. It is *recommendable* to start directly with this method under guidance of an expert. The disadvantages of the solution based approach can be overcome in this way.

The two steps mentioned so far are; assessing the client's situation and determination of the solution. Besides these steps it appears that the consultancy firms do not state any further steps in the design process for logistics. Conclusion is that structure of the design process (for as far as it exists) used by consultancy firms is nothing fancy or a tour de force, thus does not contribute to the CDP.

Final structure of the *recommended* CDP is given in figure 3.3. In paragraph 3.2 an explanation can be found on the products and activities of the CDP. The only difference is that the "solutions" changed it's place.

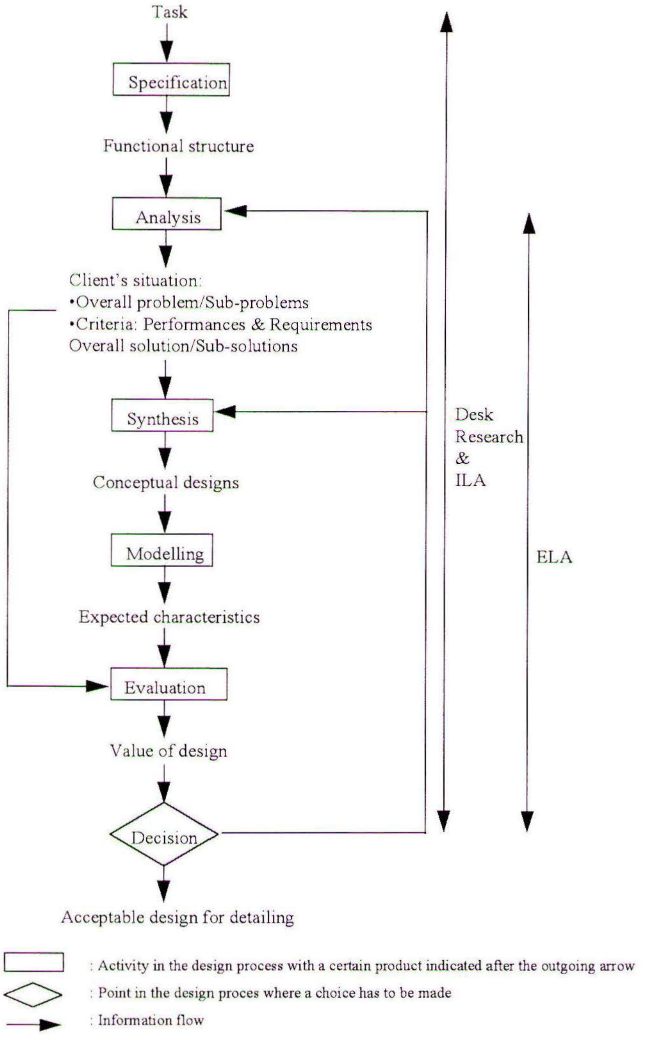


Figure 3.3: CDP with practical implications

Creativity:

Within all the consultancy firms an important aspect is the personality of a consultant. The personal capacities of the consultants are a guarantee for creativity. The capacities express themselves not only in creativity but also in know-how and experience. Recruitment procedures also focus on creative capabilities. Next to personal characteristics every consultancy firm does it's projects with teams. Teams are said to motivate creative thinking processes as well, especially when teams are multidisciplinary. Working in multidisciplinary teams supports creativity by thinking in different directions. Providing a surrounding to let out your ideas is called coaching and often is a part of the creative thinking process. Teamwork should also include the client for which the consultant works. Used techniques to stimulate creativity are kind of trivial. The most used technique is brainstorming. More techniques are used but on an implicit basis. Furthermore, the use of techniques is very individual driven. Consultancy firms do not use guidelines or something like it to stimulate the use of creative thinking techniques.

Most important conclusion is that consultancy firms acknowledge the importance of creative thinking though it is not made explicit in the designing process and not many techniques are used. This conclusion seems contradictory. Some reasons for this might be that:

- solutions for logistics issues do not need a whole lot of creative thinking for the fact that the logistics discipline only has a limited number of aspects and consultants carry a lot of experience;
- through the availability of a database with previous similar projects, a solution might quickly be reached by adopting a standard approach;
- through the availability of a benchmark database, the best performances in market are known on which a solution can be based.

The Engineering Department faces the problem that it has a lack of experience in logistics projects, that it does not possess a database with information on previous projects of relevance and that a benchmark database is not available. Whether creativity is guaranteed in the capacity of the in-house personnel is something to be determined by the Engineering Department itself.
For the fact that there is a lack of experience within the Engineering Department, it is perhaps necessary to focus more on creative thinking techniques than consultancy firms do. However you could not say that much can be gained here.
Recommendation is to build a database on which in the future actions can be taken. This database should provide for the availability of raw data, data from previous projects and for benchmark data. A database limits the need for creativity and it makes a very efficient work approach possible. Time is not needed to collect data.

Tools:
All the consultancy firms have possession of a database. Some firms also have possession of a benchmark database. Consultancy firms place great attention on the availability of databases. It was already *recommended* in the text above to build a database.
A number of consultancy firms acknowledge the importance of a quantitative approach. To support this, these firms have in-house developed quantitative tools in their possession. Which kind of decisions can be supported quantitatively could not be made clear from the investigation. One firm states that almost all decisions are quantifiable and another firm states that only a limited range of decisions are quantifiable. It could be seen that some quantitative tools are directed at cost calculations in the supply chain by means of scenario analysis.

Remark is that qualifiable data have an overweighing importance in taking decisions. This view is especially supported by the consultancy firms that do not take a quantitative approach. At the same time, this is the reason that these firms do not take a quantitative approach. A *recommendable* way to deal with this is to address qualitative aspects in the form of constraints. The quantitative approach towards designing hence is bounded by these constraints. The application of this can be seen in chapter 6.

Creativity as well as tools are being used by the consultancy firms. The description of the CDP (see paragraph 3.1) shows that creativity (synthesis) is a stage in designing and that quantitative tools are needed to support the modeling stage. Thus, these stages do exist in the design process but are not made explicit by the consultancy firms.

3.3 Conclusions and Recommendations

Throughout the previous paragraphs of this chapter a number of conclusions and recommendations were presented, which were related to the first part of the phrasing. In this paragraph a summary of these is provided.

Conclusions: CDP from a theoretical point of view:
Development of a design process is useful for the fact that quality will be improved by structuring the process in a consistent and justified work method. This resulted in the Consultancy Design Process. The design process should contain a number of characteristics.
Firstly, the iterative approach is very important because conceptual designs will have to be altered due to non-satisfying performances. Iterations (design loops) should be made at critical moments in the design process. This is where the design will be evaluated via quantitative modeling. Based on the hard facts of the quantification a choice can be made whether or not to make a new design loop. Remember that quantitative reasoning is desirable, according to the objective of the graduation project.
Secondly, divergent and convergent thinking is important. The overall problem has to be divided in sub-problems. For each sub-problem, sub-solutions will be developed which will be coordinated to an overall solution. Related to the logistics discipline, designing logistics infrastructures can be decomposed in (for example) designing transport, stock and location-allocation aspects.
From a theoretical point of view a design process was constructed, named the Consultancy Design Process (CDP). This CDP is a combination of the design models of the VDI [1986] and Pahl & Beitz [1984]. More important, it incorporates the above mentioned characteristics which a design process should have.

Conclusions: CDP from a practical point of view:
Another important characteristic to incorporate in the design process is a solution based focus. This has a number of important advantages, such as efficiency, effectivity and flexibility. The disadvantages it has can be overcome by applying this method under guidance of an expert. Solutions no longer are an outcome of the design process, but should be stated beforehand. Solutions will be stated, based on an understanding of the client with its specific problems and service requirements.
A focus on key performances is also important, which also appeared from the theoretical investigation. Due to the solution based focus, the structure of the theoretical CDP was slightly alterated. The design process itself hardly exists within consultancy firms. Thus, the absence of a structural form of design processes from the consultancy practice, does not contribute to the CDP.

Other conclusions: creativity and tools
Consultancy firms acknowledge the importance of creative thinking though not many techniques are used and it is not made explicit in the design process. Important reasons might be that the logistics discipline does not need creative thinking or the availability of databases. The creativity that consultancy firms talk about mainly can be found in personal capabilities and in multidisciplinary teams. Databases are considered as a tool supporting decision making. Databases provide for raw data, experience data from previous projects and for benchmark data. The importance of quantitative tools is not acknowledged uniformly. Qualitative aspects appear to have an overweighing importance. Qualitative aspects should be addressed as constraints for the quantitative approach to designing. The firms that acknowledge the importance of a quantitative approach, have possession of in-house developed quantitative tools.

Recommendations:
The structure of the CDP cannot be found when you look at the formal descriptions of the Customer Approach Methodology. Especially the iterative aspect and the thinking in overall-problem/sub-problems leading to sub-solutions/overall solution. Basic recommendation for that matter is to use the developed Consultancy Design Process (figure 3.3.) with all its characteristics.

Creativity mainly is incorporated in individuals and in multidisciplinary teams. This leads to the recommendation to pay attention to the people involved in a design project. The need for creativity can be compensated by the use of databases. Databases provide for a lot of important information. A database can also support quantitative tools by providing data.
Use of a database, just as quantitative tools is important, but one should know what to use these for exactly. Building a database is not the main recommendation as it does not contribute directly to the logistics engineering job. It is just supportive for designing logistics solutions.

The structure of the design process for logistics solutions has been made clear now. But, the contentual part of designing logistics solutions remains unclear. The contentual part has its place within the design loop and especially within the synthesis stage. Synthesis in the CDP partly has to be based on creativity and partly on logistics know-how. Engineering guidelines in which the logistics know-how can be incorporated do not exist. Such logistics engineering guidelines should explicate the contentual part of designing logistics solutions.
Thus, most important recommendation is to develop a concept with logistics engineering guidelines to be able to design logistics solutions. This concept should fit the CDP. In the next chapter can be seen how this recommendation is worked out in the "Second part of the Phrasing".

Part 2: Contents of the Design Process

Chapter 4: Second part of the Phrasing: Logistics Engineering Guidelines

One of the purposes of he first part of the phrasing was to provide insight in design processes with related aspects such as creativity and tools. This was necessary to make a choice for continuation of the graduation project. This chapter deals with the continuation by specifying the second part of the phrasing. In paragraph 3.4 could be read that the main recommendation is to develop logistics engineering guidelines to be able to design logistics solutions.

Figure 4.1 gives the structure of the way in which is looked at a concept for Logistics Engineering Guidelines. Parts of the logistics infrastructure will be designed when going through design loops of the CDP. Each time a part has to be designed the vertical figure will be considered (three figures is just an illustrative number).

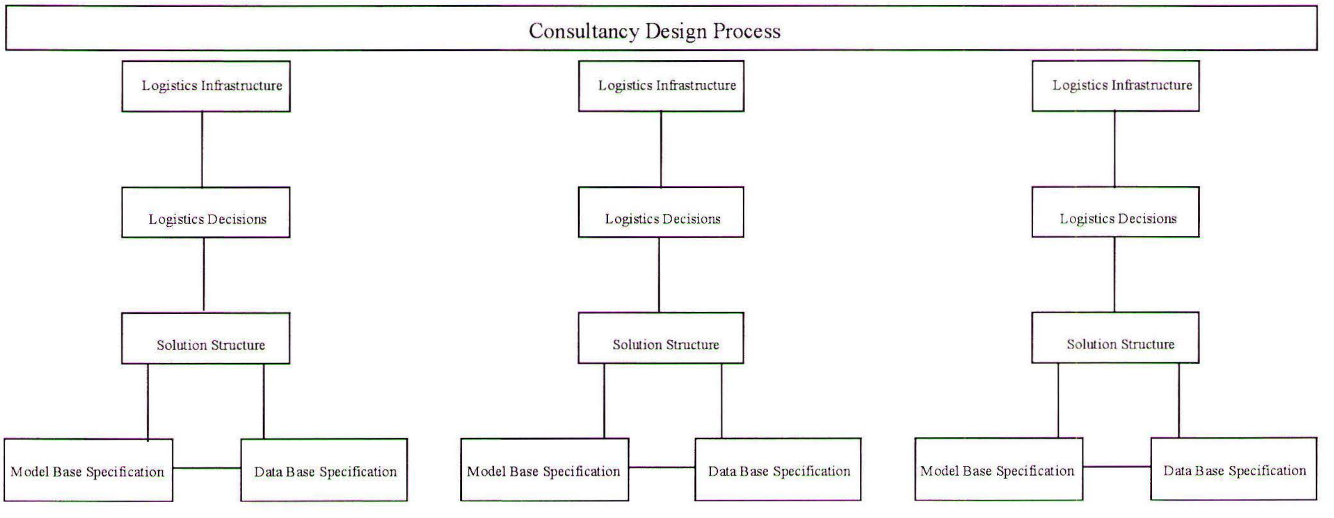


Figure 4.1: Graphical presentation of the second part of the Phrasing

The vertical figure might be seen as hierarchical. To be able to design logistics infrastructures, a number of logistics decisions have to be taken. These logistics decisions have a certain kind of Solution Structure which means the constraints, the kind of choices that have to be made and the data needed to take the logistics decisions. The Model Base Specification indicates what quantitative techniques can be used to support decision making and it indicates the logistics functionalities that software tools have to live up to.
The model base and data base work in a coherent way which is expressed by the horizontal connection. The Database supports the Model base by providing data in an efficient manner. Together they form a Decision Support System for designing logistics infrastructures.

According to this vertical figure the second part of the phrasing was split in three pieces: Logistics Decisions, Solution Structure and Model Base Specification. The data base specification is left out in the graduation project. Main reason is that the model base directly contributes to logistics solutions through it's intelligence. The data base in contrast serves more as a provider of data. Besides, building a database was not seen as the most important recommendation (see paragraph 3.4).

The second part of the phrasing for the graduation project is the following:

Logistics Decisions:
- *What logistics decisions have to be taken in designing logistics infrastructures?*
- *How do the different logistics decisions relate to each other?*
- *What kind of hierarchy is there in the order of the logistics decisions and how can decisions be made in an integrated manner?*
- *How or in what terms should the quantification of logistics decisions be done?*

Solution Structure:
- *Within which constraints should the logistics decisions be made?*
- *What kind of choices have to be made to be able to take the logistics decisions?*
- *What kind of data is necessary to be able to take the logistics decisions?*

Model Base Specification:
- *What kind of quantitative techniques can support designing of logistics infrastructures?*
- *How should a sensitivity analysis be made, meaning the factors to experiment with considering the logistics decisions to be taken?*
- *Which of these quantitative techniques are applicable for the various identified solution structures?*
- *What logistics functionalities should a quantitative tool have based on which a selection can be made?*

Chapter 5 deals with the Logistics Decisions, chapter 6 deals with the Solution Structure and chapter 7 with the Model Base Specification.

Chapter 5: Logistics Decisions

This chapter presents the logistics decisions which have to be taken in designing logistics infrastructures. The logistics decisions have to be set in a specific logistics context. This will be done by defining the logistics infrastructure and the overall objective in designing logistics infrastructures.
In paragraph 5.1 definitions can be found for the logistics infrastructure and it's two aspects: logistics network and logistics control. The overall objective clarifies "why" logistics decisions have to be taken, thus it provides in a long term focus. The overall objective can be found in paragraph 5.2. Customer service and cost performances are very important aspects of the overall objective and will be dealt with separately in paragraph 5.3.
In chapter 3, a recommendation was made to break down the overall problem in sub-problems. The overall problem is designing the logistics infrastructure. The sub-problems are the logistics decisions. The logistics decisions can be classified in three ways. The first two classifications can be read in paragraph 5.4. Here you can also find a list of all the logistics decisions which have to be taken in designing logistics infrastructures.
Paragraph 5.5 deals with the third classification. Based on a certain order dependency, logistics decisions will be placed in different design stages. Designing the logistics infrastructure via different design stages calls for an iterative approach (design loops). This will also be discussed in paragraph 5.5.
Taking logistics decisions leads to different alternatives. An applicable technique to weigh alternative designs is by balancing them via Economic Trade Off's. In paragraph 5.6 a foundation is given for the use of ETO's.

5.1 Definitions of: logistics infrastructure, logistics network and logistics control

The Engineering department is concerned with designing logistics infrastructures for which a number of logistics decisions have to be taken. To be able to specify what these logistics decisions exactly are, a profound understanding has to be gained in the exact meaning of the logistics infrastructure. Therefore, the logistics infrastructure will be defined, together with it's sub-aspects. The Engineering Department does not have a definition for logistics infrastructures. Therefore a new definition has to be created.

Logistics infrastructure and its sub-aspects: logistics network and logistics control
With the term logistics infrastructure the logistics network as well as logistics control is meant. The logistics infrastructure focuses on static aspects of logistics which are boundary providing for managing logistics at lower abstraction levels. Basically, the logistics network focuses on the physical layout and logistics control focuses on decision rules. The physical layout as well as decision rules also are static aspects and boundary providing for lower abstraction levels. Conclusion is that using the term logistics infrastructure as a cover for logistics network and logistics control is a good approach.

Definitions:
Considering a number of authors in the field of logistics, new definitions could be found for logistics network and logistics control. Basically the same definitions are used by a number of authors. In this graduation project, the term logistics infrastructure incorporates logistics network and logistics control. This is a broader definition than other authors use. Where they talk about logistics infrastructure, here the term logistics network is used. Therefore, the term logistics infrastructure will directly be replaced by logistics network, in the literature reference used.

Van Goor et al. [1994] use the following definitions:

- The logistics network is the way in which the logistics aspects of location-allocations, transport and stock are divided or the way in which they are physically organized.
- Logistics control is the way in which goods flows are managed through the channels of the infrastructure and the way in which they meet performances.

The definition of logistics network will be used in this form. The definition of logistics control is to be altered.

The alterations to be made on the definition of logistics control are the following:

1. What is missing are the elements to focus on in designing the logistics control. These elements were location-allocation, transport and stock. Kotler [1994] even distinguishes another element for logistics control, being order processing. The only reason that distribution takes place is because in the past orders were placed and for that reason, order processing influences the way distribution has to be dealt with. By means of decision rules, order processing will be controlled. Thus, order processing is clearly an element for logistics control. Suggestion is to replace "channels" in the definition by "elements" because it explicates much better where to focus on in designing the logistics control.
2. Logistics control is about management of the logistics chain. Though on a high abstraction level, focus should be on determination of decision rules and not on management. These decision rules set boundaries for logistics control at lower levels. Logistics control at lower levels is seen as the management of the supply chain and is not of concern in this graduation project. What is correct in the definition is that it should achieve predetermined performance indicators.

Proposed definitions are the following:

- *The logistics infrastructure focuses on the static and boundary providing aspects of logistics being both the aspects of logistics network and logistics control as defined below.*
- *The logistics network is the way in which the logistics aspects of location-allocations, transport and stock are divided or the way in which they are physically organized.*
- *Logistics control is the way in which decision rules are set to manage the goods flows through the elements of the infrastructure (location-allocations, transport, stock and order processing as an additional element) and the way in which decision rules are set to achieve set performances.*

5.2 Overall objective in designing logistics infrastructures

The overall objective provides for a long term focus in designing logistics infrastructures. It explicates "why" logistics decisions have to be taken. Focus during the entire design process should be on the overall objective.

Overall Objective:
Most important player in the supply chain is the customer. By satisfying the customer's needs all the business done in the supply chain earns it's right to exist.
Customer service is considered to be the ultimate source of competitive advantage [Ballou, 1992]. Anderson Consulting, an international logistics strategy consulting company, states that a successful logistics service begins with an understanding of customer service requirements. AT Kearney, also a very well known consultancy company, states that "power of the supply chain will be focused on the consumer".

Customer service performances that the supply chain accomplishes will influence the customer's perception. Reaching the highest possible customer service will drive costs to a very high level. Instead of this, one should try to reach an optimal customer service level meaning an acceptable cost level with an acceptable service level [van Goor, 1994]. Considering the cost aspect and the customer service aspect, the following overall objective for logistics engineering could be set: "Optimization of the customer service level in relation to the cost level" [Peelen, 1991]. However, increment of profits on the long term always is the main focus. Therefore it has been concluded that a better overall objective for designing logistics infrastructures is:

"Maximizing profits on the long term by balancing the customer service level in relation to the cost level".

Graphically the overall objective can be presented as in figure 5.1. The optimum reflects the point where profits are heighest, thus where the balance between customer service and costs is just right.

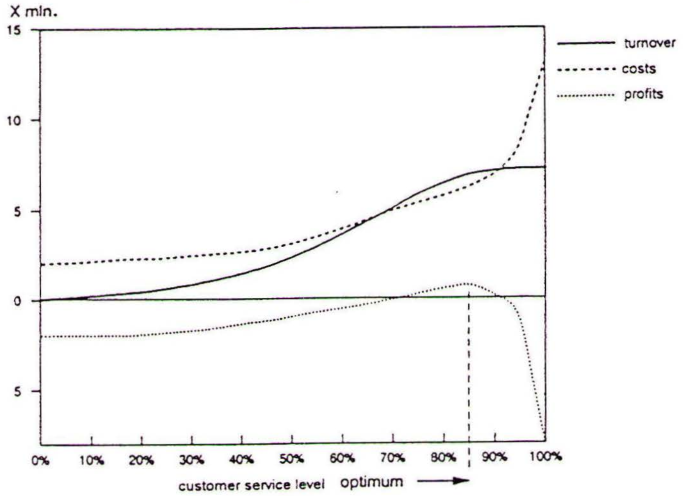


Figure 5.1: Relationship between customer service, costs, turnover and profits [van Goor et al., 1994]

The overall objective of course fits the Consultancy Design Process (see figure 3.3). It is part of the functional structure for the fact that it specifies the intended behavior of the logistics infrastructure. It is also part of the criteria as it provides requirements for customer service and cost levels.

5.3 Customer service and cost performances in designing logistics infrastructure

Customer service is a very important aspect of the overall objective and therefore will be discussed separately in this paragraph.

To provide for performances of logistics infrastructures, a focus at customer service performance is a necessity. A clear understanding of customer service leads to the basic questions of functional roles for logistics infrastructures. Starting point is to determine the "customer service and cost performances to accomplish" within the overall objective (see paragraph 5.2). Based on these performances the logistics system should be designed in an integral manner. This means that the logistics infrastructure, the control system (chain control) and the operational systems should be developed in coherence. Figure 5.2 gives a schematic presentation of the customer service viewpoint discussed here. The arrows in the figure indicate the information flows where the boxes represent activities. You can easily see that the figure fits the Logistics Control Model of BULog (appendix 7). The order of designing the logistics infrastructure, then chain control and finally the operational system, corresponds with each other. There are two ways to deal with customer service and costs. They can be used as:

1. constraints, which means that they have to be stated beforehand (see second box in the top of figure 5.2);
2. evaluation criteria, which means that realized performance levels have to be measured at the end of the design process. (The incoming arrows in the last box indicate that information is provided to be able to measure performances.) Based on the performances measured, adjustments can be made to realize performance levels in the future: or the performance levels will be adjusted or redesigns will be made. This is indicated by the arrows upward.

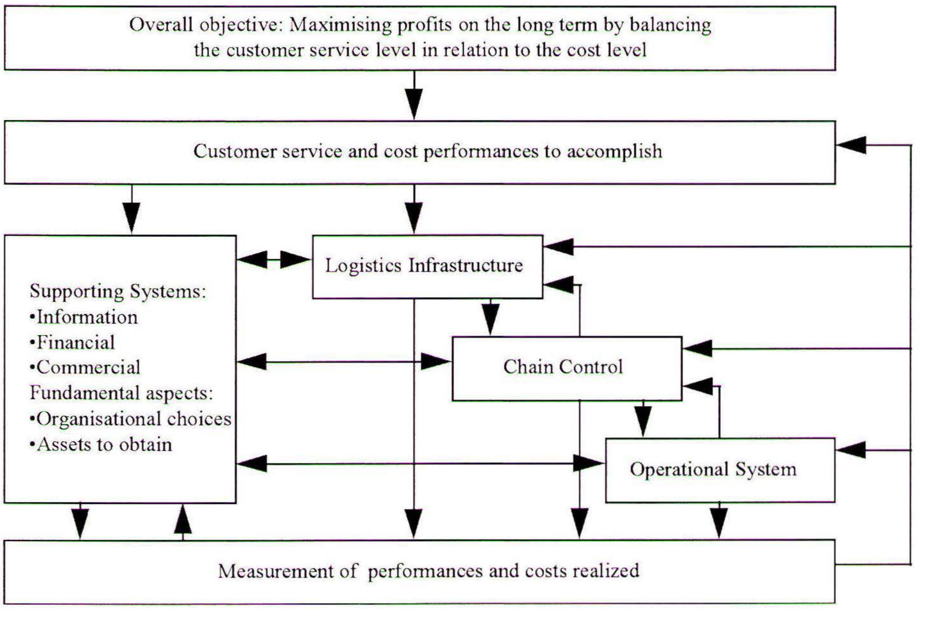


Figure 5.2: Customer service concept in designing a logistics system

Concluding can be said that: "Performance indicators for customer service and costs make visible to what extend the logistics infrastructure answers to the overall objective". Customer service performance indicators are stated in four terms [NEVEM-werkgroep, 1989]:

1. delivery time: time elapsing between the moment of placing an order and receiving the goods;
2. statistical reliability: level to which lead times according to agreements can de fulfilled. This can be quantified in two ways: the fill rate and statistical reliability.
   - fill rate means the percentage of orders which can be delivered within the agreed lead time;
   - statistical reliability refers to the standard deviation of the lead time.

   This distinction is important because of the way that customer service will be dealt with in the next chapter.
3. quality: level to which agreements on specific deliveries are fulfilled which means the right product, in the right amount at the right place and the right moment, against acceptable costs.
4. flexibility: ability to adapt to slowly evolving sales volumes, or to satisfy occasional customer demands. Flexibility has two forms [PBNA, 1993]: mix-flexibility and volume-flexibility.
   - mix-flexibility is the degree in which the product assortment can be altered within a given capacity;
   - volume-flexibility is the degree and speed in which the capacity can be varied.

Figure 5.2 finally shows that, systems for information, finance and commercial support should be developed in a parallel to support the logistics system. Furthermore, the right organizational choices (like structure and strategy) should be made and the right assets should be obtained to make things work. These aspects however fall outside the scope of the graduation project. In paragraph 6.1 you can see that they will be taken in consideration as constraints.

5.4 Classification of logistics decisions

For the Engineering Department it is very essential to know in which kind of logistics areas they want to work. This clarifies in what kind of areas they have to develop their skills. Besides, doing this makes the engineering job explicit which answers to the objective of the graduation project (see paragraph 2.2). The logistics areas will be explained by describing logistics decisions. Purpose of defining logistics decisions is to define the exact logistics scope of the Engineering department. The basic scope was already determined by the definitions (of logistics infrastructure, logistics network and logistics control) in paragraph 5.2.
In the phrasing of chapter 4 appeared that logistics decisions have to be taken to be able to design logistics infrastructures. Logistics decisions are defined as "The logistics issues that the Engineering Department wants to take account of in designing logistics infrastructures, as being a consultant and a logistics service provider".

Classification of logistics decisions:
From paragraph 3.1 the recommendation comes to think in overall-problem/sub-problems and sub-solutions/overall solution related to the logistics discipline. Main idea is to break down the overall problem of "designing logistics infrastructures" into smaller more manageable sub-problems". These smaller sub-problems are the logistics decisions. The logistics decisions can be classified in different ways. The proposed classification is three dimensional:

1. First classification is that according to Van Goor's definition. This means that decisions have to be made over the elements; location-allocation, transport and stock. Definitions of these aspects are [Bakker et al. ,1991]:
   - location-allocations: decisions on an optimal location for a facility in a logistics network or the choice of mutual dependent locations of different facilities [van de Ven, 1992];
   - transport: decisions on the right transport modes and the optimal planning of the transport connections to keep costs for logistics as low as possible;
   - stock: decisions on stock locations and stock control rules to keep stock at an optimal level in relation to other stock locations.

   First reason for this classification is that it clearly illustrates what logistics elements the decisions are focused on. Second reason is that quantification of design issues is done by making trade-offs between the aspects of locations-allocations, transport and stock [Van Goor et al., 1994]. Quantification by means of trade-offs will be dealt with later in this chapter.
   As was discussed in the previous paragraph, a fourth aspect to consider in logistics control is order processing.
2. Second classification is in decisions related to the logistics network and decisions related to logistics control. Allocation of decisions in this category will be done, based on the definitions of logistics network and logistics control as presented in paragraph 5.1. Purpose of this classification is to make clear that every time a design loop is made, something of the logistics network and something of logistics control will be designed. In an iterative way the logistics network and logistics control is designed. Figure 5.3 (partial replica of figure 3.2) presents this thought. The circles again present

design loops. The number of loops is not fixed and depends on the client's situation. This explains the "loop......" and "loop n".

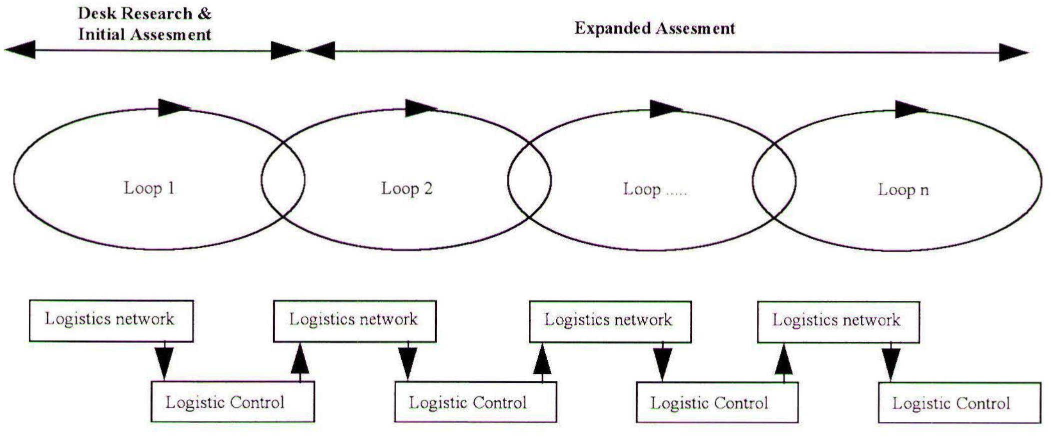


Figure 5.3: Classification in logistics network and logistics control related to design loops and the Customer Approach Methodology

The logistics decisions to be taken in designing logistics infrastructures and logistics control are presented below in figure 5.4. The decisions mentioned were derived from discussion with the platform group and the viewpoint of a number of different authors being; Ballou [1992], Handboek Logistiek [1989], van Goor [1994], Mourits [1995] and Hagdorn [1996]. In the figure, decisions are allocated according to the first two dimensions of the classification, as presented above.

Logistics network		
Location-allocation decisions	Transport decisions	Stock decisions
1. Functionalities over the supply chain, being: production, assembly, cross-dock, consolidation, deconsolidation, stock, outlet; 2. Assignment of facilities to specific locations; 3. Long term capacity of facilities (ex stock); 4. Structural goods flow connections between suppliers, facilities and customers; 5. Number and regional location of functionalities (ex stock) and facilities; 6. Product assortment of facilities (ex stock) on the long term;	7. Transport modality or combinations in modalities on the long term;	8. Long term capacity of stock holding points; 9. Number and regional location of stock holding points; 10. Product assortment of the stock activity on the long term;

Logistics control			
Locations-allocation decisions	Transport decisions	Stock decisions	Order processing
11. Short term capacity adjustments of functionalities (ex stock); 12. Positioning of the CODP[6]; 13. Product assortment of facilities on the short term;	14. Long term and short term capacity of transport connections; 15. Long term and short term product assortment of transport connections; 16. Transport modality or combinations in modalities on the short term;	17. Short term capacity adjustments of stock holding points; 18. Product assortment of stock holding points on the short term; 19. Stock control policy per stock holding point;	20. Order acceptance; 21. Delivery time release.

Figure 5.4: Classification of logistics decisions

[6] The Customer Order Decoupling Point (CODP) indicates how far the customer order penetrates the logistics manufacturing and distribution channel, thus it indicates a borderline in the tactical and operational planning and control structure. Logistics activities upstream (away from the customer) of the CODP are based on forecasts, whereas those on the customer side of the decoupling point are based on orders [van Goor et al., 1994].

A profound clarification of all logistics decisions, according to their number in figure 5.4, can be read in appendix 12.

3. Third and last classification is over different stages of the design process. Next paragraph deals with the third classification..

5.5 Design stages in the design process for logistics infrastructures

Logistics decisions are classified according to three dimensions. The first two were discussed in the previous paragraph. The third classification dimension of logistics decisions is "according to different design stages[7] in the design process for logistics infrastructures". After each design stage a certain part of the logistics infrastructure will be realized. Main focus in this classification is to allocate logistics decisions to a certain stage, which will be done based on the interdependencies a decision has with all other logistics decisions. Logistics decisions falling in one design stage are closely interrelated. This is in contrast with logistics decisions that will be allocated to different design stages. These decisions appear to have a certain order dependency (e.g. deciding over a transport modality to use can only be done when it is clear how the logistics network looks like).

Placing the logistics decisions in design stages has a number of advantages:

- While interdependencies between logistics decisions are very complex, order dependencies between them will appear;
- Closely interrelated decisions that require simultaneous handling are clustered together in one design stage. Each design stages then can be designated a specific quantitative technique (see chapter 7);
- Knowing the order dependency in decisions, it is easy to check where in the design process you are (especially interesting for the ILA where a logistics aspect with the most improvement potential will be designed);
- Project continuation can easily be seen through identification of milestones. Each design stage namely, has a number of deliverables (see chapter 6);
- It provides for a method to communicate the Engineering job to outsiders (other departments of BULog like the commercial one) and to clients. This is important as it answers to the objective of the graduation project.

Interrelationship Diagram Matrix: allocating logistics decisions to design stages
Purpose of the ID-matrix [Brassard et al., 1994] technique (as applied in the context of this graduation project) is to expose the order and interdependencies of logistics decisions. The ID-matrix provides the possibility to allocate logistics decisions to certain stages of the design process. This is done by means of identification of key drivers and key riders. A key driver is a logistics decision which relatively influences a lot of other logistics decision. A key rider is a logistics decision which relatively is influenced by a lot of other decisions. Logically, key drivers are decisions to be taken early in the design process and key riders are decisions to be taken at the end of the design process. Determination of these key drivers and key riders is the final objective of the ID-matrix technique.
Main strength of the technique is that each individual relationship between decisions is considered. Based on all the separate considerations the overall influence of a certain logistics decision is determined.

[7] A design stage, is a stage in the design process for logistics infrastructures, where a certain part of the logistics infrastructure is realised.

Filling in the matrix was done based on logistics expertise of the platform group. Every relation between decisions was reviewed very carefully especially when the relationships had very close tallies. However note that at the end, it is a judgment call.
The working of the matrix (for it was not discussed already) and the filled in matrix can be seen in appendix 13.

Conclusions from the ID-matrix:
Key drivers and riders are positioned in the first design stage respectively last design stage. The key drivers appear to give shape to the geographical part of the network. Thus other decisions with close interrelationship to this will be placed in the first design stage as well.
The key riders appear to be transport, facility assignments and control issues. However, the key riders are not placed uniformly in the last design stage. The decision on the transport mode was seen as an important aspect for the capacity of the infrastructure. Therefore, it was allocated together with other capacity decisions, in design stage 3. The decisions on facility assignments was seen completely independent of its foregoing and following design stage. For that reason, this decision stands alone in design stage 4.
Other decisions then the key drivers and key riders are placed in a certain stage based on an average score as a driver or a rider or based on an average total score (see appendix 13). Again withcoming decisions are placed in the same stage.
Based on the cluster of decisions in a certain stage the overall deliverable of each stage was set. The title of each design stage indicates this overall deliverable. The numbers of the decisions relate to those in figure 5.4.

Design stage 1 (key drivers): Geographical deployment of the infrastructure
1. Functionalities over the supply chain;
5. Number and regional location of functionalities (ex stock) and facilities;
9. Number and regional location of stock holding points;
12. Positioning of the CODP.

Design stage 2: Infrastructural flow
4. Structural goods flow connections;
6. Product assortment of facilities (ex stock) on the long term;
10. Product assortment of the stock activity on the long term;
15. Long term and short term product assortment of transport connections.

Design stage 3: Infrastructural capacity
3. Long term capacity of facilities (ex. stock);
8. Long term capacity of stock holding points.
14. Long term and short term capacity of transport connections;
19. Stock control policy per stock holding point.
7. Transport modality or combinations in modalities on the long term

Design stage 4: Detailed geographical deployment of the infrastructure
2. Assignment of facilities to specific locations; (influences 4)

Design stage 5 (key riders): Infrastructural control rules
11. Short term capacity adjustments of functionalities (ex stock);
17. Short term capacity adjustments of stock holding points;

13. Product assortment of facilities on the short term (influences 3);
18. Product assortment of stock holding points on the short term (influences 15);
16. Transport modality or combinations in modalities on the short term;
20. Order acceptance;
21. Delivery time release.

Iterative designing:
In the first three design stages a part of the logistics network and a part of the logistics control will be designed (decision numbers above ten are part of logistics control). This is exactly what was described in figure 5.1. The iterative thought of figure 5.1 can be found again in figure 5.5.
Each design stage will pass a number of design loops (iterations) until a satisfying design for that stage is reached. It might also be that more alternative designs appear to be applicable. Alternative designs (perhaps less optimal ones) which appear to be applicable can be taken along to next design stages. The best option may only then become visible.
Furthermore design loops can also take place between different design stages. Only when a next part of the infrastructure is designed, the value of what was already designed may become clear. In this matter, it has to be possible to alterate a design from a previous stage.

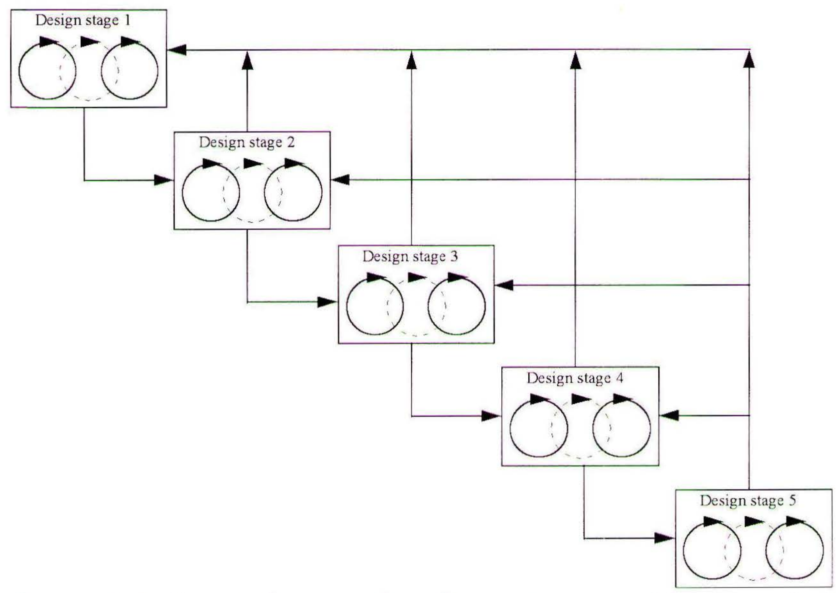


Figure 5.5: Design loops within design stages and between design stages

Design loops between design stages are also necessary because some decisions in later design stages, influence decisions in previous stages (see the notes between brackets in the allocation of decisions to the five design stages).

The dotted design loops indicate that the number of design loops in each stage is variable. The figure also shows that, from each design stage a loop can be made towards each previous stage. Forward loops however can only be made to the next design stage. This is logical because logistics decisions are placed in an order dependency. Alterations in designs for that matter have influence on all the following design stages.

5.6 Modeling of logistics decisions: Economic Trade Off's

Quantification of logistics designs has it's place in the "Modeling stage" of the Consultancy Design Process (see paragraph 3.2). Remember from paragraph 3.1 that by modeling the choice will be made to make a new iteration (design loop) or to detail a conceptual design. Thus, modeling will be done in each design loop of figure 5.5.

Within each design stage a number of alternative designs will appear that have to be weighed against each other. The technique of Economic Trade Off's (ETO) helps to support decision making by weighing of alternatives. The technique has three very fundamental steps. With relevance to this graduation project these steps are:

1. Different alternative designs have to be distinguished subject to customer service and cost performances (see overall objective in paragraph 5.2 and customer service performance indicators in paragraph 5.3) and subject to qualitative considerations. This means that for the logistics decisions in each design stage, alternative scenario's have to be considered.
2. The differences between developed designs should be identified. These differences will be expressed in logistics costs. Alternative designs are weighed against each other based on their costs and the level of customer service realized.
3. Finally a choice for a scenario can be made based on balancing the cost performances and customer service performances.

Just as in the overall objective, ETO's are made by balancing costs and customer service. This leads to the conclusion that ETO's are very useful in different stages of the design process. Purpose in this graduation project is to define ETO's for different stages in the design process. While determining the ETO's it is very important to identify which cost factors and customer service aspect should be considered in which design stage. In the next chapter, ETO's can be found for each design stage. Cost factors will be specified to a detailed level in the solution structure of chapter 6. Besides, it is made clear how customer service aspects are dealt with over the design stages.

In relation to the overall objective (see paragraph 5.2) a remark has to be made. An economic trade off means cost minimization while the overall objective is to maximize profits. This difference can be explained. Profit maximization can be done by keeping turnover at a constant level (same customer service level) while minimizing costs. Next step is to increase customer service (thus a higher turnover), while costs are kept on the same level. Then, costs will be minimized again, etc. In this way the economic trade off is not per definition a cost minimization tool but also a profit maximization tool.

Chapter 6: Solution Structure

Designing logistics infrastructures is bounded by a number of constraints. These constraints together determine the solution space in which designing has to be done. The constraints and solution space will be discussed in paragraph 6.1.
Each design stage (see chapter 5) in the design process for the logistics infrastructures, has a certain solution structure. The kind of choices to be made and the data needed to take logistics decisions will be discussed in the solution structure. The solution structure consists of five elements, which are to be addressed in a sequential order. These elements are: the logistics decisions to be taken; design prescriptions; economic trade off's to be made; required input and delivered output. Paragraph 6.2 gives a description of all five elements.
Related to the overall objective of designing logistics infrastructures, two important issues are customer service and costs. In the design prescriptions of each design stage a certain aspect of customer service will be introduced. In the economic trade off of each design stage the cost factors to consider, will be dealt with. For the ease of understanding, the customer service aspects and cost factors will be summarized in paragraph 6.3., but they will be founded in the following paragraphs. In the paragraphs 6.4 until 6.8 the solution structure for each design stage will be discussed intensively.

6.1 Constraints and solution space in designing logistics infrastructures

Qualitative data appeared to have an overweighing importance in taking logistics decisions. A recommended way of working is to address the qualitative aspects in the form of constraints. Hence, a quantitative approach towards designing is bounded by these constraints. These conclusions followed from the practical investigation towards the Consultancy Design Process (see paragraph 3.3).

Constraints that have to be taken account of in designing logistics infrastructures can be classified in three groups:

1. Restricted possibilities of the client to develop their infrastructure:
   - financial position: investment and reinvestment possibilities;
   - organization culture: resistance to change, (see also: social and cultural environment under external constraints);
   - long term agreements and contracts with third parties: co-makership, co-designership, JIT delivery conditions, prices, etc.;
   - strengths, weaknesses, opportunities and threats to consider, concerning logistics aspects of the client;
   - information availability.
2. Design freedom that the client allows:
   - What aspects of the infrastructure are available for design and for redesign or in other words, which of the logistics decisions in a certain design stage may be taken care of?
   - Which of the following policy aspects might be altered:
     - policy on logistics aspects: inventory, warehousing, transport, order processing;
     - policy on products (product strategies, new products, etc.), markets (potential markets to enter, target customers, etc.), customer service, suppliers and outsourcing;
     - policy on the budget for logistics;
     - policy on the organization structure: structure (flat in stead of strongly hierarchical, geographic business units in stead of product business units), authority, responsibilities.

3. External:
   External constraints mainly are related to the location-allocation problem[8].
   - protectionism: minimum/maximum selling volume, market accessibility, settling possibilities, import and export taxes, investment options, labor force, partnerships, border crossing costs, permits, exemptions, etc.;
   - legal regulations with respect to: the environment, labor (work conditions, insurances, wages), possible financial organization forms, permits, etc.;
   - political issues: political nature, political stability, deregulations and privatization, price regulations, etc.;
   - social and cultural environment: educational level, labor productivity, work attitude, etc.;
   - surroundings: border crossing delay, material availability, costs of material, etc.;
   - financial aspects: tax regulations, profit transfers, financial climate, interest rates, economic climate, subsidies, border crossing costs, etc.;
   - information availability of all these aspects.

The three groups of constraints together determine the solution space in which designing logistics infrastructures has to take place. Figure 6.1 presents the constraints as they determine the solution space.

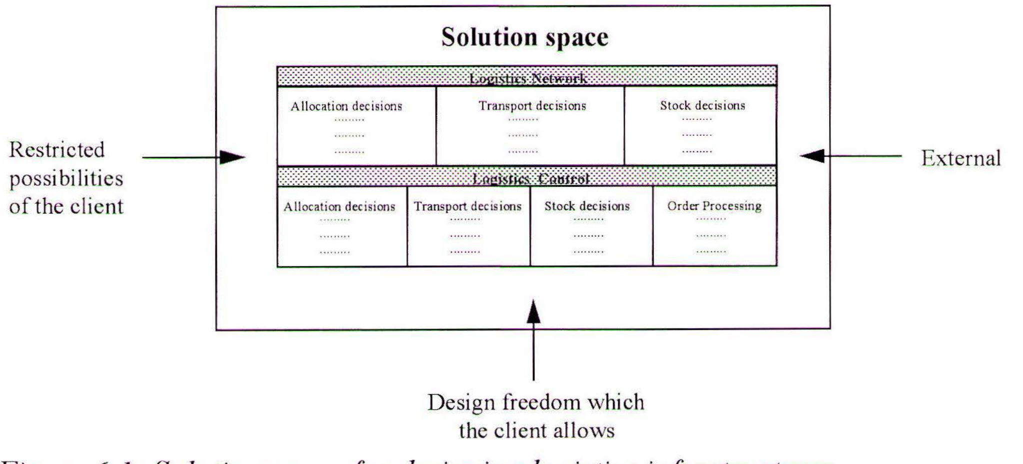


Figure 6.1: Solution space for designing logistics infrastructures

Remember from chapter 5 that designing the logistics infrastructure means taking logistics decisions. The center of the figure is formed by figure 5.2. Thus, the quantitative logistics decisions have to be taken within the qualitative defined solution space.

6.2 Elements of the Solution Structure

Logistics decisions have a certain kind of solution structure. This means that certain choices have to be made and that certain data is needed. The solution structure consists of five elements which are to be addressed in a sequential order.

1. Logistics decisions;
2. Design prescriptions;
3. Economic Trade Off ('s);

[8] Location-allocation problems are concerned with all kinds of aspects which play an important role in the choice of a location for a facility or the choice of mutual dependent locations of different facilities [van de Ven, 1992]

4. Required input;
5. Output.

The solution structure is generic for every design stage (thus the decisions in that design stage) in designing the logistics infrastructure. Besides, the solution structure will not be applied for every separate logistics decision. Reason for this is that a lot of information for the logistics decisions within one design stage is overlapping. Another reason is that decisions within one specific design stage cannot be made independently of each other.

The logistics decisions:
The previous chapter (paragraph 5.4) has illustrated how logistics decisions are classified and how they are assigned to certain design stages. Every design stage consists of a number of logistics decisions to be taken.

Design prescriptions:
The design prescriptions explain the way that Engineering has to deal with designing in succeeding design stages of the design process. The prescriptions (together with the logistics decisions and the ETO's) also explicate what kind of input is required for each design stage. The list of prescriptions is the following:

1. Increasing level of detail expressed by decreasing data aggregations in later stages of the design process.
   Logically, later in the design process more design issues will appear and more knowledge will be gathered, thus designing can be made more detailed.
   Data aggregation will also be necessary for quantitative calculations. A range of 500 products (very well possible) is too large for an optimization or simulation model. Besides it is not necessary to analyze systems in such detail as it would obscure the main results of experiments with the models. Creation of data aggregations however, is not as easy as making simple summaries [Mourits, 1995]. Various aspects require to be represented in the aggregations. Think for example of costs, volume and weight of aggregate products or rate and volume of aggregate market demand.
2. Data collection should be done based on historical information and, when possible and useful also on the basis of forecasting. Forecasting makes a proactive approach possible.
3. Increasing complexity by focusing in the beginning on critical factors and bottlenecks and later on non-critical factors as well. Reason for this is that critical factors and bottlenecks are conditional for other aspects to be designed. For every client, critical factors and bottlenecks will be different. This is the reason that they can be explicated only to a certain level.
4. Complexity can be reduced by making assumptions, for example: equal costs for handling different products, equal throughput times for cross-docking.
5. Focus in each design stage should be on the logistics aspects which are responsible for the relatively largest parts of the logistics costs. This however is very dependent on the customer, thus cannot be explicated.
6. Increasing level of customer service by including more customer service indicators in succeeding design stages.
   On infrastructural level, four customer service performance indicators were stated (see paragraph 5.3). Each performance indicator is influenced by certain logistics decisions. Hence, they can be dealt with in different design stages.
7. Designing has to be done within the infrastructural designs of previous stages. This directly follows from the classification of logistics decisions over different design stages (see chapter 5).

8. Designing is not bounded by infrastructural designs to be made in later stages. This also follows directly from the classification of logistics decisions over the different design stages.
9. Furthermore aspects which have to be determined can be set at an unlimited level in first (for example: an unlimited production capacity). This provides the possibility to see it's effect. When this appears to be non-realistic they can be set at a reasonable level.

Economic Trade Off ('s):
A foundation for the use of ETO's could be found in the previous chapter. By making a trade off different scenario's (alternative designs) for the logistics infrastructure are weighed on the basis of logistics cost performances and customer service performances. In this aspect of the problem structure all cost factors, influencing the logistics decisions of one design stage can be found. Realized cost levels should be reflected against benchmark data to evaluate their performance. For every design stage an ETO or ETO's will be determined. They differ in cost factors or the level of detail.

Required input:
The required input consists of those data needed to be able to make the logistics decisions and to make the Economic Trade Off. The input is bounded by the solution space (paragraph 6.1) and the design prescriptions. Input is also provided by the output of previous design stages. Most important outputs of previous stages will be listed again in the required input.

Output:
The outputs in every design stage are factual data (like costs realized, throughput times, customer service levels, etc.) and deliverables. Deliverables are the answers to the logistics decisions. Thus, the output specifies everything that a certain design stage has to deliver. Logically the output from one design stage provides a number of inputs for a following design stage.
It is not necessary that only one design appears from each design stage. Alternative options (also less optimal one's) which appear to be viable can be taken along to next design stages. The best option may only then become visible.

6.3 Overview of customer service aspects and costs in each design stage

Related to the overall objective of designing logistics infrastructures, two important issues are customer service and costs. For the ease of understanding these issues will be summarized in this paragraph. A profound argumentation of these issues will be found in the following paragraphs of this chapter.

In the design prescriptions of the previous paragraph could be read that more customer service aspects will be included in succeeding design stages. Figure 6.2 shows in what order customer service aspects are included in the design process.
The dark-gray areas indicate in which design stage a customer service aspect will be introduced. The light gray areas indicate that you will have to deal with the already introduced customer service aspect in designing.

	Design stage				
Customer service aspect	1	2	3	4	5
Lead time					
Reliability: fill rate					
Reliability: standard deviation					
Mix-flexibility					
Volume flexibility					
Quality					

Figure 6.2: Customer service aspect in each design stage

Just as the customer service aspect, focus in each design stage is on certain cost factors. Following table provides a detailed overview of the cost factors that will be considered in each design stage. Besides this, it provides the opportunity to check whether all cost factors are dealt with in the design process.

Cost factors	Design stage				
Installation/Maintaining costs(detailed overview):	1	2	3	4	5
• Investment/Reorganization	■				
• Depreciation	■				
• Rent/Lease sum	■				
• Equipment: investment, maintenance, depreciation, rent/lease sum, fuel, energy	■				
• Material: location dependent purchasing (also route dependent)	■			■	
• Personnel: overhead (indirect), labor (direct)	■				
• Third party contracts	■			■	
• Supporting facilities: Finance, IT, Marketing, Administration etc. (internal, external)	■			■	
• Other external costs (paragraph 6.1) due to: protectionism, financial aspects, etc.	■			■	
Production/Assembly related costs:					
• Fixed: • Installation	■				
• Extra capacity (structural)			■		
• Throughput costs:					
• Fixed costs of maintaining (per time period)		■	■		
• Variable costs: • Handling / Reconditioning		■	■		■
• Cycle- and safety stock	■	■	■		■
• Material (product dependent)	■				■
• Material: additional purchases					■
• Production costs/Machine set-up			■		■
• Purchasing externally: end-product	■				■
• Purchasing externally: capacity (facility, personnel)	■		■		■
(De)Consolidation/Cross-docking costs:					
• Fixed: • Installation	■				
• Extra capacity (structural)			■		
• Throughput costs:					
• Fixed costs of maintaining (per time period)		■	■		
• Variable costs: • Handling / Reconditioning		■	■		■
• Pipe-line stock, stock due to completion waiting times	■	■	■		■
• Equipment costs/Machine adjustments			■		■
• Purchasing externally: capacity (facility, personnel, etc.)	■		■		■
Stock holding/Outlet costs:					
• Fixed: • Installation	■				
• Extra capacity (structural)			■		
• Throughput costs:					
• Fixed costs of maintaining (per time period)		■	■		
• Variable costs: • Handling / Reconditioning		■	■		■
• Pipe-line-, cycle- and safety stock	■	■	■		■
• Equipment costs / Storage area adjustments			■		■
• Purchasing externally: capacity (facility, personnel, etc.)	■		■		■
Transport connection related costs:					
• Fixed: • Installation	■				
• Extra capacity (structural)			■		
• Throughput costs:					
• Fixed costs of maintaining the transport link (per time period)		■	■		
• Variable costs: • Handling (modality dependent) / Reconditioning		■	■	■	■
• Pipe-line stock	■	■	■		■
• Transport costs (fuel, depreciation, border crossing, etc.)	■		■	■	■
• Purchasing externally: capacity (equipment, personnel, etc.)	■		■		■
Customer service costs: no-selling, changed client relation (changes in sales)					■

Figure 6.3: Cost aspect to consider in each design stage

6.4 Solution Structure of stage 1: Geographical deployment of the infrastructure

1. Logistics decisions

- Functionalities over the supply chain;
- Number and regional location of functionalities (ex stock) and facilities;
- Number and regional location of stock-holding points;
- Positioning of the Customer Order Decoupling Point.

2. Design prescriptions

- *Lead time:* The lead time of products is a customer service aspect which is influenced by factors in every design stage. The logistics decisions of "the locations of stock holding points" and "positioning of the CODP", are very influential on the lead time to be realized. Logically you should look at those links in the geographical infrastructure that enable timely deliveries. Thus the lead time towards the market is a customer service aspect to consider from this stage on.
  Reliability: Centralization and decentralization impact the availability of stock. The fill rate aspect of reliability (see paragraph 5.3) will be influenced by this.
  Mix-flexibility is influenced by the position of the CODP. A CODP further stream upward provides more possibilities to include flexibility towards the customer. The influence, mix-flexibility has on the position of the CODP is very limited in relation to the influence of the lead time. The required lead time probably determines the possible flexibility. Conclusion is that lead time is the dominant customer service aspect and one should only be aware that mix-flexibility has a certain influence.
- Data aggregation will take place based on two aspects: over time and over volume. Aggregation in this stage will be over a long time period (e.g. 1 year). Next types of aggregations will be used in this stage:
  - products to product groups or to product assortments[9];
  - customers to geographical customer zones or to type of product demand (product market combinations[10]);
  - locations of facilities to the center of a geographical region and locations of markets to the center of the market region. This lead to more or less equal routing costs for different facilities.
- Product flow is basically determined by locations of markets and suppliers.
- Volume of product flows through the supply chain will be determined based on aggregated market demand. Thus, demand per echelon in the supply chain is not an issue.
- Throughput times for all products on the same types of facilities and transport connections are assumed to be equal.
- In this stage cost factors should not be dealt with at a detailed level. The way in which they should be dealt with are as follows:
  - equal throughput costs for all products at same facilities;
  - equal cycle stock levels for all products at same facilities;
  - stock levels (e.g. due to complementary waiting times) will be determined arbitrary (simplified Statistical Inventory Control[11] calculations) ;
  - equal transport costs and transport times on comparable transport connections.

[9] A product assortment is a range of products (not necessarily based on similar characteristics) to be dealt with at a facility, transport connection or for a certain customer market. A product group however is a range of products with similar characteristics. These characteristics have to be of importance for the reason that a product group is defined.
[10] A product-market combination (pmc) explicates which product is linked to which customer market.
[11] Statistical Inventory Control (SIC) is a technique in which levels are determined for order quantities, replenishment batch sizes and stock-review periods [Silver et al., 1994]

3. Economic Trade Off ('s)

Considerations following from the logistics decisions in this design stage implicate a focus at certain cost factors. Main considerations with their cost factors are:

- Inclusion of functionalities (thus facilities) in the chain: fixed costs of installing, variable throughput costs[12] of products versus costs of purchasing. An additional functionality does not mean an additional facility for the reason that more functionalities can be positioned in one facility. Hence, fixed costs of installing will relatively be lower when more functionalities are combined in one facility.
- (De)Consolidation/Cross-docking implies combinations (or not) of goods flows and change of transport modalities: transport costs (less transport or cheaper transport) versus extra handling costs and stock costs (pipe-line stock[13] and stock due to completion waiting times[14])
- Assembly (= value adding activity or postponement of production) implies the possibility to keep the goods flow longer together: lower stock costs.
- (De)Centralization has implications on transport (distance, frequencies, volumes) and on stock levels (safety- and pipeline stock): transport costs and stock costs.
- An outlet can be a point where goods can be obtained or where stock is located: stock costs and transport costs. Door-to-door delivery may result in exclusion of outlets: installation costs of outlets and stock costs (of outlet and previous echelon) versus transport costs.
- Location-allocation problem of facilities: costs of investment, material costs, labor costs, taxes, import/export duties, etc. (see also external constraints in paragraph 6.1), transport costs, stock holding costs (pipe line-, average- and safety stock).
- Positioning the CODP in the supply chain means higher (CODP downstream) or lower (CODP upstream) stock levels: storage costs and costs of inventory.

In general this stage is concerned with the number of facilities (one or more functionalities) and the location of these facilities. Most important cost factors in this matter are those related to the location-allocation problem and the installation costs of functionalities (thus facilities). As can be seen from the cost factors discussed above, transport costs and stock costs are the most important. Additional handling costs can be included in throughput costs for a facility. This leads to the following trade-off's:

Trade-off's:
Installation costs and variable throughput costs of functionalities (production, assembly, (de)consolidation, cross-docking, stock holding) versus transport costs and stock costs (pipe line-, cycle-, and safety stock) subject to customer service prescriptions of lead time and reliability.
Costs of owning functionalities versus costs of purchasing end-products or capacity.

4. Required input

- Sets of suppliers including potential suppliers: location, product range, prices, minimum/maximum purchasing amounts per product, supplier lead time performance;
- Sets of customers and potential customers: type of product demand (pmc), volume of demand, geographical locations, demanded lead time and reliability (related to geographical availability of products);
- Possible regional locations for all types of functionalities (thus facilities);

---

[12] Variable throughput costs is the portion of the total costs for throughput that is dependent on and varies with the production volume.
[13] Pipe line stock is the level of the physical goods flow between a supplying and a receiving party
[14] To consolidate different shipments you'll have to wait untill all the shipments are available. The goods waiting create a certain stock level.

- Characteristics of certain types of functionalities: throughput time, throughput costs
- Possible transport links and transport modalities on these links;
- Characteristics of transport modalities: speed (thus throughput time on transport connections), geographical range, capacity, cost structure;
- Cost aspects to consider in this design stage (see figure 6.4);
- Definition of purchase articles and production/assembly articles;
- Sets of products: product characteristics (see figure below), product modularity, assembly structure (for value adding);

The goods flow consists of different products with their own product characteristics. These characteristics are important for the way in which they should be dealt with in the logistics infrastructure. Van Goor et al. [1994] developed a typology which distinguishes product characteristics in a small and in a broad scope. Next figure gives an overview.

Product characteristics in a small scope				
A	B	C	D	E
Value density	Perishability	Packing density	Physical state	Volume/weight ratio
1. high	1. long	1. high	1. solid	1. high
2. low	2. short	2. low	2. liquid	2. low
			3. gas	

Product characteristics in a broad scope				
F	G	H	I	J
Product life cycle	Marketing strategy	Market form	Production stocking system	Direction of goodsflow
1. introduction	1. market penetration	1. full competition	1. continuous /on stock	1. contribution
2. grow	2. market development	2. limited competition	2. continuous /on order	2. distribution
3. maturity	3. product development	3. oligopoly	3. intermitating /on stock	
4. decline	4. diversifi-cation	4. monopoly	4. intermitating /on order	

Figure 6.4: Product characteristics

In the product characteristics a distinction can be made between quantifiable and qualifiable aspects. Categories A, B, C, D, E, I and J are directly related to logistics and have quantitative implications. The other categories, F, G and H, are qualifiable in a marketing perspective. These will have implications on business marketing policy and are taken care of in the solution space for designing (see paragraph 6.1). Other product characteristics of importance are: vulnerability, packaging, safety regulations, manageability related to stocking, transport or handling.

5. Output

- Types of functionalities needed within each supply chain to deal with the products from supplier to customer;
- Number of facilities with their functionalities in each supply chain (includes number of echelons);
- Number of facilities within each echelon;

- Regional (with respect to the constraints of the location-allocation problem) indication of facility locations;
- First indication of transport modalities to be used;
- First indication of which products can be dealt with at which facilities;
- First determination of goods flow connections, thus mutual allocation of customers, facilities and suppliers to each other based on the goods flow;
- All possible input and output links of facilities (include alternative options besides the chosen ones);
- Possible products that may be supplied by a certain supplier;
- Possible products that may be demanded by a certain market;
- Location of the CODP per product(group) market combination (pmc's);
- Lead time performances towards the market;
- Cost performances following from the ETO's.

Overall output: One or more alternative designs of the geographical infrastructure

6.5 Solution Structure of stage 2: Infrastructural flow

1. Logistics decisions
- Structural goods flow connections;
- Product assortment of facilities on the long term;
- Product assortment of the stock activity on the long term;
- Long term and short term product assortment of transport connections;

2. Design prescriptions
- *Mix-flexibility*[15]: For every product possible paths through the supply chain will be determined. By creating mix-flexibility different products can be dealt with at a certain facility or transport connection. For that reason the customer service aspect of mix-flexibility has to be considered from this stage onwards. Mix-flexibility can be created by a larger or more diverse structural capacity.
- Data aggregation on long term notice (e.g. 1 year) because in this stage the flow path for each individual product will have to be determined. Data may also be aggregated over different products as long as this does not have consequences for the flow of the individual product. Possible data aggregations may be made:
  - products to product groups based on similar flow paths through the infrastructure;
  - customers to type of product demand (pmc's);
  - locations of facilities to the center of a geographical region and locations of markets to the center of the market region.
- All product flows through the supply chain will be determined based on the aggregated market demand. Thus, demand per echelon in the supply chain is not an issue.
- Throughput times and costs for products within a product group on same types of facilities or transport connections are assumed to be the same.
- Capacities will be considered static to be able to calculate the fixed part of throughput costs. Fixed throughput costs are inversely proportional to the number of products flowing over the capacity type. Capacities in the supply chain will be derived from aggregated market demand.

[15] A distinction can be made between two types of flexibility. Mix-flexibility is the degree in which the product assortment can be altered within a given capacity. Volume-flexibility (discussed in the prescriptions of stage 3) is the degree and speed in which the capacity can be varied [PBNA, 1993]

Besides the fixed part, throughput costs also have a variable part. Variable costs only appear when a product is dealt with at a facility or transport connection.

3. Economic Trade Off ('s)

Considerations following from the logistics decisions in this design stage implicate a focus at certain cost factors. Main considerations with their cost factors are:

- Combinations of products in product groups has to be done based on those characteristics that provide combinatory advantages. Advantages in costs can be gained by combinations in: production, assembly, handling, transport, etc. Cost advantages reflect themselves in lower throughput costs, fixed[16] and variable. This type of cost advantage are "economies of scale" and "combinatory cost advantages".
  Note that, more products flowing over a facility means that fixed costs can be divided over more products, lowering the throughput costs.
- The throughput cost structure should be specified to each separate product(group).

In general this design stage is concerned with cost advantages which can be gained by grouping products. Advantages which you might think of are scale advantages or advantages resulting from combinations in production, assembly, transport, cross-docking etc.

Trade-off:
Throughput costs (fixed and variable) of different product groups at functionalities and transport connections subject to customer service prescriptions of lead time, reliability and mix-flexibility.

4. Required input

- One or more alternative designs for the geographical infrastructure;
- Customer service demands of lead time, reliability and mix-flexibility;
- Product characteristics which are important for construction of product groups, including their assembly structure;
- Possible connections between functionalities;
- Sets of suppliers including potential suppliers with their characteristics (see stage 1);
- Sets of customers and potential customers with their characteristics (see stage 1);
- Characteristics per individual functionality: throughput times and throughput costs;
- Detailed cost structure of the cost aspects to consider in this design stage (see figure 6.4).

5. Output

- Paths that individual products follow through the infrastructure;
- Definitive mutual allocation of customers, facilities and suppliers to each other based on the product flow between them. This means:
  1. input and output links of facilities specified to products and alternative possibilities;
  2. product assortment (including possible adjustments) to deal with at which facilities (what products can be produced where and what products are hold on stock and where are they stocked;
  3. product assortment (including possible adjustments) to deal with on which transport connection and what products can be dealt with together (special conditions, slow or fast moving goods);
  4. product supplier combinations;

[16] The portion of the total throughput cost that depends on the production volume. A higher volume differentiates the fixed costs of the facility over more products.

5. product market combinations.

- Definition of product groups;
- Lead time and mix-flexibility performances;
- Cost performances following from the ETO ('s) made;
- Optimal distribution of inventory and value adding activities over the available facilities.

Overall output: One or more alternative designs of the infrastructural flow and of the geographical infrastructure.

6.6 Solution Structure of stage 3: Infrastructural capacity

1. Logistics decisions

- Long term capacity of facilities (ex stock);
- Long term capacity of stock holding points;
- Long term and short term capacity of transport connections;
- Transport modality or combinations in modalities on the long term;
- Stock control policy per stock holding point.

2. Design prescriptions

- *Volume-flexibility:* Capacity (also utilization of facilities[2]) in the infrastructure makes it possible to create volume-flexibility. Extra capacity in the form of production, transport or stock holding provides the possibility to cope with demand fluctuations. Volume- as well as mix-flexibility are determined by possible alterations in: batch sizes, frequencies in production and distribution and throughput times [van der Weegen, 1989]. These three aspects determine the reaction possibilities of a system. Attracting additional capacity on the short term should be weighed against increasing the permanent level of capacity.
  Reliability: By creating extra structural capacity the standard deviation aspect of reliability can be dealt with. This is the second reliability aspect besides the fill rate (which was dealt with from the first design stage on).
- Demand in the different echelons of the supply chain is no longer directly related to market demand. From now on every echelon in the supply chain has it's own demand [PBNA, 1993].
- Data aggregation will be done on short term notice (e.g. a planning period for production, transport, etc.) to make fluctuations visible.
- Data aggregation will be based on individual product(group) flows through a facility or transport connection. Required capacity follows from these individual product(group) flows.
- Stock control policy per stock holding point and determination of the parameters for the chosen policy.
- Throughput costs of products flowing through a facility or a transport connection consists of two aspects: a part of the fixed costs and variable costs of dealing with the product. Fixed costs for example are: equipment depreciation, personnel, maintenance, administration, etc.
- Capacity costs in this matter exist of fixed and variable costs.
- Capacity and cost claims of a product within a product group are assumed to be the same. However, when differences are substantially within product groups, detailed information per product of their capacity claims, throughput times and costs should be used.

[2] Utilization is the percentage of time that a capacity type is occupied. A high degree implicates longer waiting times, thus longer throuhput times.

3. Economic Trade Off ('s)

Considerations following from the logistics decisions in this design stage implicate a focus at certain cost factors. Main considerations with their cost factors are:

- Basic capacity requirements (machines, labor, etc.) follow from the volume of the goods flowing through it: fixed part of the throughput costs.
- Volume-flexibility demands additional capacity: higher (fixed) costs of the capacity thus higher throughput costs.
- Influencing cost factors in this matter are higher throughput costs (fixed) due to additional capacity, versus customer service costs (due to changing turnover).
- Capacity of stock holding points relates to weighing capacity costs (fixed, variable) and costs of inventory (interest, storage) versus costs of transport. Stock costs and handling cost can be detailed: per product, colli.
- Capacity of the transport connection relates to the frequency of transport and the volume of each transport flow. The trade-off to be made here is transport costs versus costs of inventory (pipe line-, safety- and cycle stock: lower frequency means higher safety- and cycle stock levels).
- Flexibility can be arranged by keeping additional stock. This leads to higher safety stock and/or other parameters in the stock control policy: stock holding costs.
- Use of multi-modal transport implies extra handling when changing the modality: handling costs.
- Transport costs also relate to the utilization degree. A higher utilization degree means lower transport costs, but might imply higher stock levels thus higher stock costs. Trade-off here is transport costs versus stock costs. A larger product assortment on a transport connection for that matter might be important.
- Stock control policy means determination of a number of parameters. Choosing a policy means weighing the parameters on the basis of replenishment costs and stock costs (cycle, safety, storage) versus transport costs. Customer service also plays a big role in stock control policy. Cost factors in this matter are costs following from a certain policy versus costs of selling-no.
- Fixed costs: rent, depreciation, overhead, assets, labor, information.
- Own or purchased transport depends on: costs of own transport versus purchasing costs, fluctuations in transport (non fluctuating part in own property and purchasing peaks in demand for transport).

Trade-off's:
Throughput costs (fixed and variable) of a capacity type, handling- and inventory (storage, pipe-line, cycle, safety) costs versus transport costs subject to customer service restrictions of lead time, flexibility (volume and mix) and reliability (fill rate and standard deviation).
Costs of own control of functionalities and transport versus costs of purchasing capacity.

4. Required input

- One or more alternative designs of the infrastructural flow and of the geographical infrastructure;
- Customer service demands of lead time, reliability and flexibility;
- Dynamic demand per pmc and per facility in the supply chain and dynamics in purchasing amounts of products;
- Definitions of product groups;
- Capacity claim per product(group) on functionalities or transport modalities;
- Specified product assortments to deal with at facilities or transport connections;
- Possible transport links and transport modalities on these links;
- Characteristics of facilities: capacity of equipment and personnel, throughput times, cost structure;

- Characteristics of transport modalities: speed (thus throughput time on transport connections), geographical range, capacity, cost structure;
- Detailed cost structure per product(group) of the cost aspects to consider in this design stage (see figure 6.3).

5. Output

- Minimum/maximum capacity for each facility;
- Minimum/maximum capacity of each transport connection (dependent on restrictions such as maximum loads, transit speed, etc.);
- Set capacities for the functionalities within each facility and for the transport connections;
- Possible capacity adjustments of the transport connections;
- Used transport modality or combinations in modalities per transport connection;
- Goods flow connections with sizes and product groups;
- Sizes of shipments;
- Utilization of facilities and transport connections;
- Safety stock levels per stock holding point;
- Average frequencies of replenishment, productions, assembly, transport and batch sizes per facility or transport connection;
- Throughput times specified per product group on facilities or transport connections;
- Lead time and flexibility (-volume and -mix) performances;
- Cost performances following from the ETO's;
- Batch sizes of production and distribution.

Overall output: One or more alternative designs of the infrastructural capacity, of the infrastructural flow and of the geographical infrastructure.

6.7 Solution Structure of stage 4: Detailed geographical deployment of the infrastructure

1. Logistics decisions

- Assignment of facilities to specific locations

2. Design Prescriptions

- Goods flows specified to transport shipments.
- No aggregation on central market position anymore.
- Detailed cost structure of each transport shipment.
- Data aggregation on long term notice of ingoing and outgoing product flows of transport connections.
- For this design stage there are no additional customer service aspects to consider. Customer service performances following from previous stages should be met here. Lead time is the most important customer service aspect to consider because of the geographical positioning of facility locations.
- Stock costs due to pipe-line stock will be left out. These costs are related 1:1 with transport costs of the routing. Routing costs will be optimized, thus pipe line stock costs as well.

3. Economic Trade Off('s)

Considerations following from the logistics decisions in this design stage implicate a focus at certain cost factors. Main considerations with their cost factors are:

- Accessibility for the supply chain and for suppliers influences needed transport modality and transport time: transport costs within the region as determined in the first design stage, additional handling costs.
- Accessibility to the market influences needed transport modality and transport time: transport costs within the region, additional handling costs.
- Position in relation to the supply chain and market: routing costs[17] (determination of an optimum position).
- Position in relation to raw materials or local suppliers: purchasing costs.
- Position in relation to supporting facilities.
- Locally determined aspects: taxes, costs due to environmental regulations, local charges, etc.

Trade-off:
Alternative locations on the basis of purchasing costs (from suppliers and supply chain), transport costs (to markets and supply chain) and handling costs subject to customer service prescriptions.

4. Required input
- One or more alternative designs of the infrastructural capacity, of the infrastructural flow and of the geographical infrastructure;
- Customer service demands of lead time, reliability and flexibility;
- Regional locations of facilities;
- Mutual allocations of facilities to each other and the transport modalities used between them;
- Product assortment flowing over each transport connection;
- Replenishment frequencies and batch sizes of product(groups) per facility and per transport connection;
- Available routes with possible transport modalities and costs;
- Characteristics of transport modalities: speed (thus throughput time on transport connections), geographical range, capacity, cost structure;
- Cost aspects to consider in this design stage are those of transport and handling.

5. Output
- Location of each facility;
- Descriptions of transport connections to and from the facility: determined routings, infrastructure;
- Costs of purchasing and costs of delivery;
- Customer service performances of lead time, flexibility (volume-and mix-), quality (right product at the right place and with the right amount).

Overall output: Detailed design of the geographical infrastructure and one or more alternative designs of the infrastructural flow and infrastructural capacity

6.8 Solution Structure of stage 5: Infrastructural control rules

1. Logistics decisions
- Short term capacity adjustments of facilities (ex stock);
- Short term capacity adjustments of stock holding points;

[17] Routing costs are all the tranpsort costs related to purchasing and delivery of a certain facility. Thus it is not only about driving an optimal route in deliveries.

- Product assortment of facilities on the short term;
- Product assortment of stock holding points on the short term;
- Transport modality or combinations in modalities on the short term;
- Order acceptance;
- Delivery time release.

2. Design prescriptions

- *Delivery reliability:* Already by creating extra capacity (or in other words creating flexibility which was done in stage 2 and 3) the customer service aspect of delivery reliability was indirectly dealt with. Flexibility namely makes it possible to react to changing market demands. Order processing rules (order acceptance and delivery time release) are also important aspects in meeting predetermined reliability demands.
  Quality: Quality will also strongly be influenced by order processing rules. Quality is about meeting predetermined delivery agreements towards the market (see paragraph 5.3).
  Flexibility: Finally important aspects for flexibility are processing rules (for example: accepting orders with special demands) and rules to deal with ad-hoc decisions such as adjustments in capacity and product assortment.
  Thus, the customer service aspects; delivery reliability, quality and flexibility should be dealt with in this design stage.
  Important to know is that all mentioned customer service aspects in this stage depend very much on the existing information network and internal communication. Only by means of these, order information will be processed rightly. The information system is supporting for logistics as could be seen in figure 5.2. Development of such a system falls outside this graduation project.
- Data aggregation has to be done on short term notice (e.g. a planning period) over product groups. Basically data aggregation should be done here to determine order processing rules and possible capacity adjustments. Think of capacity checks or material checks when accepting orders.
  Thus, aggregation of products to product assortment on a certain capacity type.

3. Economic Trade Off ('s)

- Adjustments in capacity or product assortment means weighing the advantages (in customer service perspective) of the adjustment against the additional costs it implicates. Advantages can be things like higher customer service (turnover) or cost advantages in other areas (transport, other facility).
- Order acceptance and delivery time release both are of main importance for realization of short and reliable lead times. Customer service advantages have to be weighed against the extra costs of adjustments in capacity and product assortment.

Next figure explicates where decision rules for infrastructural control are needed. In the figure the whole process of an order until order acceptance and delivery time release can be seen. The process starts in the right upper corner. The shaded figures indicate where control rules are needed and what they are needed for.

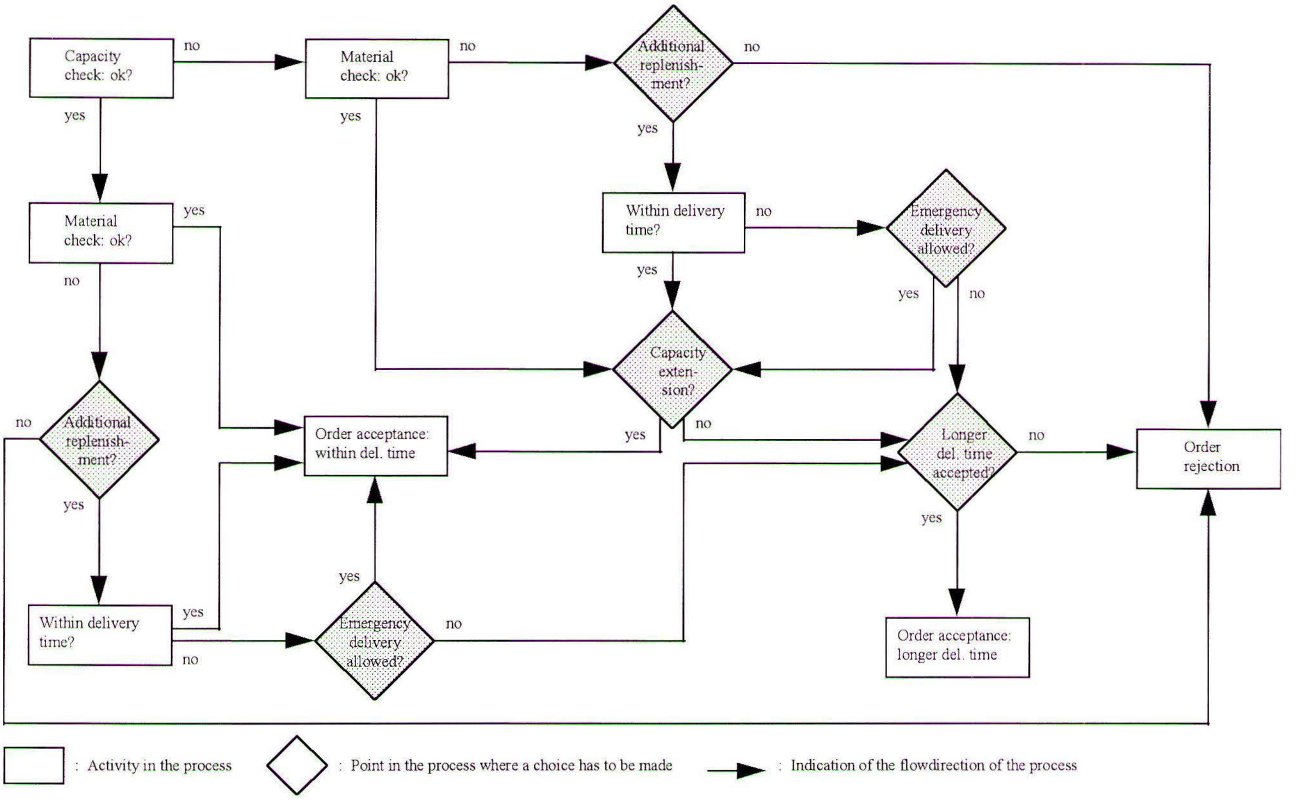


Figure 6.5: Decision diagram for logistics control rules

Concluding can be said that control rules will have to be determined to decide over:

- capacity extensions;
- additionally needed replenishments and;
- allowed emergency deliveries.

Control rules should weigh the customer service advantages and the additional customer service costs of a decision against the costs of capacity extensions, additional replenishments or emergency deliveries.

Trade-off:
Weighing additional throughput costs per product(group) to be dealt with (in production, cross-docking, transport, etc.) versus customer service costs (costs for lower service corrected with cost advantages for better service) subject to all customer service restrictions.

4. Required input

- Detailed design of the geographical infrastructure and one or more alternative designs of the infrastructural flow and infrastructural capacity;
- Dynamic demand patterns (trends, seasonal) per pmc and per facility in the supply chain
- Customer service demands of lead time, reliability, flexibility and quality;
- Customers specified to customer service priority;
- Possibilities for capacity extensions, additional replenishments and emergency deliveries;
- Stock control policy with stock levels
- Replenishment frequencies and batch sizes of product(groups) per facility and per transport connection;
- Percentage of rush orders;
- Fixed periods of transport, replenishment and assembly runs.

5. Output

- Control rules for possible capacity adjustments of facilities and transport connections on the short term;
- Control rules for possible adjustments in the product assortment on the short term considering facilities and transport connections;
- Control rules for possible emergency deliveries;
- Order acceptance rules per facility;
- Rules for delivery time release per facility;
- Lead time, flexibility, reliability and quality performances;
- Cost performances of applicable scenario's or for the final design of the infrastructure.

Overall output: Final design of the logistics infrastructure

Chapter 7: Model Base Specification

Related to this graduation project, the Model Base Specification determines which quantitative techniques are applicable for designing logistics infrastructures. Besides, it determines what logistics functionalities the techniques (which have their application in the form of a software tool) should fulfill. Purpose of this chapter is to provide an insight in those aspects on which a quantitative technique and a software tool might be chosen. It is not by any means, a profound analysis of mathematical models underlying the techniques.
Paragraph 7.1 deals with general types of quantitative techniques to support the design of logistics infrastructures. Optimization, simulation and calculation techniques will be discussed according to their characteristics, advantages and disadvantages [Mittra, 1986; Anderson et al., 1994; Akbay 1996]. Each design stage has certain characteristics due to the decisions to be taken. These characteristics can be linked to the characteristics, advantages and disadvantages of the quantitative techniques. Based on the descriptions in paragraph 7.1, conclusion can be drawn on which technique to use in which design stage. In paragraph 7.2 this will be discussed. Used quantitative techniques have their application in the form of a software tool. To select this software tool, it is necessary to specify the logistics functionalities the tool should have. This will be presented in paragraph 7.3.

7.1 Quantitative techniques

Calculation techniques underlying ETO's:
The Economic Trade Off is a method which supports decision making. It explicates the factors based on which different alternatives will be weighed. The ETO is not the real calculation technique. Underlying the ETO a number of calculation techniques are available [Mittra 1986; Hagdorn, 1996; Mourits, 1995]. These techniques can be classified in three categories:
1. optimization;
2. simulation and;
3. calculation.

Optimization:
In the logistics discipline linear programming[18] is the most widely used optimizing technique. This can be seen while looking at software providers for designing logistics infrastructures [Hagdorn, 1996]. Linear programming offers the possibility to find an optimum over a number of different scenario's. It is a static technique because changes in parameters over time are not included. A number of different categories can be distinguished within linear programming [Anderson et al., 1994]:

- Network flow problems. These problems can be described in a graphical description with nodes and interconnections between them. The network easily shows the close relationship among three types of problems. These three are:
  1. the transportation problem: minimization of costs of shipping goods from origin to destination;
  2. the assignment problem: assignment of items to nodes or interconnections to optimize the objective such as minimum transport costs, minimum time;
  3. the transshipment problem: Objective is to determine the number of items that should be shipped over each arc in the network to satisfy all destination demands against minimal transport costs.

[18] In linear programming a mathematical representation of a real-world situation is described by means of variables, equations, inequalities and an objective function. The objective states that a certain optimum is being sought.

Other network flow problems are the shortest route problem (determination of the shortest route between any pair of nodes in a network against minimal costs) and the minimal spanning tree (using arcs in the network in such a fashion that the total length of all the arcs used is minimal while reaching all nodes).

- Integer linear programming: This is the same as normal linear programming only with the additional functionality that some or all of the decision variables must be integer (on/off). Use of integer variables provides additional modeling flexibility. Result is that the number of practical applications that can be addressed with linear programming is enlarged.
- Dynamic programming is rather an approach to problem solving than it does provide an algorithm. Besides it can only deal with rather small problems. For these reasons this technique is not of interest here.

Advantages of linear programming [Akbay, 1996; Anderson et al., 1994; Mittra, 1986] are:

- It optimizes a certain objective (e.g. costs, customer service) which can be stated explicitly as a function of variables;
- Alternative scenario's are automatically generated, thus scenarios do not have to be developed separately;
- It can deal with a large number of alternative scenario's;
- Constraints can be included easily by incorporating them in equations;
- The optimum answer is provided directly as the outcome. There is no need to analyze the outcomes via statistical calculations.

But linear programming has some serious limitations which the software might not solve [Akbay, 1996; Anderson et al., 1994; Mittra, 1986]:

- It may not be possible to define the system's dynamics in a linear equation form. Besides, some models just cannot be solved by explicit analytical functions;
- It may not be possible to solve the equations or it could take a very long time due to the complexity of the model;
- Models rely on past historical data and assume that past conditions will continue in the future;
- Calculations rely heavily on availability of the right data and of all the data. Availability of data in practice is often a problem;
- The technique forces to make simplifications and assumptions, making it less accurate than simulation;
- Optimization is a deterministic technique. The real world never is deterministic, making optimization again less accurate;
- It has a risk of over-simplifying by making too much assumptions. The trick is to include just the right amount of detail to get what you want in the most efficient way.

Simulation:
Simulation mostly is used when an explicit mathematical model of a system cannot be build [Mittra, 1986]. In simulation a quantitative experimental model of a real world situation is built. Instead of looking for an optimum, the simulation approach evaluates various scenarios with respect to how well they fare on specific performance indicators, in simulation runs of the model. This provides insight in the critical parameters, which will be explored further. Objectives of simulation are to describe a current system, to explore a hypothetical system or to design an improved system. Simulation can be regarded as a systematic trial-and-error approach to solving a problem. It is suited to cope with "what if" questions.

Simulation can be discrete or continuous. Queuing theory provides the mathematical foundation for discrete simulation. Discrete simulation is event driven. The state of the model only changes when events occur. A discrete event is defined as a set of circumstances causing an instantaneous change in one or more system item descriptions (e.g. arrival of an order). In discrete event models, items move through the system. Each time interval, the state of the items running through the system can be described according to their attributes. The time interval between events usually is not equal.
Continuous simulation is time driven. At fixed time intervals, values change based directly on changes in time. These values represent the state of the simulation model. Time between intervals is equal.
Next diagram gives an overview of the differences between continuous and discrete simulation

Issue	Discrete event	Continuous
What flows	Items	Values
Time interval	Event driven	Predetermined

Figure 7.1: Discrete and continuous simulation [Simulation Dynamics Inc., 1996]

By the definition of flows instead of items, continuous simulation operates on a higher aggregate level than discrete simulation. Because of this, it is also easier and faster to build. Continuous simulation does not use capacity restrictions in contrast to discrete simulation, where this is especially important (due to the underlying queuing theory).

Most important reason to use simulation is the ability it provides to deal with stochasticity (events occurring with variable time intervals and in variable volumes). Software tools for simulation in general take this approach as well [Akbay, 1996].
Simulation is per definition dynamic and not static, for the fact that changes in time occur.

The simulation technique has a number of advantages [Akbay, 1996; van der Zee, 1997]:
- It can deal with relatively complex situations that cannot be modeled in Linear Programming. This is because simulation is not limited to the use of linear equations describing system dynamics;
- Building simulation models is becoming easier and also faster due to progress in the Information Technology-branch;
- A high level of accuracy (realistic estimates) in output can be reached through the incorporation of variability;
- Easy evaluation against set performances;
- Once the model is developed it is very useful to experiment with. Sensitivity analysis (checking influences due to alterations in parameters) and what-if questions can easily be incorporated;
- The amount of data needed is limited in comparison to linear programming;
- Insight can be gained in the variables that affect the performances most;
- Effective communication of how the system really works, thus promoting understanding and agreement on it's purpose;
- Feed-back loops can be included (e.g. when lead time exceeds 5 days, increase capacity by 1 unit).

Simulation might not be regarded as a panacea for the disadvantages it has [Akbay, 1996; van der Zee, 1997]:
- Though model building is becoming faster, it remains a time consuming exercition for large projects;
- Simulation output data will have to be analyzed with the help of statistics. When complexity gets high this might become difficult;

- It only compares alternatives instead of generating an optimum solution. An optimal answer can only be found by identifying all alternatives, evaluating each alternative accurately and comparing of each alternative fairly (against the same parameters);
- Definition of alternatives takes a lot of effort, thus the number of alternatives will be limited;
- A relatively high complexity due to stochasticity and statistics which it demands;
- Difficult to determine the right stochastic parameters (e.g. standard deviation, error);
- More difficult to include constraints than in Linear Programming.

Calculation:
Calculation means the use of all kinds of formulas and use of spread sheet calculations. Using calculations, there should be little need to focus on what may happen to the modeled system over time. Thus, its use mostly can be found in a deterministic context. This means that data used, usually are averages or raw data. Simplified optimizations also can be a part of calculations. A technique that fits in this category is that of heuristics[19]. Use of calculations in a stochastic environment is possible via the queuing theory.

Basic advantage of calculations is that it is very quick and easy to use. Besides one can use a lot of own interpretations because calculations are not bounded by the prescriptions of off-the-shelf software [Mittra, 1986]. Thus, in certain stages of the design process for the infrastructure (e.g. in the very beginning or for individual aspects of logistics decisions), making calculations could be a very good option.

Disadvantage is that the use of calculations is limited to relatively small and simple calculations. Complexity increases exponentially with the amount of data needed and the number of variables to include. To deal with this complexity, calculations will become too time consuming or due to simplifications, probably too rough. When dealing with stochasticity, it will almost become impossible to make larger calculations.

7.2 Applicable techniques per design stage

Conclusion from the previous paragraph is that the techniques of optimization, simulation and calculation are all applicable for comparing alternative scenario's. Each design stage has a number of characteristics due to the decisions to be taken. These characteristics were linked at the characteristics, advantages and disadvantages of optimization, simulation and calculation. This paragraph presents which of these techniques is best applicable per design stage.

Applicable techniques in design stage 1: Geographical deployment
The geographical infrastructure typically is a linear programming network problem. It namely is a graphical description, where the facilities represent the nodes and the transport connections the interconnections between the nodes. Especially the transportation problem of linear programming is relevant here. Main cost factors in the transportation problem are those related to shipping goods. This is also what appeared in the Economic Trade Off. Via the use of integer linear programming the facilities can be included and excluded. Use of integer variables is very useful for options like (de)consolidation, cross-docking, assembly (value added logistics) and own account or purchasing of

[19] Heuristics are procedures, based on sound logic, that are designed to yield reasonable, not necessarily mathematically optimal, answers to complex real life problems [Silver et al., 1980: p71].

functionalities. In this manner installation costs (purchasing costs) and variable throughput costs (also of importance in the ETO) can be dealt with.

In this stage an optimum is sought for the geographical organization of the infrastructure. The optimum means lowest costs against required customer service. Thus, the ability to evaluate a great number of alternative designs in linear programming, is very useful in this stage. Lead time requirements can be incorporated by selecting areas for locations of facilities.
Linear programming cannot deal with dynamics and with complexity only to a small level. Thus, the accuracy it provides is limited. In the first design stage however, this is not a problem. In the design prescriptions of chapter 6 has already been stated that data aggregations are used and a number of assumptions will be made for throughput times and cost factors.

The only reason to use simulation in this design stage would be when a profound understanding (e.g. lead time analysis, inventory analysis) has to be gained of a specific part of the geographical infrastructure. Performances can easily be evaluated with the use of simulation. Depending on the application, continuous as well as discrete simulation can both be used.
Calculations could also be useful in this stage for a focus on small aspects. Perhaps to determine where to locate facilities or to make quick calculations of throughput times and lead times. Calculation however cannot deal with the size of the whole quantitative problem in this design stage.

Applicable techniques in design stage 2: Infrastructural flow
The second design stage is directly related to the first stage. Actually, the geographical network is deployed one step further than in the first design stage. These two design stages together are related to all three categories of the network flow problem (see paragraph 7.1). Thus, the transportation problem, the assignment problem and the transshipment problem has to be dealt with.
The reasons mentioned in the first design stage to use linear programming instead of simulation and calculations, basically count for this design stage as well. The number of alternatives even is higher due to the possible flow patterns of products. One design stage further, a higher level of accuracy is also desirable. This means that the linear programming model should include more variables (follows directly from the included assignment and transshipment problem). Additional variables you can think of are: possible assignments of products to facilities or transport connections, additional customer service indicators, definition of product groups with specific cost characteristics. A higher level of detail means that data will have to be available. If this is a problem, now is the time to make it available or to make assumptions on data.

At the end of this design stage the logistics network is quite well developed. The developed concept should be evaluated now. Continuous simulation is useful here. Based on market demand, it is easy and quick to build. The relative high aggregation level it can deal with is desirable in this design stage. Finally, there is no need to include capacity restrictions, which this simulation technique cannot take account of. Conclusion is that use of continuous simulation provides the possibility to fine-tune the developed logistics network some more than can be done with linear programming.
Applications of calculation for ad hoc situations count in this design stage, just as in the first design stage.

Applicable techniques in design stage 3: Infrastructural capacity
In the first two design stages an optimum (related to costs and customer service) was found for the geographical infrastructure in combination with the infrastructural flow. There is no need to develop alternatives anymore. The developed design(s) can now be evaluated on their performances.

In this design stage the capacities needed for the infrastructure will be determined. This means that the dynamics of the real world have to be incorporated (e.g. demand fluctuation, reliability). Fluctuations in demand or a higher delivery reliability for example, ask for more capacity. These dynamics can be incorporated by accounting for stochasticity. This makes a big difference in comparance with linear programming, where the performances resulted from a static situation. Concluding, performances of the infrastructure will be evaluated on the basis of fluctuating capacities in the infrastructure. When performances are not satisfying, a higher capacity might improve them. With the use of trial and error, the right amount of capacity can be determined. Via the "what-if" method scenarios can be evaluated on sensitivities of certain parameters, such as other demand patterns or different transport costs. The possibility to adjust the simulation model until a desirable output (related to the customer service- or cost level) is reached can be provided by including feed-back loops.
Discrete simulation is the best applicable technique in design stage 3 due to: the needed dynamics, stochasticity, (thus a higher accuracy), the trial and error approach and the incorporation of capacity restrictions. Other reasons to use simulation in this stage are some important applications it has, like: detailed lead time analysis, inventory analysis and determination of needed capacities [Mourits, 1995; de Leeuw, 1996].

Determination of stock control policy is a strange one in this design stage. To choose a stock control policy a number of parameters have to be set (see appendix 12). In principle, these parameters will follow from individual calculations. After this, simulation will be used to evaluate the performances due to the chosen stock control policy.

Applicable techniques in design stage 4: Detailed geographical deployment of the infrastructure
In the ETO of design stage 4 can be seen that the problem is of a linear programming type. Here, optimal locations are sought related to optimal routing costs. This typically is a network flow problem but at a very detailed level in contrast with the network problem in the first two design stages. The shortest route problem and minimal spanning tree also might have their application here.
Again a lot of alternatives have to be weighed against each other, making linear programming applicable instead of simulation.
When the exact routes are known, performances might be evaluated using simulation. This is kind of the same as you would do in design stage 3, only on a small scale.

Applicable techniques in design stage 5: Infrastructural control rules
Control rules will have to be determined to decide over: capacity extensions, additionally needed replenishments and allowed emergency deliveries. Using simulation, the effects of such decisions can easily be evaluated by asking what-if questions. Doing this should result in realized cost performances and customer service performances. The decision diagram of paragraph 6.7 can be translated in a simulation model. Of course, the characteristics of simulation like a high level of detail and accuracy and the possibility to account for stochasticity are important. It is important that the real life situation is reflected as much as possible when dealing with customers.

7.3 Functional requirements for the software selection

The functional requirements are a logical result of the way that logistics should be dealt with, according to the chapters 5 and 6. The functional requirements were stated with the idea that a linear programming and simulation tool will be used. These appeared to be most applicable. General characteristics of linear programming (e.g. dealing with network problems, the integer variant) and simulation (e.g. accounting for fluctuating demand, performance outputs such as stock levels or utilization degrees) will not be included as functional requirements.

General requirements for both linear programming and simulation:
A facility, located at one geographic position in the infrastructure, can incorporate one or more functionalities (e.g. production and stock holding). These functionalities have different characteristics.
Requirement 1: Within a facility, it should be possible to define more than one functionality with it's specific characteristics.

Each transport connection is unique and can be characterized by a number of aspects like: transport time, transport frequency and transport batch size.
Requirement 2: It should be possible to define each individual transport connection according to it's characteristics.

Choices will be made to allocate products to functionalities and to transport connections. This also determines the flow of products through the logistics network.
Requirement 3: It should be possible to define the assortment of products to be dealt with at a functionality or on a transport connection.

Designs have to be developed within the overall objective of "balancing customer service against the cost levels". Each customer service performance indicator (lead time, reliability, flexibility and quality) can be included by making it operational (e.g. lead time per order, % of orders delivered on time, % of orders with special demands delivered on time). The total cost can be split in individual cost factors like investments, fixed throughput costs and variable throughput cost.
Requirement 4: It should be possible to include operational performance indicators and costs specified to individual cost factors.

Developed designs have to be evaluated against their realized customer service performances and realized cost levels.
Requirement 5: It should be possible to evaluate conceptual designs against operational performance indicators and costs specified to individual cost factors.

It could very well be that cost levels for same functionalities differ per facility location (e.g. labor costs, border crossing costs, investment, etc.).
Requirement 6: It should be possible to specify cost factors for each facility individually.

Though a range of products flows over a facility or transport link, each product has it's individual characteristics. As a result cost levels or customer service for individual products will probably be different. For example, this can be due to different handling times or higher cycle stock levels.
Requirement 7: It should be possible to specify cost factors per individual product in each facility.

Data aggregation always will be done based on certain characteristics. Customer demand can be aggregated to product types or to geographical markets. Products can be aggregated into product groups, for example: based on value added activities or transport on the same modality.
Besides this type of data aggregation, aggregation can also be done over time.
Requirement 8: It should be possible to give elements (such as products or customers) attributes based on which they automatically can be aggregated. Aggregation should be possible based on attributes but also based on time.

When data aggregation will take place, new cost factors will arise for the aggregated product type. Often, such cost factors can be calculated with the use of certain mathematical functions. Other reasons to include mathematical functions for example are: to calculate stock costs (based on interest rates, product value and throughput times) or to calculate transport costs for individual shipments within consolidated shipments.

Requirement 9: It should be possible to include mathematical functions to make necessary calculations.

Chapter 8: Conclusions and Recommendations

In this chapter the conclusions and recommendations of this graduation project are presented. Purpose of the conclusions is to give answer to the objective and phrasings, which were presented in chapter 4. The recommendations firstly discuss suggestions for further research. Secondly it discusses some other courses of action, which are important with relevance to the graduation project.

8.1 Conclusions

The phrasing of the second part of the graduation project consists of three parts:
1. Logistics Decisions (chapter 5);
2. Solution Structure (chapter 6);
3. Model Base Specification (chapter 7).

The conclusions related to these three parts will be discussed in the same order as the phrasing was presented. Finally, conclusions related to the objective will be presented.

8.1.1 Conclusions related to the Logistics Decisions

The logistics infrastructure consists of the logistics network and logistics control. Logistics decisions directly relate to this network and control. In total ***a range of 21 decisions*** have been identified. All these decisions have to be taken in designing logistics infrastructures.

The range of ***decisions relate to each other*** in a number of different ways. First of all, the overall objective for designing logistics infrastructures provides for a long term focus for all decisions. The overall objective clarifies the importance to balance customer service and costs, to maximize profits on the long run.
Secondly, logistics decisions are related to each other because they are seen as sub-problems of the overall problem. The overall problem is defined as "designing logistics infrastructures". The sub-problems (logistics decisions) themselves are also related to each other. This is expressed via a classification according to three aspects:
1. the elements; location-allocation, transport, stock and order processing;
2. logistics network and logistics control;
3. different design stages in the overall design process for logistics infrastructures.

Logistics decisions can be taken in a certain hierarchical order. This hierarchy expresses itself in the way that logistics decisions are placed in succeeding design stages. The range of design stages together forms the whole design process for logistics infrastructures.
Logistics decisions which relatively influence a lot of other decisions are placed at the beginning of the design process. This, in contrast to decisions which relatively are influenced by a lot of other decisions. These are placed at the end of the design process. A lot of decisions appeared to have close interrelationships, making it impossible to place them in a hierarchical order (thus in different design stages). For this reason, logistics decisions were clustered in the design stages.
The design process consists of five design stages, being:
1. Geographical deployment of the infrastructure;
2. Infrastructural flow;
3. Infrastructural capacity;
4. Detailed geographical deployment of the infrastructure;

5. Infrastructural control rules.

In the conclusions of chapter 3 already was mentioned that the iterative approach (making design loops) to designing is very useful. The iterative approach makes it possible to ***make logistics decisions in an integrated manner***.
In a number of different ways, the iterative approach was dealt with. Firstly, in each design stage, a part of the logistics network and a part of logistics control will be designed. This is in harmony with the second aspect of the classification of logistics decisions (see above). Thus, the logistics network and logistics control are developed in an integrated and stepwise fashion.
Secondly, each design stage itself will pass through a number of design loops until one or more satisfying designs are reached. Closely interrelated logistics decisions already will be taken in an integrated manner because they fall in one design stage. Next, they will be fine-tuned to each other by going through design loops.
Thirdly, iterations also can take place between different design stages which provides for an integrated approach over all logistics decisions. Only when a next part of the infrastructure is designed, the value of what was already designed may become clear. In this matter, it has to be possible to alterate designs from a previous stage.

Quantification of logistics decisions can be done with the use of Economic Trade Off's. Just as in the overall objective, this technique provides the possibility to weigh alternative designs on the basis of costs and customer service.

8.1.2 Conclusions related to the Problem Structure

Qualitative data have an overweighing importance in taking logistics decisions. A quantitative approach towards designing logistics infrastructures is bounded by these qualitative aspects. Hence, the qualitative aspects are considered as the ***constraints for taking logistics decisions***. The constraints were classified in three groups: 1. Restricted possibilities of the client to develop their infrastructure; 2. Design freedom which the client allows; 3. External. These three groups together determine the solution space in which all logistics decisions have to be taken.

Each design stage has a solutions structure, which consists of 5 elements:
1. Logistics decisions;
2. Design prescriptions;
3. Economic Trade Off's;
4. Required input;
5. Output.

The ***choices that had to be made to be able to make logistics decisions*** are specified by the Design Prescriptions and the ETO's.
In the Design Prescriptions a range of choices were made. One of the most important choices was how to deal with customer service. Customer service can be taken care of via the performance indicators of delivery time, reliability, flexibility and quality. Each performance indicator is influenced by certain logistics decisions, hence they can be dealt with in different design stages. Result was that the lead time and the fill rate aspect of reliability, will be dealt with from design stage 1 onwards. In design stage 2, mix-flexibility will be included. In design stage 3, the standard deviation aspect of reliability and volume flexibility will be included. And finally, in design stage 5 quality will be dealt with.

Another important choice was: what cost factors should be considered for the logistics decisions. In each design stage different cost factors were applied for the ETO's. Main distinctions were:
1. that the first design stage considers installation costs of logistics functionalities;
2. that the second design stage is focused on variable throughput costs as a result of combinations in product flows through the supply chain;
3. that the third design stage is related to the balance between throughput costs of capacity types, handling and inventory costs versus transport costs;
4. that the fourth design stage basically considers the location of facilities based on purchasing- and routing costs;
5. and that in the fifth design stage different control rules are weighed on the basis of additional throughput costs versus customer service costs.

Some other, smaller choices to be able to make logistics decisions, were: decreasing data aggregations further in the design process, designs are bounded by aspects from previous design stages and are not bounded by aspects of designs yet to be made.

The ***data which are necessary to make logistics*** decisions are specified in the needed input for every design stage.

In the phrasing of the solution structure was not mentioned what should be the output of each logistics decision. Logically, each logistics decision has a number of deliverables. ***Additionally*** to the phrasing, the deliverables of all logistics decisions in one design stage are specified in the output of that design stage.

8.1.3 Conclusions related to the Model Base Specification

The ***types of quantitative techniques*** that can support designing logistics infrastructures can be classified in three categories:
1. optimization;
2. simulation (discrete and continuous);
3. calculation.

These technique have certain characteristics, advantages and disadvantages. Based on these, the techniques can be distinguished in their possible application.

Each design stage has certain characteristics due to the logistics decisions to be taken. These characteristics were linked to the characteristics, advantages and disadvantages of the quantitative techniques. This resulted in ***applicable techniques per design stage***.
The first two design stages typically represent a network flow problem. A cost optimum is sought for a great number of geographical alternatives. At this point in the design process the needed level of accuracy and detail is limited. Linear programming (and it's integer variant), thus, is the most applicable technique in this design stage. At the end of the second design stage, the logistics network is quite well developed. Continuous simulation provides the possibility to fine-tune the developed concept in a an easy and quick manner.
In the third design stage discrete simulation is the applicable technique. Infrastructural capacity namely can only be calculated when the dynamics of the real world are incorporated. Using discrete simulation the developed concept will be evaluated on it's cost and customer service performances.
In the fourth design stage, again a typical network problem appears, basically related to the routing problem. Thus, linear programming again is applicable here.
In the last design stage effects of decisions on control rules have to be evaluated. With discrete simulation, such effects can easily be evaluated by asking what-if questions.

Use of calculations is to be seen as ad-hoc support for mathematical functions or via spread-sheets.

How a ***sensitivity analysis*** could be made, has not been investigated for two reasons. First reason is that it is just a study of how changes in the coefficients of variables in a model, affect the solution. Linear programming tools as well as simulation tools in general have this ability.
With sensitivity analysis, the most influencing variables for a model can be determined. However, such factors are client specific, thus sensitivity analysis always is client specific. This was the second reason to exclude the sensitivity analysis in the graduation project.

For the selection of software tools a list of 9 ***functional logistics requirements*** appeared. These requirements are especially meant for the selection of a linear programming tool and a simulation tool.

8.1.4 Conclusions related to the objective

The objective of the graduation project was: "Being able to engineer logistics infrastructures, based on quantitative reasoning and in a sound, coherent and explicit way". Conclusions will be presented for each separate aspect of the objective.
Engineering logistics infrastructures can be done with the developed concept. This concept means that logistics infrastructures will be designed by taking a number of different logistics decisions. Closely interrelated decisions will be taken together in a same design stage. Decisions in different design stages have a certain order dependency with each other. In total there are five design stages. These should be passed in a sequential order and in an iterative manner. A design stage will be ended when the developed concept has been ***quantified*** and it's cost performance and customer service performances were satisfying. For the quantification most applicable techniques are linear programming and simulation. Each design stage is designated a specific technique.

Designing logistics infrastructures according to the discussed concept is ***sound*** for the fact that on an infrastructural level all possible decisions are incorporated, not only those decisions related to the logistics network but also those related to logistics control. Furthermore, through the iterative approach it is possible to make multiple adjustments to each aspect of the design until a feasible one is reached.

Designing logistics infrastructures according to the concept, will be done in a ***coherent*** way because all interrelationships between logistics decisions are considered. Closely interrelated decisions are taken together and order dependency in decision expresses itself in different design stages. Quantitative techniques very clearly appeared to be applicable in a design stage, which proved the coherence in decisions.
The overall objective of designing logistics infrastructures is something that also contributed to a coherent approach. This objective makes sure that the focus for all logistics decisions is the same. Finally, the infrastructure consists of the logistics network and logistics control. Designing these two aspects parallel to each other, makes the infrastructure coherent.

Designing logistics infrastructures is also done in an ***explicit*** manner. A number of aspects have contributed to making it explicit, some of which are

- the Consultancy Design Process with all it's characteristics, which has given a certain structure to the design process for logistics infrastructures;
- the way in which the design process is related to the Customer Approach Methodology;
- the developed concept to design logistics infrastructures, which has three aspects: logistics decisions, solution structures and a model base specification;

- other aspects of the developed concept like: the overall objective, the presented definitions (of logistics infrastructure, logistics network and logistics control), the iterative approach, etc.

Most important is that all developed aspects are very well communicable to outsiders of the Engineering department. This in specific makes the design process explicit.

8.2 Recommendations

Case study:
Most important recommendation is to test the developed concept in a case study. Hopefully, this is a client of the Business Unit. Otherwise an external test case should be developed. Advantage of a self developed case is that there might be no restrictions related to the client and that the design freedom is not limited. Preference however goes to a case study related to a real client. Such a study always is more representative and the practical implications guarantee a future concept that is more valid.

To run a potential test case, software tools have to be applied. The in-house Extend-tool can be applied for simulation. A recommended tool to use for linear programming is the "Supply chain designer" of Caps Logistics. According to Koeman [1996] this software tool appeared to be the most appropriate for designing logistics infrastructures.

Designing versus redesigning:
A big difference between the developed concept and the engineering job for real clients is designing and redesigning. The developed concept is directly applicable for a designing situation. The Initial Assessment and Expanded Assessment will run parallel to the design process.
Most of the time however, a redesign has to be made. In the ILA something will be redesigned with a lot of improvement potential. This can be anything of the logistics infrastructure. In principle, the design process was constructed to go through in a sequential order. Thus, an important recommendation for the ELA is to return to the beginning of the design process.

Concept at a tactical level:
When the developed concept for designing logistics infrastructures has been tested and proven right an identical concept could be developed at a lower abstraction level. At a tactical level, one could also consider what logistics decisions should be taken, with what kind of solution structure, etc.
It is difficult to develop a concept without practical reflection. Besides developing a concept in a parallel with a practical reflection is more efficient for the interaction it provides. Thus it is highly recommended to develop the concept at a tactical level in a case study.

Software selection:
When the developed concept has been proven right according to the used quantitative techniques, a profound software selection can be done. The functional requirements in this matter, are one of the selection criteria. In test cases for the infrastructural concept, potential software tools could be tested as well. A procedure that might be followed for selection of software tools is the following:

- determination of requirements: functional-, system-, technical- and financial requirements;
- scanning of tools available in the market;
- first selection and based on a critical specification a shortlist can be made;
- feasibility study meaning that the performances in relation to the functional specification of the selected tools are considered. This has to be based on a practical application. A final selection can be made;

- Implementation of the tool that was chosen.

When tools might not suffice the requirements one should consider the option to incorporate an engineer with a quantitative background. Such an engineer should be able to develop complicated quantitative models.

Decision Support System:
In conjunction with the development of the Model Base (with quantitative tools), the Data Base can be developed as well (development of a data base was already recommended in chapter 3). Together they form a Decision Support System. Main advantage of a parallel development is that mutual requirements can be coordinated.

Communication:
One of the purposes of this graduation project to make engineering explicit. The means to make it explicit have been provided. Now, it has to be communicated.
For the benefit of communication outside the Engineering Department, a recommendation is to include the developed concept in the Department Descriptions and the Customer Approach Methodology (CAM). The parts of main interest are, the logistics decisions, the way they are designated to the five design stages and the iterative approach to designing.
As the CAM will be addressed for each project, communication of the concept to outsiders of the Engineering Department will happen automatically. Though it is wise to communicate the new concept one time to the whole Business Unit.

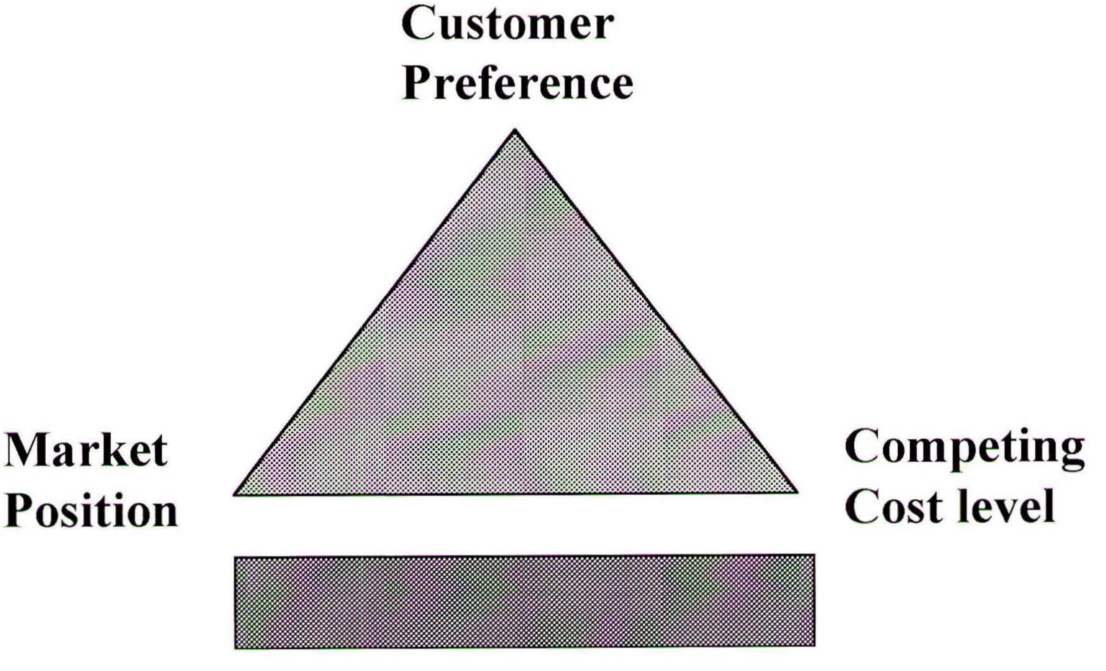
References and Sources

- Akbay, K.S., Using Simulation Optimization to find the Best Solution, *IIE Solutions*, may, 1996
- Anderson, D.R., Sweeney, D.J., Thomas, A., *An Introduction to Management Science, Quantitative Approaches to Decision Making*, 1994, Minneapolis/St. Paul: West Publishing Company
- Archer, L.B., *Design Awareness and planned creativity in industry*, 1974.
- Bakker, C.G., Goor, van, A.R., Houten, van, J.W.M., *Logistiek/Goederenstroombesturing*, 1991, Leiden: Stenfert Kroese
- Ballou, R.H., *Logistiek Management*, 1992, Schoenhoven: Academic Service
- Berenschot, Logistieke automatisering, Overdruk van drie artikelen uit het tijdschrift voor Inkoop en Logistiek, November 1996
- Bertrand, J.W.M., Wortmann, J.C., Wijngaard, J, *Produktiebeheersing en material management*, 1992, Leiden: Stenfert Kroese
- Brassard, M, Ritter, D, *The Memory Jogger II, A pocket Guide of Tools for Continuous Improvement & Effective Planning*, 1994, Methuen: Goal/QPC
- Business Unit Logistics Guidelines, Confidential internal report
- Cross, N., *Engineering Design methods*, 1989, Chisester: Wiley
- Department description, Confidential internal report
- Doremalen, van, J.B.M., Alternatieve Distributie Infrastructuren, Loose-leaf publication of the *Center for Quantifiable Methods CQM B.V.*, Eindhoven, 1997
- Eindhoven University of Technology: Industrial Engineering and Management Science, *Het Afstudeerproject*, 1997
- Findhammer, M., *Special Assignment: Recommended Consultancy Design Process for Business Unit Logistics*, 1997.
- Fleuren. H.A., den Hertog, D., *Uw ideale fysieke distributiestructuur bepalen? Hoe kwantitatieve analyze u kan helpen?*, Handboek Logistiek, 1997: C1100-1 t/m C1100-13, Alphen aan de Rijn: Samsom
- Funding Proposal Business Unit Logistics, Confidential internal report
- Goor, van, A.R., , Ploos van Amstel, M.J. en Ploos van Amstel, W., *Fysieke distributie, denken in toegevoegde waarde*, 1994, Houten: Stenfert Kroese
- Gundy, van, A.B., *Techniques of structured Problem Solving*, 1988, New York: Van Nostrand Reinhold
- Hagdorn-van der Meijden, L., *Decision Support for Strategic Planning in Logistics*, 1996, Rotterdam: Rotterdam Erasmus University
- *Handboek Logistiek*, March, 1989: pC0100-6 t/m C0100-11, Alphen aan de Rijn: Samsom
- Jones, J.C., *A method of systematic design*, 1984, Chisester: Wiley
- Kempen, P.M., Keizer, J.A., *Werkboek Advieskunde, De stagepraktijk als uitdaging*, 1996, Groningen: Wolters-Noordhoff
- Koeman, E.P., *Selectie van een softwarepekket voor het ontwerpen van distributienetwerken*, 1997, Eindhoven: Eindhoven University of Technology
- Kotler, P, *Marketing Management, Analysis, Planning, Implementation and Control*, 1994, Englewood Cliffs: Prentice Hall International
- Mittra, S.S., *Decision Support Systems, tools and techniques*, 1986, Chisester: Wiley-Interscience
- NEVEM-werkgroep, *Prestatie indicatoren in de logistiek*, 1989, Deventer: Kluwer Bedrijfs wetenschappen

- Pahl, G. & Beitz, W., *Konstruktionslehre, Handbuch fur Studium und Praxis*, 1984, Berlin: Springer
- PBNA, Koninlijke, red. van Goor, van A.R., Monhemius, W, Wortman, J.C., *Polylogistiek zakboekje*, 1993, Arnhem: PBNA
- Peelen, E., Goor, van, A.R., *Customer service als uitgangspunt voor distributiebeleid*, 1991, Leiden: Stenfert Kroese
- Roozenburg, N.F.M. & Eekels, J., *Produktontwerpen, struktuur en methoden*, 1991, Utrecht: Lemma
- VDI 2221, *Methodik zum Entwickeln und Konstruiern technischer Systeme und Produkte*, 1986, Berlin: Beuth Verlag
- Ven, van de, A.D.M., *Internationale Produktie en Logistiek*, 1992, Eindhoven: Eindhoven University of Technology
- Verschuren, P.J.M., *De probleemstelling voor een onderzoek*, 1994: p21, 32-33, Utrecht: Spectrum
- Weegen, van der, E., *Logistieke Besturing van Fysieke Distributie, samen werken aan logistieke samenwerking*, 1989, Eindhoven: Eindhoven University of Technology
- Zee, van der, D.J., *Simulation as a tool for logistics management*, 1997, Enschede: Universiteit Twente

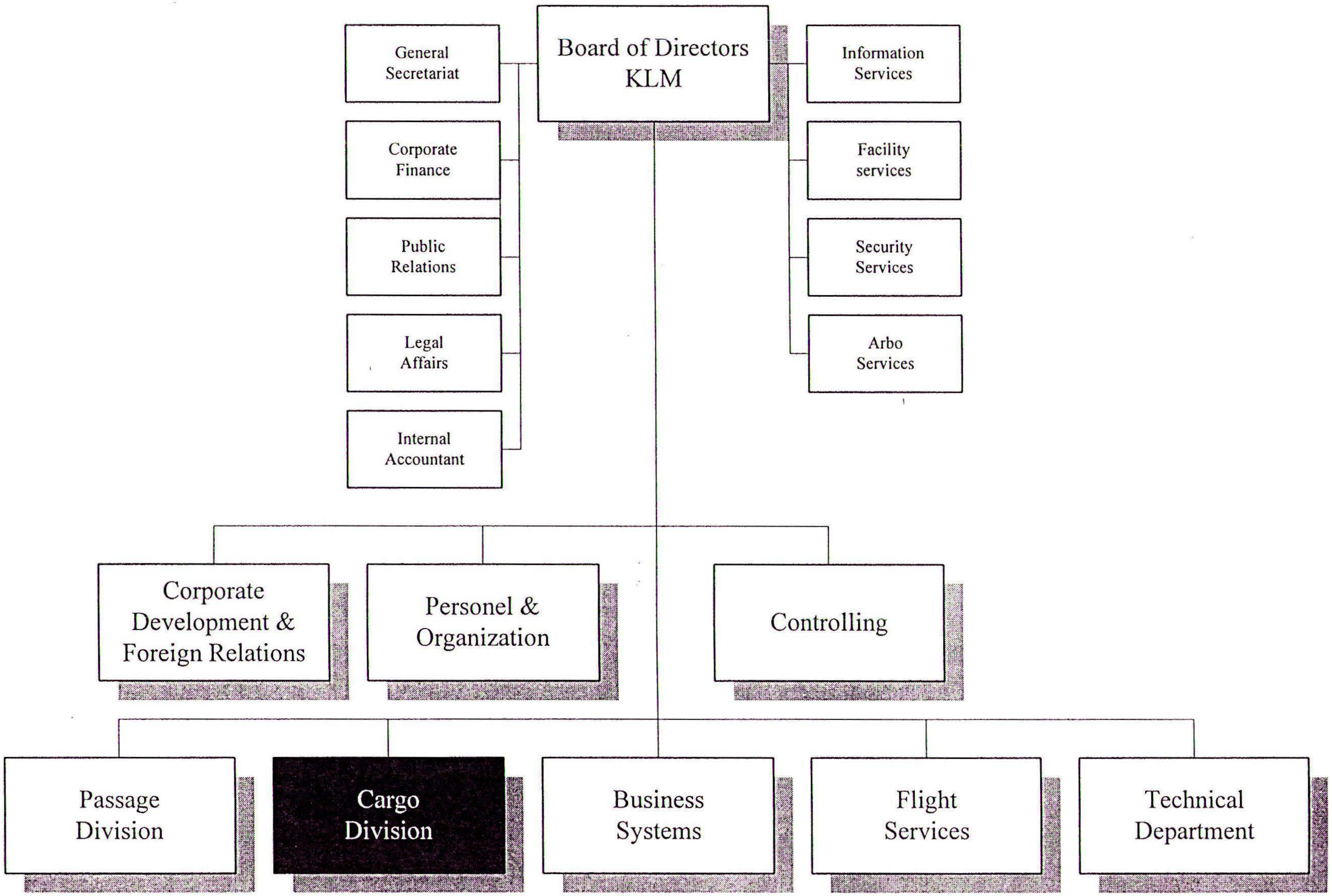
Appendices

Appendix 1: Cornerstones of KLM Policy

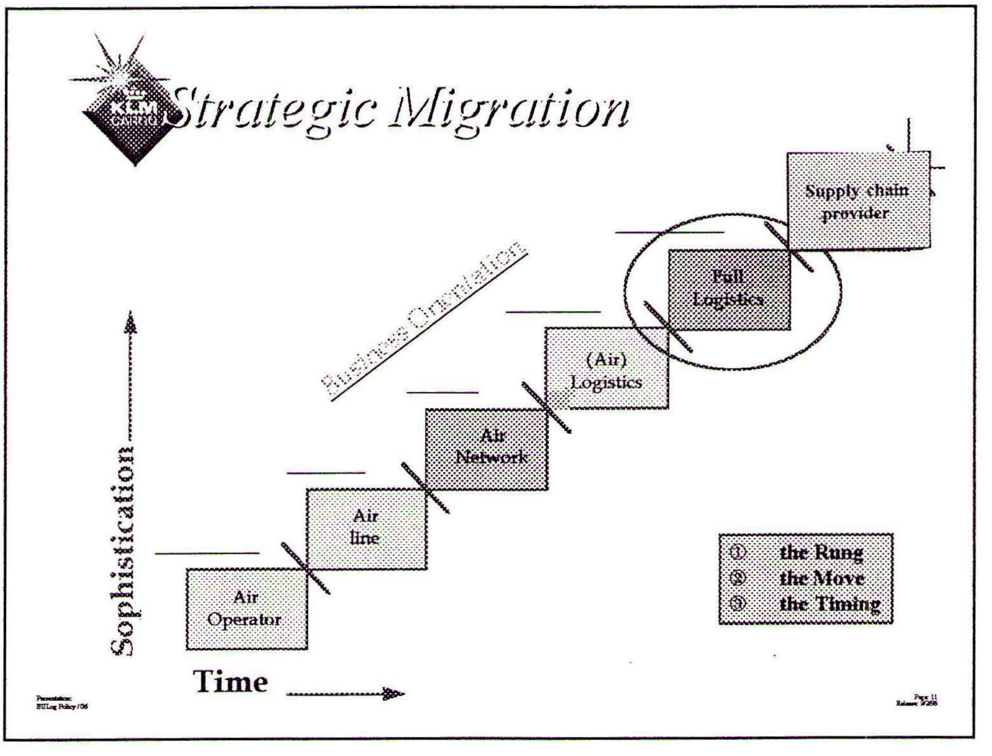


Source: Annual report KLM 1996/97

Appendix 2: Organization structure KLM

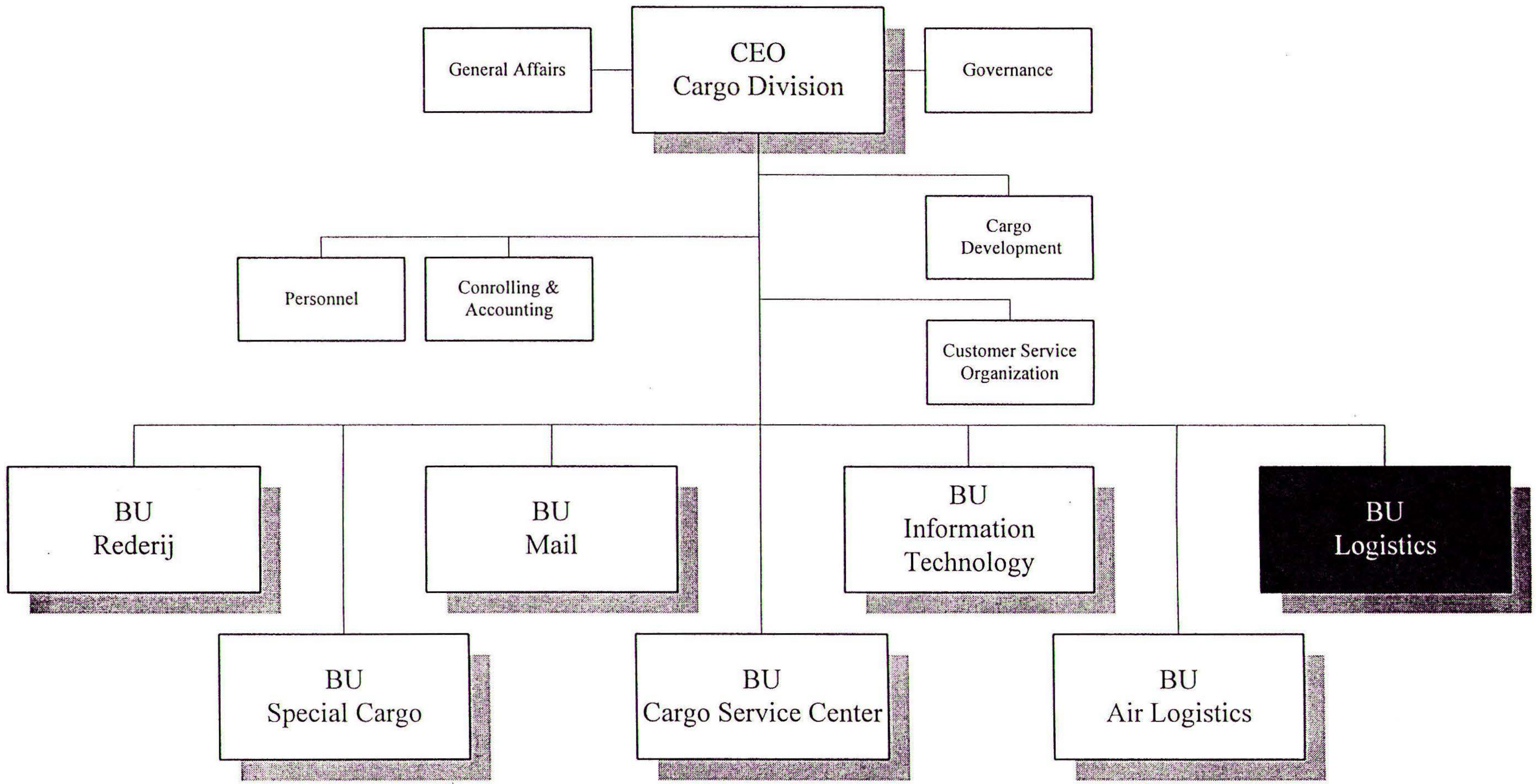


Appendix 3: Migration Ladder

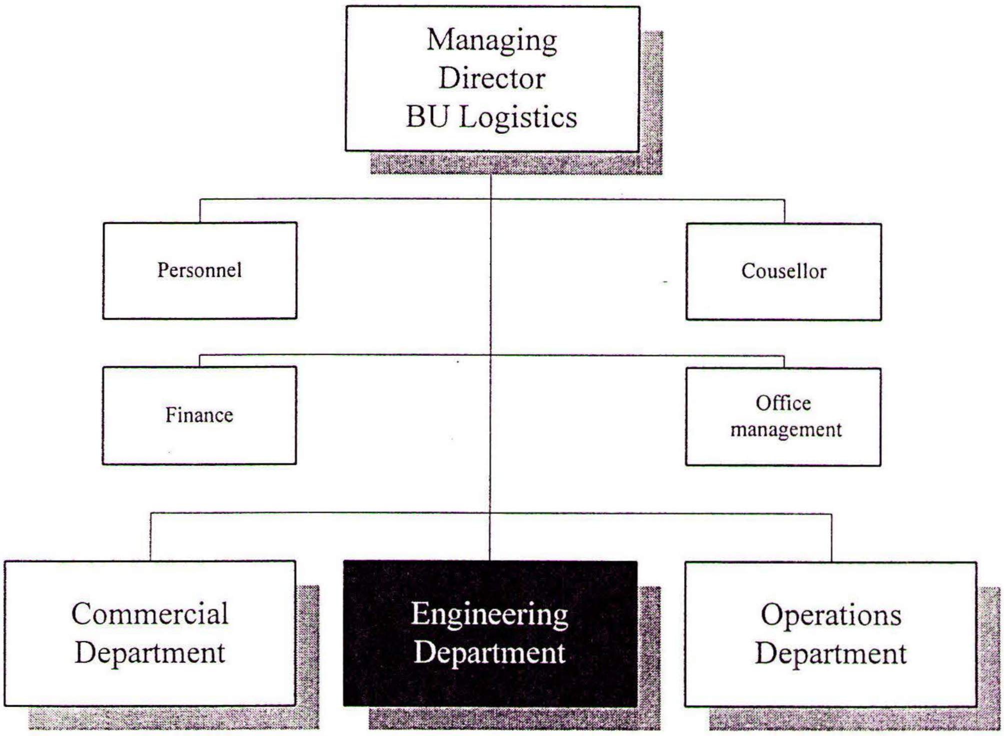


Strategic Development Department [B. Grin]

Appendix 4: Organization structure KLM-Cargo



Appendix 5: Organization structure Business Unit Logistics (BULog)



Appendix 6: Customer Approach Methodology (CAM)

Only the relevant parts of the CAM, related to this graduation project, are included. These parts are: Desk Research, Initial Logistics Assessment (ILA) and Expanded Logistics Assessment (ELA).

DESK RESEARCH (DR)

Step 1.1 Detail desired information to research unit such as social, market, competitive, financial, future status of Contact.

Step 1.2 Obtain desired information from sources : KLM Cargo, Library, D&B, Industry Publications, Professional Publications, Government Publications.

Step 1.3 Extract only relevant information based on criteria established in step 1.1

Step 1.4 Compile and complete DR report and submit to Account Manager (AM).

OBJECTIVE(S)

Using DR report, be able to perform reasonably accurate assessment of Contact in order to determine level of interest for BULog to initiate contact based on a) Contact's status as an industry/market emerging leader b) Contact's rate of market share growth, global penetration over past 2 financial exercises c) Contact's financial health particularly regarding consistent healthy performance of PROFITS, ROCE and CASH POSITION, while keeping in mind the potential of the Contact for our logistics concepts.

REQUIRED STAFF/TOOLS

- AM and research staff
- reliable sources of information
- Contact DR File, permitting up to maximum 3 pages of information, condensed and limited to only information relevant to permitting accurate assessment (perhaps simple, user friendly question/answer form easily completed by any person capable of using computer)

TIME

- Should be completed in one week

FINANCIAL

- BULog investment
- Track resource cost

INITIAL LOGISTICS ASSESSMENT (ILA)

Step 4.1	Agree with Prospect on nature, extent, detail of information required by BULog that must be provided by Prospect.
Step 4.2	Agree with Prospect on key internal resources, persons required to perform the **ILA** and arrange interviews.
Step 4.3	Conduct introductory project meeting including all parties involved and present project goals, steps, methods, tools and resources required. Give clear guidance to respective input and commitments required for successful completion of project. Ensure appropriate distribution of tasks with individual goals. Provide detailed time planning required to accomplish project.
Step 4.4	Conduct interviews with all key persons; research all available internal sources.
Step 4.5	Extract and compile information into separate report.
Step 4.6	Ensure step by step accomplishment of individual and collective goals and sticking to timeframe.
Step 4.7	Monitor progress and report regularly to project team and to Prospect through to conclusion.
Step 4.8	Provide qualitative model to Prospect.
Step 4.9	Comparative study with DR report.
Step 4.10	Draw BULog assumptions on level of interest in going on with qualification based on relevant data extracted during **ILA**. Preliminary BULog assumptions should focus on adding value by improved performance in financial results, internal efficiencies, market share, market penetration.
Step 4.11	Prepare presentation to Prospect outlining BULog assumptions and focus of attention, subsequent steps, level of BULog/Prospect involvement, desired resources and 3rd party involvement. Respective, potential preliminary expectations and commitments must be discussed/exposed at this time.

OBJECTIVE(S)

Confirm initial findings of DR. Complete desired information if missing during DR. Assist Prospect to identify strengths and weaknesses in its logistics infrastructure. Estimate improvement potential. For BULog, to gain an in-depth understanding of Prospect's business (strategy, company drivers, critical success factors) Draw preliminary assumptions permitting decision by BULog to continue or not based on qualification and quantification of key success factors required to identify change ready Prospect and key areas of activity where BULog believes it can be instrumental in value added. Elaborate preliminary proposal on BULog remuneration based on (depending on BULog level of confidence in long-term value added potential), either short term consultancy approach or more risk taking, long term proof of quantifiable value added.

REQUIRED STAFF/TOOLS

- PM, AM and Engineering staff
- Prospect staff
- financial analysis resources
- organisational analysis resources
- qualitative model needs Excel; Extend; Distom
- questionnaires

TIME

- depending on complexity of processes and capabilities to be examined - up to one week; throughput time : 4 weeks

FINANCIAL

- BULog investment
- track resource costs
- presuming use of simulation process, discuss and establish reward for BULog in case of either gain for customer and/or potential business as usual gain for KLM

EXPANDED LOGISTICS ASSESSMENT (ELA)

Step 6.1	Obtain CPI contract from Prospect and agree to composition of project team including 3rd parties, if appropriate, for conducting this part of the Project. Agree with Prospect on overall project objectives, timeframe, tools, methods, resources and monitoring methods required to successfully complete **ELA**. Agree on respective levels of involvement and commitment required in order to investigate and extract sufficient pertinent information in order to provide useful conclusions from **ELA**. Agree on estimated value/cost(s) of **ELA.**
Step 6.2	Conduct introductory project meeting including all parties involved in **ELA** and present project goals, steps, methods, tools and resources required. Give clear guidance to respective input and commitments required for successful completion of project. Provide detailed time planning required to accomplish project.
Step 6.3	Ensure appropriate assigning and distribution of tasks with individual goals. Introduce appropriate work methods, concepts and software tools as required. Agree on code of conduct required for efficient team communications.
Step 6.4	Monitor progress, provide regular progress reports and propose appropriate adjustments to original project approach, if/when required, to the project team and to Prospect through to conclusion.
Step 6.5	Conclude **ELA** with joint preparation of **ELA** report according to all relevant information extracted during **ELA** process.
Step 6.6	Report should include a clear and quantifiable conclusion that joint BULog/Prospect project has provided implementable solutions that once activated will translate into improved performance by Prospect. It should also include a clear and quantifiable conclusion that BULog has produced value added and that there is a clear feasibility study of implementation. In addition it should state a proposal on how to proceed with BULog/Prospect relationship and a clear indication of profitability for BULog.

OBJECTIVE(S)

To assess Prospect's current logistics performance. To help Prospect identify strengths and weaknesses in its logistics processes. To establish a plan for pursuing improvement opportunities. To confirm BULog's preliminary assumptions that areas of focus are in need and/or could be the subject of quantifiable performance improvement by moving to (re)design. In addition, BULog can gain an in-depth understanding of the Prospect's logistics processes in order to be able to -now and in the future- tailor BULog's products exactly to the Prospect's needs. To have a base measurement against which to evaluate the improvements realised through a (re)design project.

REQUIRED STAFF/TOOL(S)

- PM, AM and Engineering staff
- auditing experts (own or 3rd party)
- Prospect's staff
- auditing software and information management
- qualitative model needs Excel; Extend; Distom
- questionaires

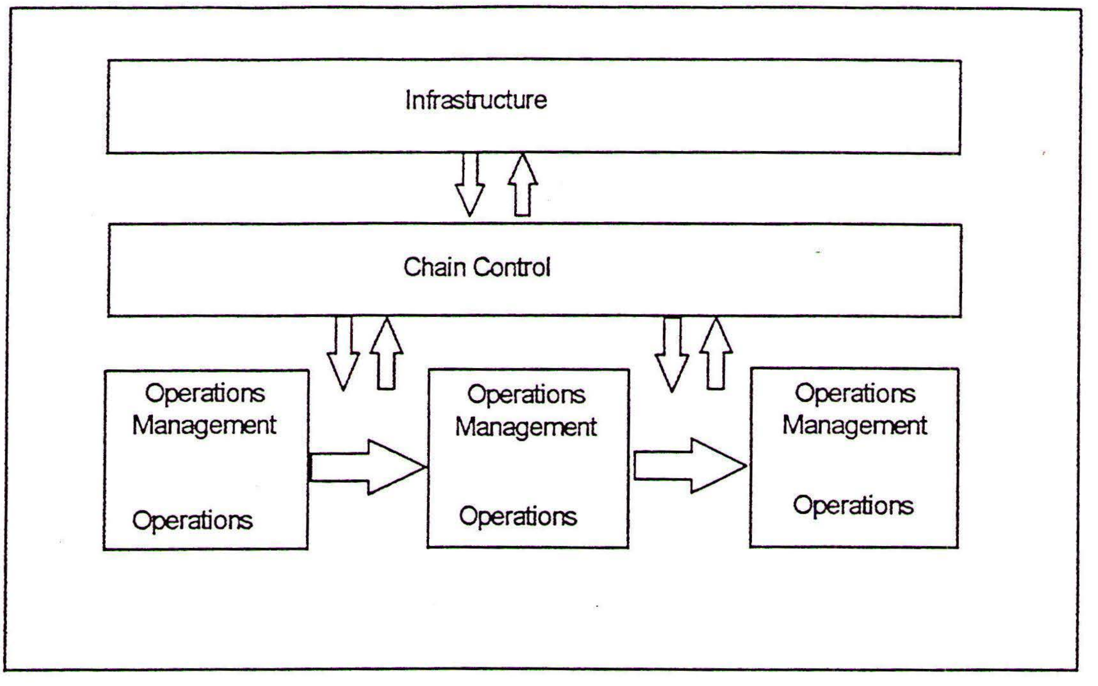
TIME

- depending on complexity of project, size of company, scope of activities to be examined - up to five weeks; throughput time : 4 months

FINANCIAL

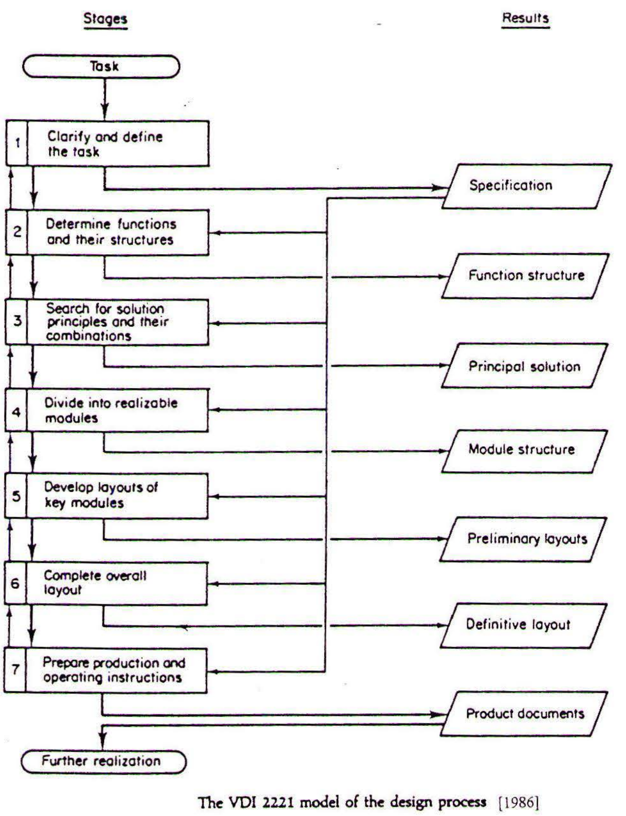
- track costs
- assesses potential for BULog in continued involvement with customer and, depending on nature of involvement, decide between application of agreement established in CPI or waiving agreement and proceeding based on business proposition offering more interesting and sustainable reward for BULog.

Appendix 7: Logistics Control Model

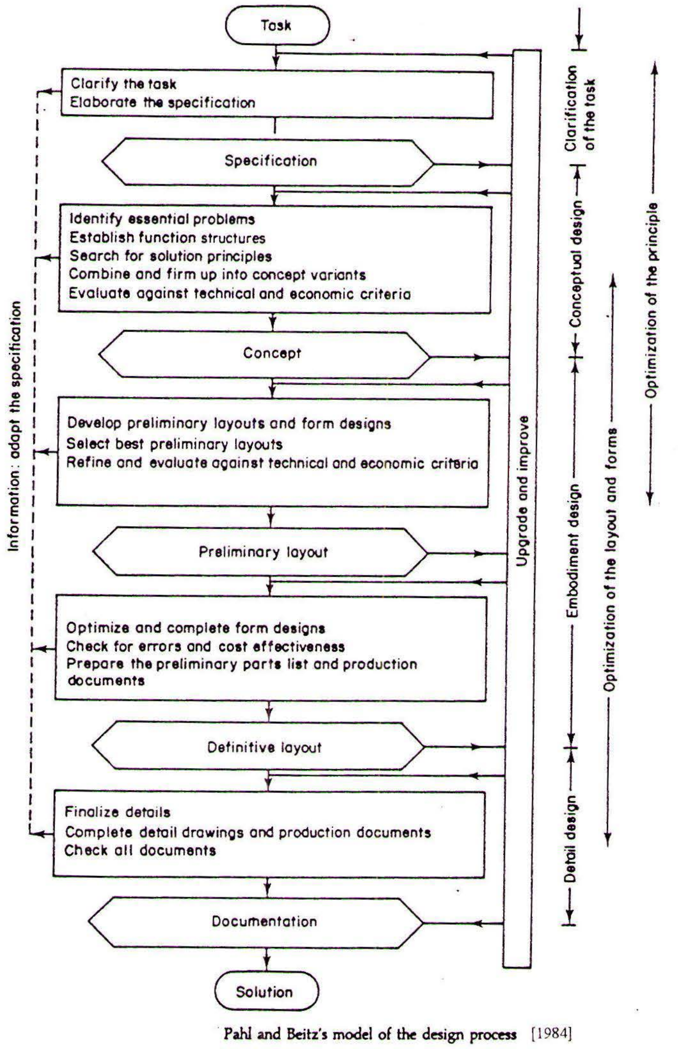


[Source: internal document]

Appendix 8: Design models of the VDI, Pahl & Beitz

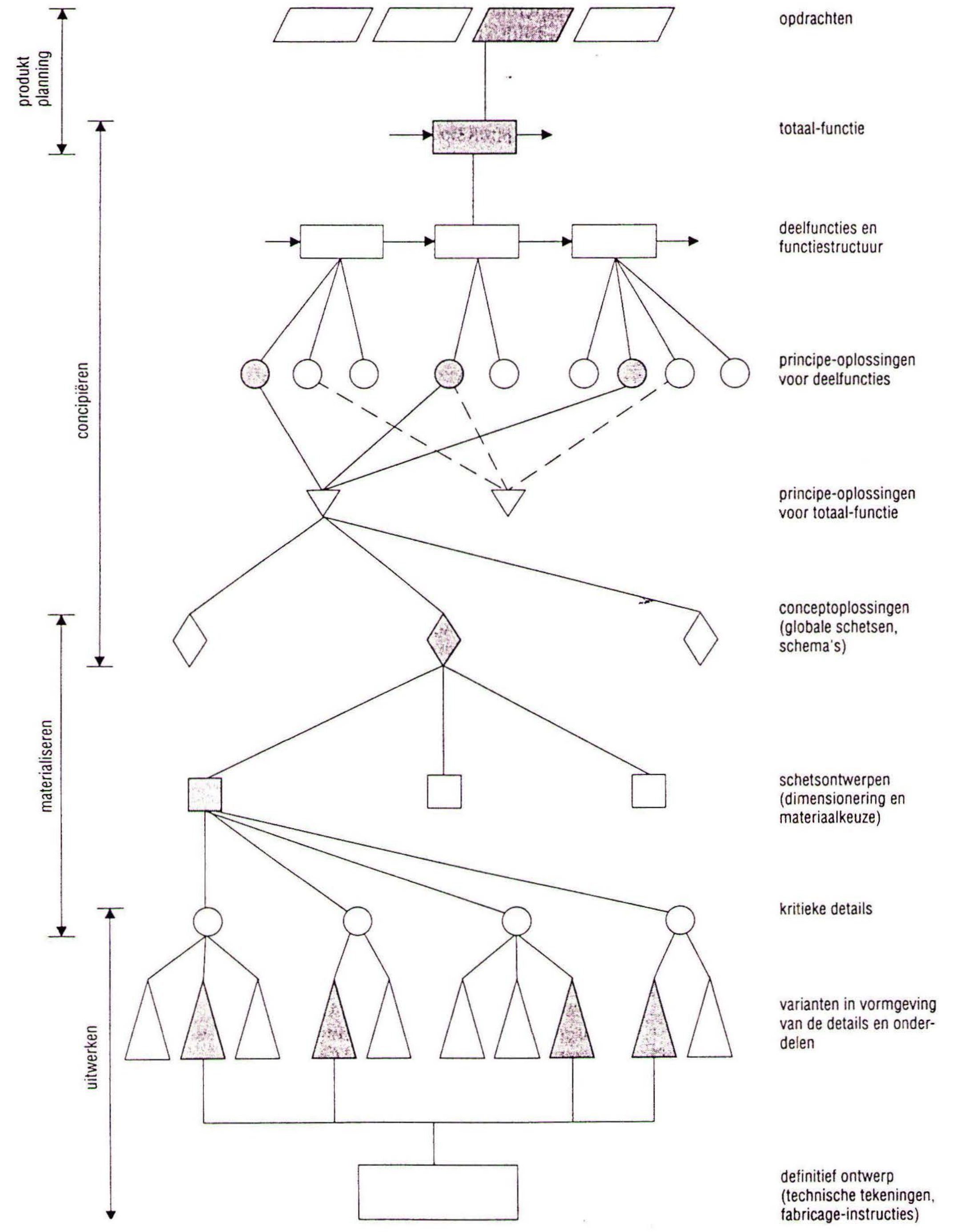


The VDI 2221 model of the design process [1986]



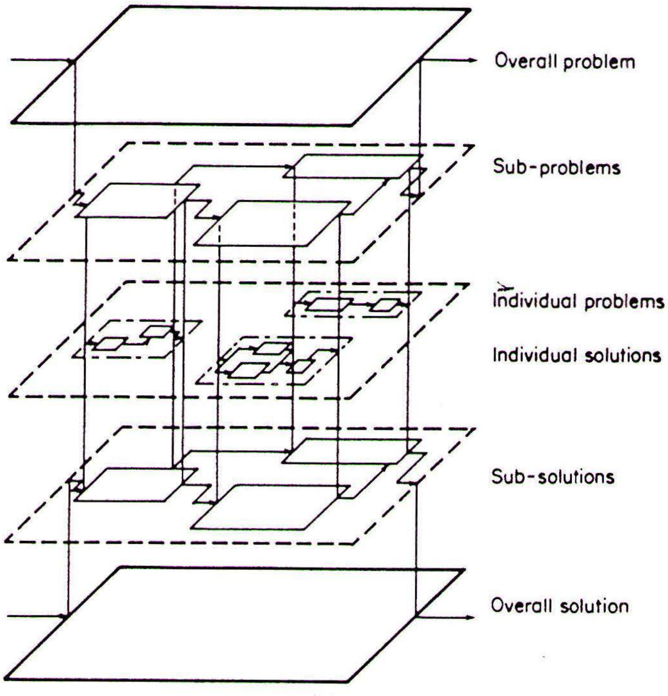
Pahl and Beitz's model of the design process [1984]

Appendix 9: Divergence and convergence in the Design Process

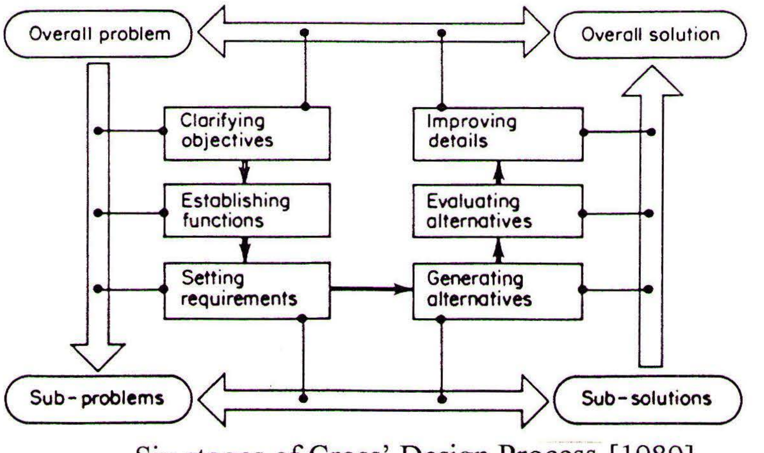


Roozenburg & Eekels [1991]

Appendix 10: The VDI model of development from problem to solution
Six stages of Cross' Design process

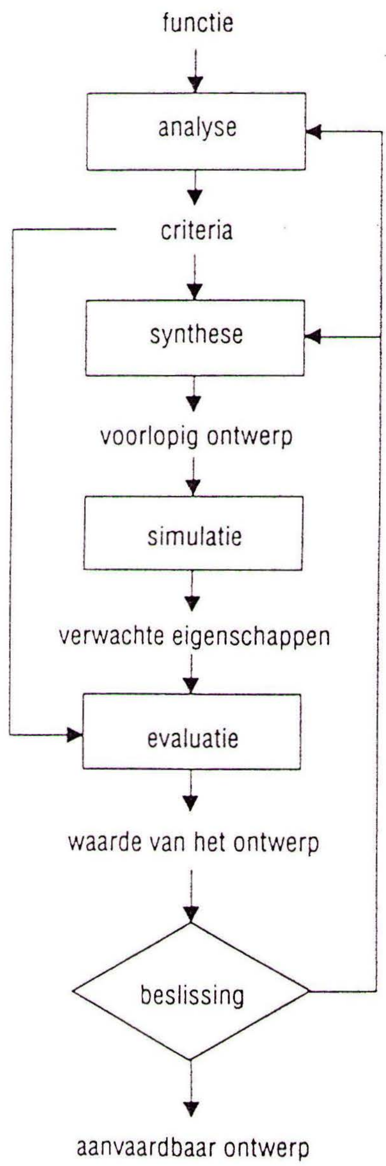


The VDI model of development from problem to solution [1986]



Six stages of Cross' Design Process [1989]

Appendix 11: Basic cycle of Designing



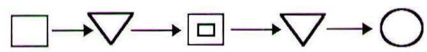
Roozenburg & Eekels [1991]

Appendix 12: Clarification of logistics decisions

The numbers below refer to the numbers used in figure 5.4

1. Determination of functionalities means which functions will de done in which order through the supply chain. The supply chain has to be seen in a horizontal manner.
   Symbols for functionality's are the following:

   □ : Production
   ▷ : Consolidation (combining goods flows)
   ⊡ : Assembly (value added logistics)
   ◁ : Deconsolidation (separating goods flows)
   ○ : Outlet
   ⧗ : Cross-dock (changing transport modality of goods flows)
   ▽ : Stock
   → : Transport

   An example of functionalities in a supply chain is: 

2. Assignment of facilities to a specific location means selecting a physical location where to put the facility. This decision is so specific that the facility can be given an address.

3/8. The long term capacity of facilities means the amount of products which can flow through a facility per time period. On the long term means the fixed capacity, which is installed at a facility.

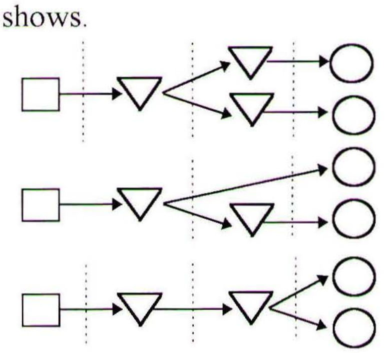
4. Structural goods flows connections means how each specific product type flows through the infrastructure. These connections are for the long term, thus structurally.

5&9. The number of functionalities means the level of centralization (or decentralization) and it means the number of echelons. Centralization can be done in different ways, vertical and horizontal, which the next example shows.

Normal structure:

Vertical centralization:

Horizontal centralization:



The dotted lines in the structures indicate echelons. The supply chain consists of a number of echelons after each other. The echelon itself indicates which functionalities are to be performed at one facility and how many parallel facilities (see stock points and outlets in the structures) there are in an echelon of the supply chain. Thus a number of functionalities can be performed at one facility (see first echelon in the vertical centralization).

6/10/15. The product assortment on the long term means what products can be dealt with at a certain facility or in the transport connection. Concerning the transport connections think of products which cannot be shipped together due to certain product conditions. For example: the combination of certain kinds of chemicals.

7. The transport modality is the used transport mode in the logistics network to physically move products. Options in modalities are: plain, train, truck, boat and pipe-line.

11/17. Capacity adjustments on the short term refer to the possibility to purchase (externally) additional capacity. It might also be possible to attract capacity from another facility of the own company.

12. Positioning of the CODP means where to place it in the supply chain. The CODP is the point in the supply chain where orders enter the company to be physically dealt with. The CODP is always related to certain product-market combinations (pmc's). A pmc explicates which product is linked to which market.

13/15/18. The product assortment on the short term means what other products can be dealt with concerning the functionality's of the facility. At a production location for example it might be possible to produce other products as well (mix flexibility).

14. The capacity of the transport connection is defined as the product amount per time period which flows through the connection. Short term adjustments in capacity refers to the possibility to purchase additional capacity. It might also be possible to attract capacity from another facility of the own company.

16. Transport modalities on the short term refer to the possibility to purchase (externally) additional transport capacity. It might also be possible to attract capacity from somewhere in the own company.

19. Stock control policy has a number of characteristic parameters which are: order point, order-up-to-level, order quantity, review period, order frequency, safety stock level [Silver et al., 1985]. This decision has to specify these parameters.

20. Order acceptance means whether or not to accept an order. This choice basically will be made based on available capacity and available material on short term notice, which is needed. The delivery time to be met is also influential. For example, an order will not be accepted if it endangers the accepted delivery time of the work in progress. Thus, rules have to be set for the way in which orders have to be accepted.

21. Delivery time release means that due dates are given to a client considering their order. This due date probably will be based on the throughput time of the activities yet to perform for that order. At this point in time rules have to be set to deal with this aspect.

Appendix 13: Working of the ID-matrix and filled-in ID-matrix

The working of the ID-matrix is as follows. The direction of a relationship between two logistics decisions is given by an arrow. The direction of the arrow indicates the stronger influence of the both. (e.g.: an arrow from decision 1 to 2 means that 1 influences 2 and 2 does not influence 1. Or it could mean that 1 influences 2 stronger than the other way around). Counting the number of outgoing arrows indicates the number of times a logistics decision is a driver. The number of incoming arrows indicates the opposite, that a logistics decision is a rider. Key drivers or riders are those decisions with the highest difference between the number of times the decision is a rider or a driver.
By means of a little symbol the strength of the relationship is indicated. Each relationship receives a score.

⊙ : score 9 ○ : score 3 △ : score 1

At the end the total score can be determined by counting the figures and multiplying them with the score. Logistics decisions with the highest scores are important decisions because they interfere strongly with other decisions. Low total scores indicate the opposite. High scoring decisions have to be taken in the beginning of the design process in contrast with low scoring decisions, which have to be taken at the end of the design process.

Logistics Decisions	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	Cause/Driver	Result/Rider	Total Score
1. Functionalities over the supply chain		○↑			⊙↑	⊙↑	△↑			⊙↑		⊙↑	○↑								⊙↑	8	0	52
2. Assignment of facilities to specific locations	○←		△↑	⊙↑	⊙←		○↑	△↑	⊙←			△←										4	4	36
3. Long term capacity of facilities (ex. stock)		△←			⊙←						⊙↑	⊙←	○←	⊙↑					⊙←	△↑	△↑	4	5	51
4. Structural goods flow connections		⊙←			⊙←	⊙←	⊙↑			⊙←			△↑	⊙↑	⊙↑							4	4	64
5. Number and regional location of functionalities (ex. stock) and facilities	⊙←	⊙↑	⊙↑	⊙↑		⊙↑	○↑	⊙↑	⊙↑			⊙←		⊙↑								8	2	84
6. Product assortment of facilities on the long term	⊙←			⊙↑	⊙←		⊙↑			△↑	○↑	⊙←	○↑		⊙↑					○↑		7	3	64
7. Transport modality or combinations in modalities on the long term	△←	○←		⊙←	○←	⊙←		○↑		⊙←		△↑		⊙←	○←						⊙↑	3	8	59
8. Long term capacity of stock holding points		△←			⊙←		○←		⊙←	△←		⊙←		○↑			⊙↑	⊙↑	⊙←	△↑	△↑	5	7	64
9. Number and regional location of stock holding points		⊙↑			⊙←			⊙↑		○↑		⊙←		⊙↑	⊙↑							5	2	57
10. Product assortment of the stock activity on the long term	⊙←			⊙↑		△←	⊙↑	△↑	○←			⊙←		△↑	⊙↑					○↑		6	4	54
11. Short term capacity adjustments of functionalities (ex. stock)			⊙←			○←						⊙←	⊙↑	△↑					○←	⊙↑	△↑	4	4	44
12. Positioning of the CODP	⊙←	△↑	⊙↑		⊙↑	⊙↑	△←	⊙↑	⊙↑	⊙↑	⊙↑				○←				⊙↑		⊙↑	10	3	95
13. Product assortment of facilities on the short term	○←		○↑	△←		○←					⊙←			△↑	○↑		○↑	○↑		⊙↑		6	4	38
14. Long term and short term capacity of transport connections			⊙←	⊙←	⊙←		⊙↑	○←	⊙←	△←	△←		△←			⊙↑	○↑		△↑	⊙↑		5	8	73
15. Long term and short term product assortment of transport connections				⊙←		⊙←	○↑		⊙←	⊙←		○↑	○←			⊙↑		⊙←				3	6	63
16. Transport modality or combinations in modalities on the short term														⊙←	⊙←			⊙←		△↑	○↑	2	3	31
17. Short term capacity adjustments of stock holding points								⊙←					○←	○←				⊙←	○←	⊙↑	△↑	2	5	37
18. Product assortment of stock holding points on the short term								⊙←					○←		⊙↑	⊙↑	⊙↑			⊙↑		4	2	48
19. Stock control policy per stock holding point			⊙↑					⊙↑			○↑	⊙←		△←			○↑					4	2	34
20. Order acceptance			△←			○←		△←		○←	⊙←		⊙←	⊙←		△←	⊙←	⊙←			⊙↑	1	10	63
21. Delivery time release	⊙←		△←				⊙←	△←			△←	⊙←				○←	△←			⊙←		0	9	43

Appendix 14: Interview questionnaire

Voorwaarden voor het interview:
- Beschikbare tijd moet minimaal 1 uur zijn, liefst 1,5 a 2 uur.
- Te interviewen persoon moet adviseur zijn op logistiek gebied (betrokken zijn bij de ontwerpprocessen).
- Te interviewen persoon moet een helicopter-view hebben over het ontwerpproces en de methoden en techneken die dit ondersteunen.

Inleiding:
- Voorstellen: Mijzelf / Onderzoek in het kader van afstuderen / Tegenprestatie
- Doelstelling van het interview uitleggen
- Opbouw van het interview
- Duur van het interview
- Discussie interessant t.o.v. concrete antwoorden
- Opstelling van geïnterviewde als zijnde "het bedrijf" i.v.m. representativiteit
- Vertrouwelijke behandeling van de verkregen informatie
- Om idee te krijgen hoe ik mijn interview kan sturen: Kunt u een typische werkdag omschrijven (doorvragen op verantwoordelijkheden en functie / woordencontext achterhalen)

Hoofdvragen (doelstellingen):
1. Op welke wijze is het ontwerpproces georganiseerd (stappen of structuur)?
2. Met wat voor methoden en technieken wordt het ontwerproces ondersteund?
3. Hoe is het pakket van methoden en technieken opgezet?

Interviewvragen:

Ontwerpproces:
1. Wat is het primaire proces/core business van het bedrijf (ook ondersteuning bij implementatie)?
2. Op welke niveaus wordt advies uitgebracht: strategisch, tactisch, operationeel?
3. Op welke wijze gaan jullie te werk als jullie logistiek advies moeten ontwerpen of ontwikkelen, dus de praktische benadering?
4. Gaat iedereen op zijn eigen manier te werk of is er een standaard werkwijze?
5. Onderscheiden jullie hierbij verschillende stappen en zou je deze stappen in een grafisch model kunnen weergeven (zo zie je de volgorde en afhankelijkheden van de stappen)?
6. Zo nee, waarom gebruiken jullie géén structuur?
7. Zo ja, waarom hanteren jullie deze structuur?
8. Wat is het doel van elke stap?
9. Wat doe je in elke stap?
10. Wat zijn essentiële stappen in het ontwerpproces en waarom?

[Stel dit onwerpproces tegenover algemene aspecten van het theoretische ontwerpproces: probleemdef., functie van het ontwerp, eisen en randvoorwaarden, creativiteit, analyse, haalbaarheid.]

1. Vindt u dat er iets verbeterd zou kunnen worden aan de structuur van het ontwerpproces, de doelen van elke stap of de werkwijze in elke stap (wat zijn problemen waar je regelmatig tegenaan loopt en waar dus schijnbare verbeteringen liggen?)
2. Zo ja, wat dan en waarom?
3. Wordt het ontwerpproces gevalideerd (qua structuur, doelen en werkwijze? Zo ja, hoe?
4. Wie zijn er betrokken bij het ontwerpproces van een bepaald project (wel/niet team per stap in het ontwerpproces)?
5. Hoe worden de verantwoordelijkheden binnen een ontwerpteam verdeeld (ook wie wat in welke stap doet)?

Methoden en technieken ter ondersteuning van het ontwerpproces:
1. Met welke methoden en technieken worden de stappen van het ontwerpproces ondersteund (schema erbij halen)?
2. Wat is het doel van elke methode: creativiteit/analyse/logistiek gebied?
3. Zijn er verder nog methoden en technieken die het ontwerpproces ondersteunen?
4. Wat zijn voordelen en nadelen van de gebruikte methoden en technieken?
5. Bestaat er samenhang tussen de verschillende methoden en technieken?
6. Zo ja, hoe dan?
7. Waar liggen de verbanden binnen het pakket?
8. Wat zijn de belangrijkste methoden of technieken die jullie gebruiken en waarom vinden jullie dat?
9. Zijn er ook methoden en technieken die niet gebruikt worden vanwege slechte ervaring, lage nut ervan, etc.?
10. Worden gevonden oplossingen voor logistieke problemen getoetst op validiteit?
11. Zo ja, hoe?

Afronding:
- Checken of alle vragen beantwoord zijn?
- Documentatie vragen: gerelateerd aan dat wat besproken is / algemene bedrijfsinformatie?
- Vervolg: terugkoppeling van wat in verslag komt?
- Bedanken.