Scenario Analysis using System Dynamics Modelling: The case of Production Portfolio Change in the Dutch Paper and Board Industry

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Abstract

A scenario analysis on plausible futures served to explore the Dutch Paper and Board – P&B – Industry's resilience towards competition in the form of an aggressive investment from outside the current industry. A System Dynamics model helped to visualize the effects on the Dutch industry's production portfolio. A scenario-space was constructed by combining three mega trends – Demand-shift for P&B products, Social awareness of recycling and Dutch business environment – and five alternative set-ups of a new facility by the prospective competitor.

The model output reveals the dominance of the Demand-shift for P&B products, reinforced by the Social awareness of recycling, for a good performance of the Dutch P&B Industry, regardless of the new facility type. The Dutch business environment offers limited scope to counterbalance the decreasing sales of P&B products. Interestingly, this industry retains growing sales and profits patterns even in the worst-case scenario.

The case study confirmed that the combination of scenario analysis and System Dynamics could support the analysis and visualization of the effects of major, competitive investments on a mature industry.

Keywords: Scenario Analysis, System Dynamics, Paper and Board, Industry, Investment.

1. Introduction

The Dutch Paper and Board Industry – Dutch P&BI – is a successful, responsible and mature industry that must operate in an increasingly competitive and dynamic environment. It is an energy-intensive sector, where volatile and increasing energy prices introduce substantial risk for eroding profits. Nowadays, the growing interest in bio-energy has led to a dramatic increase of wood prices, the raw material for virgin pulp-manufacture. Used paper exports have driven-up the prices for recycled paper, the main Dutch P&BI's feedstock. These and other trends may result in gradual changes of the sector in the coming years.

A different scenario for this production sector may also become reality: the emergence of a "nightmare competitor" (Thorpe, 2000) in the form of a new entrant to the Dutch P&BI scene. A company that has enough financial resources and access to state-of-the-art technology could design, build and operate a highly competitive new facility for pulp and/or paper in the Netherlands by exploiting economies-of-scale, innovative technology and system concepts. This is more likely as it may seem, since mergers and acquisitions have resulted in a sector dominated by a few multinational corporations. International headquarters currently manage most of the Dutch P&BI companies and only a limited number of the global pulp, paper and board conglomerates are presently active in the Netherlands. Therefore, investments in the Netherlands originating from outside the current Dutch P&BI sector appear to be possible.

Visualizing such a nightmare competitor would enable the Dutch P&BI to develop effective business strategies, which should also take into account changing policy and regulation, environmental awareness and future P&B products demand.

In this paper, a scenario analysis with the support of a quantitative model is applied to underpin the process of business strategy and policy-making with respect to investments/divestments in this industry. To this end, the process of combining scenario analysis and System Dynamics modelling is addressed to explore and evaluate production capacity changes in the Dutch P&BI subject to a variety of scenarios. The relevant trends identified in a conceptual scenario analysis are translated into inputs for a System Dynamics model and related therein to investment/divestment options since the model also captures the technical essence of this industry.

1.1. Background and Expected Behaviour

Companies in the Dutch P&BI transform new, virgin pulp and recycled fibres into P&B products (Berends, 2001; VNP 2002). Its level of vertical integration (Food and Agriculture Organization, 1973) is limited, since the industry only produces a small amount of mechanical pulp from wood and further transformation such as packaging or newsprint products is limited.

The Dutch P&BI currently comprises 27 mills owned by 17 companies. Most of these are managed from international headquarters where decisions about investments, divestments and production quantities are taken. In 2002, the mills produced approximately 3.3 million tons of final products (VNP, 2002). Those form the first link in the P&B production chain in the Netherlands, where packaging material, graphic paper and hygienic and sanitary paper is produced in order of volume. The greater part of the production is exported, except for the last category that is produced mainly for national consumption.

Since the 1980s, the Dutch P&BI has increased the use of recovered paper in its production cycle. Nowadays, the basic raw material this industry uses consists of fibres from recovered paper (75%), imported virgin wood pulp (21%) and home produced pulp (4%) (VNP, 2002) (See figure 1).

Approximately 76% of the recovered paper is imported, mainly from Germany, Belgium, the United Kingdom, France and the United States (VNP, 2002). The Dutch recovered paper industry supplies the remaining 24%. Although this industry gathers enough recovered paper to guarantee the Dutch P&BI's demand, import of certain recovered paper grades is required to meet the required basic output volume and quality (Bouwens, 2004).

Due to its dependency on import, the Dutch P&BI must pay the international market prices for wood and virgin pulp. The same holds for secondary, recycled fibres, especially after the recent increase of oil and gas prices. In both cases, transportation costs are incurred in addition to the fibres cost.

Investments in extra production capacity require large amounts of financial resources, since this is a capital–intensive industry. The competitive advantage of state-of-the art machinery investment on average last 3.75 years due to the ever increasing size of machinery available and used (Berends, 2001).

The position in global and regional markets appears to limit the Dutch P&BI's adaptability and range of options in case new competitors enter their playing field or unexpected changes in its environment occur.

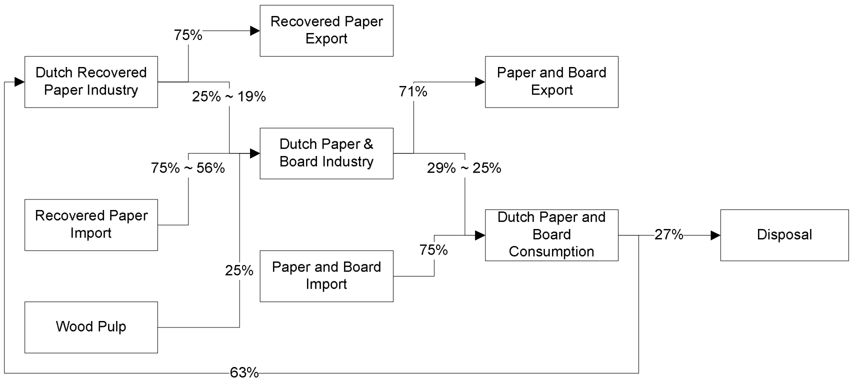


Figure 1: Flow of volumes of the Dutch Paper and Board Industry (percentage mass)

As an initial stepping-stone for initiating the discussion at industry level, this research is meant to uncover the non-linear dynamics affecting new investments in the current industry structure.

In general, this industry expects that several factors could produce in the near future the stagnation or even the decline of the current increasing trend of sold products of the Dutch P&BI. Some considered factors affecting this industry were the business climate in the Netherlands, paper and board consumption, technical developments of production machinery, social awareness for recycling, country's welfare but especially an enormous investment on paper and board production outside the current industry. The expected behaviour of the sold products before and after the introduction of a new facility for paper and board production appears in Figure 2.

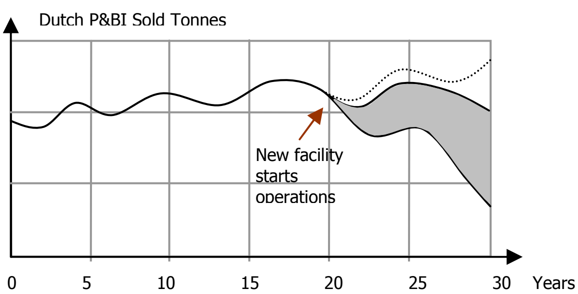


Figure 2: Dutch Paper and Board Industry's Sold Tonnes reference mode

The concern of this industry in the developments in future scenarios is reflected on the gray area which portrays the different trends of the sold products depending on the combination of environmental factors. This research also explores the performance of the current industry in alternative future scenarios when investments are done outside the current industry.

1.2. Objective, research question and outline

This paper aims at analyzing the impact on the Dutch P&BI's capacity utilisation, sales and profitability of a new investment in a state-of-the-art facility for the production of pulp and paper. The main research question is:

> *What are the economic consequences for the Dutch P&BI when a state-of-the-art, competitive facility for the processing, production and transformation of primary and/or secondary fibres is realized and competes with the Dutch P&BI?*

To support the analysis and visualization of the effects of major, competitive investments in such a mature industry, a System Dynamics model was developed and implemented by determining the boundaries, important variables, major mechanisms and performance indicators of the Dutch P&BI. From this model, the scenario-space was expanded by identifying highly important and uncertain factors that drive the system's dynamics. The combination of this scenario-space and quantitative System Dynamics model is expected to facilitate a systematic scenario analysis.

The modelling approach is presented in section 2. Section 3 addresses the model and the model testing. Section 4 focuses on the scenario construction, the new facilities' design and the scenarios' outcomes. Finally, the conclusions and limitations of this study are discussed in section 5.

2. Modelling approach

The Dutch P&BI is a complex system with dynamics that appear difficult to replicate in a model. As a first step in the modelling process, system decomposition was explicitly addressed (Dijkema et. al, 2003). A simplified model consisting of some relevant domains was developed, which is expected to facilitate the understanding of this system and its components and to learn about the system's behaviour.

A suitable model type for the Dutch P&BI is a continuous one (Wu, 2000), because it allows strategic decision-making, capacity planning and conceptual design and because the information's aggregation level is high (Industry level), the study period is long due to large investment cyclicality of this industry and the P&B production process is continuous. It is possible to describe the Dutch P&BI as a structure that contains (Roberts, 1978):

* Physical aspects: pulping, paper production and the use of recovered paper.
* Investment, price and cost policies that affect the decision-making process. These include raw materials price, end product price and government regulations.
* Feedback loops, not only informational –sales for estimating the raw material need–, but also physical –recycling of recovered paper –.

System Dynamics appears to be a suitable modelling method for this research. By applying System Dynamics (Forrester, 1961), the principles and techniques of control systems are applied in order to provide sufficient understanding of the strategic processes involved.

The conceptual model was developed by using a systems analysis approach (Miser & Quade, 1985) in order to identify factors under the influence of the Dutch P&BI and those beyond its influence. The approach identifies:

- A problem owner: An actor with a feeling of unease about a situation – the Dutch P&BI –, who sets the objectives, establishes the constraints for the solution-space and decides which solution to implement.
- Relevant external factors affecting the system's performance: The problem owner cannot or can only partially determine the value of these factors.
- Instruments: the problem owner has direct influence and which will modify the output of the system.
- Criteria: the problem owner can set a norm on these factors. Thereby, a system state is evaluated, now or in the future, based on the problem owner's objectives.

The identification of relevant external factors driving the system is key to the model development and further scenario analysis. Once identified, a reasonable number of mega-trends determining these factors can be established. Mega-trends dramatically affect the performance of the system, but the problem owner has no means to influence them.

In the modelling process, a systematic combination of mega-trends will be the input to a quantitative model of the Dutch P&BI. Any combination of mega-trend extremes represents a scenario for which the simulation can be run to explore possible future states and responses of the system.

The scenario analysis is meant to assist in the learning process of a system model in the context of policy and/or system design (Schwartz, 1997). The intention of this scenario analysis of the Dutch P&BI system's model was to describe images of the future in 20 years, which represents five consecutive investment cycles. This period provided room to observe the evolution of the installed capacity, and consequently the capital stock changes due to investments and divestments.

The quantitative model must be tested and evaluated for suitability and robustness when analyzing the model output under different scenario. The software Powersim Studio Academic 2003 was used for the simulation of the Dutch P&BI industry model.

3. The industry model development

In the previous section, a modelling approach has been introduced to enable the definition of a quantitative model. To enable any analysis of the impact of investments on the current Dutch P&BI, the simulation model must include elements that support the analysis of production capacity changes. Not only the physical domain but also the decision-domain should be represented in the model. More specifically, what are the relevant conditions for an investment decision, what are the consequences of investments in this industry regarding capacity, what happens when there is a situation of an excess capacity in this industry and how are the funds for investments in this industry generated.

To underpin the selection of the model boundaries and adequately support the analysis of investment decisions in the Dutch P&BI, literature was reviewed to explore the above-mentioned questions. Some recurrent issues regarding investment decisions at different aggregation levels and between industries were recognized that support the explanation and further analysis of the questions explored.

The following works were used to identify relevant causal relationships in the model. Trømborg, Buongiorno, & Solberg (2000) present economics and production planning, in the form of profitability and past production respectively, as the source for capacity changes. The emphasis and focus on economics or production planning, however, varies between authors. Mandal & Sohal (1998) base the capacity expansion on the increase of average sales revenue and the desired capacity in order to comply with the demand. Chowdhury & Sahu (1992) indicate that demand and a fraction of the total revenue are causes for changes in production rate. Mohapatra, Bora, & Sahu (1984) use an available fund -a reserve coming from profits after taxes- and a desired harvesting rate for changing harvesting rates.

Unlike the above-mentioned works, the following authors analyze only the production cycle, removing economics. Corben, Stevenson, & Wolstenholme (1999) see the production potential and the efficiency of the production process as direct causes of production rate changes. Minegishi & Thiel (2000) indicate that the gap between the expected and the actual rate triggers changes in production rate. Lyneis (2000) indicates an order backlog, which depends on the gap between projected demand and target utilisation.

The following works focus only on economic resources, neglecting the production cycle. Kantardgi (2003) sees that an enterprise fund for investments and the effectiveness of funds use affect the production levels. Jan & Hsiao (2004) base the improvement in manufacturing ability on increasing R&D investments.

The recurrent issues extracted from these sources are (1) the description of the characteristic production function and (2) the physical flow of the industry under study and how do these relate to (a) production capacity; (b) the changes in production capacity based on utilisation of the installed capacity; (c) the investments and divestments in relation to the utilisation of the installed capacity; and (d) the profits as a source for investments.

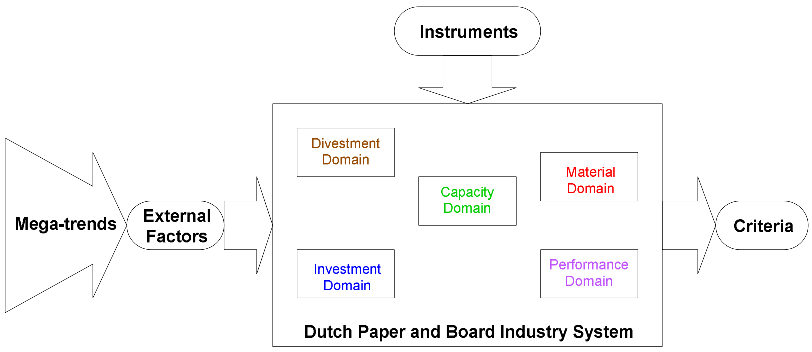


Figure 3: Initial System Diagram

Based on the systems analysis approach (Miser & Quade, 1985), it is then possible to decompose the industry model into different issues and relate each with a specific domain in the model of the Dutch P&BI, as follows (See Figure 2):

- Investment domain: this domain deals with the conditions for an investment decision and the evolution of such an investment in monetary terms.
- Capacity domain: this domain describes the changes in capacity due to investments and divestments.
- Divestment domain: this domain deals with the conditions for a divestment decision
- Material Domain: this domain deals with the physical flow and production functions of the Dutch P&BI
- Performance Domain: this domain deals with the results of the Dutch P&BI

These domains are interrelated. The modelling of each domain is described in the following sections.

3.1. Investment domain

This domain deals with the conditions for an investment decision and its evolution in monetary terms (See figure 3 for the causal diagram). A primary assumption is that resources for investments in the current structure of the Dutch P&BI come from a reserve of the generated profits. The total profits – or losses – of the Dutch P&BI are obtained from the total profits per unit of output and the amount of P&B products sold locally and internationally. In a situation of profits, a percentage of the total profits make up a reserve for future investments in capacity of any of the three production functions (wood pulp production, recycled fibres production and production of P&B). In a situation of losses, the reserve will drain at the same proportion.

A money release from the reserve will take place under the following conditions:

- the reserve for investment surpasses a certain threshold, which secures the existence of enough resources for any investment decision
- the expected capacity utilisation surpasses an upper limit, which is close to total utilisation. This indicates likelihood of insufficient production capacity in the future. The expected capacity utilisation is the comparison of the current production rate in any production function and its expected capacity after adding the extra capacity coming from the new investment.
- there growth in sales, which indicates possible increase of the expected capacity utilisation
- the profits moving average is positive, which indicates possible future profits

The amount of money released from the Reserve for Investment is equal to the Investment Requirement in each production function. In the implementation of the model presented, the value for the production of wood pulp is based on the data of Bergman & Johansson (2002), while for the recycled fibres production the value is based on the data of the positioning paper of Zittema (2005). The value for the P&B production is based on the data of Romme (1994).

The released money becomes an available budget for deploying the capacity increase, which is consumed in a certain investment period and turns into capital stock. The capital stock is subject to depreciation in a certain period.

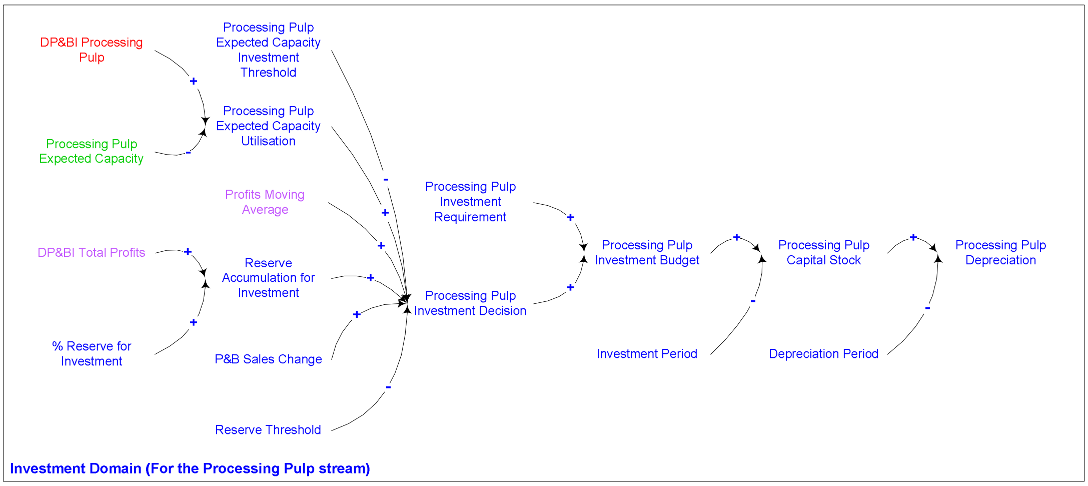


Figure 4: Investment Domain of the Dutch P&BI system

3.2. Capacity domain

This domain describes changes in production capacity due to investments and divestments (See figure 4 for the causal diagram). A capacity increase happens when an investment decision occurs and produces a money release from the Reserve for Investments. This money release translates into an expected capacity increase of any of the three production functions. Here, the expected capacity is the needed capacity level that results from the addition of capacity to the previous expected capacity. The translation from money to capacity depends on the Investment to Capacity Coefficient, which relates the produced tonnes per year with invested Euros. In the model implementation, this coefficient is assumed to be fixed and does not include the effect of economy-of-scale (ABN AMRO, 2004).

The expected capacity is the target, which the current capacity will aim to achieve. The current capacity expands to the expected capacity in a slower pace than the investment decision due to the time elapsed between the request, the delivery and the installation of the machinery and the training of the employees. These activities belong to the investment period that precedes operation of additional capacity.

With the expansion of the current capacity, the labour force increases under the assumption that new units are installed. The number new employees hired depends on the current capacity expansion and a factor translating capacity into labour (ABN AMRO, 2004). This indicates the required extra personnel per ton per year of extra capacity.

A divestment decision triggers the opposite situation. Once a divestment decision occurs, the current capacity of any of the three production functions reduces. This reduction depends on the Current Capacity, the production rate and the Current Capacity Threshold. The effect is an increase of the Current Capacity Utilisation above the threshold. The current capacity reduction affects the expected capacity, reducing it at the same pace and producing layoffs. The layoff magnitude has a direct relation with the current capacity reduction and a factor translating capacity into labour. Once the layoffs become effective, the number of employees reduces and the employees join a compensation programme for a certain period. While staying in the programme, the employees receive an annual compensation.

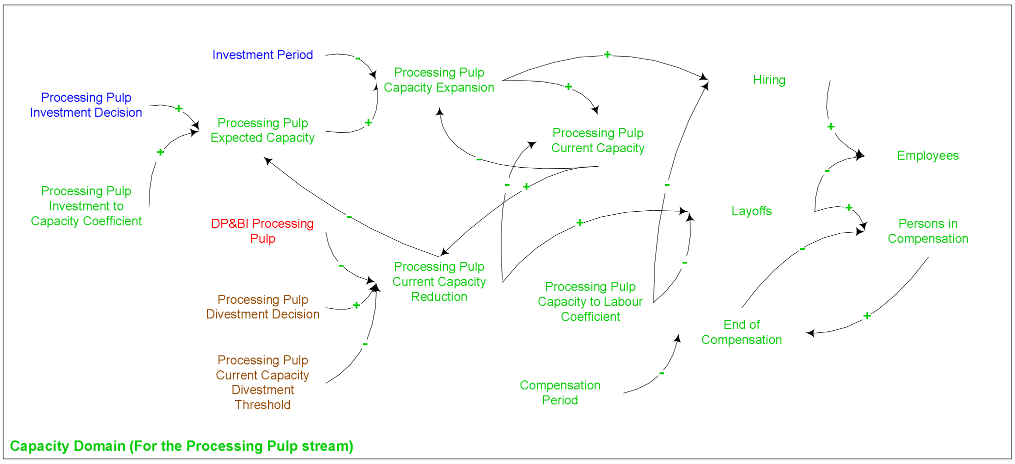


Figure 5: Capacity Domain of the Dutch P&BI system

3.3. Divestment domain

This domain deals with the conditions for a divestment decision (See figure 5 for the causal diagram). A divestment decision, and therefore a capacity reduction of the recycling P&B and P&B manufacturing production function happens under the following conditions:

- When the current capacity utilisation declines, surpassing a lower limit – current capacity utilisation threshold –, in order to prevent a situation of excessive under utilisation
- When there is a reduction from last year's sales, which indicates possible negative trend of the current capacity utilisation

Since the Dutch P&BI has the possibility to buy pulp for its P&B production the condition of sales reduction is not necessary for the pulping pulpwood production function.

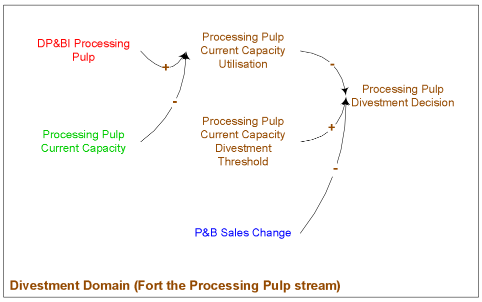


Figure 6: Divestment Domain of the Dutch P&BI system

3.4. Material Domain

This domain deals with the physical flow and production functions of the Dutch P&BI (See figure 6 for the stock-and-flow diagram). The Dutch P&BI uses new and recycled wood fibres for its production process. Based on the Raw Material Requirement, it produces new wood fibres and purchases the required amount of new fibres and recovered P&B for the production process. Changes in the P&B Sales Forecast will change the new and recycled fibres requirements. New wood fibres are locally produced and/or purchased to cover the requirement for new fibres. In addition, the amount of produced wood pulp has a direct relation with the current available production capacity.

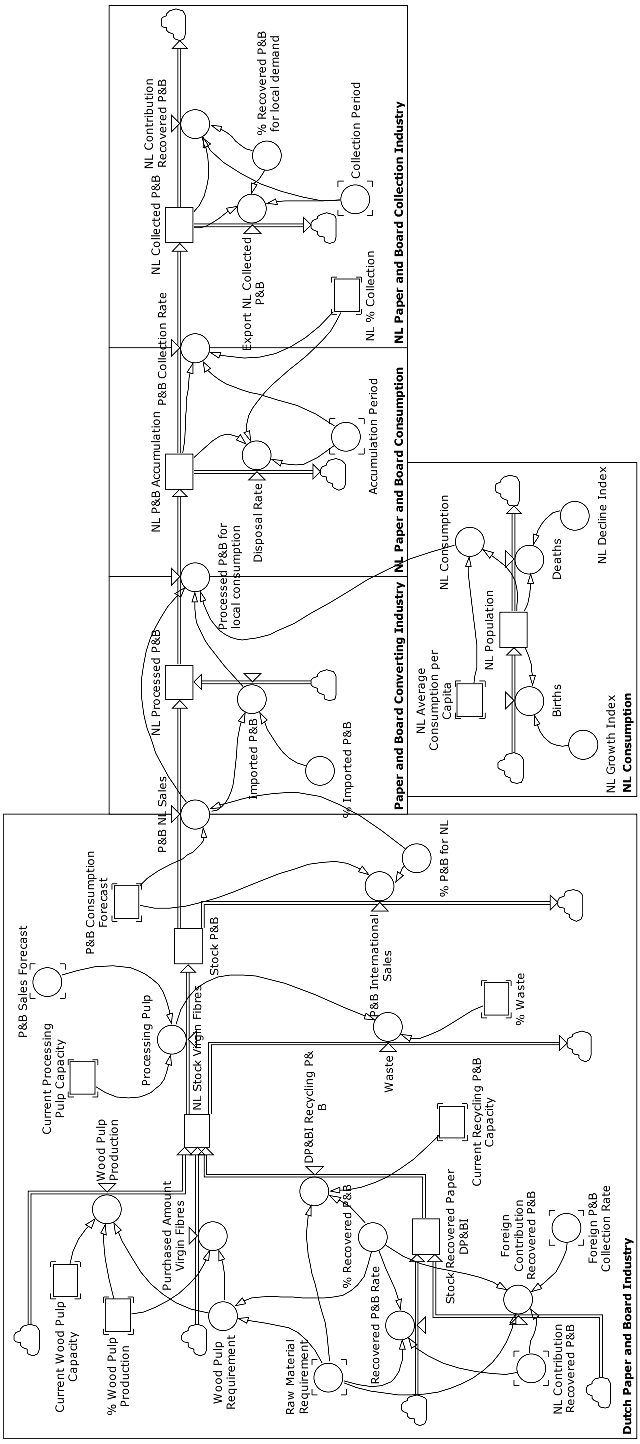


Figure 7: Material Domain of the Dutch P&BI system

The greater part of the recycled wood fibres is produced from P&B recovered in foreign countries. These have been aggregated in countries that have an organized system for P&B collection. An important amount of recycled wood fibres originates from P&B recovered in the Netherlands. The increasing P&B consumption makes available more recovered P&B from both sources, which secures the supply of recycled fibres to the Dutch P&B Industry.

New and recycled wood fibres are combined in a certain proportion. Changes in the proportion of new and recycled wood fibres will affect the final mix to produce P&B products.

Depending on the available capacity, recovered P&B is recycled and mixed with new wood fibres to produce P&B products, which become part of the available stock for local and international sales. Based on the P&B Consumption Forecast and the % P&B for NL, this stock is used to satisfy local and international demand. The historical data from the Confederation of European Paper Industry[1] served as a basis for the evaluation of the suitability of extrapolation as a method to obtain future values of Raw Material Need, % Non-Fibrous Material, % Recovered Paper, % Wood Pulp Production, % Waste, NL Average Consumption and Foreign Average Consumption.

End consumers utilize end P&B goods, which are transformed by the P&B Conversion Industry into end P&B goods. The amount of P&B finally consumed depends on the population and its per capita average consumption. The Paper and Board Recovery Industry collects P&B products from households and businesses once the end consumers have used and discarded them.

3.5. Performance domain

This domain deals with the results of the Dutch P&BI (See figure 7 for the causal diagram). A basic assumption is that market-clearing mechanisms set the quantity of products sold based on the price level. According to neoclassical economics theory this mechanism also sets the industry profits (e.g. Mankiw (1998); Png (1998); Himmelweit, Simonetti, & Trigg (2001)).

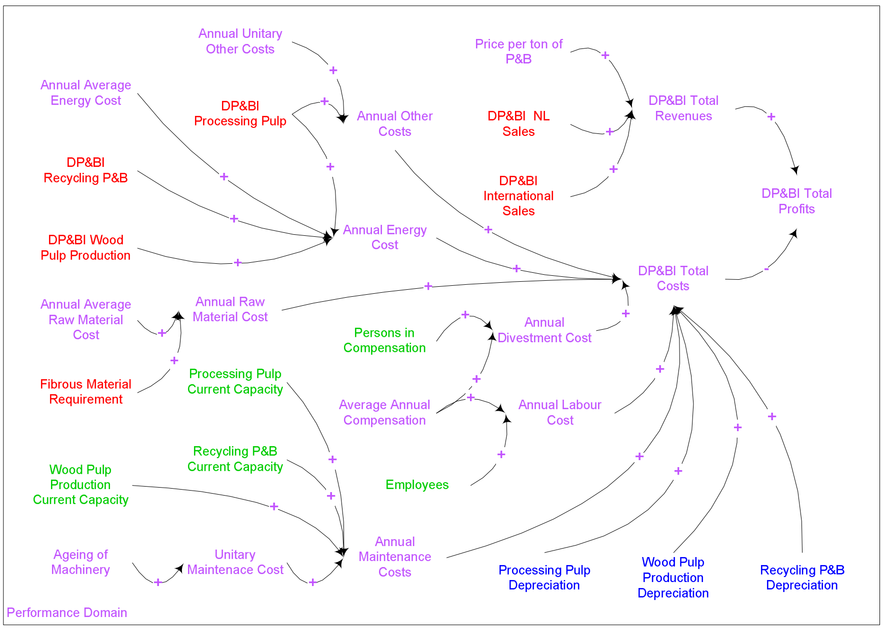


Figure 8: Performance Domain of the Dutch P&BI system

[1] http://www.vnp-online.nl/index.cfm?firm=vnp&fuseaction=show.page&pageId=160

According to Neoclassical Economics, total revenues and total costs determine total profits. Total revenue is obtained from the sales of P&B products, both locally and internationally, while taking prices as given. From the sector research by ABN AMRO (2004) it was possible to extract average costs per item produced.

The average cost relates to the purchase of pulpwood or woodchips, wood pulp and recovered P&B. Annual Other Costs are indirect costs that relate to the P&B production rate. Annual Energy Costs takes into account the energy use in each production function. Annual Labour Costs relates to the number of employees in the Dutch P&BI and their Average Annual Compensation. Annual Divestment Cost takes into account the Persons in Compensation and the Average Annual Compensation. Annual Maintenance Costs relates to the Current Capacity in each production function and Annual Unitary Maintenance Costs, which increases with the ageing of the machinery. Depreciation Cost in each production function comes from the Investment Domain.

3.6. Conceptual overview

The information of each domain, structured by means of causal loop diagrams, is presented in a system diagram showing the relevant domains (See Figure 8).

While developing the description of each domain, external factors, instruments and criteria were identified. External factors are beyond the control of the Dutch P&BI; instruments are factors the Dutch P&BI has control over and criteria provide information about the situation of the system.

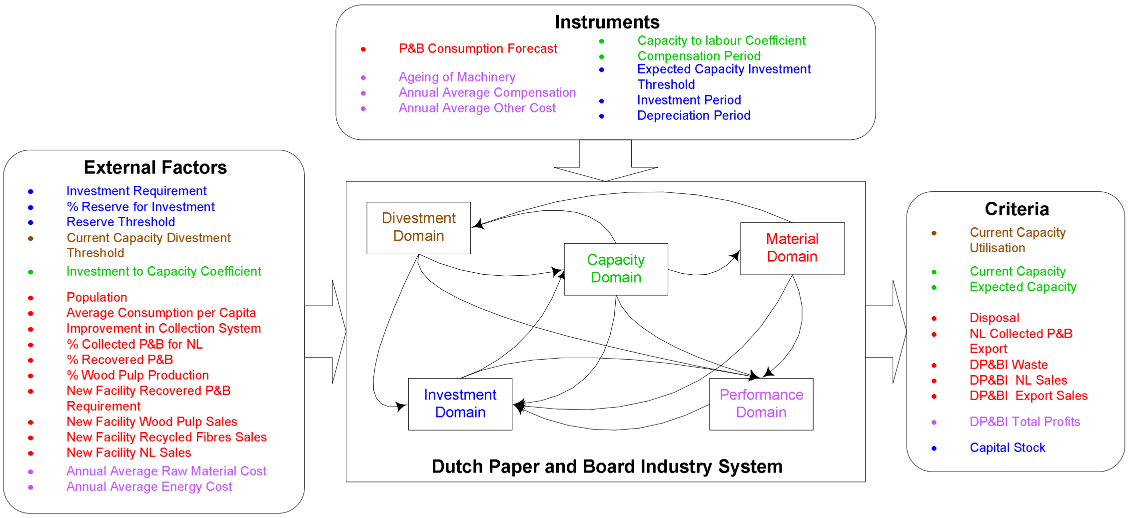


Figure 9: Performance Domain of the Dutch P&BI system

This conceptual model is transformed into a quantitative representation[2] by establishing the corresponding equations that reflect relations between variables using System Dynamics symbols.

[2] The complete model is available at http://www.tbm.tudelft.nl/live/binaries/e857ec2b-ca87-4360-aa70-d8a068d6bba7/doc/CM.ChiongMeza.pdf

3.7. Model testing

The list elaborated by Barlas (1996) served as a starting point for the selection of tests supporting the validation of the Dutch P&BI system's model. The final application of a test depends on the data availability from the real system.

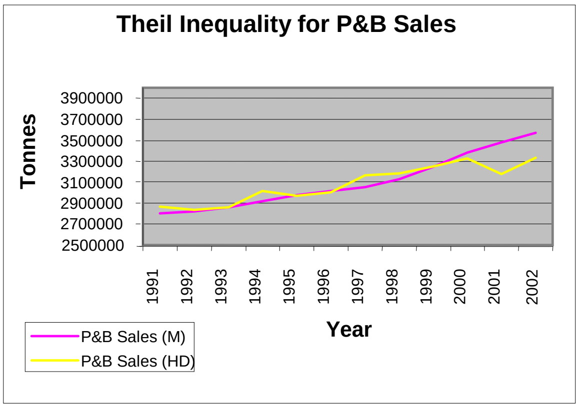
Barlas (1996) present three groups of test. The first group named 'Direct structure tests' focus on the relations in the model by comparing it with the knowledge of the real system, without running the simulation model. The second group called 'Structure-oriented behaviour tests' runs the model to study the structure of the model indirectly. The third group, appointed as 'Behaviour pattern tests', assesses the trends of the model output based on the data of the real system.

From the 'Direct structure tests', the following were conducted: theoretical structure and parameter confirmation, direct extreme conditions, empirical structure confirmation, empirical parameter confirmation and face validation with some members of the Knowledge Centre Paper and Board.

From the 'Structure-oriented behaviour tests', the following were conducted: extreme conditions and behaviour sensitivity analysis.

To observe the behaviour pattern, Theil inequality statistics (Sterman, 1984), provided a measure of proximity between the model output and the real system data based on the Mean Square Error. Figure 9 presents an example of the measure of Theil inequality for the P&B Sales.

Year	P&B Sales (M)	P&B Sales (HD)
1991	2798438	2862000
1992	2817911	2833000
1993	2857551	2857000
1994	2916186	3011000
1995	2971922	2968000
1996	3012042	3000000
1997	3050540	3162000
1998	3125158	3180000
1999	3250085	3255000
2000	3380537	3332000
2001	3482670	3174000
2002	3571674	3338000
2003	3670262	3341000



$U^M = 0.09$ $U^S = 0.52$ $U^C = 0.39$

Figure 10: Theil inequality statistics for P&B Sales

The Mean Square Error is composed by the difference in averages, variances and covariance. The average difference (U^M) represents a constant shift of the model data in relation to the historical data. The variance difference (U^S) represents different amplitudes in fluctuation of the model data in relation to the historical data. The covariance difference (U^C) represents a point-by-point difference of the model data in relation to the historical data. In this example, the model output mainly differs in amplitude and point-by-point accuracy from the historical data.

After performing the selected tests, the results provided sufficient confidence on the model structure.

4. Scenario analysis

Once the Dutch P&BI system's model has been established and tested for suitability, it is exposed to different scenarios in order to observe its behaviour in possible futures.

4.1. Scenario Construction

The systematic plan of Schwartz (1997) for designing environmental scenarios has served as a guideline. The purpose is to identify mega trends and arrange them in a way that they span the scenario space. The criteria for selecting mega trends are to choose those with high importance regarding the effect on the policy objectives and with high uncertainty in future developments (Schwartz, 1997). After making a preliminary list of relevant trends and evaluating them following the definition of mega trends, the ones that met these criteria were:

- Demand-shift for P&B products: its importance is high because it affects the future P&B production; its development is uncertain because of the availability of competitive substitute products and technologies
- Social awareness for the use of recycled material: its importance is high because it affects the mix of fibres in the production of P&B; its impact is uncertain because the availability of recovered P&B appears to depend increasingly on the volatile evolution of fuel prices, as recovered P&B is a source of energy.
- Dutch business environment: the importance is high because it depends on the different government coalitions in each administration period, which in turn influences the decisions taken at international headquarters related to the continuity of Dutch mills. These decisions are also uncertain because of the factors that are considered in addition to good performance.

Regarding the demand-shift for P&B products, one extreme represents an intensive use of paper while the other extreme is massive P&B substitution. Concerning the social awareness of the use of recycled material, on the one end of the scale there is a tendency to use only recycled wood fibres, on the other end a preference for virgin wood fibres. About the Dutch business environment, one extreme represents a supportive business environment; the other extreme would represent a discouraging business environment.

Initially, each combination of the mega-trend extremes produces a possible image of the future (See Table1). Analysis of some of these combinations does not require urgent simulation. This is the case for combinations six and eight of table 1: In a situation of declining demand-shift for P&B products and a discouraging business environment, no matter the social awareness of recycled material, future investments on capacity expansion are not attractive given the adverse atmosphere. The other combinations of mega trends, however, do require simulation for suitable analyses using the System Dynamics model, because the system's behaviour is hard to predict. This is the case for combinations one to five and seven of Table 1.

In each combination, the mega trend of social awareness of recycled material supports the choice of a new facility's set-up for the scenario analysis from the five configurations that are presented in section 4.2. When the trend points toward recycled material, the set-ups dealing with this input become suitable for testing. The set-ups using new wood fibres become suitable for testing when the trend points toward new wood fibres.

Additionally, the level of demand-shift for P&B products helps to determine the production capacity of each set-up (See section 4.2).

Table 1: Combination of mega trends and related environmental scenarios' name

Combination of Mega trends	Demand-shift for P&B products	Social awareness of recycled material	Dutch business environment	Environmental Scenario
1	Intensive use	Recycled fibres	Supportive	Endless sustainable paper
2	Intensive use	Recycled fibres	Discouraging	Poor environmental industry
3	Intensive use	New wood fibres	Supportive	Endless woody paper
4	Intensive use	New wood fibres	Discouraging	Poor woody industry
5	Substitution	Recycled fibres	Supportive	Autumn of sustainable paper
6	Substitution	Recycled fibres	Discouraging	Decay of the paper age
7	Substitution	New wood fibres	Supportive	Autumn of woody paper
8	Substitution	New wood fibres	Discouraging	Decay of the paper age

Once the outline of each scenario is completed, a description of how mega trends create a possible future for the Dutch P&BI is developed. Following the order of table 1, the worldview of each combination is described:

- *Endless sustainable paper*: The demand-shift for P&B products grows because there is little P&B substitution with other materials and technologies; this demand increase means more P&B products consumption and therefore more P&B recovery. The P&B production includes more recycled fibres in their process as there is more social awareness regarding recycled material use; this comes with the increasing P&B consumption. A supportive business environment provides favourable conditions, which gives a final impulse for new investments by external parties on large capacities using recycled fibres in their production processes.
- *Poor environmental industry*: Here the demand-shift for P&B products also grows because there is little P&B substitution with other materials and technologies; this increase in demand means more P&B products consumption and therefore more P&B recovery. The P&B production includes more recycled fibres in their process since there is more social consciousness about recycled material use; this comes with the increasing P&B consumption. However, a discouraging business environment provides unfavourable conditions, which reduces the chances for new investments focused on large capacities but may still be attractive for investments directed to smaller capacities processing recycled fibres.
- *Endless woody paper*: This worldview is similar to the endless sustainable paper. The difference is the little social awareness for the environment and therefore for

the recovered P&B use in the production process. Here, new investments focus on large capacities transforming pulpwood into new wood fibres.

- *Poor woody industry*: The demand-shift for P&B products grows because there is little P&B substitution with other materials and technologies; this increase in demand means more consumption of P&B products and therefore more P&B recovery. However, there is little social awareness for the environment and therefore for the recovered P&B reuse in the production process. At the same time, a discouraging business environment provides unfavourable conditions, which reduces the chances for new investments oriented to large capacities. However, it is still attractive to invest in smaller capacities that transform pulpwood into new wood fibres.
- *Autumn of sustainable paper*: The demand-shift for P&B products declines due to the P&B substitution with other materials and technologies. This decrease in demand means less consumption of P&B products and therefore less P&B recovering. However, there is social awareness for the environment and therefore for the recovered P&B use in the production process. Simultaneously, a supportive business environment provides favourable conditions, creating incentives for new investments at a small scale with the focus on processing recycled fibres.
- *Autumn of woody paper*: This worldview is similar to the autumn of sustainable paper. The difference is the little social awareness for the environment and therefore for the recovered P&B use in the production process. Here, new investments focus on small capacities transforming pulpwood into new wood fibres.

4.2. Scenario implementation

Concerning the mega trends, the related factors that will be inputs to the System Dynamics model should adapt to match the scenario description.

When dealing with the demand-shift for P&B products, the average consumption per capita will increase in a situation of intensive use and it will decrease in a situation of substitution.

When the mega trend of social awareness of recycled material tends to more recycled fibres use, the improvement in collection system (i.e. % Collection NL, % collected P&B for NL, % recovered P&B) will increase, while % wood pulp production and annual average raw material cost will decrease. When the mega trend of social awareness of recycled material tends to more new wood fibres use, the opposite will occur.

When dealing with a supportive Dutch business environment, the % reserve for investment will increase while the reserve threshold and the current capacity divestment threshold will decrease. In the situation of a discouraging Dutch business environment, the opposite will occur. Appendix 1 presents the input values of the external factors regarding the mega trends.

4.3. New Facility

The effect of an investment from outside the current Dutch P&BI is analysed by adding a new facility for pulp and/or paper production that competes with the Dutch P&BI in national and international sales. The Dutch P&BI deals with this new facility as an external factor, which means that it cannot exert influence on the new facility, but the new facility will affect the dynamics of the Dutch P&BI.

The emergence of a new facility provides new insights about the Dutch P&BI's continuity, because any investment out of the industry's current structure could mean less improvement in the current production functions' capacity and stagnation of its capital stock. This new facility will basically affect the raw materials supply to the Dutch P&BI and the P&B products supply to the market, triggering changes that would affect the behaviour of the Dutch P&BI system's domains.

The set-ups for the new facility considered are a wood pulp plant, a recycled fibres plant, a P&B plant using wood pulp, a P&B plant using recycled fibres and a P&B plant using wood pulp and recycled fibres. Both set-ups are based on the production functions of the Dutch P&BI: wood pulp production, P&B production and recycled fibres production. The relevant domains for the new facility's design are the investment, the depreciation of the capital stock, the installation of the capacity, the performance (in terms of profits or losses generated by the new facility) and the production function(s). It is assumed that the new facility will provide P&B products to the market at competitive prices; thereby covering part of the Dutch P&BI forecasted demand and therefore reducing its sales. The new facility for producing P&B products with mixed fibres will follow the same trends of the Dutch P&BI regarding raw material purchase, raw materials proportions, waste production and P&B price volatility.

The P&B demand in each environmental scenario will help to determine the capacity for each set-up in each combination (See reference values in Appendix 2). These values become the medium capacity (MC) for the final production function or the only production function in the new facility's set-up. An increase and decrease in 50% of the medium capacity become the small capacity (SC) and the large capacity (LC) respectively (See transformed capacities in relation with the environmental scenario in Appendix 3). Since little information about P&B machinery cost is available, the gathered information for each production function was adapted from the average values by means of the formula for the calculation of investment costs by regression:

$$\left(\frac{I}{I_o}\right) = \left(\frac{C}{C_o}\right)^{\alpha}$$

In the formula, I_o and I represent the original and the new investment costs; C_o and C represent the original and the new plant capacity, and α is the regression exponent. It is possible to reduce unitary costs in dedicated plants, i.e. plants optimally adapted to a process or product (Rauch & Plooy, 2003). However, when a plant produces small quantities, the capital costs of such a plant become very important since it heads oppositely to the variable costs. In the introduced formula, α provides the influence magnitude of the capital cost at different capacities. The α values for most plants and equipments are normally around 0.6 or 0.7 (Humphreys & Wellman, 1996) while the average is typically 0.65 (Gerrard, 2000). This average was used for estimating different capacities of each production function, because the equipment inventory of Humphrey and Wellman only has a general approximation to the paper production process equipment.

The different capacities and the corresponding investment budgets in relation to the defined scenarios based on the values of Appendix 2 and the formula for the calculation of investment costs by regression were obtained as follows. For new facilities with two or three production functions, the final production function (P&B production) determines the capacity of the previous production function (recycling P&B and / or pulping pulpwood) depending on the waste proportion (5% for P&B production, 30% for recycling and 25% for pulping). Additionally, the recycled fibres proportion when producing P&B also affects the previous production function capacity in the case of a facility with three production functions. Afterwards, the formula for the calculation of investment costs by regression supports the transformation of the investment budgets from the calculated production (See the adjusted capacities in Appendix 4).

Each relevant set-up of the new facility will run independently from other set-ups in each scenario in order to observe the individual performance and make comparisons of the outcomes.

Once the input data is established for each scenario and facility, it is possible to run the simulation model to analyse the Dutch P&BI system model's dynamics.

4.4. Scenario results

The following section presents the results of the scenarios related to new facilities producing and/or processing recycled fibres. These results relate to the scenarios of new facilities producing and/or processing new wood fibres. The objective is to compare the outcomes of the same criteria in different scenarios with different new facilities and identify the best and the worst case for the Dutch P&BI.

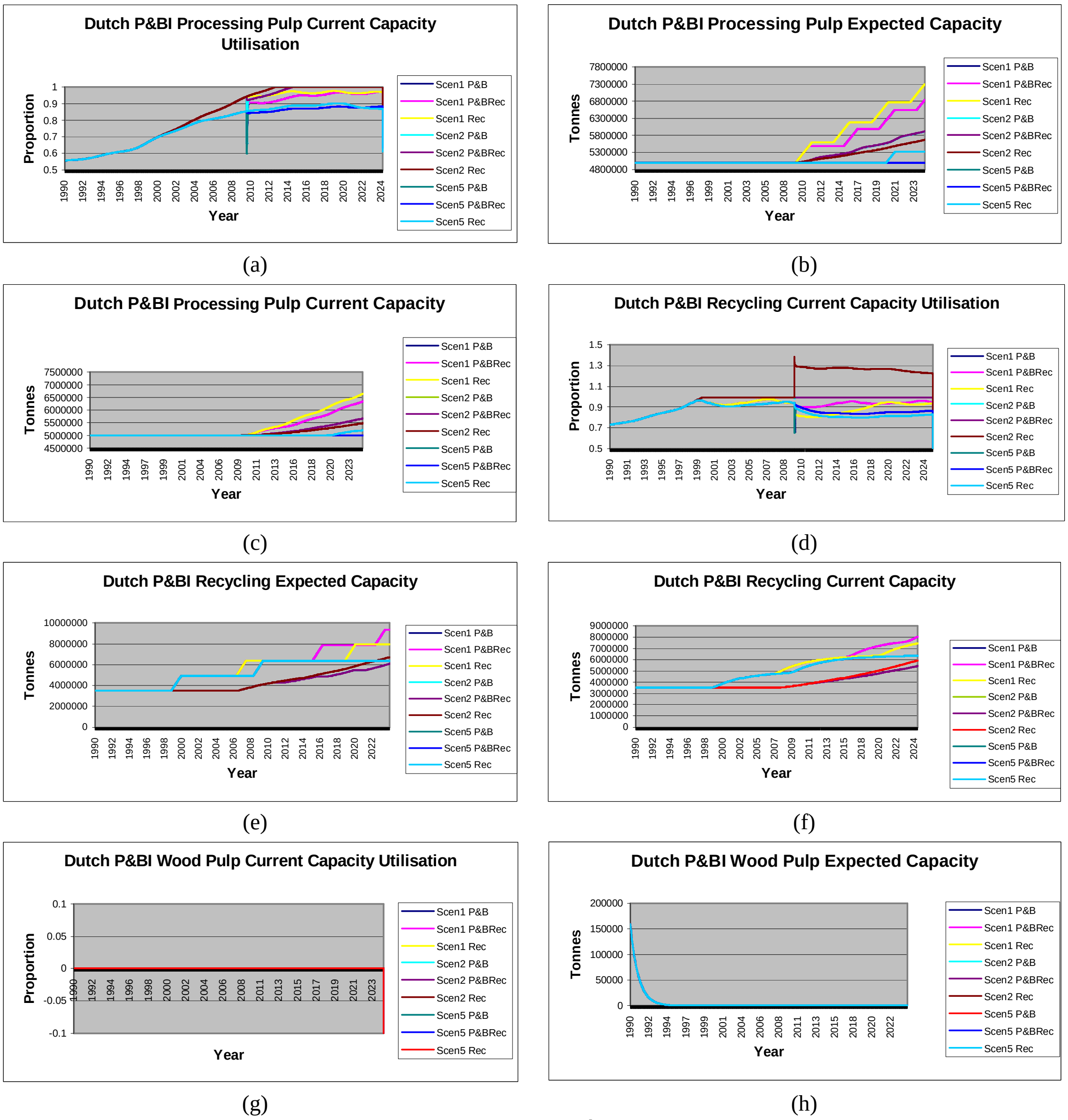
** Results of Scenarios related to Recycled Fibres*

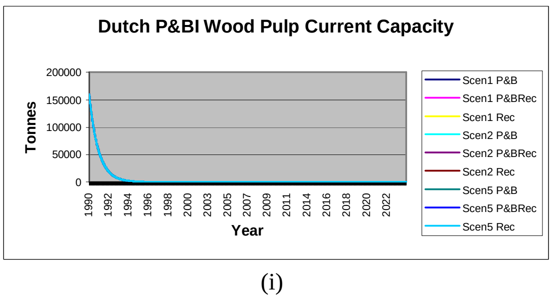
The current capacity utilisation of the Dutch P&BI processing pulp production function continues to grow in the three scenarios with different new facilities' capacities using recycled fibres in its production process (See Figure 10.a). The smallest growth belongs to the scenario "autumn of the sustainable paper" in which the average consumption decreases due to the use of P&B substitutes. An extreme decline of the P&B consumption decreases the current capacity utilisation of the producing pulp production function and a new facility even with the small capacity affects this utilisation (Scen5 P&B, Scen5 P&B Rec and Scen5 Rec). The largest growth belongs to the scenario "poor environmental industry" where the Dutch business environment is discouraging. In this scenario, the medium capacity of the new recycling facility in the environment (Scen2 Rec) leaves more market to the Dutch P&BI.

In almost all cases, the expected capacity and the current capacity expands (See Figure 10.b and c). The earliest capacity expansion is in 2009 and corresponds to the facility producing recycled fibres in the scenario "endless sustainable paper". The exception is the facility producing P&B with only recycled fibres in the scenario "autumn of the sustainable paper" (Scen5 P&B Rec). The intervals between capacity expansions are larger than 4 years. An unexpected result is that the facility producing Recycled Fibres and the one producing P&B in this scenario only slow down the increase of the current capacity utilisation of the Dutch P&BI processing pulp production function but finally it reaches the same level achieved in the scenario with a recycling facility. It is worth mentioning that the inverse picks in the graph correspond to the moment when the new facilities for P&B production start operations due to the initial calculation of the sales rate.

For the recycling current capacity utilisation, the simulations show that it reaches a stable behaviour after 1999 with some variations after 2010, when the new facilities start operations (See Figure 10.d). The exception corresponds to the new facility, which only transforms recovered P&B into fibres at medium capacity, becoming the best current capacity utilisation of this production function.

Figure 11: Dutch P&BI capacity related outputs when new facilities recycle P&B





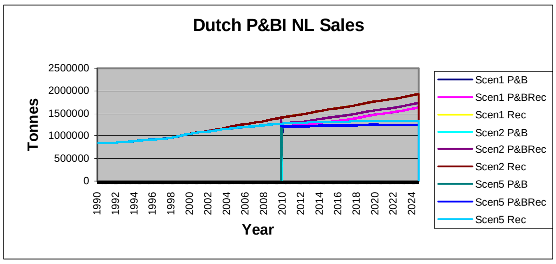
Legend:

- Scen1 P&B: Scenario 1 with a mixed fibres P&B facility
- Scen1 P&B Rec: Scenario 1 with a recycled fibres P&B facility
- Scen1 Rec: Scenario 1 with a recycled fibres facility
- Scen2 P&B: Scenario 2 with a mixed fibres P&B facility
- Scen2 P&B Rec: Scenario 2 with a recycled fibres P&B facility
- Scen2 Rec: Scenario 2 with a recycled fibres facility
- Scen5 P&B: Scenario 5 with a mixed fibres P&B facility
- Scen5 P&B Rec: Scenario 5 with a recycled fibres P&B facility
- Scen5 Rec: Scenario 5 with a recycled fibres facility

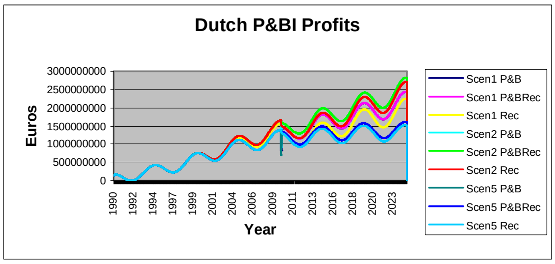
These capacity utilisations occur together with expansion of expected and current capacity in all scenarios (See Figure 9.e and f). The earliest one starts in 1999 and corresponds to the facility producing recycled fibres in the scenario “autumn of the sustainable paper”.

The current capacity utilisation of the wood pulp production function is null in the simulations because these scenarios emphasized the use of recovered P&B (See Figure 10.g). No increments in the expected capacity or the current capacity occur (See Figure 10.h and i).

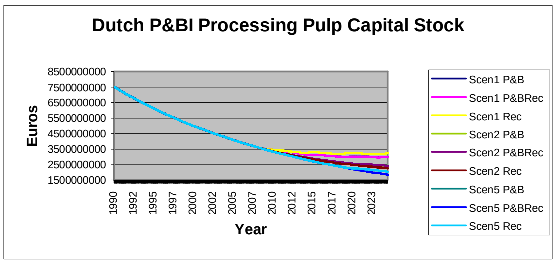
Figure 12: Dutch P&BI sales, profits and capital stock output when new facilities recycle P&B



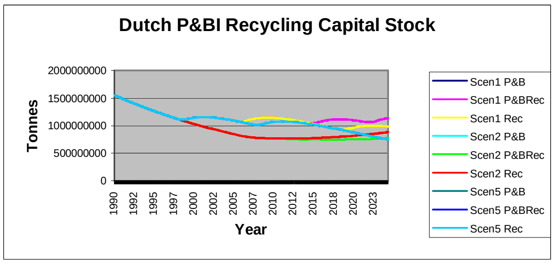
(a)



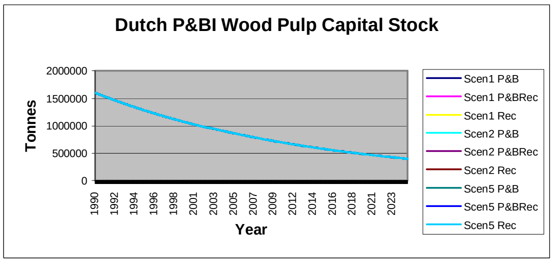
(b)



(c)



(d)



(e)

Legend:

- Scen1 P&B: Scenario 1 with a mixed fibres P&B facility
- Scen1 P&B Rec: Scenario 1 with a recycled fibres P&B facility
- Scen1 Rec: Scenario 1 with a recycled fibres facility
- Scen2 P&B: Scenario 2 with a mixed fibres P&B facility
- Scen2 P&B Rec: Scenario 2 with a recycled fibres P&B facility
- Scen2 Rec: Scenario 2 with a recycled fibres facility
- Scen5 P&B: Scenario 5 with a mixed fibres P&B facility
- Scen5 P&B Rec: Scenario 5 with a recycled fibres P&B facility
- Scen5 Rec: Scenario 5 with a recycled fibres facility

The P&B NL Sales of the Dutch P&BI continues to grow, with some inverse picks when the new facilities producing P&B start operations (See Figure 11.a). The best situation is when the new facility recycles fibres in the “poor environmental industry” scenario (Scen2 Rec) and the worst corresponds to the new facility producing P&B with only recycled fibres in the “autumn of sustainable paper” scenario (Scen5 P&B Rec).

In general, the Dutch P&BI’s results grow following the fluctuation patterns identified in the historical data of the sales, which is embedded in the simulation model (See Figure 11.b). The best growth comes in the “poor environmental industry” scenario when the new facility recycles fibres (Scen2 Rec) and the worst happens in the “autumn of sustainable paper” scenario with the new facility recycles fibres (Scen5 Rec).

The capital stock in each production function behaves according to the expected capacity expansion (See Figure 11.c, d and e). For processing pulp, the change in capital stock occurs in 2009 and corresponds to the scenario “endless sustainable paper” with the facility producing recycled fibres. For the recycling production function, the earliest change starts in 1999 and corresponds to the scenario “autumn of the sustainable paper” with the facility producing recycled fibres. The wood pulp production function shows no changes, which coincides with no changes in the expected capacity.

** Results of Scenarios related to New Wood Fibres*
The current capacity utilisation of the processing pulp production function starts growing but tends to stabilize in the last third of the simulation period in the three scenarios with different new facilities' capacities that use new wood fibres in its production process (See Figure 12.a). The smallest growth belongs to the scenario "autumn of the woody paper" in which the average consumption decreases due to the use of substitutes of P&B. An extreme reduction of the P&B consumption decreases the current capacity utilisation of the producing pulp production function and even a new facility with the small capacity affects this utilisation (Scen7 New, Scen7 P&B New and Scen7 P&B). The largest growth belongs to two scenarios: the "endless woody paper" and the "poor woody industry" where the P&B average consumption increases but the Dutch business environment is supportive in the former and discouraging in the latter. In the "poor woody industry" scenario, the medium capacity of the new facility producing new wood fibres leaves more market to the Dutch P&BI, allowing a faster growth of the current capacity utilisation.

When there is P&B production with only new wood fibres, the growth is less steep but reaches the same level at the end of the simulation period. In the "endless woody paper", the growth is slightly less steep than in the previous situation but also reaches the same level at the end of the simulation period. In these scenarios, the increasing average consumption compensates the competition for the market share.

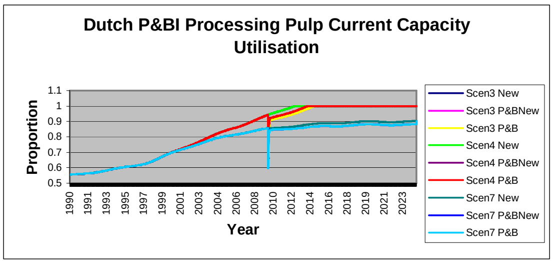
For the recycling current capacity utilisation, the simulations show a continuous growth (See Figure 12.d). Similar to the processing pulp current capacity utilisation, the smallest growth belongs to the scenario "autumn of the woody paper" while the largest growth belongs to the "endless woody paper" and the "poor woody industry" with the same type of new facility's set-ups in each scenario.

The current capacity utilisation of the wood pulp production function is one in all the simulations because these scenarios emphasized the use of new wood pulp for the P&B production (See Figure 12.g). The above-mentioned levels of capacity utilisation occurred without an expansion of the expected production capacity in any production function (See Figure 12.b, e and h). Consistently, the current capacity of each production function remains the same (See Figure 12.c, f and i).

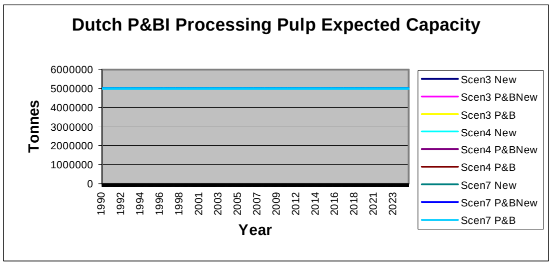
The NL Sales of P&B produced by the Dutch P&BI continues to grow only in the "poor woody industry" with a new wood pulp set-up. In other cases, there is a slight decrease in the previous trend before a new growth, e.g. Scen3 P&B and Scen4 P&B, or there is trend toward a steady state, e.g. Scen7 P&B New and Scen7 P&B (See Figure 13.a).

In general, the results of the Dutch P&BI grow following the fluctuation patterns identified in the historical data of the sales, which is embedded in the simulation model (See Figure 13.b). The best growth comes in the "poor woody industry" scenario when the new facility produces new wood pulp (Scen4 New) and the worst corresponds to the "autumn of woody paper" scenario with the new facility producing P&B (Scen7 P&B).

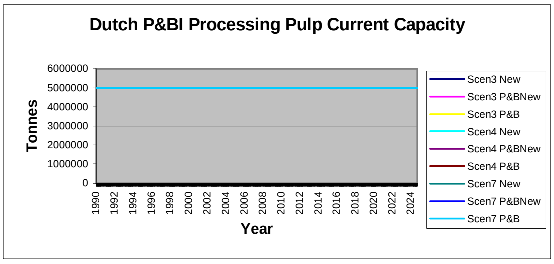
Figure 13: Dutch P&BI capacity related output when new facilities produce new wood pulp



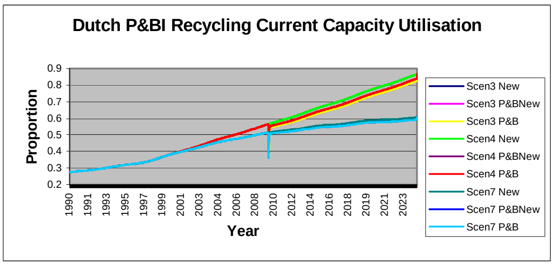
(a)



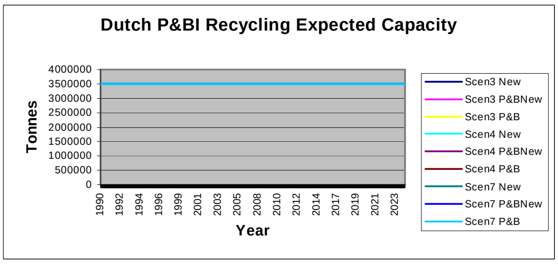
(b)



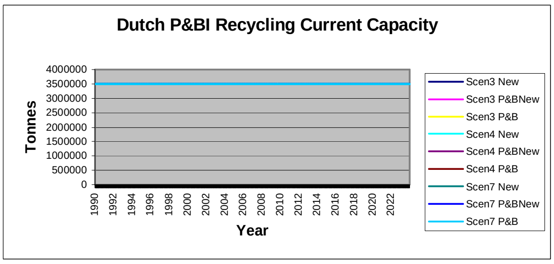
(c)



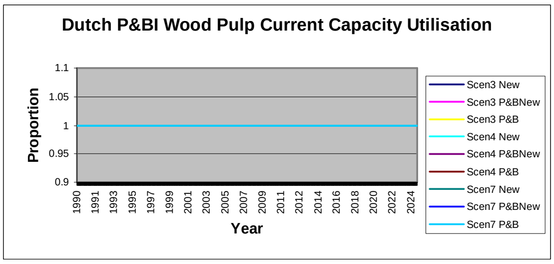
(d)



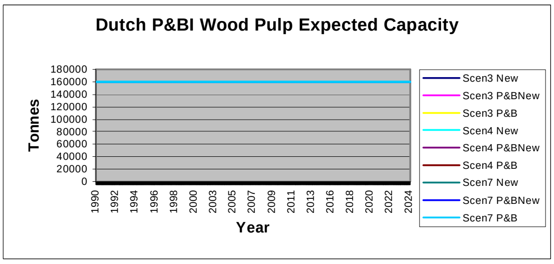
(e)



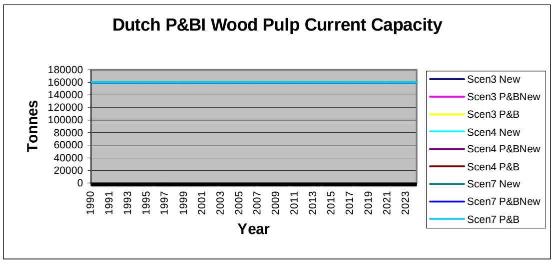
(f)



(g)



(h)



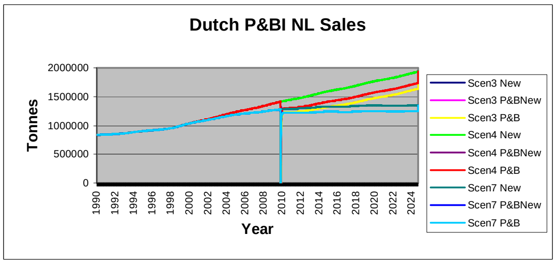
(i)

Legend:

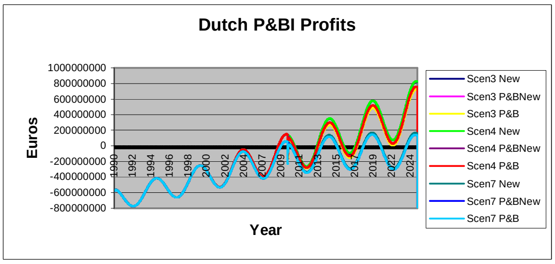
- Scen3 New: Scenario 3 with a new wood fibres facility
- Scen3 P&B New: Scenario 3 with a new wood fibres P&B facility
- Scen3 P&B: Scenario 3 with a mixed fibres P&B facility
- Scen4 New: Scenario 4 with a new wood fibres facility
- Scen4 P&B New: Scenario 4 with a new wood fibres P&B facility
- Scen4 P&B: Scenario 4 with a mixed fibres P&B facility
- Scen7 New: Scenario 7 with a new wood fibres facility
- Scen7 P&B New: Scenario 7 with a new wood fibres P&B facility
- Scen7 P&B: Scenario 7 with a mixed fibres P&B facility

The capital stock in each production function behaves according to the behaviour of the expected capacity (See Figure 13.c, d and e). Since there was no expansion of the capacity of any production function, the capital stock continues to decrease in time.

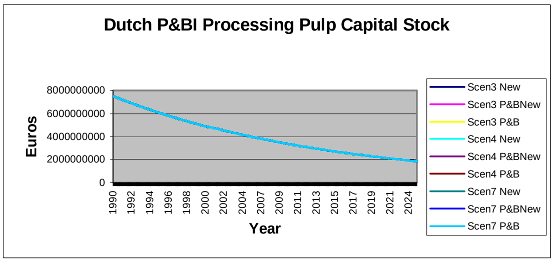
Figure 14: Dutch P&BI sales, profits and capital stock output when new facilities produce new wood pulp



(a)



(b)



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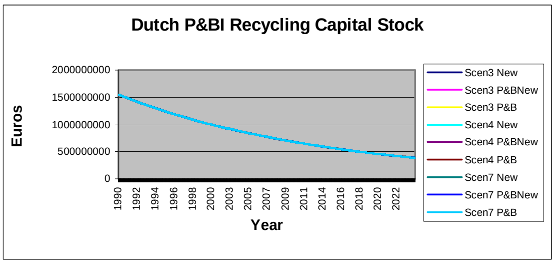
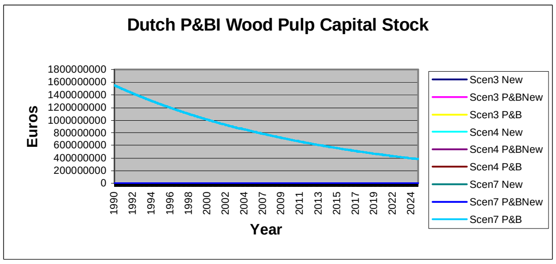


(d)



(e)

Legend:

- Scen3 New: Scenario 3 with a new wood fibres facility
- Scen3 P&B New: Scenario 3 with a new wood fibres P&B facility
- Scen3 P&B: Scenario 3 with a mixed fibres P&B facility
- Scen4 New: Scenario 4 with a new wood fibres facility
- Scen4 P&B New: Scenario 4 with a new wood fibres P&B facility
- Scen4 P&B: Scenario 4 with a mixed fibres P&B facility
- Scen7 New: Scenario 7 with a new wood fibres facility
- Scen7 P&B New: Scenario 7 with a new wood fibres P&B facility
- Scen7 P&B: Scenario 7 with a mixed fibres P&B facility

5. Discussion and conclusion

The main research question focused on the impact of a nightmare competitor on the current Dutch P&BI under different circumstances. The combination of three mega trends that influence the Dutch P&BI system's external factors produced six scenarios, which were combined with five alternative set-ups of a new facility competing with the existing industry. A System Dynamics model was developed and the scenarios were used as input to the developed model. Simultaneously, the combination of scenario analysis and System Dynamics was observed.

Regarding the scenarios related to recycled fibres, the best scenario for the Dutch P&BI is the "poor environmental industry" while the new facility produces P&B using recycled fibres only. In this scenario, the current capacity utilisation of the pulp processing and recycling production functions grow as well as the sales and the profits. The worst scenario results occur in the "autumn of the sustainable paper", while interacting with a new facility using recycled fibres. Here, three criteria show the lowest performance, i.e. the current capacity utilisation, the national sales and the profits.

Regarding the scenarios related to virgin wood fibres, the best scenarios for the Dutch P&BI are the "endless woody paper" and the "poor woody industry" scenario, while interacting with a new facility using new wood fibres. Here, the current capacity utilisation of the processing pulp and recycling production functions grow as well as the sales and the profits. The worst case results occur in the "autumn of the sustainable paper", while interacting with a new facility that produces P&B with mixed fibres. Therein, five criteria show the lowest performance, i.e. the current capacity utilisation, the national sales and the profits. The low performance during low P&B demand while competing with a new wood fibres facility may reflect the efficient process of the new entrant, which reduces the sales of the incumbent industry.

A common result in both groups of scenarios is the dominating role of the Demand-shift for P&B products. The Dutch P&BI achieves high values when this mega trend points to the growing side while it performs low when this mega trend points to the decreasing side. Moreover, the Social Awareness for recycling P&B supports the achievement of high values since recycled paper prices are lower than new wood fibres. Additionally, the Supporting business environment seems to have little effect to compensate a decreasing P&B demand.

The Dutch P&BI currently has a restricted decision-making power since the main decisions about investments, divestments and production quantities are made at international headquarters, which limits their range of means to take action. With this restricted decision-making power, the Dutch P&BI should focus on the optimization of their current production processes, the efficient use of resources and the recycling of produced waste in order to reduce the current cost structure of the production process. While this cost reduction results in a more competitive Dutch P&BI and appreciation by the international headquarters, it remains to be seen whether cost reduction will also win new investments for the Dutch P&BI.

The execution of this research project involved the analysis of Dutch P&BI production capacities interacting with different facilities in different scenarios. The construction of the Dutch P&BI model supported the identification of possible necessary changes of its own capacity in order to cope with changes in demand, use of raw material and Dutch business environment. When dealing with capacity expansions, the model supports the visualization of the future profits that this expansion may provide. The Dutch P&BI should concentrate on achieving economically feasible and sustainable capacity changes by persuading the international headquarters with the support of this new evaluation tool.

Concerning the combination of Scenario Analysis and System Dynamics, the result was a simulation model suitable for exploring the system's behaviour in the present and future based on certain assumptions while providing general figures of some performance indicators.

The systematic plan of Schwartz (1997) for designing environmental scenarios was enhanced by the quantitative approach of System Dynamics modelling and vice versa. The design of the Dutch P&BI's model by means of System Dynamics and the delineation of the model boundaries using the systems approach (Miser & Quade, 1985) assisted the process of identifying factors outside the scope of the problem owner. A further analysis of those factors concerning their importance and uncertainty in relation to the Dutch P&BI's system facilitated the identification of mega-trends for expanding the scenario space. The basic scenario analysis and the quantitative model supported the methodical definition of the quantitative characteristics of each scenario and the type of new facilities involved, which facilitated the study of evolutionary patterns resulting from the interaction of the Dutch P&BI in different scenarios with new facilities.

The answers of the research questions as well as the recommendations must be understood while taking into account the limitations of this research project during its execution. Several choices were made in order to achieve balance between academic demands and business needs, aggregation level and availability of information, technical limitations of continuous models and project management. These choices obviously had a repercussion in the model design.

One repercussion is that the Dutch P&BI model does not include all the features of the real system. For example, the model does not include the evaluation of the elapsed investment period to prevent a new expansion in production capacity in the Dutch P&BI in the same period, which is on average 3.7 years. During the model testing, some capacity expansion investments on the processing pulp and recycling production functions did take place before that. In reality, carrying out another investment while the previous one is currently deployed would be difficult since new machinery installation is a long process; however, this may reflect a possible situation in which the Dutch P&BI must quickly adjust to an increasing demand.

Another topic is the testing of the developed model. While national level information was used for the construction of the model, European level information was used for the validation though it is possible that the latter is a compilation of country level information. The need for independent sources of information for validation purposes is still necessary.

The purpose of modelling the Dutch P&BI and its interaction with a new facility was to design an abstract and simplified view of some relevant domains in order to facilitate the understanding of production capacity changes because of investment and divestment and learn about the behaviour of the system in the present and in the future based on certain assumptions. The simplification of the real system implies the exclusion of several variables, such as policies for recruitment of human resources or policies for merchandising, or the reduction of variables, such as the variation of energy prices and fibres prices. This simplification helped to focus on those elements that contribute more to the analysis based on a set of assumptions. This model therefore does not fully represent the complete Dutch P&BI but only the parts relevant in the research project executed.

As a follow-up study, the declining scenarios that were not included in this research could be further analysed in order to observe the industry dynamics and identify levers for managing this industry in an unfavourable scenario.

6. Acknowledgement

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8. Appendix

Appendix 1: Input values for External Factors

Mega Trend	External Factor	Value	Decreasing Trend	Increasing Trend
Demand-shift for P&B products	Average Consumption per Capita	-0.035*	-0.038*	-0.031*
Social awareness for the use of recycled material	Improvement in Collection System	0.0102	0.0051	0.0153
	% Collected P&B for NL	0.3	0.15	0.45
	% Recovered P&B	0.7488	0.3799	1
	% Wood Pulp Production	-0.0067	-0.0038	-0.0105
	Annual Average Raw Material Cost	327.43	491.15	163.72
Business environment in the Netherlands	Reserve Threshold	600000000	900000000	300000000
	Current Capacity Divestment Threshold	0.2	0.3	0.1
	% Reserve for Investment	0.1	0.05	0.15

* This value increases the initial shift of the special construction of this variable model equation (See footnote 2).

Appendix 2: Reference values for capacity and investment per production function

Production Function	Capacity (tonnes)	Investment (€)
Wood Pulp Production	700 000	400 000 000
Recycled Fibres Production	700 000	310 000 000
P&B Production	200 000	300 000 000

Appendix 3: Capacities in relation with environmental scenarios

New Facility's Set-up	**Environmental Scenario**					
						
New Fibres Production	--	--	LC	MC	--	SC
Recycled Fibres Production	LC	MC	--	--	SC	--
P&B Production with new fibres	--	--	LC	MC	--	SC
P&B Production with recycled fibres	LC	MC	--	--	SC	--
P&B Production with mixed fibres	LC	MC	--	--	SC	--
SC: Small Capacity	MC: Medium Capacity			LC: Large Capacity		

Appendix 4: Adjusted capacities for the new facilities' set-ups

New Facility with One Production Function

Size	**Recycled Fibres Production**		**New Fibres Production**	
	Capacity (ton)	**Investment (€)**	**Capacity (ton)**	**Investment (€)**
Small	350000	197556897	350000	254912125
Medium	700000	310000000	700000	400000000
Large	1050000	403479071	1050000	520618156

New Facility with Two Production Function

Size	**P&B Production**		**Recycled Fibres Production**		**New Fibres Production**	
	Capacity (ton)	**Investment (€)**	**Capacity (ton)**	**Investment (€)**	**Capacity (ton)**	**Investment (€)**
Small	100000	191184094	150376	114081152	140351	140746013
Medium	200000	300000000	300752	179012516	280702	220854167
Large	300000	390463617	451128	232992914	421053	287451723

New Facility with Three Production Function

Size	**P&B Production**		**Recycled Fibres Production**		**New Fibres Production**	
	Capacity (ton)	**Investment (€)**	**Capacity (ton)**	**Investment (€)**	**Capacity (ton)**	**Investment (€)**
Small	100000	191184094	112602	94526089	35256	57338835
Medium	200000	300000000	225203	148327333	70512	89974276
Large	300000	390463617	337805	193054757	105768	117105604