MASTER

The enterprise simulation framework
building a simulation model for setting up a new business

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The Enterprise Simulation Framework

Building a Simulation Model for Setting up a New Business

Bridging the gap between rational thinking and guts feeling

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Management Summary

This assignment was issued in order to investigate how to set up a thesis project for a Technology Management student that is following the Technology Entrepreneurship Program. This program facilitates the possibility to combine the final project of one of the master studies with the start-up of a new venture based on a TU/e technology. For a student of the Master of Science Program Innovation Management it is often hard to define a good project, because the scientific value of a project is often opposite to the practical value of the project (the value for the new enterprise and the entrepreneur). System dynamics simulation should provide both scientific as practical value in such a project. This however is not certain and has to be researched, resulting in the following main question: Can system dynamics be effectively used in a graduation project (in the Innovation Management MSc program) that is linked to the development of a business plan for a technology start-up? And if so, what is the best way to do that? (Chapter 1)

A business plan can have various purposes. The most important are: to crystallize the idea, to test the viability if the idea, and to determine the fiscal needs and raise finance. The business plan can consist of several elements from now on called ‘aspects’. These aspects have different roles in the business plan development process. The first role is called ‘input and boundaries’ this role refers to those aspects that do not describe the chosen strategy but merely describe the domain in which one wants to operate. The aspects within this category are: Idea, Product/Technology, Applications/Markets, Entrepreneur(s), SWOT/Risks and Startup-aspects. The second role considers the strategic decisions. Here one elaborates a strategy within the chosen domain. One determines how the strategy enables the enterprise to reach certain goals. This role is divided in three parts. In the first part one designs a desired situation, in the second one defines a development plan how to reach that situation and in the third part one describes what the effects are of the chosen strategy. The third role covers aspects that help clarify the report. This concerns the introduction management summary and conclusion. (Chapter 2)

System dynamics is founded in 1957 by Jay W. Forrester. He developed a model to explain huge supply-chain fluctuations caused by minor shifts in demand. He used a simple model consisting of: organizational structure, delays in decisions and actions and policy on purchasing and inventories. He used computer simulation to calculate the development of the variables per time unit. Later in 1990, Peter Senge developed a way of thinking called ‘systems thinking’. System thinking builds forth on the notion that all phenomena can be viewed as (part of or resulting from) a system. System thinking can be viewed as a paradigm; a way of explaining and analyzing reality. It combines the traditional ‘rational’ way of thinking (left brain thinking) with more intuitive right brain thinking, also called gut feeling. System dynamics can be called a language that incorporates both left brain as right brain thinking. Furthermore system dynamics can be considered as a methodology. It consists of five phases: Problem structuring, causal loop modeling, dynamic modeling, scenario planning and modeling, and implementation and organizational learning. (Chapter 3)

To structure the modeling process and make it more efficient and effective, a framework is developed called: ‘The Enterprise Simulation Framework’. This framework consists of four simple steps. During step 1 the demand is determined without considering any capacity issues. Step 2 focuses on the required capacities and the influence of the available capacities on demand. Step 3 is used to determine the different (financial) effects resulting from step 1 and 2. Finally step 4 enables sustaining competitive advantage, this is done by repeating steps 1 to 3 for future situations. A basic model of step 1 and 2 is available. Also for step 3 a model is available; however the model depends largely on the other models developed for the specific enterprise. During step four, the first three steps will be repeated anticipating on (possible) future situations. (Chapter 4)

To make clear what the deliverables of a thesis project should be and how different methodological cycles need to be incorporated, a six phase project structure is developed. The structure ensures that the project has both scientific as practical value. During the project there are more scientific oriented deliverables and more practical deliverables. Considering the first the supervisor is an important extra stakeholder. (Chapter 5)
To test the generated ideas and adjust them if necessary, a pilot project was set up. The main conclusion was that it is not possible to build a model of the entire new enterprise. We learned that one should focus on certain important aspects and slowly extend the models that are already available. (Chapter 6)

The overall conclusion is that it is a good idea to use system dynamics for the specified thesis projects, but only if three requirements are met. The first is that the goal of the thesis project is to generate insights not hard figures. There also need to be a good project structure with multiple stakeholders. Finally there has to be intense supervision, because the students generally are not used to the way of thinking and modeling that comes with system dynamics simulation. (Chapter 7)
Preface

This report is the result of my thesis project for the Technology Management faculty of the Technological University of Eindhoven. My supervisors are Prof. Dr. A.G.L. (Sjoerd) Romme, Prof. Dr. L.H.J. (Leo) Verhoef and Dr. Ir. P.J.A. (Peter) Verdaasdonk. The project is an assignment issued by the TM-faculty. I decided to do this assignment because I always have had an interest in setting up new businesses. I have written a business plan for my cousin and I liked the process and the challenge of writing a good business plan. Furthermore the reason why I choose to study Technology Management is because I wanted to set up my own business. I still have that ambition and time will tell if I will have that opportunity. Besides my interest in entrepreneurship, I have a special interest in computer technology and in particular computer simulation. I was not familiar with system dynamics simulation before I took the assignment, but the idea to not only simulate the hard factors but also the soft ones sounded as a step forward in making good business plans.

The resulting ideas and structures give a good idea of how a business plan should be developed based on current practices. The aspects that are currently included in a well developed business plan are structured and a procedure how to include these aspects in a simulation model is presented. However the structures and procedures also open up a way to look to the business plan from a different angle. Today's practice focuses on the effects and results in terms of invested and gained money. This structure makes it possible to evaluate the effects of the business (plan) also in terms of for instance customer satisfaction, employee satisfaction and environmental pressure. How to do this has to be determined in further research.

I would like to thank my supervisor Prof. Dr. Sjoerd Romme for giving me a lot of freedom in determining the boundaries of the assignment. I also want to thank Nico Verloop and Julio Pino Molina for providing input and feedback. Finally I want to thank Mark Wilde for reviewing my report.
Introduction

The last couple of decades entrepreneurship is more and more recognized as the striving engine of modern economies. The economic growth of a country or region depends for a large part on the entrepreneurial activity of that country or region. Governments now try to actively stimulate entrepreneurial activity and innovation through policies and educational programs. The region Eindhoven is also actively stimulating the creation of new ventures. Organizations like Incubator 3+ and TU/e Innovation Lab support techno start-ups in the region and organize lectures discussing entrepreneurship.

To stimulate the entrepreneurial ambitions of its students and to facilitate means to increase the chances of success of new ventures set up by these student, the TU/e have set up an educational program dedicated to entrepreneurship. This Certificate program Technology Entrepreneurship facilitates the possibility to combine the final program of the Master of Science Programs of the TU/e with the setting up of a new business.

A new technology venture needs to have expertise in the technological field the company wants to operate in. However besides this expertise it is also important to have expertise in the entrepreneurial domain. A good way to include this expertise is to have a student of the Master of Science Program Innovation Management in the entrepreneurial team. This student has a throughout educational background on various management fields like strategy, logistics, information technology and human resources. However in practice it turns out to be difficult to formulate a challenging assignment that uses this management background and invites to apply this knowledge to an entrepreneurial situation.

One of the difficulties is that most management fields focus on the optimization of actual situations, while entrepreneurial business planning focuses on future situations. One way to overcome this problem is to simulate the future situations and apply different (managerial) policies to these situations. The simulation results then can be used to compare these policies and develop a combination of policies that generate the best results. How to do this will be the subject of this report.
Chapter 1 The Assignment

1.1 Problem Definition

The assignment is issued by the department of Technology management of the Technical University of Eindhoven (TU/e), more specifically the capacity group Organizational Science and Marketing (OSM). The capacity group OSM is partly responsible for the Technology Entrepreneurship program.

1.1.1 The Certificate Technology Entrepreneurship

Since a few years it is possible at Eindhoven University of Technology for MSc students to participate in the Certificate program Technology Entrepreneurship (CTE). The objective of the CTE program is to develop entrepreneurial skills and capabilities of master students at the TU/e, in the context of starting up a technology firm. The certificate consists of three parts: elective courses, a Master class in entrepreneurial skills, individual graduation projects, and the development of a business plan. Concerning the elective courses, the student needs to choose courses from a list that is composed annually. The total amount of ECTS of these courses has to be at least 9. The entrepreneurial skills program runs parallel to the graduation project and focuses on specific entrepreneurial skills. Before the start of the program, the students will go through an assessment to determine which skills need to be improved during the program. The skills will be improved by several workshops and personal coaching.

A CTE graduation project (ATE) is based on an innovative idea developed at the TU/e. Typically, these ideas need a substantial amount of knowledge input to translate it to a commercial product and/or service. Therefore, the first phase of the TE program involves determining which knowledge is needed. This knowledge is often not available in one person. This requires to define several graduation projects (of different study programs) drawing on the same initial idea. Each graduation project is done independently form the others, but applies to the same base-idea – be it from a different angle. In these separate projects, the students need to attain the usual scientific level that is demanded for a master degree. This means that all students need to comply with the requirements of their MSc programs. The amount of ECTS depends on the MSc program. Furthermore the students need to write an integrated business plan. This plan is the concluding piece of the ATE-trail, it is however not part of the graduation project, but it is obligatory for the certificate.

Figure 1.1. Overview of the CTE structure.
An ATE-team can, for example, consist of a student from Applied Physics, Mechanical Engineering and Technology Management. For the student from applied physics and mechanical engineering, the graduation assignment is often quite clear and most probably will be in the area of product or process development (e.g. testing a prototype of the new process or product in the lab). The student from applied physics can, for instance, further develop the technology upon which the innovative idea is based and the student from mechanical engineering can design the production process. However, the assignment for the Technology Management student is not so straightforward. It seems clear that the focus of this student should be more on the entrepreneurial side of the business, instead of the technological side. There are many entrepreneurial topics to research, but in practice it still turns out to be hard to define a good assignment.

There are two important demands on the CTE graduation project. First the project needs to address a problem that directly applies to the new business idea/plan. In addition, the graduation project needs to be of such a high scientific level, that it will comply with the graduation standards of the TU/e. Many entrepreneurial research questions are direct of interest to the new business, but do not involve knowledge at the MSc level. For instance, a market research, in which 100 potential customers are called and interviewed through a questionnaire. This type of study can be more effectively conducted as a BSc project. One of the main problems of business plans, in general, is that the link between the entrepreneurs, the business model and the financial results is often not very clear. Especially the transition from the more qualitative information that describes the entrepreneurs and the business model, to the more quantitative information that describes the financial projections. For example, the relation between the business model and the amount of goods sold per month remains unclear. Often an estimation is given and in best case the premises that lead to this estimation are made explicit. But a complete picture of the relations between premises, input variables and output variables is usually missing.

1.1.2 Computer Simulation

A possible solution to both the CTE graduation project requirements and the problem of business plans in general could be to use computer simulation to investigate certain aspects of the business plan. Considering the CTE graduation project the subject of the assignment can be a problem that is directly derived from the business plan. Research questions can be for instance: What is the value of my business at a certain time? Which product should I launch first? Etc. And the method that will be used, simulation, can lift the assignment to a high enough technical scientific level. In order to simulate the systems of interest need to be modeled and in order to ensure that the results have any value, a good developed analytical method need to be used.

There are different kinds of computer simulations that can be used for evaluating business systems. Most important are: Discrete event simulation, System Dynamics and Monte Carlo simulation.

Discrete event simulation models are very suitable to follow a certain object (entity) through a system and to determine the performance of that system. It is especially effective when calculating the throughput-time of a system at certain capacities. Draw backs are that it is very hard to incorporate control rules for instance to adjust capacities during a simulation run and that it is also very hard to integrate different systems that do not use the same entity. For instance modeling the resulting effects of marketing & sales (number of salesmen), distribution (number of sold products) and R&D (number of new patents) is practically impossible to incorporate in a workable model.

System dynamics appears to be very helpful to investigate what the effect of certain relations on the increase or decrease of certain variables is. With respect to business systems this approach is particularly useful for modeling the growth or decline of a resource. Moreover, it serves to uncover the mechanisms that cause reinforcing growth or decline and so called balancing mechanisms that slow down growth and bend variables to certain (stable) values.
Monte Carlo methods are useful for modeling phenomena with significant uncertainty in inputs, such as the calculation of risk in business. It is especially useful in studying systems with a large number of coupled degrees, such as liquids, disordered materials etc. (Source: http://en.wikipedia.org/wiki/Monte_carlo_method)

An example is a model that can calculate $\pi$. One draws a quarter of a circle within a square, such that the centre of the circle is right on one of the corners and the radius is equal to the length of 1 side. The chance that a random point within the square is also within the quarter of a circle is equal to $\pi/4$. The more random points generated, the better the estimation of $\pi$. (Figure 1.2)

![Figure 1.2 Estimating $\pi$ through Monte-Carlo Simulation](image)

The focus of the project will be on the question how system dynamics can be used when graduating on a business plan. From the three discussed computer simulation methods system dynamics seems most suitable. This is because writing and evaluating a business plan involves decisions concerning many different aspects and variables. Systems dynamics is very suitable for determining the relations between both 'hard' and 'soft' variables. After explicating the relations of a system through system dynamics, the parameters that are used in the relations have to be set to evaluate the consequences of certain decisions in combination with certain parameters. However because the simulations will reflect the behavior of a system in the future, the exact values of these parameters are unknown and therefore need to be estimated. This is mostly done by rational reasoning in combination with empirical field information of comparable systems. (Figure 1.3)

It might be possible that in complicated situations it is much more effective to use Monte Carlo simulation. This is very interesting to investigate, but will not be within the scope of this assignment.
1.2 The Assignment

1.2.1 The research questions

The idea is that students will graduate on an assignment, in which they will use system dynamics to optimize certain aspects of a business plan. However it is not clear whether or not this is a good idea. To evaluate this idea, one needs to clarify the different components of the idea and how they relate to each other. The main components of the idea are: ‘students who want to graduate on an assignment’, ‘system dynamics’ and ‘a business plan’. The first thing that needs to be made clear is what is meant by ‘a business plan’ and what its relation is with respect to the other components. After that, this also has to be done for ‘system dynamics’ and ‘students who want to graduate on an assignment’. With respect to the last component, two things need to be made clear. Firstly, how should students set up their assignment in order to make sure that they create enough added value within the time limits, to graduate on the assignment. And secondly, the more practical side of the graduation project, so what tools and infrastructure are needed and how should the project be structured in order to execute the assignment as good as possible. (Figure 1.4)

These aspects that need to be made clear are translated into one main question and four sub-questions. The main question of my assignment will be: Can system dynamics be effectively used in a graduation project (in the Innovation Management MSc program) that is linked to the development of a business plan for a technology start-up? And if so, what is the best way to do that?

First the four sub-questions will be answered and after that the main question will be answered in the conclusion.

The four sub-questions are as follows:

1. How can one decide which aspects of a business plan are interesting to simulate? To answer this question it first is important to understand what the purpose of the business plan is. In other words, why is it needed and what is its role in the whole business development process. Therefore I will begin with explaining what new business development is. After that I will discuss what the purpose of the business plan is. Then one needs to determine what the important aspects of a business plan are. What sort of information needs to be provided and how do these subjects relate to each other? At last one has to evaluate what aspects of a business plan are most critical and what role these aspects play in a model.
2. *Are there system dynamics models that can simulate interesting aspects of a business plan?*  
First will be explained what system dynamics is. What is its origin and how does it work?  
Then I will discuss what models there are in literature and how we could use these models to  
built a good model for the business plan. The models need to be translated to the specific  
situation and often multiple models need to be integrated.

3. *Do the results of the simulation runs have enough added value?* First I will discuss the  
reliability of the results of the simulation runs. How should one interpret these results, what  
decisions can be made based on them and for which questions is system dynamics most  
preferable? I will investigate for which questions alternative methods can also be used and  
how much work is needed to build a good model. After that I will develop a procedure to build  
a basic model that answers the most important questions. The procedure will present steps to  
built a basic model and extend it to a more and more complete model.

4. *How should the thesis project be organized?* In this section the more practical side of the  
graduation project will be discussed. First will be evaluated how the project structure will look  
like. Then will be decided which simulation tool is appropriate. And finally the supportive  
infrastructure that is needed will be determined.
Figure 1.4. The assignment
1.2.2 The Deliverables

The overall goal of the project is to make clear if system dynamics can be used to graduate on a business plan and how this should be done. To reach this goal two kinds of activities need to be done. First, research needs to be done to gain insights in the answers to the research questions. This research will lead to a framework that gives a basis for using system dynamics for investigating business plans. This framework will be called: the Enterprise Simulation Framework (ESF). Second, these insights need to be communicated in such a way that it becomes clear for all involved parties when to use system dynamics in a graduation project linked to a business plan, and how one can do this. What research needs to be done will be discussed later in the report. However, the deliverables providing the communication aspect will now be discussed.

Firstly of course this report will be the main deliverable. It gives insight in the answers of the research questions and how these questions are investigated. It further gives a full description of the ESF. The second deliverable will be a protocol in which the most important aspects of a graduation project according to the ESF will be described. The third delivery will be 2 presentations to explain the research questions and their answers. The first presentation will mainly be to explain the research questions and to explain the basic setup of the ESF. It will focus on the structure of a business plan and the basic steps of the ESF. The second presentation will merely focus on the total ESF and during this meeting the protocol will be presented. Finally during the development of the protocol the parties that are going to use the protocol and those parties that have to approve it will be involved to evaluate it and to create sufficient support basis within the organization.

1.3 Execution Plan

The formulated research questions will be investigated during this project. There will be three different phases in the project. In the first phase the research questions will be researched through literature and interviews. An important result will be the basic structure of the ESF. During the second phase a test case project will run to evaluate the framework and further develop it. The last phase will be to evaluate the test case and to develop the protocol.

1.3.1 Phase one

To be able to know what the purpose and structure of a business plan is the project starts with a short review of what different organizations consider a model business plan according to the information they provide to the public. Different organizations have different views of what a business plan should look like. Comparing these views helps to understand what information is commonly demanded and what aspects are only interesting in certain situations. After that a literature review provides full understanding of the purpose, structure and content of a well defined business plan. Next to the literature review some interviews with experts in this field will make the picture complete. This forms the basis for answering sub-question one.

Considering sub-question 2 there will be also a literature review. It is very important to know what system dynamics is and how it can be used. First the focus will be on books that explain the basics of systems dynamics and then it will shift more to literature that describes the use of system dynamics for strategic problems. Also with respect to system dynamics experts will be interviewed to fully understand the possibilities of system dynamics.

Based on the research considering sub-questions 1 and 2, the first step to answer sub-question 3 will be done. After the interesting strategic questions and available models are determined, it is possible to structure these questions in a way that enables effective and efficient modeling. This is needed because most questions are interrelated. In other words, the answers of most questions depend on the answers of other questions. To make clear what questions need to be answered first and what questions can be answered later, a framework will be developed. This framework consists of a number of steps that provides a basis for answering the most important strategic questions.
Considering the fourth sub-question an evaluation of the available tools will be made. The most interesting tools will be listed and compared. Together with my supervisor a tool will be chosen that will be used to simulate with. This tool will be explored and tested with respect to its capabilities and user friendliness.

Finally the phase will be used to look for a suitable start-up to use as an example case in the next phase.

1.3.2 Phase two
The case example selected in phase one will be used to test the developed structure of the framework and further elaborate the steps of the framework. The business needs to be in its start-up phase, which means that it is currently developing and implementing its strategy and that it is not older than 2 years. Secondly the business is preferably based on a TU/e technology and if that is possible already part of the CTE program. During this phase different models to simulate the development of the specific company will be build and integrated according to the ESF.

Together with the entrepreneur(s) of the selected company, one or more research questions will be defined. The question(s) will form the assignment during the example case.

In this phase the first presentation will take place focusing on explaining the research questions and the basic setup of the ESF.

1.3.2 Phase three
In the last phase the example case will be evaluated. What aspects of the project where most difficult and what is the best way to do them? Further the ESF will be discussed and determined will be what aspects need further research to be fully developed. During this phase the protocol will be developed and also the last presentation will take place.
Chapter 2 The Business Plan

Writing a business plan is no goal on its own, but part of a greater process, namely starting a new business. Therefore, in the first section this greater process will be described. In the second section the role of the business plan will be further specified. The third section will evaluate of what kind of information a business plan consist of. The final section will determine the structure and roles of the different aspects.

2.1 The New Business Development Process

2.1.1 Entrepreneurship

Building a new business is a continuous process that starts with an idea and stops when the business is successful or the idea turns out to be not viable. However, the entrepreneurial activity should continue even when the business is successful in order to keep it successful or make it even more successful. There are a lot of different views on what entrepreneurial activity is and what the role of the entrepreneur is.

At first glance it seems that entrepreneurs are people who set up their own business. However, according to Carland et al., 1984, as quoted by Kirby (2003) on page 10, not everybody that owns a business is an entrepreneur. They suggest that: ‘An entrepreneur is an individual who establishes and manages a business for the principal purposes of profit and growth. The entrepreneur is characterized principally by innovative behaviour and will employ strategic management practices in the business. An entrepreneurial venture is one that engages in at least one of Schumpeter’s four categories of behaviour: that is, the principal goals of an entrepreneurial venture are profitability and growth and the business is characterized by innovative strategic practices.’

Moreover, entrepreneurship is not confined solely to new ventures. In other words, entrepreneurs do not only work for themselves in their own businesses. Many large organizations are entrepreneurial and many entrepreneurs can be found in such organizations. This leads to the view that entrepreneurship is not about the act of founding or owning a (usually small) business, but about a pattern of behaviour or a set of behavioural characteristics. (Kirby, 2003) There are many of such behavioural definitions. A very appealing one is the one from Timmons (1989) as quoted by Kirby (2003) on page 11. Entrepreneurship is: ‘...the ability to create and build something from practically nothing. It is initiating, doing, achieving and building an enterprise or organisation, rather than just watching, analyzing or describing one. It is the knack for sensing an opportunity where others see chaos, contradiction and confusion.’

Joseph Schumpeter (1883 – 1950) (From: http://en.wikipedia.org/wiki/Joseph_Schumpeter) ‘The concept of entrepreneurship cannot be fully understood without his contributions, being probably the first scholar to develop its theories. He gave two theories, sometimes called Mark I and Mark II. In the first one, the early one, Schumpeter argued that the innovation and technological change of a nation comes from the entrepreneurs, or wild spirits. He came up with the German word Unternehmergeist, meaning entrepreneur-spirit. He believed that these individuals are the ones who make things work in the economy of the country. In Mark II, later in the United States, he pointed out that the ones who really move the innovation and economy are the big companies which have the resources and capital to invest in research and development. Both arguments might be complementary today.

The English literature referred to use the French word entrepreneurship, but perhaps the German one would be more correct to understand the entrepreneur studies.’

The notion that entrepreneurs know what to do is also shared by Carland et al (2000). An entrepreneur knows what knowledge is needed and how to translate this knowledge into actions. In other words, he is able to mobilize resources to achieve a specific business or social goal. Kirby (2003) further stresses the fact that doing something new and innovative always comes with uncertainty and risks. The entrepreneur however has the ability to assess opportunities and initiate appropriate actions to ensure
success. It is essentially this task (gathering the right knowledge, assessing the opportunity and evaluating which actions need to take place in order to reach success) that will be evaluated with respect to computer simulation.

The subject entrepreneurship has already been discussed at least since Joseph Schumpeter (see above). This is mostly done by people with an economic background. Entrepreneurship as a scientific field on its own is however still very young. Determining its boundaries is hard, since a clear generally accepted definition of entrepreneurship lacks. Since the year 2000 quite some books where published that focused on entrepreneurship. To give an impression some are incorporated in the reference list. However it is questionable if all these books have a significant contribution to the development of entrepreneurship as a scientific field. It will take time and effort to fully develop the field to a real science. Bruyat and Julien (2000) explain this as follows: ‘The field of entrepreneurship, and in particular the study of its archetype (the entrepreneurial venture), is undoubtedly one of the most complex in the social sciences. It therefore offers a considerable challenge to researchers in the 21st century. If we are to take up this challenge, we will have to borrow methods and tools from other disciplines and fields, and we will undoubtedly have to invent new ones. At the same time, we must be careful not to dissipate our efforts.’

2.1.2 Evaluating the opportunity

From the entrepreneurs’ perspective, perhaps the most critical aspect of enterprise formation is narrowing in on the best opportunity. Most people see many opportunities but find it difficult to know when to select a specific one and act on it. One useful method of selecting an opportunity is to look for the sweet spot that matches opportunity with interests and capabilities, as shown in figure 2.1. (Dorf and Byers, 2005) Most entrepreneurs-to-be will experience a set of good opportunities that flow by over time. They also will have interests, activities, and tasks they like to do. Furthermore, they have capacities or skills and knowledge that qualify for certain tasks. Good opportunities display the characteristics of a potential to solve important problems within economic constraints. So, the entrepreneur seeks a timely, solvable, important problem with a favorable context that can lead to profitability.

![Figure 2.1 The Sweet Spot (Dorf and Byers, 2005)]
It is the entrepreneur who adds value to the opportunity by creating a response to a good opportunity. The opportunity, and a general response to it, is not unique – many recognize but few possess the relevant passion or solve the problem as well as the capabilities to do so. It is really the passion and capabilities that distinguish the entrepreneurial team. The selection process consists of looking for the best match of opportunity, capabilities, and interest (passion). (Dorf and Byers, 2005) In other words the success of a new venture does not only depend on the attractiveness of the opportunity but for a great part also on the passion and capabilities of the entrepreneurial team.

2.1.3 The actual start up process

First I will discuss different views of how the start-up process is structured. Starting up a business is quite a complex process and many ways lead to Rome. Dorf and Byers (2005) recognize four different steps:

1. The founding team or individual has the necessary skills or acquires them.
2. The team identifies the opportunity that attracts them and matches their skills. They create a solution to match the opportunity.
3. They acquire (or possess) the financial and physical resources to launch the business by locating investors and partners.
4. They complete an arrangement or contract with their partners, investors, and within the founder team to launch the business and share the ownership and wealth created.

It is remarkable that according to this structure, the team first acquires the necessary skills and after that looks for an opportunity that matches their skills. Of course in practice it can be that some skills will be acquired after identifying the opportunity, but the point is to choose an opportunity that lies within the team’s field of expertise. During the next phase the idea to provide a solution to match the opportunity is further elaborated. The next phase is used to gather the required resources and prepare them for being (used as) part of the new venture. The last step is to actually make the deals and launch the business. Notice that these steps do not include anything concerning the development of the technology into a marketable product or service.

Barrow et al. (2001) also recognize a number of phases. These phases really zoom in on the planning process, which can best be compared with step two of Dorf and Byers’s (2005) four steps. Now, only the phases and their overall structure will be described, the aspects of each phase will be described in more detail in section 2.4 ‘Aspects of the business plan.’ In their book Barrow et al. (2001) composed a number of assignments per phase that together form the basis of a complete business plan. These are the seven phases of Barrow et al. (2001):

**Phase 1: History and position to date.** In this phase one describes the idea, mission statement and objectives, the management team and its skills and experience and the product or service and its current development.

**Phase 2: Market research.** This phase concentrates on gathering market research data, like customer needs, market segments and competitors’ strengths and weaknesses.

**Phase 3: Competitive business strategy.** Now the marketing will be developed and decisions concerning price, promotion, location and channels of distribution will be made.

**Phase 4: Operations.** Here all activities that will make the strategy happen, need to be detailed. Subjects such as manufacturing, purchasing, selling, employing people, legal matters and insurance need to be specified.

**Phase 5: Forecasting results.** Now the developed strategy has to be translated into forecasts of the expected results of the venture. Included need to be the sales volumes, pro forma profit and loss, cash flows, balance sheet and break-even analysis.

Keep in mind that the first five phases are not separate from each other, in fact information gained in a certain phase can lead to new insights concerning a previous phase.

**Phase 6: Business controls.** Keeping track of the business and its aspects after launch is very important. This phase is dedicated to specifying how this will be done. Important issues are, the bookkeeping system, sales and marketing planning records, customer record cards, personnel files and production control information.

**Phase 7: Writing up and presenting your business plan.** The previous phases generated a lot of information. To have a good overview and a complete picture of this information, it can be compiled
into a written business plan. While writing the plan, it is good to keep in mind for what audience it is written.

In the first five phases the actual strategy development takes place, in short the proposed structure is as follows: First determine roughly what problem the new venture is going to solve and how good it is in solving the problem. Then determine the current market situation. After that, develop a strategy. Next fill in how this strategy will be executed. In phase five the consequences of this strategy on the development of the new venture will be examined.

2.2 The Purpose of the Business Plan

2.2.1 Crystallize the idea
According to Barrows et al. (2001) constructing a business plan is perhaps the most important step in launching any new venture or expanding an existing one. They state that it takes between 200 and 400 man hours to build a plan with which it is possible to crystallize and focus your ideas and test your resolve about entering or expanding your business. 'Once completed, your business plan serves as a blueprint to follow which, like any map, improves the user's chances of reaching his destination.' Kirby (2003) states this as follows: 'Essentially the purpose of the business plan is to help the business founder crystallize his/her ideas — to consider all aspects of the business and see how they fit together.' When starting up a business a lot of decisions need to be made and actions need to be taken. In order to make good decisions and take the right actions, first a lot of information needs to be gathered and analyzed. This information, the analysis, the decisions and the actions that need to take place can be reported in a (written) business plan to provide a good overview. A business plan can serve as a step between the intangible abstractness of an idea and the concrete reality of an actual business.

2.2.2 Test viability of the idea
According to Kirby (2003) another function of the business plan is to test the viability if the idea and sets out what the business expects to achieve, together with the resources and actions required. Once developed it acts as a map showing what is expected to be done and when. Thus not only does it check the commercial and technical viability of the idea, but it sets goals and objectives, and allows monitoring of actual progress. Barrows et al. (2001) suggest that using their systematic approach to planning enables you to make your mistakes on paper, rather than in the marketplace.

2.2.3 Determining fiscal needs and raising finance
The plan should show how much money is needed, what it is needed for and when, and for how long it is required. Some of the main reasons why new and small businesses fail are under-capitalization and problems with cashflow. Many fail with full order books because they lack the resources to serve them. A soundly prepared business plan can help avoid such difficulties. (Kirby, 2003)

The business plan can further be used to persuade external financial institutions to fund the project. Potential financiers will want to see a plan for the proposed business and a good business plan will help to raise the requisite funding. According to Barrow et al. (2001) as also quoted by Kirby (2003) financiers are looking for the following five things:

1. Evidence of market orientation and focus. The business plan must demonstrate that the needs of the customer are recognized, rather than that the entrepreneurs are only simply fascinated by an innovative idea. A plan that devotes more space to technical descriptions of the products than to descriptions of the market and the marketing strategy, will probably not be well received
2. Evidence of customer acceptance. It is important for financiers to know that the product or service will sell. Therefore the plan has to mention if the product or service is already used by the customer, even if it was on trial or demonstration basis. If the product is still in prototype stage, the plan needs to show that the 'problem' that the innovation is going to solve is a substantial one and that a large number of customers will pay for it.
3. **Proprietary position.** Protecting the idea by patents, copyrights, trademark protection or licensing can limit the competition in the first stage. This can help to reduce the riskiness of the venture, at least from the financier’s perspective.

4. **Financer’s needs.** By Kirby this point is called *Return*. There are two kinds of financing. First there are loans, typically the financing party then is a bank. The new venture will receive an amount of money from the bank and will repay the bank on a monthly or quarterly basis. It will also pay interest, which will generate the profit for the bank. The bank will base their decision whether or not they will grant their loan on how much assets the new venture has. This is important because it practically assures that the new venture can always repay the loan. The bank will find it more important that there is a steady stream of earnings almost from the moment they will grant the loan, then that the new venture grows rapidly. However banks will want the new venture to grow in order to be able to sell more loans or other services like insurances and tax advice. New and fast growing businesses generally do not make a lot of profit (yet), so it is hard for them to cover the monthly payments.

The second way to raise finance for the new venture is through ownership of the stocks. The founders can bring in money or (a part of the) stocks can be sold to other parties, mainly venture capitalist, business angels and family or friends. The other party buys a share of the stocks and thereby owns a part of the venture. Because the profit of the new venture is low, it generally is not possible to pay out any dividends, therefore the only reason the venture capitalist joins is to sell the stocks for a higher price. They hope the business will grow very fast, so they can liquidate the stocks in about 3-7 years with high profit, through the Stock exchange or by selling the stocks to a corporate buyer.

5. **Believable forecast.** A good business plan includes a well thought through realistic sales forecast. Because venture capitalists are looking for high-growth firms, the entrepreneurial team often promises figures that are way too high to achieve. Venture capitalist often handles a couple of thousand requests per year, so they know what the realistic sales forecast rage is for a certain branch. If a certain forecast is way out of range they will seriously doubt the entrepreneurial team. A structured way of deriving the forecast is crucial and it is important to state the assumptions it is based on. It is also recommended to have a pessimistic, realistic and optimistic forecast. If the realistic forecast appears to be not very high growth, it is better to go to a bank because they consider a modest forecast as a virtue.

According to Kirby (2003) there is another point, not mentioned by Barrow et al., that is important to investors. This concerns the founder or entrepreneurial team of the new venture. Kirby states that most financiers would prefer to see a bad idea with a good entrepreneur than to see a good idea with a bad entrepreneur. ‘With a good entrepreneur, a bad idea has a chance of success, while a good idea can be ruined in the hands of a poor entrepreneur.’

### PARSER an acronym for evaluating financing propositions

To show the importance of the founder / entrepreneur, in his book Kirby (2003) refers to a bank that uses the acronym PARSER for evaluating any proposition. The P stands for ‘Person’ which means that it first looks at several aspects of the founder. It looks at the founders’ character (background, integrity, reliability), competence (training, qualifications, track record, experience) and capital (both financial and personal) resources. The other aspects of PARSER are the Amount of funding required, the method of Repayment, the Security and Expediency of the ‘investment’ and the level of Remuneration (Compensation).

### 2.2.5 Give insight in the planning process

Preparing a business plan will give you an insight in the planning process. (Barrow et al., 2001) Kirby explains that if the performance of the business varies from that identified in the plan, the reasons for this and the implications for the business need to be considered, and any remedial action taken. According to him this however is one of the most neglected aspects of the business plan. Once produced the plan is often put away and never used again.
2.2.6 Make the entrepreneur feel more confident

An interesting idea from Barrow et al. (2001) is that once completed, a business plan would make the entrepreneur feel more confident about his or her ability to set up and operate the venture. This sounds very straightforward, since it is inspiring to, even be it to some extend, know what actions need to be done and what the results of the actions will be.

2.3 The Different aspects of The Business Plan

2.3.1 Organizational sources and literature review

To determine what aspects a business plan can appear in a business plan, 10 different sources are consulted. See table 2.1. On the vertical axis the most important aspects are listed. An aspect refers to the sort of information or to the way of describing certain information. If a certain aspect appears in a (model) plan of a certain source, the corresponding cell is filled with a number. The number refers to the number of the chapter in which the corresponding aspect is discussed in a (model) business plan of the source.

It appears that all sources use different aspects in their business plans. Also the number of chapters differs tremendously. According to the KVK a good business plan consists of 4 chapters and according to www.planware.org it consists of 14 chapters. In this table only the aspects that are meant explicitly are by the sources. It can be that aspects that are not mentioned do appear (as part of another aspect) in a plan that is written by one of the sources. The column 'Verhoef' states which aspects are part of the business plan of Procare. This plan is based on the method developed by professor Verhoef, who is a professor at the TU/e in the field of entrepreneurship.

<table>
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<tr>
<th>Aspects of a business plan</th>
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Table 2.1 The different aspects of a business plan.

The column 'Number of times' refers to the number of times an aspect is mentioned. In the next column 'Importance' a categorization is made based on the frequency stated in the column 'Number of times'. In category 1 one can find the aspects that are mentioned most and in category 10 the aspects that are mentioned the least. This gives an indication which aspects are expected at least.

The aspects are divided in three categories, which are: Input / boundaries, Strategic decisions and Clarify report. These categories tell something about the role of the aspect within the plan. In chapter 2.4 these roles and their mutual relationships will be further described.
2.3.2 The different aspects

The aspects recognized in table 2.1 will be discussed here. The intention is to give a clear view of which subjects are part of a certain aspect. This will make it possible to structure the business plan creation process. Therefore each aspect will be described only shortly. The references regarding these descriptions can be found in table 2.1. Also for a more throughout description of how to gather the information and make the decisions concerning the different subjects, one can consult the sources mentioned in table 2.1.

1. **Introduction.** Here some information is given about what kind of company it is, why and by whom the plan is written and what the structure of the plan will be. It is also possible to remark that the plan is confidential and explain how one can contact the author of the plan.

2. **Management summary.** This is an important aspect. This aspect shortly describes each part of the plan. It has to be written in such way that it invites the reader to continue reading.

3. **Strategy, strategic goals.** This concerns the vision, mission, values, strategy, strategic goals and objectives. Described will be what the organization will look like in 5 years and roughly how this will be done.

4. **SWOT.** The SWOT-analysis will determine the Strengths and Weaknesses of the new venture and the Opportunities and Threats that the environment provides.

5. **Value Drivers / Value Blocks.** This is a way to clarify the interrelationship and the implications of the results of the SWOT-analysis. For different elements of the business, the strong and the weak points are pointed out.

6. **Present status / current developments.** This involves how the idea started and what is already developed, produced and sold.

7. **Start-up aspects.** Questions like: ‘What will be the legal form of the business?’, ‘Who will be the owners?’ and ‘What kind of licenses and insurances are needed?’.

8. **Description of product or service.** Here a general description of the product or service will be given. Also the most important features and their advantages will be discussed.

9. **Market profile.** Things like how big the market is, what segments there are, trends, competitors and user/customer profiles will be described.

10. **Marketing strategy, sales plans / projections.** How is the company going to sell and market its products? What sales amounts are expected? How are competitors handled? What are the costs of sales?

11. **Management team / The entrepreneur.** This concerns who the entrepreneur is and how the management team looks like. Also their most important skills and expertise are discussed here.

12. **Financial situation founder / entrepreneur.** This can be interesting, because that helps to determine how much (extra) income the entrepreneur needs, and thereby how much profit the business needs to generate. It is also important if the entrepreneur carries financial risks. This is especially relevant when the business is no legal entity on its own.

13. **Technology / R&D.** In this section the developments, plans and resources in the area of Research and Development will be described. Important is also to determine in where the new venture is ahead of the competition.

14. **Operational plans.** Here the most important elements of the production process, the distribution process and the service process will be described. Issues like how is it organized, the resources and the costs are discussed.

15. **Systems and Organization.** Here things like organizational structures and administrative systems are discussed.

16. **Risks.** It can be good to explicitly name the risks. Most risks follow directly from the SWOT-analysis, but one can also think of for example a crucial resource that suddenly is not available anymore. For each risk also a description of how to handle that risk will be given. The point is to show that the risks do not stand in the way of reaching success, or that the chances are minimal.

17. **Implementation / Roadmap.** Here the most important choices, a timescale and the actions to execute the plan are given.

18. **Financial projections.** This concerns projections of: pro forma profit and loss, cash flows, balance sheet and break-even analysis. Also the most important expected ratio’s will be given. It is advisable to put the detailed financial calculations in the appendix.
19. **Funding / financing.** Here a summary of the financial demands, possible sources and probable conditions will be given. Also an expected duration how long it will take before investors will profit from their investment.

20. **Exit strategy.** This can discuss two kinds of exit strategies. The first is what will happen if the company has no chance of succeeding anymore. Explained will be how to reduce the damage as much as possible. The other kind of exit strategy concerns the situation that the company turns out to be successful. What are the possibilities to cash the stocks?

21. **Conclusion.** Explain why the company will succeed and has to be supported.

Whether or not all these aspects need to be included in the written plan depends on what kind of business it is and what the purpose and audience of the plan is. In any case these aspects all need to be considered when setting up the business.

**2.4 The Three different Roles**

As already mentioned, there are different roles that the aspects of a business plan can fulfill. It is important to make this classification, because it makes it possible to identify the role a certain aspect plays when building a simulation model. How a simulation model based on this classification can be build will be discussed in chapter 4.

**2.4.1 Input and boundaries**

The first role is called input and boundaries, this is in general also the first step in developing a business plan. When writing a business plan, first one has to determine in which domain one wants to operate. These decisions can be viewed in a later stage as the boundaries in which one seeks the optimum strategy. One also needs to find all relevant information within this domain. This information will be the input for the strategy-development-process. That what initiates the development of a business plan will be called an idea.

**Idea**

Starting up a business always starts with an idea. This is in general a thought of one or more entrepreneurs, to start activities based on a certain technology, product or service in a certain application or market. In the next step these three elements will be defined and described more precisely.

**Product / Technology**

Concerning the technology / product or service it is important to describe the current situation in terms of already developed patents, prototypes and expertise, but also in terms of resources that can be devoted to R &D. Here these things and their most important attributes will be described. Also discussed will be what new things and attributes are possible through R&D and which things and attributes R&D can improve. In this stage one needs to focus on what is possible, it is not the intent to already set up an R&D-plan.

**Applications / Markets**

Specified most be on what applications / markets the business will focus. This market can be specified by focusing on a certain sector or industry, a certain geographical market and/or a specific demographical market. The size of the market, the trends and the most important competitors will be described. The question which segment will be entered first, is in this stage not important. Now the point is to determine on which market the company will focus for the time span of the plan and not to develop the marketing strategy.

**Entrepreneur(s)**

With respect to the entrepreneurs, three things need to be described. Firstly, what the qualities and expertise of the entrepreneurs are. Secondly, the current situation according to: family situation, income situation and financial situation with respect to (capital) property and participation in other companies. And thirdly, the motivation and personal goals of the entrepreneurs.
**SWOT / Risks**

After these elements are specified, a SWOT analysis will be used to determine the strengths and weaknesses of the company, as specified, and which opportunities and threats from the environment have to be taken in account. Also the possibilities to keep the most crucial risks as low as possible will be discussed.

**Startup-aspects**

Also the more formal aspects need to be specified. One needs to determine what the best legal form for the organization is. Also decided will be who the owner(s) will be and who will have the rights to make important decisions. Furthermore the required permits, certificates and insurances to operate in the specified domain need to be identified.

![Diagram of From Idea to Domain and From Strategy to Goals](image)

**2.4.2 Strategic decisions**

After determining the operational domain and its specifications, decisions must be made concerning how to operate in that domain. The main characteristics of how to operate within the domain will be determined by the strategy.

**Design desired situation**

In this first part, a description of the organization, according to the chosen strategy, at different points in time, will be given. For each aspect, both the initial situation and other expected possibilities should be described.
**Strategy**

Before defining the strategy, it should be clear what the thoughts are about the development of the technology in the specific market, the goals within that market and important aspects which ensure quality. Usually these follow from defining the corporate Vision, Mission and Values. Further, Critical Success Factors can be used to determine what factors are crucial for the success of the company. These things make clear what is important when further setting up and developing the business. Subsequently it should be formulated how the company will function at start up (should the company already be founded, then the current affairs will be described). I.e. the business model should be described. In case it is anticipated that in the near future another business model will be used or important changes will take place, those, too, should be described. When these expected situations are defined, a series of projections of the strategy in time appears. Currently, however, the processes which guide these changes are not clear, but will be determined in a later chapter.

**Product**

Here the products that will be offered at the start of the company will be described. Aspects like the name, the components it is built of, the costs of the parts and the functional attributes will be discussed. In case the assortment changes during the plan, also the new situations will be described.

**Market**

This point illustrates which market segments will be served at the start of the company. A segment can be specified with respect to many dimensions. Think of: geographically, demographically, price and quality. Again if changes are expected, also the new situations will be described.

**Management Team**

The composition and qualities of the team will be described, and again also the expected situations.

**Production Resources**

When it is clear which products will be offered, it is possible to determine the required means of production. Issues like the production process, required investments and costs per product are discussed.

**Marketing and Distribution**

For each product-market-combination an explanation of what marketing efforts are needed and how the products will be distributed. Important for example is, if any advertisements are needed, and if so, how this will be done. Another important issue is the amount of sales points and where any stocks will be kept.

**Supporting Organization**

Here a short description of the organizational structure will be given. Under this heading all management layers belong and departments and functions that do not belong to Production Resources and Marketing and Distribution. Also the cost structure of the supporting organization will be described. This section can also include (supporting) agents outside organizational boundaries like: the council of recommendation, important investors etc.

**Development plan**

This part describes how the organization moves from the initial situation to the next situation and from that situation to the next. This continues until the whole horizon of the plan is treated. It explains which development processes will enable the desired situation and what investments are needed.

**Process Innovation**

It is important that the right production resources are available at the right time. This aspect will point out what steps will be taken to acquire these means and how the requirements will be met.
Product Innovation
When the company will bring new products to the marketplace, which still have to be developed or are not fully developed yet, it has to be specified how these products will be developed.

Market Innovation
Serving new (segments) of markets, often means that new marketing activities and distribution channels are needed. Here will a description of how to set up these activities and channels will be given.

Organization Optimization
When the organization grows or is otherwise changing, the supporting organization often needs to change too. An explanation of how these changes need to take place (as good as possible) need to be given.

Effects
The described development processes need to make sure that the achieved situations comply to the specified requirements. These can be requirements with respect to quality, user friendliness, delivery time, delivery performance, manageability and this list can probably be endlessly long. It is very important that the reached situations satisfy these requirements and the development processes need to continue until these situations comply (on an acceptable level) to desired specifications.

There is however a second strategically very important issue that determines how desired a situation is. This concerns the financial implications of the situation. That is how high the costs and revenues are in a specific situation. These things are important because they determine if the (financial) strategic goals will be reached. When trying to reach the desired situations, besides satisfying the requirements, one also needs to steer on the financial consequences of the reached situation. The effects that the development processes have on the ability to reach the financial goals, will be discussed in the next subsections. In each case the operational costs as well as the depreciation costs, in other words the cost of investments, will be accounted. Also the development costs, which are the costs to get from one situation to another, will be included.

Reducing Primary Costs
Process innovation as well as product innovation needs, to take place in such way that the costs to produce the product are as low as possible. This is done by taking this in account when developing the product, and also when developing the production process. The expected primary costs in every situation will be described.

Raise Turnover
This can be done by developing a more attractive product and by offering the product to a more attractive market. Also better marketing activities and distribution channels can enable a higher price or more sales. The expected turnover for every situation will be described.

Reducing Secondary Costs
More efficient marketing activities and distribution channels as well as a better organized supporting organization can reduce the secondary costs. The secondary costs in every situation will be described.

Growth Organization
A higher turnover in general means that the organization is growing. Of course directly in financial terms, but often also in terms like number of Full-Time Employees, market share and number of different products. Here, the expected growth is stated. This will be done in terms that are relevant when determining the progress in reaching the strategic goals, like: turnover, number of FTE’s and market share.
Increasing Profit

Reducing the primary and secondary costs as well as increasing the turnover, all have a positive effect on the profit. Increasing the profit can also have a positive effect on reaching other strategic goals, like yield and Return On Investment. Furthermore if the profit is stated in terms of cashflow, the course of the cashflow determines the break-even point. A higher profit can mean that the break-even point is reached faster. Here the expected profit will also be expressed in terms relevant for the strategic goals, like: profit, yield, ROI and break-even point.

Strategic Goals

Especially for starting companies, the growth of the organization is the most important strategic goal. It is also important that the business is makes as much profit as possible, or that the loss is kept as small as possible. Often the growth of the business and the profit reinforce each other. However especially in the beginning it can be that one has to choose between the two. In that case the money that would be profit is invested back into the company. The goals that are formulated here, are then compared with the information that is determined at ‘Growth Organization’ and ‘Increasing Profit’.

Furthermore de total financial needs will be determined and compared with the capital that is available. When more capital is needed, an explanation will be given how this extra capital will be attained.

Method of Professor Verhoef

The classification in roles shows many resemblances with the chapter structure used in the method of Professor Verhoef. The information which is part of the role ‘Input and Boundaries’ can be found in the first two chapters. In chapter 1 ‘Company profile’ the idea, the entrepreneur(s), the product / technology and the start-up aspects are described. Also the SWOT can be described here, but one can also do that in the chapter ‘Challenge’. In chapter 2 ‘Market Analysis’ the aspect called applications / markets is described.

The aspects of ‘Strategic Decisions’ are discussed in the next three chapters. Chapter 3 ‘Challenge’ treats the strategy and strategic goals. The next chapter, chapter 4 ‘Roadmap’ explains how the business develops during the horizon of the plan. In this chapter the other points of ‘Design Desired Situation’ and those of ‘Development Plan’ will be described. Chapter 5 ‘Finance’ discusses the topics of ‘Effects’.

2.4.3 Clarify report

This role is only relevant in the written business plan. The purpose of the introduction, management summary and conclusion is to make the plan better to understand and more readable. The content of these aspects strongly depend on the purpose and the audience of the plan. These aspects are usually written last, when the other aspects are already clear.
Chapter 3 System Dynamics

3.1 Introducing System Dynamics

3.1.1 Jay W. Forrester

System dynamics is founded and largely developed by Jay W. Forrester. He was born in 1918 on a cattle ranch in Nebraska in the middle of the United States. (Forrester, 1989) He then went to the Engineering College at the University of Nebraska. After finishing university he got a job at the Massachusetts Institute of Technology. During World War II he worked with there with Gordon Brown who was a pioneer in “feedback control systems”, to develop servomechanisms for the control of radar antennas and gun mounts. At the end of World War II Forrester started to work on a project to build an aircraft flight simulator. The aim was that the simulator could take wind tunnel data from a model plane and predict the behavior of the airplane before it was build. This simulator was planned as an analog computer but such a computer could not solve the problem at hand. Through a long sequence of changes they came to design the ‘Whirlwind digital computer for experimental development of military combat information systems’, which eventually became the SAGE (Semi-Automatic Ground Environment) air defense system for North America. (Figure 3.1)

Figure 3.1. Jay Forrester (far left, standing) and Norman Taylor (far left, pointing) inspect completed circuitry of the Whirlwind digital computer. (Ref. F-5003)

In 1956 he felt the pioneering days in digital computers were over and since he had quite some management experience, because he was running a several billion dollar operation for quite some years, he decided to join the Sloan School of Management. The Sloan School of Management is a part of MIT that was founded in 1952 with a grant of ten million dollars from Alfred Sloan, who built the modern General Motors Corporation. The idea was that a management school in a technical environment would develop differently than one in a liberal arts environment like Harvard, but when Forrester joined in 1956 only standard courses were introduced. At that time Forrester thought that applying technology to management meant either to push forward the field of operations research, or to explore the use of computers for the handling of management information. Concerning the latter he
thought that the school could not have so much impact because quite some companies were already busy in that area. Operations research on the other hand looked interesting, but was not working with issues that made the difference between corporate success and failure. It did not have the practical importance that Forrester always worked toward.

During his first years at the management school he had an interesting conversation with some people from General Electric. They wondered why some of their plants were sometimes working three or four shifts and then a few years later, half the people would be laid off. Fluctuating demand caused by business cycles was not convincing as the entire reason. He talked with them about how they made hiring and inventory decisions and started some pencil and paper simulation. It was in fact a table which started with columns for inventories, employees, and orders. These conditions and the policies that were followed, then determined how many people would be hired the following week. This resulted in a new condition of employment, inventories, and production, etc. The simulation showed that even with constant incoming orders, one could get employment instability as a consequence of commonly used decision-making policies. This made clear that there was potential for an oscillatory or unstable system that was entirely internally determined. Forrester refers to this first inventory control system with pencil and paper simulation as the beginning of system dynamics.

3.1.2 Industrial Dynamics – A major breakthrough for decision makers

The first article dedicated to system dynamics is Forrester’s article called: “Industrial Dynamics – A major breakthrough for decision makers” that was published in Harvard Business Review in 1958. This article provides a very good picture of the potentials of system dynamics. Therefore I will now first give a short summary of a part and then discuss it afterwards. And repeat that until the end of the article.

In this article Forrester predicted a major change in management and management education: (Page 2) “The next big step in management education will be the development of a basis for fitting together the many management functions into a meaningful whole. Around this central core specialized subjects and experience will take place on more significance. Men can be developed more rapidly. They will be able to start from a point now accessible only through long training or fortuitous experience.”

The new management concepts are based on (1) the recent advantages of electronic data processing, (2) an improved understanding of decision making, (3) experience in analyzing and simulating the characteristics of complex systems (point 2 and 3 both through recent military research) and (4) largely on 20 years of research in information-feedback systems.

(Discussion) Forrester was right that companies and management education more and more started to recognize the need that one needs to look beyond the boundaries of its own (functional) department. However it cannot be said that there now is a “central core” that forms the basis from which any subject is being analyzed. Furthermore, to have a better idea why the four developments he refers to can be considered as the basis for his concepts, one needs to remind that all these developments were closely related to his previous work, research and education.

To illustrate how these concepts and approaches apply to specific business problems, he focuses on one of the main ideas he specified, namely that: (Page6) “...the system (meaning not the paperwork, forms and procedures, but the interrelations between all the company operations) behaves according to the characteristics of the whole and not according to the characteristics of the individual parts.” He explains this through a model of the production and distribution functions, which later also includes promotional effort, noting that a complete picture should include research, engineering and sales. The three kinds of information needed for the model are: organizational structure, delays in decisions and actions, and policy on purchasing orders and inventories.

The structure of the model is in fact a three level supply chain: a factory delivers to distributors, which deliver to retailers, which finally deliver to customers. And besides a physical stream there is an upward information stream: the customers order at the retailers, which in turn order at the distributors.
that finally order at the factory. The numbers in figure 3.2 are the delays in weeks. Concerning the policy there are three kinds of orders: orders that reflect sales, orders to retain the target inventory levels and orders to fill the supply lines with in-process orders and shipments.

By expressing these relations and policies mathematically it is possible to simulate the behavior under various conditions. The first interesting effect that appeared was that when the consumer order rate increased with 10 percent and then remained constant; the whole system starts to fluctuate way beyond that 10 percent, with a factory production output peak of 40 percent above normal level and a downfall to three percent below normal level. (Figure 3.3) So, it showed that a little external shock could have an enormous effect on required capacity, due to the internal structure of the system. Similar behavior is also shown when consumer orders are stochastically and when the production capacity is bound to limits the behavior is even more extreme.

Being able to predict the behavior of a system and to explain why it behaves that way can be very valuable. Even more valuable can it be, to do experiments to determine what changes can improve the behavior of the system. Experiments show that shorter delays as well as retail directly ordering from the factory, show improvements. Also planning production from retail sales data can improve stability. Another possibility is to not refill inventory immediately, but spread this out over a couple of periods. This then becomes a consideration between fluctuating production orders and fluctuating inventories. Now the model is extended by adding advertising to it. Experiments show that a shock in the amount of prospective buyers of ten percent causes the system to show a stable oscillating pattern. In fact in the long term the advertisements are causing the system to oscillate.

(Discussion) While trying to solve a specific problem for people at General Electrics, Forrester discovered that the mechanisms that caused this specific problem were actually quite common procedures and probably present in most production companies. So instead of modeling a specific (problem) situation he was actually modeling a general phenomenon. Moreover he found out that some procedures that tried to solve the problem actually increased the problem or even became the reason why the problem stayed; they became the cause of the problem. The value of the model was that it did not only show where the specific (example-) case could be improved, but also how comparable production-distribution systems could be made more robust. Here Forrester also shows that a good developed model can easily be extended and that this makes it possible to analyze behavior that covers multiple functions of an organization.

At the end of the article, Forrester suggested six high priority areas of study that he believed business and educational leaders should concentrate on:

1. **Money flow.** Models such as discussed should be extended to include money flow and costs, to see how the financial position and its profitability depend on operating decisions.

2. **Consumer market and advertising.** An orderly behavioral structure can be established to structure and explain experience and empirical knowledge of marketing, advertising, and
consumer behavior. A single unified market model should be developed that can cover the whole product life cycle.

3. **Capital investment.** It is important to know what motivations and decisions lead to construction, use and discard of capital equipment. Sources of investment funds, changes in productivity and the danger to over expand capital investment are all aspects strongly determine company growth.

4. **Research and development.** Understanding the effect of different research policies is difficult, since the time between research policy decisions and the resulting influence on company profit and growth is relatively long. It must be clear how this influence can be related to financial resources, production capacity and market development.

5. **Economic conditions.** Besides the internal mechanisms also outside conditions and mechanisms influence company evolution. Therefore the influence of the national and international economic system should be included.

6. **Case studies.** Testing the developed methods in real situations, will help to develop means to cope with the complexities of actual management problems.

(Discussion) Since Forrester's article quite some models in these directions are made, however apart from his 1961 book Industry Dynamics (see below), no main central model that integrated all these subject has been developed. Also very few of the developed models are from a real entrepreneurial perspective.

He also defined four goals to which the industrial dynamics educational program at MIT is aimed at:

1. To develop in the manager a better intuitive feel for the time-varying behavior of industrial and economic systems.

2. To provide a background showing how the major aspects of a company are related to one another, so that the developing manager can derive the greatest benefit from his work experience.

3. To help predict the future course of an existing organization.

4. To improve the future prospects of a company.

(Discussion) All these four goals are perfect for the TE-program thesis project. Where the manager would be the entrepreneur doing the project and the existing organization / company would be the technology start-up the entrepreneur is setting up.

In 1961 Forrester published the first system dynamics book called 'Industry Dynamics'. This book builds further on the '58 article, it explains how to build a system dynamics model and expands the company model in the suggested directions.

### 3.1.3 The further development of System Dynamics

In 1968 system dynamics expanded in various dimensions. Geographically, because Mannheim University in Germany started to research and teach it, and also concerning its field of application, because it moved from corporate modeling to broader social systems. The first book Forrester published in this new domain was called 'Urban Dynamics'. The Urban Dynamics model was, and still is, very controversial because it showed that many well-known urban policies are either ineffective or make urban problems worse. (Online Book) Then in 1970 Forrester was invited by the Club of Rome (http://www.clubofrome.org/). This organization was convinced that the exponential growth of the world's population will demand too much from the world's carrying capacity, which eventually will result in global crisis. They asked if system dynamics could address this problem and Forrester replied that it could. The model showed a collapse of the world socioeconomic system sometime during the twenty-first century, if steps were not taken to lessen the demands on the earth's carrying capacity. The book based on the model called 'World Dynamics' gained a lot of publicity and after that 'Limits to growth' that was based on an improved version got even more attention.

Nowadays there are quite some educational programs that contain system dynamics courses or even are entirely dedicated to learning system dynamics. An example of the latter is the master's degree
program in system dynamics at the University of Bergen in Norway. Here the first year is dedicated to developing knowledge of system dynamics and to learn how to build models. During the second year the student needs to write a thesis with the following objective: “To practice and develop the skills necessary to do good system dynamics work, as well as developing skills to manage and carry out a research project.” This program is provided by the geology department. The subject of the thesis can be chosen by the student him/herself, however it should preferable be in one of the research areas of the system dynamics group.

MIT itself now has an interesting program that focuses on systems design in combination with management, called: System Design + Management. This is an interdisciplinary curriculum and is taught by faculty from all departments in MIT’s School of Engineering and at MIT Sloan and from many in the School of Science and in the School of Humanities, Arts and Social Sciences. A complete list of system dynamics courses can be found at: http://www.systemdynamics.org/courses_in_sd.htm

### 3.2 Paradigm, Language and Methodology

#### 3.2.1 Systems Thinking

From his experiences with system dynamics, Peter Senge and others from MIT, developed a view of how organizations should learn. He defined five disciplines for organizational learning, which he describes in his book The Fifth Discipline (Peter Senge, 1990), which was published in 1990. These are: personal mastery (the notion that an organization can only learn if the people within learn first), mental models, building shared vision, team learning and he called the fifth discipline: systems thinking.

<table>
<thead>
<tr>
<th>Systems Thinking: The Fifth Discipline</th>
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<td>The Informal Encyclopaedia of Education (<a href="http://www.infed.org">http://www.infed.org</a>) describes Peter Senge’s ‘fifth discipline’ as follows: ‘Systemic thinking is the conceptual cornerstone (“The Fifth Discipline”) of his approach. It is the discipline that integrates the others, fusing them into a coherent body of theory and practice (ibid.: 12). Systems theory’s ability to comprehend and address the whole, and to examine the interrelationship between the parts provides, for Peter Senge, both the incentive and the means to integrate the disciplines.’ <a href="http://www.infed.org.uk/thinkers/senge.htm">http://www.infed.org.uk/thinkers/senge.htm</a></td>
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Systems thinking builds forth on the notion that all phenomena can be viewed as (part of or the result from) a system. To be able to explain these phenomena and to know how to handle them, one needs to understand the mechanisms that constitute these systems.

Maani and Cavani describe systems thinking as an emerging discipline for understanding complexity and change. They recognize that system dynamics has three dimensions: paradigm, language and methodology.

#### 3.2.2 Paradigm

According to Maani and Cavani (2000) Systems Thinking is a way of thinking about and describing dynamical relations that influence the behavior of systems. They refer to Richmond who explains that it consists of three ways of thinking (Richmond, 1997):

- **Dynamical thinking**: recognize that the world is not static and that things change constantly.
- **Operational thinking**: understand the ‘mechanisms’ of operational thinking and how things ‘really work’.
- **Closed-loop thinking**: recognize that cause and effect are not linear and that the end (effect) often has influence on the means (cause).

According to wikipedia.org (dutch pages), in philosophy the term paradigm refers to a coherent scheme of models and theories which form an intellectual framework with which ‘reality’ is analysed. Longer existing paradigms often are not experienced as such anymore; education makes a paradigm ‘obvious’.

Thomas Kuhn is most famous for his book *The Structure of Scientific Revolutions* (SSR) (1962) wherein he argued that science does not progress via a linear accumulation of new knowledge, but undergoes periodic revolutions that he called "paradigm shifts", in which the nature of scientific inquiry within a particular field is abruptly transformed. In general, science is broken up into three distinct stages. Prescience, which lacks a central paradigm, comes first. This is followed by "normal science", when scientists attempt to enlarge the central paradigm by "puzzle-solving". Thus, the failure of a result to conform to the paradigm is seen not as refuting the paradigm, but as the mistake of the researcher, contra Popper's refutability criterion. As anomalous results build up, science reaches a crisis, at which point a new paradigm, which subsumes the old results along with the anomalous results into one framework, is accepted.

If we consider systems thinking as a paradigm within the field of management science, it is interesting to evaluate what its role is within the scientific field in the terms developed by Thomas Kuhn. (See above). Although Senges' book was very popular and 'organizational learning' is by some considered as the buzzword of the nineties, systems thinking (its underlying paradigm) cannot, at least at this moment, be considered as the central paradigm that would give the field of management science the status of 'normal science'. This thought is fed by the fact that systems thinking and simulation through systems dynamics is not common management practice in the majority of organizations. Some however hold the view that, especially in management science, there can be quite a gap between what is considered as commonly accepted within the scientific field and commonly accepted within the actual practice of organizations. Even then this thought still holds if you consider that most management education programs do not teach students to use systems thinking as the primary way to analyze during their research projects and/or their work. Interesting to examine is what would be the current central paradigm, in other words, what paradigm has to reach crisis, so that system dynamics will have the chance to become the central paradigm?

Michael Ballé (1994) calls this current central paradigm 'classical rationality'. He refers to the discovery of Sperry and Gazzaniga that our left and our right brain work differently. Several dimensions are suggested to describe the observed differences. The most important are (Left-Right): Logic-Intuition, Reason-Emotion, Active-Receptive, Language-Visual recognition, Reading-Images/patterns, Writing-Depth, Linear processing-Parallel processing, Analysis-Synthesis. Furthermore the right brain can be referred to as holistic.

According to Ballé (1994) our approach to rationality has traditionally been very left brain. Rational thought is supposed to be articulate (composed of several distinct parts or segments (www.babylon.com)) and analytic. Charles Hampden-Turner, a senior researcher at the London Business School, explains that this tendency evolved out of necessity because it had advantages in the early stages of industrial development: '...analysis is the best way of understanding simple mechanisms: it reveals their working by dissection when their function is essentially a sum of parts put to purpose. But the advantage of this style of thinking diminishes when organizations grow large and products constitute complex wholes which encompass many satisfactions. Analysis is of less value when the focus shifts from machines to human systems and social teams because here nothing is gained from dividing the whole into parts. What a group knows and discovers is potentially more than can be carried away in the heads of its separate members.'

This left brain preference has got a strong influence on our decision making. (Ballé, 1994) Decisions need to be made based on facts not on feelings. The individual is held responsible, not the group, this promotes individualism. And because a person alone often cannot solve a problem, this can lead to a tendency that when a problem occurs, it is always someone else's problem; it is 'their problem'. The preference for measurable facts leads to a focus on profits rather than well being. This also has the effect that improvements are mostly sought in (measurable) technology advances rather than in the motivational field. Furthermore the sequential nature of left brain thinking leads to a short term and task oriented vision. It is more important to get things done then to question if what we do is ultimately of value or not.
Only using the left brain preference can have unexpected undesired consequences. (Ballé, 1994) A short term solution can turn out to be a long term disaster. Or for example: spending great amounts of money on technology improvements can have no effect, because the real problem lies within the motivational field. Nevertheless right brain thinking cannot be an alternative. Acting on gut feeling can be very effective when someone works alone and has a very good overview of all relevant aspects. However right brain thinking is mostly non-verbal; it perceives and processes images and feelings and is difficult to articulate and therefore to communicate to others. So when situations become complex and especially when one needs to work with different people, the need for communication makes it very hard to only use right-brain thinking. It would be great to somehow include right-brain and left-brain perspectives in our thinking, even be it for the simple fact that we otherwise would neglect a lot of information. But moreover both sorts of information are very decisive for the way things go, using both can greatly improve the outcome of our decision making.

According to Ballé (1994) systems thinking provide a means to use both left and right brain thinking in our analysis and decision making. Visually it would look somewhat like figure 3.4.

![Figure 3.4. Systems thinking: Combining left-brain and right-brain thinking.](image)

Dennis Sherman (2002, p. 1) explains systems thinking as follows: ‘Systems thinking is a big idea – the idea that you really can understand and tame the complexity of the real world. This complexity cannot be wished away, but if you look at the world at the right way, and have the confidence to embrace complexity rather than being cowed by it, it can indeed be tamed.’

### 3.2.3 Language

Maani and Cavani (2000) say that as a language systems thinking provides a tool to understand complexity and to make dynamical decisions. The systems dynamics language:

- Is visual and works with diagrams.
- Has a set of precise rules.
- Translate perceptions in explicit rules.
- Emphasize closed dependencies (it is a circular language).

So, system thinking as a language has both left and right brain perspectives.

### 3.2.4 Methodology

Systems Thinking uses a set of modeling- and learning techniques. The modeling techniques can be used to understand the structure of a system and the interconnection of its components.
Maani and Cavana distinguish 5 phases in what they call the ‘systems thinking and modelling process’.

1. Problem structuring
2. Causal loop modeling
3. Dynamic modeling
4. Scenario planning and modeling
5. Implementation and organizational learning

**Problem structuring**

First the situation or issue at hand is defined and the scope and boundaries of the study are defined. Also the objectives need to be clearly established, taking into account multiple stakeholders and perspectives. After that preliminary information and data need to be collected. Sources can be: media reports, historical and statistical records, policy documents, previous studies, and stakeholder interviews. (Maani and Cavana, 2000) This phase is very similar to the first phase of general problem solving methodologies like those described in ‘Problem Solving in Organizations’ (Aken, Berends and Bij, 2007)

**Causal loop modeling**

To start the analysis one needs to identify what the main relevant variables are. If possible, try to draw a graph of how (you think that) the variable roughly behaves over time. Now we need to determine how these variables relate to each other.

If a certain variable has an influence on another variable, the effect of this influence can be in two ways. It can either be that when the first variable increases the second also increases, or that when the first increases the second decreases. So, in the first case the two variables change in the same direction and in the second case they change in the opposite direction.

An example of the first would be: Increasing marketing expenditure has such influence on the amount of customers that this amount also increases. See (Figure 3.5), in the figure the small s at the end of the arrow indicates that the variables move in the same direction. An example of the latter would be: Increasing the amount of customers has the effect that the amount of potential customers decreases. See (Figure 3.6), here the o indicates that the variables move in the opposite direction.

Now one can combine multiple relations in one diagram. For example, if one has more customers, then one earns more money and can spend more on marketing. (Figure 3.7) Because the variables strengthen each other this is called a reinforcing loop. There is also another type of loop, called a balancing loop. More potential customers means that it is easier to get (new) customers. But getting more customers, means that there are less potential customers left. So the more customers you have the slower your amount of customers will increase. (Figure 3.8)

It is also possible to combine different loops (Figure 3.9). By identifying relationships, reinforcing and balancing loops and combining these loops, one can build a so called causal loop diagram (CLD).
According to Maani and Cavani, this is a tool for revealing the causal relationships among a set of Variables (or factors) operating in a system.

\[
\begin{array}{ccc}
\text{Marketing} & \rightarrow & \text{My Customers} \\
\downarrow & & \downarrow \\
\text{Potential Customers} & \rightarrow & \text{My Customers}
\end{array}
\]

Figure 3.9. A Causal Loop Diagram

**Dynamic Modeling**

To be able to quantify the system one is modeling, one needs to translate the causal loop diagram into a dynamic model. I will explain how to do this using the causal loop diagram of figure 3.9, which we will call the ‘customer example’.

First one needs to identify what variables are accumulations of certain units. If you consider customers being a firm’s customer for a certain period of time, then you can count the amounts of customers you have at a certain moment. So ‘My Customers’ then is an accumulation of the unit customer. We then call this variable a Stock. ‘Potential Customers’ is also a stock, because it is also possible to count the amount of potential customers when one would put the time on hold at a certain moment. Furthermore, in this system, a certain amount of customers per time unit change from being a potential customer to being our customer. So these customers Flow from the stock ‘Potential Customers’ to the stock ‘My Customers’. This amount of new customers per time unit (‘My New Customers’ in Figure 3.10) is called a Flow.

After the stocks and flows are determined, one needs to decide how many customers there will be at the starting situation and how many customers per period will flow from one stock to the other. Figure 3.10 shows the Dynamic model of these two stocks and the flow and also a graph that shows the Behavior Over Time (BOT) of both stocks.

\[
\begin{array}{ccc}
\text{Potential Customers} & \rightarrow & \text{My New Customers} \\
\downarrow & & \downarrow \\
\text{My Customers} & \rightarrow & \text{My Customers}
\end{array}
\]

Figure 3.10. Two stocks and one Flow

Now is ‘Marketing’ also a stock? ‘Marketing’ actually was defined as ‘marketing expenditure’, it refers to the amount of money per time period spend on marketing. When time is set still, it disappears, this means it is no stock. It is no flow either because there are no Stocks containing money. In fact it Converts extra money gained from sales into an increase of the amount of new customers. Therefore in this model ‘Marketing’ can be considered as a Converter.

Now to build the whole dynamic model from the causal loop diagram we need to include the relation that the more ‘Potential Customers’ there are, the easier it is to get new customers. Which means the less ‘Potential Customers’, the harder it is to get new customers, in other words the smaller the ‘My
New Customers' Flow will be. Figure 3.11 shows how the total model looks like and how the stocks now behave. Now the flow depends on the two mechanisms we added.

**Scenario planning and modeling**
After the dynamic model is complete one defines various policies and strategies. A policy refers to changes to a single internal variable. A strategy is a combination of a set of policies and as such deals with internal or controllable changes. It is also possible to test these strategies under varying external conditions; this is referred to as scenario modeling.

**Implementation and organizational learning**
After deciding which strategy is preferred, this strategy needs to be implemented. Good strategy implementation does not mean only changing a few protocols. It is important that stakeholders understand why certain decisions are made and how they need to work with the new system. To support these goals the developed simulation models can be enhanced by extending them into a management flight simulator also called microworld. This microworld is in fact the same model, only an interactive and user-friendly interface is added.

### 3.3 Reference Models

#### 3.3.1 Two ways of using system dynamics
Forrester presented the model in his article as a model that can explain several general phenomena that can occur in all production companies. He presented system dynamics as a way to gain general knowledge of how (corporate) systems work. (System Dynamics as a learning method) He used system dynamics as a language to discover and describe certain insights, but moreover to 'prove' that these insights are true (under certain conditions), so that others can also learn this knowledge. Maani and Cavani however present the 'systems thinking and modelling process' as a problem solving tool. They use system dynamics to model a certain problem within a certain organisation, and to find the best solution for this specific situation. (System Dynamics as a problem solving method)

These two different views are complementary. In fact to reach either goal, whether it is to gain general knowledge or to solve a specific problem, one should use the strength of the other perspective. Forrester did first build a model to help to solve the problem of a certain company and after that he translated the model into a general model. In fact he didn’t really change it he just described what general knowledge the model generates. Vice versa when one builds a model to solve a specific problem it is wise to first evaluate what general models are available and what knowledge they provide before starting to build a new model. If one is lucky the required model is already available and maybe only need the right numbers to be inserted, but in many cases the available models can serve as building blocks for the new model.
There are two kinds of general reference models. First of all there are models that explain certain phenomena or systems in the real world, like Forrester's model. These learning models provide the ability to learn what mechanisms are behind a phenomenon or how to model a certain kind of system, for example a production-distribution system. Secondly there are reference models that explain how to model a certain mechanism; these models are called 'systems archetypes'. A system archetype refers to a certain set of relations that have a specific behaviour. In this type of reference models the focus is purely on the structure, not the content, so the names of the variables are unimportant.

3.3.2 Systems Archetypes

The systems archetype that comes closest to our customer example would be the 'Limits to success' archetype. This archetype is also called 'Limits to growth'. It consists of a reinforcing and a balancing loop. (Figure 3.12) Maani and Cavana (2000) explain this archetype as follows on page 42 “The reinforcing loop symbolises the desirable effect of motivation and hard work on one’s performance which, in turn, further motivates one toward an even greater exertion, and so on. The balancing loop, on the other hand, acknowledges the fact that there are ‘other’ (limiting) forces such as fatigue and burnout that, if unchecked can slow and even reverse the prospects of success.”

![Figure 3.12 Limits to success archetype](image)

In the customer example the constraint would be that the total market (Potential Customers + My Customers) is fixed. Because I can never have more customers (Performance) than there are on the total market (Constraint), it is obvious that my performance cannot grow unlimited. The strength of the archetype is, that it can also show the limits when they are less obvious. Maani and Cavana give an example where an Airline grew very fast and expanded their fleet size rapidly from the increasing revenue (Effort). However increasing their service capacity went way slower, therefore this service capacity became their 'Constraint'. The increasing number of passengers (Performance) that demanded service caused the service quality (Limiting action) to go down. The effect of the decreasing service quality was that passenger growth slowed down. The airline finally went bankrupt within six years after takeoff.

Other archetypes are:

**Fixes that fail** (Maani and Cavana, 2000; Vennix, 1996): This archetype explains how to model the following situation: When a problem becomes visible because a certain problem symptom occurs, one takes a certain action to solve the problem. This seems to work, however after a while the problem symptom comes back. What happens is that the fix has an unintended consequence that is stronger and causes the problem to sustain.

**Shifting the burden** (Maani and Cavana, 2000): This archetype is somewhat like the fixes that fail archetype only now there are 2 kinds of fixes: a quick fix and a fundamental solution. The quick fix has a side effect that it counteracts the fundamental solution. So putting more attention on the quick fix, gives short term relieve, but makes that the fundamental solution diminishes. This makes the problem only worse in the long term, and so the situation can end up in a vicious cycle.

**Tragedy of the commons** (Maani and Cavana, 2000): If a certain desirable activity or situation becomes the object of an ever-increasing demand, sometimes this leads to undesirable and sometimes disastrous outcomes for all concerned. This archetype explains how this works and how to model that. Vennix (1996) also explains the following archetypes (p. 60-66): *Delayed Balancing Process, Escalation, Limits to Growth, Sucess to the Sucessful*. Sterman (2000) discusses two archetypes that
focus on how to keep track of objects that can have different stages or attribute values, these are: *Aging chain* and *Coflow* (p. 469-512)

### 3.3.3 Learning models

During the 50 years that systems dynamics exists, a lot of system dynamic models are build. Ranging from corporate models, to models of natural processes, to models of chemical reactions, to social-demographic models. The most famous are the models mentioned in paragraph 3.1 that Forrester and his colleagues build.

When starting up a new business, all these kind of models can possibly be interesting and relevant in a certain way. It depends on the activities of the new business, what kind of systems and phenomena are important to understand. When demand depends greatly on social-demographic developments it can be very helpful to build a model that explains these developments. Models on almost any subject can be found in journals like ‘System Dynamics Review’.

There are quite some models that explain corporate systems and phenomena. It is interesting to determine which models in general are especially relevant when starting up a new high-tech enterprise and how to use these learning models to build a model of one’s new enterprise. Chapter 4 provides a framework to do this on an efficient and effective way, called ‘The Enterprise Simulation Framework’.
4.1 Setting up the Framework

When writing a business plan, one describes the current situation, what actions one plans to do and what the effects of these actions are. Concerning the current situation we consider most pieces of information as facts, but a lot of information can only be fully understood when it is placed into context. However, because it is hard to know the whole context or maybe even impossible to objectively determine what can be considered as part of the context, we assume a certain piece of information has a certain meaning. What one considers as the context of a certain piece of information depends on one's reference framework; this determines one's perspective. Furthermore, this context also consists of pieces of information that need to be placed in their context, etc.

The simple fact that our product is worth something, can be seen as the most crucial piece of information for even considering setting up a new business. Recognizing that this statement (that the product is worth something) is actually not a fact but an assumption, opens up a way to examine in what context this piece of information needs to be placed to have an idea of its meaning. In other words, what other assumptions form the context that give this assumption its meaning? Or, on what other assumptions is this assumption based?

The assumption that the product is worth something can be viewed from many perspectives each with its own assumptions. From the perspective of an entrepreneur setting up its own business, in order to make a profit from that product, the product is worth something based on (at least) the following assumptions:

- There are parties that have a need for the product.
- These parties are willing to pay a certain amount of money for acquiring and using this product.
- The amount of money these parties pay to acquire the product is more than the total costs for the entrepreneur to produce and deliver the product.

All these assumptions need to be examined to be able to have an idea what the statement that our product is worth something means; to know if it is a plausible assumption. Now examining these assumptions separately makes no sense and is often not even possible. Determining if there is a need for the product (1), requires that for certain parties its value in terms of functionality and quality is higher than the price that these parties need to pay. To know how much money parties are willing (and able) to pay (2), one needs to know what value you can offer them. To know what value you can offer them you need to know what the product may cost you, which depends on the price customers want to pay (3). These interrelations and the notion that these assumptions have their own underlying assumptions, make that examining the assumptions that underlie a certain statement can very quickly become quite a complex process. To say something about these assumptions in the future and how they develop over time is even more difficult. Simulation can help to discover what assumptions form the basis of the business plan and to examine how they relate to each other.

The success of a strategy is greatly determined by the demand for the product and the required capacities to fulfill this demand. Forrester (Forrester, 1975 see also Sterman, 2000) developed a model that explains 3 important loops that influence demand. (See Figure 4.1) This model will form the starting point for developing a framework of different models to simulate a new venture, in order to place assumptions in their context and examine their (inter-)relations.
Production capacity

Figure 4.1. Three loops that influence demand

It is possible to first examine the reinforcing loop without considering the balancing loops, assuming that orders are delivered immediately. So the first step of the framework is to determine demand, without considering any capacity constrains or delays. The next step is to evaluate what capacities are needed and what influence these capacities have on demand. Thirdly the financial implications will be evaluated. And finally we will examine how we will make sure the company strategy ensures long term survival and growth targets. So the four steps to build a simulation model according to the Enterprise Simulation Framework are as shown in figure 4.2

4.2 Step 1: Determine the Expected Demand

In Forrester’s Model Industrial Dynamics (Forrester, 1958), Forrester focuses on supply and assumes a certain demand level. He then added marketing (sales effort) as an influence on the assumed demand level. Later he also describes that delivery delay, price and quality influences demand. Figure 4.3 (Forrester, 1975, p. 68) describes the flows that connect the company with the market.
Possible competitors are also connected in this way to the market. Nowadays one of the most important factors influencing demand is competition. Especially for a starting company the demand is unknown and its development largely depends on competing companies. Warren (2002) developed a model that incorporates Forrester's sales effort reinforcing loop. (Figure 4.4) However now there is a pool of potential customers from which our company and rival companies gain customers. Quality and price are now included as part of the 'Relative Value' and two loops are added. The first is a balancing loop, enabling the mechanism that the less potential customers there are the less new customers per period there will be. And the other is a reinforcing loop referring to the so called 'Word of Mouth' effect. This means that because satisfied customers will talk about your product to other potential customers, some of these customers will now also (consider to) buy your product, which increases the amount of new customers per period. Warren's model does not consider the effect of delivery delay on sales effectiveness. However as explained before in the first step of the framework we will model the development of demand without taking this factor into account.

Figure 4.4 Basic demand model

In summary the expected demand now depends on the following factors: 1. The relative value of our value proposition. 2. The amount of potential customers. 3. The effectiveness of our marketing efforts. 4. The effect of word of mouth mechanisms. To determine the expected demand, each of these factors should be investigated. The aim is to describe the effects of these factors in numbers that can be used in the simulation. A procedure to determine these effects is described below:

The relative value of our value proposition is a measure for the attractiveness of the product from the perspective of (potential) customers of a certain market. The relative value is determined by how much these customers value the different attributes of the product. So after determining which products will (potentially) be offered, for each product one needs to determine which attributes contribute to the value proposition. Now each attribute have to be valued with a score between 1 and 10. This can be
done by the intuition of the entrepreneur or by interviewing (potential) customers or experts. If it is an attribute already offered in the market place or one has a good few what the possibilities are, the attribute can also be valued by comparing the product with other (possible) products that have the same attribute. For instance if it concerns processing speed of a laptop computer, one can make a range of lowest and highest available speed. Now one can define a relationship between speed and attribute score. For example, if lowest is 1200Mhz and highest 3000Mhz:

\[
\text{Speed} = 1000 + \text{Attribute score} \times 200 \text{ or: } \text{Attribute score} = \frac{\text{Speed} - 1000}{200}
\]

It is also possible to define a non-linear relationship. It is further possible to include a shifting range in the simulation models. Now for each target market, we need to specify how important customers consider the different attributes to be. In other words, which attributes are ‘high priority’ and which ‘low priority’? This can be done by assigning a weight factor to each attribute in such way that the sum of the weight factors is 1. (or 100%) For each product-market combination we can now determine the overall value by multiplying each attribute score by the corresponding weight factor of the market. (Figure 4.5) To determine the relative value we also need to include the price of the product, which can be done in 2 ways. The first is to consider the price as one of the attributes. (Figure 4.6) In this case there is a negative relation between the attribute score and the price level. The second way to include the price is to divide the overall value by the price level. The relation between price and price level also do not have to be linear and also the range can shift.

The amount of potential customers has influence on how fast new customers will be gained. The more potential customers, the easier it is to get new customers. Concerning the initial situation it is important to clarify exactly what is meant by ‘potential customers’. In general one specifies for each market which parties are actively considering purchasing our product or a similar one with the same functionality at this moment. (Warren, 2002) This means these parties are interested in such a product and able to pay its price, but still need to evaluate which product offers enough value compared to its price. Especially for a product with a new and therefore (relatively) unknown functionality, it makes more sense to also regard those parties that would actively consider this or such a product if they would know the functionality is possible, as the potential customers. The total market at a certain moment consists of the potential customers, plus our customers, plus our rivals’ customers. The stocks in the model all are sorts of customers. This is because then it is easy to see the differences and to understand the mechanisms of the model. However counting the amounts in these stocks in average number of products sold per period has certain advantages. In the first place it is easier to include the possibility that a customer first buys a few products and if satisfied buys more later. (This then can be seen as an ‘Internal Word of Mouth’ effect. Secondly it is easier in later steps to determine the required capacities.
The ‘New Customer Development Rate’ in Figure X, is included because the amount of potential customers does not have to be constant. It is possible that because of an improved value proposition or a good marketing strategy, other parties than before become interested in our product. To know how many new potential customers there will be over time, we need to know how many parties per period, are convinced that the value proposition is now high enough and able to afford our product. Therefore, first we must determine the total amount of parties that can ever become interested in, and able to afford our product; the amount of ‘Ever Likely Customers’. The actual new potential customers rate depends on the (increase of the) industry overall value and the industry total marketing. The industry total value is important because parties that first where not interested can become interested if at least one of the competing suppliers on the market, offers a high enough value, compared to the price. So, customer-development rates are commonly driven by the most attractive product on offer, or something close to the most attractive, allowing for the possibility that all customers will be aware of the best that is available. (Warren, 2002) It is further possible that also the amount of ever likely customers can change. This can be because of increasing awareness from industry-wide word of mouth. It is also possible that infrastructural or PEST-analysis factors influence the amount of ever likely customers. For example: economic growth can have the effect that people in general have more money to spend, meaning there will be more people that are ever likely to be able to afford the product.

1. Concerning the effectiveness of our marketing effort, the extent of these efforts mainly depend on the amount of money we dedicate to marketing; our marketing budget. This budget can (directly) depend on gained revenue’s. In that case from each earned Euro a percentage flows to the marketing budget. It can also be a fixed amount based on other considerations. Another option is that is composed of both; a fixed amount increased with a percentage of the revenues. At the very beginning when revenues are still zero or minimal, it is more or less necessary to include a fixed amount, to generate the first sales. With most new ventures, this goes naturally because marketing will mostly consist of the hours the entrepreneur(s) make. These hours generally do not depend on the current revenues. After the marketing budget for each period is clear, the effectiveness per Euro needs to be determined. This depends on what marketing activities are going to take place. It is possible that the activities will mainly consist of sales representatives that travel to potential customers. In that case the amount of representatives that the budget allows and the customers per month each representative is able to persuade to actively consider the product can be estimated. If marketing consists mainly of television-commercials, the amount per commercial can be estimated. Now the total marketing effectiveness per time period, for example per month, will be: The marketing budget per month times the amount of new customers that will seriously consider our product per spend euro.

2. Word of mouth mechanisms can be explained as follows. Selling products that indeed have added value for the customer can have the effect that customers recommend your product to other potential customers. Because of this, these potential customers can also become interested our product. This means that the amount of customers that actively consider our product does not only consist of parties we try to reach through our marketing efforts (we take the initiative), but also of parties that try to reach us (these parties take the initiative). To know the word of mouth effectiveness, we need to determine how many customers will become interested through other customers that already bought the product. The total amount of potential customers from word of mouth mechanisms per period, is the current amount of customers times the word of mouth effectiveness.

The ‘Word of Mouth Growth Factor’, ‘Relative Value’ and ‘Marketing Growth Factor’ together result in the ‘New Customer Incentive’. To calculate the number of new customers per period, the ‘New Customer Incentive’ needs to be multiplied by the ‘Total Market Share Free’. This percentage tells which part of the market consists of potential customers and is calculated as follows: Potential Customers / Total Market = Total Market Share Free. (Figure X) Our expected demand further depends on the expected demand of our rivals. To determine the expected demand of our rivals, for each of the rivals the same four factors have to be investigated.
4.3 Step 2: Matching Capacities to Demand

4.3.1 The capacity problem
Step 1 focused on the development of demand, assuming endless supply. This step focuses on the capacities that are required to deliver the product. Now why is it so important to examine the capacity requirements thoroughly already in the business planning process? One aspect is to see if the costs to produce and deliver the product, are lower then the price the customer wants to pay. The idea is to add up the raw material costs, the man- and machine hour costs and the overhead costs and then determine the costs per product. Another aspect is to make sure there is enough capacity available to be able to deliver demand. The third aspect is to determine how much capital needs to be invested, to judge if the required raised financial resources are or can be made available.

Now a simple procedure would be to first look if the cost per product is lower than its price (determine profit per product), then calculate how much capacity is needed to meet demand and lastly to derive the required capacity investments from this calculated capacity. Now one could judge the situation on the required investments and the profit (profit per product multiplied with demand).

All these capacity requirements need to be judged separately, however they strongly depend on each other. Furthermore if one makes these interrelations explicit, quite some hidden assumptions that strongly influence these capacity aspects will be exposed.

To determine the total cost per product, the man- and machine hour costs need to be determined. However these strongly depend on utilization. For example, a machine that costs 20,000 Euro per year and can run 50*40=2000 hours a year has got a machine hour cost of 10 Euro per hour, if it would be running those 2000 hours. However if demand is still low and it runs only 200 hours, the machine hour cost is 100 Euro an hour.
The Behavior Over Time graph of the model developed in step 1 will in general be quite a fluent line; it shows the main trends. In reality demand will mostly not be that smooth, because demand is stochastically, it is full of small short time fluctuations. While running the business it is hard to determine whether an increase in demand is just a random fluctuation, a trend that really demands a change in available capacity, or composed of (a little) of both. How can one detect if the demand really is higher?

4.3.2 Random fluctuations with a constant demand level

First we discuss the situation that demand is stable and assuming that random fluctuations are continuously present. These random fluctuations influence the stability of the production capacity on various ways, depending on the policies. Figure 4.8 shows a simple model of a company that has a certain demand presented by the order rate and a certain amount of goods that it produces. The backlog is the amount of orders that have not been shipped yet. So the higher the backlog, the more orders are waiting. The amount of goods that is shipped is the same as the shipment rate. Random fluctuations in demand imply that the order rate changes frequently; it is stochastic.

There are four extreme policies how to handle these fluctuations:

1. The first policy is a ‘no end-product inventory’ situation, for example a production to order situation, and the aim is to keep as much of the system as stable as possible. To do this ‘goods produced’ is held constant. With no end-product inventory this means that ‘Goods shipped’ and ‘Shipment Rate’ are constant too. So the variations in order rate will totally end up in variations in the backlog. (See figure 4.9, where a V stands for variable and a C for constant) This means that the delivery times will change enormously and this is something customers might not like. An example would be an ice-salesman who constantly makes only one sort of ice-cream at a fixed speed. Customers wait in the line till their turn. However if there are no customers left and the ice salesman keeps producing at the same speed, there starts to be an inventory (the situation switches to policy 3) and the ice creams will melt. So in order to keep producing a filled backlog of waiting customers is needed. To make sure this is always the case, one has to start with quite a high ‘pool of unfilled orders’ (backlog) that forms a buffer. When it concerns a production to order situation where production can only start after a corresponding order is placed this is only possible if there are enough ‘unreleased production orders’ to keep producing on the same level. To know how many ‘unreleased production orders’ there are, we need to divide the backlog into a part containing ‘unreleased production orders’ and a part with ‘released production orders’. We will see how to do that in section 4.3.3.

2. The next policy is a production to order situation and all orders need to be produced immediately. Now the backlog fluctuates minimal and all fluctuations go directly to the ‘Goods produced’. This means that capacity must be available and dismissible instantly or utilization will fluctuate tremendously. Also there need to be huge amounts of raw materials
and the raw material inventory will also fluctuate. Concerning the delivery time, the time between order placed and goods shipped is now exactly the production time. An example would be a formula 1 pit-stop where the number of service spots (with their own crew) is at least as much as the number of cars on the track. During the race any possible amount of cars at any time can be served immediately. (Figure 4.10)

Figure 4.9. Policy 1

Figure 4.10. Policy 2

Now if it is possible to have an end-product inventory, the inventory is quite useless when the inventory is held constant and ‘goods produced’ is held constant too. ‘Goods shipped’ is then also constant and you end up with the situation that the backlog absorbs all fluctuations like in policy one when there was no inventory. So having an inventory is only useful if either the inventory level fluctuates or the number of goods fluctuates (or both).

3. This policy concerns the situation that there is an inventory and that the ‘Goods produced’ remains constant. Now the inventory level will absorb all variations and will fluctuate enormously. However if the order rate is higher for a while the inventory level will only fall down. So huge amounts of inventory levels are required to always be able to ship. (Figure 4.11)

4. The fourth policy is that the inventory is kept at a certain level (which is high enough to always be able to directly ship the amount of products demanded in a single period) and ‘Goods produced’ each period is exactly the amount of products that the inventory needs to refill to that certain inventory level. This is only possible if goods are produced instantly. (Figure 4.12)

Figure 4.11. Policy 3

Figure 4.12. Policy 4

These four policies are summarized in Figure 4.13. Of course in real organizations it is very likely that a mixture of policies is used. For example, a combination of policy 1 and 2. The variations are then partly absorbed by the backlog and partly by the amount of goods produced. This can be done by
always producing half of the fixed amount of policy 1 and then add up half of the order rate like policy 2.

<table>
<thead>
<tr>
<th>No End-</th>
<th>Production Fixed</th>
<th>Production Unstable</th>
</tr>
</thead>
<tbody>
<tr>
<td>product</td>
<td>Variations are totally absorbed by the backlog. The time between order and shipment varies enormously.</td>
<td>Variations are totally absorbed by the amount of produced goods. The required capacity varies enormously. The time between order and shipment equals the production time.</td>
</tr>
<tr>
<td>Inventory</td>
<td>Variations are totally absorbed by the end-product inventory. The inventory level varies enormously and high inventories are needed. The time between order and shipment is zero.</td>
<td>Variations are totally absorbed by the amount of produced goods. The required capacity varies enormously. The required inventory level depends on the production time. The time between order and shipment is zero.</td>
</tr>
</tbody>
</table>

Figure 4.13. Variation absorption with a constant level of demand

4.3.3 Random fluctuations with an increasing demand level

Now we have an idea what kind of policies there are to absorb random fluctuations when the demand level is constant, we can see what effect certain trends in demand have for the various policies. Let’s say the average demand per period starts with 100 and increases with 10 each period. The order rate now is a stochastic with an increasing mean and the rest of the system remains the same.

1. With policy 1 the only thing that happens is that the backlog rises very high. There is an increasing demand, but no higher production rates or an inventory to deliver from, so it will directly result in customers waiting.

2. Since with policy 2 the external orders are the direct production orders, the production rates increase on the same pace and if production time would be 0 there will be no backlog. However because the backlog now in fact is the amount of orders times the production time, the backlog increases since the amount of orders increase. And the longer the production times the faster the backlog increases.

3. With policy 3 the inventory keeps decreasing and the moment the inventory is 0 and nothing else changes the situation turns into policy 1. The policy 3 model is then no longer applicable.

4. Concerning policy 4 we first examine what happens if the production time is 0. First only the production increases. However at a certain point in some periods the order quantity becomes higher than the inventory level and delivering all products directly from the inventory is not possible. The part that is not delivered becomes backlog, so every time this occurs the backlog increases. This situation then can be considered as a policy 2 situation with a maximum production amount, because the highest production order will be to totally refill the fixed inventory level. Now because the production orders keep getting higher and the backlog also start to increase, at a certain point it is necessary to always refill the total inventory and the production rate is then constant and the situation is like policy 1; the first X orders in line are shipped where X the fixed amount of goods produced in the last period.

Now we examine the situation that the production time is greater than 0. Here also the production increases but because of the time lag between shipping and the corresponding production refill the inventory decreases.
Because the maximum amount of goods that can be shipped is the total available inventory in that period and the production orders are exactly the amount of shipped goods, the production order maximum also decreases. So at a certain moment external orders are equal or over this production order maximum and the production rate remains constant on this level. (Figures 4.15 and 4.16)

These mechanisms make that the point that demand cannot be directly delivered from inventory comes even faster. So the higher the production time the faster the situation turns into policy 2 and eventually policy 1 and the lower the production rate.

So depending on the policies that are used, trends in demand have different effects on the system. Assuming that production times are never 0 and inventories never unlimited, these policies used for constant demand will always end up increasing the backlog. However when ending up in policy 1 the delivery time also increases and when ending up in policy 2 it does not.
Figure 4.16 Policy 4 for constant demand when demand is actually increasing (non-stochastic order rate)

Now the increase of delivery times (in other words: having a lot of customers that want your product and are waiting to pay, only you just are not able to deliver) is one of the biggest hazards. So it is important to make sure to not end up in policy 1. If end-inventory is not possible a pure policy 2 situation would be very interesting only then capacity should be virtually unlimited or instantly adjustable. In most occasions this is not possible or at least very expensive.

Figure 4.17. Combining policy 1 and policy 2

So the most usual solution then is a combination of policy 1 and 2 where there is a certain maximum capacity; that is the number of production starts has a certain limit. If demand is under this maximum capacity, the situation is like policy 2 and if it is over this capacity maximum it is like policy 1. One way to model this, is to let the production rate be the minimum of the order rate and this production
capacity. The problem then is that there will never be a production order to make those goods that did not fit within the capacity. So we must some how remember how many goods still need to be produced. Furthermore, if the maximum capacity is flexible we need to know what it is, before deciding how many goods will start production. This makes that we need to make some adjustments to the model, see Figure 4.17.

When both demand and capacity are stable, the closer capacity is to demand, the more the behavior looks like policy 1. In other words the more fluctuation is seen in delivery times. Now if demand has a certain growing trend and demand starts to be always over the fixed capacity the situation shifts to an only policy 1 situation, (very similar as discussed with policy 4 shifting to 1 situation). So to keep a policy 1+2 situation, as demand increases, capacity needs to increase too. The question is how one knows when this is happening and the capacity needs to increase. The best indication that the situation is shifting to policy 1 is that the average delivery time increases. So, if the average delivery delay, which is the average delivery time minus the production time, is higher than a certain value a capacity increase order needs to be issued. This value must not be to low, otherwise capacity will also be increased when demand is constant and random fluctuations cause some accidental high order rates in a row. And not too high otherwise the delay will frustrate too many customers. Furthermore in the beginning a reliable smoothed delivery delay is difficult to calculate. Therefore also the smoothed utilization needs to be higher than (for example) 80% to decide to increase capacity.

After the decision is made to increase capacity, the extra capacity will be available after a certain period. The amount of extra capacity that needs to be added must be at least enough to lower the average delivery delay under its maximum. But if it is too much, a lot of capacity remains unused (at least for a while). If demand is increasing in a straight line a few experiments can be done to determine what amount works best. This can be a fixed amount or an amount that depends on a system variable. A good rule is to have a fixed amount plus a part, for example half, of the current capacity.

Capacity increase = Fixed amount + k * current capacity

If the growth rate is not stable but there is an exponential growth, this rule is also usable. Then the more exponential the growth, the higher the k should be. Throughout research how to determine the optimal capacity increase is now possible. When the growth rate is exponential, simulations show that the delivery delay will always increase enormously around capacity expansions. This very much depends on the time between the decision to increase capacity and the actual capacity increase. To prevent high peaks in delivery delay, it is good to have all plans how to increase the capacity available, so that one can take action immediately. (Figure 4.18)
Also more research needs to be done to make the model more complete. There still are a lot of assumptions that do not hold in practice. For example, the model assumes that there are always enough raw materials to start any amount of production orders. Also even if the delivery times are endless, the customers that have placed an order, all wait until they get delivered, in other words there are no customers that loose their patience and cancel their order. To take this into account one needs to keep track how long a customer is waiting and compare that with a certain death line. Or if the average waiting time of unreleased orders is higher then a certain time, a part of the orders is cancelled. Furthermore research needs to be done with respect to other policy combinations, for instance how to prevent a policy 3 situation to turn into a policy 1 situation. Also multi stage supply chains can be analyzed by linking multiple capacity models. Ideas how to further develop the model can be found in Industrial Dynamics (Forrester, 1961).

4.3.4 Combining the demand and capacity models

The demand model of step 1 can be linked to the capacity model. The ‘marketing budget’ can now be linked to the ‘shipping rate’ through a ‘payment delay’. The budget is then based on real cash flow instead of sales figures. Now also the ‘word of mouth effectiveness’ can be based on the ‘shipping rate’. Furthermore the amount of new sales/customers can now also depend on the delivery delay. The higher the delivery delay, the lower the amount of new sales/customers. (Figure 4.20)

Demand furthermore depends on the value of the value proposition; one or more models need to be developed to describe how the components of the product each contribute to this value proposition. For instance if the product is a laptop computer, the speed on which it can run programs depends on the CPU (Central Processing Unit), the memory the hard disk speed, etc. So a model can show what components need to be improved in order to improve the value proposition.

For every aspect of the ‘Design Desired Situation’ section of Figure 2.2, one or more models can be build that describe the interaction of demand and capacity. A model that explains (the) mechanisms of a certain ‘aspect’ will be called an ‘aspect-model’. The Strategy model can be a model that describes the major decisions like for example launching a new product, entering a new market, expanding the management team or building a new plant or office. However we will first focus on the initial situation, without considering how we will make a future decision whether or not we will offer our product also to another market. In other words the strategy model will first be a static and not a dynamic model, so it is not necessary to develop a simulation model of it yet. Now for each Product a model can be build as described above, the main focus is now to specify the value proposition. For each Market the model of Warren (2002) needs to be specified, first focusing on potential customers, market growth rate, ever likely customers and competitors. Then describe the price range and attribute weight factors. Concerning the Management Team, the overall strength of the team can be specified to the people that form the team, a bit similar as the product models. Strengths can influence variables within the team model and within other models, like: marketing effectiveness, the effect of high delivery delays, capacity increase delays, scores on attributes of the value proposition etc.

In the first place the Production Resources need to be described as in the capacity model. But what happens when an order is released? What determines the possible amount of production starts? If it concerns the number of service spots in the pit stop, it is quite easy to count them but if it is a certain bottleneck machine it may not be so easy to determine which machine it is, and how many goods per time unit it produces. Also if the capacity of that machine is increased, another machine can form the bottleneck. Furthermore if the production process is complex it, can be hard to determine the production time (stochastic). It is also possible that the capacity constraint is merely the number of goods in the production system (work in progress) which is limited. The possible amount of production starts then depends on the work in progress and also the production time can depend on the work in progress. The model above only tells when it is time to increase capacity and not how the capacity is structured. Therefore it can be necessary to also model the process itself. The Marketing and Distribution model determines the ‘New Customer Incentive’ as explained in Figure 4.7. It is possible that supply chain aspects also have influence on the sales rate.

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Figure 4.19 Overview Total Model
Just like the management team model, the Supporting Organization model translates the strengths of the organizational structure and supporting departments into influences on variables of other models. Furthermore it can contain other variables such as, administrative costs and delays, payment costs and delays, staff recruitment costs and delays etc.

All the specified capacities and strengths have to be established. It is often not that simple to determine, how this will happen, what the costs are and how long it takes. The 'Development Plan' section of Figure 2.2 contains blocks that focus on how to develop these capacities and strengths. Process Innovation contains models that show how the production process will be developed. Will there first be a pilot line? How will new machines or methods be developed? Do we outsource these developments? What kinds of tests are needed? Different set up procedures can be developed and compared. Product Innovation will focus on how the different components and attributes of the product will be developed. What R&D processes and capacities are needed? Then one needs to know how the market will be entered. This can be done through models that belong to Market Innovation. How will the marketing effectiveness be established? What capacities are needed to make the market aware and interested for our product and how will we develop these capacities? Finally the Supporting Organization has to be set up. How do we acquire the financial and administrative systems? How do we develop recruitment methods? How do we train our employees?

4.4 Step 3: Implications for Turnover, Costs and Profit

When we know what capacities are required, how (much) they will be used, what they will cost and how much they will produce, we can calculate the total costs and benefits of the specified strategy. Concerning the Primary Costs we can make 1 or more models to calculate the cash flows, the required capital investments, the value of the inventories or work in progress, the (primary) costs per product etc. Now we can also make decision rules when one or more of these variables are too high and what needs to happen to reduce them. For instance if the (primary) costs per product are too high, the production process, the product design or both need to change. Figure 2.2 shows that these two processes can affect the primary costs. Another important aspect is to compare the required cash flow (liquidity) that is needed to establish a certain capacity; if it is not available it first needs to be acquired by for example a loan. The corresponding delay depends on (infrastructural) agreements and the strengths and capacities of the management team and supportive organizations. Figure 2.2 furthermore shows what developments affect the Turnover and Secondary Costs. Just as for the Primary Costs for these aspects also variables and decision rules can be determined. It is also possible to set budgets that are used in other models through these models. Growth Organization keeps track of how big the organization is in terms of turnover, sales, employees etc. compared to a previous period. These variables can be compared to other variables and also be extended with decision rules. For example: when the sales is declining compared with 1 month ago and the amount of potential customers is still more than 75% of the total market, the marketing and R&D budgets of the current product will be increased and the process innovation budget will be decreased. Such variables and decision rules are also possible for the Profit. Lastly a model can be developed that keeps track of certain overall figures like what and when was the lowest cash balance, the break-even point or the overall profitability. These figures can only be determined after the simulation and therefore cannot be influenced anymore, neither can these variables be part of a decision rule. They can be compared with, or help to determine, the Strategic Goals. This can be input for changes in the whole simulation model or for developing other strategies.

In current practice it is very common to only model the (financial) effects. There are quite some software packages on the market like for example Finan. These packages assume certain demand and capacity developments and are able to calculate all kinds of interesting figures, like Return On Investments, Breakeven Point etc. When writing a business plan it is advisable to enter the information gained from the ESF-simulations into a reliable package like Finan. This has several reasons:

Firstly, at this moment a lot of ESF-models have not been (fully) developed yet. For example: no model has been developed yet that explains the mechanisms of Process Innovation (in the ESF-setting). This is the case for most aspect-models, so it takes a lot of time to develop a simulation model
that includes all relevant aspects. During one thesis project only a limited amount of time is available, so one has to choose which aspects one wants to include in the simulation model(s). If one uses an existing package to calculate the ‘Effects’, it is possible to focus the modeling on the aspects of ‘Desired Situation’ and ‘Development Plan’. However to quickly determine the effects of a strategy it is advisable to have a simple SD-model in the simulation run that roughly calculates these effects. Secondly, if the models planned in the Effects section of Figure 2.2 are not part of or contain any feedback loops, so the functionality of these models would merely be to calculate and add up money flows, it has no use to develop different system dynamics models in this area. The calculations can be done by an existing package. In this case it is also advisable to only build a simple effect model. Thirdly, models like Finan have a long development history and are tested intensively in practice. This development made it possible that the software is able to ensure that the figures entered into it need to be consistent. Entering the information obtained from the simulation(s) into such a package therefore enables one to see if the information is consistent. This makes it possible to check the consistency of the developed model and increase its validity.

4.5 Step 4: Enable Sustainable Competitive Advantage

During steps 1, 2 and 3 the modeling focuses on the initial situation; one uses the models to be able to decide how to start. For example: which product-market combinations will be offered first? In this step we will model how the company can be sustainable in the market or is even able to grow to other markets. To do this we need to repeat steps 1, 2 and 3 and specify the blocks of Figure 2.2 for the new desired situation. The strategy model can now include decision rules concerning major decisions like a possible new product-market combination launch. For example: If the total cash flow is positive for 3 months in a row and the R&D progress of a new product is that far that all attributes have a score of at least 6, then we will start the necessary processes to launch this new product. In other words it is the final ‘go’ – ‘no-go’-decision. Other blocks now need to include models of the new desired situation. If it concerns a new product with an existing market, a new Product model and a new Marketing & Distribution model needs to be developed. Also the market model has to be changed to include sales from both the existing product(s) as the new product. And if the new product has the same Production Resources as the existing one(s), the capacity is shared and decision rules need to be developed to dedicate capacity to the different products. Concerning the ‘Development Plan’ one needs to make models how the conditions that result in the new product-market combination will be reached. In the example there needs to be R&D capacities to make sure that all attributes reach at least 6. Further more models can be developed to determine what capacities are required to be able to actually launch the new product and for example to determine the time between the ‘go’ decision and the first sales. Finally the new models need to be incorporated in the ‘Effects’.
Chapter 5 Project Structure and Required Infrastructure

5.1 Project Structure

5.1.1 Goals and deliveries

Writing a business plan is quite a complex process. Using simulation can improve the results of this process; however unless a good project structure is used there is a fair chance that the process becomes so complex that it does not improve the result at all. As discussed in chapter 3 there are two ways of using System Dynamics, as a learning method and as a problem solving method. Writing a good business plan means that all relevant aspects are thought trough as good as possible. One needs to learn how the mechanisms that together form a business (system) work. This can be done by experimenting with different models that explain aspects of the business. The insights that these models provide can be used as input for the business plan. (System Dynamics as a learning method) However not all relevant mechanisms are modeled yet. Moreover for each business other mechanisms and assumptions form the basis of the business. Therefore during each project a company specific (set of) model(s) needs to be developed. This can best be done by combining and tailoring the existing models and if necessary developing new models that supplement the existing ones. (System Dynamics as a problem solving method)

In the methodology discussion below it becomes clear that from a methodological perspective, one of the goals also needs to be to develop new general insights and theories. This goal is also important, because it helps to develop the ESF. This helps future students to learn more general insights and develop more complex models.

The project will be concluded with a description of how the strategy will be implemented in the form of a business plan. Figure 5.1 shows a summary of the goals and the corresponding deliveries.

<table>
<thead>
<tr>
<th>Goals</th>
<th>Deliveries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Learn general insights and theories</td>
<td>Literature review and model reflection</td>
</tr>
<tr>
<td>Understand mechanisms of new company</td>
<td>Company specific model</td>
</tr>
<tr>
<td>Evaluate possible strategies</td>
<td>Description of experiments and implications</td>
</tr>
<tr>
<td>Develop new general insights and theories</td>
<td>(Description of) New learning models</td>
</tr>
<tr>
<td>Decide how to set up the new company</td>
<td>Written business plan</td>
</tr>
</tbody>
</table>

Figure 5.1. Goals and Deliveries

In fact the first four goals are deliveries for the Masters Degree thesis project and the last delivery is a delivery for the Certificate Technology Entrepreneurship.

5.1.2 Methodology

For a Technology Management thesis project two basic methodological designs are commonly used. The empirical cycle is used when the project is aimed at improving or developing a theory that explains a certain observed empirical phenomenon. The regulative cycle is used when the project is aimed at solving a certain specific problem (situation). (Aken et al, 2007) Both cycles consist of several phases as shown in figures 5.2 and 5.3.
In short the empirical cycle is as follows: By explicitly specifying hypotheses from empirical data (induction) and defining these hypotheses in measurable variables (deduction), a theory with predictive value is developed. This theory will be tested with new empirical data and the results will be interpreted from the perspective of the new theory (evaluation). This can generate ideas for researching other observations and developing new hypothesis. So, here the researcher tries to explain something, through a new developed theory that can predict that a certain phenomenon will occur in a certain situation. However he is not part of the situation and has no influence on the occurrence of the phenomenon.

The Regulative Cycle starts with the identification of a problem, followed by a further diagnosis of that problem. After that a plan is developed how to solve the problem. Then the plan is implemented (intervention) and finally an evaluation takes place to determine if the problem is solved. Here the researcher acts on the notion that there is a problem. He needs to design the solution which will, in his view (according to an agreed norm), solve the problem best. Here designing the solution means not only to design the desired situation but also how the solution will be implemented. The researcher is part of the situation, if he does not act, nothing happens, the problem will not be solved and the project will not succeed. (See Table 5.1)

The ESF-thesis project has in fact elements of both cycles. At first sight it looks to have more resemblances with the regulative cycle. This is because the focus of the project will be on a specific ‘problem situation'; the entrepreneur wants to know how to set up his business as good as possible. The best solution needs to be designed from the perspective of the entrepreneur in the form of a business plan and the value of the plan can only really be determined if it is implemented. This methodology is very sufficient to help the entrepreneur define how he wants to set up his business and to gain understanding what assumptions form the basis for his decisions.

However there are some reasons why viewing the thesis project solely from this perspective is not sufficient. Implementation of the business plan cannot be within the scope of the thesis project. Furthermore, apart from the entrepreneur(s), there are no parties that need to agree with the norm (the demands) that form the basis for deciding what the best solution is, or parties that need to agree with
the (implementation) plan. This makes that the party having the problem, the party providing the solution and the party that needs to accept and value the solution, all are one and the same person; the entrepreneur.

Furthermore, the regulative cycle works from the principle that the problem (situation) is already present and it tries to determine to what extent a solution will solve the problem. When writing a business plan, the 'problem' actually is a complex whole, consisting of a series of 'problems' that might occur at certain moments and can have different consequences. A large part of the problem is in fact to predict which problems are likely to occur and in what extent.

Using the empirical cycle for the thesis project does not have the problem that all stakeholders in the project are in fact the same person. In that case the goal of the project is not to solve a problem, but to form a certain (general) theory. The assignment is an agreement to develop a general theory that explains one or more aspects of the business plan. This usually is an agreement between the university supervisor and the researcher. The university supervisor is a clear stakeholder and has great influence on what will be researched and how the research will be done. There is a clear distinction between the researcher and the principal. Furthermore, the focus of the research now is to formulate a theory that explains certain aspects of the business plan. This makes it possible not only for specific stakeholders, but also to understand when and why problems might occur and how they can be prevented.

From the perspective of the development of the ESF, the project structure is in fact a version of the learning or reflective cycle that van Aken (2004) developed, see figure 5.4. The type of problem can be specified as 'strategy development for high-tech startups through SD simulation' and the chosen cases are the new enterprises the students are setting up. However, from the perspective of the student, the thesis project can also be seen as a 'strategy simulation cycle'. (Figure 5.5) Now the case is the new enterprise the student is setting up and the problems are those issues that need to be solved in order to know how to set up the business.

5.1.2 The six phases
Based on the methodological discussion and the five goals with their corresponding deliveries, a six phase project structure is developed. (See figure 5.6)

Phase 1
The first step is to determine the domain and gain information concerning the aspects in the 'From Idea to Domain' section of figure 2.2. Then according to the SWOT analysis and start-up aspects the entrepreneur(s) determine(s) if there is any possibility to successfully start activities in this domain. If the entrepreneur(s) see so many weaknesses that they do not have any faith in success or it is simply not possible to get a certain required license, it makes no sense to develop strategies or even think of simulating these strategies. So before developing a strategy one needs to make sure that (1) the domain is such that it is interesting to explore what activities are possible. If this is not the case (2) one can
choose to formulate the idea and corresponding domain differently or (3) decide not to set up the business and to look for a better opportunity.

Also during this phase the student needs to get acquainted with system dynamics by doing a short literature review. This report provides a basis for learning the main system dynamics concepts and a guide will be presented to quickly get acquainted with the field.

**Phase 2**

When deciding that the defined domain is worthwhile to explore, one can start to define different strategies that could be interesting for the new venture. It is important to try to define various strategies before starting to model, because it greatly determines the modeling process and at this time the entrepreneur is still open minded for different ideas. Putting a lot of energy into modeling a certain strategy can cause that the focus is so much on this strategy that one becomes blind for other possibly better strategies. The goal of the modeling and simulation process should be to determine the best strategy not to prove that a strategy has certain results.

The Enterprise Simulation Framework provides a structured way to develop models that support the business planning process. The student will evaluate the current models and determine how these models can help him/her to develop insights how to set up the new business. The student can learn (from) the mechanisms that are explained in the current models and see what influence these mechanisms can have on his/her own business. The student needs to be critical and examine the completeness and relevance of the models. He or she needs to develop a view of what variables and mechanisms are not modeled yet or explained well enough, which do have an important contribution to the success of the new enterprise.

Phase 1 and 2 are part of the 'Literature review and research proposal'. This is an assignment which has to be done before the actual thesis project starts. At the end of this assignment the student needs to hand in the first delivery. This report contains: a short literature review of system dynamics, a description of the new enterprise domain, a review of the current ESF models and a description of the different possible strategies for the new enterprise.

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**Project structure**

<table>
<thead>
<tr>
<th>Literature review and research proposal</th>
<th>System dynamics as a learning method</th>
<th>System dynamics as a problem solving method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Literature review on system dynamics</td>
<td>Evaluate the current ESF models in terms of completeness and relevance</td>
<td>Determine how the ESF models need to be improved and/or what new models need to be developed to be able to evaluate the defined strategies</td>
</tr>
<tr>
<td>Define the new enterprise domain</td>
<td>Define different possible strategies for the new enterprise</td>
<td></td>
</tr>
<tr>
<td>Write business plan based on the lessons learned from experimenting with the ESF models</td>
<td>Describe the results of the experiments and the implications for the new enterprise</td>
<td>Develop and/or improve the specified models based on available literature, interviews and/or empirical data</td>
</tr>
<tr>
<td></td>
<td>Describe the general value of the developed models and how they relate to the other ESF models</td>
<td>Make an experimental design and test the defined strategies under various conditions</td>
</tr>
</tbody>
</table>

Figure 5.6. The ESF project structure
Phase 3
At the start of the actual thesis project, the student will determine how the ESF models need to be improved and/or what new models need to be developed to be able to evaluate the defined strategies. This phase is comparable with the diagnosis phase of the regulative cycle. The defined strategies are modeled according to the available models for as far as possible. This shows what information is still missing and which assumptions still need to be explicitly made. It also makes clear what aspects and mechanisms still need to be modeled. Now an execution plan will be defined. It explains how and when the required information will be gathered and analyzed and which aspects and mechanisms will be modeled. It is important that the university supervisor agrees that the specified aspects and mechanisms are not (fully) covered in an available model yet and are indeed of significant importance.

Phase 4
Now the actual model development will start. This process is actually an almost endless series of empirical cycles. It starts with doing observations, which is in this case a very broad concept. Observations can be ideas from literature, interviews, empirical data, available models and even from the models the student is developing. From the observations hypotheses are derived, which can be in the form of single relations, sets of relations, loops or even sets of loops. After that the hypotheses will be modeled and tested. The behavior that the model shows can be evaluated and can serve as observations to define new hypotheses. These new hypotheses can be modeled again etc. At a certain moment the developed model(s) cover all desired aspects and mechanisms and an integrated model can be developed to test the defined strategies. (Delivery 2) Finally according to an experimental design the strategies will be tested under various conditions.

Phase 5
After the final experiments, the results of these experiments and all relevant previous experiments will be described. Furthermore the implications of these experiments and the lessons learned for the new enterprise (strategy) will be described. (Delivery 3) Furthermore a general version or the (new) developed models will be made and. The value of these models and how they relate to the other ESF models will be described. This general learning model will be added to the ESF and will serve as input for future students. (Delivery 4)

Phase 6
The final step is to write the business plan based on the lessons learned. The content of the plan depends on the goal and the audience of the plan, but must reflect the main strategic decisions developed during the simulations. (Delivery 5)

5.2 Supportive infrastructure

5.2.1 Simulation tool
When Forrester did his first computer simulations back in 1957, he used a compiler called SIMPLE ("Simulation of Industrial Management Problems with Lots of Equations"). This compiler was able to translate any set of equations into computer code, in order to run any simulation. This functionality still is the main feature of the current generation of system dynamics tools, which makes that the functionality of the available tools is very similar. The tools do have some differences in user interface and (optional) settings. But because system dynamics simulation is quite intuitive most differences are easy to overcome. However there is one tool called iThink, that has a whole extra interface layer to build so called ‘microworlds’ (already discussed in chapter 3). This extra feature makes it possible to increase the convenience and quality of learning models. At the TU/e there is experience with iThink and another tool called Vensim. Both tools are very suitable for the thesis projects, but we decided to use iThink since learning models are an important part of the thesis project.

5.2.2 Internet site
An important infrastructural requirement is a website that is accessible by the ESF-theses students and their supervisors. This website provides a platform to exchange ideas and information. First the
different sorts of information (content) that will be available through the website will be discussed. After that the (technical) requirements and possible solutions will be discussed. Concluded by a description of the chosen solution.

Content
The website will provide the following (relatively) static information:

- **Project structure.** Information concerning the basic set up of the thesis project as summarized in figure 5.6.
- **ESF basic steps.** Information about the four basic steps to build the simulation model as summarized in figure 4.2.
- **Business plan structure.** Information about the general structure of a business plan like the proposed structure of figure 2.2.
- **General system dynamics information.** Information concerning the field of system dynamics like the information provided in chapter 3

It will furthermore provide the following dynamic information:

- **Available ESF models.** Both a description and the actual model in iThink of the developed ESF-models must be provided. A new model will only be added as part of the ‘available ESF models’ after the corresponding thesis project has ended.
- **Current thesis students.** Information concerning the students that are working on a ESF-thesis project at this moment will be provided, like their: contact information, background, business, associates, supervisors. This is important because students can have the opportunity to contact and learn from each other.
- **Current thesis projects.** It is important to know what kind of models are currently under development. When students need to define their assignment, this overview makes it easier to see what aspects are not already the focus of a current project. Part of the assignment after all is to develop a new learning model concerning a certain aspect.
- **Forum.** The idea to build a forum that provides a means to have group discussions sounds very interesting. People can post models (under development) and ask for feedback. However because e-mail as a way of communication is sufficient so a forum is no high priority.

Requirements
The following (technical) requirements will be taken into account:

- **Reachability.** First of all the website needs to be at a location on the internet that can easily be found by the thesis students. The reachability is even more important because not only the thesis students have to be able to find it, but also students that might be interested in doing an ESF-thesis project or people that are interested in some other way
- **Accessibility.** Only a part of the content of the website should be accessible for everybody on the internet. Especially information about persons and companies, but also concerning developed models should only be accessible by the students and their supervisors
- **Dynamic content.** As pointed out above, part of the content is dynamic. This means that it is not sufficient to change that information on the internet by a weekly or monthly upload by an administrator, but that it must be possible to change the content immediately by the users of the website.
- **Clear user interface.** It is important to be able to navigate easily through the website.

Possible solutions
These solutions seem to be most interesting:

- **Studyweb.** This solution is quite simple. The website is in fact a course on studyweb called: ESF-thesis project. The biggest advantage is that the ‘site’ then immediately can have dynamic content. Is also easy to make sure that certain content can only be viewed by thesis students. However a person without studyweb access cannot view anything at all of the website. This also makes that a person who searches the website on the internet will never find it. Finally the user interface of studyweb is not adjustable and the folder construction can very fast become difficult to navigate through.
Entrepreneurship website TU/e. The idea is to extend the current entrepreneurship website with a section dedicated to the ESF-thesis projects. In this case the website is much easier to reach and findable also by persons that search the internet for it. It is furthermore possible to design a clear interface. However now it is not so easy to have dynamic content and make certain content only accessible by students and supervisors. Although it is possible it will take quite some time and resources.

Description of chosen solution
Both solutions have serious drawbacks. Extending the entrepreneurship website could be done in such way that it meets all requirements is a possibility, but only in the long term. The chosen short term solution is a combination of both studyweb and the entrepreneurship website, as follows:

- **Content with restricted access on studyweb.** At this moment there is no dynamic content that needs to be easily reachable and accessible, so all dynamic content will be offered through the studyweb. The static content that needs restricted access will also be offered this way. For the time being this will be the information concerning the business plan structure and the general system dynamics information.
- **Content with free access on the entrepreneurship website.** A few web pages will be added to the entrepreneurship website that will provide the content that needs to be freely and easily accessible. For now this concerns information concerning the project structure and the ESF basic steps.

5.2.3 Organizational tasks
The developed set-up for the ESF-thesis project implies that certain tasks need to be performed. A good organization of these tasks helps to ensure the quality and scientific value of the projects. Also the learning effort and convenience can be increased by a good execution of these tasks. The following tasks have been recognized:

**Coordinating supervision** A smooth running of multiple parallel ESF thesis projects requires a person with a coordinating role. This coordinator needs to have throughout knowledge of the available models and the models currently in development. This is needed to make sure that the assignments are not overlapping and all have enough scientific added value. This person also needs to ensure model consistency within and between models.

**External communication** Another task will be to communicate the possibilities of the ESF thesis project to potential new participants. The project must be integrated within the rest of the educational program by cooperation with (and coordination between) other courses.

**Website maintenance** There need to be a person that makes sure the information available on the internet is frequently updated. Especially the dynamic content is only useful if it is up to date.

**Feedback and problem solving** Finally a person is needed that provides general feedback and helps to solve practical (modeling) problems.

To enable overall consistency and efficiency these tasks can best be done by the same person. This can be one of the supervisors, a PhD-student, a student-assistant or a research-assistant.
Chapter 6 Example Case: Validus Technologies

6.1 The Business
While developing the basic setup of the ESF, several starting enterprises were contacted. The contacted enterprises have been asked if they were interested in cooperating in a TU/e research project and if they could provide their business plan (if available). The business plans were reviewed in order to get an idea of the basic aspects of a business plan in general (resulting in figure 2.2) and of the specific businesses. The latter was needed in order to select a business to test the developed framework. Several selection criteria were defined in order to select the start-up situation that was as close as possible to an actual ESF-thesis project. There were mandatory criteria and preferred criteria: Mandatory:

- The business needs to be in its start-up phase, which means that it is currently developing and implementing its strategy and that it is not older than 2 years
- The business is based on an innovative idea or technology

Preferably:

- The business is based on a TU/e technology
- The business is already part of the CTE program

Based on these criteria Validus Technologies was selected because this start-up satisfied all criteria. It is a CTE start-up started by three TU/e students. The idea is to produce labels that can be used to determine the validity of an item; in other words it is used to make sure one is really dealing with the item one is looking for, and not with a fake version. An innovative technology developed at the TU/e, makes it possible to produce labels that are very suitable for this task. They decided to first focus on the medicine market, because here the problem of forging is significant and the price per product (package) is relatively high.

6.2 Research Assignment
Validus Technologies agreed to participate in the simulation project. At that moment the entrepreneurs were negotiating with potential investors. A very important issue in such a process is what the value is of the enterprise at the time of investing. Therefore we agreed on the following research question for the simulation project: What is the current value of the business?

The generally used method to determine the value of an investment is the Discounted Cash Flow method. It is a relatively simple method where all cash flows that the investment generates are added up. However a cash flow further away in time is less certain to occur (in that amount). Therefore for each cash flow that is expected in the future, a discount for each period between the moment of valuing and the expected occurrence of that cash flow is taken into account. So in order to determine the value by the DCF method the cash flows (for the near future) need to be determined. This resulted in the following assignment: Determine the cash flows for the coming 5 years.

6.3 Building the Model
During the assignment it became clear that to estimate all cash flows a model of all processes of the entire business would be necessary. Such a model would require the development of models concerning all aspects and all (inter-)relations. Developing an aspect-model from scratch takes a lot of time, so we learned that including all relevant aspects cannot and should not be the scope of the project. Instead a project should include as many relevant available aspect-models as possible and add those pieces to the model that are crucial for the assignment.

Before the assignment, the cash flows were already determined by spread-sheet calculations. These calculations were based on an estimated market share of 10% after five years of operation. This assumption was based on interviews with experts in the market and from the entrepreneurial field. First we determined the value of the organization according to these (spread-sheet) cash flows with the financial tool Finan.
At the time this assignment started, the basic demand model of section 4.2 was practically ready. We started by specifying the variables and parameters and simulate the expected demand development. It became clear that the variables ‘Word of mouth effect’ and ‘Marketing effectiveness’ were not easy to determine, but where very decisive for the outcome of the simulations. Further research is needed to make good estimations of these two variables. However we did some experiments with some rough estimations.

6.4 Results

After the simulations Validus made some adjustments to the valuing and financing of the company. They were able to make agreements to provide the start-up capital. Later on a model was developed that captured all financial streams from both the demand and capacity models. (Figure 6.1) The model shows the value of the company and of the investments in the company.

Because this model was finished at the end of my project, there was no time to specify the model for Validus and calculated the cash flows and values. However a model description can be found in the appendices and the model can be used as a basis for developing financial models for other businesses.
Chapter 7 Conclusion and Recommendations

7.1 Conclusion
At the beginning of my research the following main research question was defined:
Can system dynamics be effectively used in a graduation project (in the Innovation Management MSc program) that is linked to the development of a business plan for a technology start-up? And if so, what is the best way to do that?
I will first discuss and answer the first part of the question and after that the second.

There are several reasons to claim why it would be a good idea to use system dynamics when developing a business plan in the setting of a graduation project. First of all the field of entrepreneurial science is not a grown up science yet at this moment. There is no central paradigm or method that can be considered as the core of the scientific field. System dynamics, embedded in system thinking, can serve as a paradigm for the field of entrepreneurial science because it provides a solid framework to approach any entrepreneurial issue. It is possible to involve any and all aspects of the business plan in the simulations. System dynamics can be used both as learning and as problem solving method. It is important to recognise that it is not sufficient that the entrepreneur first decides what he or she wants and after that analyses how to set up the business according to these decisions. It is way better to first analyse how to set up the business (in a certain domain), because only then it becomes clear what the possibilities (options) are and what the implications are for choosing a certain option. After what he or she learned from the analysis the entrepreneur can make better decisions what he or she wants. System dynamics modelling and analysis is a good means for learning and is very suitable for comparing the implications of certain decisions. It is possible to learn from and incorporate previously build models.

There are also some arguments claiming that this is not a good idea. System dynamics is relatively unknown. Even though it is applicable in many situations and exists already for 50 years, there are not many people that have even heard of system dynamics. It is also rarely used within current organisations. System dynamics is usually not considered as a rational way of analysis. The idea that it works with assumptions rather than facts, give system dynamics a ‘fuzzy’ non-scientific image. Furthermore if someone ‘takes it seriously’, it takes quite some time and effort to understand the way of thinking that underlies system dynamics and systems thinking. From that perspective, it does not make sense to put a lot of effort in something that does not even result in hard figures.

More practically, if the student is doing an assignment where his own new enterprise is in fact issuing the assignment to research how the enterprise should be set up, then the principal, the researcher and (in a certain way) the research object is one and the same person. Such a situation where all stakeholders are in fact the same person can never be a good basis for scientific research. Furthermore building a system dynamics model has no clear boundaries; it is very hard to define a thesis assignment that is challenging, but at the same time doable within time limits. There are not many people that have throughout understanding of system dynamics and can supervise the thesis projects and the difficulty to define good assignments requires intense supervision and feedback. This makes it hard to keep the scientific value of the thesis projects on a high enough level.

My final conclusion concerning the first part of the main research question is that it is possible to effectively use system dynamics to in a graduation project (in the Innovation Management MSc program) that is linked to the development of a business plan for a technology start-up, provided that the goal is to generate insights and not hard figures, that there is a good project structure with multiple stakeholders and also an intense supervision.

This brings us to the second part of the main research question: And if so, what is the best way to do that? The quality of the thesis projects depend on how the three requirements mentioned above are filled in, explained as follows:

The goal is to generate insights and not hard figures If the focus of the projects lie in generating hard figures, and the quality of the project is measured by the quality of the figures, then the quality of the projects will in general be low. This is because in the simulation (often many) assumptions are made
to base input figures on. Because little deviations of these input figures can cause large deviations in
the output figures, the reliability of these figures is not very high. Furthermore simulation can only
show the results of a certain combination of assumptions (with their mechanisms), but does not say
anything about whether or not all relevant assumptions are included. In other words it is only a way to
enable internal validity (consistency) and does not say anything about the external validity. However
a business plan always (also) considers future development with lots of uncertainty, knowing all
figures exactly and knowing all factors that are relevant is just not possible. In other words the
reliability and validity of generated figures always depends on the ‘quality’ of the underlying
assumptions, with what ever method used.
In case the focus shifts to generating insights that are important to successfully develop a new (high-
tech) enterprise, and one measures the quality of the thesis project by the amount of insights generated
and by the way the insights are interpreted with respect to the new enterprise, the quality of the
projects can be very high. System dynamics is a good means to generate insights and to learn how to
apply them to a particular enterprise.

There is a good project structure with multiple stakeholders
Without a clear structure and multiple
stakeholders, the researcher can easily become lost, which tears down the quality of the project. First
of all to make the modelling efforts efficient and effective, a framework is developed called the
Enterprise Simulation Framework. It has four simple steps and provides a means to structure models
that cover different aspects of the business plan. Also a project structure is developed that explains the
different steps and deliveries of the project. In this structure the supervisor is (and in some sense the
ESF itself) are important extra stakeholders. This is because one of the deliveries now is a contribution
to the ESF. This will be in the form of one or more new models that explain mechanisms that are
relevant for high-tech start ups in general. These models will be added to the existing models in the
framework.

Intense supervision
As always the quality of the thesis project, both from a scientific perspective as
from the perspective that students that needs to learn new things and moreover needs to prove that he
or she deserves a Masters Degree, greatly depends on the input and feedback the supervisor provides.
However in this case it is extra important because the student is not used to the way of thinking that
comes with system dynamics and there is not much experience with these kinds of projects.

7.2 Recommendations

There are number of recommended further research directions. The first concerns research
recommendations for the ESF thesis students concerning what ESF models need to be developed and
what improvements can be made on current models. These recommendations are already explained in
chapter 4. However I want to give some more recommendations that can be interesting after a
sufficient set of models is available. At first meta-studies can be performed to analyze how students
determined a certain kind of variable or mechanism. This can concern for example: delays, stochastic
distributions, starting values, parameters, decision rules.
The second direction concerns the research project structure, infrastructure and organization. These
designs are not tested in practice, it is recommended to evaluate them and if necessary adjust them.
For example it is not very clear what information exactly needs to be provided to the students and
other interested parties and in what form.
Something that is also interesting to investigate is to determine other effects beside the financial
effects. The last step in figure 2.2 and step 3 of figure 4.2 both focus on the financial effects. However
it is also possible to focus on other effects. The first idea is to determine how satisfied the employees
are when a certain strategy will be implemented. This can be done by simulating the effects of a
strategy on certain employee attributes, like the effects on morale, on skill-level of employees, on
employee-loyalty, etc. It is also possible to focus on environmental pressure, like on amount of waste,
on emission of gasses that pollute, on energy use, on use of scarce materials, etc. In that case the
‘effects’ step consists of blocks that simulate the effects on respectively employee satisfaction and
environmental pressure. Other possibilities are to evaluate customer satisfaction or supply chain
integration.
Furthermore analysis can be done with respect to the learning effect of the projects. Previous
participants can be asked how they applied the learned insights and what insights they were missing
during the development of their enterprise.
Also research can be done to evaluate how system dynamics can be incorporated into other courses. To increase the quality of the projects, it can help to introduce system dynamics earlier in the educational program. It is interesting to research how and when this can be done.
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• Informal Education – Peter Senge [http://www.infed.org.uk/thinkers/senge.htm](http://www.infed.org.uk/thinkers/senge.htm)
• iThink simulation software [http://www.iseesystems.com](http://www.iseesystems.com)
• KVK (Chamber of Commerce) Kamer van Koophandel. [http://www.kvk.nl](http://www.kvk.nl)
• Leren.nl [http://www.leren.nl](http://www.leren.nl)
• MIT - Systems Design + Management [http://sdm.mit.edu](http://sdm.mit.edu)
• New Venture [http://www.newventure.nl](http://www.newventure.nl)
• Planware.org [http://www.planware.org](http://www.planware.org)
• System Dynamics Society [http://www.systemdynamics.org](http://www.systemdynamics.org)
• University of Bergen – Masters program System Dynamics [http://students.uib.no/?link_id=147&sublink_id=&toplink_id=&mode=show_page&content_id=279&modus=vis_studieprogram&kode=MASV-SYSDY](http://students.uib.no/?link_id=147&sublink_id=&toplink_id=&mode=show_page&content_id=279&modus=vis_studieprogram&kode=MASV-SYSDY)
• University of Bergen - System Dynamics Group: [http://www.ifi.uib.no/sd](http://www.ifi.uib.no/sd)
• Vensim simulation software [http://www.ensim.com](http://www.ensim.com)
• Verhoef. Prof. Dr. Leo - Professor at Eindhoven University of Technology [http://w3.tue.nl/en](http://w3.tue.nl/en)
Appendix 1 Interviews

At the start of the project I did some interviews to get to know different views on how a business plan should look like and how system dynamics can contribute to making a good plan. The interviews eventually more provided a background. Eventually the use of the interviews was more that they provided a background, rather than that they provided direct input for the developed methods and ideas. Therefore I will not describe the interviews and their content. However I will provide the main questions and the persons that were interviewed.

The following questions are the main interview questions. These questions are asked to every interviewee:
1. What kind of organization is your current employer?
2. What is your function within the organization?
3. What education did you perceive?
4. Which aspects are needed in a good business plan?
5. Which aspects need to be connected?
6. Which connections are often not present (well enough)?
7. Which methods and techniques are there to connect the different aspects in a proper way, and/or to evaluate if the aspects already are connected in a proper way?
8. How can simulation support these methods and techniques (to couple different aspects)?
9. What other methods and techniques are possible when one uses simulation?
10. Which simulation software packages can be used best when using these methods and techniques?
11. Do these software packages apply to the defined criteria (see below)? During the interviews these criteria were never discussed. Furthermore because the software package was chosen based on the criteria discussed in section 5.2, the whole list of criteria is not included in this appendix.
12. Are these packages suitable for the analysis of startups?
13. What is the most logical order to write/define the different aspects of a business plan?
14. What (kind of) information is hardest to acquire?
15. What are the best ways to acquire this information?

The following persons were interviewed:
- Roel Verdonschot. Working at the IMK which is the Dutch institute for small- and medium businesses. They focus more on retail and other businesses that are not very innovative.
- Joop Dat. Developed a way to write an integrated business plan called Stratecution. The competences of business are captured in different dimensions. The entrepreneur’s character and other attributes with and then compares it with more hard/financial figures are determined by questionnaires.
- Charles Corbett. A professor working at the University of California Los Angeles. At that university there already is an educational program for entrepreneurs including businessplan-thesis-project.
- Henk Akkermans. Professor at the University of Tilburg (UvT). He is an expert in system dynamics and gave courses SD at the TU/e in the past.
Appendix 2 Demand Model

Market 1
STOCKS
Potential_Sales(t) = Potential_Sales(t - dt) + (- New_Sales_PD_1) * dt
INIT Potential_Sales = 1000
Explanation:
• This is the maximum possible sales increase; the demand that is not fulfilled (yet).
  This stock declines when Product 1 has new sales.
• Units: Products
• INIT: Start value at t=0

Sales_PD_1(t) = Sales_PD_1(t - dt) + (New_Sales_PD_1) * dt
INIT Sales_PD_1 = 0
Explanation:
• This is the current amount of sales of product 1. This stock increases when Product 1
  has new sales.
• Units: Products
• INIT: Start value at t=0

FLOWS:
New_Sales_PD_1 = New_Cust_Incentive*Total_Market_Share_Free
Explanation:
• This is the current amount of new sales of product 1. This flow depends on the New
  Customer Incentive and the Total Market Share Free. The higher these 2 variables are
  the higher the amount of new sales of product 1.
• Units: Products/Time unit
• INIT: Start value at t=0

AUXILLIARIES:
Total_Market = Potential_Sales + Sales_PD_1
Explanation:
• This is the total amount of sales possible within this market.
• Units: Products

Total_Market_Share_Free = Potential_Sales/Total_Market
Explanation:
• This is the percentage of the total demand within this market that is not fulfilled (yet).
• Units: percentage

Upper_price_bound = 10
Explanation:
• This is the maximum price that can be asked for the product
• Units: Euro

Lower_price_bound = 0.1
Explanation:
• This is the minimum price that can be asked for the product
• Units: Euro

Weight_Factors[1] = 0.4
Explanation:

- This is a number between 0 and 1. It determines how important attribute value 1 is when calculating the overall value.
- Units: dimensionless

\[ \text{Weight\_Factors}[2] = 0.3 \]

Explanation:

- This is a number between 0 and 1. It determines how important attribute value 2 is when calculating the overall value.
- Units: dimensionless

\[ \text{Weight\_Factors}[3] = 0.3 \]

Explanation:

- This is a number between 0 and 1. It determines how important attribute value 3 is when calculating the overall value.
- Units: dimensionless

**Marketing and Distribution Product 1 Market 1**

**AUXILIARIES:**

\[ \text{Available\_Salesforce\_FTE} = \frac{\text{Marketing\_Budget}}{\text{Cost\_1\_FTE\_Salesforce}} \]

Explanation:

- This is a number between 0 and 1. It determines how important attribute value 3 is when calculating the overall value.
- Units: dimensionless

\[ \text{Cost\_1\_FTE\_Salesforce} = 1000 \]

Explanation:

- This is the amount of money that 1 Full Time Employee within the sales force costs per time unit.
- Units: Euro

\[ \text{Current\_Amount\_of\_Sales\_PD\_1} = \text{Sales\_PD\_1} \]

Explanation:

- This number is in fact the same number as Sales\_PD\_1 in the Market 1 section. It serves as a dummy to make the model more clear.
- Units: Products

\[ \text{Extra\_Marketing\_Budget\_per\_Product\_Sold} = 1 \]

Explanation:

- This number represents the amount of money that is added to the marketing budget for each product sold in that period.
- Units: Euro

\[ \text{Marketing\_Effectiveness} = 1 \]

Explanation:

- This parameter determines how many extra customers (in terms of sales) will actively consider our product for each FTE dedicated to marketing in that period.
- Units: Sales / Euro

\[ \text{Marketing\_Growth\_Factor} = \text{Available\_Salesforce\_FTE} \times \text{Marketing\_Effectiveness} \]

Explanation:
• This factor represents the amount of extra customers (in terms of sales) will actively consider our product. It depends on the size of our sales force and on the effectiveness of our marketing efforts.

• Units: Sales

Marketing Budget = Marketing starting budget + (Extra_Marketing_Budget per Product Sold*Current Amount of Sales PD_1)

Explanation:
• This is the amount of money that is dedicated to our marketing efforts. It consists of a part that is fixed or at least not depending on the amount of sales and a part that depends on the amount of sales.
• Units: dimensionless

Marketing starting budget = 1000
Explanation:
• This is the amount of money that will be spent on marketing each period. In this model it is fixed but it can depend on other variables.
• Units: dimensionless

New_Cust_Incentive = Relative Value * (Marketing Growth Factor+Word of Mouth Growth Factor)

Explanation:
• This is the amount of new customers (in terms of sales) in that period in case the total market is available. First the total amount of customers actively considering the product is calculated by adding those from our marketing efforts to those from word of mouth effects. The amount of customers that will actually buy our product depends on the relative value of our product.
• Units: Products

Overall_Value = ARRAYSUM(Value_Attributes[*])

Explanation:
• This is the value the product has independent of the price. It is the weighted mean of the attribute scores.
• Units: dimensionless

Price = 9
Explanation:
• This is the amount of money that will be asked for the product.
• Units: Euro

Price_Level = ((Price-Lower_price_bound)/(Upper_price_bound-Lower_price_bound)*9)+1

Explanation:
• This is a level between 1 and 10 that indicates how high the price of the product is compared to the highest and lowest possible price.
• Units: dimensionless

Relative_Value = (Overall_Value/20)+((10-Price_Level)/20)

Explanation:
• This parameter determines what the value of the product is compared to the price.
• Units: dimensionless

Value_Attributes[Attributes] = Weight_Factors[Attributes]*Rating_Attributes[Attributes]

Explanation:
• This is a number determining the weighted value of each attribute.
• Units: dimensionless

Word_of_Mouth_Effectiveness = 0.1

Explanation:
• This is a parameter that determines how many customers (in terms of sales) will actively consider our product, per product sold the previous period.
• Units: Products / Product

Word_of_Mouth_Growth_Factor = Current_Amount_of_Sales_PD_1 * Word_of_Mouth_Effectiveness

Explanation:
• This is the amount of customers (in terms of sales) that will actively consider our product from word of mouth effects.
• Units: Products

Product 1
CONVERTERS:
Rating_Attributes[Attributes] = 6

Explanation:
• This is a number between 1 and 10. It represents how high the product scores on the attribute.
• Units: dimensionless

Graphical functions
There are no graphical functions in this model.

Simulation parameters
• Unit of time = weeks.
• Total simulation time = 260 weeks
• Simulation algorithm: Euler’s method.
• Step size (dt) = 0.25.

Model development
The development of the model is already discussed in the report.
Appendix 3 Capacity Model

Policy 1
STOCKS:
Sales(t) = Sales(t - dt) + (new_sales) * dt
INIT Sales = 100
   Explanation:
   • This is the demand level of the current period. It represents the average number of
   products sold that period.
   • Units: Products
   • INIT: Start value at t=0

Backlog(t) = Backlog(t - dt) + (Order_Rate - Shipment_Rate) * dt
INIT Backlog = 500
   Explanation:
   • This is the number of orders (1 product per order) waiting to be fulfilled.
   • Units: Products
   • INIT: Start value at t=0

Inventory(t) = Inventory(t - dt) + (Goods_produced - Goods_shipped) * dt
INIT Inventory = 0
   Explanation:
   • This is the number of products that is waiting to be shipped. With policy 1 this number
   is 0.
   • Units: Products
   • INIT: Start value at t=0

FLOWS:
new_sales = 0
   Explanation:
   • This is the increase in demand level. It determines with how many products the
   average demand increases.
   • Units: Products

Order_Rate = NORMAL(Sales,50)
   Explanation:
   • This is the total number of products that is ordered in that time period. It is a
   stochastic with its mean equal to the demand level (as defined in the stock ‘Sales’).
   • Units: Products

Shipment_Rate = Goods_shipped
   Explanation:
   • This is the number of products that is shipped to the customer that period.
   • Units: Products

Goods_produced = 100
   Explanation:
   • This is the number of products that is produced that period. With policy 1 it is a fixed
   amount.
   • Units: Products
\[
\text{Goods\_shipped} = \text{MIN}(\text{Goods\_produced}, \text{Backlog})
\]

**Explanation:**
- This is the number of products that is shipped that period. With policy 1 this number is the amount of goods produced, provided that there are enough orders in the backlog to ship the goods to. If this is not the case the goods that cannot be shipped will become inventory and the situation shifts to a policy 3 situation.
- **Units:** Products

**Policy 2**

**STOCKS:**

\[
\text{Sales}(t) = \text{Sales}(t - \text{dt}) + (\text{new\_sales}) \times \text{dt}
\]

**INIT** \text{Sales} = 100

**Explanation:**
- This is the demand level of the current period. It represents the average number of products sold that period.
- **Units:** Products
- **INIT:** Start value at \( t=0 \)

\[
\text{Backlog}(t) = \text{Backlog}(t - \text{dt}) + (\text{Order\_Rate} - \text{Shipment\_Rate}) \times \text{dt}
\]

**INIT** \text{Backlog} = 0

**Explanation:**
- This is the number of orders (1 product per order) waiting to be fulfilled.
- **Units:** Products
- **INIT:** Start value at \( t=0 \)

\[
\text{Inventory}(t) = \text{Inventory}(t - \text{dt}) + (\text{Goods\_produced} - \text{Goods\_shipped}) \times \text{dt}
\]

**INIT** \text{Inventory} = 0

**Explanation:**
- This is the number of products that is waiting to be shipped. With policy 2 this number is 0.
- **Units:** Products
- **INIT:** Start value at \( t=0 \)

**FLOWS:**

\text{new\_sales} = 0

**Explanation:**
- This is the increase in demand level. It determines with how many products the average demand increases.
- **Units:** Products

\text{Order\_Rate} = \text{NORMAL}(\text{Sales}, 50)

**Explanation:**
- This is the total number of products that is ordered in that time period. It is a stochastic with its mean equal to the demand level (as defined in the stock 'Sales').
- **Units:** Products

\text{Shipment\_Rate} = \text{Goods\_shipped}

**Explanation:**
- This is the number of products that is shipped to the customer that period.
- **Units:** Products

\text{Goods\_produced} = \text{Production\_time}

**Explanation:**
• This is the number of products that is produced that period. With policy 2 it is equal to the order rate \( x \) time units ago. Here \( x \) is equal to the production time (as defined in the auxiliary 'production time').
• Units: Products

Goods_shipped = Goods_produced
   Explanation:
   • This is the number of products that is shipped that period. With policy 2 this is the same amount as the number of goods produced.
   • Units: Products

AUXILLARIES
Production_time = DELAY(Order_Rate,2,0)
   Explanation:
   • This is the time between the start of a production order and the completion of that order.
   • Units: Time units

Policy 3
STOCKS:
Sales(t) = Sales(t - dt) + (new_sales) * dt
INIT Sales = 100
   Explanation:
   • This is the demand level of the current period. It represents the average number of products sold that period.
   • Units: Products
   • INIT: Start value at \( t=0 \)

Backlog(t) = Backlog(t - dt) + (Order_Rate - Shipment_Rate) * dt
INIT Backlog = 0
   Explanation:
   • This is the number of orders (1 product per order) waiting to be fulfilled. With policy 3 this number is always 0, provided that there is always enough inventory to deliver directly. If this is not the case (anymore) the situation shifts to a policy 1 or a policy 1+3 situation.
   • Units: Products
   • INIT: Start value at \( t=0 \)

Inventory(t) = Inventory(t - dt) + (Goods_produced - Goods_shipped) * dt
INIT Inventory = 500
   Explanation:
   • This is the number of products that is waiting to be shipped. With policy 3 the initial number of products need to be relatively high because fluctuations are entirely absorbed by the inventory.
   • Units: Products
   • INIT: Start value at \( t=500 \)

FLOWS:
new_sales = 0
   Explanation:
   • This is the increase in demand level. It determines with how many products the average demand increases.
   • Units: Products
Order_Rate = NORMAL(Sales, 50)

Explanation:
- This is the total number of products that is ordered in that time period. It is a stochastic with its mean equal to the demand level (as defined in the stock ‘Sales’).
- Units: Products

Shipment_Rate = Min(Order_Rate, Inventory)

Explanation:
- This is the number of products that is shipped to the customer that period. With policy 3 this is the same amount as the order rate, provided that there are enough products in the inventory.
- Units: Products

Goods_produced = 100

Explanation:
- This is the number of products that is produced that period. With policy 3 it is a fixed amount.
- Units: Products

Goods_shipped = Shipment_Rate

Explanation:
- This is the number of products that is shipped to the customer that period.
- Units: Products

Policy 4
STOCKS:
Sales(t) = Sales(t - dt) + (new_sales) * dt
INIT Sales = 100

Explanation:
- This is the demand level of the current period. It represents the average number of products sold that period.
- Units: Products
- INIT: Start value at t=0

Backlog(t) = Backlog(t - dt) + (Order_Rate - Shipment_Rate) * dt
INIT Backlog = 0

Explanation:
- This is the number of orders (1 product per order) waiting to be fulfilled. With policy 4 this number is always 0, provided that there is always enough inventory to deliver directly. If this is not the case (anymore) the situation shifts to a policy 1 or a policy 1+3 situation.
- Units: Products
- INIT: Start value at t=0

Inventory(t) = Inventory(t - dt) + (Goods_produced - Goods_shipped) * dt
INIT Inventory = 500

Explanation:
- This is the number of products that is waiting to be shipped. With policy 4 the initial number of products needs to be moderate because fluctuations are absorbed by the number of products produced, but need to be directly delivered from the inventory.
- Units: Products
- INIT: Start value at t=0
FLOWS:

\[\text{new\_sales} = 0\]

*Explanation:*
- This is the increase in demand level. It determines with how many products the average demand increases.
- Units: Products

\[\text{Order\_Rate} = \text{NORMAL(Sales,50)}\]

*Explanation:*
- This is the total number of products that is ordered in that time period. It is a stochastic with its mean equal to the demand level (as defined in the stock 'Sales').
- Units: Products

\[\text{Shipment\_Rate} = \text{Min(Order\_Rate,Inventory)}\]

*Explanation:*
- This is the number of products that is shipped to the customer that period. With policy 4 this is the same amount as the order rate, provided that there are enough products in the inventory.
- Units: Products

\[\text{Goods\_produced} = \text{Production\_time}\]

*Explanation:*
- This is the number of products that is produced that period. With policy 4 it is equal to the number of goods shipped \(x\) time units ago. Here \(x\) is equal to the production time (as defined in the auxiliary 'production time').
- Units: Products

\[\text{Goods\_shipped} = \text{Shipment\_Rate}\]

*Explanation:*
- This is the number of products that is shipped to the customer that period.
- Units: Products

AUXILLARIES

\[\text{Production\_time} = \text{DELAY(Goods\_shipped,4,100)}\]

*Explanation:*
- This is the time between the start of a production order and the completion of that order.
- Units: Time units

Graphical functions

There are no graphical functions in this model.

Simulation parameters

- Unit of time = weeks.
- Total simulation time = 260 weeks
- Simulation algorithm: Euler's method.
- Step size (dt) = 0.25.

Model development

The development of the model is already discussed in the report.
Appendix 4 Overall Financial Effects Model

Overall financial effects
STOCKS:
Cash_balance(t) = Cash_balance(t - dt) + (Cash_In - Cash_Out) * dt
INIT Cash_balance = 0
   Explanation:
   • This is the amount of money currently available. It is determined by the amount of money available 1 period ago plus the amount of money received last period, minus the amount of money spend in that period.
   • Units: Euro
   • INIT: Start value at t=0

Money_loaned(t) = Money_loaned(t - dt) + (Take_loan - Repay_loan) * dt
INIT Money_loaned = 0
   Explanation:
   • This is the amount of money currently loaned from any external party. It is determined by the amount of money loaned 1 period ago plus the amount of money received from extra loans taken last period, minus the amount of money repaid in that period.
   • Units: Euro
   • INIT: Start value at t=0

Money_Invested(t) = Money_Invested(t - dt) + (Investment) * dt
INIT Money_Invested = 0
   Explanation:
   • This is the amount of money currently invested by any external party. It is determined by the amount of money invested 1 period ago plus the amount of money invested extra last period.
   • Units: Euro
   • INIT: Start value at t=0

Return(t) = Return(t - dt) + (Profit_Cashed) * dt
INIT Return = 0
   Explanation:
   • This is the amount of money ever cashed by investors as profit from their investment. It is determined by the amount of money cashed 1 period ago plus the amount of money cashed extra last period.
   • Units: Euro
   • INIT: Start value at t=0

Company_value(t) = Company_value(t - dt) + (Discounted_cashflow) * dt
INIT Company_value = 0
   Explanation:
   • This is the value of the company at t=0 according to the Discounted Cashflow Method when the cashflows till the current period are taken into account.
   • Units: Euro
   • INIT: Start value at t=0

Investment_value(t) = Investment_value(t - dt) + (Discounted_cashflow_2) * dt
INIT Investment_value = 0
   Explanation:
• This is the amount of money ever cashed by investors as profit from their investment. It is determined by the amount of money cashed 1 period ago plus the amount of money cashed extra last period.
• Units: Euro
• INIT: Start value at t=0

FLOWS:
Cash_In = Investment+Take_loan+Revenue

Explanation:
• This is the amount of money received in the current period.
• Units: Euro

Cash_Out = Fixed_Costs+Interest_Payed+Variable_Costs+Repay_loan+
Capacity_Increase_Costs+Marketing_Budget+Profit_Cashed

Explanation:
• This is the amount of money spend in the current period.
• Units: Euro

Discounted_cashflow = Cash_flow*Discount_factor

Explanation:
• These are all cashflows of the company during the current period, multiplied by a discount factor.
• Units: Euro

Discounted_cashflow_2 = Cash_flow_2*Discount_factor_2

Explanation:
• These are all cashflows involved by any investment in the company during the current period, multiplied by a discount factor.
• Units: Euro

Investment = IF(0<TIME) AND(TIME<2) THEN(130000) ELSE(0)

Explanation:
• This flow determines the investments in the company. In this case there is 1 investment of 130000 Euro in period 1.
• Units: Euro

Take_loan = IF(0<TIME) AND(TIME<2) THEN(30000) ELSE(Capacity_Increase_Costs)

Explanation:
• This flow determines the loans the company takes. In this case there is 1 loan of 30000 Euro in period 1 and each capacity increase step is financed through a (corresponding loan.
• Units: Euro

Repay_loan = 100

Explanation:
• This flow determines the amount of money the company repays each period.
• Units: Euro

Profit_Cashed = IF(TIME>104)AND(Smoothed_Cash_Balance>50000)THEN(MAX(((Smoothed_Cash_Balance-10000)*0.5)/52,0))ELSE(0)

Explanation:
• This is the amount of money investors will cash during this period. Only after 104 weeks and if the cash balance is higher than 50000, any profit will be cashed. The amount of money cashed per year is half of the cash surplus higher than 10000. Per week it is this amount divided by 52.
• Units: Euro

AUXILLARIES:
Capacity_Increase_Costs = Capacity_increase*Costs_per_capacity_increase_unit
Explanation:
• This is the amount of money spend this period on increasing capacity.
• Units: Euro

Cash_flow = Cash_In-Cash_Out
Explanation:
• This is the overall change in available money this period.
• Units: Euro

Cash_flow_2 = Profit_Cashed-Investment
Explanation:
• This is the overall change in money invested this period.
• Units: Euro

Cost_per_Available_Capacity_unit = 0.5
Explanation:
• This is the amount of money that needs to be spent to keep 1 capacity unit available.
• Units: Euro

Cost_per_Product = 5
Explanation:
• This is the amount of money that needs to be spent to produce 1 product.
• Units: Euro

Costs_per_capacity_increase_unit = 20
Explanation:
• This is the amount of money that needs to be spent to make 1 capacity unit available.
• Units: Euro

Discount_factor = (1-0.10)^(TIME/52)
Explanation:
• This factor determines to what extend cashflows during a later period are weighted less when determining the value of the company. Per year the cashflows are weighted 10% less.
• Units: Euro

Discount_factor_2 = (1-0.10)^(TIME/52)
Explanation:
• This factor determines to what extend cashflows during a later period are weighted less when determining the value of the investment(s). Per year the cashflows are weighted 10% less.
• Units: Euro

Fixed_Costs = Capacity*Cost_per_Available_Capacity_unit+Overhead_Costs
Explanation:
• This variable represents all costs that are not directly depending on the amount of products produced.
  • Units: Euro

Interest_Payed = Money_Loaned*Interest_rate

Explanation:
• This is the amount of money that is paid as interest this period. It depends on the amount of money loaned and the interest rate.
  • Units: Euro

Interest_rate = 0.08/52

Explanation:
• This factor determines the amount of interest paid this period. In this case it is 8%.
  • Units: Euro

Overhead_Costs = 0

Explanation:
• This is the amount of money paid this period that does not belong to any of the other costs.
  • Units: Euro

Payment_Delay = DELAY(Shipment_Rate,5)

Explanation:
• This represents the (average) time between the sales of a product and the corresponding receiving of money.
  • Units: Euro

Return_On_Investment = Return/MAX(Money_Invested,1)

Explanation:
• This factor shows how good the investment is till now. It is a commonly used quality rating for investments.
  • Units: Euro

Revenue = Payment_Delay*Price

Explanation:
• This is the amount of money earned from sales this period.
  • Units: Euro

Smoothed_Cash_Balance = SMTH1(Cash_balance,52)

Explanation:
• This is the amount of cash available on average the last 52 weeks.
  • Units: Euro

Variable_costs = Production_Start*Cost_per_Product

Explanation:
• These are the total costs that are directly depending on the amount of products produced.
  • Units: Euro

Graphical functions
There are no graphical functions in this model.

Simulation parameters
- Unit of time = weeks.
- Total simulation time = 260 weeks
- Simulation algorithm: Euler's method.
- Step size (dt) = 0.25.

Model development
The development of the model is already discussed in the report.
Appendix 5 E. S. F. Thesis Project Protocol

The Enterprise Simulation Framework Thesis Project (ESFTP) is one of the possible ways to fill in the final project of the Certificate TU/e Technology Entrepreneurship. (See Figure 1) It is especially interesting for students that do their thesis project for one of the master studies of the Technology Management department.

Figure 1 Certificate TU/e Technology Entrepreneurship

There are 5 main goals and corresponding deliveries as shown in figure 2. The general insights and theories refer to insights and theories within the field of strategy and entrepreneurship, but are general in the sense that they are not company specific.

<table>
<thead>
<tr>
<th>Goals</th>
<th>Deliveries</th>
</tr>
</thead>
<tbody>
<tr>
<td>Learn general insights and theories</td>
<td>Literature review and model reflection</td>
</tr>
<tr>
<td>Understand mechanisms of new company</td>
<td>Company specific model</td>
</tr>
<tr>
<td>Evaluate possible strategies</td>
<td>Description of experiments and implications</td>
</tr>
<tr>
<td>Develop new general insights and theories</td>
<td>(Description of) New learning models</td>
</tr>
<tr>
<td>Decide how to set up the new company</td>
<td>Written business plan</td>
</tr>
</tbody>
</table>

Figure 2. Main goals and deliveries.

A six phase project structure is developed. The phases are as follows:

Phase 1
The first step is to determine the domain and gain information concerning the aspects in the ‘From Idea to Domain’ section of figure 3. Then according to the SWOT analysis and start-up aspects the entrepreneur(s) determine(s) if there is any possibility to successfully start activities in this domain. If the entrepreneur(s) see so many weaknesses that they do not have any faith in success or it is simply not possible to get a certain required license, it makes no sense to develop strategies or even think of simulating these strategies. So before developing a strategy one needs to make sure that (1) the domain
is such that it is interesting to explore what activities are possible. If this is not the case (2) one can choose to formulate the idea and corresponding domain differently or (3) decide not to set up the business and to look for a better opportunity.

Figure 3. From Idea to Domain and From Strategy to Goals

Also during this phase the student needs to get acquainted with system dynamics by doing a short literature review. This report provides a basis for learning the main system dynamics concepts and a guide will be presented to quickly get acquainted with the field.

Phase 2
When deciding that the defined domain is worthwhile to explore, one can start to define different strategies that could be interesting for the new venture. It is important to try to define various strategies before starting to model, because it greatly determines the modeling process and at this time the entrepreneur is still open minded for different ideas. Putting a lot of energy into modeling a certain strategy can cause that the focus is so much on this strategy that one becomes blind for other possibly better strategies. The goal of the modeling and simulation process should be to determine the best strategy not to prove that a strategy has certain results.

The Enterprise Simulation Framework provides a structured way to develop models that support the business planning process. The student will evaluate the current models and determine how these models can help him/her to develop insights how to set up the new business. The student can learn (from) the mechanisms that are explained in the current models and see what influence these mechanisms can have on his/her own business. The student needs to be critical and examine the completeness and relevance of the models. He or she needs to develop a view of what variables and mechanisms are not modeled yet or explained well enough, which do have an important contribution to the success of the new enterprise.
Phase 1 and 2 are part of the 'Literature review and research proposal'. This is an assignment which has to be done before the actual thesis project starts. At the end of this assignment the student needs to hand in the first delivery. This report contains: a short literature review of system dynamics, a description of the new enterprise domain, a review of the current ESF models and a description of the different possible strategies for the new enterprise.

**Figure 4. The ESF project structure**

**Phase 3**
At the start of the actual thesis project, the student will determine how the ESF models need to be improved and/or what new models need to be developed to be able to evaluate the defined strategies. This phase is comparable with the diagnosis phase of the regulative cycle. The defined strategies are modeled according to the available models for as far as possible. This shows what information is still missing and which assumptions still need to be explicitly made. It also makes clear what aspects and mechanisms still need to be modeled. Now an execution plan will be defined. It explains how and when the required information will be gathered and analyzed and which aspects and mechanisms will be modeled. It is important that the university supervisor agrees that the specified aspects and mechanisms are not (fully) covered in an available model yet and are indeed of significant importance.

**Phase 4**
Now the actual model development will start. This process is actually an almost endless series of empirical cycles. It starts with doing observations, which is in this case a very broad concept. Observations can be ideas from literature, interviews, empirical data, available models and even from the models the student is developing. From the observations hypotheses are derived, which can be in the form of single relations, sets of relations, loops or even sets of loops. After that the hypotheses will be modeled and tested. The behavior that the model shows can be evaluated and can serve as observations to define new hypotheses. These new hypotheses can be modeled again etc. The basic framework in what order the different kind of models can best be developed is shown in figure 5.
Figure 5. The four basic steps.

At a certain moment the developed model(s) cover all desired aspects and mechanisms and an integrated model can be developed to test the defined strategies. (Delivery 2) Finally according to an experimental design the strategies will be tested under various conditions.

Phase 5
After the final experiments, the results of these experiments and all relevant previous experiments will be described. Furthermore the implications of these experiments and the lessons learned for the new enterprise (strategy) will be described. (Delivery 3) Furthermore a general version or the (new) developed models will be made and. The value of these models and how they relate to the other ESF models will be described. This general learning model will be added to the ESF and will serve as input for future students. (Delivery 4)

Phase 6
The final step is to write the business plan based on the lessons learned. The content of the plan depends on the goal and the audience of the plan, but must reflect the main strategic decisions developed during the simulations. (Delivery 5)

Literature review suggestions
To have a better understanding of the set-up of the ESF Thesis Project itself the report called ‘The Enterprise Simulation Framework’ written by Arjan de Vries, can be read before the actual literature review. It also provides links for interesting websites and the literature list can be used as a starting point for the literature review.

The following section provides a suggestion how to get acquainted with system dynamics.

A good starter is the Online book provided by the U.S. Department of Energy called ‘Introduction to system dynamics’ It can be found at http://www.systemdynamics.org/DL-IntroSysDyn/index.html Also a pdf-version will be available on internet.

Books to continue reading after that are:

Below are suggestions for interesting literature discussing entrepreneurship and in particular the business plan.
Finally some interesting websites.

- Businessbox [http://www.businessbox.nl](http://www.businessbox.nl)
- Club of Rome [http://www.clubofrome.org](http://www.clubofrome.org)
- Finan [http://www.finan.nl](http://www.finan.nl)
- Informal Education [http://www.infed.org.uk](http://www.infed.org.uk)
- iThink simulation software [http://www.iseesystems.com](http://www.iseesystems.com)
- KVK (Chamber of Commerce) Kamer van Koophandel. [http://www.kvk.nl](http://www.kvk.nl)
- New Venture [http://www.newventure.nl](http://www.newventure.nl)
- Planware.org [http://www.planware.org](http://www.planware.org)
- System Dynamics Society [http://www.systemdynamics.org](http://www.systemdynamics.org)
- University of Bergen - System Dynamics Group: [http://www.ifi.uib.no/sd](http://www.ifi.uib.no/sd)
- Vensim simulation software [http://www.vensim.com](http://www.vensim.com)